

Fire Alarm System Research – Where it's been and where it's going

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Fire Alarm System Research We've Come A Long Way!....Or Have We?



- First Alarms - roving watchmen using hand bell-ringers or church sextons ringing church bells or factory steam whistles
- Telegraph Invented by Sam Morse in 1840s

From the beginning of recorded history people have learned that early response to fires had positive results in controlling those fires. When someone discovered a fire the fire brigades and fire departments were alerted by roving watchmen using hand bell-ringers or church sextons ringing church bells or factory steam whistles. Unfortunately these systems did not provide very much detail and often directed the fire department to the wrong location. But with the advent of the telegraph, invented in the early 1840's by Samuel F. B. Morse, firefighters were given a faster and more accurate fire reporting system.

In 1847, New York became the first American city to begin construction of a municipal fire alarm system required by ordinance “to construct a line of telegraph, by setting posts in the ground, ... for communicating alarms of fire from the City Hall to different fire stations, and [to] instruct the different bell-ringers in the use of said invention.”

- March 1851 Channing/Farmer Municipal Fire Alarm System Installed in Boston
- April 30, 1852 First Alarm Transmitted

In March 1851, William Channing, a young doctor and avid fire buff, and Moses G. Farmer convinced the city of Boston to install their version of a municipal alarm system using Samuel Morse's printing register as a major component of the system. “The system consisted of 40 miles of wire to connect the central station to 40 signal boxes and 19 bells in churches, schools and fire engine houses.”¹ The system had some technical flaws but

after these were resolved, the system would transmit an electric impulse from a code wheel breaking the circuit and record a Morse code dot or dash on the printing register. On April 30, 1852, within 24 hours of being placed in service, a fire alarm was transmitted for a fire on Causeway Street.

- March 1855 John Gamewell hears Channing Lecture at Smithsonian regarding Boston System
- Gamewell Buys Rights to Construct Public Fire Alarm Systems in USA

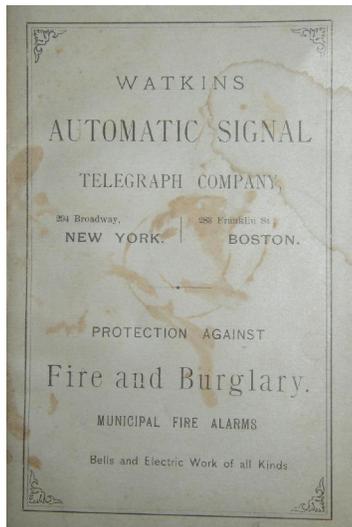
William Channing presented many lectures on the Boston fire alarm system and it was during his lecture in March 1855 at the Smithsonian Institute that John N. Gamewell first heard about the new invention. Mr. Gamewell was a South Carolina postmaster and telegraph agent. Gamewell was so impressed with the potential of the Channing/Farmer system that he bought the rights to construct these fire alarm systems, first in the South and the West, and then for the entire U.S.A. In 1856, Gamewell joined with his brother-in-law, James M. Gardiner, who had an extensive knowledge of clocks and other intricate mechanisms. By 1871, Gardiner and Gamewell had improved their product line utilizing spring driven models of the fire alarm signal boxes and a “noninterference pull” box design from Edwin Rogers and Moses G. Crane. In 1880, Gardiner patented his design to eliminate interference between fire alarm boxes transmitting at the same time. Although in the late 1800s 36 other companies were in the public fire alarm telegraph manufacturing business, the Gamewell Company held a 95% share of the U.S.A. market.

In 1866, Mr. Greenwood, Superintendent of the Fire Alarm and Police Telegraph in San Francisco said: “A careful study during the past year reveals the fact that, out of the one hundred and nine actual fires that have occurred, fully two-thirds of the alarms have been struck [by the automatic telegraph fire alarm boxes] before any appearance of the fire could be seen from the top of the City Hall.” [1]

[1] San Francisco Municipal Reports 1865 - 1866, For the Fiscal Year Ending June 30, 1866. San Francisco: Towne and Bacon Co., p. 218

In 1871 private companies, for example American District Telegraph (ADT), Holmes Electric Protective and Rhode Island Electric Protective, were founded to serve the public using commercial central stations in “districts” of a city to provide messenger service and later electric burglar alarm and fire alarm telegraph service to homes and businesses.

