SMOKE ALARMS
AND
THE INVESTIGATION
OF
FATAL FIRES

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“ENGINEERING A SAFER WORLD”

“Individuals no longer have the ability to control the risks around them and are demanding that government assume greater responsibility for assuring public safety through laws and various form of oversight and regulations as companies struggle to balance the safety risks with pressure to satisfy time to market and budgetary pressures. ***Ways to design more effective regulatory strategies without impeding economic goals are needed.”***

WHO REGULATES FIRE SAFETY?

- In the United States, many aspects of fire safety are "outsourced" to non-governmental organizations, "Voluntary Standards Organizations (VSO's).
- National Fire Protection Association – Non-profit that creates "Standards and Codes adopted by State and Federal Agencies, e.g NFPA 72, National Fire Alarm Code.
- Underwriters Laboratories – UL Standards are used to assess products; test components, materials, systems and performance, e.g UL217, Standard for Smoke Alarms.
- Building Codes will typically mandate smoke alarms, *"installed in accordance with NFPA 72, and that meet the requirements of UL217."*

"CONSIDER THE VIOXX CASE."

WHAT IS A VSO?

- There are thousands of voluntary consensus safety standards organizations (VSO's). They regulate consumer products, e.g. UL and building design, e.g. NFPA. In many cases these standards bring industry groups, government agencies, and consumer groups together to agree on best consumer product safety practices. Most voluntary standards committees are open to the public for participation and membership for a nominal membership fee. Individual voluntary standards are available for purchase from the relevant voluntary standard development organization.

HOWEVER ….

- “In many cases these standards bring industry groups, government agencies, and consumer groups together to agree on best consumer product safety practices.”
- *However, since it takes time and money to participate these standard meeting are typically dominated by the regulated industry.*

HOWEVER ….

- “Most voluntary standards committees are open to the public for participation and membership for a nominal membership fee.”
- *However, active participation requires a major commitment of time of time, ($), and often travel (more $).*

HOWEVER ….

- “Individual voluntary standards are available for purchase from the relevant voluntary standard development organization.”
- *However, when governments adopt these standards, designers and builders have to buy them regardless of the cost. This allows the standards organizations to have a monopoly.*

ADM. HYMAN RICKOVER - 1970

- “The typical industry-controlled code or standard is formulated by a committee elected or appointed by a technical society or similar group. Many of the committee members are drawn from the manufacturers to whom the code is to be applied. Others are drawn from engineering consulting firms and various Government organizations. However, since near unanimous agreement in the committee must generally be obtained to set requirements or to change them, <u>the code represents a minimum level of requirements that is acceptable to industry</u>. …”

ADM. HYMAN RICKOVER - 1970

- "… In a subtle way, the use of industry codes or standards tends to create a false sense of security. Described by code committees and by the language of many codes themselves as safety rules, they tend to inhibit those legally responsible for protecting the public from taking the necessary action to safeguard health and well-being. Many states and municipalities have incorporated these codes into their laws, thus, in effect delegating to code committees their own responsibility for protecting the public."

“CONSENSUS” PROCESS

- Both UL and NFPA are American national Standards Institute (ANSI) Approved Consensus Processes.
- Both have multiple committee member categories: consumer, industry, independent expert, etc., and no one category can have more than 1/3 of the membership.
- This would appear t prevent any one category from dominating, however many “independent” experts consult for the industry and since a 2/3’s majority is required to get items approved the industry can veto any inconvenient requirements.

WHO IS IN CHARGE?

- The consumer product safety laws require CPSC to rely on voluntary standards if it determines that
  - (1) compliance with a voluntary standard would eliminate or adequately reduce the risk of injury identified and
  - (2) there is likely to be substantial compliance with the voluntary standard.
- *However ….*

HOWEVER ….

- Who determines that risk is “adequately reduced?”
- Who determines that compliance is “substantial?”
- It seems that, once a voluntary standard is set up by the industry and most in the industry comply, <u>the burden of proof is on the government </u>to prove it is not adequate or that compliance is not substantial.

