

Some Neglected Areas in Fire Safety Engineering

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ABSTRACT

Fire safety engineering has developed remarkably well over the last 4 decades, yet there are certain areas that have been systematically neglected or overlooked. On the basis of his long career in the profession, the author offers a number of areas for consideration where improvements are still clearly needed. These include: (1) learning from fire incidents in a systematic way; (2) studying fires in residential houses; (3) collecting statistics which are meaningful; (4) developing cost-effective codes and standards; and (5) considering the unintended consequences of fire safety provisions. Issues in each of these areas are illustrated with concrete examples.

Keywords: codes & standards; fire safety engineering; fire safety science; fire statistics; research.

1. INTRODUCTION

The author of this paper has been working in the fire safety profession since 1972, meaning almost since the beginning of the field as a scientifically-based profession, at least within the United States. For the last two decades, he has also worked extensively as a forensic expert, studying actual fires that have caused death, injury, or serious economic losses. In May 2013 he was invited to present a Keynote address at the Conference of the BIV, which is the SFPE Chapter in Sweden. The topic chosen was to focus on some neglected areas in fire safety engineering. There may be many suggestions of such areas, thus, a selection had to be made on the basis of personal experience in the profession. As a result of this, it became appropriate to structure this presentation as a first-person narrative, rather than in a conventional third-person point of view, which might imply an unwarranted claim of universal support for these opinions. Apart from slight editing, this paper is the lecture presented at BIV.

In the US, broad scientific efforts to study fire started only about 1970, and in most parts of the world it was a little later than that. The British started producing very important research at the Fire Research Station right after World War II, but this did not have much effect on the rest of the world, since personnel were lacking with proper education to make use of this information. Efforts in Sweden started in the late 1960s, however, and even slightly earlier in Japan. While this is a long span in someone's career, it is a short time for a field to reach maturity. It is a long enough period, however,

to take stock and see what is being done well, and what is not. In this lecture, I would like focus on the latter, since it is more helpful to learn what are the shortcomings, than it is to be content with a job well done. The field has made very gratifying progress in these last four decades, so I do want to spend a moment to discuss that. The most remarkable positive achievement I think has been the SFPE Handbook [1], published first in 1988. For the newcomers to the field, I must point out the situation in 1987. At that time, there were numerous books discussing building codes or giving practical advice (e.g., the NFPA Handbook). But the only significant books in English in the field that would be considered science-based were Dougal Drysdale's *An Introduction to Fire Dynamics* [2] (1985) and T.T. Lie's *Fire and Buildings* [3] (1972), and even the latter was a slim and modest tome. But with the publication of the first edition of the SFPE Handbook in 1988 all of a sudden we could properly describe this as a science-based profession.

Now that we are agreed that the profession is at least suitably established and has a science base, I would like to discuss five areas where I think we have not made adequate progress. These are:

- (1) Learning from fire incidents in a systematic way;
- (2) Studying fires in residential houses;
- (3) Collecting statistics which are meaningful;
- (4) Developing cost-effective codes and standards;
- (5) Considering the unintended consequences of fire safety provisions.

In addition, in 1996 [4], 1999 [5], and 2007 [6] I wrote about limitations of fire models and, even more so, problems in how they are used, thus I will not revisit those areas here, even though they are still short of a good solution.

2. LEARNING FROM FIRE INCIDENTS IN A SYSTEMATIC WAY

Fire safety engineering (FSE) is an applied profession. To be competent, it has to have a strong science and research base, but nonetheless it must respond to fires in a realistic and rational way. The only way to do this is to have good knowledge about real fires that occur. It should hardly need saying that the only way to learn what happened in a fire is to do a fire investigation. But it is important to emphasize that the person doing the investigation must be highly skilled and trained in that area. In addition, the investigation is of no value whatsoever, unless the findings get disseminated into the profession. I speak as an American, but I believe the situation is very similar in most, if not all, countries. In the US, there are almost no fruits of this endeavor. To see why, we need to consider some details. Almost every fire of significance gets investigated by two fire investigators, the first one from the fire department, and the second from the insurance company. There are many thousands of fire investigators in the US. But this effort does not produce the expected societal benefit. There are mainly two reasons for this:

