Fire and Smoke Control: An Historical Perspective

ASHRAE's involvement in fire and smoke control has greatly increased since the first ASHRAE symposium on this topic was held in 1968

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At the 1968 ASHRAE Annual Meeting in Lake Placid, New York, the symposium *Fire Hazards in Buildings and Air-Handling Systems*[1] was held. This symposium marked the start of a period of ASHRAE fire-related activity that is still ongoing.

The symposium was jointly chaired by Alastair Simmonds and Clint Phillips. The eight papers presented included such topics as principles of fire protection, fire problems with HVAC systems, protection of duct openings and penetrations, and smoke problems in buildings. The main focus of most of the papers was identification of fire problems that were relevant to ASHRAE.

In commemoration of the ASHRAE Centennial, the following brief history of ASHRAE's activities in fire and smoke control is presented. Some events that lead up to ASHRAE's activity in this area are also discussed as background information.

About the author

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1939 NBFU Study

No history of fire and smoke control would be complete without mention of the National Board of Fire Underwriters (NBFU) study[2] of fire in air moving systems based on data from January 1936 to April 1938.

Of the 25 fires recorded, 19 involved combustion of parts of the air moving system; ducts, duct linings and filters burned. In five cases not involving fire in the HVAC system, smoke was distributed by the system.

The report recommended that HVAC systems be shut down during fire situations to prevent them from spreading smoke and supplying combustion air to the fire. The NBFU study and standards under consideration were of concern to the members of the American Society of Refrigeration Engineers (ASRE), a predecessor society of ASHRAE.

In 1939, ASRE president Charles Leopold wrote, "As an industry, we are certainly vitally interested in both the smoke and fire hazard and glad to accept [a] ruling that will provide real protection, but we should be most careful to avoid additional cost burden to the consumer, unless we can demonstrate that the additional devices or arrangements will give the protection expected. . ."[3]

The current air-conditioning standard of the National Fire Protection Association (NFPA 90A) reflects the findings of the NBFU study by materials requirements for parts of the system in contact with the air stream and requirements for system shutdown in fire situations. However, NFPA 90A also provides for systems to go into a special smoke control mode of operation during fires, as discussed below.[4]

Seattle Federal Office Building

Harold (Bud) Nelson attended the Lake Placid symposium and, two years later at the ASHRAE symposium in San Francisco, he presented the paper, "Relating Air-Handling Requirements in Fire Codes and Standards to Fire Safety in Buildings."

The concepts in this paper set the stage for Nelson's International Conference on Firesafety in High-Rise Buildings of April 1971. This famous conference was held in Arlie, Virginia and became commonly known as the Arlie House Conference.

Nelson was the head of fire protection for the US General Services Administration (GSA). The topics at the Arlie House Conference included compartmentation, extinguishment, preventative maintenance, fire resistance, people movement, emergency communications and smoke control.

The participants included Irwin Benjamin, chief of the Fire Research Section of National Bureau of Standards (now the National Institute of Standards and Technology); Charles Shaftner, vice-president of Siska and Hennessy; Joseph Newman, vice-president of Tishman Research Corp.; Joseph Fitzgerald, building commissioner

of Chicago; Rolf Jensen, chairman of fire protection engineering at Illinois Institute of Technology; and Henry Roux, manager of ceiling systems research of Armstrong.

Because GSA is an agency of the US federal government, it has code authority for its own buildings. This put GSA in a unique position to apply the new concepts of the Arlie House Conference.

The conference was reconvened in October 1971 at GSA headquarters in Washington DC. There, innovative ideas from the April meeting were adapted into a design concept for the Seattle Federal Office Building.

Today, after more than two decades, the fire safety features of this building still seem modern. For example, this was the first building to be built with a smoke control system that exhausted a fire zone and pressurized surrounding zones.

A new technical committee

A direct outgrowth of the Lake Placid symposium was the formation of ASHRAE Technical Committee 6.6, Fire Safety in Buildings. Alastair Simmonds was the first chair of TC 6.6 in 1969, and Grant Wilson became the second chair in 1970.

In those early days, much of the effort was to find the proper role for the committee. In 1972, the committee name and number changed to TC 5.6, Fire and Smoke Control. Over the next decade, TC 5.6 was chaired by Bayliss (Bill) Erdely and Robert Taylor.

The vitality and wide-ranging fire interests of TC 5.6 during these early years were contagious. The committee meetings had large attendance. The symposiums, seminars and forums produced by the committee were popular places for the exchange of technical information and system concepts concerning fire and smoke control.

In those early years, the committee also found time to develop a chapter for the *ASHRAE Handbook* and to play a vital role in member education. In later years, the committee became well-focused and highly efficient at almost every aspect of technical committee effort.

Programs at Society meetings

A second ASHRAE symposium entitled *Fire Hazards in Buildings* was held in 1970 in San Francisco.[5] Grant Wilson chaired this symposium, and three of the six papers presented directly addressed smoke control.