DIFFERENCES IN SMOKE ALARM TECHNOLOGY AND SMOKE CHARACTERISTICS

"Why it matters to fire investigators."

Some Basic Information -Ion

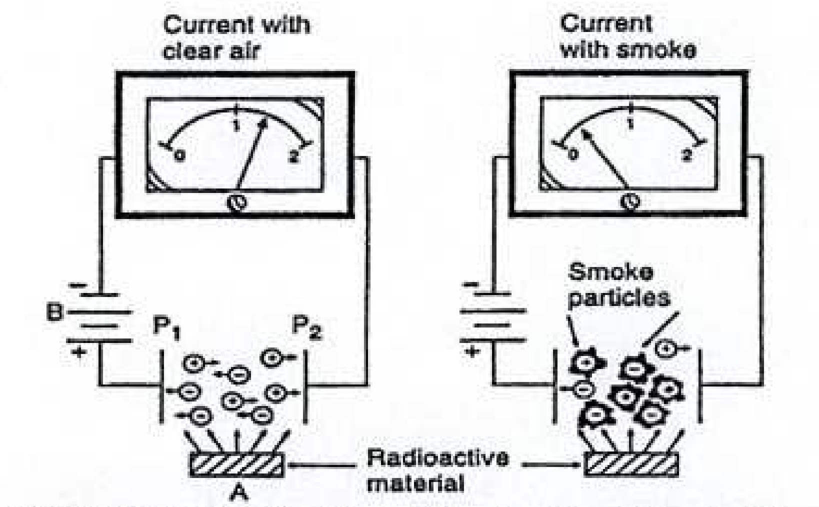


FIGURE 1: Illustration of Ionization Principle[6]

When smoke enters the ionization chamber, it disrupts this current -- the smoke particles attach to the ions and neutralize them. The smoke alarm senses the drop in current between the plates and sets off the horn. They are more sensitive to "small particle smoke." Sources are cooking and flaming fires. In the smoldering mode white pine tends to give off smaller particles than other woods or plastics.

Some Basic Information - Photo

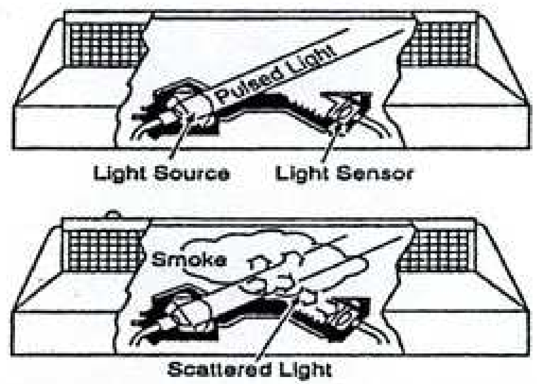


FIGURE 2 Illustration of Photoelectric Principle[6]

In the normal case, the light from the light source on the left shoots straight across and misses the sensor. When smoke enters the chamber, however, the smoke particles scatter the light and some amount of light hits the sensor: The sensor then sets off the horn in the smoke alarm. Photoelectric are more sensitive to "larger particle smoke." Sources are all smoldering fires and many flaming fires.

Toast Smoke vs. Real Smoke

Ionization is approx 20 times more sensitive to particles with 0.2 micrometer diam. (toast), than particles with 1.0 micrometer diam. (smoldering).