The first electric fire sensor to see commercial use was designed by William B. Watkins. By the early 1870’s, Watkins had developed remotely monitored fire alarm systems using heat detectors and in 1873 formed the first private fire alarm company called the Boston Automatic Fire Alarm Company, now known as AFA, Automatic Fire Alarm Company.



Photograph of a sales/marketing brochure from the Watkins Company.

“The Automatic Fire Alarm Telegraph is operated by any dangerous Heat, and detects the presence of fire at its commencement. The apparatus, usually set at 125 Fahrenheit, is placed on the ceiling at regular intervals in every room, office, closet, and elevator in the Building...”

“The alarm is given directly to the Insurance patrol and fire department. It tells the *exact location of the fire* to the companies *before they leave their station*, giving the particular building and floor. Each instrument performs the service of a constant, vigilant watchman, ready to act in time of danger in every part of the building.”



One of the first fusible link heat detectors

The first electric fire detector was developed in Brooklyn, NY in 1863 by Alexander Ross, however the first electric fire sensor to see commercial use was designed by another New Yorker, William B. Watkins. By the early 1870s, Watkins had developed remotely monitored fire alarm systems using heat detectors and in 1873 formed the first private fire alarm company (Boston AFA) which survives to this day as AFA Protective Systems (Headquartered in Syosset, NY). Watkins developed the “Watkins Thermostat”, the precursor to the self-restoring bi-metallic heat detector used in fire alarm systems in the 21st century.

In the 1896 Handbook of the Underwriters’ Bureau of New England the authors state, “... there is no reason why a thermostat system should not be superior to a watchman and clock for a majority of risks.”

In the early 1900s, ADT, Holmes Protective, AFA, Grinnell and Automatic Fire Protection (AFP) established contracts with each other to supply detection, sprinkler systems, sprinkler system supervisory equipment and central station monitoring services. As business in the fire alarm and monitoring fields grew, so did the development of the devices used for detection. George Smith was the first to patent a pneumatic system in 1907, later known as the Aero Automatic Fire Alarm. ADT, AFA, ATMO and others developed similar “rate-of-rise” principle pneumatic heat detectors.



“Typical” pneumatic heat detector

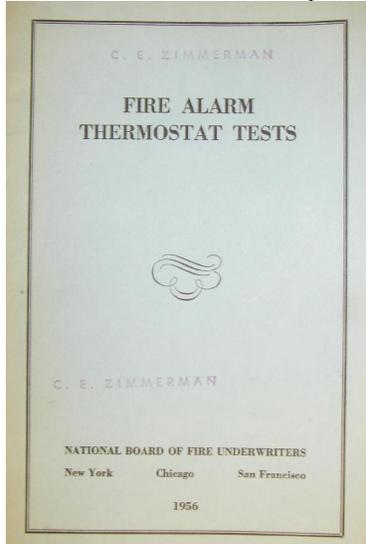
In their (1923) standards for Watchman Service and Fire Alarm the G.A. Insurance Co. states the “Watchman must make hourly rounds at approved stations, 6 p.m. to 6 a.m. and also during the day on Sundays, holidays, or when the building is idle. For watchmen, locked lantern burning lard oil, sperm or signal oil is preferred. Electric flashlight [is] also approved.”

They include a quote attributed to the National Board of Fire Underwriters that, “A fire alarm system when it is an integral part of a central office watchman’s supervisory system is considered superior to any other means of transmitting an alarm of fire.”

Heat Detector Tests Conducted By UL Sponsored By NBFU in 1956

A Series of Tests Conducted in Rooms of Different Volumes Smooth vs. Beam Ceilings

Results Still Used Today! Work was published in the booklet shown below:



Committee on Fire Research and the Fire Research Conference of the Division Of Engineering of the National Research Council
Proposed Fire Research Program - 1959

Emphasis on:

- Ignition
- Fire Growth
- Fire Spread

Focus: Forest Fires!

