

**Statement for the Record**  
**National Institute of Standards and Technology**  
**to the**  
**Boston City Council Committee on Public Safety**  
**August 6, 2007**

This statement provides technical information on smoke detector technology based on research conducted by the U.S. Commerce Department's National Institute of Standards and Technology (NIST), especially on the differences between ionization and photoelectric technology.

NIST is a non-regulatory federal research agency that specializes in measurement and basic standards, and has been engaged in fire research for more than a century. Our mission is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.

Prior to 1988 NIST was known as the National Bureau of Standards (NBS). NIST staff has been involved in research and standards development related to smoke detectors and fire alarms for approximately four decades. We interact with the National Fire Protection Association (NFPA), Underwriters Laboratories (UL), the U.S. Fire Administration (USFA), the Consumer Product Safety Commission (CPSC), and other federal agencies on technical matters concerning fire sensing and fire alarm technologies. The output of NIST research on smoke alarms is freely available for downloading from the NIST web site (<http://smokealarm.nist.gov/>).

Smoldering fires are inherently different from flaming fires, and the operating principle for a photoelectric detector is distinct from the operating principle of an ionization detector .

*Smoldering* can occur only in a porous solid; for example, polyurethane foam, shredded paper, or cotton. The rate of smoldering is limited by the ability of air to penetrate the porous fuel, and hence the rate at which heat is released from a smoldering fire is low, as is the rate of carbon monoxide (CO) production. The smoke layer from a smoldering fire grows slowly and smoke can accumulate well below the ceiling, especially in rooms other than the room of fire origin.

Another important aspect of a smoldering fire is that it produces smoke particles that are relatively large (greater than one micrometer).

*Flaming* fires can occur in all types of fuels, including porous and non-porous solids, liquids, and gases. Air has easy access to a flaming fire, which means that the rate at which heat is released is high. Smoke and fire gases, including CO, can be produced at a higher rate in a flaming fire than in a smoldering fire. The smoke layer is hotter and can build up near the ceiling of the room of fire origin as well as elsewhere in a building. Flaming fires produce a very large number of smoke particles that can be relatively small (less than one micrometer).

The above discussion distinguishes between smoldering and flaming fires; the following describes the different characteristics of photoelectric and ionization detectors, and why they react the way they do in smoldering and flaming fires. The bottom line is that each type of detector has its advantages and disadvantages.

An *ionization* detector responds to the movement through an electric field of ions produced by a small radioactive source in the smoke alarm chamber. When smoke particles move into the chamber they inhibit the motion of the ions, altering the electrical current. Fires that produce a large number of particles (i.e., flaming fires) are sensed more easily with an ion detector. A *photoelectric* detector operates on the principle of light scattered from the surface of particles. Because large particles have much more surface area than small particles, a photoelectric detector is more sensitive to the large particles produced in a smoldering fire. The sensitivity requirements of the UL standard are identical for both types of detectors, and neither detector responds to carbon monoxide or heat.

The general trends from a 2004 NIST experimental study into the behavior of smoke alarms are consistent with several previous scientific studies showing that *properly installed and maintained ionization and photoelectric alarms provide enough time to save lives for most of the population under many fire scenarios*. However, ionization detectors have been shown to sometimes fail to alarm in a smoldering fire even when visibility in the room is significantly degraded by smoke. Most photoelectric detectors alarm substantially sooner in these situations. In the NIST experiments the photoelectric detectors sensed smoldering fires on average 30

minutes earlier than the ionization detectors. The same study demonstrated that ionization detectors responded, on average, 50 seconds earlier than photoelectric detectors during flaming fire experiments. *The relative margins of safety associated with a 30 minute earlier warning in a slow growing smoldering fire compared to a 50 second earlier warning for a fast growing flaming fire is difficult to determine.*

