Neglected areas in fire safety

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This material is presented in the hope that the fire service will considered this information, discuss it among their peers and use it to evaluate their specific departments operations. It is intended to encourage fire officials to initiate changes based upon new evidence coming from the scientific community. This article contains implications for the two major divisions of a fire agency: operations and prevention. Those involved in fire suppression may have to review tactics and strategy. Fire prevention may have to consider changes in fire and building codes or fire investigation techniques.

We were requested to review this articles content and implications. Our belief is that this article addresses a concern that the fire profession is currently facing. Its recommendations are valid and the information important for our future actions. The last paragraph in this article represents our collective thoughts about the use of this information.

Ronny J Coleman and Hugh Council

INTRODUCTION

Since about 1970, the fire safety profession in the U.S. has had the benefit of a strong contribution of science to the field. This has helped everyone from fire chiefs, to lay persons, to engineers and code officials. Yet there are areas which have been neglected due to lack of awareness of the issues. Five of those areas will be examined here:

(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.

Learning from fire incidents in a systematic way

The best way to improve fire safety is to have good knowledge about real fires that occur. And the only way to learn what happened in a fire is to do a fire investigation. For this to be valuable, the person doing the investigation must be highly skilled and trained in that area. Yet, in the U.S., there are almost no fruits of this endeavor. To see why, the process must be understood. Almost every fire of significance gets investigated by two fire investigators, the first one from the fire department, 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 some fire departments, well-trained investigators are tasked with the job. Yet, in others, the fire investigator position is a slot a person has to fill for a couple of years just to climb the promotion ladder. This results in disinterested employees doing a desultory job.

(2) The information from the investigation reports is not disseminated. This problem has several 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 are discussed 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 to be disseminated.
- 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 some 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 U.S. 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. The only place where details of actual fires are regularly published are *Fire Engineering* and *Firehouse* magazines, which carry such stories in almost every issue. But these stories focus solely on suppression tactics, and do not delve in causes of ignition, fire spread, or casualties.

Studying fires in residential houses

In the U.S., 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%[1]. 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 U.S., where about 50% of high-rise buildings are sprinklered and building codes prevent the use of interior finishes prone to rapid fire spread. The experience is 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 fire deaths in these structures are minuscule[2].

The issues here are especially relevant to human factors studies. 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. 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 are 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 needs 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) don't chain the exit doors. Yet, our building

[1] Statistics from Fire in the United States, 15th ed., FEMA, 2009, and High-Rise Building Fires, NFPA, 2011.

[2] The fire safety profession cannot prevent losses due to bombing by airplanes.

codes take the inverse strategy again: an overwhelming plethora of requirements for commercial buildings, even more so for high-rise buildings, and much less protection for residences.

Collecting statistics which are meaningful

First, we have to consider what are the most important questions that we would like to ask of a statistical database, and it is likely that these are of topmost interest:

- *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?*

How did the fire start?

The NFIRS 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 limited. Since fire departments do not have electrical engineers on staff, it should be essential to get this information fed in from insurance company investigations. But even more basically, one 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.

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 systems 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 in the emergency? An additional problem is that fire departments often do not investigate further when occupants tell them they had detectors, but remnants of the devices do not show up in a quick search of debris.

How did the occupants cope?

One of the main reasons that persons die or are badly injured in fires, is because they made some bad decisions in coping with the fire. Thus, it should be essential to document their coping behavior, and this should be fed into NFIRS. But at the moment, NFIRS has no capability of dealing with this crucial question. It is well-known, at least to persons working in the forensic field, that often occupants do unwise things, such as trying to fight large fires or reentering burning buildings. Most pathetically, some persons get badly burned when they, exceedingly unwisely, try to carry out burning mattresses, Christmas trees, or other burning objects.

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 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 serious problem is that 'injuries' are treated as a yes/no question. 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.'

How effective was the fire department?