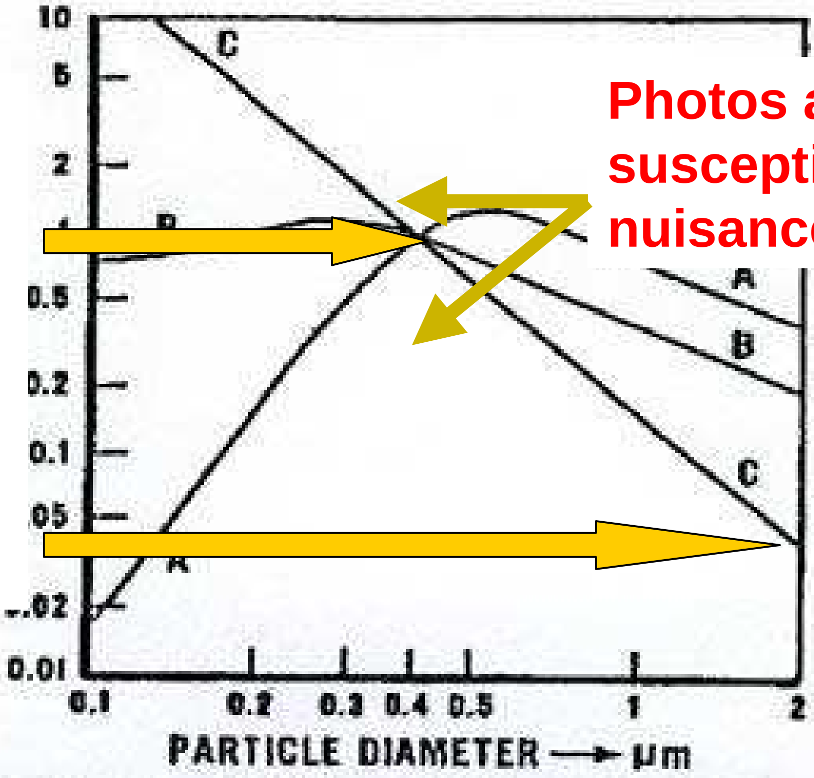


Figure 4: Relative Sensitivities of Three Technologies as a Function of Particle Diameter[11]

Photos are about 10X less susceptible to "small" nuisance smoke.

A = beam photo B = spot photo C = ionization

HISTORY OF SMOKE ALARMS

- In the mid 70's, Smoke Alarms start to become popular. Manufacturers work with UL to create 2 Standards:
  - UL167 for Ionization Alarms(only flaming fires) and
  - UL168 for photoelectric alarms (only smoldering fires)
- Research is conducted at "Indiana Dunes," (75-76) by UL and NBS, to tests smoke alarms. They conclude that both technologies are effective.
- Research is used to develop a single smoke alarm standard, UL217. It includes 4 flaming tests similar to UL167 and a new smoldering test

HISTORY OF SMOKE ALARMS

- The new smoldering test is based on the fires at Indiana Dunes, which used cotton mattresses.
- The researchers have trouble finding a material tat allows the ionization to pass the test at 7% obscuration per foot. They settle on "white pine." (I suspect that this was done because at the time only the ionization could be battery powered.)
- The researchers suggest (1979) that this should be considered a 1st generation test and that more research should be done to insure they are testing for all the types of smoke that can be produced in a fire.

HISTORY OF SMOKE ALARMS

- Another smoke detector research project was undertaken by the LA FD (1980). It was called the CALCHIEFS Test. It concluded that photoelectric were superior to ionization. (WHAT HAD CHANGED?)
- The CALCHIEFS used modern furniture which was synthetic and by that time the photoelectric alarms had improved through the use of LED technology, which improved detection and allowed them to be battery powered. (These key changes were overlooked by researchers and industry kept relying on the "Indiana Dunes," results.)

HISTORY OF SMOKE ALARMS

- In the late 80's, the "Industry Advisory Council" for UL217 modified the standard to allow less sensitive ionization smoke alarms to be sold. (They were attempting to solve the nuisance alarm problem.) Someone should have reviewed the statistics to check the following:
  - Did the % of fatalities with disabled alarms go down. (NO.)
  - Did the % of fatalities with working alarms go up. (YES.)
- In 1997, The US Fire Administration (USFA) stated the following, *"But the % of deaths with detectors, especially the upward trend, is disturbing since there is a widespread belief that an operating detector will save lives. Further study is needed to show what other factors were involved with these deaths."*

Isn't it the job of the USFA to do this study?

