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Recent Advances In Residential Smoke Detection

National Bureau of Standards

Richard Bright

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RICHARD G. BRIGHT, *Research Engineer*

National Bureau of Standards

THE LOSS OF LIFE BY FIRE IN THE HOME is a significant problem in the United States. If the homes had been equipped with an early-warning fire detection device, between 40 percent and 50 percent of the people killed in these fires might have been saved. One early-warning fire detection device that shows great promise is the single-station smoke detector, a fact that is being recognized by more and more American code authorities. As a consequence, an increasing number of the US building codes are requiring the installation of single-station smoke detectors in all new housing.

There are problems, however, with several of the single-station smoke detectors on the market. In addition, there are no published performance standards for these detectors — standards that would improve the quality of smoke detectors offered for sale and would eliminate many of the problems.

The National Bureau of Standards, in conjunction with the approvals of testing laboratories and the detector manufacturers, is developing performance standards for the single-station smoke detector. Development and publication of these standards will have a material effect on improving the quality of smoke detectors sold in this country.

Fire kills nearly 12,000 people each year in the United States and results in injuries to several hundred thousand more. Fire is the third leading cause of accidental deaths, exceeded only by falls and motor vehicle incidents.

A comparison of the fire death rate in the United States with that of several other countries, as shown in Table 1, will give you some idea of the magnitude of the problem. While differing reporting procedures make international comparisons a bit unreliable, it seems clear that the United States has a death-per-million rate nearly twice that of second-ranked Canada and three times that of Great Britain.

The reasons for this great difference in the fire death rate between the United States and other technologically-advanced countries are obscure. Whatever the reasons, this difference is cause for concern.

Over one-half of the 12,000 fatalities from fire in the United States occur in dwellings — somewhere between 6,000 and 7,000 per annum. By dwelling, we mean multifamily occupancies such as apartments, single-family housing (including semidetached as well as detached housing), and mobile homes.

Table 1. Fire Deaths Per Capita For 1972 — World Wide

Country	*Fire Deaths Per Million Persons*
United States	57.1
Canada	29.2
United Kingdom	18.1
Sweden	18.0
Finland	16.3
Australia	14.8
Japan	14.0
Denmark	12.7
New Zealand	9.8
Belgium	6.8
The Netherlands	5.8
France	4.9
Italy	2.9

Source: FIRE JOURNAL, Vol. 67, No. 6 (Nov. 1973), p. 51.

The chance of multiple loss of life from fire occurring in a dwelling, as compared to other occupancies, is even greater, as Figure 1 indicates.

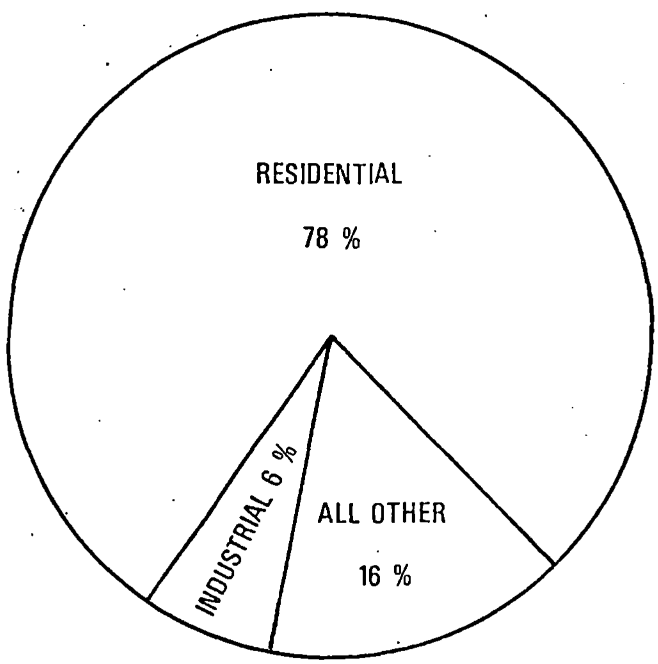
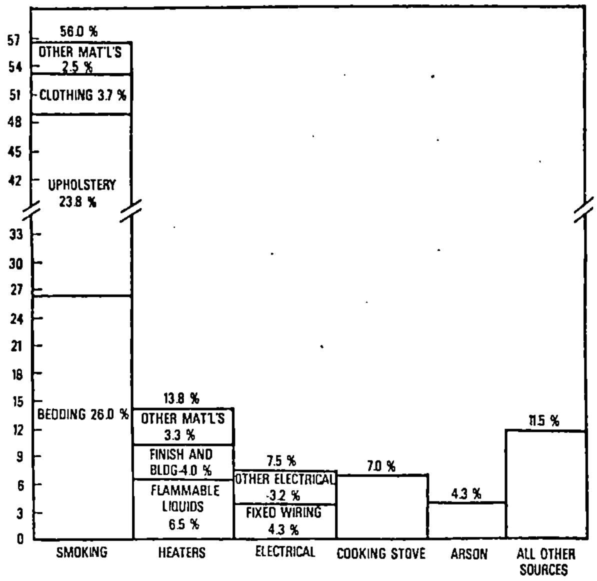


Figure 1. Multiple-death fires by occupancy (three deaths or more). Source: NFPA statistics.



SOURCE: NFPA No. FR 72-1, "A STUDY OF RESIDENTIAL FIRES" 1972

Figure 2. How fatal residential fires start.

