September 7, 1978

UNITED STATES
NUCLEAR REGULATORY COMMISSION

SECY-78-492

INFORMATION REPORT

For: The Commissioners

From: Robert B. Minogue, Director
Office of Standards Development

Thru: for Executive Director for Operations

Subject: IONIZATION TYPE SMOKE DETECTORS

Purpose: To report to the Commission an interim analysis of the environmental effects of ionization smoke detectors

Discussion: In considering award of a contract for a comprehensive study of many kinds of consumer products containing radioactive material, the Commission requested* the staff to prepare an interim report on ionization type smoke detectors. The contractor is scheduled to give first and extensive consideration to smoke detectors and to report on this part of his study in about 8 months.

The enclosed executive summary and interim staff analysis of the environmental effects of ionization type smoke detectors are in response to the Commission's request. The interim staff analysis shows that:

(1) smoke detectors containing radioactive material are being extensively used to meet a recognized need for early warning of fire, and

(2) there is only a small radiation risk associated with manufacture, use and disposal of smoke detectors containing radioactive material.

The Office of Nuclear Material Safety and Safeguards concurs in this paper.

Robert B. Minogue, Director
Office of Standards Development

Enclosures:
1. Executive Summary - Smoke Detectors
2. An Interim Staff Analysis of the Environmental Effects of Ionization Type Smoke Detectors

*By SECY memo to EDO 7-11-78 on SECY 78-242

Contact:
Donovan A. Smith, SD
443-5946

EXECUTIVE SUMMARY

Smoke Detectors

Background: Upon review of SECY-78-242 "Proposed Contract Award for a Study of Consumer Products Containing Radioactive Material" the Commission requested that the contractor give first priority to ionization smoke detectors in implementing the contract. It also requested that within 30 (working) days the staff prepare an analysis, including a cost-benefit analysis, of the environmental effects of ionization smoke detectors on the basis of information currently available. It was recommended that the staff consult with the National Bureau of Standards about the effectiveness of smoke detectors, estimate the occupational exposures and related health effects for persons manufacturing ionization smoke detectors, and include the results of the recent NRC sponsored study of smoke detectors by Oak Ridge National Laboratory.

The attached report is in response to the above request. The following is a brief summary of the report.

Every year in this decade 7,500 U.S. citizens have died, 310,000 have been injured and more than $4 billion worth of personal property has been destroyed by fire. More than 40% of those lives could have been saved with smoke detectors. They provide a reliable early warning system in the event of fire. In his Proclamation of August 8, 1978 designating Oct. 8-14, 1978 as Fire Prevention week, President Carter urges American families and other property owners to install smoke detectors.

There are presently two types of smoke detectors on the market: the photoelectric smoke detector that contains no radioactive material and the ionization chamber smoke detector that does contain radioactive material. Technically speaking, there are differences between these two types of detectors that keep them from being equivalent. The ionization type smoke detector performs better on flaming fires than does the photoelectric and on the smoldering fires the converse is true. At least 2 major manufacturers have developed smoke detectors that combine the photoelectric detection chamber and the ionization chamber in a single unit. These "photo-ion" detectors are undergoing functional testing at Underwriters' Laboratories and are expected to be on the market by Christmas of 1978.

There have been significant developments in photoelectric type detectors in the past 4 or 5 years. One major change was the conversion from incandescent light sources to light-emitting diodes. With that change and the attendant lower power requirements, it became possible to produce battery operated photoelectric type detectors. In responding to an inquiry about the need for ionization type detectors in view of advancements in the photoelectrics, an NBS spokesman recently stated "... the photoelectric smoke detectors presently on the market exhibit large differences in performance characteristics from one manufacturers' brand to another. Even so, assuming that all available photoelectric smoke detectors were of the highest proficiency possible within the technology, a reappraisal would have to then be made as to whether ionization type smoke detectors still have a role to play in home fire safety. But as a matter of fact, we are probably a year or two or more away from that state-of-the-technical-art and, as a consequence, the same period of time away from the aforementioned appraisal." With respect to cost, photoelectric detectors are inherently more costly (by about 20%) to produce than comparable ion chamber smoke detectors due to the number and sophistication of components required.

The residential smoke detector market has grown tremendously in the past several years because of (a) many state, county and city codes which now require use of smoke detectors, and (b) aggressive promotion by manufacturers. In 1971 there were an estimated 50,000 detectors sold for home use; in 1977 there were an estimated 10,000,000 sold. About 95% of those are ionization type smoke detectors and 92% are battery operated. The average price in 1971 was about $50; in 1977, about $20.

Almost all ionization type smoke detectors contain small quantities of Am-241. Under NRC regulations (which became effective in 1969, prior to NEPA so an environmental impact assessment was not made) the user of an Am-241 smoke detector is exempt from regulations but the manufacturer must obtain a specific license from NRC to distribute his product. That license is not granted until NRC's technical reviewer has determined that the safety criteria in the regulations are satisfied.

Ionization type smoke detectors cause occupational exposures to two groups of NRC licensees: those licensees that make the detectors and those licensees that make the radioactive sources that are used in the detectors. Reports from NRC licensees making the detectors show distribution of 7,400,000 detectors containing a total of 36 curies of Am-241 for the period July 1, 1976 to June 30, 1977. Staff evaluations show a total (collective) occupational dose for detector manufacturers of about 30 person-rem. An estimate of the risk to a large population exposed year after year to a dose of 30 person-rem is the potential development of 3×10^{-3} excess fatal cancers per year or 3 in 1,000 years. Similar staff evaluations show a total (collective) occupational dose of about 20 person-rem for manufacturers of the Am-241 sources used in the 7,400,000 detectors. This exposure rate may be related to a potential for development of 2 excess fatal cancers in 1,000 years.

Users of Am-241 smoke detectors may receive a total (collective) annual dose of about 140 person-rem in normal use. This estimate is based on a detector population of 24,000,000 in households and 2,400,000 in commercial or industrial buildings. Maximum individual dose commitments and collective doses to firemen, based on results of fire tests at ORNL, are estimated to be 10 millirem and 0.028 person-rem, respectively. The estimated dose (collective) associated with all post-fire investigations, clean up and salvage could be about 10 person-rem.

Am-241 smoke detectors are expected to last 10 years or longer. Accordingly, to date it is unlikely that many have been disposed of. To assess the consequences of eventual disposal of worn out detectors by homeowners, the staff assumed an equilibrium population of 24,000,000 detectors and an annual disposal of 10% of that population. The assessment concludes that Am-241 smoke detectors, when disposed of with normal household refuse, do not present a significant risk to man or the environment. The underlying assumption leading to this conclusion is that the detectors will be dispersed in very large quantities of other household solid waste. Also, Am-241 does not readily enter the food chain.

Recent high temperature fire testing by Oak Ridge National Laboratory of Am-241 smoke detector sources, either tested separately or in whole smoke detectors, consistently produced airborne contamination less than 0.1% of the source. This is well within the 1% criterion given in the internationally recognized Nuclear Energy Agency standard for smoke detectors. The results of the ORNL tests have been used in this report.

AN INTERIM STAFF ANALYSIS OF THE ENVIRONMENTAL EFFECTS OF IONIZATION TYPE SMOKE DETECTORS

Contact:
Donovan A. Smith
443-5946

August 1978

CONTENTS

I. SUMMARY

Upon review of SECY-78-242 "Proposed Contract Award of a Study of Consumer Products Containing Radioactive Material" the Commission requested the staff to prepare, within 30 working days and on the basis of information currently available, an analysis of the environmental effects of ionization type smoke detectors. This report is in response to that request.

Within the last 2 or 3 years, ionization type smoke detectors have become extensively used in the U.S. During the period of July 1, 1976, to June 30, 1977, a reported 7,400,000 detectors containing 36 curies of Am-241 were distributed.

The manufacturers of the smoke detectors are licensed by NRC to produce and distribute their detectors. The users of the detectors are not subject to any regulatory requirements. At the end of its useful life, in about 10 years, the detector is expected to be discarded along with other household and industrial solid waste. As discussed in this report, this means of disposal does not present a significant radiation problem because the quantities of Am-241 are small, the volume of solid waste is large, plants do not readily assimilate Am-241 and humans do not readily assimilate Am-241 when ingested.

Occupational radiation doses associated with manufacture of the Am-241 sources and the smoke detectors containing the sources are estimated to total about 50 person rem for 1977. Exposure of a population of radiation workers at this rate for a period of 1,000 years might cause 5 cancer deaths. Other radiation

doses are estimated to total about 200 person rem annually. To develop this latter estimate, an equilibrium population of 24,000,000 smoke detectors in residences (15% of all residences) and 2,400,000 detectors in industrial use was assumed. The detectors used in residences were assumed to contain 2 uCi of Am-241; industrial detectors were assumed to contain 10 uCi of Am-241. A detector was assumed to last 10 years. These assumptions are believed to be reasonable for the equilibrium population.

Each year about 7,500 persons die in building fires in the U.S. An estimated 40% of those deaths could be prevented by use of smoke detectors. With the scenario developed in this report wherein 15% of all homes have ionization type smoke detectors, an estimated 450 lives would be saved annually. With this scenario, use of a greater number of detectors would save more lives.

The need for smoke detectors is unquestioned. The need for ionization type detectors is questioned because there are non-radioactive photoelectric type detectors on the market. Technically speaking, there are differences between the two types that keep them from being equivalent. The ionization type performs better on flaming fires than does the photoelectric and on smoldering fires the converse is true. By Christmas of 1978 a new "photo-ion" detector will reach the market. It will combine an ionization chamber and a photoelectric chamber in a single unit.

The prevention of 450 fire deaths indicated above should not be interpreted as a statement that the use of only ionization type detectors could achieve this prevention. The incremental benefit, in terms of saving of lives, of ionization detectors over photoelectric detectors is unknown to the staff. At this time the staff knows of no data showing any clear overall performance advantage of one type over the other with respect to preventing fire deaths. The staff notes, however, that a photoelectric type detector tends to cost about $5 more than does an ionization type. If a detector lasts 10 years, a simple calculation shows it would cost about $50,000 to save 1 person rem from ionization type smoke detectors.

II. DESCRIPTION AND USE

Ionization type smoke detectors use a radioactive source to transform the air inside them into a conductor of electric current. A small current passes through this "ionized" air. When smoke particles enter the detector, they impede the flow of current. Electronic circuitry monitors the current reduction and sets off an alarm when the current gets too low.

Ionization detectors as a type respond particularly well to the "smoke" generated by a flaming fire. They require very little current, so they can be powered effectively by batteries. A battery-powered detector can be installed almost anywhere, since it needs no electrical outlet. And such a detector will work even in a power failure.The October 1976 edition of Consumer Reports lists its drawbacks: Ionization detectors are typically relatively insensitive to smoke from a smoldering fire. And battery-powered models must have their batteries replaced at periodic intervals.(A copy of the article from Consumer Reports is attached as Exhibit "1".)

The radioactive material used to "ionize" the air in the smoke detector is usually the radioisotope americium 241 (Am-241) or the radioisotope radium 226 (Ra-226). Am-241 is a byproduct material and subject to NRC regulations. Ra-226 is a naturally occurring radioisotope and is not subject to NRC regulations. Although Ra-226 has been extensively used, current Ra-226 smoke detector sales are on the order of 1% of the market. Manufacture of Ra-226 smoke detectors is regulated by some State radiation control programs using the recommendations of NARM Guide #3. NARM Guide #3 was prepared by a Task Force under the Conference of Radiation Control Directors. NRC people served as resource persons to the Task Force. NARM Guide #3 applies essentially the same standards to Ra-226 smoke detectors as are found in NRC regulations.

NRC provisions for Am-241 smoke detectors are in 10 CFR 30.20 and 10 CFR 32.26 - 32.29. These regulatory requirements were issued as proposed regulations late in 1968 and were issued as effective regulations early in 1969. Section 10 CFR 30.20 authorizes the user to possess, use and dispose of the Am-241 smoke detectors and not be subject to any regulatory requirements. Sections 10 CFR 32.26 - 32.29 contain the requirements for issuance of licenses authorizing the manufacture and distribution of Am-241 smoke detectors. To obtain a license the manufacturer, among other things, is required to describe fully the radiation safety features of his product. The NRC's technical reviewer must determine that the submitted information satisfies the safety requirements set out in the regulations before the license is issued. The NRC regulates the distribution of Am-241 smoke detectors in both Agreement States and non-Agreement States. It should be noted that NRC regulations treat only radiation safety aspects of the smoke detectors.

State and local ordinances pertaining to smoke detectors usually address when and where they must be used and what detectors are acceptable from a functional standpoint. Detectors usually are required to have the approval of a nationally recognized testing laboratory. Most manufacturers have their detectors tested by Underwriters Laboratories, Inc. to UL Standard 217. Literature directed to the consumer and distributed by the National Bureau of Standards and the National Fire Prevention and Control Administration, U.S. Department of Commerce advise the consumer; "The detector you buy should be approved by a major testing laboratory such as Underwriters Laboratories, Inc. (UL)."

Ionization type smoke detectors have been used in commercial and industrial installations for over 25 years. The first units contained Ra-226. About 15 years ago, the first Am-241 units were distributed in the U.S. and used under a general license which required controlled disposal. Those units contained up to 130 microcuries each of Am-241. Comparable units, because of technical advances, now contain less than 1 microcurie of Am-241.

The residential market for smoke detectors far exceeds the industrial market. This has been true for the last 5 years and is expected to continue. The residential use of smoke detectors has been vigorously promoted by manufacturers. The National Fire Prevention and Control Administration, NBS and Housing and Urban Development also have promoted their use in efforts to reduce fire deaths in the home.

Smoke detectors are easy to purchase. They are sold in hardware stores, drug stores, food stores, department stores, etc. and by enterprising groups such as Scouts, civic associations and volunteer fire departments.

Installation in the home is simple. For a battery operated unit it normally requires only a screwdriver and five minutes effort. Instructions for locating detectors are widely distributed. Units should be tested monthly by holding a lighted match near the detector. Repairs generally consist of replacement of the battery about once a year. Many units provide for emitting a warning signal near the end-of-life of the battery. Most manufacturers provide a 1 year service warranty on their detectors whereby they will be repaired without charge if returned to the manufacturer and if the warranty card has been filed with the manufacturer.

On occasion a particular model smoke detector has developed a particular functional problem and undergone "recall." One widely publicized "recall" began in January 1977. In this instance, the detector, a 120 VAC-powered unit, contained a carbon-composition resistor inadvertently undersized for the power it was called upon to dissipate. When the resistor failed, it occasionally arced and burned. This, in turn, tended to ignite a large, paper shield used to keep curious fingers out of the electronics. Unfortunately, the paper was not flame-proofed and the resulting fire from the paper has, on occasion, resulted in flame and/or heat exposure to the surface upon which the detector was installed. Despite efforts by the manufacturer of the detector, extensive publicity, and strong encouragement by the Consumer Product Safety Commission, about half of the 115,000 units involved have not been accounted for.

Ionization type smoke detectors for the home are estimated to last about 10 years. Since most such detectors have been in use less than 3 years, relatively few have been disposed of. However, when the detector reaches the end of its useful life, it will likely be discarded along with other solid household wastes. As discussed later in this report, such action will not cause a safety problem. Many detectors carry labels that recommend return to the manufacturer for disposal. In view of the inconvenience and cost involved, relatively few homeowners are expected to follow this recommendation.

Some industrially used ionization type smoke detectors may be returned to the manufacturers. As explained by one manufacturer, the industrial units are usually part of an expensive fire detection and control system which is designed to last for the life of the building. And, when the building is to be demolished, the detector system is likely to be returned to the manufacturer for its salvage value.

EXHIBIT 1

Smoke Detectors

The 750,000 residential fires each year are responsible for 57 per cent of U.S. deaths by fire. Most of those deaths occur at night during sleeping hours, and many could be prevented if the burning homes had fire-alarm systems to wake sleepers before they became victims. A fire-alarm system needn't be elaborate; there are now devices priced at about $40 to $60 that should serve well.

Of course, an alarm is only one aspect of a total program of home fire safety, which should include fire-prevention measures, fire extinguishers (for small blazes only, see CONSUMER REPORTS, January 1976), and the development of alternate escape routes from the house in case of fire. Information on all of these is available from the National Fire Protection Association (470 Atlantic Ave., Boston, Mass. 02210) or your local fire department.

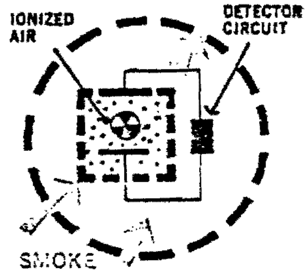
Fires have "signatures"—characteristic ways in which they make their presence known. An obvious signature is, of course, heat. Though heat-triggered alarm systems are widely used in industrial and commercial buildings, heat is one of the poorer signatures on which to base a lifesaving system. Smoke reveals the presence of fire much sooner than heat does, a fact that makes smoke detectors better than heat detectors as early-warning devices for homes.

The devices CU evaluated are "single-station" units—independent boxes that you mount on a ceiling or high on a wall. Such units require no special wiring; they are plugged into an ordinary a-c outlet or are battery-powered. The ones we tested are shallow plastic enclosures that hug the ceiling or wall. They're no more obtrusive than, say, the housing for door chimes or a small ceiling light fixture.

HOW THEY WORK

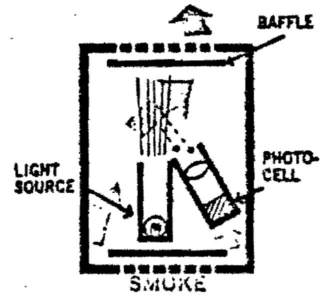
There are two types of smoke detector commonly used in the home; each has its strengths and weaknesses.

Ionization detectors use a radioactive source to transform the air inside them into a conductor of electric current. A small current passes through this "ionized" air. When smoke particles enter the detector, they impede the flow of current. Electronic circuitry monitors the current reduction and sets off an alarm when the current gets too low.