In the 2004 NIST study, average times to untenable conditions for flaming and smoldering *furniture* fires were found to be shorter by 17% and 47%, respectively, than those found in the 1975 NBS study (also known as the Indiana Dunes study). On the other hand, the average time for the *cooking* fires to reach untenable conditions was 120% longer in the current study. Since the cooking materials were similar in the two studies, NIST concluded—on the basis of the shorter time to untenable conditions in the furniture fires—that a major factor in the increase in fire growth rate is due to differences in modern furniture materials and construction compared to furniture manufactured four decades ago. The reduction in time to untenable conditions from a fire (either flaming or smoldering) in modern, synthetic materials indicates the need to determine the ability of standard test methods to ensure safe performance of modern (and legacy) residential fire alarms. Both NIST and UL are involved in research that will assess whether or not modifications are required in the standard to accommodate the changing threat.

An important conclusion from the 2004 NIST study was that the available safe egress time provided by a smoke alarm would be sufficient, in many cases, only if households follow the requirements in NFPA's National Fire Alarm Code (NFPA 72) for new construction, which requires the installation of fire alarms at more locations in order to improve audibility in bedrooms where occupants sleep with the door closed, and to provide warning to the occupants of bedrooms with closed doors when the fire starts in that bedroom. NFPA 72 also requires two ways out of a sleeping room, one of which is generally a window. With the bedroom door closed there is more time in which to use the window exit should the primary exit be blocked.

Audibility of smoke alarms remains an issue, particularly for sleeping children and adults impaired with alcohol or other drugs. For existing residences that do not fall under the "new construction" requirements of NFPA 72, or for new residences where the state or local building regulatory agency has not adopted the requirements, the following approaches are suggested to

reduce problems associated with inaudibility: placing smoke alarms in bedrooms, interconnecting smoke alarms, changing alarm tones, and providing better home fire escape planning. Interconnection of the smoke alarms ensures all alarms respond to a fire event.

Nationally-collected data on fire incidents do not specifically classify fire sources as smoldering and/or flaming; however, NFPA estimates that more than one-fourth of home fire deaths involve fires with an extended period of initial smoldering.

In NIST's smoke alarm research, and in applications in the field, it is documented that most common ionization detectors have a propensity to produce nuisance alarms during cooking activities. NIST examined a broad range of activities (including cooking) that yield nuisance alarms. The published field observations guided the nuisance alarm scenarios studied. Specifically, the sensitivity to alarm threshold, distance from the source, background air flows, and alarm sensor (photoelectric or ionization) were examined. Additional measurements were made with aerosol instrumentation to provide a more fundamental understanding of nuisance alarm sources than has been previously published. Given the scenarios examined, both photoelectric and ionization alarms produced nuisance alarms, but NIST does not mean to imply that they are *equally* susceptible to such nuisance alarms. Most field data suggest that ionization alarms have a greater propensity to nuisance alarm than photoelectric alarms, possibly indicating that certain activities such as cooking dominate reported nuisance alarms in the field.

To reduce the impact of nuisance alarms, NFPA 72 requires that smoke alarms not be located directly in cooking areas, and that any alarm located within 20 feet of a cooking appliance be photoelectric. Studies have shown that this should be reasonably effective except where some cooking techniques (blackening, deep frying, and broiling especially in a broiler that is not clean) are employed. However, photoelectric detectors may also alarm to these more egregious cooking styles. The second biggest nuisance alarm culprit is steam from showers where both detector types are equally susceptible.

**In summary, the research conducted by NIST staff leads to the conclusion that both ionization and photoelectric alarms provide enough time to save lives for most of the population under many fire scenarios; however, ionization alarms may not always alarm**

**even when a room is filled with smoke from a smoldering fire, exposing the most sensitive populations with mobility limitations to an undetermined risk. Photoelectric detectors can provide a lot more warning time than ionization detectors in a smoldering fire; at the same time a smoldering fires can take a longer period to become dangerous. Ionization detectors can provide a little more time than photoelectric detectors in a flaming fire; in this case there can be little time to spare.** Changes in furnishing materials and construction over the past decades have reduced the time available for safe egress in any fire. NIST is currently conducting research to assess whether or not modifications may be needed in the standard test method for certifying residential smoke alarms to accommodate the changing threat.