- 1959 *Operation School Burning*
 - First tests to conclude smoke detectors provide higher level of life safety [than heat detectors]
- 1961 *Operation School Burning No. 2* - Definitive studies of comparative response of heat and smoke detection devices for the next fifteen years

1967 FDI Heat Detector Research

Environments of Fire Detectors – Phase 1: Effect of Fire Size, Ceiling Height and Material
Gunner Heskestad and Mike Delichatsios

Results: NFPA 72 – Annex C

1968 – Fire Research and Safety Act

Provided clear recognition of national need for increased activity to prevent and suppress a fire

Fire Research – Emphasis on the City

The Act Recognized the Reduction of Fire Losses Come From Action Along Many Fronts - Research Being One of Them And That More Basic Research Was Needed

“the nation’s basic fire research effort must come primarily from Federal agencies, the universities, and other non-profit organizations operating in the public interest.”

- Study of early stage gaseous products of thermal degradation associated with the ignition process
- Determination of thermal output of early-stage combustion of various materials
- Study of convective dilution and the convection of hot products to remote points.

“A case can be made for the claim that the reduction in annual fire losses would be greater per dollar spent on research on cheaper and better fire detection devices than in any other fire research area”

In the mid-1970’s the National Bureau of Standards (Now the National Institute of Standards and Technology – NIST) contracted with Illinois Institute of Technology Research Institute and Underwriter’s Laboratories to obtain data regarding the performance of smoke detectors and their effectiveness in residential environments. The tests were performed in houses located in the Indiana Dunes Area and were the first to evaluate detection performance based on the amount of “escape time” offered when the detector was actuated. The results of the tests were published as Phase I and II, “Detector Sensitivity and Siting Requirements for Dwellings.” Based on the test results, smoke detection on every level of a home was proven to provide adequate escape time in roughly 90% of the fire scenarios. An independent study in 1976 by the Minneapolis, Minnesota Fire Department resulted in conclusions nearly identical to the results of the Dunes Tests. Other tests on Los Angeles, California and Ontario, Canada led to significant changes in the installation, maintenance and use of smoke detectors.

FDI Duct Smoke Detector Research

- The Fire Detection Institute was requested to develop a research proposal to address the issues raised in a public proposal relative to duct smoke detectors.
- The Fire Detection Institute issued a Request for Proposals to the research community in August of 1997.

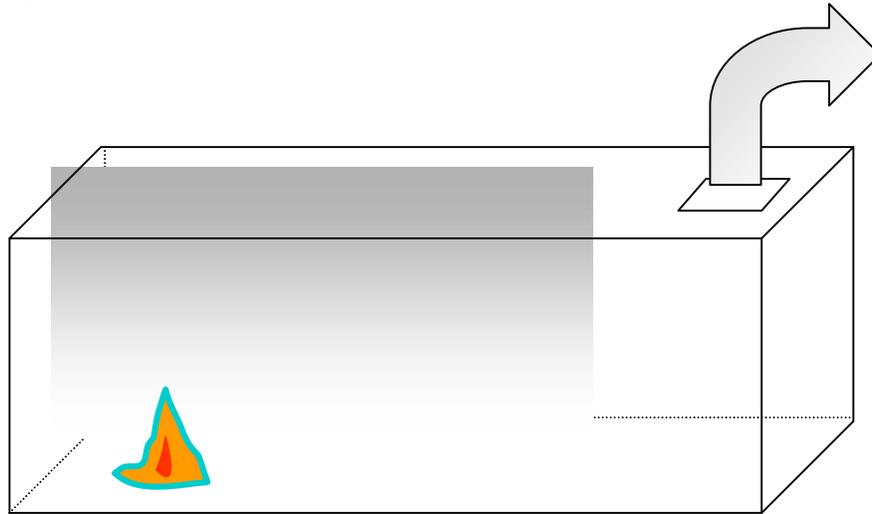
None of the responses to the RFP, taken as a single proposal fulfilled all of the requirements for the research program. However, the FDI BoD saw an opportunity to achieve the objectives of the research effort by forging collaboration between two of the respondents. The FDI developed a proposed research project built around the combination of two proposals into a single coordinated program.

This coordinated program employing two research contractors as them submitted to the fire alarm community with a request for financial participation.

The funding participants include three trade associations, one public (national) research organization, six manufactures of duct smoke detectors and the FDI.