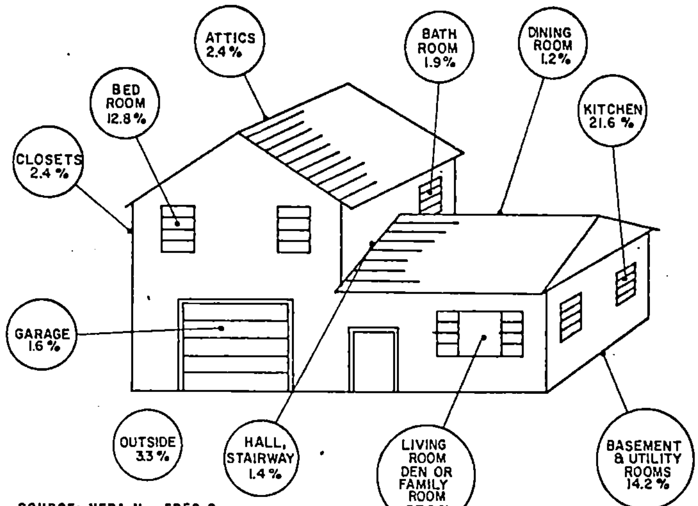
How fatal fires start in dwellings is shown in Figure 2. Note that the act of smoking accounts for 56 percent of the fire initiations, and that the item first ignited was bedding or upholstery almost 50 percent of the time.

Where fatal fires start is shown in Figure 3. The living room or lounge and bedrooms together account for 50 percent of the total. Basement or utility rooms and kitchens account for the other large segment of fire origin – some 35.8 percent of the total.

The time of occurrence of dwelling fires is divided almost evenly between night and day, as shown in Figure 4. Those dwelling fires that result in a fatality have nearly the same division, with more persons losing their lives in daytime fires than in nighttime fires. This is shown in Figure 5.

However, if we look at the time of occurrence for those dwelling fires resulting in multiple loss of life, a different picture emerges. In this case, 75 percent of all the multiple loss-of-life fires occur at night, with only 25 percent occurring in the daylight hours. This is shown in Figure 6. The significance of this is that the people were apparently asleep and unaware of the development of the fire until late into the fire incident, too late to save themselves. From this kind of data, one can conjecture that if the dwelling had been equipped with some type of early-warning fire detection device, many of these fatalities could have been avoided.

Fortunately, the magnitude of the residential fire fatality problem in the United States has been receiving increasing attention from code authorities, standards-writing organizations, manufacturers, governmental bodies, and the public at large. Recently, the President's National Commission on Fire Prevention and Control issued its final report.[1] In this report, the



SOURCE: NFPA No. FR56-2

Figure 3. Where fatal residential fires start.

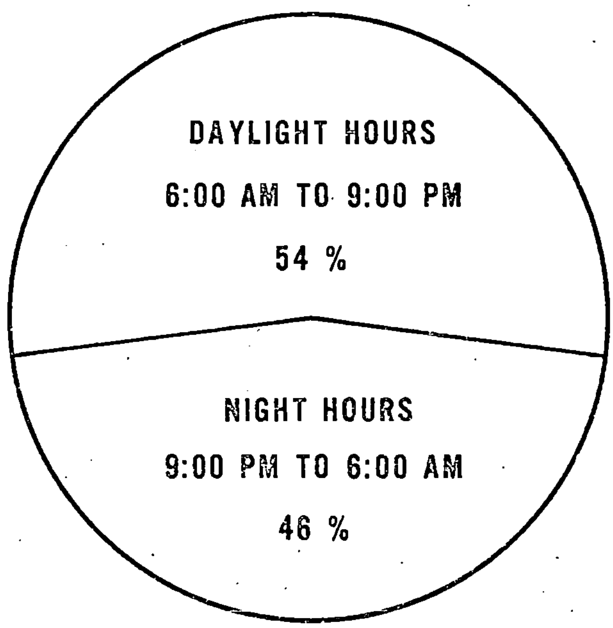
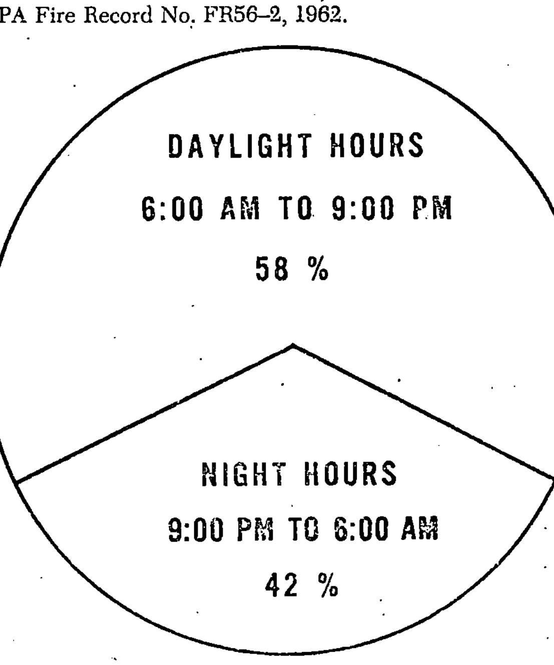


Figure 4. Home fires, time of occurrence. Source: NFPA Fire Record No. FR56–2, 1962.

Figure 5. Home fires with fatalities, time of occurrence. Source: NFPA Fire Record No. FR56–2, 1962.



[1] *America Burning,* The Report of the National Commission on Fire Prevention and Control (Washington, D.C.: Superintendent of Documents, US Government Printing Office, 1973).