Ionization detectors as a type respond particularly well to the "smoke" generated by a flaming fire. They require very little current, so they can be powered effectively by batteries. A battery-powered detector can be installed almost anywhere, since it needs no electrical outlet. And, of course, such a detector will work even in a power failure. The drawbacks: Ionization detectors are typically relatively insensitive to smoke from a smoldering fire. And battery-powered models must have their batteries replaced at periodic intervals.

Photoelectric detectors have a lamp that directs a light beam into a chamber. The chamber contains a light-sensitive photocell, which is normally tucked out of the way of the lamp's direct beam. But when smoke enters the chamber, the smoke particles scatter the light beam. The photocell now "sees" the light and, at a preset point, sets off an alarm.



A typical photoelectric detector is relatively sensitive to smoke from smoldering fires but reacts rather slowly to flaming fires—about the reverse of the ionization detectors' performance. The photoelectric models must be connected to an electrical outlet, which limits their installation possibilities somewhat and renders them inoperative should your power fail for one reason or another.

DETECTING FIRES

The causes of fires are many and varied. They range from the slow spontaneous combustion produced by a pile of greasy rags to sudden flares after a lightning strike. Similarly, fires grow in a variety of ways. So we had to try out our detectors on a number of different kinds of fires, ranging from smoldering ones to open blazes. The box on page 557 describes our test methods.

With a smoke detector, the prime requirement is speed of response; a matter of minutes or even seconds can spell the difference between entrapment and escape. In general, our tests confirmed the reputations of the two detector types.

The ionization detectors, as a class, responded quickly (within about two minutes) to flaring fires that produced little or no visible smoke. The photoelectric detectors generally ignored the smokeless blazes for as long as we allowed the tests to run (about 10 minutes). On the other hand, photoelectric models sounded the alarm on the smoldering fires reasonably well (in about 20 minutes). The ionization detectors eventually responded to the smoldering fires, but as a group they responded much later than the photoelectrics —an average of some 30 minutes later.

Both types of detector responded to our two other kinds of fire within fairly short intervals of one another.

So much for the general differences between the types. The basis of our Ratings lies in the specifics. One photoelectric model performed about like another. But there were some marked differences among the ionization detectors.

Alone among the ionization models, the *Guardion* responded consistently and quickly to a smoldering fire. That response makes the *Guardion* the most desirable model for installations that will consist of only one detector. We have therefore check-rated it. The *Honeywell* also turned in a commendable performance; it reacted to every test situation, though somewhat later than the *Guardion* did. The captions on the facing page show the time range of responses for the two types—and for the check-rated *Guardion*.

One ionization model, the *Master*, was conspicuously slow. Our two samples responded to the smoldering fire only once in six tries. The *Master* even did poorly with our flaring fire, the type of fire on which the other ionization models excelled. A third sample of the *Master* did no better.

FEATURES AND FOIBLES

Though speed of response is crucial, convenient and effective alarm operation also depends on other factors:

Checking provisions. All the units respond to some sort of check-test meant to assure you that the detector is functioning. Some models provide a test button or lever; others recommend that owners blow smoke (from a cigarette or snuffed candle, for example) into the detector. Prudent owners will check out their detectors once a week.

The minor differences in ease of checking probably depend mainly on the habits of the detector's owner and on the particular installation. Smokers, for instance, have a readier source of smoke than nonsmokers do, so nonsmokers will find a test button easier to use. But a button can be inconvenient when a detector is mounted on the ceiling or high on a wall. An external test button has an advantage over an internal one, which requires you to take off the detector's cover (they come off easily).

Note that lightning can cause voltage to surge in household electrical circuits. The plug-in units should be checked for proper operation after a lightning storm to make sure that a surge hasn't damaged the detector.

Batteries. All the battery-operated models warn you when their batteries run low. The warning itself is an intermittent signal, rather like a hiccup. The alarms will still function for a considerable period after the low-battery signals start. But it's a good idea to have a replacement battery on hand rather than hunt for proper batteries in the stores later.

The hunt could be a particularly long one with the *G.E. Home Sentry*, the *Kwikset*, and the *Master*, all of which use a rather hard-to-find 12.6-volt battery *(Mallory 304116)*, designed especially for smoke detectors. The *BRK* and the *Sears* use an 11.2-volt mercury battery that seems to be a bit better stocked (it's available, for instance, as *Mallory TR431* or as *Sears 5709*). The batteries easiest to replace are the alkaline nine-volt battery for the *Guardion* and the six AA alkaline cells for the *Smokegard;* those are widely sold in many stores, even in supermarkets.

Battery-function signals. Cool temperatures sometimes cause battery voltage to fall. For that reason, you may hear a battery-powered detector perversely chirping its "replace battery" signal in the wee hours of the morning, when your home has cooled about as much as it's going to. At that point, it's quite natural to remove the battery, to silence the alarm, and go back to bed. If you forget to replace the battery, your detector will be in no position to protect you.

Three models provide a useful reminder to replace batteries in such situations. The *Smokegard* has a small light that winks when the batteries are in place and working; it goes off when batteries are dead, unduly weak, or removed. With the *G.E. Home Sentry*, a warning flag pops out at the first low-battery beep and stays out until you push it back into the unit. The *Guardion* will also signal with a red flag when you remove the battery. The arrangements on the *Smokegard* and the *G.E. Home Sentry* continue to warn of dead batteries even after the detector has stopped giving its audible signal. That situation could arise if the detector had started to signal while you were away on an extended vacation. Its manufacturer says that the *Guardion* will continue its audible low-battery warning for 30 days, but CU didn't attempt to confirm that by test.

In plug-in detectors, the equivalent of a dead battery is a power failure, blown fuse, or tripped circuit breaker. When that happens, a pilot light goes off. The photoelectric models also sound a pulsating signal if their bulb burns out.

Alarm sounds. The units ranged in loudness from 82 to 90 decibels. That's reasonably loud, but not ear-piercing; it should be enough to wake most sleepers if the detector is located near the bedroom. Unfortunately, a number of models varied in loudness from sample to sample, so we couldn't pinpoint which models might be inherently louder than others. The *Kwikset* has a pulsating alarm judged likelier than most to awaken a deep sleeper.

Many of the units gave their first indication of response to a smoldering fire by tiny hiccups, or brief activations of the alarm. The hiccups increased in frequency until, after a few minutes, the alarm finally became steady. We'd rather have the full alarm at the first sign of smoke.

Nuisance alarms. Smoke detectors can't differentiate friendly from deadly fires; a burned hamburger or smoky fireplace may alarm them just as much as a burning house. To avoid frequent nuisance alarms, don't install a detector in a kitchen or in a room with a fireplace. Furnace rooms aren't a good idea, either—a gust of wind could cause a small backdraft in your furnace, setting off the alarm. The same goes for garages, because of car exhaust.

CU installed the rather sensitive *Guardion* in several homes to check for possible nuisance alarms. And, indeed, it did go off now and then in response to smoke from cooking, even though it had been installed at some distance from the kitchens. But we believe an alarm that sometimes goes off when there is no danger is a lot better than one that stays silent when needed. One can learn to live with a few nuisance alarms. (It may help to regard them as reassuring, though unscheduled, tests of the detector.) Fanning the smoke away from the detector will usually silence it quickly. No detector was so prone to nuisance alarms as to invite disconnection.

The *Honeywell* does come with instructions that tell users how to reduce the unit's sensitivity to avoid nuisance alarms. Honeywell claims that the unit will be sensitive enough for its purpose even at its lowest setting. We did not check that claim. But since the unit's control allows only a very small adjustment, its sensitivity ought not to be affected much.

Multiple hookups. A number of models, named in the Ratings, allow you to interconnect from two to five separate detectors so that all of the alarms sound when any one o

CU'S TESTS: FIRES ON DEMAND

Producing fires big enough to simulate those most likely to occur at home posed a difficult problem for CU's engineers. So did creating fires similar enough to each other to serve as a basis of fair comparison among the models under test. Here's how we proceeded:

Our first job was to find a room suitable for testing. It had to be big enough so that smoke would have to travel some distance before it reached a detector, to simulate the conditions under which early warning can make a difference. It also had to have a viewing window and be virtually gas-tight and draft-free.

A sound-film studio used by CU provided near-ideal conditions. We installed an exhaust system to clear the room of smoke after tests. We also designed and built a computer-controlled data-acquisition system that sensed when each alarm went off, noted the amount of smoke present near the detector at that time, and correlated the results.

We tested the detectors with four kinds of fires, each made from different materials:

1. Strips of newspaper, piled in a wire-mesh cylinder (about 12 inches in diameter) to a depth of about a foot and ignited with a match. This test simulated a fast blaze relatively free from visible smoke (a wastebasket fire, for instance).
2. A pyre of three layers of ¾x¾-inch wood strips laid out in a pattern suggested by the National Bureau of Standards. Lit by a small pan of alcohol, the pyre smoldered for a bit, creating ample quantities of smoke. After 30 seconds or so, the flames started to grow into a substantial blaze while the smoke diminished. Many fires start and propagate that way.
3. Polyurethane foam—a 9x9x3-inch rectangular slab cut from cushioning meant for a chair or sofa. Ignited by alcohol, the material produced ample amounts of smoke and flame.
4. Cotton upholstery stuffing, ignited with an electric charcoal starter. No flame ever appeared in this test. The stuffing smoldered, slowly filling our room with choking, slow-moving layers of white smoke. This test was our longest; it took well over an hour. We considered it a good simulation of fires that result from smoking in bed, among other things.

Each of CU's test samples (and we tested at least two of every model) underwent at least three exposures to each of our four classes of fire.

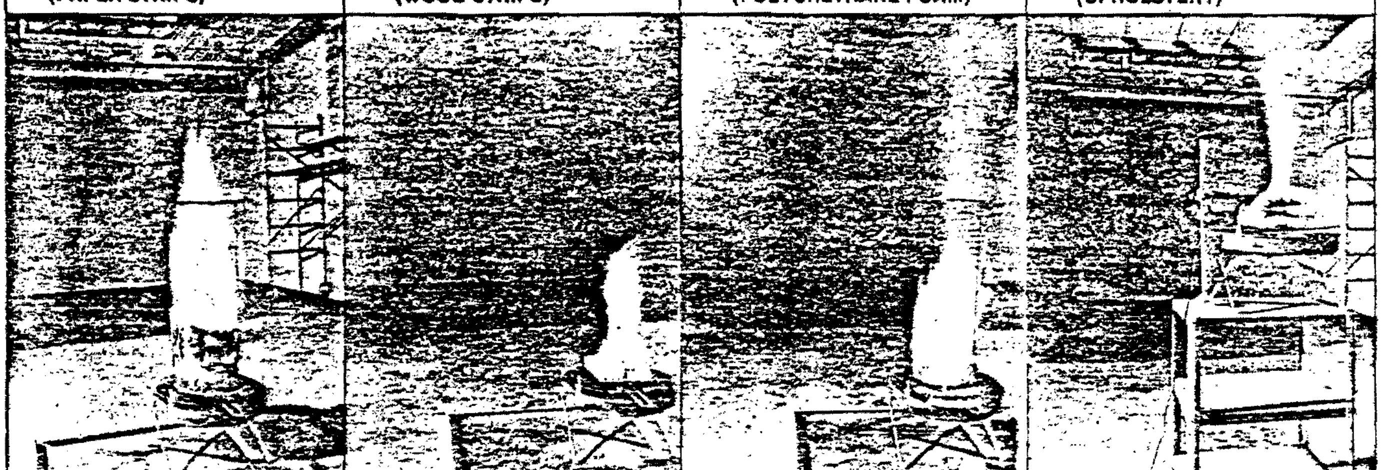
Nearly all the detectors either stipulate ceiling mounting or allow, in addition, the option of a wall mount. However, two photoelectric models (the *Captain Kelly* and the *Nutone*), insist on wall mounting between 6 and 12 inches from the ceiling. Yet other models that appear identical to the *Captain Kelly* are not so restrictive. Accordingly, we first tested every model on the ceiling of our test chamber. We then tested on the wall those whose instructions suggest or require wall-mounting.

Well, the manufacturers were right—at least when it comes to smoldering fires. The two that stipulate wall-mounting, and all others that make it an option, went off faster on the wall than on the ceiling, in response to our smoldering fire. And that despite the fact that the detectors were mounted about five feet farther from the source of fire. Even the *Guardion*, already a speedy responder, responded more quickly when mounted on the wall.

Why? Probably because the smoldering fires produced layers of smoke that rose rather slowly. (That slow-rising effect could be peculiar to our draft-free room; other rooms might distribute smoke differently.)

In addition to indicating differences among models and types of detectors, our tests also confirmed the inferiority of heat as the basis of an early warning system. Our test room has a heat-triggered sprinkler system, and it was much closer to our fires than the detectors were. One after another, the smoke detectors sounded their alarms. But during all our testing, the sprinkler system never went off. Our fires, though real enough, just didn't produce the necessary heat.

TYPICAL RESPONSE TIMES FOR FOUR TYPES OF FIRE (excluding unusual cases)



	1 FAST, "SMOKELESS" (PAPER STRIPS)	2 SMOLDERING TO FLAMING (WOOD STRIPS)	3 FAST, SMOKY (POLYURETHANE FOAM)	4 SMOLDERING (UPHOLSTERY)
PHOTOELECTRIC MODELS:	☒	1.75-11.5 MIN.	2.0-3.0 MIN.	6-30 MIN.
IONIZATION MODELS:	0.5-2.0 MIN.	1.50-5.0 MIN.	1.5-3.0 MIN.	40-55 MIN.
✓GUARDION:	0.5-0.7 MIN.	2.5-4.0 MIN.	1.5-2.0 MIN.	5-25 MIN.

☒ *Most did not respond during course of fire (about 10 min.).*

them senses smoke. That could obviously provide a much earlier warning of a fire in a remote part of the house than a single detector, but would require extensive wiring.

Maintenance. In addition to replacing the batteries in the models that use them, there are a few other small maintenance chores to face. With the ionization detectors, a yearly vacuuming is often suggested. Three models (the *BRK*, *Sears*, and *Master*) require occasional cleaning with alcohol.

Most of the photoelectric models recommend a yearly light brushing or vacuuming of three spongy filters and a cleaning of the removable labyrinth through which smoke must pass in these models before it reaches the detection chamber. In addition, the bulb will have to be replaced when it burns out. (All the photoelectrics come with a spare bulb. But others should be easy to find at an electronics store.)

Insects may pose an additional problem, especially with plug-in models, where the warmth of the bulb and internal parts acts as an attractant. Periodic checking is advisable.

RADIOACTIVE? DON'T WORRY

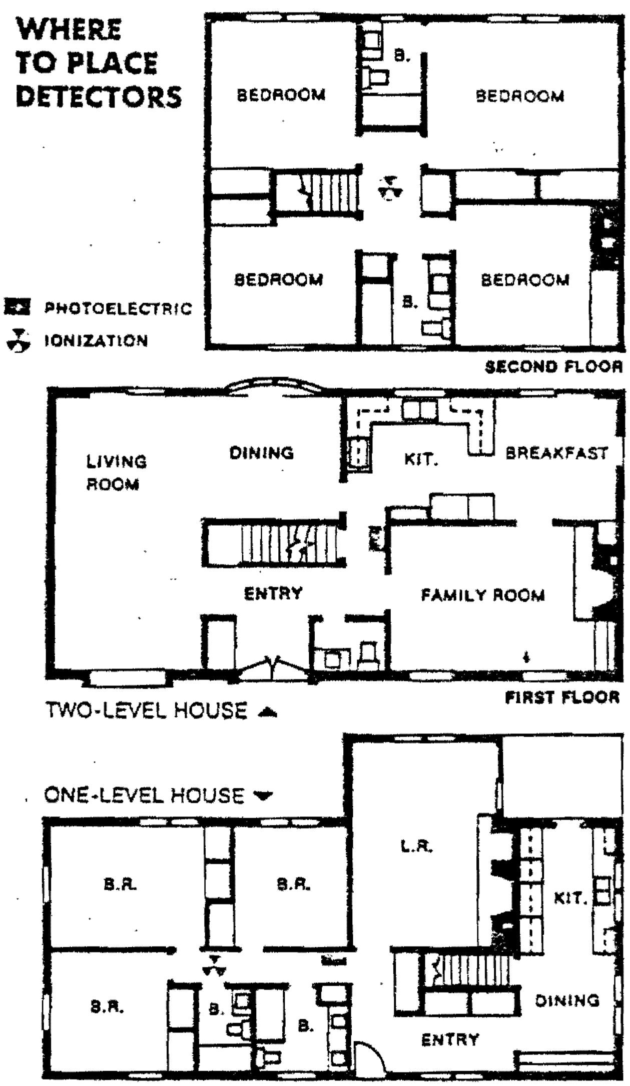
Ionization detectors contain a small amount of radioactive material to ionize the air in their detection chambe so that the air will conduct electricity. We checked the su face of each assembled unit with a Geiger counter and cou not detect any radiation beyond ordinary background ra ation. Nonetheless, it's wise to keep these detectors out the reach of children. The ordinary mounting location of smoke detector, on the ceiling or high on a wall, shou easily serve that purpose.

The units all detail standard warnings, intended to e courage correct disposal procedures. Those procedures ge erally call for returning the unit to the manufacturer. Whe this is not possible (if the manufacturer has gone out business, for example), turn the unit in to your local fi department. If this is not convenient for some reason, wri to the U.S. Nuclear Regulatory Commission, Washingtc D.C. 20555, for advice.

RECOMMENDATIONS

There's no clear answer to the question of whether t photoelectric or ionization detector represents a better b for safety in the home. By and large, our tests confirm t

WHERE TO PLACE DETECTORS



As the Recommendations section of the accompanying report notes, CU suggests a system made up of one ionization and one photoelectric detector. Where you put them depends on the layout of your house.

