Fire Safety Challenges in the 21st Century

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ABSTRACT: The twentieth century was a time of great change and growth in society as well as in fire safety. As we begin a new century, it is important to reflect on these changes, as well as the fire safety challenges in the future.

These challenges go beyond the day to day work of fire protection engineers. This paper reviews challenges that exist in the areas of fire prevention, firefighter safety, and fire protection.

The overriding fire safety challenge we face is to focus on reducing the cost of fire to our society. This will require national and international leadership, focus, resources, and motivation. The key to our future success is research: policy, scientific, and field research. Through these efforts, we can come to understand the fire problem, what fire safety efforts and measures are effective, and how these effective measures can be implemented to reduce the cost of fire in our society.

This paper is based on Dr. Beyler's 2000 Guise Medal Lecture.

KEY WORDS: fire prevention, firefighter safety, fire protection, research, costs, safety, performance-based design, fire codes and standards, test methods, education, fire losses, prescriptive requirements, fire safety design.

THE FIRE PROBLEM

IN LOOKING AT our future challenges, it is useful to reflect on our fire safety performance over time. Deaths due to fire have been steadily decreasing since the early part of the 20th century. Annual fire death rates per thousand in the U.S. have dropped by 85% since World War I (see Figure 1). The fire deaths in homes have decreased from 6,000 per year in the 1970s to 2,895 per year in 1999 (see Figure 2). Similar progress has been made in firefighter deaths. In terms of fire injuries, the record shows no clear progress for civilians or firefighters (see Figure 3). In terms of life loss, impressive progress has been made. The long-term trend is certainly the result of many complex factors with roots in both our society and our technology. The reductions produced between the 1970s and the 1990s are widely attributed to residential smoke detectors. In the 1970s, the percent of homes with smoke detectors was in single digits. In the 1990s, the percentage is in the nineties.

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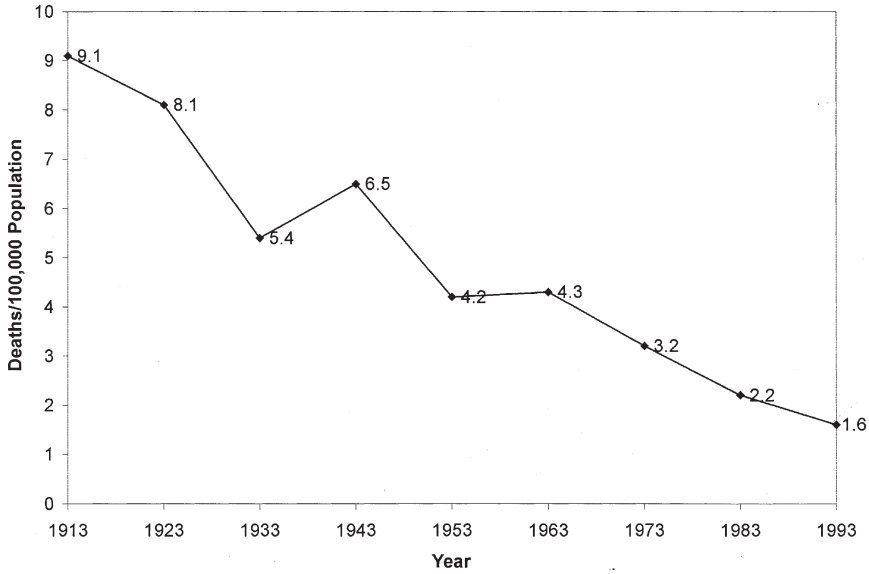

Figure 1. *Fire deaths per year per 100,000 population over the 20th century in the U.S. (adapted from Hall and Cote, 1997 [1]).*

