SYMPOSIUM

ON

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IONIZATION SMOKE DETECTION, ITS APPLICATION TO LIFE SAFETY IN DWELLINGS

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Household smoke detectors, conceived only a few years ago, are about to become necessary and required household appliances. One of the principal reasons for the current revival in home fire safety has been due to the rapid technological development of single station ionization detectors.

A single station detector is defined as an assembly which incorporates the detection element, control circuitry and the alarm sounding device in one unit, operated from either an internal power source or power obtained at the point of installation.

The purpose of this paper will be to try to assess the effectiveness as well as to identify the limitations of the ionization principle as applied to home fire safety by reference to three basic sources of information. Included is a summary of a sample survey of detector users, a summary of potentially hazardous fires reported to date in protected occupancies, and a response to industry concerns from the accumulated reports and experiences of one manufacturer.

Not included are comparisons with any other forms of fire detection. The requirement for at least one approved smoke detector is now a part of national model building codes[1] and is gradually becoming part of local building code ordinances in many cities in the United States. Because of the general acceptance of smoke detectors as life saving devices, it is mandatory that the fire protection industry recognize the limits of their application as clearly as they recognize their potential for saving lives.

History of Development

The use of the ionization principle in fire detectors began in Europe through the patented developments of W. C. Jaeger, Malenfeld, Switzerland, and the later

improvements of Ernst Meili, Bad Ragaz, Switzerland. These developments are detailed in a series of patents dating from 1942 [2] and now forming the basis for products of the Cerberus Company of Männedorf, Switzerland. Ionization detectors were originally developed for high value property protection, such as institutional, commercial and industrial buildings. Original designs used what is now referred to as a high voltage chamber. That chamber design is still the most widely used form of commercial ionization detector in use today. These devices were applied to inter-connected systems and required high voltage wiring. High voltage chambers required high quantities of radiation and were relatively expensive.

With the introduction of the MOS FET (Metal Oxide Semiconductor, Field Effect Transistor), low voltage chambers, using lower quantities of radiation, were introduced into systems using low voltage wiring. Subsequently, these systems were developed for application to dwellings. Because of the high cost of installation of these systems for dwellings, their use has been limited.

Another factor limiting use of the ionization principle in dwellings was the lack of national radiation standards. The U. S. Atomic Energy Commission first allowed ionization detectors for distribution, exempt from licensing, in 1969. [3]

The accepted use of Americium 241, a relatively pure, low energy alpha emitter as the radiation source, was a major consideration of the U.S. AEC in their decision to allow exempt distribution.

At this point in time, it became possible to assemble, produce and distribute low cost, single station, ionization detectors for use in dwellings. The extremely low current, of approximately 50 microamperes, required to monitor low voltage chambers made it possible to develop battery powered devices, with a battery life of at least one year. Almost simultaneous to this development, single station detectors using line voltage power were introduced.

Legislation

With the overwhelming statistics of home fire fatalities in the United States and with the advent of low cost early warning ionization detectors, both government and national model building code authorities began to seriously consider their use in new dwellings. The availability of smoke detectors using a photoelectric principle also enabled building codes to identify more than one principle of detection, produced by several manufacturers, insuring a competitive market source.

The International Conference of Building Officials, at their 1973 Fall Conference, passed a resolution to require "a product of combustion detector, other than heat --- " for each new apartment and each new one and two-family dwelling unit, as part of the 1973 Edition of the Uniform Building Code. Although the terminology suggested the use of only ionization detectors, in fact, it was intended to include approved detectors using both the ionization and photoelectric principles. Within one year, a similar requirement was added to the Basic Building Code. In 1973, a similar requirement, restricted to only apartments, was made for inclusion in the Standard Building Code. The following year this was extended to include one and two-family dwellings and also requiring a second smoke detector for basement stairways, when applicable.

Further emphasis was added by the report of the President's Commission on Fire Prevention and Control in the report submitted to Congress May 4, 1973. The National Fire Protection Association recognized the value of single station smoke detectors in their 1972 Revisions to Pamphlet No. 74, Household Fire Warning Equipment. In 1974, the NFPA Pamphlet No. 74 was further revised to consider that "multiple levels of protection" were considered acceptable, with the minimum requirement, referred to as Level 4, of only one or two smoke detectors in a typical dwelling.