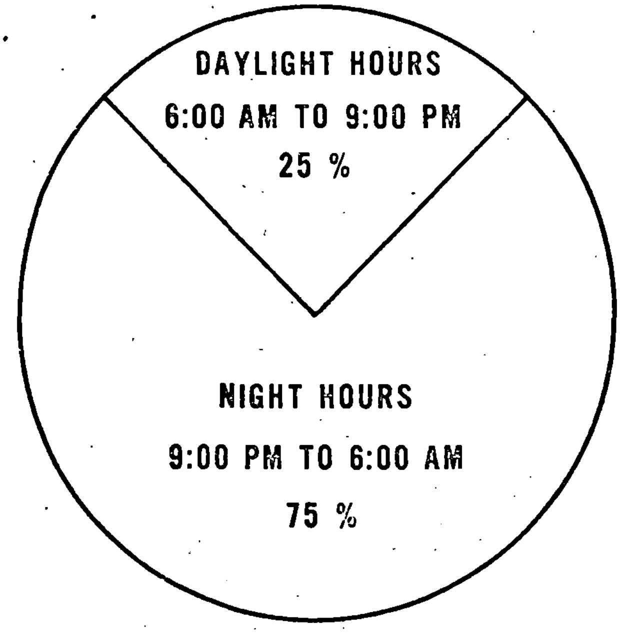


Figure 6. Home fires with multiple fatalities, time of occurrence. Source: NFPA Fire Record No. FR56–2, 1962.

Commission urged that Americans protect themselves and their families by installing approved, early-warning fire detectors and alarms in their homes.

The only nationally-recognized American standard on the subject of fire warning systems for the home is the NFPA's Standard No. 74, *Household Fire Warning Equipment*. The 1972 edition of this Standard required the installation of a smoke detector outside the sleeping areas and heat detectors in all other rooms and major areas of the house. Such a system is costly, with estimates ranging between $700 and $1,200 for a typical three-bedroom house with basement. The magnitude of this cost has worked against the widespread adoption of this Standard by various local code authorities in the United States.

The 1974 edition of NFPA No. 74, however, recognizes the fact that smoke detector technology has advanced to the point where the judicious installation of one or two smoke detectors could be more effective than a house full of heat detectors in alerting dwelling occupants to fire.

From available statistical data, it appears that most dwelling fires start by smoldering. For example, in 1963, the Los Angeles Fire Department reported the results of a study of 4,151 dwelling fires that occurred during 1960 in their city and concluded that 75 percent began as slow, smoldering fires.[2] In other words, the first combustion product to originate from the incipient fire is likely to be smoke. Therefore, it would appear that a smoke detector is more suitable as an early-warning fire detection device than a heat detector is.

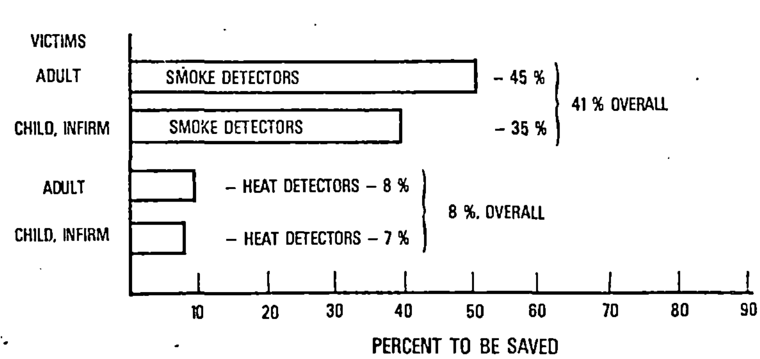
[2] "Los Angeles Fire Department Tests — Fire Detection Systems in Dwellings," NFPA *Quarterly*, Vol. 56, No. 3 (January 1963) p. 201.

The most definitive study of the lifesaving effects of fire warning systems in homes was done by McGuire and Ruscoe of the National Research Council of Canada.[3] In their study, they reviewed a series of dwelling fires in the Province of Ontario that resulted in 342 fatalities. Only unshared separate dwellings were examined. Two types of detector installations were considered. In the first, fixed-temperature heat detectors were assumed to have been installed at the top of all stairways and in the area of fire origin, which would mean one detector in each room. In the second, two smoke detectors (sensitive, ion-chamber-type) were assumed to be installed — one at the top of any basement stairs, and one at the top of the stairway to the second floor in two-story dwellings or one between the sleeping and living areas in single-story dwellings.

A judgment of the warning times to be expected in each fire was made, along with a judgment of the lifesaving potential for both types of detection equipment. The results are given in Figure 7. For smoke detectors, the lifesaving potential was estimated to be 41 percent. For heat detectors, the lifesaving potential was estimated to be 8 percent. While limited in scope, these estimates appear to be the only data of this type that are available.

The McGuire-Ruscoe study was theoretical in nature. To supplement their study, it would be helpful to have the results of some side-by-side fire tests of heat and smoke detectors in a typical dwelling environment using traditional dwelling fire sources. Such an

[3] J. H. McGuire and B. E. Ruscoe, *The Value of a Fire Detector in the Home,* Fire Study No. 9 (Ottawa, Ont.: National Research Council of Canada, Division of Building Research, December 1962).



SOURCE: McGUIRE, J.H., ETAL. " THE VALUE OF A FIRE DETECTOR IN THE HOME, NRC 7162, 1962

Figure 7. Lives to be saved with fire detectors.

experiment was conducted by the Bloomington, Minnesota Fire Department in 1969.[4]

A series of fire tests were conducted in a small dwelling typical of the houses in Bloomington. The house was about 30 feet (nine meters) long by 30 feet (nine meters) wide, and consisted of a basement, a first floor and an attic. There was a door at the foot of the attic stairs, but none at the top or bottom of the basement stairs. The door to the attic was kept open throughout the tests.

Heat detectors combining rate-of-rise and fixed temperature (136°F; 58°C) were installed – two in the basement, one in each of the five rooms and the center hall on the first floor, and one at the head of the attic stairs. Ionization-type smoke detectors were installed – one at the head of the basement stairs, one in the first floor hall, one at the top of the attic stairs, and one in the attic. One photoelectric-type smoke detector was installed at the top of the attic stairs.

