Chapter 12: AFTERWORD

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12.1 A VIEW AHEAD

The previous 11 chapters comprise an objective account of a focused and sustained research effort to effect a change in the state of fire suppression science and technology. The following few pages are a personal prognosis of the evolution of the context into which that technology will be applied and the changes that I believe will result. The ideas have been shaped by my 35 years in fire safety, attendance at hundreds of science, technology, and engineering conferences, and innumerable discussions with friends, colleagues, and adversaries.

The threat that led to the revisitation of clean fire suppressant chemicals toward the end of the 20th century was truly global in expanse. As such, it differed from the motivations for the earlier fire suppression research, e.g., reduced toxicity and greater efficiency. Even though the worldwide losses of life and property mitigated by effective fire protection approach those of global magnitude[1], fire protection is treated by our societies as a regional issue. Our success at localizing the impact of a fire, the cumulative benefit of millennia of empiricism and science, has moved fire control far down the list of perceived global societal necessities. Fires exist and there are local people who put them out.

We can thus presume that when the next issue affecting fire suppression arises, the outcome will be comparable to what we have experienced over the past three decades. An updated set of cultural values, manifested as societal criteria, will emerge. The fire protection community will be called upon to re-assess the necessity and mode of fire suppression in each application. For those cases where such capability is an integral part of providing safety, continuity of operation, preservation of property, etc., we will develop new criteria for acceptable agents and systems. The fire research community and the fire protection industries will then commence the research and engineering to realize the needed capability within the new bounds. The Next Generation Fire Suppression Technology Program (NGP) has provided extensive knowledge for responding to the current threat and provided a durable basis for responding to future stimuli. This knowledge should ease the transitions to new fire protection systems.

During the decade of the NGP, both research and practical solutions for fire control have come a long way. There are forces, already in motion, that over the next few decades will define the future of how fire safety is delivered. Thus, my prognosis is that, by the end of the 21st century:

- Performance-based codes will have replaced the current prescriptive versions. Facility constructors, owners and operators will be required to provide a communally chosen degree of safety. They will have broad flexibility of design and will have to demonstrate that they have achieved the safety objectives.
- Driven by increased international trade, fire standards for product qualification will have been harmonized worldwide, likely within the construct of performance-based codes. Because of the conservative nature of countries and industries, many of these standards will be compromises and thus have the potential to fall short of their purposes.
- People around the world will have accumulated increased possessions and furnishings, as already enjoyed by those in the wealthier countries. As a result, fire loads in dwellings and offices will increase, presenting a larger challenge to building and fire codes.
- The development of fire safety technology, much of it derived from military research investments, will continue to be a (limited) commercially successful undertaking.
- The public will have high expectation for low (*i.e.*, perceived zero) risk. The continued increase in the average age of the population will further increase the demands for safety measures.
- Environmental risk and benefit will receive increased attention.
- Municipal and corporate budgets (*e.g.,* for fire service staff) will continue to be under pressure.
- More sophisticated systems will have become increasingly automated to improve reliability in the face of an insufficient pool of knowledgeable service people.

All of these will drive the development and implementation of installed fire control technologies. By the end of the 21st century, I believe that life loss from fires in the United States and the other developed countries will have diminished by an order of magnitude. There will be similar decreases underway in countries with emerging economies. New hardware and materials technologies will have enabled this accomplishment while decreasing the total cost of fire as well.

Success in the delivery of fire safety has generally resulted from the compounded effectiveness of redundant tactics, e.g., fire resistant walls *plus* fire-retardant products. Performance-based codes are intended to reduce cost and improve design flexibility, both of which are easier to provide when including a fire suppression system. I thus expect that automatic fire suppression will become far more widespread than it is today. In particular, by the end of the 21st century, I expect we will at least see the following:

- Detectors with multiple sensors, backed by pattern recognition software, should soon provide ever earlier recognition of a fire and rejection of spurious signals from non-fire sources. Smart and early fire detection combined with next generation fire suppression devices will ensure the quenching of most fires at non-hazardous levels and with no complications from nuisance alarms.
- Commercial and public buildings and spaces with contents of high or unique value will be protected with low volume water systems, systems using short atmospheric lifetime fluorinated organic suppressants, or systems based on a new generation of solid propellant fire extinguishers (SPFEs).
- New and renovated residences will have fixed central or localized suppression systems using the above technologies.

- In current dwellings that are still occupied and unrenovated 100 years from now, plug-in units, probably based on SPFEs, will be installed.

To mitigate in-flight fires in aircraft cabins and cargo bays, new very low flammability materials are under exploration in such establishments as the Federal Aviation Administration Technical Center. Use of these materials will reduce the frequency and severity of such fires from their already low levels to virtual non-existence.