One detector should be placed *on the ceiling* of a corridor or hallway just outside the bedroom doors. In that position, it will be most readily heard during the sleeping hours when most fires break out. That detector should be an ionization model, because of its sensitivity to quick-burning fires in which the smoke rises quickly and moves along the ceiling.

The second detector should be a photoelectric device. In a two-level house, put it downstairs in the general living quarters—if possible, close to the stairway leading to the sleeping quarters, though not in the kitchen. In single-level homes, the second detector can be put some distance away from the bedrooms and toward the living quarters—down the corridor from the bedrooms, for instance. It should be *wall-mounted* no closer than six inches nor farther than 12 inches from the ceiling and away from a corner. Make sure you plug the detector into an outlet that's "live" all the time, not into one operated by a wall switch.

Those who insist on smoking in bed face the special problem of a fire that can start in the bed itself. In that special case, CU recommends installation of an extra detector, preferably the check-rated *Guardion*, directly over the bed. It will respond quickly enough to a smoldering fire or even a flare-up to alert or wake the smoker. (True, it may also respond to the smoker's own smoke now and then, but that might discourage the dangerous habit of smoking in bed.)

Virtually all the instructions with the detectors state that bedroom doors are best closed for safety, to slow the progress of hot gases and smoke, extending the occupants' chance to escape. But a recent study for the National Bureau of Standards notes that such traditional reasoning is questionable *if you install a smoke detector.* An open door lets sleepers hear the alarm more easily, affording extra time for escape. And should a fire start in a bedroom itself, the detector will respond more quickly if the door is open and will alert other occupants of the house faster.

strengths and weaknesses of each. Statistically, smoky fires cause the greatest number of deaths, and photoelectric models reacted to smoldering fire faster than ionization models did. But home furnishings that burn with an open flame also cause great damage, and ionization models are more likely to react fast to that sort of fire.

We therefore believe that a good system would consist of at least two smoke detectors—one plug-in photoelectric detector and one battery-operated ionization detector. The differing sensitivities of the two types supplement each other nicely. And each provides backup protection against failure of the other as well as an additional alarm.

If we had to limit ourselves to a single detector, the battery-powered *Guardion FB1*, at $50, is the clear first choice. It was unique among the ionization models in its rapid response to both flaming and smoldering fires. The *Guardion FB1* is also the best of the tested ionization models for systems consisting of two or more detectors. As a second choice, for those who prefer a plug-in rather than a battery unit, the *Honeywell* also responded to all the test fires, albeit more slowly to smoldering fires than the *Guardion*.

The choice among the photoelectric models is not as clear-cut, since all worked well in CU's tests. But note that their list prices range from $40 to $60. We suggest you price-shop a bit, since discounts may well be available, and select the cheapest tested model you can find.

RATINGS
SMOKE DETECTORS

Listed by type. Within type, listed except as noted in order of estimated overall quality based mainly on speed of response in CU's tests. Dimensions are rounded to nearest ¼ in. All a-c powered detectors have a pilot light that goes out during a power failure. All battery-powered detectors emit a repeating signal when batteries should be replaced. Mounting locations and maintenance recommendations are as stated by the manufacturers. Prices are list, rounded to nearest dollar; discounts are often available. All models were judged Acceptable.

IONIZATION DETECTORS

✔ **GUARDION FB1** (Pyr-A-Larm, Inc., Cedar Knolls, N.J.), $50. 2 in. deep, 7 in. in diameter. Powered by one 9-volt alkaline battery. Red flag pops out if battery is removed. Test procedure: Blow smoke into unit. For ceiling or wall mounting. Maintenance: No stated recommendations (but CU suggests periodic vacuuming).

HONEYWELL TC49A-1187 (Honeywell, Inc., Minneapolis), approx. $40. 2½ in. deep, 6¼ in. in diameter. A-c powered; line cord (accessory kit 190192A) 8 ft., 2 in. long or can be wired directly to outlet box. Test procedure: Blow smoke into unit. For ceiling or wall mounting. Maintenance: Vacuum clean once a year. User can adjust sensitivity (see story). Up to 3 units can be interconnected.

■ *The following detectors were judged approximately equal in overall quality. Listed alphabetically.*

BRK SS74R (BRK Electronics Div., Pittway Corp., Aurora, Ill.), $50. 2 in. deep, 7 in. in diameter. Powered by one 11.2-volt mercury battery. Test procedure: Blow smoke into unit. Ceiling mounting preferred. Maintenance: Clean chamber with cotton swab and rubbing alcohol once a year or after a fire.

FIRE ALERT RSD117L/117AL (Fenwal Div., Walter Kidde & Co., Ashland, Mass.), $45. 2¼ in. deep, 6 in. in diameter. A-c powered. Test procedure: Blow smoke into unit. For ceiling or wall mounting. Maintenance: Vacuum clean once a year.

G.E. HOME SENTRY 8201-001 (General Electric Co., Bridgeport, Conn.), $55. 1¾ in. deep, 6¼ in. long, 6½ in. wide. Powered by one 12.6-volt mercury battery. In addition to audible low-battery warning, has a "Replace Battery" flag; flag cannot be reset if unit contains no battery. Test provision: External button. Ceiling mounting preferred. Maintenance: Vacuum clean periodically.

KWIKSET 911 355 (Kwikset Sales & Service Co., Anaheim, Calif.), $63. 1¾ in. deep, 6 in. in diameter. Powered by one 12.6-volt mercury battery. Alarm consists of pulsating blasts, judged advantageous for heavy sleepers. Test procedure: Blow smoke into unit. Ceiling mounting preferred. Maintenance: Vacuum clean periodically.

SEARS Cat. No. 57073 (Sears, Roebuck), approx. $43. 2 in. deep, 7 in. in diameter. Powered by one 11.2-volt mercury battery. Test procedure: Blow smoke into unit. Ceiling mounting preferred. Maintenance: Clean chamber with cotton swab and rubbing alcohol once a year or after a fire. This model is not listed in the current catalog but may be available in some Sears retail stores.

SMOKEGARD 800A (Statitrol Corp., Lakewood, Colo.), $55. 2¾ in. deep, 6 in. long, 6 in. wide. Powered by six 1.5-volt AA alkaline batteries. Pulsing pilot light indicates batteries are installed and functioning. Test procedure: Blow smoke into unit. For ceiling mounting only. Maintenance: Vacuum clean once a year or when changing batteries.

■ *The following model was slower in response than any other detector.*

MASTER 2551 (Master Lock Co., Milwaukee), $60. 2 in. deep, 5 in. long, 5 in. wide. Powered by one 12.6-volt mercury battery. Test provision: External button. For ceiling or wall mounting. Maintenance: Clean chamber with cotton swab and rubbing alcohol after long service or when check with test button indicates need.

PHOTOELECTRIC DETECTORS

■ *The following detectors, all a-c powered, were judged approximately equal in overall quality. Listed alphabetically.*

CAPTAIN KELLY PSD12 (Gillette Co., Boston), $40. 2¼ in. deep, 6¼ in. in diameter. Test provision: Internal lever (cover twists off easily). For wall mounting only. Maintenance: Vacuum clean filter. According to the company, this model has been discontinued but may still be available in some stores.

NUTONE S181 (Nutone Division, Scovill Mfg. Co., Cincinnati), $50. 2¼ in. deep, 6½ in. long, 6½ in. wide. Test provision: External lever or blow smoke into unit. For wall mounting only. Maintenance: Filters require cleaning; no time interval mentioned. According to the company, this model has been discontinued.

PYROTECTOR 3004 (Pyrotector, Inc., Hingham, Mass.), approx. $45. 2 in. deep, 6¼ in. long, 6¼ in. wide. Test procedure: Blow smoke into unit. For ceiling or wall mounting. Maintenance: No stated recommendations.

RITTENHOUSE S7670 (Rittenhouse Div., Emerson Electric Co., Honeoye Falls, N.Y.), $45. 2¼ in. deep, 6¼ in. in diameter. Test provision: Internal lever (cover twists off easily). For ceiling or wall mounting. Maintenance: Clean filters with brush or vacuum when bulb fails. Also available as model S7671, same price, equipped for interconnection.

WESTINGHOUSE 100-1 (Westinghouse Security Systems Inc., Pittsburgh), $50. 2¼ in. deep, 6¼ in. in diameter. Test provision: Internal lever (cover twists off easily). For ceiling or wall mounting. Maintenance: Clean filters with brush or vacuum when bulb fails. Also available as model 100-2, same price, equipped for interconnection.

WHITE RODGERS 5083A-1 (White Rodgers Div., Emerson Electric Co., St. Louis), $47. 2¼ in. deep, 6¼ in. in diameter. Test provision: Internal lever (cover twists off easily). For ceiling or wall mounting. Maintenance: Clean filters with brush or vacuum when bulb fails. Also available as model 5083A-2, same price, equipped for interconnection.

EXHIBIT 2

§ 30.20 Gas and aerosol detectors containing byproduct material.

(a) Except for persons who manufacture, process, produce, or initially transfer for sale or distribution* gas and aerosol detectors containing byproduct material,* any person is exempt from the requirements for a license set forth in section 81 of the Act and from the regulations in Parts 20 and 30-35* of this chapter to the extent that such person receives, possesses, uses, transfers,* owns, or acquires byproduct material in gas and aerosol detectors designed to protect life or property from fires and airborne hazards, and manufactured, processed, produced, or initially* transferred in accordance with a specific license issued pursuant to § 32.26 of this chapter which license authorizes the initial transfer of the product for use under this section.

(b) Any person who desires to manufacture, process, or produce gas and aerosol detectors containing byproduct material, or to initially* transfer such products for use pursuant to paragraph (a) of this section, should apply for a license pursuant to § 32.26 of this chapter, which license states that the product may be initially* transferred by the licensee to persons exempt from the regulations pursuant to paragraph (a) of this section or equivalent regulations of an Agreement State.

§ 32.26 Gas and aerosol detectors containing byproduct material: requirements for license to manufacture, process, produce, or initially* transfer.

An application for a specific license to manufacture, process, or produce gas and aerosol detectors containing byproduct material and designed to protect life or property from fires and airborne hazards, or to initially* transfer some products for use pursuant to § 30.20 of this chapter or equivalent regulations of an Agreement State, will be approved if:

(a) The applicant satisfies the general requirements specified in § 30.33 of this chapter: *Provided, however,* That the requirements of §§ 30.33(a) (2) and (3) do not apply to an application for a license to transfer byproduct material in gas and aerosol detectors manufactured, processed or produced pursuant to a license issued by an Agreement State.

(b) The applicant submits sufficient information relating to the design, manufacture, prototype testing, quality control procedures, labeling or marking, and conditions of handling, storage, use, and disposal of the gas and aerosol detector to demonstrate that the product will meet the safety criteria set forth in § 32.27. The information should include:

(1) A description of the product and its intended use or uses;

(2) The type and quantity of byproduct material in each unit;

(3) Chemical and physical form of the byproduct material in the product and changes in chemical and physical form that may occur during the useful life of the product;

(4) Solubility in water and body fluids of the forms of the byproduct material identified in subparagraphs (3) and (12) of this paragraph;

(5) Details of construction and design of the product as related to containment and shielding of the byproduct material and other safety features under normal and severe conditions of handling, storage, use, and disposal of the product;

(6) Maximum external radiation levels at 5 and 25 centimeters from any external surface of the product, averaged over an area not to exceed 10 square centimeters, and the method of measurement;

(7) Degree of access of human beings to the product during normal handling and use;

(8) Total quantity of byproduct material expected to be distributed in the product annually;

(9) The expected useful life of the product;

(10) The proposed method of labeling or marking each unit with identification of the manufacturer or initial transferor* of the product and the byproduct material in the product;

(11) Procedures for prototype testing of the product to demonstrate the effectiveness of the containment, shielding, and other safety features under both normal and severe conditions of handling, storage, use, and disposal of the product.

(12) Results of the prototype testing of the product, including any change in the form of the byproduct material contained in the product, the extent to which the byproduct material may be released to the environment, any increase in external radiation levels, and any other changes in safety features;

(13) The estimated external radiation doses and dose commitments relevant to the safety criteria in § 32.27 and the basis for such estimates;

(14) A determination that the probabilities with respect to the doses referred to in § 32.27(c) meet the criteria of that paragraph;

(15) Quality control procedures to be followed in the fabrication of production lots of the product and the quality control standards the product will be required to meet; and

(16) Any additional information, including experimental studies and tests, required by the Commission.

§ 32.27 Same: safety criteria.

An applicant for a license under § 32.26 shall demonstrate that the product is designed and will be manufactured so that:

(a) In normal use and disposal of a single exempt unit, and in normal handling and storage of the quantities of exempt units likely to accumulate in one location during marketing, distribution, installation, and servicing of the product, it is unlikely that the external radiation dose in any one year, or the dose commitment resulting from the intake of radioactive material in any one year, to a suitable sample of the group of individuals expected to be most highly exposed to radiation or radioactive material from the product will exceed the dose to the appropriate organs as specified in Column I of the table in § 32.28.

(b) It is unlikely that there will be a significant reduction in the effectiveness of the containment, shielding, or other safety features of the product from wear and abuse likely to occur in normal handling and use of the product during its useful life.

(c) In use and disposal of a single exempt unit, and in handling and storage of the quantities of exempt units likely to accumulate in one location during marketing, distribution, installation, and servicing of the product, the probability is low that the containment, shielding, or other safety features of the product would fail under such circumstances that a person would receive an external radiation dose or dose commitment in excess of the dose to the appropriate organ as specified in Column II of the table in § 32.28, and the probability is negligible that a person would receive an external radiation dose or dose commitment in excess of the dose to the appropriate organ as specified in Column III of the table in § 32.28.[2]

[2] It is the intent of this paragraph that as the magnitude of the potential dose increases above that permitted under normal conditions, the probability that any individual will receive such a dose must decrease. The probabilities have been expressed in general terms to emphasize the approximate nature of the estimates which are to be made. The following values may be used as guides in estimating compliance with the criteria:

Low—not more than 1 such failure per year for each 10,000 exempt units distributed.

Negligible—not more than 1 such failure per year for each 1 million exempt units distributed.

§ 32.28 Same: table of organ doses.

Part of body	Column I (rem)	Column II (rem)	Column III (rem)
Whole body; head and trunk; active blood-forming organs; gonads; or lens of eye ----	0.005	0.5	15
Hands and forearms; feet and ankles; localized areas of skin averaged over areas no larger than 1 square centimer -----------	0.075	7.5	200
Other organs ----------	0.015	1.5	50

§ 32.29 Conditions of licenses issued under § 32.26: quality control, labeling, and reports of* transfers.

Each person licensed under § 32.26 shall:

(a) Carry out adequate control procedures in the manufacture of the product to assure that each production lot meets the quality control standards approved by the Commission;

(b) Label or mark each unit so that the manufacturer or initial transferor* of the product and the byproduct material in the product can be identified; and provide such other information with each unit as may be required by the Commission, including disposal instructions when appropriate; and

(c) File an annual report with the Director of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, with a copy to the appropriate NRC Regional Office listed in Appendix D of Part 20 of this chapter,† which shall include the following information on products* transferred to other persons for use under § 30.20 of this chapter or equivalent regulations of an Agreement State: (1) A description or identification of the type of each product;* (2) for each radionuclide in each type of product, the total quantity of the radionuclide;* and (3) the number of units of each type of product* during the reporting period. If no* transfer of byproduct material have been made pursuant to § 32.26 during the reporting period, the report shall so indicate. The report shall cover the year ending June 30, and shall be filed within 30 days thereafter.

III. MARKET FOR SMOKE DETECTORS

Need

August 8, 1978, President Carter designated October 8-14, 1978, as FIRE PREVENTION WEEK. In his proclamation, he states:

> "Fire causes more loss of life and property in the United States than all other natural disasters combined. In the home, fire is the second most frequent cause of accidental death. Volunteer and professional firefighters bear a disproportionate burden of the human costs of fire; firefighting is still America's most hazardous profession.
>
> Every year in this decade 7,500 U.S. citizens have died, 310,000 have been injured and more than $4 billion worth of personal property has been destroyed. America's fire incidents, casualties, and dollar loss per capita are among the very highest in the industrialized world.
>
> Because fire deaths most often occur in homes, I call upon American families and other property owners to install smoke detectors, ..."

In the National Bureau of Standards' publication NBS Technical Note 839, "Fire Detection: The State-of-the-Art," it is stated that "...When the costs of burn treatment, productivity loss, insurance operations and fire department operations are added to the direct fire loss figures the total cost of fire approaches 11.4 billion dollars. Any fire, no matter how large it may become, begins as a small fire. In its earliest stages most fires are innocuous and are easily controlled. ...The earlier in its history of development that a fire can be detected, the better are the chances of escape for those persons in potential danger and the sooner suppression methods can be brought to bear on the fire. The purpose of detection is two-fold, it can reduce life loss and it can reduce property loss. Where human lives are at risk, time becomes an important factor. ...Appropriately selected and properly installed, fire detection devices can have a major effect on losses of life."

A frequently quoted Canadian study of the circumstances surrounding 342 dwelling fire deaths in Ontario, Canada indicates that the use of smoke detection devices could result in a 41 percent saving of life. Other studies suggest even a higher saving of life could be achieved with smoke detectors.

Many state and local regulatory bodies now have building codes that require the use of smoke detectors in dwellings. Attached as Exhibit "2" is a copy of the Montgomery County, Maryland regulation for smoke detection. Throughout the U.S. there are somewhere between 8,500 and 14,000 building codes. Nearly all of these code jurisdictions subscribe to a model code and there are essentially four of these in the U.S. During about the last 7 years, all 4 of the model codes have picked up the concept of requiring a smoke detector in every new unit of housing. Many of the local regulations, for example the Montgomery County regulation that became effective July 1, 1978, require smoke detectors in both new and existing occupied dwelling units.