TREND IN FATALIES
WITH WORKING DETECTORS

	% OF FATAL FIRES WITH WORKING DETECTORS	% OF HOMES WITH DETECTORS	% OF FIRES WITH WORKING DETECTORS
1988	9%	81%	38%
1990	19%	86%	42%
1994	19%	93%	49%
1996	21%	93%	52%
1998	29%	94%	55%
2001	39%	95%	55%

FROM 1994 – 2001

% OF FATAL FIRES WITH WORKING SMOKE DETECTORS <u>INCREASED 100%</u>

% OF HOMES WITH SMOKE DETECTORS <u>INCREASED 2%</u>

% OF FIRE WITH WORKING SMOKE DETECTORS <u>INCREASED 12%</u>

HISTORY OF SMOKE ALARMS

- Independently, Staff at the CPSC and the Boston Fire Dept. reached a conclusion that there may be a problem with ionization alarms. (In the early 90's, some Norwegian researchers, using UL217 detectors, had reached the same conclusion as the CALCHIEFS.
- CPSC raised the issue at UL Meeting but were repeatedly rebuffed by industry and UL staff.
- I made a proposal to the NFPA Fire Alarm Code and was told, "Your data <u>is not compelling enough </u>... to put companies out of business."

HISTORY OF SMOKE ALARMS

What was not so obvious was the relative ability of different alarms to detect major kinds of fires. Jay Fleming became particularly concerned over this issue, and specifically questioned the ability of ionization type alarms to detect certain smoldering kinds of fires. CPSC was also an advocate for the installation of working smoke alarms, having conducted a national survey that revealed the extent of the problem of non-working alarms. By establishing communications with the CPSC, Jay described his concern over the performance of ionization alarms <u>and helped CPSC understand its importance.</u> As a result, CPSC developed a major new fire test program to evaluate the ability of different types of alarms to detect different types of real fires. Jay Fleming was especially instrumental in helping justify this study. (CPSC Letter to BFD)

NIST RESULTS

(From NIST Answers to Jay Fleming's Questions - 2007)

TYPE	#	ASET		PASS/FAIL	
		PHOTO	ION	PHOTO	ION
SMOL	12	2064+/-950	*197 +/-336*	12/12	6/12
FLAM*	16	124+/-64	175+/-70	8/16	16/16
COOK	4	608+/-476	777+/-244	4/4	4/4

1. What NIST called a flaming fire was an "fast" fire. (This should be rare while occupants sleeping.)
2. For cooking, the most common "normal" flaming fire, the photo was slower than on but still provided 10 mins. ASET.
3. Ion failed in many smoldering tests. (Even though NIST did not measure tenability along paths of egress.)

QUOTES FROM 2008 MEETING AT CPSC

- **NFPA Rep** - As organizations, we are all pretty close on the main issues, and on photoelectric vs. ionization. For harmonization to succeed, will we have to refute the Fleming argument?
- **Safety Org Rep** ($ from Industry) - Is anyone willing to go to the media to refute this information? Are we sure that there isn't any other information that is hiding under a rock? And who refutes Fleming's "science"?
- **USFA Rep** - We're not going to solve this today. No single message will squelch Fleming.
- **NFPA Rep** - Not a lot of organizations represented here would be comfortable or able to demonize the opposition.

HISTORY OF SMOKE ALARMS

- Despite these results, it was deemed that more research was needed. (Paralysis by Analysis)
- I started to file dozens of complaints with the CPSC and push for changes in other states.
- Eventually, Vermont, Maine, Ohio, Parts of CA, and Australia and New Zealand, mandated photoelectric alarms.
- In 2016 UL finally approved 3 new tests: a smoldering plastic, a Flaming Plastic, a Cooking Nuisance.

I had first suggested the need for these tests in a research paper in 1997.

"ENGINEERING A SAFER WORLD"

"Encourage a shift in the emphasis in accident analysis from "cause" – which has a limiting blame orientation – to understanding accidents in terms of reasons, that is, why the events and errors occurred."

NFPA 921
(Non- "Cause and Origin" Issues)

- *NFPA 921 Section 4.4.1 The investigator should … make suggestions for code enforcement, code promulgation, or changes; make suggestions to manufacturers, industry associations, or government agency action.*
- *NFPA 921 Section 21.5 … the fire investigator may be required to do a failure analysis and to determine responsibility. It is only through the determination of such responsibility for the fire that remedial codes and standards, … can be undertaken.*

Despite this language, except in major fires, code improvement is seldom considered a priority by the investigator.