International statistics of home fire fatalities appear to be significantly less in other countries than in the United States. Nevertheless, it is anticipated that similar requirements for smoke detectors in dwellings will soon be found in many foreign countries where living standards are comparable to the United States.

Industry Responsibility

With the inertia of this new demand for general application of household smoke detectors, it is very important that the fire detection industry protect the confidence of the public in these future developments by rigidly policing the quality and effectiveness of all approved fire detection devices.

The ionization principle, through its long use in commercial systems, has demonstrated its effectiveness in a large variety of fires, under varying circumstances and in the early stages of fire development. However, it should not be assumed that this principle, nor any other principle of smoke detection developed today, is totally effective for all types of fires, under all environments, and in all types of structures. It is important, therefore, that the limitations of each method of fire or smoke detection be well identified to insure its proper application.

Approvals and Listings

Model building codes and government specifications require that smoke detectors be "approved" or "listed" by a nationally recognized test laboratory. Although there is more than one such laboratory, no smoke detector can be considered totally acceptable for distribution in the United States today unless it is listed by Underwriters' Laboratories, Inc., Northbrook, Illinois. UL test standards are designed to meet the standards of their specific area of intended use as well as the standards of the National Fire Protection Association. Single station smoke detectors listed by Underwriters' Laboratories are considered

acceptable to meet the requirements of NFPA Pamphlet No. 74. There are many additional environmental conditions, construction features and sensitivity requirements which UL, together with their industry advisory committees, consider necessary for household devices. UL listing, then, certifies a minimum level of acceptability and does not necessarily identify the ultimate in performance.

Ionization Principle Evaluation

Any evaluation of the ionization principle of smoke detection must first recognize that there are a wide variety of configurations of ionization chambers. In addition, there are varying values, as well as different types, of radiation material. Each ionization detector design incorporates uniquely different characteristics. Each may respond differently to changes in temperature, humidity, air velocity or barometric pressure. There are significant differences in response to different types of smoke or products of combustion. However, with all of these differences, there are also certain common characteristics and it is these common characteristics that form the basis for this evaluation.

Any manufacturer, when asked for his opinion of a principle which is fundamental to his products, must necessarily be biased. A biased evaluation of the ionization principle might suggest an ennumeration of its desirable features, such as sensitivity to "invisible" products of combustion, detection of "incipient" fires and many other fine characteristics that should make this principle ideal as an early warning smoke detector. The evaluation, to improve its believability, should also include a small list of so called "precautions" in application. However, the final biased evaluation would clearly identify the ionization principle as being 99.9% effective in all possible fire circumstances.

What Could Have Happened

With the increasing numbers of ionization smoke detectors installed in homes during the past four years, the statistical quantity of fire incident reports received from distributors, dwelling occupants or the fire services, are now becoming meaningful. However, because there are no mandatory requirements nor automatic methods of reporting all fire incidents, the numbers of fires reported are obviously understated and the reports are incomplete.

From the sales records of one manufacturer at the end of 1974, making allowance for installation delays, inventories, etc., over 200,000 dwellings in the U.S. had been equipped with at least one of its single station ionization smoke detectors and for a minimum period of one year. The maximum length of service was three and one-half years with the first of these detectors installed during 1971.

Based upon a recent survey, sponsored jointly by the National Bureau of Standards and the U.S. Consumer Product Safety Commission,(5) it was estimated there were 4.5 million dwelling fires in the United States during the twelve months prior to April, 1974. If the survey is correct, there could have been 12,000 fires in these 200,000 detector equipped dwellings during 1974.

This is based on an estimated 73 million dwellings, including one and two-family dwellings, mobile homes and apartments. The survey suggests that one fire occurred in every 16 homes during that year. The survey definition of a fire was that "An accident was considered a fire if it emitted smoke or flames and was not started intentionally."

In those same 200,000 dwellings, there could have been 17.9 fatalities during 1974, or one fatal fire in every 12,250 homes.