The above mentioned state and local regulations have created a "mandatory" market. There also has developed within the past 3 or 4 years a "voluntary" market for residential smoke detectors. It is reported that when one major detector manufacturer entered the market in 1976, it spent $2.5 million on network television advertisements its first year. That advertising campaign helped the distribution rate for smoke detectors to jump from several hundred thousand annually to several million annually.

<u>Distribution Rates and Number of Distributors</u>

In November, 1968 the Atomic Energy Commission published its proposed exemption for smoke detectors containing byproduct material (Am-241, etc.). At that time, there were an estimated 150,000 ionization type smoke detectors in use. About 90,000 of those units contained radium, the remainder, Am-241. In August, 1978 there is estimated to be on the order of 20,000,000 Am-241 smoke detectors in use, on the order of 1 or 2 million radium units and a few tens of thousands Ni-63 units in use. Relatively few radium units are still distributed; Am-241 has almost completely replaced radium in units now manufactured. The table below shows the growth in number of persons specifically licensed by NRC (AEC) to distribute, the number of units and millicuries of Am-241 distributed during the reporting year, and the rapid decline in the average amount of Am-241 per unit. The staff does not have good data on the number of photoelectric detectors distributed, although an NBS spokesman recently estimated that about 95% of the smoke detectors now going to the residential market are ionization type.

It may be noted that initially the ionization type smoke detectors were distributed for the industrial and commercial market. The domestic (dwelling place) market has developed only within the past 3 or 4 years. An NBS spokesman recently estimated that by the end of 1977, the annual rate of production of domestic detectors was somewhere around 10 million units per year. He speculated that the market would continue to absorb some 10 to 12 million domestic smoke detectors for the next two or three years before the demand slackens.

Attached as Exhibit "3" is a list of NRC specific licensees that were authorized as of July 12, 1978, to distribute smoke detectors.

DISTRIBUTION OF SMOKE DETECTORS CONTAINING Am-241

Year*	# Licensees Reporting	Units	Milli-curies	Microcuries ave. per unit
1970	1	50,000	4,692	94
1971	3	65,371	5,515.760	79
1972	3	120,859	8,367.859	69
1973	4	254,454	11,111.284	43.7
1974	6	386,596	9,156.776	23.7
1975	9	690,533	10,779.028	15.6
1976	10	3,208,063	19,756.253	6.15
1977	18	7,379,646	35,931.455	4.87
1978**	-	-	-	-
		12,155,522	105,310.41	11.5

*A "1970" report year covers the period of July 1, 1969, to June 30, 1970.

** On July 12, 1978, there were 48 licensees. 11 of those licenses were issued in calendar year 1978 and thus the holders of those licenses are unlikely to have achieved significant production and distribution. However, 1978 reports now being filed by the licensees and reviewed by the staff are expected to show a significant increase in the number of units distributed and a further reduction in the average number of microcuries per unit.

EXHIBIT 1

GUARDIØN

BATTERY POWERED FIRE AND SMOKE DETECTOR

INVEST IN YOUR FAMILY'S FUTURE

Model FB-1

SALE!

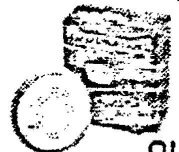
$21.99

Mfr. List 39.95

The GUARDION Model FB-1 will respond in all four stages of a fire, including the earliest incipient stage before there is visible smoke or flame or noticeable heat. The ionization chamber contains two charged plates and an alpha source that ionizes entering air molecules. When products of combustion enter the chamber, they impede the flow of ions. This reduces the flow of current between the plates and causes a voltage shift that triggers the alarm through a field effect transistor (FET). The FB-1 gives you both early response and increased stability.

RATED #1 BY LEADING CONSUMER LABORATORY

Honeywell Smoke & Fire Detector

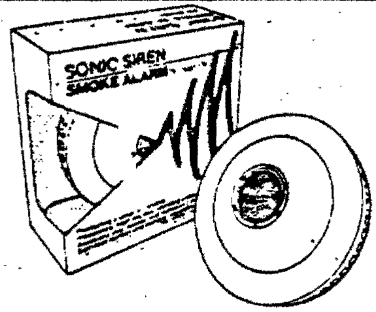


$5.00 FACTORY REBATE

- Exclusive sensitivity adjustment.
- Dual ionization chamber.
- Detects all 4 stages of fire.
- Largest push-to-test disc.
- 30 day low battery alarm.
- Includes 9 volt battery.
- Solid state electronics.
- Fast installation.

OUR SPECIAL LOW PRICE.... $17.99
LESS REBATE..... $5.00

YOUR COST $12.88



NEW LOW PRICE

SONIC SIREN© SMOKE ALARM

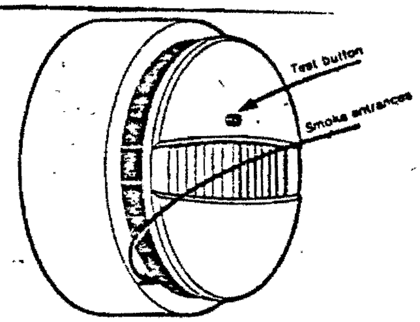
Unique warning siren can be heard above all major brands...combined.

- Warns of fire before you can smell smoke or see flames.
- Operates on only one 9v battery (inexpensive, easily available)
- Know unit is working properly
- Red light flashes when unit is properly powered; audible "trunk sounds when battery is weak.

$19.88

"PHOTO-ELECTRIC" ResAlarm

Division of Ellenco, Inc.



SMOKE DETECTION ALARMS

Battery-Operated Model

Can be used anywhere, homes, apartments, mobile homes, even in boats and campers! Include 9-volt alkaline battery with an approximate life of 1 year. Low-cost replacement battery is readily available at grocery, hardware, discount, electronic supply, or drug store. A trouble-alarm (intermittent beeping) signals when battery needs replacing.

Mfr. List $49.95

$24.99

Smoke Detection

A. REQUIREMENT: It shall be the responsibility of the owner of each new and existing occupied dwelling unit to install smoke detectors in each such dwelling unit as hereinafter provided. Said smoke detectors shall be capable of sensing visible or invisible particles of combustion and providing a suitable audible alarm thereof; further, they shall be installed by July 1, 1978, in the manner hereinafter provided (unless any other provision of County, State or Federal law shall require installation before that date). Failure to install smoke detectors as and where required by said date will subject the property owner to the penalties set forth in Section 22-22 of the Fire Safety Code of Montgomery County.

B. LOCATION: (1) At least one smoke detector shall be installed to protect each sleeping area. A sleeping area is defined as the area or areas of the family living unit in which the bedrooms (or sleeping rooms) are located. Where bedrooms or rooms ordinarily used for sleeping are separated by other-use areas (such as kitchens or living rooms, but not bathrooms or closets), they shall be considered as separate sleeping areas for the purposes of this section.

(2) At least one smoke detector shall be installed at the head (top) of each stairway leading up to an occupied area in such a manner as to assure that rising smoke is not obstructed in reaching the detector and the detector intercepts rising smoke before it reaches the sleeping area.

C. ALTERNATIVE: As an alternative to self-contained smoke detectors, an approved fire detection system may be installed. Each fire detection system must be individually approved and a permit issued therefore by the Department of Fire and Rescue Services.

D. EQUIPMENT: All devices, combinations of devices, and equipment required herein are to be installed in conformance with the Building Code and this section, and approved by the Montgomery County Department of Fire and Rescue Services and listed by said Department for the purposes for which they are intended; said list may be subsequently amended by the Department of Fire and Rescue Services as necessary. Such approval shall be permanent unless the Director subsequently finds that the equipment is hazardous or unreliable, in which case, the Director may suspend or revoke approval. The Director may in any such case determine whether replacement of existing installation shall be required. Transfer to the inactive list shall not affect equipment approval.

E. INSTALLATION: In new residential dwellings, smoke detectors shall be wired directly (hard-wired) to the building's power supply. In existing dwellings within multi-family buildings of ten units or more, the detectors shall meet the multi-family building power source requirements of State law, or in the absence of State law, the requirements hereunder covering other existing dwellings. In other existing dwellings, it is preferred that smoke detectors be wired directly to the power supply, however, said detectors may be powered by self-monitored battery or operated in a plug-in outlet which is fitted with a plug restrainer device, provided the outlet is not controlled by any switch other than the main power supply.

F. CERTIFICATION AT CHANGE IN OCCUPANCY: After July 1, 1978, at every change of occupancy of every dwelling unit occasioned by or incidental to a sale, lease or sub-lease of said unit, it shall be the duty of the grantor thereof (i.e., the seller, lessor or sub-lessor, as the case may be) to certify, before occupancy, to the new occupant that all smoke detectors as required by this section (or other applicable laws) are installed and in proper working condition. Failure to comply with this subsection shall be punishable as set forth herein; provided, however, that this subsection shall not be construed to vitiate or render void any contract, lease or sublease subject hereto.

G. PERMITS AND FEES: No smoke detector or alternative system shall be directly connected (permantly wired) to the electrical system of the structure unless an electrical permit shall have first been obtained from the Department of Environmental Protection or the municipal electrical permit authority having jurisdiction. The County Executive is hereby authorized to adopt a fee schedule for the issuance of said permit which shall not exceed the cost of administration of this section; further, the County Executive is authorized to waive, partially or wholly, the fee requirement at his discrestion, or to issue multiple permits under the payment of a single fee.

H. SUPPLEMENTAL STANDARDS: This section is intended to be used with and supplemented by the applicable provisions of the National Fire Protection Association Standards 72-E and 74, 1974 Editions, which are hereby incorporated herein; however, if there shall be any conflict between this statute and the said supplemental standards, this statute and any rules and regulations adopted pursuant thereto shall prevail.

NOTE: To reduce printing costs, title to the bill and certain other non-essential items have been deleted from this reprint. This bill was signed into law by the County Executive on September 14, 1976.

The National Fire Protection Association's pamphlet #74, "Household Fire Warning Equipment," contains detailed information on smoke detectors. To get a copy, send $1.00 to the Association at 470 Atlantic Ave., Boston, Massachusetts 12210.

The Montgomery County Department of Fire and Rescue Services does not recommend specific manufacturers of smoke detectors, but does maintain a list of approved models.

To find out if a smoke detector you are considering is on the approved list, or if you have other questions, call the Division of Fire Prevention at 468-4153 or your local fire station (listed in the C & P phone directory)

Department of Fire-Rescue Services
Division of Fire Prevention
Montgomery County, Maryland

Smoke Detectors Are Required by Law

Smoke detectors must be installed in all Montgomery County dwelling units by July 1, 1978. The following diagrams illustrate the minimum protection required by law. The "Smoke Detectors" section of the Montgomery County Code is printed on the reverse of this sheet.

Where to locate the basic smoke detector

The major threat from fire in a dwelling is at night when everyone is asleep. The principal threat to persons in sleeping areas comes from fires in the remainder of the house, therefore, basic smoke detector(s) are best located between the bedroom areas and the rest of the house. In homes with only one bedroom area on one floor, the basic smoke detector shall be located as shown in Figure 1.

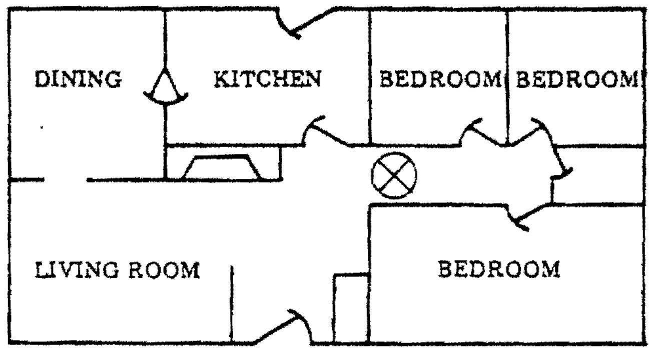


Figure 1. A basic smoke detector (indicated by cross) shall be located between the sleeping area and the rest of the house.

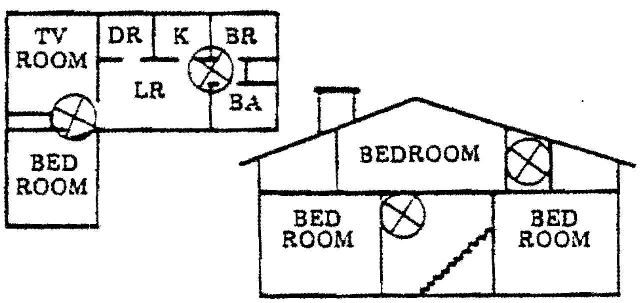


Figure 2. In homes with more than one sleeping area, a smoke detector (indicated by cross) should be provided to protect each.

Homes with more than one bedroom

In homes with more than one sleeping area or with bedrooms on more than one floor, more than one basic smoke detector will be needed as shown in Figure 2. Location of the smoke detector outside the bedrooms presupposes that the occupants sleep with their doors shut to provide a barrier to the smoke thus gaining additional seconds for escape.

Homes with stairways

Most homes have one or more stairs. Heat from fire will carry smoke and toxic gases upward into stairs. A smoke detector is needed at the head (top) of *each* stairs including the basement as shown in Figure 3. Stairs are usually a common path of exit and must be preserved as a possible escape route. Alternate escape routes should be planned and practiced during a fire drill at home. Note: A smoke detector is not required in stairs going to unoccupied areas, e.g. attic.

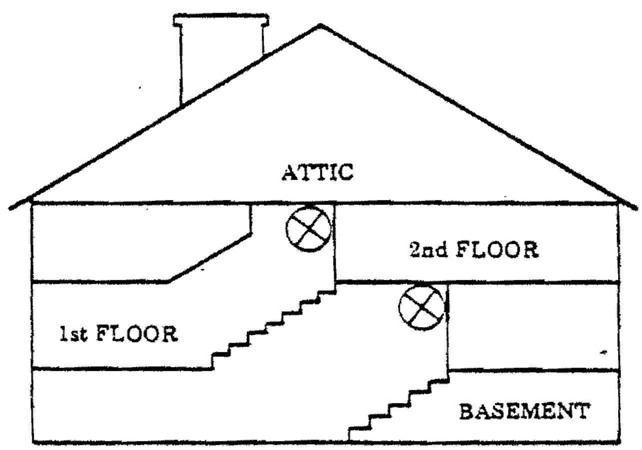


Figure 3. In homes with stairs a smoke detector (indicated by cross) should be at the head (top) of each.

IMPORTANT NOTE: Above examples illustrate minimum smoke detection requirements in residential units. Additional smoke detectors or an early warning fire detection system should be considered.

EXHIBIT 3

DISTRIBUTION OF SMOKE DETECTORS

A.R.F. Products, Inc. 30-17707-01E
Gardner Road
Raton, New Mexico 87740

C&H Electronics, Inc. 04-17260-01E
11454 Long Beach Blvd
Lynwood, CA 90262

Casady Engineering Associates 04-17370-01E
560 Alaska Avenue
Torrance, CA 90503

City Tool & Manufacturing Co., Inc. 48-16514-02E
1002 12th Street
Watertown, WI 53094

Conrac Corporation 06-17292-02E
Cramer Division
Mill Rock Road
Old Saybrook, CT 06475

Cosmos Industries, Inc. 31-17748-01E
55 Washington Street
Brooklyn, NY 11201

Edwards Company, Inc. 06-15809-03E
90 Connecticut Avenue
Norwalk, CT 06856

Electromagnetic Industries 09-17650-01E
Square D. Company
2305 Calumet Street
Clearwater, FL 33515

Electrons Company 29-08449-03E
65 Passaic Avenue
Fairfield, NJ 07006

Emergency Products Corp. 29-17180-02E
25 Eastmans Road
Parsippany, New Jersey 07054

Emerson Electric Co. 05-13943-01E
Statitrol Division
140 South Union Blvd.
Lakewood, Colorado 80228

Smoke Detectors Cont'd

Empire Machines and Systems, Inc. 31-17459-01E
Shore Road
Glenwood Landing, New York 11547

Emhart Corporation 06-15214-02E
P.O. Box 2730
Hartford, CT 06101

Entronic Corporation 24-16322-02E
4348 Riverline Drive
Earth City, MO 63045

Firetek Corporation 29-15775-02E
53 Thomas Road
Hawthorne, NJ 07506

Firex Corporation 12-15537-02E
2470 Wisconsin Avenue
Downers Grove, IL 60515

Gamewell Corporation 20-18116-02E
7 Industrial Park Road
Medway, MA 02053

General Electric Company 20-02573-04E
Housewares Business Division
Homer Avenue
Ashland, MA 01721

General Time Corp. 12-02748-06E
Westclox Division
LaSalle, IL 61301

Graviner, Inc. 29-14930-02E
1121 Bristol Road
Mountainside, NJ 07092

Gulf & Western Mfg. Co. 20-16171-02E
91 Bartlett Street
Marlborough, MA 01752

Hochiki-America Company 04-14886-01E
21804 Belshire
Hawaiian Garden, CA 90716

EXHIBIT 3

Smoke Detectors Cont'd

Honeywell, Inc. 12-12267-03E
1500 West Dundee Road
Arlington Heights, IL 60004

Honeywell, Inc. 22-01870-14E
2701 Fourth Avenue South
Minneapolis, MN 55408

Ion Track Industries, Inc. 20-15525-02E
Three A Street
Burlington, MA 01803

K-F Industries 37-16174-02E
230 W. Dauphin Street
Philadelphia, PA 19133

Lake Center Industries 22-17541-03E
111 Market Street
Winoma, MN 55987

Minnesota Mining & Manufacturing Co. 22-00057-55E
3M Center
St. Paul, MN 55010

Nittan Corp. 12-16029-01E
1299 Rand Road
Des Plaines, IL 60016

Notifier Company 26-17445-o1E
P.O. Box 4584
3700 N. 56th Street
Lincoln, NB 68504

On-Guard Corporation of America 29-17399-OwE
350 Gotham Parkway
Carlstadt , NJ 07072

Oster Corporation 48-17407-02E
5055 North Lydell Avenue
Milwaukee, WI 53217

Pittway Corp. 12-15023-02E
BRK Electronics Division
780 McClure Avenue
Aurora, IL 60507

PYA International 04-17827-01E
201 South Lake Avenue Suite 81
Pasadena, CA 91101

Smoke Detectors

Pyrotronic Division 29-08864-04E
Baker Protective Services
8 Ridgedale Avenue
Cedar Knolls, NJ 07927

Pyr-A-Larm, Inc. 10-17090-01E
Industrial Blvd.
Dublin, GA 31021

Republic Industries, Inc. 12-15641-02E
Division of Dor-O-Matic
7350 W. Wilson Avenue
Chicago, IL 60656

Security Engineering, Inc. 32-16736-01E
Clemmons, NC 27012

Sensor-Tec, Inc. 16-17089-01E
9401 West HY 42
P.O. Box 31
Goshen, KY 40026

Simplex Time Recorder Co. 20-17584-02E
26 South Lincoln Street
Gardner, MA 03217

Superior Industries, Inc. 42-17456-01E
10797 Harry Hines Blvd.
Dallas, TX 75220

Teledyne Water-Pik 05-16698-01E
1730 East Prospect
Fort Collins, CO 80521

Ultra Electronics, Inc. 04-16163-01E
10315 Woodley Avenue
Grand Hills, CA 91344

Unitec, Inc. 05-15863-01E
3910 South Mariposa
Englewood, CO 80110

Universal Security Systems, Inc. 19-17694-01E
10324 South Dolfield Road
Owings Mills, MD 21117

Smoke Detectors Cont'd

Walter Kidde & Co., Inc. 20-15285-02E
Fenwal Division
400 Main Street
Ashland, MA 01721

Wellen Industries, 04-17640-01E
3020 Redhill Avenue
Costa Mesa, CA 92626

Western Supply Company 46-17879-01E
506 Second Avenue
Seattle, WA 98104

Wing Corporation 29-13180-02E
215 Highland Avenue
Westmont, NJ 08108

IV. OCCUPATIONAL DOSES FOR Am-241 SOURCE AND SMOKE DETECTOR MANUFACTURERS

ESTIMATE OF RISK TO WORKERS PRODUCING AND PROCESSING Am-241 SOURCES FOR IONIZATION TYPE PRODUCTS OF COMBUSTION DETECTORS AT TWO U.S. PLANTS

Donovan A. Smith

The following estimate of collective dose and related health effects in the U.S. production and distribution of Am-241 sources for use in ionization type products of combustion detectors (smoke detectors) is based on information from the the two manufacturers of the sources.