NFPA 921
(Non- "Cause and Origin" Issues)

- Section 4.3.8 Expectation Bias. Expectation bias is a well-established phenomenon that occurs in scientific analysis when investigator(s) reach a premature conclusion without having examined or considered all of the relevant data.
- Section 4.3.9* Confirmation Bias. Different hypotheses may be compatible with the same data. When using the scientific method, testing of hypotheses should be designed to disprove the hypothesis. Confirmation bias occurs when the investigator instead tries to prove the hypothesis.

Both types of biases occur in many, perhaps most investigations regarding the effectiveness of smoke alarms.

THE “REAL WORLD”

- In most cases, fire investigators focus on the cause of the fire. i.e. was it accidental or incendiary (arson). If it is not a crime, or a high profile fire, they usually do not do an in-depth investigation. They seldom consider the cause of the fatality, injury or property loss.
- Even when they consider items beyond “cause of the fire,” they seldom go beyond proximate events.
- Most fire investigators are “local” so they have little incentive to look at factors that might be systemic. Particularly systemic factors that might be operating on a national level. By ignoring systemic causes, we are losing opportunities to save lives.

"ENGINEERING A SAFER WORLD"

- Mistaken Assumption - Accidents are caused by chains of directly related events.
- The selection of initiating event s arbitrary and previous event and conditions could always be added.
- The backward chaining may also stop because of the difficulty in backtracking "through a human."
- At least three types of factors have to be considered:
    1. Proximate Event Chains
    2. Conditions that allowed events to occur, that can usually be directly mapped to events.
    3. Systemic factors, often only indirectly related.

WHO OR WHAT IS AT FAULT?

- When a fire fatality occurs with a disabled smoke alarm, the fire official often blames the victim for disabling the alarm. (Proximate Event)
- Sometimes they will blame the landlord for failing to maintain the alarm. (Conditions that allowed events to occur.)
- They never consider <u>systemic factors</u>:
  - Should the code specify specific technology for some locations?
  - Should the code clarify responsibility between the landlord and the tenant.
  - Should the alarm manufacturers put warnings on alarm regarding “nuisance alarms?

REASONS FOR BIASED INVESTIGATIONS

1) Investigators assume that people do not die if the alarm operates.
2) Investigators assume that if smoke reaches the alarm it will operate. “Scientific” and “independent” fire tests support this assumption.
3) Smoke Alarms (ionization smoke alarms) are responsible for the huge reduction in fire deaths over the past 30 years.
4) Smoke Alarms (ionization smoke alarms) reduce the chances of dying in a fire by 50%.

Are these valid assumptions?

MANY FATALITES HAVE *WORKING* ALARMS?