- The Fire Detection Institute developed a collaborative research program using proposals obtained from the University of Maryland and National Research Council - CANADA.
- By December, 1998, The Fire Detection Institute has obtained commitments for the requisite funding and executed research contracts in May, 1999.
- Overall goal was to determine the efficacy of duct smoke detectors in fire alarm system design
- Investigated Dilution Effects, Comparative driving forces and smoke ageing effects

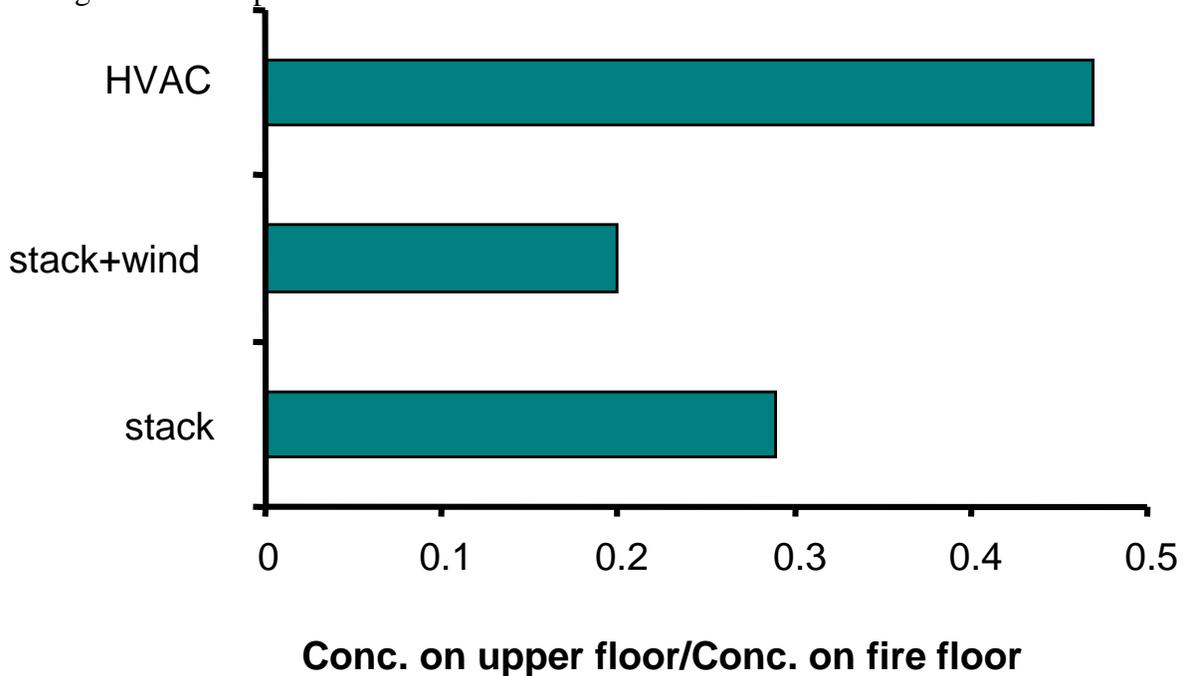
Dilution effects of smoke in ducts was studied at the University of Maryland and equations were developed to determine those