Amersham Searle and Nuclear Radiation Developments, Inc., are specifically licensed to manufacture and/or distribute Am-241 foils for smoke detectors. Telephone conversations between their representatives and NRC staff (JMBell and DASmith, SD) indicate that for calendar year 1977 one of the specific licensees incurred about 2.03×10^{-7} man rem per microcurie of Am-241 handled and the other incurred about 8.24×10^{-7} man rem per microcurie of Am-241 handled. An explanation for the difference in the factors was not investigated.

If we assume that each of the two foil suppliers distributed 50% of the 35.9 Ci Am-241 that was distributed in the 1977 reporting year and that the above factors for man rem per microcurie handled apply, it follows that:

$$(2.03 \times 10^{-7})(50\%)(35.9 \times 10^{6}) + (8.24 \times 10^{-7})(50\%)(35.9 \times 10^{6}) = 18.4 \text{ man rem}$$

The total risk estimates associated with 18.4 man rem are:

From ICRP-26, risk of excess fatal cancers: 10^{-4}/man rem

Total risk = $(18.4 \text{ man rem/yr})(10^{-4}\text{/man rem}) = 1.84 \times 10^{-3}$/year

or 2×10^{-3}/year

From BEIR, risk of excess fatal cancers:

Absolute model: $417/5 \times 10^6$ man rem or 8.34×10^{-5}/man rem

Total risk = (18.4 man rem/yr)(8.34×10^{-5}/man rem)

= 1.53×10^{-3}/year or 2×10^{-3}/year

Relative model: $925/5 \times 10^6$ man rem or 1.85×10^{-4}/man rem

Total risk = (18.4 man rem)(1.85×10^{-4}/man rem)

= 3.40×10^{-3}/year or 3×10^{-3}/year

Estimated Total Risk Range:

The estimated total risk range can then be given as

2×10^{-3}/year to 3×10^{-3}/year

in terms of the probability of the eventual development of excess fatal cancers in a large population exposed year after year to the estimated dose used in the calculations.

Because of the currency of the ICRP-26 risk factor, we feel that the best estimate is probably 2×10^{-3} excess fatal cancers per year. In other words, it would require about 1,000 years of exposure at the rate estimated here in order to give a probability of the eventual development of 2 excess fatal cancers.

Data with respect to internal dose (air samples, bioassays) was not available. However, because of the good radiation safety practices required as a condition of licensing and because of inspection of the manufacturers, it is considered very unlikely that any internal dose would accrue.

ESTIMATE OF RISK TO WORKERS ASSEMBLING AND PROCESSING IONIZATION TYPE PRODUCTS OF COMBUSTION DETECTORS AT EIGHTEEN U. S. PLANTS

Jack M. Bell

The following estimate of collective dose and related health effects in the U. S. ionization smoke detector industry is based on data from three manufacturers. The production data for these three manufacturers range from relatively low (about 6000 units per year) through relatively high (about 2.8 million units per year) with the third manufacturer at an in between position (about 1 million units per year). Similarly, the average amount of americium-241 per unit varied from about 0.35 microcurie to about 3.5 microcuries per unit.

Although personnel dose data was obtained for each of three manufacturers, details concerning dose distribution among all workers, badged (monitored) and unbadged, was available for only one manufacturer. This manufacturer's estimate of average dose per unbadged worker was used as the basis for estimating dose to unbadged workers at the other 17 fire detector distributors' plants. The dose and risk estimates are based on 18 plants reporting smoke detector distribution during the periods under investigation. Dose data was available for two of the manufacturers for 1975 only and was used in conjunction with 1975 distribution figures.

The production data (assumed to be the same as reported distribution figures) were available from annual reports filed with NMSS, as required by Section 32.29 of 10 CFR Part 32. Personnel dose data were available only for those voluntarily reporting whole body personnel dose data for 1975, as requested by the NRC in its August 25, 1976 letter. Some supplemental dose estimates for unbadged workers were obtained from one manufacturer during a visit to its plant. Section 20.407 of 10 CFR Part 20 does not require reporting of personnel monitoring data for fire detector manufacturers. In addition, there has not been any special interest in personnel doses associated with fire detector manufacturing since the radioactive material is firmly bound in a protective matrix and radiation levels are so low (about 15×10^{-3} microroentgens per hour at 1 meter from 1 microcurie of americium-241). As a result, personnel dose data are not readily available. Given time for a more thorough study, additional useful data could probably be obtained from fire detector manufacturers.

Other radioactive materials used in detectors, such as carbon-14 and nickel-63 have not been specifically considered since (1) personnel doses associated with these materials would be very much lower than those associated with americium-241, (2) only three manufacturers were licensed to distribute such detectors (1 for C-14 and 2 for Ni-63), and (3) only one manufacturer has reported any distribution and no manufacturer has submitted a report indicating any current distribution. Also, this estimate of dose does not include consideration of dose associated with radioactive materials, such as radium, not subject to regulatory control by the Commission.

Data with respect to internal dose (air samples, bioassays) was not available. However, because of the manufacturing and radiation safety standards (e.g., radiation source design and test and facility contamination surveys) applied in the licensing and inspection of the manufacturers, it is considered very unlikely that any internal dose would accrue. This estimate includes only detector manufacturing activities and does not include doses that may result from radiation source manufacturing and distribution and detector transportation, warehousing, distribution, installation, repair and disposal.

Obviously, there are inaccuracies in the personnel monitoring data. Additional error is involved because of the lack of perfect correlation between manufacturing data (units and amounts of americium-241 processed) and personnel monitoring data. However, it is our feeling that the estimates that follow are quite conservative for the following reasons:

1. A significant number of the licensees do not manufacture detectors at all, but only import the product and, at most, repackage and distribute them.
2. A significant number of those who manufacture detectors do not handle the americium-241-bearing foils directly, i.e., the foil manufacturer delivers the foil installed in a detector component (e.g., an ion chamber) or the foil is "remotely" installed in each unit by machine. This should not only reduce personnel doses from individual foils, but perhaps more significantly the dose resulting

from exposure to the radiation from large quantities of foils in transfer receptacles at each assembler's work station.

3. The total activity in each detector has steadily declined over the years from on the order of 100 microcuries to less than 5 microcuries. In fact, the largest manufacturer for whom data is used in this estimate has reduced the amount of activity in its residential smoke detectors by a factor of five in the last year.

Estimate of Annual Total Dose and Dose Per Unit Activity:

Manufacturer A	
Workers directly involved in assembly (badged):	2.930 man-rem*
Other workers (unbadged):	6.000
Manufacturer B	
Workers directly involved in assembly (badged):	0.925
Other workers (unbadged):	1.896
Manufacturer C	
Workers directly involved in assembly (badged):	0.100
Other workers (unbadged):	0.205
TOTAL:	12.056 man-rem

Total units manufactured by manufacturers A, B and C contained a total of 13,582,333.5 microcuries of americium-241.

*The ratio 6000/2930 = 2.05 is used in estimating the dose to "other workers" for the two manufacturers for whom such data was not available.

Dose per microcurie:

$$\frac{12.056 \text{ man-rem}}{13,582,333.5 \text{ uCi}} = 8.876 \times 10^{-7} \frac{\text{man-rem}}{\text{microcurie}}$$

Total activity processed by all 18 licensees reporting:

35,931,454.9 microcuries.

Total (collective) dose for 18 licensees:

$$(35,931,454.9 \text{ microcuries})(8.876 \times 10^{-7} \frac{\text{man-rem}}{\text{microcurie}})$$

$$= \underline{31.893 \text{ man-rem}}$$

Total Risk Estimates:

From ICRP-26, risk of excess fatal cancers:

10^{-2}/sv or 10^{-4}/man-rem

Total risk = (31.893 man-rem/yr)(10^{-4}/man-rem) = $\underline{31.893 \times 10^{-4}/yr}$

From BEIR , risk of excess fatal cancers:

Absolute model: 417/5 x 10^6 man-rem or $\underline{8.34 \times 10^{-5}}$/man-rem

Total risk = (31.893 man-rem/yr)(8.34 x 10^{-5}/man-rem)

= $\underline{2.66 \times 10^{-3}/yr}$

Relative model: 925/5 x 10^6 man-rem or $\underline{1.85 \times 10^{-4}}$/man-rem

Total risk = (31.893 man-rem/yr)(1.85 x 10^{-4}/man-rem)

= $\underline{5.9 \times 10^{-3}/yr}$

Estimated Total Risk Range:

The estimated total risk range can then be given as

$$3 \times 10^{-3}/\text{year to } 6 \times 10^{-3}/\text{year}$$

in terms of the potential for the eventual development of excess fatal cancers in a large population exposed year after year to the estimated dose used in the calculations.

Because of the currency of the ICRP-26 risk factor, we feel that the best estimate is probably 3×10^{-3} excess fatal cancers per year. In other words, it would require about 1,000 years of exposure at the rate estimated here in order to result in the potential for the eventual development of 3 excess fatal cancers.

V. RADIATION EXPOSURES FOR TRANSPORT, DISTRIBUTION, USE AND DISPOSAL OF Am-241 SMOKE DETECTORS

ESTIMATED RISK FOR 1977 TRANSPORT OF Am-241 SMOKE DETECTORS FROM DETECTOR MANUFACTURERS

Donovan A. Smith

Reports submitted pursuant to 10 CFR 32.29 show 7,379,646 smoke detectors containing 35.9 Ci Am-241 distributed in the 1977 reporting year. An estimate of the man-rems and risk associated with transportation of those detectors follows:

I. per p. 29 of the NEA Smoke Detector Standard, the exposure rate constant for Am-241 is 0.015 r/hr at 1 meter per curie. Thus, the unshielded radiation level at 1 meter from 35.9 Ci Am-241 would be 538.5 mr/hr. This radiation is of low energy and easily shielded, thus it is reasonable to assume that detector components and packaging will cause absorption of 90% of the radiation such that an estimated 50 TIs*will be associated with the transport of the detectors containing Am-241.

II. NUREG-170, Vol. 1, "FES on Transport of Radioactive Material by Air and Other Modes," pp. 1-18, 4-40, 5-34 and 3-14 indicate that normal transport of 50 TIs might be equated to 0.4 man rem and normal plus accident risk for Am-241 smoke detector transport might be 0.00005 cancer fatalities. This indication is arrived at as follows:

p. 1-18 shows "Limited" as 7.74 x 10^3 TI for 1975. (Smoke detectors would be in the "Limited" type shipments.)

*TI = Transport Index and means "...The highest radiation dose rate, in millirem per hour at three feet from any accessible surface of the package. ..."

p. 4-40 shows 63.3 person-rem dose associated with transport of 7.74×10^3 TI. Thus, transport of 50 TI could be related to:

$$\frac{50}{7.74 \times 10^3} \times 63.3 = 0.4 \text{ person-rem}$$

p. 3-14 shows 121.6 expected latent cancer fatalities per million person-rem dose to the population. Thus 0.4 person-rem could be related to:

$$\frac{0.4}{1{,}000{,}000} \times 121.6 = 49 \times 10^{-6} \text{ expected latent cancer fatalities}$$

p. 5-34 shows 5.79×10^{-5} latent cancer fatalities associated with accidents related to all "Limited" shipments for 1975. The "Limited" category included 2×10^3 Ci for the year. In 1977, about 36 curies of Am-241 were shipped in smoke detectors. If we assume that the radioactive hazard is proportional to the activity, *the accident risk from Am-241 in smoke detectors is:

$$\frac{36}{2 \times 10^3} \times 5.79 \times 10^{-5} = 1 \times 10^{-6} \text{ latent cancer fatalities}$$

Thus the total transport risk of normal plus accidents is:

$$49 \times 10^{-6} + 1 \times 10^{-6} = 5 \times 10^{-5} \text{ potential latent cancer fatalities for 1977}$$

*Admittedly this is a rough assumption. Am-241, in an accessible form is much more radiotoxic than tritium, for example. However, in the form likely to be encountered in a detector, the Am-241 is likely to be relatively inaccessible for uptake by the body. Other radioisotopes, e.g., tritium, are likely to be in a form that is readily taken up by the body. This rough assumption appears adequate for our purposes here in view of the very small risk involved.

Estimate of Doses From Distribution of Ionization Chamber Smoke Detectors (Warehousing)

Catherine R. Mattsen

In order to determine the doses to workers in wholesale operations and catalog warehouses, we would have, if time permitted, gathered some more data on number of workers in such activities, number of warehouses nation-wide, typical numbers of detectors stored in one location at a given time, average throughtime of an ionization chamber smoke detector shipment in a warehouse or wholesaler, etc.

At this time we have only limited information but have made some rough estimates as to these factors. For the purpose of this assessment we have assumed 1000* residential type detectors in storage in either type of warehouse on the average, ten thousand wholesale employees, eighty thousand catalogue warehouse employees. Also, we've estimated that the average worker spends 2000 hours at an average distance of 10 meters from the 1000 stored detectors. Using the same reasoning as we did in estimating the effect of shielding of numbers of detectors to each other in the case of the retail store display, we have estimated that 1000 detectors stacked together yield a radiation field equal to that of 100 unshielded detectors. This results in a radiation level of 0.015 μrad/hr. at 10 meters and an average individual annual dose of 30 μrad. For the 10,000 wholesale employees this means an annual collective dose of 0.3 man rad and for the catalog warehouse employees, 2.4 man rad for a total annual collective dose of 2.7 man rad.

---

*This number may be low, however, as explained on the following page, when detectors are stacked in numbers, radiation from the detectors in the back rows is effectively shielded by the detectors in the front rows.

Estimate of Doses From Distribution (Retailers and Customers)

Catherine R. Mattsen

In considering doses to people in retail stores we have used the same estimated exposure rate constant that we had calculated from the reported radiation levels in safety evaluations and used to estimate user doses. This had yielded .0085 Rm^2/Cih as compared to the specific gamma constant for americium-241 of .015Rm^2/Cih. These radiation levels were the maximum measured taken at the point of least self-shielding of the detector. We will assume here then that each detector acts as at least two half value layers when shielding another detector. Thus when detectors are stacked in numbers (e.g., in a retail store display) the second row detectors are shielded by those in the first and the radiation level reaching a person thus shielded would be equal to or less than 1/4 that resulting from the presence of those detectors in the first row. And any detector that is shielded by two others would have its component of the dose cut to 1/16 of an unshielded one, etc.

Taking this into consideration and some additional shielding from the packaging, we have estimated that although there may be as many as 100 detectors stacked in a store display that the radiation level would not exceed that which would result from 20 detectors unshielded.

We have then assumed that the entire population (210 million people) on the average spends 30 minutes at two meters from such a display, which results in an average individual per capita dose of 0.15 µrad or a collective dose of 7.8 man rad.

The maximally exposed individual is the retail salesperson working in the department who routinely remains in proximity to the detectors (near the display, in storage, and transporting from back room, etc.). The maximum individual dose was then calculated for a person who remains at an average distance of 2 meters for 2000 hours per year with a resultant dose of 0.15 mrad. This individual is exposed much more than most retail store workers (particularly those working in stores where no detectors are sold). So we have estimated that the average retail store worker receives one thousandth of this maximum dose. The resultant collective dose for the approximately 8 million retail workers in the U. S. is 1.2 man rad for a total of 9 man rad from detectors in retail stores.

The contribution to doses from the transport by truck, etc., of detectors is covered in a separate section.