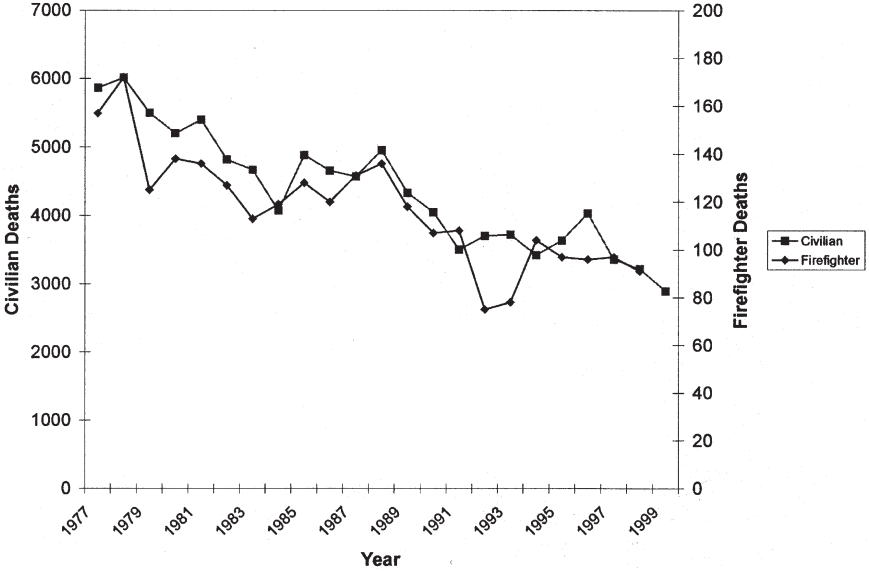

Figure 2. *Fire deaths per year for civilians (in the home) and firefighters since 1977 in the U.S. (adapted from Karter, 2000 [2] and Washburn et al., 1999 [3]).*

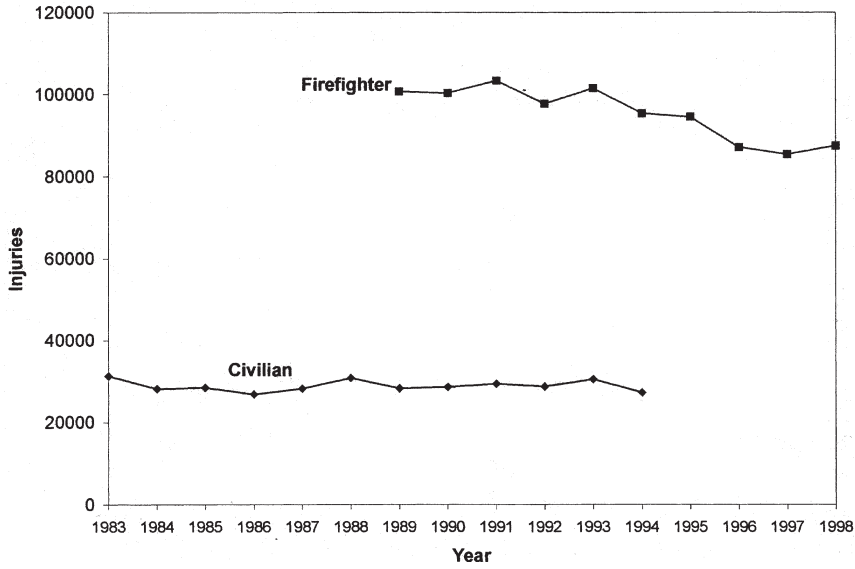

Figure 3. *Fire injuries per year for civilians and firefighters in the U.S. (adapted from Hall and Cote, 1997 [1]; Karter, 2000 [2] and Karter and LeBlanc, 1999 [4]).*

Our progress in property protection is less clear and dramatic. Over the last century, per capita direct property fire losses have been essentially steady in constant dollar terms (see Figure 4). The loss as a fraction of gross national product dropped markedly during this period, though most of the progress occurred in the first half of the century. Focusing on the past twenty years, the number of fire incidents has been reduced by half, while the direct property loss, based on constant dollar average per structure fire, has been relatively steady (see Figures 5 and 6). It would seem that we are making progress.

However, the cost of fire is not merely the direct property loss [5]. In fact, the direct property damage may be less than 10% of the total cost of fire. Meade [6] estimates that the total cost of fire in the U.S. in 1990 was around $100 billion, while direct property losses were under $10 billion. Clearly, minimizing the total cost of fire can be a very different thing than minimizing direct property loss. Table 1 shows the major cost areas based on information available in the Meade Report. While these costs are very approximate, they tell an important story. Hall's analysis of 1996 data [7] refined and updated Meade's analysis of 1990 data. The notable increases are in human costs, in rapidly rising fire service costs, and in increasing building costs, resulting from increased building activity. The increase in human costs results from Hall's revised valuations of injuries and deaths, rather than a change in the number of injuries and deaths since Meade's report.