Well into the 21st century and beyond, aircraft will still be flying on petroleum-derived fuels. (Some workhorse aircraft have extensive lifetimes. For instance, the first 737 flew in 1967[2], and the first B-52 flew in 1954.[3]) Thus, in-flight fires in engine nacelles, fuel tanks, and (in combat) dry bays will continue to be of concern.

Under the present system performance requirements, NGP research has made fire suppression engineering far easier. Designers can proceed with the implementation of C_2F_5H (HFC-125) systems, since it is unlikely that a superior fluid will be discovered for these specialized applications. The volatility requirement (i.e., effectiveness at -40 ºC) is restrictive. However, should a risk analysis allow for relaxing this requirement, NGP research has indicated the few potentially productive chemical directions for moderately less volatile fluids (Chapter 7). In general, new knowledge of how to optimize agent delivery, understanding of transport of agents to obstructed fires, and guidance for the time duration of agent release will help reduce weight and storage volume penalties associated with the evolution from halon 1301 (Chapter 8). The advanced total cost and cost/benefit methodology (Chapter 10) is already enabling choices among competing technologies. There is potential for the use of intumescent materials to restrict the air flow through an engine nacelle and improve the efficiency of any fire suppressant.

NGP research has brought new life to the consideration of two existing fire suppression technologies (Chapter 9). For military aircraft, powder panels now offer a cost- and mass-effective alternative to fluid-based systems for dry bays. Additional testing of the improved designs and examination of powders with catalytic fire suppression capability will further add to their economic and operational benefits. Similar advances in solid propellant fire extinguishers make them competitive with fluid-based systems for engine nacelles and with fluids and powder panels for dry bays. The NGP identified families of compounds from which to select chemicals for inclusion within the propellant or for downstream delivery. The hot exhaust removes the volatility constraint and allows the choice of additive to be made on other grounds, such as cost or materials compatibility.

Nonetheless, there are still some substantive gaps in the full knowledge base needed for the design and implementation of aircraft fire suppression systems.

- Screening for cardiotoxicity from an acute exposure to a fire suppressant. The NGP results indicated that effective fluid suppressants will contain bromine, iodine, or phosphorus atoms. The principal effect of concern from inhalation of a brominated or iodinated compound is cardiac arrhythmia. No accurate test has been identified that predicts the outcome of the dog exposure test described in Chapter 6. Moreover, objections have been raised that the dog test itself is not predictive of human reaction to these chemicals. Physiologically based pharmacokinetic (PBPK) modeling now provides a basis for relating environmental exposure to the concentration of agent in the bloodstream. It remains to develop a quantitative relationship between that concentration and actual harm to people, including those people of heightened sensitivity. The movement of the world away from the use of laboratory animals speaks further for the need of an in vitro test or a chemical measurement, such as octanol-water partitioning.

- Predictive capability for fire suppression system performance. Full-scale testing of chemicals and delivery systems in realistic aircraft-like test fixtures is still necessary to demonstrate acceptability. The NGP developed knowledge of the behavior of agent vapors and aerosols in cluttered environments, the effects of timing and mass loading of the incoming air stream, and flame quenching dynamics. The research has shown that CFD models, combined with validating experiments, can lead to accurate prediction of the success or failure of an injected agent in putting out a fire (Chapter 8). However, the in-flight performance of a fire suppression system is strongly influenced by the initial and boundary conditions surrounding the fire and the fire "compartment." It remains for succeeding engineering to extend the NGP simulation results to achieve assured replication of the performance of the range of suppression system operations for the suite of possible fire and fire suppression events. The results would serve as a design tool and as the basis for simplified system certification.
- Instrumentation for new chemicals. The NGP was successful in developing technology for high speed, real-time, in situ monitoring of HFC-125 (Chapter 5). This is the most likely agent to be implemented as a compressed fluid. The NGP also demonstrated that the incorporation of a molecule containing, e.g., bromine, iodine, potassium, or phosphorus atoms, into a solid propellant fire extinguisher (SPFE) led to a highly efficient system. As the use of such additives evolves, quantification methods for the active species will be essential for system design and certification. The lack of an established method for potassium atom concentration measurement has already delayed acceptance of an advanced SPFE system.

Filling these gaps is within the capability of the appropriate technical communities, and I believe this will occur.

12.2 REFERENCES

1. Gann, R.G., "A Millennial View of Fire Suppression," 2000, in Gann, R.G., Burgess, S.R., Whisner, K.C., and Reneke, P.A., eds., Papers from 1991-2006 Halon Options Technical Working Conferences (HOTWC), CD-ROM, NIST SP 984-4, National Institute of Standards and Technology, Gaithersburg, MD, (2006).

2. http://www.b737.org.uk/history.htm

3. http://www.af.mil/factsheets/factsheet.asp?fsID=83