Radiation Doses to the Public Under Normal Conditions of Use (Including Installation and Maintenance)

Catherine R. Mattsen

During normal use of ionization chamber smoke detectors (ICSD's) the exposures are limited to that from external radiation. In estimating these doses we have taken radiation levels reported in safety evaluations done by the licensing technical staff for approximately half of all licensees and estimated an average radiation level for a typical detector. The resulting collective doses as shown below for ICSD's in homes and commercial buildings total about 140 man rad.

Doses from ICSD's installed in private homes.

In this assessment we have assumed that the average activity per ICSD installed in private homes in 2 μ Ci. The scenario is as follows:

Normal Use:

- There are an average of 3 persons per household.
- There are an average of 2 ICSD's per household (of those which have any)
- The average person is at an average distance of 2 meters from each ICSD one hour per day.

Maintenance

- The home owner on the average handles each ICSD for 5 minutes, 12 times/year when installing unit, changing batteries, testing and vacuum cleaning the unit and shutting off false alarms.
- The average distance of source to body during above procedures is estimated at 50 cm.

This results in an individual annual dose of 1.35 μrad for use, and 0.06 μrad for maintenance and an annual collective dose of 4.11 man rad per million installed ICSD's.

Thus, if 15% of the approximately 80 million households in the U.S. had ICSD's installed, there would be 12 million households with ICSD's or a total of 24 million installed ICSD's. The annual collective dose from normal use would be 100 man rad from ICSD's installed in private homes.

Doses from ICSD's Installed in Industrial, Commercial and Public Buildings

In estimating the doses from commercial type ICSD's, it is assumed that the average activity per detector is 10 μCi and that on the average, two persons spend 2000 hours/year at an average distance of 4 meters from each detector. Here a maintenance dose would not significantly add to the collective dose. This scenario is taken from the NEA "Recommendations for Ionization Chamber Smoke Detectors in Implementation of Radiation Protection Standards." This results in an average individual annual dose of 9.2 μrad or a collective dose of 18.5 man rad per million installed commercial ICSD's.

Thus, if there are 10% the number of commercial ICSD's as those in private homes or 2.4 million the result would be a collective dose of about 44 man rad.

Equations Used:

$$\dot{D}_a = \frac{0.87 \times \Gamma \times A}{d^2}$$

Γ: We have used an estimated exposure rate constant calculated from the radiation levels reported in the safety evaluations of ~ half of all licensees. Thus the estimate is realistic as it takes into account the shielding of the detector housing (0.0085 Rm^2/Cih).

A: activity (of Am-241)

0.87 is the absorbed dose (rad in air) delivered by 1R

It is assumed that the mean whole body dose rate to an individual at a distance d(m) from an ICSD is equal to $\dot{D}_a$ (rad/hr) the dose rate in air.

$$D_i = \dot{D}_a t$$

t is the number of hours per year spent at a distance d from the detector.

The annual collective dose S (man rad) to the population of a given country is then given by

$$S = D_i \times n \times p$$

n is the number of installed ICSD's

p is the number of individuals exposed for a time t at distance d.

ESTIMATE OF DOSES RESULTING FROM THE DESTRUCTION OF ICSD's IN FIRES

Catherine R. Mattsen

One conceivable hazard from ionization-type smoke detectors might result from damage to the detector such that the encasement is completely broken and the source is exposed and itself damaged. The most likely cause of this would be a severe fire. The main route by which any released radioisotope could be taken internally is inhalation of airborne particulates. There are many factors working together which determine how much of the radioactive material may actually be inhaled by an individual and how much will reach a critical organ. They are: the quantity released, the fraction of that released which can become airborne, the fraction of that airborne which remains in the vicinity of an individual such that it can be inhaled, and the particle size which determines what fraction is respirable. Another unknown is the solubility, which determines what fraction of that inhaled reaches the blood stream and subsequently the critical organ. Each of these in turn depends on a number of factors, some of which are difficult to predict quantitatively.

In order to estimate what percentage of the americium might be released as respirable airborne particulates, we have referred to the results of tests recently conducted at Oak Ridge National Laboratory. In these tests americium foils and whole smoke detectors have been subjected to temperatures as high as 1200° C for one hour (in addition to the 2 to 3 hours of heating to attain that temperature). In these tests, the foils consistently released as airborne particulates close to 0.01% of the total Am-241 in the foils and the maximum airborne release from any one foil approached 0.1%. In the whole detector tests (3 tests) about 0.05% became airborne.

Individual Doses to Firemen From Fighting Residential Fires

Following is a table of results using this data and some assumptions concerning the percent inhaled. From the table one can note that we've used a 5 μCi source for a worst case in a residential fire and 2 μCi as an average. The amount of activity released as airborne respirable particulates would be difficult to predict without knowing more about the chemical form, particle size, etc. but has been estimated from the ORNL data.

	Approach 1 Maximum individual dose (worst case)	Approach 2 Typical for severe fire with fireman present no respiratory protection
Source (up to 5 μCi for different models)	5 μCi	2 μCi
% of total that becomes airborne	0.1%	0.01%
% of airborne which is inhaled	0.1%	0.1%
Amount inhaled	5×10^{-6} μCi	2×10^{-7} μCi
Amount deposited in bone (critical organ)	3.1×10^{-7} μCi	1.26×10^{-8} μCi
First year dose to the bone	0.23 mrem	0.0092 mrem
50 yr. dose commitment	10 mrem	.41 mrem

In calculating maximum individual dose to a fireman involved in a residential fire we have assumed 0.1% released as respirable airborne particulates and for an average we have assumed 0.01%. We do not actually know what fraction of the airborne particulates are of respirable size. The percent inhaled depends on room size, degree of ventilation and the like, which affect the dispersal, and on the time that an individual is present in an area where this contamination has dispersed. Even in a non-fire situation an individual can only inhale a small portion of what has been dispersed in an area, though he may be present for extended periods; and in the fire situation it is highly unlikely for an individual to be in the area of this contamination for more than a short period of time without inhaling a lethal amount of combustion products.

Taking all this into consideration, it seems reasonable to accept the 10 mrem result of the first approach as the maximum 50-yr dose commitment expected from a single incident.

Collective Dose to Firemen From Fires Involving ICSD's in Private Homes

From 1975 figures it was estimated that there are 350,000 fires in non-residential buildings per year and 920,000 fires in residences per year.

If 15% of households have ICSD's installed, presumably 15% of fires in residences would involve ICSD's or a total of 138,000 residential fires per year with ICSD's present. We've assumed that 5% of these fires are serious enough to effect serious damage to the detector. We believe this to be very conservative particularly because the operation of the smoke detectors would increase the chances that the fire would be controlled before it progressed this far. With this assumption however there would be 6900 such fires per year. We have then assumed that in 1% of these fires an average of 1 fireman is exposed to the average dose calculated by approach 2 of the preceding table. This assumption seems reasonable as it is unlikely that a fireman would be present in a severe case without respiratory equipment without succumbing to smoke inhalation. Because of the danger of smoke inhalation firemen routinely use respiratory protection equipment. Thus 69 firemen per year receive a 50-yr dose commitment to the bone of 0.41 mrem or a total annual collective bone dose of 0.028 man rem.

Doses to Firemen Involved in Non-Residential Building Fires Involving Commercial ICSD's

It seems even more unlikely that a fireman would inhale americium in a fire of the magnitude that would result in serious damage of ICSD's in commercial installations as such a fire would preclude his presence without respiratory protection. Even though there could be an average of 120 μCi per building (assuming an average of 12 commercial ICSD's of about 10 μCi each per building) it did not seem worthwhile to try to create a scenario for such an exposure. In an unusual case the individual dose might be higher in such a situation, however the collective dose at most would be on the same order of magnitude as that from residential fires and both of these sources of exposure still contribute little to the total collective dose from manufacture, use, etc.

Doses to Individuals Involved in Cleanup Procedures Following a Fire and to Fire Investigators

Here we wish to consider possible intake of Am^{241} by individuals involved in the cleanup of debris remaining after a fire. The americium that was released due to the fire has since been dispersed to some extent and presumably a portion of this has settled out in the debris. At this time lower concentrations of americium exist; however, the fire and smoke hazards are no longer precluding personnel from the site. In this case, intake of the radionuclide can occur by inhalation of resuspended particles, ingestion, and by absorption into the blood directly through skin or by way of minor skin abrasion. However, for americium oxide, the primary route is inhalation of resuspended particles.

First, we are concerned about the individual involved in cleanup following a house fire, presumably the resident or some other person who is not going to be involved in the situation repeatedly. Again, we will take a realistic though conservative approach for the worst case.

We can see that fire investigators will be similarly exposed repeatedly and have estimated an average dose for such exposure such that collective doses can be calculated.

The table below outlines our method and shows the estimated factors and the results for individual doses.

Table Outlining Method of Calculating Amount Inhaled During Cleanup, Salvage, and/or Investigation Following A Residential Fire and Resulting Dose Commitments

	Maximum Individual Dose	Average Individual Dose
Total radioactive material	5 μCi	2 μCi
% of total released in fine particulates	0.1%	0.1%
% remaining in vicinity	100%	10%
Total amount remaining in debris in vicinity	5×10^{-3} μCi	2×10^{-4} μCi
Area settled out in	10 m^2	10 m^2
Contamination level	5×10^{-4} μCi/m^2	2×10^{-5} μCi/m^2
Resuspension factor	10^{-5} m^{-1}	10^{-6} m^{-1}
Concentration in air	5×10^{-9} μCi/m^3	2×10^{-11} μCi/m^3
Breathing rate	10 m^3/workday	10 m^3/workday
Time individual spends during these operations	one 8-hr workday	one 8-hr workday
Amount inhaled	5×10^{-8} μCI	2×10^{-10} μCi
Amount deposited in bone	3.15×10^{-9} μCI	1.26×10^{-11} μCi
First year dose (to the bone)	2.31×10^{-3} mrem	9.26×10^{-6} mrem
50-yr dose commitment	0.1 mrem	0.0004 mrem

The percent released is based on the ORNL fire tests on whole smoke detectors. In these tests, the sources became unrecognizable in the rubble. However, when the portion of debris containing the highest concentration of radioactivity was sieved, less than 1% of the activity was found in particle sizes of 10 microns or less (0.6%). In our assessment we have assumed that 0.1% of the source is released in the form of fine particulates which are both resuspendable and respirable.

One can also note from the table that we have assumed, in the case of an average residential fire, that one tenth of the contamination remains with the debris at the site, the remainder being carried off and dispersed outside the house or apartment. This is reasonable, since in most cases where the smoke detector is seriously damaged, the dwelling would be also and there would be adequate routes of escape of airborne particles. For the worst case 100% is assumed to settle out in the immediate area. This area even in the calculation of average dose is conservatively assumed to be only 10 square meters. Also, we've assumed a fairly high though typical resuspension factor of 10^{-6} m^{-1} for the average and a maximum realistic estimate of 10^{-5} m^{-1} for the worst case.

Collective Doses Resulting From Cleanup, Salvage, and Fire Investigation Following a Fire

In order to estimate the collective dose from cleanup, salvage and fire investigation, we have made the same assumptions which previously led to the estimate of 6900 fires per year involving the destruction of ICSD's in private homes. In addition we've assumed that on the average 3 people each work an average of 8 hours in the above procedures in each incident. This results in an annual collective organ (bone) dose commitment of 8.3 man rem.

In order to determine what individual and collective doses would result from these same procedures in cases involving commercial detectors, more background information would be needed to create a realistic scenario. This aspect should be investigated by the contractor employed to study consumer products containing radioactive material.

Within the time frame of this study we can only roughly estimate the collective doses. Since our scenario assumes that the number of commercial detectors installed is one tenth that of residential detectors and that the average activity per detector is five times that in residential installations, the total activity distributed in this type of detector is one half of the total activity distributed in residential detectors. Thus we've estimated that the collective dose resulting from procedures following fires involving commercial ICSD's is on the order of one half that resulting from residential fire cleanup procedures or an annual collective organ (bone) dose commitment of about 4.2 man rem.

Estimate of Doses From Destruction of ICSD's in a Warehouse Fire

Catherine R. Mattsen

Another possible source of radiation exposure as a result of the distribution of ICSD's is a fire in a warehouse causing the destruction of many ICSD's and the release of Am 241 such that it might be inhaled.

It is quite unlikely that an individual, fireman or other, would be present during such a fire. If one were, he would need respiratory protection to keep from inhaling toxic combustion products. However, we have done an estimate of the worst possible dose from such a situation. Also, we have considered possible doses to individuals involved in cleanup, salvage, and fire investigation procedures following such a fire.

Our scenario starts with 1000 ICSD's each containing 5 µCi, for a total of 5000 µCi. We have then followed the same steps as in our residential fire scenario with appropriate changes.

These changes are:

1. We have assumed for the case of the firefighter a fraction inhaled of one-tenth of that in a residence or 10^{-4} of the total airborne. (The volume into which the material is dispersed is larger and the firefighter is less likely to be in the area of highest concentration.)

2. In estimating the cleanup dose, we have assumed only 0.01% of the total radioactive material is released in fine particulates as compared to the 0.1% used for the residential

fire. (Since the detectors are packaged, crated and stacked, a lesser amount of the material could be released and resuspended on the average from all of the detectors.)

As can be seen in the following table, the resultant doses are 0.1 rem to the firefighter and 10 mrem to cleanup personnel. Note again, these are the maximum individual doses; since such an occurrence would be extremely rare, there is no need to consider collective doses.

Outline of method used to estimate doses from a warehouse fire with 1000 detectors - (worst case) -

Firefighting	Total radioactive material	5000 μCi
	% of total airborne	0.01%
	Fraction inhaled	10^{-4}
	Amount inhaled	5×10^{-5} μCi
	Amount deposited in bone	3.1×10^{-6} μCi
	First year dose	2.31 mrem
	50-year dose commitment	0.1 rem
Cleanup or Investigation	Total radioactive material	5000 μCi
	% of total released in fine particulates	0.01%
	% remaining in vicinity	100%
	Total amount remaining in debris in vicinity	0.5 μCi
	Area settled out in	$10\ m^2$
	Contamination level	0.05 $\mu Ci/m^2$
	Resuspension factor	$10^{-5}\ m^{-1}$
	Concentration in air	$5 \times 10^{-7}\ \mu Ci/m^3$
	Breathing rate	$10\ m^3$/8-hr workday

Cleanup or Investigation (Cont'd)	Time individual spends during these operations	one 8-hr workday
	Amount inhaled	5×10^{-6} µCi
	Amount deposited in bone	3.1×10^{-7} µCi
	First year dose (to the bone)	0.23 mrem
	50-year dose commitment	10 mrem

ANALYSIS OF THE ENVIRONMENTAL EFFECTS OF DISPOSING OF IONIZATION TYPE SMOKE DETECTORS USED IN THE HOME

Neil S. Landau

I. INTRODUCTION

Ionization type smoke detectors containing small amounts of radioactive material, usually americium-241 (Am-241), are commonly used in homes. In the U.S., the Nuclear Regulatory Commission (NRC) strictly regulates detector manufacturers and distributors to ensure distribution of only those detectors meeting the requirement of 10 CFR Part 32. There are no regulatory requirements imposed on the homeowner who uses the ionization smoke detector because the detectors constitute a neglible radiation risk while in use. However, it is reasonable to ask about the consequences of unregulated disposal of worn out, discarded detectors. The NRC staff has considered this question and concludes that uncontrolled disposal of ionization type smoke detectors used in homes does not present a significant risk to either the public or the environment. This conclusion is the result of the following assessment.

In the course of making this assessment, we had to make assumptions and estimates when firm data were not available. When possible, we made realistic assumptions and estimates. When there was serious doubt in making estimates, we made conservative assumptions, assuming worst cases, greatest possible releases, largest possible ingestion and so on. Therefore, the conclusions presented on environmental contamination, food chain concentrations, and health effects are upper limits, overestimating the probable true effects. But due to the lack of good data on some points, the magnitude of the overestimation is unknown.

II. ASSESSMENT

A. Introduction

A typical ionization type smoke detector for home use contains about 2.0 microcuries (μCi) of Am-241 within a housing which bears a label recommending return of the detector to the manufacturer for disposal. Although the user is encouraged to return the detector for disposal, such action is neither required by regulations nor is it assumed for safety analysis purposes. We have analyzed the consequences of ionization smoke detector disposal assuming that all are disposed of as normal household solid waste at the end of their useful life.

B. Principal Assumptions and Estimates

The following estimates were used to assess the hazard from uncontrolled disposal of household ionization smoke detectors:

Number of housing units................80 million*

Number of housing units with
  ionization smoke detectors...........12 million

Detectors per housing unit..............2

Total number of household ioniza-
  tion smoke detectors in use..........24 million

*Census data, 1975

Average Am-241 content of

a detector........................... 2 microcuries

Average useful life of a detector......10 years

Using these estimates, the equilibrium disposal rate of detectors is 2.4 million per year, each containing 2 microcuries (μCi) of Am-241 oxide, for a total of 4.8 Ci per year. Assuming detector users treat old detectors as common trash, the detectors will be dispersed in the rest of the household waste. About 1.2×10^{11} kg (130 million tons) of solid household waste is disposed of annually in the U.S.* It is assumed that on the average, a household will discard a smoke detector every five years, together with about 7000 kg (15,000 lb) of waste, occupying about 70 m^3 (2500 ft^3).**

C. Production of Solid Waste

The estimated average per capita production of household solid waste in the U.S. is about 1.5 kg/day (3.2 lb/day) or 530 kg/yr (1170 lb/yr).*** The per capita rate of production has recently been dropping slowly, presumably due in part to changes in materials used for packaging and in consumer goods. The present total annual solid household waste production is about 1.20×10^{11} kg/yr (130 million tons). Household solid waste has an estimated weight composition as follows:****

* EPA, "Fourth Report to Congress on Resources Recovery and Waste Reduction," SW-600, August 1977

** The estimated density of household solid waste is 0.1 g/cm^3, or 1/10 that of water.

*** EPA, "Fourth Report to Congress, August 1977

**** Ibid. and P. N. Cheremisinoff and R. A. Young, "Incineration of Solid Waste", Pollution Engineering, June 1975, pp. 20-27.