A series of five test fires were conducted in various parts of the dwelling depicting a number of fires ranging from smoldering to open burning. In every test, the smoke detectors responded before the heat detectors did so. Even the smoke detectors remote from the fire origin responded before the heat detectors except in two cases, a simulated grease fire in the kitchen and a wastebasket fire in the living room. In these two cases, the heat detectors in the kitchen and the living room responded 45 seconds and 30 seconds, respectively, before the remote smoke detectors operated.

The type of smoke detector commonly used for residential fire protection in the United States is called the single-station smoke detector. It is a smoke detector in which the sensing chamber, the alarm-sounding device, and the electrical power transformation means are all housed within the detector enclosure. These detectors are designed to be fastened to the ceiling or hung on the wall, and then connected by a power cord to a nearby electrical outlet. Alternatively, the detectors may be mounted directly on electrical outlet boxes, in which case the detectors will be equipped with short electrical leads or plugs for connecting them to the dwelling's electrical power inside the outlet box.

The single-station smoke detector differs from the commercial smoke detector (which is referred to as a unit smoke detector in the United States) in that commercial smoke detectors must be connected by wiring back to a control panel. It is the control panel that supplies the electricity to the unit smoke detector, receives the alarm signal from the detector, and sends a separate signal to alarm sounding devices. The single-station smoke detector is, in a sense, a self-contained automatic fire alarm system.

Essentially, two different smoke-sensing modes are used by these single-station smoke detectors. In the one detector, which is referred to as a photoelectric smoke detector, the principle of scattered or reflected light is used (Figure 8). Under no-smoke conditions, the chamber is dark, and the light shines across the chamber and is received in a light trap on the far side. When smoke is present in the chamber, a photocell, located on the side of the chamber at right angles to the light source, sees the light scattered off of the smoke particles and, at a suitable illumination level, triggers the circuitry to the alarm horn.

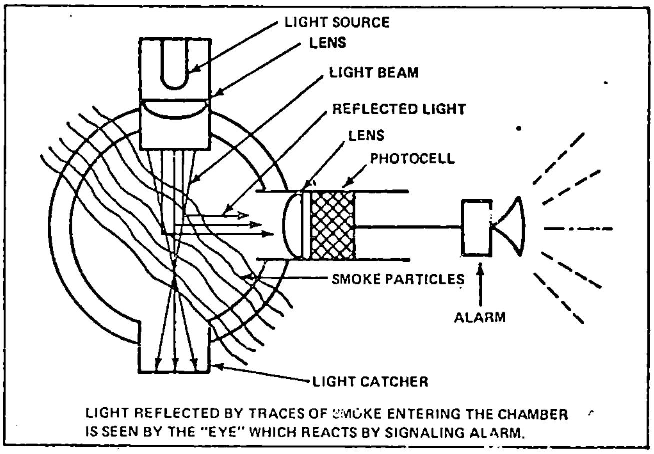


Figure 8. Photoelectric smoke detector chamber.

In the other type of detector, which is referred to as an ionization chamber smoke detector, a radioactive source material is used to ionize the air within the sensing chamber (see Figure 9). The ionization of the air results in a very small electrical current flow.

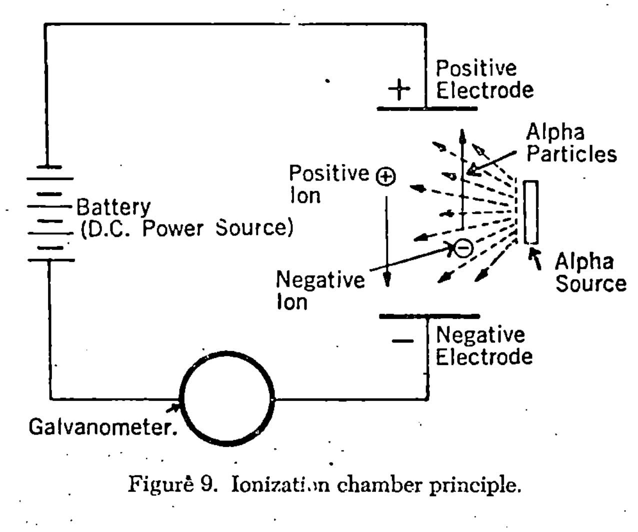


Figure 9. Ionization chamber principle.

[4] "Home Fire Alarm Tests," FIRE JOURNAL, Vol. 65, No. 4 (July 1971), p. 12.

When smoke particulates from a fire enter the chamber, the presence of the particulate results in a reduction in current flow. This reduction is sensed by appropriate electronic circuitry. At some predetermined reduction point, the circuitry is triggered, resulting in the sounding of the alarm horn.

There has been much discussion in the United States recently about the relative merits of the photoelectric and the ion chamber detectors. In our opinion, neither detector is superior to the other under all possible fire conditions. The photoelectric detector senses the larger smoke particles, those in the visible range. The ion chamber detector senses the smaller smoke particles, those in the nonvisible range. In general, the smoke from a typical dwelling fire will be composed of a wide range of particle sizes. A portion of these particles will be in the ion chamber detector range and a portion in the photoelectric detector range.

In general, it can be stated that if the fire is a slow, smoldering fire without any flame, a good photoelectric detector will be superior to a good ion chamber detector in terms of detection time. Conversely, if flaming is present in the fire, a good ion chamber will be faster than a good photoelectric detector in terms of detection time.

The problem in residential fire detection, as we see it, is that one cannot foretell with any degree of certainty what types of fires are likely to predominate under all conditions. Hence, given the present state of knowledge, either detector can suffice for residential, early-warning fire detection purposes.

As previously mentioned, both of these two types of single-station detectors are designed to be connected to the dwelling's electrical power. The ionization chamber smoke detector, because of its extremely low electrical power consumption, lends itself to battery operation. At the present time, there are at least five battery-operated, ionization chamber smoke detectors of the single-station type on the market in the United States. We know of at least six more that are under development.