This is based on the 1973, NFPA estimates of 6,493 home fire fatalities.(6) Adjusting for the multiple-death residential fires involving 700 persons and 165 fires, there were approximately 5,950 fatal fires in dwellings, averaging 1.1 fatalities per fire.

There could have been over 80 occupants injured from fire in those 200,000 dwellings.

This is based on the assumption that one-half of the 1973, NFPA estimates of injured, were fire fighters and it also assumes, as with fatalities, that 55.5% of all injuries occurred in dwelling fires.

To date, there have been no fatalities nor injuries from fire or smoke reported to one manufacturer in any of these 200,000 dwellings.

What Causes Alarms - Sample Survey of One Manufacturers' Employees

To determine the number and causes of alarms likely to be experienced in dwellings, the following sample survey was conducted among one manufacturers' factory personnel, having at least one ionization smoke detector in their dwelling for varying lengths of time.

(Refer to Table No. 1)

The following are supplementary notes to Table No. 1:

1) The above survey is a tabulation of results from written questionnaires received from factory employees of one manufacturer during September, 1974. Employees were requested not to sign questionnaires.

2) Types of dwellings were varied, comprising approximately 55% one-story, single family homes with basements; 22% were apartments; 14% were mobile homes and 6% other types.

3) One hundred and two homes used only one detector, one home used two detectors and one home used five detectors. There were a total of 104 dwellings, using 109 detectors.

4) All detectors used batteries for primary power, however, events related to the use of batteries have intentionally been excluded.

5) Detectors were tested an average of once every five weeks. (Instruction manuals recommend testing weekly.)

6) One incident was reported of heavy smoke where the detector did not alarm. An investigation revealed this to be a kitchen accident involving two ounces of Crisco (vegetable shortening) which was consumed in an open pan with no evidence of an actual fire.

Summary of Sample Survey results:

It must first be recognized that the survey information results from each individual's recall of a rare circumstance. This might be considered reasonably accurate for recalling within a period of ninety (90) days, but is subject to a multiple error for recall periods as long as three years. The above summary would indicate that only one out of every two ionization detectors installed would experience an alarm from any of the above causes each year. In over half of those questionnaires from users who reported an alarm, there were unsolicited positive comments such as "the alarm was reassuring," or "it gave us a sense of security."

From the comments received, it would be safe to conjecture that one or two false alarms per year, per detector, where the cause of alarm is evident, would not be considered annoying nor unreasonable to a normal occupant. All of the occupants in this survey were reasonably adept mentally and physically. Consideration must be given, however, to those occupants who may be elderly, handicapped or, in other ways, physically or mentally ill.

Industry Trends for Higher Sensitivity

Among many knowledgeable persons in the fire protection industry, there is an expressed desire for higher sensitivities or earlier detector response to a variety of types of smoke. The desire for the earliest possible response to an ignition source is understandable. However, as single station smoke detectors with higher sensitivities are forced into homes through legislation, the

tolerance of a typical occupant to relatively frequent false alarms from legitimate smoke sources, will likely be much lower. The ultimate result could become so negative as to destroy public confidence in the real value of smoke detectors in dwellings.

Reports of Hazardous Fires Detected

A total of fifteen fire incidents in the United States which were considered to have been potentially fatal to one or more occupants, has been reported to one manufacturer since June, 1972. In each of these reports one of its single station ionization detectors alerted the occupants in time to effect a safe escape. Property loss also was significantly reduced or eliminated in each incident. The following Table summarizes those reports:

(Refer to Table No. 2)

Supplementary notes to Table No. 2:

1) Six of these fires, or 40%, had not previously been reported to the local fire department. (Unreported fires were subsequently investigated by the fire department. It was determined in each case that there was a reasonable possibility of causing a potential fatality.)

2) Three fires involved smoldering fabrics and one smoldering wood. Average horizontal distance from ignition source to detector location was approximately 30 feet. The Bedford, New Hampshire fire started from a smoldering couch with the detector approximately 80 feet from the ignition source and mounted 15 inches below the ceiling on a bedroom door jam. This is not a recommended location. Not classed as a smoldering fire was the garage fire in Aurora, Colorado. Although the fire started as smoldering cardboard, it is believed to have burst into flame before the detector, located at the opposite end of the house, caused an alarm.