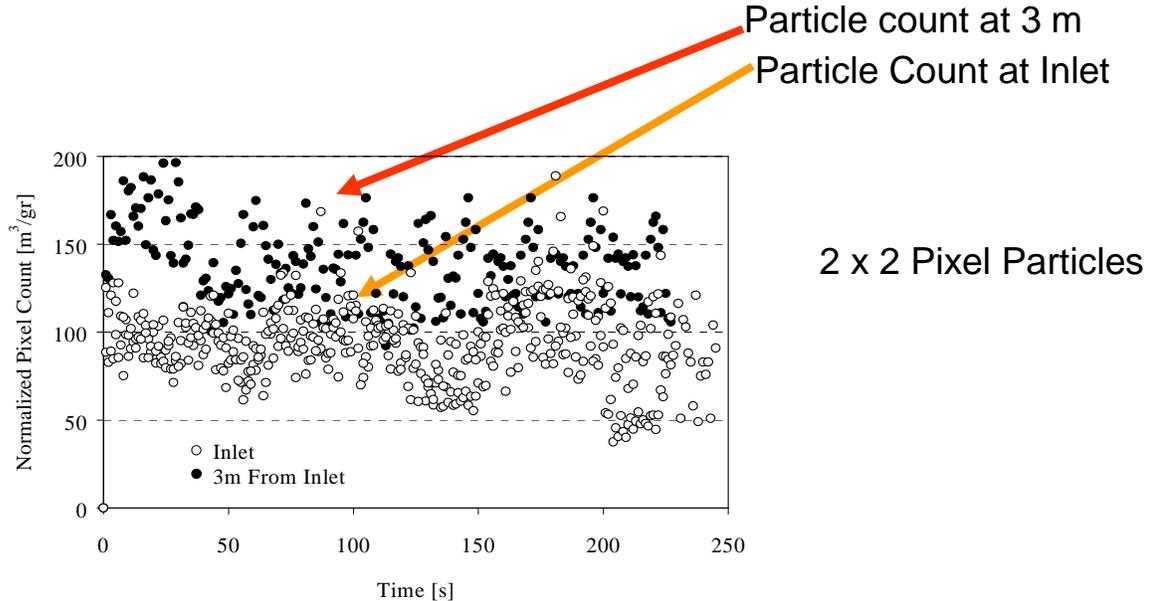
$$D(t) = \left(\frac{D_m}{\chi_a \Delta H_c} \right) \left(\frac{\dot{Q}_f}{\dot{V}_{exh}} \right)$$

effects.

In addition the comparative driving forces affecting smoke travel in ducts was studied and the figure below captures that effort:



The smoke particle count was also measured at the inlet and at 3 meters to determine the amount of coagulation.



The result of the study was issued and titled:

Investigation into the Application of Duct Smoke Detectors in Heating, Ventilating and Air Conditioning Systems: Final Report

The results were also delivered in 2005 at the January Conference of this Research Conference

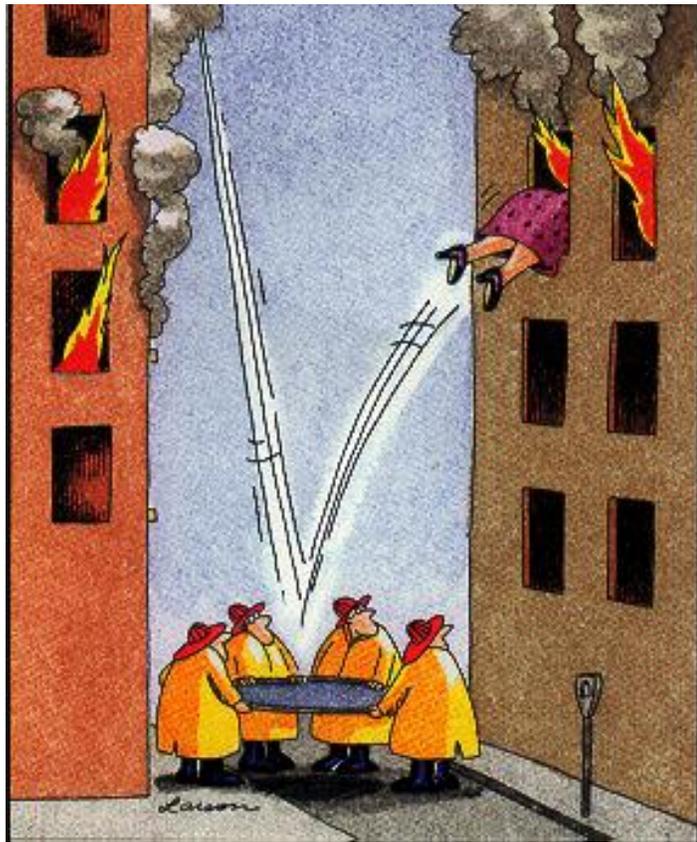
2001 FDI – NEMA Research Initiative Meeting

- Performance metrics of smoke detectors
- Methods to relate smoke sensor signals to fire characteristics
- Response of smoke detectors to specific fuels

Background for New Initiative

- Foundation Research Advisory Council on Fire Detection and Alarm Futures
- Fire Detection Institute
- Similar goals, common participants
- Recommendation to combine efforts toward research planning
- FDI and Foundation Boards approve decision – spring, 2005
- **Mission** - To advance the implementation of detection and alarm system technology through research and communication programs, closely tied to the needs of NFPA Technical Committees.
- **Membership** -The Council is open to all individuals who support its mission; liaison with Foundation Board, NFPA Tech committees, elected chair and vice chair
- Performance of Detectors with Ceilings with Deep Beams or Deep Beam Pockets
- Tenability: Performance Goals and Occupant Response – defining design fires, occupant response (for varied populations) and tenability limits