Battery-operated smoke detectors have two advantages and one disadvantage when compared to detectors operated from the dwelling's electrical power. One advantage is that if the electrical power in the dwelling should be off, either due to an interruption from the utility company or an interruption caused by a fire within the dwelling, the detector will still function. The other advantage is that, if it is decided to install a smoke detector in an existing dwelling and an appropriately-placed electrical outlet is not available, this is of no consequence to the battery-operated detector. The major disadvantage is that the batteries will need periodic replacement, generally once a year.

Two types of batteries are presently used in these battery-operated detectors: alkaline batteries and mercury batteries. Alkaline batteries exhibit a declining voltage during their useful life (see Figure 10). Detectors using these batteries must adopt some means of avoiding a reduction in sensitivity as the battery voltage declines. One method used is to incorporate suitable voltage-regulation circuitry in the detector. Another method requires a periodic, usually monthly, resetting of the detector's sensitivity by the householder. The former method is, in our opinion, preferable.

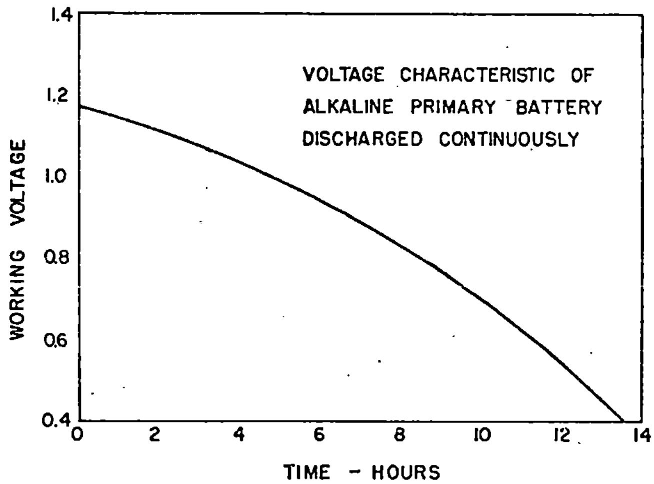


Figure 10.

Mercury batteries exhibit a reasonably constant voltage throughout their useful life (see Figure 11). As a consequence, detectors using these batteries maintain a fairly constant sensitivity throughout the life of the battery without the necessity for voltage regulation or sensitivity adjustments.

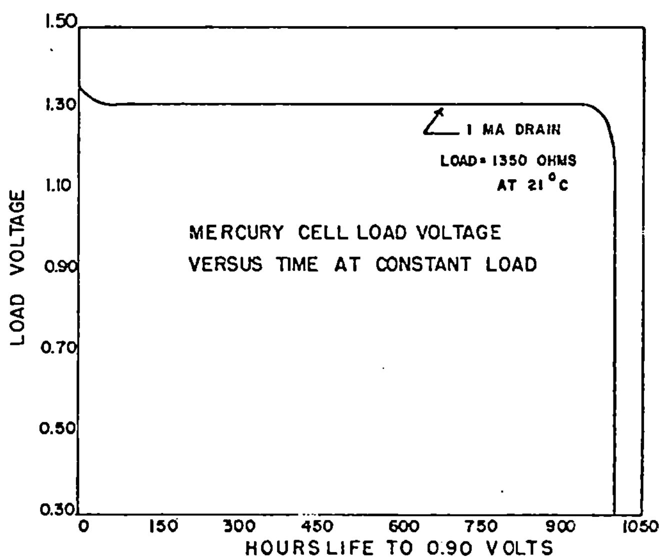


Figure 11.

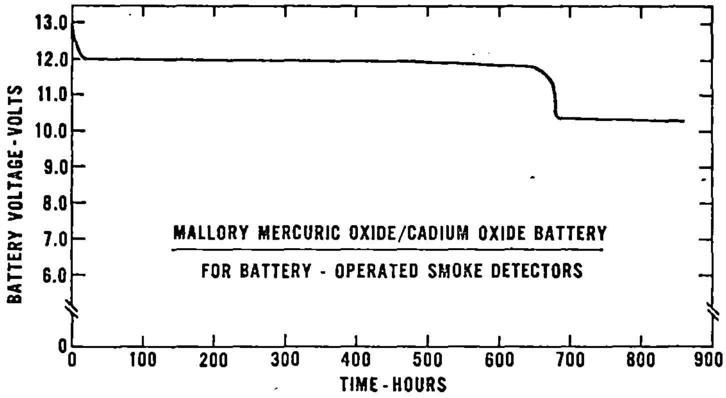


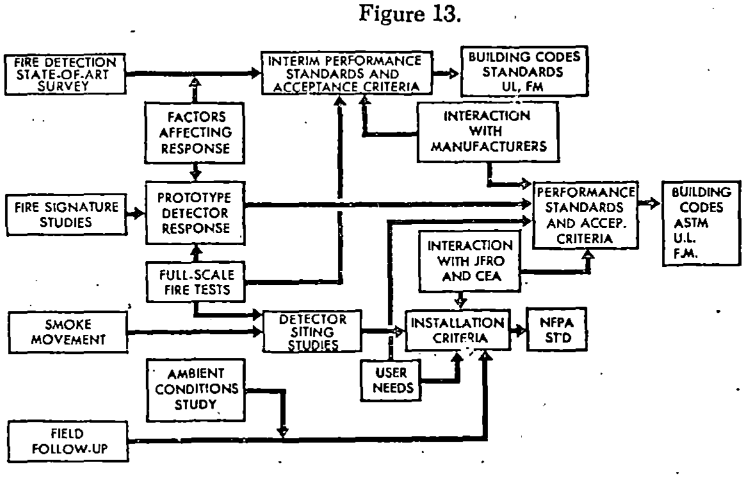
Figure 12.