- (1) The job standards (training and educational requirements) for doing this work are not very high. In quite a few fire departments, personnel are required to spend a couple of years doing fire investigation in order to get promoted, and while some of them prove to be both competent and enthusiastic, this cannot be said about all of them.
- (2) The information from the investigation reports is not disseminated. We have to subdivide this problem into its components:
 - For most fire departments, their reports are public documents. You can go and demand to see a report and you will be allowed. But there is absolutely no mechanism to distribute this information to the profession, apart from the National Fire Incident Reporting System (NFIRS) statistics, which I will discuss later.
 - While the insurance company will almost invariably send a fire investigator who will investigate and write a report, this information is secret. The insurance companies do nothing to help the profession by disseminating any fire incident information. In fact, they behave as if they believe that they will gain some sort of competitive advantage by revealing nothing, even though every company has a similar experience and there is actually nothing they gain, since they all learn the same things independently.
 - In some fire cases where litigation is pursued, an engineering analysis is done that is able to identify root causes of failures of components or inadequate fire safety designs. But such documents are again typically secret*. With regards both to investigation and engineering reports, the present approach only allows continued loss of property and life and provides no valuable lessons for fire safety engineering.
 - No publication medium exists to facilitate the learning process. Until about 15 years ago, the National Fire Protection Association (NFPA) used to operate a fire investigation department. While they did not do this on a systematic basis, nonetheless they sent fire investigators to fires they deemed important, and these investigators prepared quite detailed reports that were freely disseminated. A similar effort was carried on by the US Fire Administration, but that again disappeared about the same time. The NFPA Fire Journal used to regularly carry articles giving details of larger or more important fires. This effort, again, was cut back so much that it is effectively non-existent. One very positive aspect of the profession is that we currently have a half dozen, or more, high quality technical or academic type journals. These occasionally carry an article on fire investigation, but this is so rare

* I am one of the small number of people who do get to see a significant number of reports since I work as a forensic expert and get to read court documents that are otherwise not available.

that it does not help much. The only place (again, speaking only for the US) where details of actual fires are regularly published are *Fire Engineering* and *Firehouse* magazines. These carry such stories in almost every issue. But the magazines are solely intended for firefighters, thus they focus only on fireground tactics and personnel safety, not on any areas of engineering interest. If you want to find out about a specific large fire, you can Google it, but of course Google does not make a systematic study of anything.

The foundation of any science is the systematic collection of data. In the case of fire safety science or engineering, obviously the most important data are the data on actual fires. If no means exist for doing this, it cannot be a sound underpinnings of the science. What is very disappointing here is that the profession had better resources in this area in the 1990s than it does today.

3. STUDYING FIRES IN RESIDENTIAL HOUSES

In the US, about 97% of fire deaths in buildings occur in residences, with 3% in all other types of buildings. About 1% of the residential fire deaths are in high-rise buildings, and there are generally zero deaths in high-rise office buildings. The above statistics refer to building fires; out of the total fire deaths, vehicle fires account for around 20% [7]. Taken together, this says that if research is to provide any tangible benefit, it has to be focused on residential fires, and to a much smaller extent, vehicle fires. It is also clear that the fire problem in high-rise buildings—of any sort—is essentially non-existent. Again, this refers solely to the US situation, where about 50% of high-rise buildings are sprinklered and strict building codes prevent the use of interior finishes prone to rapid fire spread. The experience is clearly different in less well developed countries, where spectacular high-rise building fires still keep occurring.

It is disappointing to see that research studies are essentially in inverse relation to the actual need in this area. There is a minuscule amount of work done on fires in within individual residences, where the overwhelming number of fire deaths occur. Conversely, high-rise fires are studied in painful (if not realistic) detail, despite the fact that you won't die in a US high-rise building from fire, unless the building gets attacked by an airplane, and the ability of the FSE profession to remedy the latter situation is not contemplated. I do not criticize researchers for this situation, since their work has to be funded by some institution, generally a government agency, and such agencies to a large extent dictate the problems they want to have addressed. But it is undeniably a social malapportionment of resources on a grand scale.

I need to emphasize that the issues here are especially relevant to human factors studies. Fire dynamics is relatively similar in buildings small and large, thus this leaves human factors as the area where the differences are large. To be prepared for the fatal

high-rise fire that is not going to happen, there have been countless studies focused on observing people march down a high-rise staircase. Yet, this research not only does not seem to have a potential to remedy anything, there is in fact nothing to remedy, since the fire losses are just not there. But even a hundred years ago, when there were no sprinklers in tall buildings, geometrical inadequacy of staircases was almost never the problem. Instead, problems were more likely to be a chained-shut exit door or a lack of warning to start evacuating until it is too late. Neither of these problems is cured by a careful study of fire drills.