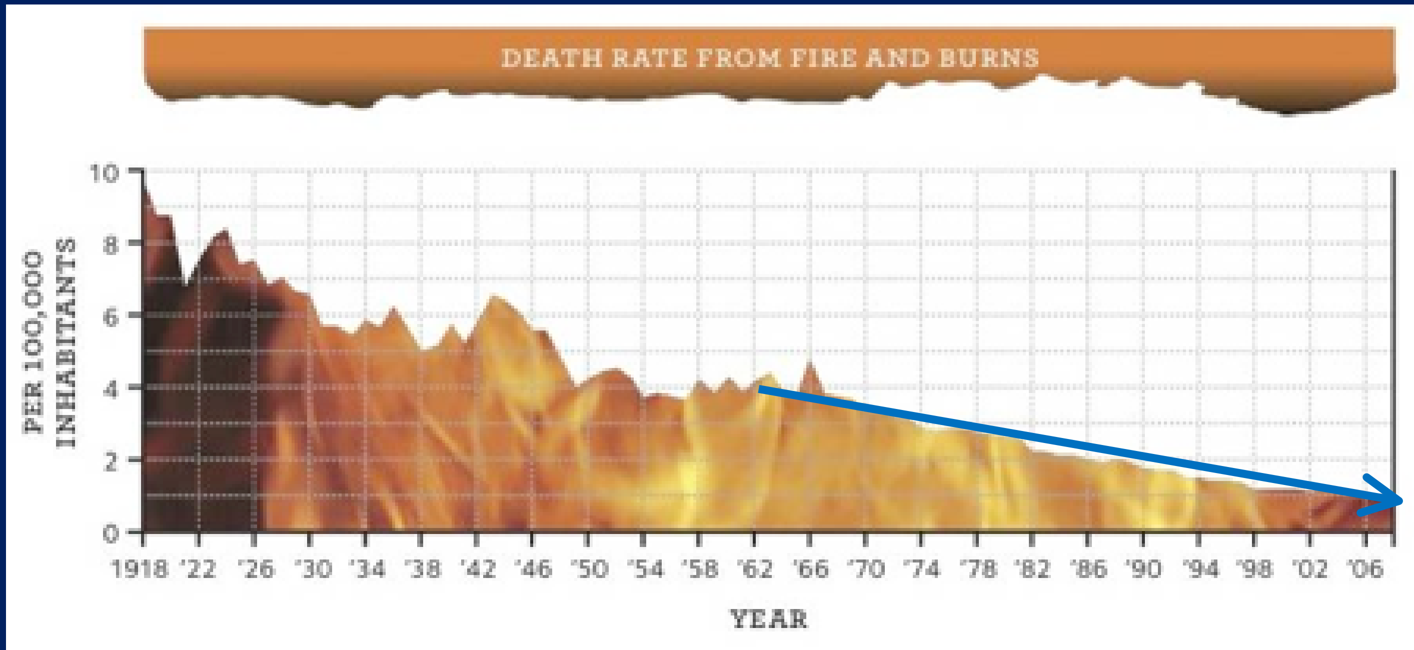
- From typical news story – *"Working smoke detectors were present <u>in only about 27% of fatal fires</u> officials say often the batteries are bad, or there are no alarms."* (Large FD)
- The 27% is very misleading. 96 (fatalities with operating alarms) / 362 (total fatalities) does = 27%.
- However , when the *"<u>unknowns are distributed</u>"* you get the following numbers.
  - **% fatalities with working alarms – 151 (42%)**
  - % fatalities with alarms present but not working – 92 (25%)
  - % fatalities with no smoke alarms 18 **(33%)**

More fatalities occur with working alarms than when no alarms is present. But this doesn't "fit" with pre-packages simple safety messages.

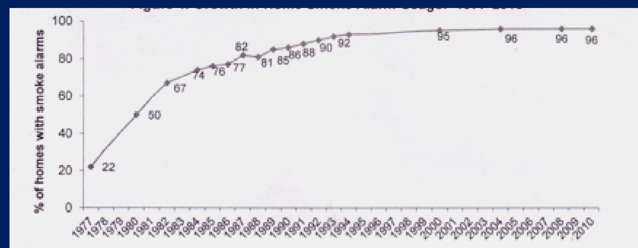
WAS THIS "NEW" INFORMATION?

- **Factory Mutual (Heskestad - 1974)**
  - *"The ionization detector performed adequately in the protectable flaming fire starts, and,* ***in general, inadequately everywhere in the smoldering fire starts****.*
- **Los Angeles Fire Dept. (Cal Chiefs – 1981)** –
  - *"Results of these tests strongly point to photoelectric detectors being more reliable in warning against the hazards of visible smoke build-up from the slow smoldering fire so common to residential occupancies."*
- **Norwegian Researchers 1991 (UL217 Alarms were used.)**
  - *"The ionization detectors detected smoke from a smoldering fire much later than optical (photoelectric) detectors. There are reasons to indicate that this detection principle would not provide adequate safety during this type of fire"*

ARE SMOKE ALARMS RESPONSIBLE FOR REDUCTION IN FIRE DEATHS?



If the main reason for the reduction in fire deaths was due to smoke alarms the decline should have been steepest when alarm usage increased the fastest.



DO SMOKE ALARMS REDUCE THE RISK OF A FIRE FATALITY BY 50% ?