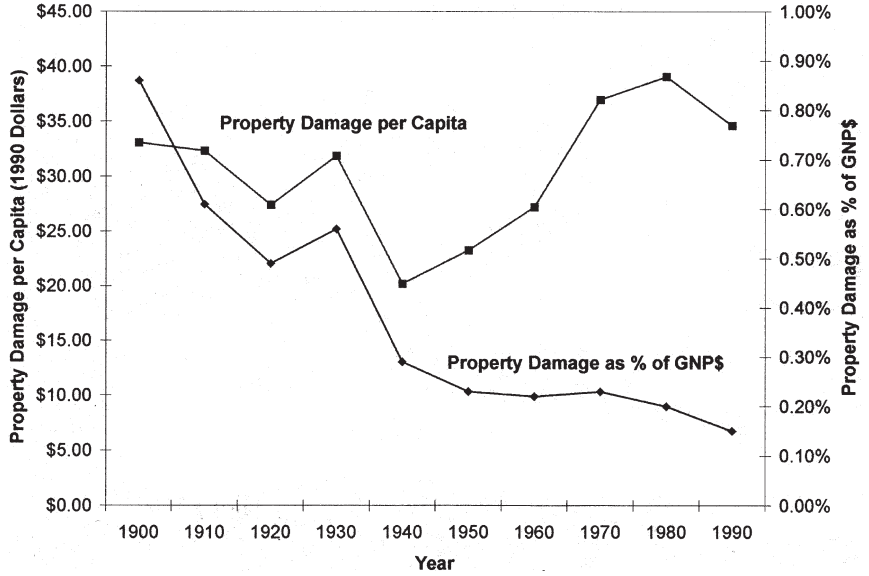

Figure 4. *Property damage trends during the 20th century in the U.S. (adapted from Hall and Cote, 1997 [1]).*

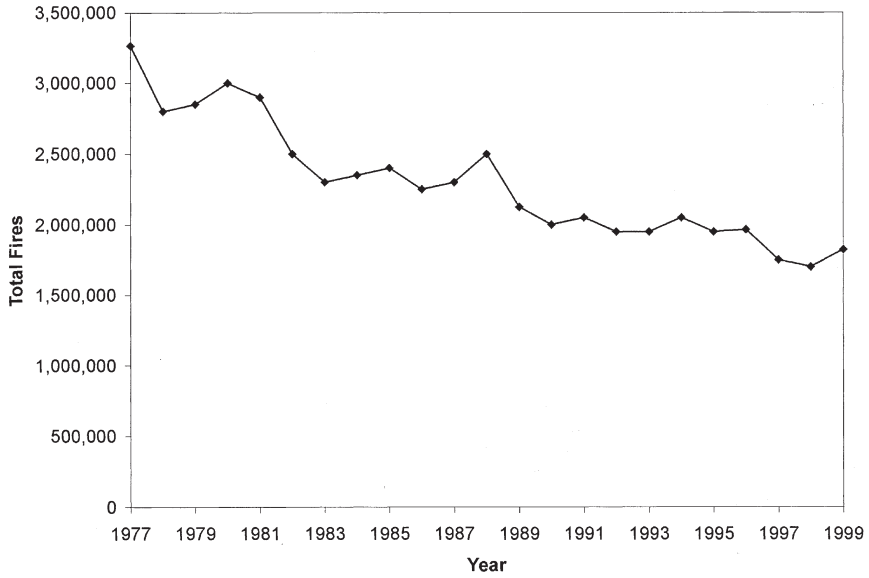

Figure 5. *Number of fires in the U.S. from 1977 (adapted from Karter, 2000 [2]).*