The same situation is reflected in building codes, not just in the research area. In the context of today's robust sprinkler systems, there really need to be only three rules for high-rise building safety: (1) make sure it is fully sprinklered with a properly designed and maintained sprinkler system[†]; (2) keep the stairways and egress passages clear, and (3) do not chain the exit doors shut. Yet, our building codes take the inverse strategy again: an overwhelming plethora of requirements for commercial buildings, even more so for high-rise buildings, and a much lower grade of provisions for residences.

You cannot solve a problem if you put your resources into where the problem is not, as opposed to where it actually is. My own belief is that this situation is largely due to the fear by public officials of adverse publicity. If the news media reports that "a father, mother, and two children died in a house fire today," the story is generally limited in its impact. I believe the officials are afraid that, potentially, there could be story about 4 people dying on the 50th floor of some high-rise building, and it would create the impression that they have not been doing their job, whereas the house fire outcome seems not to reflect on their job. This fear does not work to the benefit of society, and I will return to the question of misallocated resources later in this paper.

4. COLLECTING STATISTICS WHICH ARE MEANINGFUL

I know very little about the statistics collected in other countries, so I shall speak of the situation in the US; however, I have not seen that other countries would be much ahead of the US in this regards. First, we have to consider what are the most important questions that we would like to ask of a statistical database. In my view, these would be topmost:

[†] I am not making the same comment with regards to sprinkler systems for industrial or warehouse occupancies. We still have very serious—though rarely lethal—fires in such fully sprinklered buildings. This is most commonly due to change of occupancy from low to high hazard, without making appropriate upgrades to the sprinkler system. A smaller number of incidents are due to failures to properly maintain the water supply to the sprinkler system.

- *How did the fire start?*
- *How were the occupants alerted?*
- *How did the occupants cope?*
- *How many persons died, were seriously injured, or non-seriously injured?*
- *How effective was the fire department?*

4.1 How Did the Fire Start?

The US NFIRS data system has several data elements pertaining to this question. But the information obtained is much less than would be desired. Much has to do with the first major point of discussion above, namely that external fire investigation results do not get fed into the system. This is complemented by the fact that fire department expertise is sometimes very limited. For example, electrical fires are clearly important, yet there is no US fire department which has an electrical engineer on staff who could competently delve into this. But even more basically, we would certainly want to know if the fire started as smoldering or flaming combustion. This is essential! Yet, there is no information collected on this.

4.2 How Were the Occupants Alerted?

The NFIRS data form does ask for some information on smoke detectors, but this is hardly adequate. For instance, it is now very well understood that ionization detectors are poor at sensing smoldering fires, while photoelectric units give a much better response. But the NFIRS system does not ask what kind was in use. Then there is the question of effectiveness. The form gives several choices, but this does not answer a crucial question: Did the occupants first learn of the fire due to the detector sounding, or did it activate after they were already well aware of what was happening, and became just a disruptive noise to contend with during the emergency? In my own experience of studying actual fires, I find that even questions that are asked by the NFIRS form are often not taken seriously by the fire department. For example, an important question block is “Detector failure reason.” The supposition is that the fire department personnel will investigate why the detector failed to warn, if that was what occurred. But too often I simply see a note in the narrative that they “Did not find any detectors, although occupants told us they had (one or more).”

4.3 How Did the Occupants Cope?

Back in the 1970s and 1980s, one of the very early concerns of fire safety science was to understand what occupants did in fires. Two efforts were noteworthy in this regards. Prof. John Bryan at the University of Maryland investigated and documented numerous fire incidents, from the point of view of occupants’ behavior. He presented extensive data studying residential and diverse occupancies in the 70s [8], then narrowing down to health care occupancies in the 80s [9]. Bud Levin at NIST on the other hand took an engineering approach (even though he was a psychologist) and developed the first-

ever evacuation model which attempted a certain level of behavioral realism [10]. It is dismaying to see that, to this day, the majority of evacuation modeling efforts take into account no aspect of human behavior at all, and they represent evacuation like a flow of water or marbles downstream. But Levin understood that, when hearing a fire alarm, a person is highly unlikely to (get dressed if needed, then) proceed marching to the exit. Instead, he realized that especially in a private house, a person is likely to investigate the nature of the fire, possibly attempt some firefighting, search for family members, and sometimes do various other tasks before even attempting to set forth on the exit path.