Table 3. Risk Estimate (Deaths per 100 Fires) vs. Smoke Alarm Status
US Home Fires, NFPA 2007 – 2011[38]

<table>
<tr><th></th><th>Present and Operated</th><th>Present and Did not Operate</th><th>Not Present</th><th>Risk Change with Operating Alarms</th></tr>
<tr><td rowspan="2">All Fires (Non-confined and Confined)</td><td rowspan="2">0.53
(1020/1919)</td><td>1.94
(590/304)</td><td>.95
(950/998)</td><td rowspan="2">-55%
(0.53-1.18)/(1.18)</td></tr>
<tr><td colspan="2">1.18
(1540/1303)</td></tr>
<tr><td rowspan="2">Only
Non-confined Fires</td><td rowspan="2">1.22
(1020/837)</td><td>3.02
(590/195)</td><td>1.24
(950/767)</td><td rowspan="2">-24%
(1.22-1.60)/(1.60)</td></tr>
<tr><td colspan="2">1.60
(1540/962)</td></tr>
<tr><td rowspan="2">Only Non-confined Fires – Assuming Risk with Non Operating Alarms = Risk with No Alarms</td><td rowspan="2">1.63
(1368/837)</td><td>1.24
(242/195)</td><td>1.24
(950/767)</td><td rowspan="2">+24%
(1.63-1.24)/(1.63)</td></tr>
<tr><td colspan="2">1.24
(1192/962)</td></tr>
</table>

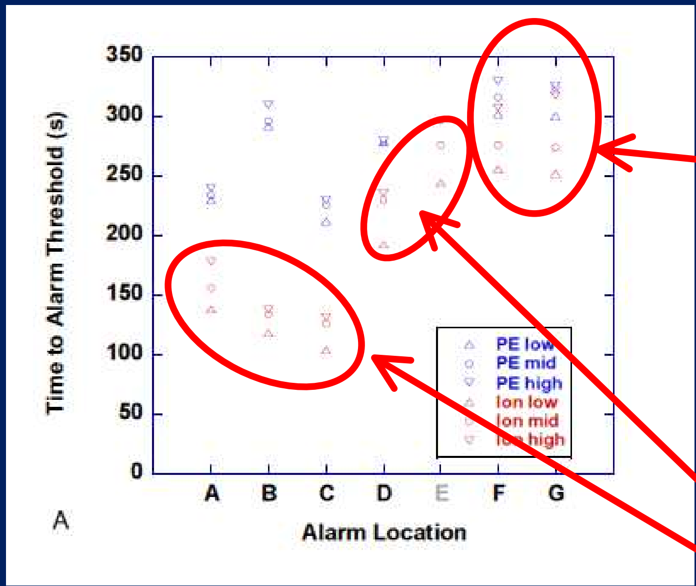
The risk for the cases in which the alarm did not operate should be the same as when it is not there. It is actually much higher, which supports a hypothesis that Investigators are overestimating the times when a smoke alarm did not operate.

NUISANCE ALARMS

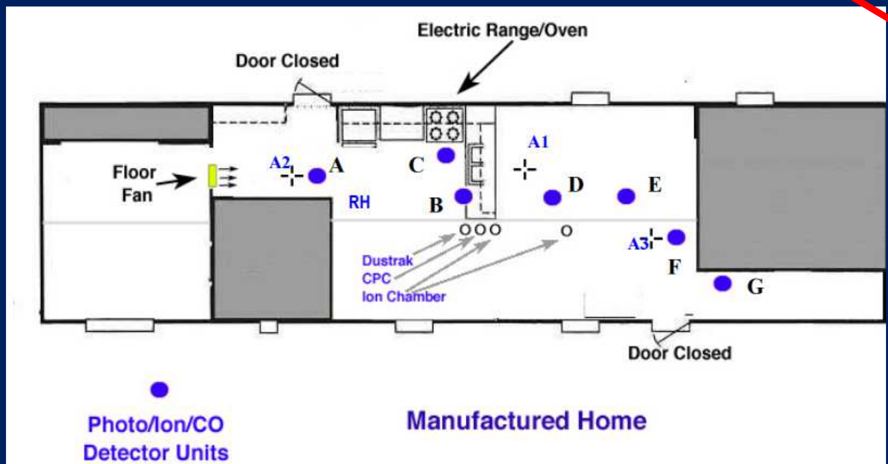
Who is responsible for a disabled alarm problem? It depends on your point of view.