Metal	9%
Glass	9%
Yard Waste	20%
Wood	4%
Plastic	3%
Paper	29%
Food	18%
Other	8%

This solid waste weighs about 0.1 g/cm^3 (6.2 lb/ft^3). The per capita generation rate of 1.5 kg/day means each person generates about 0.015 m^3/day (0.52 ft^3/day) or 5.3 m^3/year (190 ft^3/year). Thus, for a population of 210 million the total amount of household waste generated in the U.S. is about 1.2×10^9 m^3/year (4.2×10^{10} ft^3/year). Often the muncipalities reduce this volume by pulverization, compaction, incineration or other means.

D. Collection

Much of the solid waste generated in the U.S. is disposed of by municipalities. Most (85 to 90%) of muncipal solid waste is collected and transported to disposal sites.* The waste is often compacted prior to, or during collection. Collection vehicle compactors can generate pressures of about 7×10^4 Pa (10 lb/in^2) on the waste, reducing its volume by about 70%. This pressure will not release the Am-241 sealed in a smoke detector, although it may crush the plastic cover of most smoke detectors.

*Black, Muhich, Klee, Hickman and Vaughn, "National Survey of Community Solid Waste Practices, 1968," presented at the 1968 Meeting of the Institute for Solid Wastes, American Public Works Association, October 1968.

E. Disposal

Most solid wastes are disposed of either by land disposal or by incineration followed by land disposal of the residue. Some other techniques such as ocean disposal, composting, animal feeding, and recycling, account for about 2% of the total solid waste disposal.

1. Land Disposal

85% to 90% of all collected solid waste is deposited in one of the 12,000 land disposal sites in the U.S. Only 6% of these are classified as sanitary land fills, where the waste is compacted, spread and promptly covered with fill dirt.* The remaining land disposal sites include dumps and areas of waste burning, exposing the waste to fire and weather for varying periods. The conversion of all land disposal sites to sanitary landfills is being encouraged.

Discarded smoke detectors disposed of in land sites will be mixed with large quantities of inert (non-radioactive) waste. For this analysis we estimate 1.2×10^{11} kg (130 million tons) of waste and 2.4×10^{6} ionization smoke detectors are disposed of each year. This is 40,000 kg (55 tons) of waste per detector. The radiation level at one meter from an unshielded one curie Am-241 source is 16 mrad/hr**, or 0.032 μrad/hr from a 2 μCi Am-241 source from electromagnetic radiation. The 55 tons of waste per detector, and the small activity per detector, 2.0 μCi, combine to make the external radiation dose insignificant. Additional shielding will result from covering the waste with soil. Covering waste is common

*Boegly, Haynes, Hise, Compere and Griffith, "MIUS Technology Evaluation: Solid Waste Collection and Disposal," ORNL-HUD-MIUS-9, September 1973.

**D. H. Denham, Health Physics 16, 475, 1969 practice in order to reclaim the land for further use. Leaching of radioactive material into surrounding water is not expected to be significant because the americium oxide in the units is quite insoluble. Americium in soils and sediments has been shown to be immobile.*

The highest concentration of Am-241 in the food chain due to land disposal of smoke detectors would be in plants grown in soil contaminated by Am-241 escaping from the source. Animals do not concentrate Am ingested in their food.**

The following scenario to estimate the effects of Am-241 in the food-chain is very conservative: Due to a lack of firm data, we have had to make the following assumptions: (1) By some means all the Am-241 in every discarded detector is dissolved in and is evenly dispersed through a large volume of waste; (2) the waste is the same as soil; (3) all the Am-241 in the waste is available for intake into food plants; (4) the plants' uptake fractions are all at the upper limit of the experimental evidence, 10^{-4} and; (5) 10% of a person's diet, or of the U.S. population diet in the collective dose estimate, may consist of plants grown in smoke detector contaminated waste.

Each of these assumptions is conservative, but to an unknown extent because data are not available for realistic estimates. First, the Am-241 in the detectors is in a chemical and physical form severely restricting dissolution; it is also known that even dissolved Am-241 does not migrate readily through soil. Second, the Am-241 in the waste may not act like Am-241 in soil. Third, an undetermined amount of the Am-241 dissolved in the waste will never be exposed to edible plant uptake and will escape the food chain. Fourth, the average uptake by the edible parts of food plants

* Emery and Klopfer, "The Distribution of Transuranic Elements in a Freshwater Pond Ecosystem," BNWL-SA-5424, May 1975.

** EPA, "Fourth Report to Congress," SW-600, Annex II, August 1977.

is not known. We have used the upper limit for intake of 10^{-4}. Fifth, although it may be possible that the diet of an individual could consist, to a significant degree, of plants grown in solid waste containing smoke detectors, it is much less likely that such a large fraction of the national diet could be grown in such waste.

Our calculations show there will be one detector per 70 m^3. If all the 2 μCi of Am-241 were released from each detector, the soil concentration might be about 0.03 $\mu Ci/m^3$, or assuming a specific gravity for soil of 1, 3×10^{-14} Ci/g. Experiments have shown that the plants take up about 10^{-4} or less of the soluble americium in the soil.* So plants grown exclusively in this waste could contain about (3×10^{-14} Ci/g) x (10^{-4} uptake), or 3×10^{-18} Ci/g. Data show the normal U.S. diet contains about 2×10^{-17} Ci/g of α-particle emitters, so the added Am-241 could increase the intake of α-activity by about 1.5% in a person for whom these plants constitute 10% of the diet.** Eating 50 kg/yr of such plants may result in ingesting 0.15 pCi/yr. Over 50 years this will result in an average radiation dose to the individual's bones of 0.057 μrem/yr, or 2.9 μrem for 50 years. If the entire U.S. population consumed plants grown in such soil and each person ingested 0.15 pCi/yr of Am-241, the resultant collective bone dose could be about 600 rem over the 50 year period, or 12 rem/yr on the average. Over 50 years of exposure this radiation could cause 0.004 cancer deaths, or 8×10^{-5} deaths per year of exposure.***

*Bulman, Concentration of Actinides in the Food Chain, NRPB-R44, June 1976

**Report to the United Nation s Scientific Committee on the Effects of Atomic Radiation, General Assembly, 17th Session, Supplement No. 16 (A/5216), 1962

***NRC, Reactor Safety Study, Appendix VI, NUREG-75/014, October 1975

2. Incineration

Incineration by municipal facilities is one of the principal ways of disposing of solid waste. In 1972 about 2×10^{10} kg (20 million tons) of municipal solid waste was incinerated in the U.S., about 10% of all (household and industrial) solid waste produced.* As land fill space becomes more scarce, incineration may become a much more important disposal method. In some large cities 70% of the solid waste is being incinerated.

Combustion temperatures in municipal incinerators today are usually at or below 1200° C. (2200° F.), with smaller units generally operating at lower temperatures. Recent developments in municipal waste incineration indicate that temperatures as high as 1650° C. (3000° F.) may be reached soon. These higher temperature units will require the waste be pulverized, possibly mixed with fossil fuels, and blown into the combustion zone. Noncombustibles would normally be removed from the waste before pulverization. Some new municipal facilities are also being designed to recover the waste heat as steam, or indirectly as electrical power.

Most large incinerators have emission control systems to reduce environmental pollution. These systems reduce the quantity of radioactive material which might be released to the atmosphere should a smoke detector source be incinerated and release some activity. Table 1 lists typical particulate emissions for several types of waste incineration methods.

---

*Brinkerhoff, "Inventory of Intermediate-Size Incinerators in the United States - 1972," Pollution Engineering 5 (11), pp. 33-38, 1973.

Table 1. Typical particulate emission factors for various methods of solid waste incineration

Method of incineration	Emission factor (lb/ton)	Emission factor (g/kg)
Municipal incinerators		
Uncontrolled	30	15
Minimum control	14	7
Medium control	6	3
Maximum control	0.9	0.5
Residential incinerators		
Intermediate-size		
Uncontrolled	30	15
Modified	6	3
Domestic-size		
Uncontrolled	35	17.5
Modified	7	3.5
Trench	57	18.5
Open-pit	16	8
Conical burner	10-60	5-30

Source: U.S. Environmental Protection Agency, Compilation of of Air Pollutant Emission Factors, Publication No. AP-42, Air Pollution Technical Information Center, Environmental Protection Agency, Research Triangle Park, N.C. 27711, April 1973.

The residue from incineration consists of ashes, slag, and particulates from emission control systems. This residue is normally collected and deposited in land disposal sites.

The following estimates were used to assess the radiation hazard from incinerating solid waste containing ionization smoke detectors:

Annual weight of incinerated solid waste . . . 2×10^{10} kg (20 million tons)

Annual volume of incinerated solid waste . . . 2×10^{8} m^3 (7×10^{9} ft^3)

Number of municipal incinerators 150*

Height of incinerator plant stack . . . . . . 50 m (165 ft)

Activity fraction released 1%

Assuming that by some chance all ionization type smoke detectors thrown away are incinerated, and that the waste and activity is evenly distributed between all municipal incinerators, the maximum downwind concentration of Am-241 at ground level averaged over the year is calculated to be less than 2×10^{-11} $\mu Ci/m^3$. This is insignificant when compared to the maximum permissible concentration for soluble Am-241 in unrestricted areas accessible to the general public, 2×10^{-7} $\mu Ci/m^3$.**

Incineration reduces the volume of solid waste to 5% of its initial volume, and reduces its weight to about 15% of the original.*** Using the

---

*"1977 Survey of Resources Recovery and Energy Conversion Practices," Waste Age 8 (3), 3/77.

**10 CFR Part 20.

***Cheremismoff and Young, "Incineration of Solid Waste," Pollution Engineering, June 1975.

annual figures above, the residue is calculated to weigh 3×10^9 kg (3 million tons) and take up 1×10^7 m^3 (3×10^7 ft^3). Thus, smoke detector residues will be mixed with very large quantities of radiologically inert material, which will provide considerable radiation shielding. The chances of a radioactive source being at the surface of the residue, with no shielding, will be remote. As indicated in § II.E.1 above, leaching of Am-241 from the residue into ground water will not be a significant problem.

The methods described in § II.E.1 for treating Am-241 in the food chain also apply to Am-241 in incinerator wastes. If the 0.48 Ci/yr of Am-241 from incinerated smoke detectors is dispersed in the 3×10^9 kg (1×10^7 m^3) of residue, the Am-241 concentration may be 1.6×10^{-13} Ci/g of residue, or 0.048 $\mu Ci/m^3$. Plants grown exclusively in such residue could have Am-241 concentrations of about 2×10^{-17} Ci/g. A person whose diet consisted of 50 kg/year, about 10% of his diet, of such plants for 50 years years might receive an additional bone dose of about 19 μrem over a 50 year exposure time. However, in this case, the entire population could not receive this same dose because if everyone ate 50 kg/yr of plants containing 2×10^{-17} Ci/g, over 20 Ci/yr of Am-241 would have to be added to the residue. Since only 0.48 Ci/yr could enter the residue, this limits the collective dose. Assuming 0.48 Ci/yr in the waste and a 10^{-4} plant uptake, the maximum collective bone dose for 50 years of exposure is calculated to be about 900 rem, or an average of 18 rem/yr. Over 50 years of exposure, this radiation could be expected to cause 0.006 cancer deaths, or 1.2×10^{-4} deaths per year of exposure.

3. Recovery of Waste Materials

Recovery of materials from incinerator wastes is becoming a reality, with up to 10% of waste metal and glass reclaimed. Therefore it is appropriate to assess the risk of contaminating the recovered material with Am-241 from discarded ionization type smoke detectors. For the assessment we have made the following estimates:

Weight fraction of metal in solid wastes 9%

Weight fraction of glass in solid wastes 9%

Weight fraction of glass and metal actually reclaimed. . . .10%

Activity fraction reclaimed from smoke detectors 10%

These estimates, with the assumption that all 2.4×10^6 detectors discarded annually are incinerated, result in a calculated average concentration of about 2.4 μμCi of Am-241 per gram of metal reclaimed. Even if all the 0.48 Ci per year of reclaimed Am-241 were used in plating, the use resulting in the greatest imaginable radiation hazard, the activity levels would be far below surface contamination level guideline limits.* Even if all 4.8 Ci per year disposed of were recovered and used in plating, the activity would be far below the limits.

F. Conclusion

The preceding assessment shows that ionization type smoke detectors containing Am-241, when disposed of with normal household refuse, do not present a signficant risk to man or the environment. The underlying assumption leading to this conclusion is that the detectors will be widely

*"Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," U.S. Nuclear Regulatory Commission, Division of Fuel Cycle and Material Safety, Washington, D.C., December, 1975 (DRAFT).

dispersed in a very large amount of radiologically inert solid waste. Furthermore, Am-241 does not readily enter the food chain. Conceivably a regulatory requirement could be imposed to require the return of all discarded detectors to the manufacturers or others for disposal as radioactive material. Such a requirement, even if it were practical to enforce, does not seem to be justified in view of the insignificant risk of uncontrolled disposal, the small additional radiation exposure associated with collection for controlled disposal, and the costs associated with setting up and running a collection and controlled disposal system.

DISPOSAL OF INDUSTRIAL IONIZATION SMOKE DETECTORS

Neil Landau

The environmental effects of disposing of industrial smoke detectors containing Am-241 were estimated in the same way as was done for household smoke detectors. The same assumptions and estimates were used , with the following two exceptions: (1) Industrial detectors contain an average of 10 μCi of Am-241, five times the quantity in a home smoke detector, and; (2) There will be 240,000 industrial detectors disposed of per year, one-tenth the number of home smoke detectors.

These assumptions lead to the following estimated environmental effects for industrial smoke detectors disposed of on land:

Am-241 concentration in solid waste . . . . 1.5×10^{-14} Ci/g

Resultant Am-241 concentration in plants. . . . . . 1.5×10^{-18} Ci/g

Maximum 50 year bone dose to an individual. . . . . 1.5 μrem

Maximum 50 year collective bone dose

(to a population of 210 million). . . . . 300 rem

Resultant cancer deaths from 50 years of

collective exposure 0.002

For detectors disposed of by incineration, the effects would be:

Am-241 concentration in residue . . . . 1×10^{-13} Ci/g

Resultant Am-241 concentration in plants. . . . . . 1×10^{-17} Ci/g

Maximum 50 year bone dose to an individual. . . . . 10 μrem

Maximum 50 year collective bone dose

(to 210 million population) . . . . 450 rem

Resultant cancer deaths from 50 years of

collective exposure. 0.006

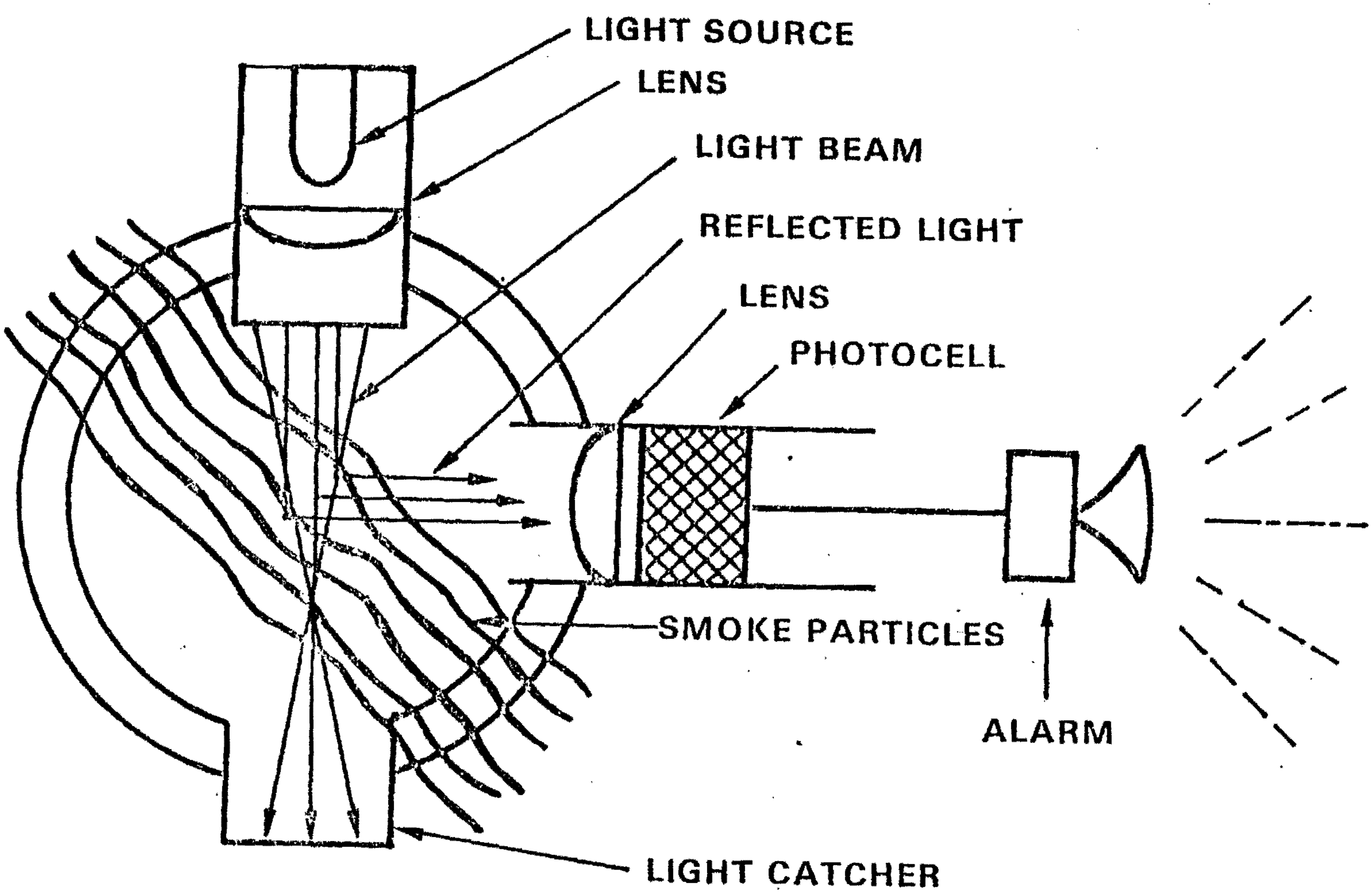
VI. ALTERNATIVES

James J. Henry

1. Detectors other than ionization chamber smoke detectors. In the market for domestic fire detectors, there are four alternatives: ionization chamber smoke detectors; photoelectric and other optical smoke detectors; combination photo-ion smoke detectors; and heat detectors. Ionization and optical detectors are sensors of products of combustion. Heat detectors are sensors of temperature or rate of rise of temperature.