I mention the above situation in connection with gathering of meaningful statistics, since it is completely obvious that NFIRS data are not of much value to anyone trying to understand escape from fires. The data forms basically ask no questions whatsoever about the history of the occupants' movements. Thus, while behavioral evacuation models to exist (even though they are outnumbered by mechanistic ones), it is hard to see that a model can be good if input data for it are unavailable.

Turning here to the question of what the fire safety engineer should do, I think the first answer has to be "get started," since that has not happened. If fire deaths are overwhelmingly in the home, that really should be the focus of the profession[‡], if the desire is to provide a social benefit and not just provide employment for engineers. The profession can justifiably congratulate itself for the success of smoke detectors. But this occurred several decades ago in the US and in various other industrialized countries, so what should next be done? I do not have easy answers here, but I do not believe answers will come unless there is a focused discussion on the topic first, and I have not seen that happening.

4.4 How Many Persons Died, Were Seriously Injured, or Non-Seriously Injured?

This would seem to be the most trivial of data collection exercises, yet it is done very badly. Generally, if a victim is tallied as dead, then this is an accurate recording of facts. But what about the injured persons? First, if a person is breathing and gets taken away in an ambulance, this is listed as an 'injury.' But if the victim has 80% burns on the body, the likelihood is high that in less than a week they will be deceased. Yet, the fire departments have no system in place to account for this. It would not take much effort. All it would take would be a very modest file-tracking, so that a fire service person can contact the hospital, say 60 days later, and enquire: "Is person X alive or dead?" An accurate record would then take this possibly updated status into account. Another

[‡] I realize that a certain amount of FSE effort and resources necessarily have to go towards protecting high-value properties even if there a negligible risk of death or injury in those situations. However, I do not accept that this should be sole, or even the primary, focus of the profession.

serious problem is that ‘injuries’ are treated as a yes/no question. This is obtuse. There is a world of difference concerning the effects of the fire on a person who went to hospital with a sprained ankle, versus one with burns over much of the body. Yet both are coded identically, ‘injured.’

4.5 *How Effective Was the Fire Department?*

I can only suppose that this question is not studied since too many fire departments are embarrassed by their poor service record; there is no other plausible reason for this. To assess the fire department effectiveness, the data to be collected can be simple:

- The time the alarm was received
- The time the first equipment was dispatched
- The staffing level of the first dispatched engine
- The time the first engine arrived on scene (as contrasted to equipment that does not put water on the fire)
- The time that water was first applied
- The time that the fire was controlled
- The percent of the structure that was destroyed by the fire.

NFIRS currently does include all of these except the crucial “time water was first applied.” But there are problems. It is all too common to find that the fire department never fills in much of the required data, especially the time that fire was controlled. But there is an even yet greater problem. The data are effectively kept from the public. A person might very well want to know, how does my fire department perform, compared to other fire departments in the area? While the crucial performance variable of the time water began to be applied cannot be found, at least one could compare fire department effectiveness by measuring the time from receipt of alarm to first engine on scene. The time from receipt of alarm to fire being controlled would also be a good measure. Yet, the citizen cannot get these data. In principle, there are two delivery mechanisms: (1) the raw NFIRS records themselves, or (2) statistical reports prepared by some organization. But the only two organizations preparing reports are NFPA and US Fire Administration, and they have deliberately stayed away from anything that could be construed as evaluating fire departments. On the other hand, unlike many other government databases, the NFIRS data is not available on line. Instead, the person would have to buy the data collection at \$500 per each year. Even if he were to do that, analyzing the data is also not easy, since the data cannot be accommodated within a spreadsheet and a specialized statistical data analysis program is needed.

Building destruction is probably the best measure of a fire department’s effectiveness, since a more effective firefighting operation will lead to lower destruction. At the present, NFIRS does ask for dollar estimates of loss to building and contents, along with the pre-incident value. But this data request is generally without value for two reasons: (1) Fire service personnel are not trained in assessing building costs; and (2) They often simply

ignore this request. It would not seem hard to train the personnel to estimate costs, but I have never encountered a single item of training material which would try to do so. It would make better sense to convert this into percentage questions: What percent of the structure was burned; and, what percent was damaged by smoke but not heat?