In the United States, battery-operated smoke detectors are required to give an audible trouble signal when the batteries are approaching the end of their useful life. With the alkaline batteries, this is accomplished relatively easily by picking off an appropriate low-voltage point on the voltage curve. With the mercury battery, the problem is more difficult.

As stated earlier, the mercury battery voltage remains fairly constant until the end of its life. At this point, however, the voltage drops off rapidly — so rapidly, in fact, that it is not always possible to guarantee a trouble signal before the battery is dead. To overcome this problem, one manufacturer uses two batteries — one to power the detector and one to power the trouble signal at the end of the first battery's life. This, of course, increases the original cost of the detector as well as the annual maintenance cost.

Recently, the Mallory Battery Company developed a new mercury battery designed specifically for battery-operated smoke detectors. This battery is a hybrid of mercuric oxide and cadmium oxide cells. The combination of these two types of cells produces a battery with two voltages (see Figure 12). The detector operates on the upper battery voltage curve throughout most of its life. As the battery approaches the end of its life, it drops about 1½ volts. This is sufficient to engage the trouble circuitry. The battery is reported to have sufficient life left at this point to

Figure 13.



power the trouble signal for seven days, as required by the approval agencies in the United States.

At the present time, there is no nationally-recognized performance standard for the single-station smoke detector in the United States, although there are standards for the commercial or system smoke detectors. This does not mean that these detectors are not being approved by our nationally-recognized testing laboratories such as Underwriters' Laboratories, Inc., Factory Mutual, and Underwriters' Laboratories of Canada. What it has meant is that each laboratory is testing and approving them according to differing criteria.

It is because of this lack of standardization of test procedures that the National Bureau of Standards is active in the single-station smoke detector field. Figure 13 will give you some idea of our program. Our ultimate goal is the production of performance standards and acceptance criteria for single-station smoke detectors. We are presently working in the areas you see to the left of the chart.

During the course of this program, we have examined nearly all of the smoke detectors on the market in the United States, both single-station and commercial types. Early in the program, we discovered several problems with single-station smoke detectors, problems that we will attempt to eliminate with suitable elements in our planned performance evaluation procedures.

One of the major problems we found, and it is one we consider crucial to the performance of early-warning smoke detectors, is one that we refer to as ease-of-entry. Some of the smoke detectors we have examined have great difficulty in permitting smoke to enter the detector sensing chamber unless the smoke is moving at an appreciable velocity, say 50 feet per minute (15 meters per minute) or higher. Our own experiments, and experiments of others, indicate that the smoke from smoldering fires in dwellings may have velocities as low as seven feet per minute (2 meters per minute). Obviously, if we are to expect detection of these incipient fire conditions quickly enough to give the dwelling occupants sufficient warning to save themselves, the smoke detectors used must be capable of detecting smoke at the lowest velocities to be anticipated, provided the appropriate smoke concentrations have been reached. I might add that we have observed the same entry problem with both ionization chamber and photoelectric smoke detectors, though the reasons for the entry problem in these two types of detectors appear to differ somewhat.

The laboratory apparatus we use for testing the response of smoke detectors is shown in Figure 14. We are presently using punks as our smoke source. The

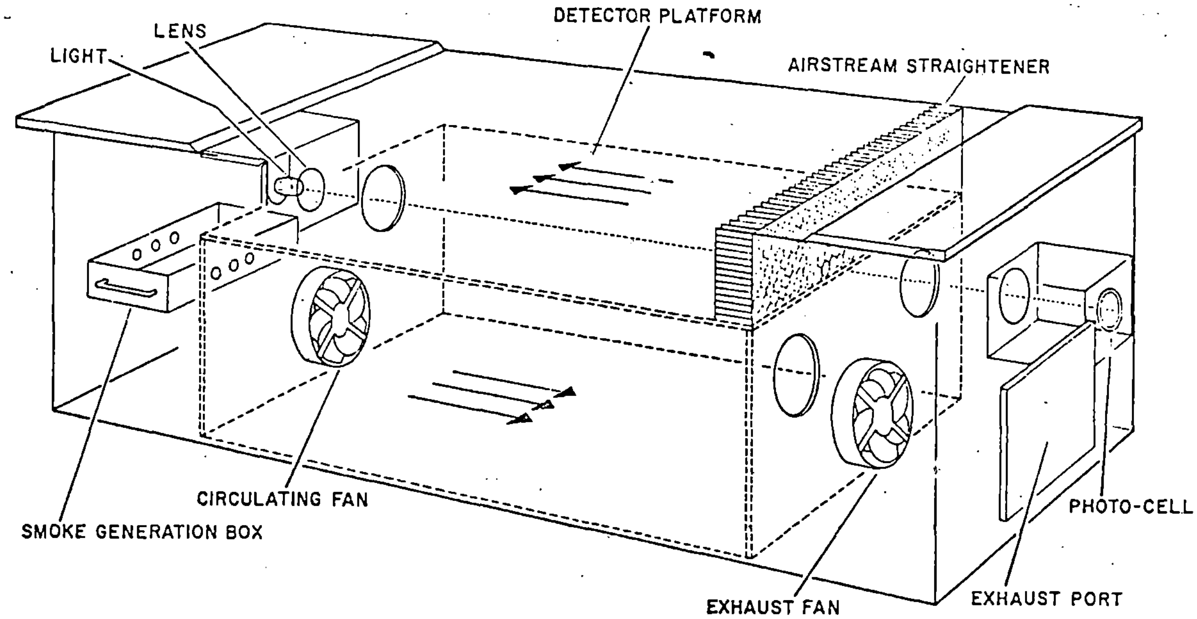


Figure 14. Smoke detector test chamber.

buildup of smoke is generally linear with respect to time. The circulating fan is used to vary the velocities within the test box. With this test box, we are able to produce velocities as high as 200 feet per minute (61 meters per minute) or as low as 15 feet per minute (4½ meters per minute). We are not able to go below 15 feet per minute and maintain homogeneous smoke conditions at the present time.