3) Thirteen of these fires occurred during the sleeping hours, between 10:00 p.m. and 6:00 a.m. Each of the two daytime fires, if not detected, could have caused occupants to be trapped.

The following summary demonstrates a surprisingly close similarity of these fire locations to the NFPA estimates of "where fatal residential fires start":

SUMMARY
OF
REPORTS OF HAZARDOUS FIRES DETECTED - VERSUS - (7)
NFPA ESTIMATES OF "WHERE FATAL RESIDENTIAL FIRES START"

Location	No. of Fires	Per Cent	NFPA (NFPA #FR72-1)
Livingroom, family room	5	33.3%	33.8%
Basement or furnace room	3	20	25.7
Kitchen	2	13.3	16.2
Bedroom	2	13.3	12.1
Bathroom	1	6.7	4
Garage	1	6.7	1.4
Outside	1	6.7	1.4
	15	100.0%	94.6%

Summary

An evaluation of the effectiveness and limitations of single station ionization smoke detectors for life safety cannot be complete without a review of the many concerns expressed within the industry.

The following is a list of concerns as expressed by industry personalities, criticisms from manufacturers of competitive principles, or by laymen in the subject. Although specific answers to these questions are subject to a manufacturer's biased opinion, the following responses are based upon correspondence and contacts with users, dealers, distributors and fire service personnel.

1) Will they false alarm in a room full of smokers?

The above survey report, Table No. 1, demonstrates the possibility of alarm from heavy smoker concentration. Typical dwellings differ from commercial buildings in that they may include lower ceilings and smaller rooms, increasing the probability of alarm from large concentrations of smokers.

2) Will they respond to smoldering smoke?

The response to slow, smoldering smoke is an issue that requires careful definition, but, nevertheless, represents a characteristic of the ionization principle which is of concern to all manufacturers. The ability of the detector to discriminate between smoke, as found in a room full of smokers, and potentially hazardous smoke starting from smoldering condition, where smoke moves very slowly, is the characteristic which each manufacturer gives a disproportionate amount of attention. It should be remembered that the heavy cigarette smoke condition is relatively stable whereas the

potentially hazardous smoke is always a growing condition. The question, then, becomes one of which point in time, relative to increasing smoke development, should the detector cause an alarm in sufficient time to allow a safe exit from the dwelling.

3) Will they be reliable?

Disregarding power sources, the ionization principle of detection has demonstrated a high degree of reliability throughout its history.

4) Are they serviceable?

Field service reports to date do not indicate long-term service problems, except for periodic removal of household dusts from the sensing chamber area.

5) Will they cause excessive alarms and become an annoyance?

The question of "how many alarms are too many" will vary, depending on the attitude of the occupant. Future industry experience from a larger sampling of users may provide better answers.

6) With an ionization detector located on a hall ceiling near the bedroom, should bedroom doors be left open?

Sleeping with bedroom doors closed, regardless of the principle of detection, is a rule that should not be violated. In addition to detector considerations, a closed bedroom door will allow at least three minutes longer to escape.

7) With bedroom doors closed, how can a detector sense fires starting in the bedroom?

Regardless of the principle of detection, there is no protection in the bedroom of fire source. The obvious solution for a higher level of protection is to install separate smoke detectors in each

8) Can one be located in the kitchen?

From the alarm survey, it has been demonstrated that an ionization detector located in the kitchen will likely cause excessive alarms. However, there have been comments from experienced users, indicating their desire for a detector in the kitchen to warn against unattended cooking accidents. Except for a special circumstance, kitchen locations are not recommended.

9) What happens with a general power failure?

The lack of protection caused by power failure to a line-powered smoke detector has generally been regarded as insignificant. However, from the small sample of hazardous fire reports, summarized in Table No. 2, the garage fire in Aurora, Colorado, disabled the telephone and the circuit breaker panel located in the garage. A general power failure, particularly in cold climates, requires occupants to light candles and start fireplaces, both of which are hazardous activities, particularly in darkness.

10) Can one be located in the garage?