- Better Quantification of Detector Response
- FDS Smoke Detector Algorithm Validation
- Performance Metrics For Area Smoke Detection, Sensitivity and Smoke Entry Factor
- Spacing Guidelines for Sloped Ceilings with Joists, Beams, and Bays
- Quantification of the Performance Benefit of Placing Smoke Detection in Hospital Patient Rooms
- HVAC Shutdown versus HVAC Dampers
- Library of Flame Spectra of Combustible/flammable Liquids and Flammable Gases
- Fire Alarm Audibility For Elderly And Children
- Strobe Effectiveness
- Better Human Interface For Firefighters
- Direct View Design Criteria For Visible Notification Appliances
- Advanced software for large facilities – self monitoring/feedback, in-field validation, version control/mgt
- Mass Notification
- Cost Effective Low Frequency Technology
- Video Image Smoke and Flame Detection
- Integration of Fire Alarm and Premises Security Technology/Interface
- Use of Combustion Product Gas Sensors for Fire Detection
- Performance of Detectors with Ceilings with Deep Beams or Deep Beam Pockets
- Performance Evaluation of Residential Fire Alarms – today's fuel loads, today's alarm technology
- New Test Method for Detector Response to Smoldering Fires
- New Nuisance Alarm Test Protocols – test protocols to evaluate whether detectors are immune to welding, cooking oil, smoking, and/or steam false alarms
- Overall Alarm System Reliability – use NFPA 72's requirements for regular testing as a tool to gather installed system performance data (using a new test report form).
- U.S. Nuisance and False Alarm Survey



We solve one problem only to discover another!

Recent Research Needs Assessment

- Study the effect of frequency of audible notification appliances and sound pressure level on the receipt and arousal of sleeping persons. Include the effects of subject age, hearing ability and sleep mode.
- Develop guidelines or standards for the content and delivery of emergency voice communication messages for a variety of situations
- Study the effectiveness of notification systems. Which systems are most effective in obtaining the desired response for different situations, occupancies, ages, etc.? How does the use of two or more technologies affect the effectiveness?
- Develop a guide for fire protection professionals addressing the design of intelligible voice communication systems.
- Develop engineering tools to predict the performance of smoke and heat detectors on ceilings with beams, joists or other obstructions.
- Develop and validate a smoke detector response algorithm for use with the NIST FDS fire model. Compare the code enforcement “system” in cities of lowest fire death rate vs. highest to see what is working and what isn’t. Gather and use available fire alarm inspection, testing and maintenance data to report on the reliability and effectiveness of fire detection and alarm systems.
- Develop a statistically valid, performance based approach to inspection, testing and maintenance of fire alarm system components and systems. Identify and propose use of standard quality control techniques and measures to model system performance, expected availability and failure rates (mission, not just

component) and establish performance requirements for a variety of risk scenarios.

- Develop standards for the application, design, installation, location, performance and maintenance of video smoke and flame detection.
- Defining tenability – levels of irritants.

At This Meeting:

- Response of Residential Smoke Alarms at Low Flow Velocities
- RTI
- Smoke Detector Performance for Level Ceilings with Deep Beams and Deep Beam Pockets
- An Algorithm for Fast and Reliable Fire Detection
- Visual Appliances in Large Spaces
- Reducing Fire Deaths in the Aged: Optimizing the Smoke Alarm Signal

Ultimately We Need More Investment in Detection and Alarm Systems Research!

I encourage everyone in attendance to use the research presented here to move forward to our goal of a fire safe environment.

“What we do for ourselves dies with us. What we do for others and the world remains and is immortal.” Albert Pine, 1851

Sources:

The History of Fire Alarm Systems - Richard Bukowski, P.E., FSFPE,

Wayne D. Moore, P.E., FSFPE

Investigation into the Application of Duct Smoke Detectors in Heating, Ventilating and Air Conditioning Systems: Final Report, Fire Detection Institute, John M. Cholin, P.E., Project Manager