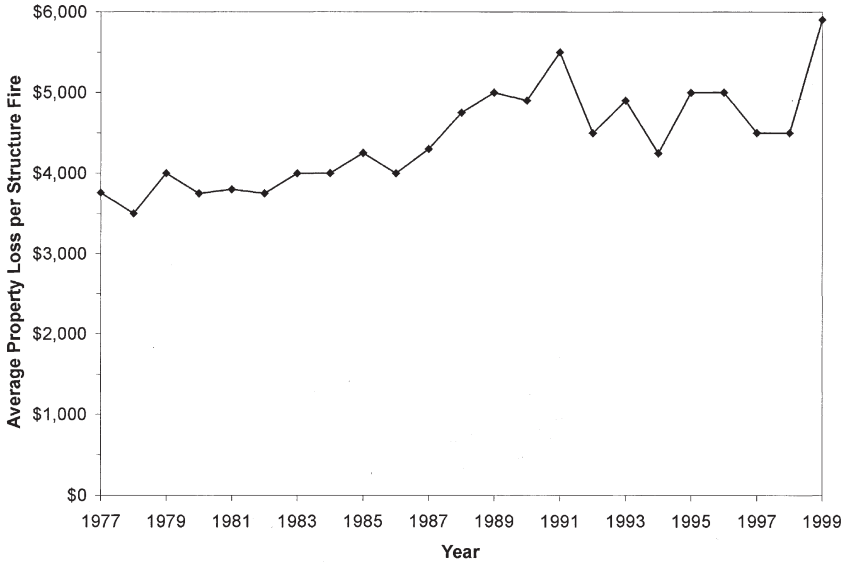

***Figure 6**. Average property loss per structure fire in the U.S. Adjusted for inflation (adapted from Karter, 2000 [2]).*

If the goal is to reduce the total cost of fire, direct property loss is clearly only one component of that cost. Table 1 indicates that we spend twice the resources to deal with fire losses and prevent fire losses than the fire losses themselves. The efficiency and effectiveness of these very expensive measures bear great scrutiny.

Table 1. A rough estimate of the cost of fire.

Cost Component	1990 (Meade) Cost ($ billions)	1996 (Hall, J.) Cost ($ billions)
Fire Losses—Total	31	62
property	9	12
interruption	9	2
injuries and deaths	13	48
Insurance	6	6
Fire Service*	10	18
Fire Prevention and Protection—Total	49	58
building	21	26
equipment	18	20
maintenance	6	7
other	4	5
Total	96	144

*The fire service cost does not include the value of the replacement cost of volunteer firefighters.

FIRE SAFETY CHALLENGES

An economist might find there to be a single fire safety challenge; to minimize the total cost of fire. Others might assert that the current fire losses are clearly socially acceptable (based on the inattention of the public to fire as a political issue), and hence the challenge is to provide the current level of protection at the least cost. Alternately, others might assert that the current expenditures for fire safety are clearly socially acceptable, and hence the challenge is to provide the best level of protection possible with the current level of expenditure. Whatever one's view, the provision of cost effective fire safety is a key challenge we face.

It is fair to say that today a building can be made and maintained to be as fire safe as is desired. The real questions are: what is safe enough and how can a defined level of safety be achieved at the least cost? We need to determine the effectiveness and cost efficiency of existing methods and search for methods that enhance effectiveness or improve cost efficiency.

Fire Prevention

Preventing fires is the first line of defense in fire safety. Our successes in this area are difficult to assess, though the trend in the number of fires attended by the fire department is a reasonable measure. Over the last two decades, the number of structure fires has been reduced from about one million per year to about a half million per year. This figure could result from actual reductions in the number of fires as well as early warning of fires that are terminated without fire department response. Whatever the basis for the reduction, this represents progress. Nonetheless, it is also all too easy to identify consumer or industrial products that have led to numerous fires. Products, like halogen torchiere lamps, coffee pots, toaster ovens, and Christmas decorations, to name but a few, have been produced and sold in large numbers and were later found to have been major causes of fires. The test methods designed to identify these dangerous products are either poorly conceived or poorly used. Often the products remain in use long after the hazard is identified and, in some cases, there is no remedial action at all.

Mass production has been the means by which once expensive items become affordable and available to the masses. In most regards, mass production makes our job of identifying hazards and eliminating them more tractable. With mass-produced items, the cost of testing and inspection is shared over a very large number of units, so greater safety can be afforded. However, when a mass-produced product is a hazard, the harm is also done on a mass scale. The involvement of the public in the formulation and implementation of test methods and inspections is at this time very slight. The standards that exist are largely the product of the industry that produces the product. Public scrutiny tends to follow failures in the field when harm has already been done in large numbers. There is a

need for more focus on implementing high quality test methods for products with broad input from industry and the public sector. There is a need to further develop our ability to identify failures in the field and respond to identified failures in a swift and effective manner.