- **The <u>consumer</u> who disables it?**
- **The <u>landlord</u> who does not maintain it?**
- **The <u>manufacturer</u> who does not warn the consumer?**
- **The <u>standards organization</u> that does not test for this problem?**
- **The <u>public agency,</u> USFA, CPSC etc. that does not educate the public?**

NIST – TOASTING BREAD
FIGURE 147 (SMALLER PARTICLES)



The response of ionization and photoelectric start to cross as the distance reaches 15-17 feet. This is likely due to "smoke agglomeration" (smaller particles combine to form larger particles.



The same alarms (ionizations) that fail to respond to thick levels of "large particle" smoke are supersensitive to small particle aerosols. This leads to disabled alarms.

NUISANCE ALARM RESEARCH (US)

- Alaska 2000 (US) - Homes with ionization alarms had more than 8 times the rate of false alarms as those with photoelectric alarms. **19% of the ionization** were disconnected compared with 4% of the photoelectric devices.
- Washington State 2008 (US) -Ionization were more likely than photoelectric units to have alarmed (78% vs 39%), and alarmed more often (56% vs 17% had 3 alarm episodes). At 9 months after installation, **20% of ionization**, vs 5% of photoelectric alarms were non-functional, a difference that persisted at 15 months.

Approx 20% of fire fatalities occur with non-operational alarms

THE MASSACHUSETTS EXPERIENCE

Table 4. Fire Death Rates per 1 Million Population[42]

Years	US	Mass.	Maine + RI Verm + NH (a)	Conn.	New York
1980 – 1984	23	20.9	22.0	12.5	20.9
1995 – 1999	12.8	9.0	9.0	9.6	11.8
2006 – 2010	9.8	4.4	7.7	6.8	8.2
% Change 80/84 – 95/99	-44%	**-57%**	-59%	-23%	-43%
% Change 95/99 – 06/10 (b)	-23%	**-51%**	-14%	-29%	-30%
% Change 80/84 – 06/10	-57%	**-78%**	*-65%*	*-45%*	*-60%*
			Average = -57%		

(a) The smaller states were lumped together since small populations have larger variances.

(b) Since the late 1990s, the rate of reduction in the fire death rate is dropping twice as fast as the U.S. as well as the surrounding states.

- In 1997 the Massachusetts state Building Code started requiring photoelectric smoke alarms within 20 feet of a kitchen or a bathroom. (Nuisance Problem)
- In 2012, the Massachusetts Fire and Building Codes determined that ionization smoke alarms could not be used as stand-alone alarms. (Response Problem)

THE MASSACHUSETTS EXPERIENCE

Smoke Alarm Analysis of Fatal Fires January 2013 - August 2015							
		Condition of Battery					
Alarm Type	Power Source	Dead	Partially Removed	Removed	Undetermined	Working	Total
Ion/CO	Battery	3		1		4	8
Photo/ CO	Battery				1	2	3
Ion	120V/ Battery	6	6	8	18	7	45
Photo	Battery				1	2	3
Undetermined	Battery	2		3	6		11
Grand Total		11	6	12	26	15	70

- The smoke alarm status was only determined in about 50% of the fatal fires.
- Photo alarms were found in only 11% (6/59) of fires.
- No fatalities occurred with disabled photos.
- many fatalities occurred with disabled ion alarms.
- Data shows that the majority of alarms in Mass are photoelectric, but only 10% of fatalities (6/59).

DETECTORS / VIOXX

In my opinion, there seem to be many similarities in both "disasters." I think the Smoke Detector History deserves a similar STAMP analysis that has been done for the VIOXX History.

- Industry has "captured the regulators."
- Industry funds a lot of the peer reviewed research.
- The people in a position to notice the problem, for VIOXX - physicians, for smoke detectors – fire investigators, did not have enough information at their disposal nor a method to collect and collate data.