Photoelectric smoke detectors. Sensors for the photoelectric type detectors must be line-operated and located where visible particulate matter from fires can enter the detector. Inside the detector is a small, dark chamber. When gray-colored smoke enters the chamber in sufficient mass to provide up to 4% obscuration (10% for black-colored smoke) of a standard light beam projected over a one foot distance, the light from the detector's light bulb is refracted and reflected into the detector's photoelectric cell. The increase in light intensity on the light sensitive receptor of the photoelectric cell initiates a signal which is converted into an alarm. Figure A is a schematic drawing showing the principle of the reflected beam type of photoelectric detector.

Other optical smoke detectors. In an effort to develop an optical detector that will operate on a battery for at least one year before battery replacement, manufacturers are now relying on light-emitting



LIGHT REFLECTED BY TRACES OF SMOKE ENTERING THE CHAMBER IS SEEN BY THE "EYE" WHICH REACTS BY SIGNALING ALARM.

Figure A. Photoelectric Smoke Detector Chamber diodes (instead of light bulbs) and photodiodes or phototransistors (instead of photocells). This combination permits the use of short bursts of red light from a pulsed LED scattered by visible particulates to activate almost instantaneously the light sensing elements of the photoreceivers. The design calls for moving the photoreceiver from the traditional 90° side-scatter position to the far-forward-scatter position which, incidently, results in a better response to black smoke than the side-scatter design.

Photo-ion smoke detectors. At a hearing on July 28, 1978, in the District of Columbia on a smoke detector law, BRK Electronics publicly announced the forthcoming availability of a detector that combines an optical smoke sensor with an ionization chamber sensor.

The detector combines the best characteristics of the two types of sensors for detecting fires and, by gating their responses, reduces the probabilities of false alarms from cooking fumes, heavy tobacco smoke, steam, sprays and mists, and similar particulates.

Heat detectors. Sensors for the heat detectors must be located where heat rising from an unfriendly fire can affect a bimetallic strip (thermostat) or melt a fusible metal. The temperature response at 135° to 165°F closes a circuit and thus activitates a mechanical or electronic alarm. The mode of operation of heat detectors requires that at least one be located in each room under surveillance and, accordingly, are not normally single-station fire detectors (more than one heat sensor may activate a central alarm).

2. Radionuclides other than AM-241. Ionization chamber smoke detectors were originally designed to utilize Ra-226. An estimated 1 to 2 million smoke detectors containing Ra-226 are still in use and one known manufacturer is distributing this type of smoke detector in the U.S. Ra-226 adequately ionizes air for sensing smoke, but it has the drawback of constantly emitting very low levels of Rn-222, a radioactive gas, into the atmosphere around the smoke detectors.

Some early models of ionization chamber smoke detectors authorized for distribution for use under the Commission's class exemption for gas and aerosol detectors contained Ni-63 or C-14. An estimated 10 thousand of these are still in use. There were difficulties in generating sufficient ions for meeting sensitivity limits for smoke detection when using beta particle ionization of the air in smoke detectors' chambers. New, improved electronics including integrated circuits could permit design of new smoke detectors, utilizing beta particle emitters, that will respond to specified paper, plastic packaging, gasoline, and wood fires within specified time limits.

In response to a petition for rule making, the Commission in 1963 exempted from licensing and regulatory requirements persons using fire detection units containing uranium. The petitioner made only 12 prototype models of the smoke detectors and never entered the commercial market.

3. Quantities of Am-241 radioactivity. Most currently approved models of ionization chamber smoke detectors utilizing Am-241 contain up to 5 microcuries of activity. Manufacturers are striving to reduce the total quantity of activity to one microcurie or less, in response to restrictive limits on smoke detectors destined for the European market. At least six ionization chamber designs licensed for distribution in the U.S. market contain less than one microcurie of activity. This has come about from advances in solid-state electronics for responding to extremely small changes (signals) in extremely small electrical currents (background or noise).

Within the last several years, the use of integrated circuits to compensate for temperature and atmospheric effects has made it possible to dispense with the reference ionization chamber. The side benefits of the single chamber over the dual chamber include a possible reduction in cost of detectors, a reduction in the quantity of activity per unit, and integration of the ionization chamber with a photodiode or phototransistor optical sensor, i.e., the photo-ion detector discussed previously.

Benefits and costs of alternatives. Photoelectric and other optical smoke detectors respond to gray- and black-colored smoke. They are designed to reduce the potential for false alarms from low concentrations of gray-colored smoke.

Photoelectric and other optical smoke detectors do not respond adequately to invisible products of combustion. The paper fire and plastic packing material fire in the test protocol for smoke detectors are of a size to generate enough smoke (in addition to invisible combustion products) to mask the deficiency of the optical detectors. Photoelectric smoke detectors with incandescent lights must be line operated, either plugged into an electrical outlet or directly wired into an electrical circuit.

The nature of light sensing makes the optical detectors less sensitive as dust, grease, and dirt build a light-reducing layer over the light sensing element of the photoreceiver. This requires periodic maintenance to keep a high level of light transmission onto the light sensor.

Steam, sprays, mists, and other smoke-mimicking particulates entering the optical detector can cause false alarms. This factor requires careful selection of the locations of optical detectors to keep the interfering material out of the sensitive volume of the detector.

One drawback of the battery-powered optical detectors is cost. The number and sophistication of components required make the detectors inherently more costly to produce than comparable ionization chamber smoke detectors.

Photo-ion smoke detectors have the advantages of being able to detect both visible and invisible products of combustion and being designed to reduce the probabilities of false alarms from smoke-mimicking particulates.

Although photo-ion smoke detectors are not yet on the market (expected in the fall of 1978), it is expected the combination unit will inherently cost more than either an ionization chamber or optical smoke detector.

Heat detectors have the advantages of being immune to most environmental conditions (except high temperatures, of course) and of being mechanical in operation (thus independent of outside sources of power).

To be useful as detectors of fires, the heat sensing portion of the heat detectors must be located where radiant, convective, or conductive heat from an unfriendly fire can exceed the temperature setpoint of the heat detectors. This factor requires that at least one heat detector be located in each room under surveillance.

Two radionuclides other than Am-241 that have been used in ionization chamber smoke detectors, Ni-63 and C-14, have the advantage of being less radiotoxic than an equivalent quantity of Am-241 activity.

New smoke detectors utilizing beta particle emitters likely will cost more than equivalent detectors containing Am-241 because of the sophisticated components needed for beta-ionized chambers.

The quantities of Am-241 radioactivity in ionization chamber smoke detectors have been reduced primarily as comparatively large Am-241 sources plus electronics became more costly than smaller Am-241 sources plus improved electronics. New generation combination detectors (photo-ion) are using integrated circuits to replace the reference ionization chamber. This will further reduce the quantity of activity per smoke detector.

VII. SUMMARY OF BENEFITS AND COST OF IONIZATION TYPE SMOKE DETECTOR

A. Benefits

1. Benefit in reducing property damage:

The primary purpose of installing smoke detectors in private homes, hotels, old peoples' homes etc. is to prevent loss of life in fires by giving early warning and thus allowing occupants to escape. Although smoke detectors in industrial and public buildings can also save lives, the main reason for installing them has been to reduce property damage.

It is difficult to estimate how much property losses will be reduced by widespread installation of smoke detectors for a number of reasons. There are many factors involved and in the short time allotted to this particular study the staff did not develop an estimate. We have been told that in some countries the fire insurance companies offer reduced premium to customers using approved smoke detectors. Accordingly, information on the property saving benefit of smoke detectors may be possessed by insurance companies and its availability should be investigated during the course of the extensive consumer products study by the contractor.

2. Benefit in reducing loss of life:

An estimated 450 fire deaths would be prevented annually by use of our assumed 24,000,000 detectors in 15% of all homes and 2,400,000 detectors in non-residential buildings. This very rough estimate is obtained simply by multiplying the number of deaths in buildings (7,500) by the estimated fraction saved if a detector were used (40%) and by the assumed fraction of homes and non-residential buildings equipped with smoke detectors (15%). Similarly, 18,600 fire injuries would be prevented.

B. Costs

1. Purchase and maintenance costs:

Purchase of the assumed 24,000,000 residential and 2,400,000 industrial detectors would require, at an average of $25/detector, $660,000,000. If we assume a 10-year life for a detector, we have an annual purchase cost of $66,000,000.

Annual replacement of a battery in a battery-powered detector usually will cost less than $1, however some earlier models required special batteries costing up to about $10. Some small amount for electricity, probably less than $1, would be spent annually by a user of a line powered detector. Maintenance costs, other than batteries, should be minimal since a defective unit probably would be replaced rather than repaired.

2. Estimated radiation doses to man, person-rem/year:

Workers at radioactive source manufacturing facilities (1977 assumed typical)	18.4
Workers at smoke detector manufacturing facilities (1977 assumed typical)	32.
Workers transporting smoke detectors (1977 assumed typical)	0.4
Workers at wholesale and catalogue warehouses	2.7
Salespersons and customers at retail facilities	9
Users (person exposed when 24×10^6 residential and 2.4×10^6 non-residential in use)	143
Firemen (collective critical organ, bone, dose commitment)	.03
Clean up personnel after fires (collective critical organ, bone, dose commitment)	12.5
Persons exposed via disposal and food chain: (Collective critical organ, bone, dose commitment)	45.
Total	263.03

C. Incremental Benefits/Costs of Ionization Smoke Detectors When Compared with Photoelectric Detectors

If the assumption is made that either ionization type or photoelectric type detectors would save the above mentioned property damage and prevent 450 fire deaths annually, the question arises as to possible incremental benefits/costs of ionization types when compared with photoelectric types. One apparent incremental factor at this time is the difference in purchase price of the two types. If we assume that the average photoelectric detector costs $5 more than the average ionization detector, and if we assume annual replacement of 10% of the 24,000,000 residential and 2,400,000 non-residential detectors, it follows that use of the ionization type would save users $13,200,000 annually. This savings (benefit) would be at the cost of incurring about 260 person rem. This is approximately $50,000 per person rem.

VIII. FREQUENTLY ASKED QUESTIONS ABOUT IONIZATION TYPE SMOKE DETECTORS

1. Why does the NRC permit the use of smoke detectors that emit radiation when there are non-radioactive, photoelectric smoke detectors on the market that will do the job?

Staff Response: The level of radiation from smoke detectors containing radioactive material is so low as to be virtually insignificant. With respect to function of the ionization type and the photoelectric type detectors, the staff relies on experts at the Center for Fire Research at the National Bureau of Standards. Those experts explain that, technically speaking, the two types are not equivalent but rather they are complementary. The preferred detector would be one which incorporates both detection principles. Such a detector is expected to reach the U.S. market before Christmas of 1978.

On occasion it is argued by critics of the ionization type that it must be equivalent functionally to the photoelectric type since both pass the same functional acceptance test at Underwriters Laboratories (UL). Although the UL test regime is widely accepted, there is general recognition of need for improvement in the tests. Both NBS personnel and an international group are actively developing functional tests. The Consumer Products Safety Commission has underway a study at Southwest Research Institute to evaluate the effectiveness of existing functional standards for smoke detectors.

*Attached as Exhibit "1" is an editorial from the Washington Post that also addresses this question.

Even if it is assumed that photoelectric and ionization type detectors now provide equivalent protection when used in the home, a question might reasonably remain as to the propriety of an NRC decision to prohibit use in view of the very low radiation risk and the higher price that is presently associated with the photoelectric type. At this low level of risk, some persons would prefer to have an opportunity to make their own choice of whether to accept or reject it, and also whether to pay the additional cost in dollars.

2. Labels on ionization type smoke detectors usually are located inside the detector cover. Should not the potential buyer be able to see the label before he purchases the detector, gets it home, starts installation and then discovers it contains radioactive material?

Staff Response: The regulation (10 CFR Part 32) is not specific with respect to location of the labels on smoke detectors. It is the present practice of manufacturers to locate the label inside the cover of the smoke detector and close to the radioactive source. The staff is presently re-examining this practice and will address label location in a Regulatory Guide. The staff is in general agreement that a would-be purchaser, particularly one with a concern about radiation, should be able to ascertain the radioactive content of a smoke detector before he makes his purchase.

3. Labels on ionization type smoke detectors frequently carry a recommendation that the detector be returned to the manufacturer for disposal. Should not more specific instructions for return be provided to the homeowner?

Staff Response: The manufacturers' practice of recommending return for disposal is a carry-over from early models intended for industrial use and containing up to 80 or 130 microcuries of Am-241. It was not unusual for an industrial building to have a dozen or more such detectors in a single system and, looking forward to removal from use, it seemed reasonable to recommend return to the manufacturer for disposal. At the same time, the potential disposal problems did not seem to warrant a regulatory requirement for disposal.

Smoke detectors used in the home contain an average of about 2 microcuries of Am-241. As discussed earlier in this report, their disposal along with other household waste does not cause a significant radiation problem. To return all the detectors to the manufacturer, however, would be a significant expense. To ship a packaged smoke detector, by the cheapest way, from Rockville, Md. to St. Louis, Mo., costs $1.18. If the expense of shipment is added to the expense of preparing the package for shipment and taking it to the post office, a total cost on the order of $3/detector would likely be incurred. It is highly unlikely that homeowners would voluntarily accept this cost.

In view of the costs involved with homeowners' return of detectors for controlled disposal and in view of the very small radiation risk, in lieu of providing more specific return procedures it would be preferable to delete the recommendation in the label that the homeowner return the detector.

The Washington Post

AN INDEPENDENT NEWSPAPER

A12 TUESDAY, JANUARY 4, 1977

Fire Detectors and Safety

FOR SOME TIME now, we have been watching with considerable interest the dispute between two leading consumer protection groups—Consumers Union and Health Research Group—over the safety and utility of ionization smoke detectors. The argument, like any squabble between two like-minded groups, is fascinating. But this one has some other overtones. The product in dispute—systems that warn people against fires in their homes—is important. And the difference in the approaches of the two groups suggests the dangers that lurk out there when public interest groups push their expertise too far.

It all began in mid-September when the Health Research Group, which is affiliated with Ralph Nader's Public Citizen organization, denounced ionization smoke detectors because they contain a radioactive agent. It called them "mindless and dangerous" and urged that all four million of them then in use be recalled and destroyed. At the same time, Consumers Union, an organization that has been testing products and providing consumer information for 40 years, was readying a report calling these detectors safe and highly useful in giving early warning of some kinds of home fires. The article recommending the use in homes of an ionization detector as well as one of the photoelectric type appeared in October's *Consumer Reports*. And the fight was on.

Dr. Sidney M. Wolfe, director of Health Research, told Consumers Union that it had not carefully considered questions of safety and efficiency, had failed to test for radiation leaks under certain conditions, and had ignored other nuclear-related hazards. He contended that even an official of the Nuclear Regulatory Commission "had conceded that the NRC found no inaccuracies in our report." He concluded that the devices subject workers and residents to the risk of harmful radiation. "The issue," he said, "is not *how much* radiation is released but why this extra amount of radiation exposure is necessary at all." Underpinning his argument were the fact that photoelectric smoke detectors sense smoldering fires faster than ionization ones and the assertion that since 75 per cent of home fires start out as smoldering ones, there is no need for another kind of detector.

Now, charges of that type are body blows when they are aimed at an organization like Consumers Union, whose stock in trade is the accuracy of its testing procedures. So it was not surprising when it returned the fire in its January publication. It said Dr. Wolfe's fears are "unwarranted" and his conclusions "are wrong." The second largest cause of home fire deaths, it said, are open blazes which photoelectric detectors generally ignore while ionization ones do not. As to the amount of radiation, Consumers Union insisted that the data show the detectors produce so little that there is "virtually no hazard." It said that the Health Research Group's warning against using these detectors, if followed by the public, "could lead to tragic consequences including the possible loss of hundreds of lives." And it quoted the same NRC official as saying that the Health Research Group's report "was inaccurate in that it left out anything that would have tipped the balance against the HRG's viewpoint."

We are sure this is not the last word. The language in *Consumer Reports* is a direct challenge to the thoughtfulness and care with which the Health Research Group evaluated these devices. But at the moment, it seems to us that Consumers Union is pretty far ahead. Its data make a substantial case that these detectors are not dangerous in normal use and do provide a substantial amount of protection that other detectors do not provide. The findings of the Nuclear Regulatory Commission support those safety conclusions. But you can judge for yourself by reading both reports.

The thin ice that it seems to us the Health Research Group is on results from its quick response to one particular threat to life—radiation—without weighing the degree of danger against the benefits to be gained. This same approach to consumer safety problems has appeared again and again recently in the arguments advanced by some other fairly new public-interest organizations. It arises either because they are so eager to reduce one particular threat that they fail to weigh the plusses and minuses or because they need something new every once in a while to keep them going. In either case, the results are the same—an undermining of their effectiveness. That, it seems to us, is going to be a growing problem for organizations which are created to push specific public-interest programs. It is quite easy for them to slip over the line which the public sees as dividing special-interest groups from public-interest groups.