ION VS. PHOTO - IS THERE A "QUALITATIVE" DIFFERENCE FOR LIFE SAFETY?

(IF YES, WHY ISN'T THIS INFORMATION BEING COMMUNICATED TO THE PUBLIC?)

JOSEPH M. FLEMING

DEPUTY CHIEF

BOSTON FIRE DEPT.

FOR

BOSTON CITY COUNCIL – JULY 9, 2007

SOME BASIC INFORMATION -ION

An ionization chamber is very simple. It consists of two plates with a voltage across them, along with a radioactive source of ionizing radiation. The alpha particles generated by the americium ionize the air in the chamber. The negative electron is attracted to the plate with a positive voltage, and the positive atom is attracted to the plate with a negative voltage (opposites attract, just like with magnets). The electronics in the smoke detector sense the small amount of electrical current that these electrons and ions moving toward the plates represent.

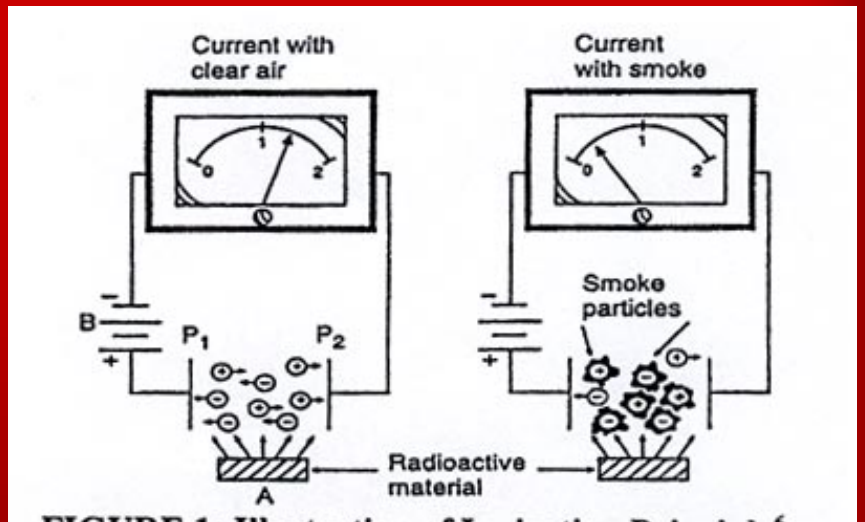

FIGURE 1: Illustration of Ionization Principle[6]

When smoke enters the ionization chamber, it disrupts this current -- the smoke particles attach to the ions and neutralize them. The smoke detector senses the drop in current between the plates and sets off the horn

SOME BASIC INFORMATION - PHOTO

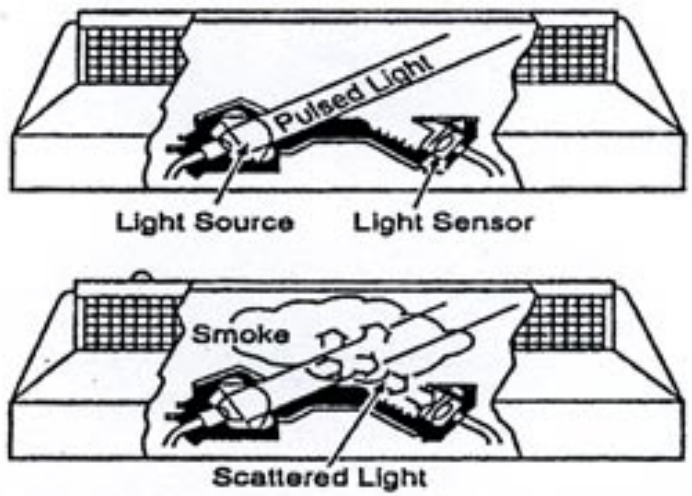

FIGURE 2 Illustration of Photoelectric Principle[6]

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 detector.