A detector located in a garage, much like the kitchen, may cause excessive alarms. However, reports of experience from two installations in garages report no false alarms. Large quantities of products of combustion are generated by automobile exhausts. It is well known that high concentrations of carbon monoxide are usually present as well. For attached garages, and particularly those located under a portion of a living area, an ionization detector may be considered valuable. One other consideration should be to review the environmental temperature limits established for the specific detector.

11) With a known cause of false alarms, how can the alarm be turned off?

When occupants are handicapped or elderly, an alarm can be frightening. A convenient yet identifiable method of disabling an alarm may become an important characteristic in future detector designs.

12) Can one be located near a fireplace?

Although an ionization detector will not cause an alarm to a normally operating fireplace, the alarm survey in Table No. 1 demonstrates its value in detecting backdrafts or blocked flues.

13) What is its value when the dwelling is unoccupied?

The purpose of the single station smoke detector is to protect the lives of occupants, particularly when they are asleep, from fires in the dwelling. Reports have been received, however, of four incidents where persons outside the dwelling have heard the alarms and taken action to prevent serious property loss.

14) Will the alarm be loud enough?

There have been no reports received to date where an activated alarm has not been heard either at night or during the day.

15) With only one bedroom area detector, what about a remote basement fire?

This is a question of dangerous probabilities. The solution, of course, is at least one additional detector located at the top of the basement stairway.

Conclusion

The most important statistic contained herein is that there have been no reports received to date by one manufacturerof any fatalities or injuries in over 200,000 dwellings, equipped for one year, with at least one single station ionization smoke detector.

Of real concern is that sixteen to twenty reports or letters have been received to date which indicated a relatively heavy smoke density at the detector - without an alarm. In some cases these were found to be potentially hazardous smoke conditions which were discovered and corrected before the detector responded. Most of these incidents were the result of a self-extinguishing circumstance, wherein a limited quantity of fuel was expended. In no case was there a report of significant smoke damage and, of course, no fatalities nor injuries.

The hazardous fire reports, Table No. 2, however, included three smoldering fires. In each case, the alarm response time was adequate to allow safe exit by the normal route. In no case was it necessary to use alternate exit routes.

Of greater concern is the industry trend to higher sensitivities when, in fact, public reaction to unnecessary alarms has not been well defined. With present levels of sensitivities, there is evidence to suggest that the installation of early warning smoke detectors in small apartments, where the detector is in close proximity to the kitchen, will result in many unnecessary alarms. As with the unpopular seat belt alarms required in automobiles, detectors, likewise, may become disconnected or in other ways, disabled.

What appears to be a tragic example of this possibility resulted in a fatality in Coram, New York, 9:00 a.m., December 2, 1974. The following are quotes from NEWSDAY/THE ISLAND, a local newspaper. "The smoke detecting alarm system, located in a ceiling of the hallway between the two bedrooms, had been deactivated when its battery was removed ----." "A lot of people we spoke to (other apartment tenants) had taken their alarm batteries out. They're very sensitive, and some people said that steam from the shower or cooking smoke would set them off." "On March 27, we (the owner) inspected the apartment, tested the alarm and installed a new battery." "He (the owner) said that although the fire was limited to the Fasman apartment, the other alarms in the building had all gone off, blaring loudly, because of the smoke."

The fatality, who may have started the fire himself in his own bedroom, was a three-year old child. The detector in this circumstance, like other detectors in the same apartment building, had been disabled because it may have been too sensitive.

The ionization principle as applied to smoke detection in the home, is developing an excellent track record for effectiveness in detecting potentially hazardous fires. Its limitations thus far have not proved to be a deterrent to its life saving capabilities. Of greater importance are the practical areas of judgement, such as the number of detectors required, their location and their ability to awaken sleeping occupants, all of which relate to smoke detectors using any principle of early smoke detection.

And finally, the potential problem of higher sensitivities, for, like the boy in the wilderness, detectors cannot "cry wolf" too often - less their crys go unheeded!

REFERENCES

(1) Uniform Building Code (UBC), 1973 Edition, Chapter 13, Section 1310, and Chapter 14, Section 1413.
Basic Building Code (BBC), 1973 Revision, Chapter 12, Section 1216.3.4.
Southern Standard Building (SBC), 1974 Revision, Chapter 11, Section 1127.