5. DEVELOPING COST-EFFECTIVE CODES AND STANDARDS

More is better, if you don't have to pay for it! But clearly we do have to pay for fire safety in buildings. Here, it is most important to distinguish provisions for houses, versus other categories of buildings, including high-rise structures of all kinds. The US building codes have traditionally and inappropriately taken an inverse stand with regulation. Private houses have relatively few code restrictions placed on them, while all other categories of buildings have greatly more stringent regulation. Yet, as we saw above, this is the exact opposite of where the fire casualty problems lie. Thus, immediately one may get the sense that there is a serious misallocation of societal resources.

Even more problematic is the fact that new building code provisions are almost never justified on a cost/benefit basis, even in the application of performance-based codes. Yet, this is the only legitimate basis for allocating resources, at least in countries which are not theocracies, where I presume the rationale for any social action would be: "Our religious scriptures command that this be done." Should we feed the hungry, or provide redundant, ineffectual code provisions that simply use up the resources of the society? It is truly disappointing that we have evolved such a poor system for allocation of our resources. In the US today, building code provisions basically get enacted in the following manner. Someone identifies that—under some combination of circumstances—a hazard could be created. Sometimes there is one case incident where something went wrong, but many times there are zero incidents. It's just that someone thought that, conceivably, something could go wrong. A code change proposal is made and it is debated. The people doing the debating are a mixture of manufacturers and government officials, with trivial representation by any other sectors of society. There will generally be a particular manufacturer, or a particular industry, which will see increased sales from the new regulation. Thus, they argue strenuously that the public is at risk unless the new provision is enacted (which will, of course, enrich them). The government officials are generally honest but they typically have no basis for rejecting the proposal. There are no data presented showing what the new proposal will cost and, conversely, what—if any—deaths or injuries would be averted. In some cases enriching one sector of manufacturers would be detrimental to the sales of another group's products. In such a case, there will be a fiery dialogue back and forth between these industries. But at the end of the day, the government officials will take a decision one way or another, and no cost/benefit data will have ever be seen. In some cases, there are some research data put on the table that ostensibly quantify the hazard. But this is never accompanied by any risk analysis which would cost out the benefits and the economic burden.

The above process pertains to all building code provisions. But fire safety provisions are generally the most onerous and least well-justified part of the code. There is generally not much excessive provisions made for, say, the load-bearing strength of columns, or proper drainage of plumbing. But fire safety provisions have historically been added onto time and again, without any consideration of costs and benefits. The only similar status in the US codes seem to be the electrical provisions, where the concept of cost-effectiveness seems never to play a role, except in the rare case of an industry supporting it, for example allowing steel conduits to be replaced with ones of PVC. I would like to see the fire safety profession be of unequivocal benefit to society. But I believe this requires that costs of fire safety provisions be taken into account seriously.

6. CONSIDERING THE UNINTENDED CONSEQUENCES OF FIRE SAFETY PROVISIONS

Fire safety measures have often been undertaken with too little consideration for potential problems that might be created. In the 1980s we had a problem in the US whereby FR-treated plywood started to be encouraged by building codes as roof sheathing material. In a very few years, many of these roofs started to collapse, since the chemicals used had not been tested for the effects on strength, yet turned out to destroy the strength of wood fibers by progressive hydrolysis. In the same era, polybutylene pipes became popular as a low-cost material for fire sprinkler piping, only to fail rapidly from interactions with water contaminants. But in this section I will focus primarily on 'solutions' that created serious health problems.

For many, many years, asbestos was a 'wonder tool' of the FSE profession. Often, simply adding asbestos to just about anything was seen as a good solution. Now of course it not only is an embarrassment, but, in the US, led to essentially every building product manufacturer who ever used it in their products, even to a limited extent, into going bankrupt due to lawsuits against asbestos.

In the same way, carbon tetrachloride was widely used as a fire extinguisher, even in people's homes. It is indeed very effective in stopping chain-branching combustion reactions. However, the toxicity was eventually recognized and it became a substance limited to industrial uses where personnel exposure is carefully controlled.

Polychlorinated biphenyls (PCBs) were the best, most fire-safe transformer fluids invented. It was a simple and obvious way to limit fire hazards from large, oil-filled transformers. Eventually, of course, these substances were recognized to be highly toxic and stopped being allowed as a transformer fluid.

In the early part of the 20th century, ammonia was the most common refrigerant fluid. It is moderately toxic, combustible, and corrosive to a number of materials. In 1928,

Freon [11] was invented and was a big boost for both fire safety and functional reasons. It is fire safe, has no significant corrosion aspects, and is not a problem as regards acute inhalation toxicity. Eventually, a big problem did become apparent: when dispersed into the atmosphere, it acts to destroy the planet's ozone layer, which is necessary for the health of living creatures.