According to Meade and Hall, we spend $20 billion a year in assuring fire safe products. One must question if this money is being efficiently spent. In many instances, it appears that product safety is made a simple matter of satisfying legalistic requirements and is not really about creating safe products at all. The torte system stands as a potential remedy for safety failures, but this method is an after-the-fact remedy that, at its best, may alter behavior out of fear of subsequent litigation. At its worst, litigation is expensive, inefficient, and compensates only a fraction of those harmed. The improvement of product fire safety through a more thoughtful approach to test method development, through enhanced vigilance, and through improved identification of failures is a major challenge.

Beyond the safety of the equipment itself, the installation of the equipment in buildings requires ongoing vigilance through inspections and issuing permits. These activities fall in part to the public sector and in part to the installer. There are no opportunities for economies of scale in this area. Safe installations are made one at a time, though the original equipment design can make this easy or difficult. The key to success here is education and vigilance.

The other primary component of fire prevention is education. Fire prevention education has always been the stepchild in the fire community, never really getting the resources and attention it requires and deserves. We need to approach education in a creative and focused manner. This area, like many in fire safety, requires real, ongoing attention by the fire safety community as a whole. There is a strong need to improve both the awareness and informational aspects of education.

Firefighter Safety

While firefighter deaths have decreased from 150 per year to 100 per year over the past two decades, injuries among firefighters have been essentially unchanged over that period. This has occurred at the same time that building fire safety costs have increased and during a period of time where a federal agency has been focused on the needs of the fire service where none previously existed. We have increased technology and increased attention, but firefighter safety has not been commensurately reduced. Clearly, we have missed something here and insightful creative analysis is required. Firefighter safety is a public sector issue. While the fire service is a local government responsibility, the problems faced are national in scope. The national efforts over the past decades have been ineffective and the federal government has failed to provide the leadership required in addressing this issue. Leadership and new perspectives on the problem are needed.

Fire Protection

Today, in fire protection engineering circles, the buzzword is performance-based design. It is a noble and rational concept that has the capability to allow implementation of effective cost-efficient fire protection. It allows and requires that the details of a specific building be considered in the fire safety design in a way that is not possible in a prescriptive code-based specification approach. It also requires explicit statement of the fire safety goals and objectives for the building.

Performance-based design is straightforward for individual elements of the fire safety system. Our understanding of one or more aspects of fire protection can be used to provide a known level of performance of a single element. For example, the goal of assuring that the building will not collapse as a result of fire can be approached with existing analytical tools. While the analysis may be complex, the basis for the assessment clearly exists. However, our ability to set goals and evaluate the performance of the entire fire safety system is poorly developed. Such methods are being studied in Australia [8] and Canada [9], but there is much work to be done. We need to develop methods for measuring fire safety performance. Developing the methods required to implement performance-based design at the fire safety system level is a major challenge we face in the 21st century.

We also face challenges in developing the technical and regulatory infrastructure needed to support performance-based design. The recent *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* [10] is an important step forward in this arena. The *SFPE Guide* is based on other documents produced internationally and it describes the process of performance-based design. It is a process document, rather than a technical document. There remains a need for a library of technical documents that describe the analytical tools that are the substance of performance-based design. The *SFPE Handbook of Fire Protection Engineering* [11] and the emerging *SFPE Engineering Practice Guides* [12–14] are the beginnings of such a library of documents. This process of defining the technology is a significant challenge for our profession.

While the technical basis for performance-based design has existed for decades in several areas of fire safety design, we will rely upon the continued growth of fire science to extend the depth and scope of performance-based design. Performance-based design does not require continued growth in fire science, but reaping increasing rewards from performance-based design does require it. While the consolidation of knowledge into engineering tools or models continues, the enabling research that will underpin the tools of tomorrow is being ignored. Our funding of enabling research in fire is the lowest it has been in my professional lifetime. We are already paying a price for this neglect. If we continue to neglect enabling research, we will forego much of the promise of performance-based design. Funding high quality enabling fire research is a challenge to our society in the 21st century.

While research funding is sorely in need of enhancement, money will not be

enough. With the limited resources we now have, we are not realizing the gains that can and should be made. Our research community lacks clear leadership and purpose. The case for a coherent research program has not been made, and the fire community is not firmly committed to research goals and objectives. While the symposia organized by SFPE and WPI [15,16] have provided valuable opportunities for discussion, we don't need additional symposia and meetings on research goals. We need focus, direction, and leadership. It is our challenge to develop this leadership and to develop a vision that meets the needs of the community, which the community can support. This is our profession's challenge for the 21st century.