(2) Patent #2,465,377, W.C. Jaeger, Gas-Sensing Control Means With Gas-Discharge Device, March 29, 1949, (U.S.).
Patent #2,702,898, E. Meili, Gas-Responsive Control Apparatus, February 22, 1955, (U.S.).

(3) Published 11/26/69, Federal Register #34FR18870
Pyrotronics, Inc., Notice of Exemption of Fire Detection Units.

(4) NFPA No. 74, Household Fire Warning Equipment, 1974 - National Fire Protection Association.

(5) "Survey Results in New Data on Household Fires," by Benjamin Buchbinder, as published in DIMENSIONS/NBS, January 1975.

(6) "Fires and Fire Losses Classified," 1973 - FIRE JOURNAL - September 1974 (Annual NFPA Estimates).

(7) A Study of Fatal Residential Fires, National Fire Protection Association, No. FR72-1, (Figure 6), August 1974.

(8) NFPA Fire Quarterly, April 1960, Page 308.

TABLE NO. 1

SAMPLE SURVEY

ALARM EXPERIENCES OF SINGLE STATION IONIZATION SMOKE DETECTORS

se of Alarm	No. of Alarms	Months of Detector Usage	Projected Average Alarms Per Year	Projected Alarms Per Year, Per 1,000 Detectors
chen, burning food	1	1	12	
" " "	1	3	4	
" " "	1	11	1.1	
" " "	1	30	.4	
" " "	1	18	.7	
" " "	1	5	2.4	
" " "	1	16	.8	
" " "	1	18	.6	
" " "	1	38	.3	
" " "	1	27	.4	
Total			22.7	208
apparent reason	1	10	1.2	
" "	1	27	.4	
" "	1	19	.6	
" "	1	2	6.0	
Total			8.2	75
replace flue closed	1	21	.6	
" " "	1	18	.7	
" " "	1	5	2.4	
Total			3.7	34
avy smoking	1	2	6.0	
" "	1	10	1.2	
Total			7.2	66
r velocity from register	1	5	2.4	
" " "	1	18	.7	
Total			3.1	28
ing oven cleaner near unit (Easy-Off)	1	16	.7	6
rning grass outside dwelling (accidental, window open)	1	7	1.7	16
se of blow torch in house	1	10	1.1	10
sement bedding material in an adjacent townhouse (party wall at basement ceiling unfinished)	1	9	1.3	12
TOTAL	25			455

TABLE NO. 2

REPORTS OF HAZARDOUS FIRES DETECTED

ate	Location	Time	Occupants	Location	Ignition	Detectors
7/72	Las Vegas, Nev.	12:30AM	5	Kitchen	Cooking	1
5/72	Lexington, N. C.	12:30AM	1	Lv. Rm.	Smoking Couch	1
24/72	Bedford, N.H.	1:00AM	3	Fam. Rm.	Smoking Couch	1
29/72	Aumsville, Oregon	4:00AM	4	Bedroom	Electric Htr.	1
/73	Wellesley Hills, MA	11:00PM	2	Lv. Rm.	Fireplace	1
/73	Juneau, Alaska	5:00AM	4	Lv. Rm.	Floor Furnace	1
15/73	Chicago, Ill.	2:00AM	4	Basement	Electric Furnace	1
4/74	Scotch Plains, N.J.	11:00PM	5	Basement	Unknown	3
4/74	Foster City, Calif.	3:00AM	4	Outside	House Next Door	3
4/74	Cuyahoga Falls, Ohio	12:00AM	2	Basement	TV (Lightning)	1
9/74	Philadelphia, Pa.	1:30PM	3	Bedroom	Unknown	1
26/74	Anchorage, Alaska	9:00AM	1	Kitchen	Oil Stove	1
25/74	Aurora, Colo.	6:00AM	3	Bathroom	Cig. Lighter (Child)	2
15/74	Denver, Colo.	1:00AM	4	Fam. Rm.	Unknown	2
22/74	Aurora, Colo.	5:00AM	4	Garage	Extension Service Light	1