Very similar benefits and harm were found with the Halon family of fire suppression agents, especially Halon 1301 (bromotrifluoromethane). Halons are halogenated hydrocarbon compounds rather similar to Freon and were widely used for fixed (and some portable) fire suppression systems in various industrial and commercial applications, including onboard Air Force airplanes. Halons have also been discontinued along with the Freon compounds, for the same reason.

The latest family of substances which were introduced for fire safety purposes, only to later be found to be a serious toxicological problem have been halogenated flame retardants that are added to plastics or foams. In consumer applications, it was unfortunate that for most such uses, the concentrations were low enough so they would not prevent fires, but high enough to produce harm, including accumulating in mothers' milk and leading to decreased IQ and neurological damage to children [12,13]. Of most concern to our profession is the fact that these compounds are now suspected of contributing to the increases incidence of cancers seen in US firefighters, including odd cancers such as testicular cancer [14]. Up to this point, the flame retardant manufacturers have been in denial and fighting a rear-guard action to preserve this market, even though very recently some of them are offering 'green alternatives.' This family of halogenated flame retardant compounds is especially problematical since its toxicity increases when exposed to heat, pyrolyzed, or combusted, producing dioxin and furan compounds in the process. Even proponents of the halogenated organic FR compounds are on record [15] as noting that dioxins are "the most toxic family of chemicals ever studied."

Many of these past problems were caused because knowledge about harm to health did not yet exist at the time. But appropriate methods do exist now, and have existed for several decades. Thus, for example, it is truly distressing to see that TDCPP, or tris-(1,3-dichloro-2-propyl)-phosphate, which was identified as harmful to health in 1978 [16] and removed from use in children's sleepwear, is currently still sold for FR-treating polyurethane foams.

The approach to toxic chemicals differs in different countries, but in the US, government regulation has been almost totally ineffectual. Laws are such that only foods, drugs, and pesticides must be tested and approved prior to sale, while more recently ozone-depleting chemicals have been subjected to control. All other categories of chemicals receive essentially no control and the chemical companies can make and sell what they wish. The US actually never signed the Stockholm Convention treaty,

which has banned several of the most harmful FR chemicals. Some US States have individually been taking action against certain chemicals, but national regulation remains inadequate.

Thus, FR chemical makers, and some fire science specialists, have continued to promote harmful chemicals on the basis that they can help mitigate fires. To me, this has been personally distressing, since the industry primarily based its claims on a 1988 study of FR chemicals for which I was the lead author [17]. The study found that—in the products tested—the FR chemicals were so effective that materials showed only negligible combustion; consequently, acute toxicity problems were minimal. The industry took these findings and created an advertising campaign which suggested that all FR-treated products will behave in a comparable manner, including consumer-sector goods such as FR-treated furniture foams or thermal insulation products. The facts, however, are very different. (1) The products tested were state-of-the-art formulations, containing greater loadings of FR chemicals than do consumer products. (2) The room fire tests that were run were ones where all of the products in the room were heavily FR loaded. This configuration does indeed accord with a state-of-the-art scenario where all products would be heavily FR loaded. But this type of arrangement does not reflect on the residential environment, where many products have never had FR chemicals added and never will, while others use FR chemicals but in amounts which are ineffectual for fire safety. I had already published a report in 1982 [18] which clearly showed that FR chemicals, in the amounts used, had nil effect on the fire safety of residential upholstered furniture. Yet the industry chose to ignore those findings and, instead, claim that the results on state-of-the-art type formulations somehow indicate what happens in house fires with consumer goods.

The FSE profession generally still has not faced up to the issue of the toxicological problems of halogenated organic FR compounds. This, one would hope, will be happening soon. However, in the broader context, it is truly important that the lesson should be learned that proposed ‘wonder’ solutions to fire safety problems be scrutinized very carefully for potential harm, prior to being adopted into widespread use. Unfortunately, the track record is not reassuring. None of the debacles discussed above seem to have led the profession to contemplate the wisdom that is always taught to first-year medical students: *Primum, non nocere* (“First, do no harm”).

7. CONCLUSIONS

Unlike 40 years ago, fire safety engineering these days can properly be considered a science-based profession. The impressive achievements of these four decades comprise a remarkably list, well documented in the SFPE Handbook [19]. Yet, there are areas of notably weakness and the ones discussed here stand out as being especially worth considering and remediating.

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