Performance-based design includes these two separate concepts; design that considers the details of the individual building, and design that explicitly states and achieves a stated set of fire safety goals and objectives. The first goal is properly exclusive to performance-based design. The second is not. Whether the design is based on specifications or performance-based design, it is possible to establish explicit goals and objectives for the design.

Our fire and building codes today are complex, evolving documents with no statement of the level of fire safety that is implied by the requirements. Indeed, not only is the level of safety not stated, it is both unknown and variable. There are often multiple means of satisfying code requirements and there is no assurance that the level of safety afforded by each means is equivalent to the other. Simply stated we do not know what level of safety we are getting. The same methods that can evaluate the rationality and consistency of prescriptive methods can be used to assess fire performance in individual building designs. As such, performance-based design may be the motivating factor that gives rise to methodologies we have always needed to improve our code specifications for fire safety.

While performance-based design has an important role to play in building fire safety design, it is most likely that most buildings will continue to be designed within a specification code framework. This means that in order to make meaningful impacts on fire safety in general, rationality and consistency need to be brought to our specification codes. So behind all this talk of performance-based design is a larger issue of rational fire safety design. This is a larger and more significant issue than performance-based design, since there is no time in the foreseeable near term that performance-based design will dominate over specification codes as an approach to designing fire safety. Our overall fire safety performance for the near future is tied not to performance-based design, but to the rationality of our specification codes. Our challenge as a fire safety community is to develop the methods to assess the performance of specification codes and to rationalize these codes.

UNDERLYING ISSUES

The challenges identified in the previous section are summarized in Table 2. Of

Table 2. Fire safety challenges.

Fire Prevention
• Develop test methods to better define product fire safety performance requirements. • Develop a more inclusive standards making process for product fire safety requirements. • Develop methods for identifying failures in the field and for addressing identified failures. • Identify fire safety education needs and develop creative and focused materials that increase awareness and provide the needed information.
Firefighter Safety
• Reexamine and refocus our efforts in firefighter safety to substantially reduce both injuries and fatalities.
Fire Protection
• Develop methods for higher level performance-based design and technical documents to support fire safety analysis and design. • Develop methods for assessing the fire safety performance and costs of prescribed fire safety measures. • Rationalize our prescriptive fire safety measures through the use of method for assessing fire safety performance. • Reinvigorate basic fire research and focus the research to provide a solid foundation for fire protection engineering.

course, the discussion and the table are incomplete. These broad challenges implicitly contain within them many more focused challenges that need to be met to achieve our broad goal of reducing the cost of fire.

There are several issues that underlie the challenges we face today in the fire safety community. First and foremost, we do not now adequately understand the fire problem itself. The Meade and Hall reports are important efforts to develop an understanding of the fire problem as a whole. However, they also provide an indication of the modest underpinnings for their analysis that underscores our lack of substantive understanding of most aspects of the fire problem. We are unable to even provide credible estimates of the component costs of fire, much less provide a credible understanding of why these fires arise or why the level of damage from these fires results. A corollary to this lack of understanding of the fire problem is our lack of understanding of the effectiveness of the fire safety measures available and in use today. Our codes demand building features that have poorly understood impacts on fire losses. Fire costs the United States 150 billion dollars per year, and we really do not know why the cost is this high, what current efforts are critical to limiting current losses, and which efforts are not effective. We cannot assess the cost effectiveness of the expenditures we currently make

in addressing fire safety concerns. Our poor understanding of the fire problem itself severely limits our ability to rationally address the issue of providing a fire safe environment.

Beyond our very limited understanding of the fire problem, we are collectively not focused on long-term improvements in fire safety. Our efforts are narrow and short-term, and lack a clear vision of how these efforts do or could play a role in the larger goal of reducing the cost of fire. Our businesses, our government, and all our institutions have become so focused on short-term, focused goals, that we have lost track of our broader goals and objectives for fire safety in our society.

The overriding fire safety challenge we face is to focus on our goal of reducing the cost of fire to our society. This will require national and international leadership, focus, resources, and motivation. The key to our future success is research: policy, scientific, and field research. Through these efforts, we will come to understand the fire problem, what fire safety efforts and measures are effective, and how these effective measures can be implemented to reduce the cost of fire in our society.

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