Irwin Benjamin presented a paper about the research needs in fire and smoke control including a discussion of related work in NBS's Fire Program. John McGuire, George Tamura and Grant Wilson of the National Research Council of Canada (NRCC) presented the other two smoke control papers.

This was a major change from Lake Placid, where there were no smoke control papers. However, Hutcheon and Shorter of NRCC presented a paper at Lake Placid about smoke problems in high-rise buildings including an analysis of smoke movement due to stack effect.

Symposiums were held in 1971 and 1972 where papers were presented on a broad range of fire topics including codes,

A series of full-scale fire tests was conducted at the Henry Grady Hotel in Atlanta, Georgia.

fire tests, fire safety, fire hazards, fire testing and sprinklers.[6,7] Only one of the 10 papers at these symposiums was primarily about smoke control, but the emphasis changed again with the next symposium.

At the 1973 symposium in Louisville, all of the papers addressed smoke control.[8] More importantly, research results were presented about two landmark projects involving full-scale fire tests of stairwell pressurization systems.

One project was presented by Norman Koplon of the Building Department of the City of Atlanta, Georgia. This project consisted of a series of full-scale fire tests at the 13-story Henry Grady Hotel in Atlanta.

The other project was by Paul DeCicco of the Polytechnic Institute of Brooklyn. DeCicco's fire tests were of a stairwell smoke control system in a 22-story building at 30 Church Street in Manhattan.

Both projects showed that stairwell pressurization is feasible and can maintain tenable conditions in the stairwell during evacuation.

At the 1973 symposium, Robert Cresci (also of the Polytechnic Institute of Brooklyn) published an analysis of DeCicco's stair pressurization system tests. Cresci's analysis extended the earlier NRCC work to include stairwell pressure losses due to friction and mass flow through open doorways.

Cresci constructed a scale model of DeCicco's stairwell, and observed stationary vortices in the flow from open stairwell doors. These vortices reduce the effective size of an open doorway, and the flow is about one-half of what would be expected without vortices. This reduced flow is so important that the 1992 ASHRAE smoke control book incorporates it in stairwell pressurization analyses.[10]

By 1973, ASHRAE meetings had become the major venue for presenting the results of smoke control research. Examination of the many smoke control papers in *ASHRAE Transactions* for the years after 1973 shows that these programs played a major role in the presentation and exchange of technical ideas and system concepts among researchers, designers, manufacturers, code officials and the fire service.

ASHRAE Handbook Chapter

Three years after the Lake Placid symposium, Frank Powell of NBS and Grant Wilson of NRCC met in Washington, DC where they finished a draft of what became the "Fire and Smoke Control" chapter of the 1973 *ASHRAE Handbook*. This chapter provided general information about fire protection, smoke production, smoke movement and smoke control.

For many ASHRAE engineers, this chapter was their first exposure to smoke control and fire protection of HVAC systems. Fire protection included discussions of compartmentation, fire spread, fuel loading, detection, alarms, communication and fire suppression.

In the decades since this first fire and smoke control chapter, many advances have been made in smoke control and in fire protection in general. Laboratories throughout the world have conducted many smoke control research projects, and designers have developed and refined many kinds of smoke control systems.

The advances in fire protection include a shift from property protection to life safety, increased understanding and use of sprinklers, increased understanding of human behavior during fires, increased understanding of the nature of fire growth and smoke spread, and use of computer models.

The fire and smoke control chapter has been extensively revised to describe the place of smoke control and fire protection of HVAC systems in fire protection engineering, the basic principles of smoke control, computer analysis of smoke control systems, and a number of systems to achieve smoke control.

Education

In 1975 and 1976, Bill Schmidt of the US Veterans Administration organized and moderated a series of two-day seminars entitled *New Techniques for Life and Fire Safety in Buildings* which were sponsored by ASHRAE.

These seminars were held in Atlanta, Chicago, Cleveland, Dallas, Los Angeles, New York, Philadelphia, San Francisco and Toronto. The speakers included Irwin Benjamin, Rolf Jensen, Norman Koplon, Richard Masters, Anne Richards, Brooks Semple, Robert Taylor and William Webb.

These seminars were significant in that they spread an awareness of current fire protection issues with special emphasis on the lethality of smoke and on approaches for dealing with smoke.

Taylor developed an exciting series of slides of fire scenes with accompanying stories of fire growth and firefighting. The Henry Grady Hotel experiments and the Church Street experiments were described in detail. Semple discussed stairwell pressurization and the pressure sandwich (later renamed zoned smoke control) with

an enthusiasm that always held the interest of the audience. The Seattle Federal Office Building was presented as a prime example of a zoned smoke control system.

Schmidt explained the fundamentals of stack effect and smoke movement in a clear manner. He explained that fans did not have to shut down during fires, but could be used as part of a smoke control system to restrict smoke spread.