NFIRS could potentially serve to quantify the effectiveness of fire departments; this would then help those departments improve which need to. 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 of 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." However, 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.

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 asks for dollar estimates of loss to building and contents, along with the pre-incident value. But this data request is generally without value since: (1) Fire service personnel are not trained in assessing building costs; and (2) they often ignore this request. In view of this, it would be better to ask percentage questions: What percent of the structure was burned; and, What percent was damaged by smoke but not heat? This would be feasible for the firefighters and much more informative.

Developing cost-effective codes and standards

More is better, if you don't have to pay for it! However, society does have to pay the costs arising due to fire safety requirements. The basic problem is that new building code provisions are almost never justified on a cost/benefit basis. Yet, this is the only legitimate basis for allocating resources. In the US building codes, not only is there no requirement for quantifying the effectiveness of any provision, but the system is largely dominated by manufacturers, who stand to gain whenever additional hardware requirements are enacted, even if these have very little positive effect on fire safety. It would be of tremendous value not just with regards to fire safety provisions, but across the board, if building codes were reformulated to require a viable benefit/cost ratio for both old and new provisions.

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 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. These are functional failures, but the worst examples are 'solutions' that create serious health problems.

In this regard, the history of the fire safety profession is filled with substances which were heartily promoted, only to discover later that they create serious problems for the health of people or the environment:

- asbestos
- carbon tetrachloride extinguishers
- polychlorinated biphenyls (PCBs)
- Freon refrigerants and solvents
- Halon fire suppression agents.

The latest family of substances which were introduced for fire safety purposes, only to later be found to be a serious toxicological problem are halogenated flame retardants that are added to plastics or foams. In consumer applications, the concentrations used have been 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[3]. 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 U.S. firefighters, including odd cancers such as testicular cancer[4]. This family of halogenated flame retardant compounds is especially problematical since its toxicity increases when exposed to heat, pyrolyzed, or combusted, producing highly toxic dioxin and furan compounds in the process. Even proponents of the halogenated organic FR compounds are on record[5] as noting that dioxins are "*the most toxic family of chemicals ever studied*."

Concerning harm from unintended consequences of fire safety provisions, it is essential that the fire safety profession espouse the wisdom that is always taught to first-year medical students: *Primum, non nocere* ("First, do no harm").

CONCLUSIONS

In the beginning of this article, it was mentioned that the fire safety profession is currently benefiting from the work of scientists at many different levels. One cannot help but observe that the very tactics and strategy of the fire service is currently under review.

Using science to provide safer means of combating fires is currently being discussed at many agencies. For example, the work being done by Underwriters Laboratories (UL) and the National Institute of Standards and Technology (NIST) is substantiating a need for changing fire service tactics and strategy based upon scientific fact.

This article proposes that we foster a stronger working relationship between the fire service and the scientific community. Building of future bridges that are based on scientific evidence between the scientists and the fire service will improve upon the delivery system to better protect our communities. It should also help us with the need to improve upon firefighter safety. This is going to require a change of attitude on the part of the fire service. It will require a different relationship with the scientific community. It will also require a different level of dialogue at the national and the international level.

[3] Babrauskas, V., Blum, A., Daley, R., and Birnbaum, L., Flame Retardants in Furniture Foam: Benefits and Risks, pp. 265-278 in *Fire Safety Science—Proc. 10th Intl. Symp.*, Intl. Assn. for Fire Safety Science, London (2011).

[4] LeMasters, G. K., et al., Cancer Risk Among Firefighters: A Review and Meta-Analysis of 32 Studies, *J. of Occupational & Environmental Medicine* **48**, 1189-1202 (2006).

[5] Zaikov, G. E., and Lomakin, S. M., Polymeric Flame Retardants: Problems and Decisions, pp. 243-259 in *Handbook of Environmental Degradation of Materials*, M. Kutz, ed., William Andrew Publ., Norwich NY (2005).