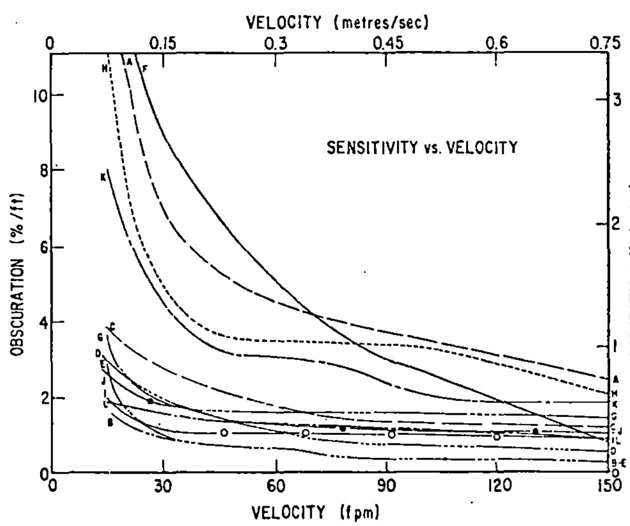
Figure 15 shows some of the results of tests run on several smoke detectors. The vertical axis represents the optical density of the smoke at alarm and the horizontal axis represents the velocity of the smoke-laden air. A few of the detectors exhibited reasonably flat response at all velocities. Four became rather insensitive at low air velocities. Two detectors, *E* and *G*, show a marked upward turn at velocities below 30 feet per minute (nine meters per minute).

These entry problems appear to be due to myriad reasons, too numerous to describe here. Suffice it to say it is only recently that some of the detector manufacturers have become aware of this problem. Several are now subjecting their detector designs to careful analysis of the detector's response characteristics to slowly-moving smoke. One photoelectric detector, recently introduced into the United States market, employs a chimney effect and literally pulls the smoke through the detector. This manufacturer has positioned heat-producing resistors within his sensing chamber to create the chimney effect.

Some of the single-station smoke detectors sold in the United States are designed to be mounted on the ceiling and some on the walls up near the ceiling; others are dual-purpose in that they may be mounted in either position. Based on our experience, we believe that the ceiling may be a better location in some instances, and the wall in other instances. The wall position is particularly preferred if the home is heated by a radiant heating system installed in the ceiling. This type of heating is used frequently in the more temperate climates of the United States. Radiant heating in the ceiling creates a thermal barrier at the ceiling, which tends to limit the penetration of smoke to the ceiling unless the fire has developed sufficient thermal energy of its own to push the smoke through to the ceiling.

Regardless of the location of the detector, ceiling or wall, the detector should perform adequately. We have not found this to be a problem with most of the ceiling-mounted detectors. But we have found that some detectors designed for wall mounting have great difficulty in detecting smoke in this position, while others do not. This pattern occurs more often with the photoelectric detector than with the ionization chamber detector. The difficulty appears to be related

Figure 15.



to the placement of heat-producing sources within the detector. Improper placement of the heat-producing sources can result in thermal barriers within the detector. These thermal barriers hinder or block the entry of smoke into the detector.

Single-station smoke detectors for the home should be reliable in that they should not malfunction, experience shifts in sensitivity, sound an alarm to other than a real fire condition, or require any more than an absolute minimum of attention during their life span. We do not think it unreasonable to expect that this life span should be thirty years or more. As one might expect, we are far short of this goal, at the present time, for most of the single-station smoke detectors on the market.

Malfunctioning of detectors is a very real problem. We have had experience with detectors that literally self-destructed and, in so doing, very nearly set fire to the surfaces to which they were fastened. The problem apparently arises from two sources. One source is transient electrical surges that appear on the electrical wiring to the detector, surges with which the detector is not able to cope. The other source is electrical faults occurring within the detector circuitry while it is operating at normal voltage, faults which have resulted in destruction of the detector through overheating. Our opinion is that detectors that use an internal transformer to reduce the household voltage to the detector voltage are better protected against electrical line transients than detectors using resistors to drop the voltage to the detector. Nevertheless, there has been some problem with shorts in transformers resulting in overheating of the transformers. Fortunately, the detectors generally detect their own smoke and sound an alarm before they are completely destroyed.

In general, photoelectric smoke detectors tend to become *less* sensitive with time, and ionization chamber smoke detectors tend to become *more* sensitive with time. In the former case, the detectors may become so insensitive that they do not respond to early fire conditions. In the latter case, the increasing sensitivity of the ionization chamber detectors will result in an increase in false alarms. Neither shift is desirable, and both can be minimized through careful design of the circuitry of the sensing chambers, and by careful selection of the components to be used in the circuitry.

The ionization chamber detector appears to be more false alarm-prone than the photoelectric detector in the home environment. Several types of combustion products may be present at one time or another in the home environment, products that lie in the sensing range of the ionization chamber smoke detector. These include combustion products from cigarettes and cigars, from cooking processes, and from fireplaces. The major problem seems to be from cooking. If the ionization chamber detector is remote from the kitchen, say at the top of the stairs outside the bedroom area, false alarms are infrequent. But if the detector is close to the kitchen, the reverse is true. This means that if the living unit is reasonably small, such as an efficiency apartment or similar, the detector will, in such cases, be too close to the kitchen to avoid false alarms. Under these conditions, a photoelectric detector may be preferable to the ionization chamber detector.

For long-term reliability, the ionization chamber detector has inherent advantages over the photoelectric detector. At the present time, the incandescent light source used in the photoelectric detector has a finite life of some three to five years. At the end of this period, the bulb will fail. When it does, the detector will sound a trouble alarm and the householder will need to change the bulb. Each photoelectric detector is equipped with at least one spare bulb to facilitate replacement.