Over the next few years, Semple, Taylor and Schmidt presented numerous one-day smoke control seminars to many ASHRAE chapters throughout North America. These seminars were well received, and the speakers became so well identified with the subject that they became known as the *Smokey Trio*. The details of the seminars changed with time, but the basic emphasis was always the same: tell people about the smoke problem and about smoke control as a solution.

In the 1980s, numerous ASHRAE chapters presented smoke control seminars that addressed advances in smoke control technology. Jack Buckley, Mike Dillon, Dick Masters, this author plus members of the Smokey Trio were frequent speakers at these seminars.

Buckley, Dillon and Masters all drew on their extensive design experience to provide practical information about smoke control systems, code compliance and acceptance testing. I presented research results, fundamental principles, design analysis and system concepts based on my own research at NBS (later NIST) and the research conducted by others at numerous laboratories throughout the world.

The emphasis was changing from a strong sales pitch to the nuts-and-bolts of giving engineers the tools to design smoke control systems that work.

Smoke control design book

In 1978 at the ASHRAE Annual Meeting in Albuquerque, I was surprised to find that smoke control systems were almost totally designed by rule-of-thumb. At this meeting, one designer even expressed the erroneous idea that smoke control design was beyond the capability of engineering analysis.

A research project was established to develop an ASHRAE smoke control design book. I headed up this project at NBS with assistance from John Fothergill of Integrated Systems Inc. The book was based on the research already mentioned and other research conducted in England, France, Japan, West Germany, as well as research conducted at NBS and NRCC.

Francis Fung and, later, I conducted numerous smoke control projects at NBS including field tests, computer analysis and conceptual studies. George Tamura and his associates at NRCC conducted similar research plus they established a base of experimental data about the leakage of commercial buildings.

The resulting 1983 book, *Design of Smoke Control Systems for Buildings*, addressed fundamental concepts, computer analysis of smoke control systems, stairwell pressurization, zoned smoke control and acceptance testing.[9] Finally, engineers had the ability to design smoke control systems based on the principles of engineering.

After the publication of the smoke control book, research and development continued. NBS and NRCC conducted a joint elevator smoke control project including conceptual studies, theoretical analysis and full-scale fire experiments. NBS conducted a series of field tests of zoned smoke control systems in hospitals. NRCC conducted pressurized stairwell research.

Designers continued to refine smoke control systems. Smoke control in shopping malls based on plume theory has been extensively used in the United Kingdom, and analytical work has been conducted in both the United States and the United Kingdom that extended this application to smoke control in atria.

To provide information about these topics, I and James Milke of the Fire Protection Engineering Department of the University of Maryland headed up an ASHRAE project to extensively revise and expand the smoke control book, The resulting 1992 book, entitled *Design of Smoke Management Systems*,[10] was jointly published by ASHRAE and the Society of Fire Protection Engineers (SFPE). ASHRAE and SFPE also have a joint series of two-day courses using this new book as the text.

System components

In the early days of smoke control, it was often stated that the HVAC system could be used with little modification to control smoke. Most systems only needed to have some dampers added and the controls modified.

There were no standards for these *smoke dampers*, and members of TC 5.6 supported the efforts at Underwriters Laboratory to develop UL 555S which is the standard for leakage rated dampers for smoke control systems.

An ASHRAE research project is studying the effects of air flow at elevated temperatures on performance of fire dampers. ASHRAE SPC 149P is also developing a standard test method for smoke control fans. Further, TC 5.6 has sponsored the formation of the Task Group on Smoke Management Components to study the operating requirements of fans, ducts, dampers, controls and other components of smoke management systems.

TC 5.6 current activities

Under the chairmanship of Jack Buckley (1982-85), Mike Dillon (1986-88), John Klote (1989-90) and Bill Webb (1991-92), TC 5.6 has become an efficient machine. The TC has produced programs at Society meetings, sponsored articles in the *ASHRAE Journal*, updated the *ASHRAE Handbook* chapter on fire and smoke control, developed and managed research projects, and sponsored standards projects.

In addition to the standards project SPC 149P, GPC 5P has completed a guide for commissioning smoke management systems. TC 5.6 has broadened its activities beyond just smoke control to general fire concerns of HVAC systems.

While the TC became highly productive, most of the committee meeting time became dedicated to handling details of routine business. One of the goals of Louis Bentsen, current TC 5.6 chairman, is to foster the exchange of new ideas.

Bentsen has improved subcommittee efficiency, which allows the committee to deal with routine matters even more efficiently. The time saved at TC 5.6 meetings has been devoted to a period of general discussion, which allows the presentation and debate of new concepts and approaches.

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Numerous HVAC design engineers, fire protection engineers, code officials, firefighters and other professionals have made significant contributions to ASHRAE's fire and smoke control efforts. While it is impossible to thank all of these people individually, it should be noted that the advances since the Lake Placid symposium would not have been possible without their efforts. ■

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