The ionization chamber detector, on the other hand, uses a radioactive source material that has a half-life far beyond the life expectancy of the home in which it is installed. This feature, coupled with the fact that the detector consumes very little electrical power and thereby reduces the electrical stress on the associated circuitry, results in an inherently longer life detector without maintenance. Research is underway in the United States to produce longer-life light sources for the photoelectric detector. A photoelectric detector using a light-emitting diode is now being marketed. It will be some time, however, before we know the life expectancy of photoelectric detectors using light-emitting diodes. It is reasonable to expect that light-emitting diodes will have a longer life than incandescent light sources. But how *much* longer that life will be remains to be proved.

Recently, an increasing number of American manufacturers of smoke detectors have begun producing residential smoke detectors utilizing a solid-state, semiconductor crystal sensitive to combustible gases (see Figure 16). These sensors were first developed by and are being manufactured in Japan as combustible gas detectors.

The semiconductor crystal is an *N*-type with a metallic-oxide coating. Embedded heater coils are used to maintain the crystal at a temperature of approximately 482°F (250°C) in order to maintain a high level of electron mobility. The elevated crystal temperature also seems to prevent the condensation of water vapor on the crystal, which would tend to reduce the crystal's surface conductivity. In addition, this elevated temperature burns off any residue on the crystal's surface. The presence of combustible gases causes a reduction in the surface resistance of the sensor. This reduction in resistance results in an increased current flow which is used to trigger an alarm. As a fire detector, these sensors appear to be responsive to only oxidizable gases released by the fire. This would indicate that these devices will only sense fires burning with incomplete combustion. If combustion of the material is fairly complete, the sensor is not responsive to the fire.

When tested in a small-scale, laboratory-type, smoke-sensitivity test chamber, such as the one shown in Figure 14, the semiconductor gas sensor appears to have equivalent response to the typical photoelectric and ionization-type smoke detectors. This is mainly due to the fact that the combustibles used in this test chamber are generally smoldering materials with an insufficient thermal energy output to consume a significant amount of the combustible gases emitted. In large-scale testing that we have conducted with flaming combustibles, where an adequate supply of oxygen is available for complete combustion, our results have shown the semiconductor gas sensor to be unresponsive. It should be noted that the better photoelectric and ionization smoke detectors had no problem detecting these same large-scale fires.

The biggest problem that can be foreseen in the use of these gas sensors as residential smoke detectors is that of false alarms. Since this sensor is responsive to any combustible gas, it will respond to a vast number of ambient conditions normally found within the home. The use of any number of household aerosol products near the device as well as ammonia, alcohol, perfumes, aerosols from cooking, or even rapid changes in ambient relative humidity can cause false alarms. The sensor is not specifically sensitive to any single combustible gas. As a consequence, the presence of several combustible gases can produce an additive effect that can result in a false alarm, even though none of the individual combustible gases is present in sufficient quantity to induce an alarm.

These two characteristics of the semiconductor gas sensor — that is, its unresponsiveness to fires undergoing complete combustion and the sensor's possible undue-susceptibility to false alarms — mitigate against its use as a residential fire detector.

SUMMARY

The United States leads all nations in deaths due to fire. Most of these fire deaths occur in the home; a high percentage of these take place while people are asleep. While it is true that some of these fatalities may have been prevented if the home had been equipped throughout with heat detectors, the large cost has limited the acceptance of this approach. It is now apparent that more lives can be saved, and at considerably less expense, by the use of one or two strategically placed, single-station smoke detectors.

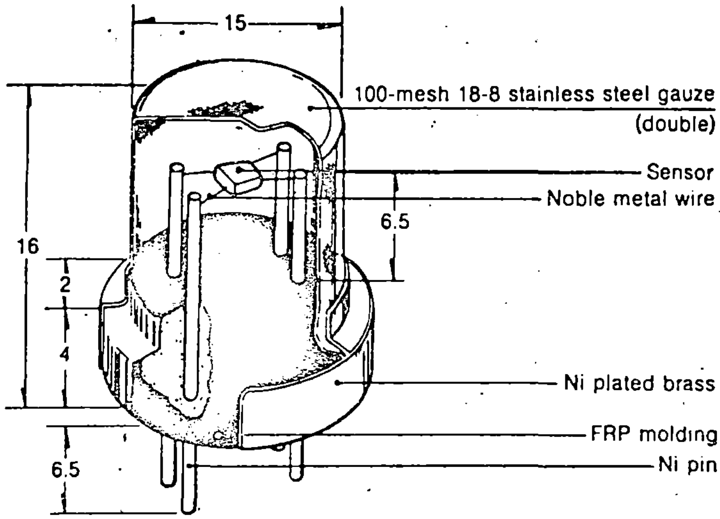


Figure 16. Combustible gas detector utilizing a solid-state semiconductor crystal sensor.

The various code authorities are aware of the magnitude of the residential fire fatality problem. More and more, these code authorities are requiring single-station smoke detectors in all newly-constructed apartments and homes. However, the state-of-the-art with respect to single-station smoke detectors is deficient in terms of the quality of some of the devices on the market. This is primarily due to the lack of acceptable performance standards for single-station smoke detectors in the United States.

Standard methods of evaluation are under development at the National Bureau of Standards, working in conjunction with the testing and approvals laboratories and the major manufacturers of single-station smoke detectors.

It can be anticipated that in the not-too-distant future, the quality of smoke detectors available on the United States market for residential application will be significantly improved over those available today. There is, at the moment, so much activity in smoke detector technology in this country that I predict the next three to five years will produce a new generation of smoke detectors using smoke-sensing methods completely different from those presently in use. △