TOAST SMOKE VS. REAL SMOKE

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

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

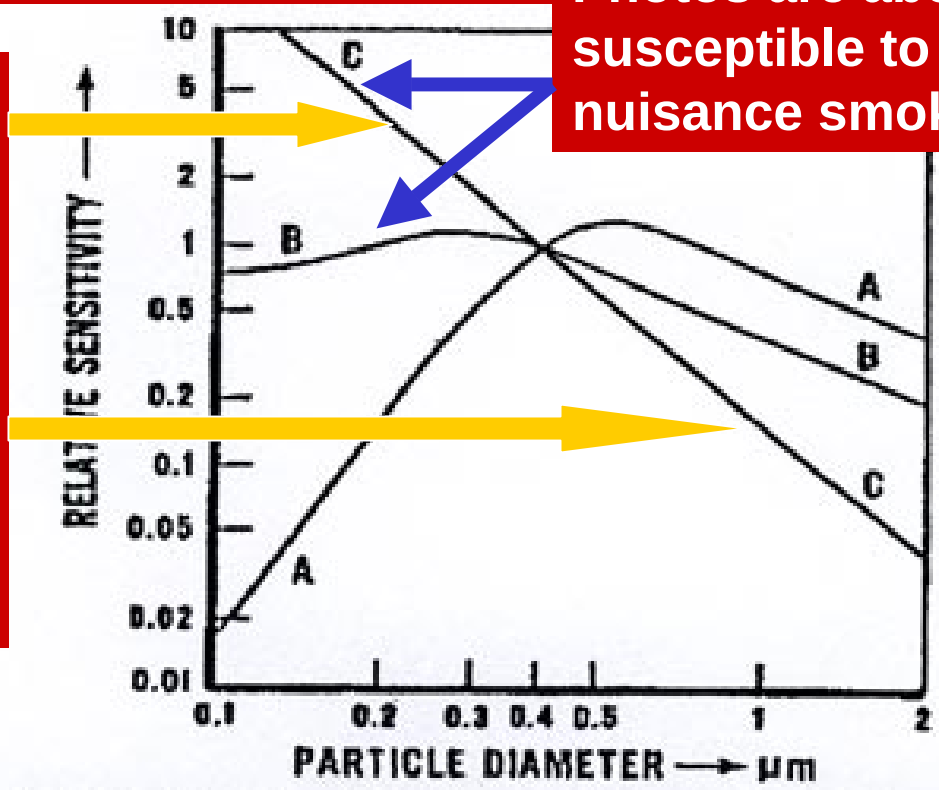

Figure 4: Relative Sensitivities of Three Technologies as a Function of Particle Diameter[11]

A = beam photo B = spot photo C = ionization

CHIEF FLEMING'S EFFORT TO EDUCATE PUBLIC

- **Research used to justify NIST Home Some Alarm Report and UL Smoke Characterization Report.**
- **Research used to justify Mass Building Code requirement for photos near kitchens and bathrooms. (Since 1998)**
- **Research used by FAC (Australia to justify reccomending photos to public.**
- **Research used by Indiana State Fire Marshal to justify reccomending photos to public. Research given to Fire Investigators.**
- **Over 35 complaints filed with the CPSC in last 2 years. (Only 1 partialy investigated .)**

REASONS USED TO PROVE SMOKE ALARMS (IONS) WORK*

- **Groups like the IAFC, NFPA, USFA tell us that they work. This advice based upon:**
- **Historically, tests, such as the "NIST Home Smoke Alarm Tests of 2001" show they work.**
- **They pass the UL217 Approval Tests.**
- **Most people die in flaming fires and ion best for flaming fires.**
- **Statistics Support Claim**
  - ***Smoke detectors reduce fire risk by 40-50%***
  - ***fatalities have decreased by ½ since smoke detector started to be installed.***
- **They operate when toast is burned so obviously, they must operate in real fires.**

Indiana Dunes - Key Findings
From Bukowski (NIST) "Debate" in Reno 2005)

- **Either ion or photo provide adequate escape time (average of 17 minutes)**
- **Higher sensitivity provided more escape time (esp. for smoldering)**
- **Heat provided little life saving potential**
- **Forced air heat spread smoke into closed bedrooms; fires in closed bedrooms were lethal to occupants**
- **Response of 2nd level detectors inadequate for 1st level fires (every level requirement)**
- **Detectors at each end of a long hallway**
- **Ion faster on flaming, photo faster on smoldering**
- **No difference in ceiling or wall (<12in from ceiling) mount**

Bukowski, R.W., Christian, W.J. and Waterman, T.E., Detector Siting and Sensitivity Requirements for Dwellings, available at http://smokealarm.nist.gov/

Additional Testing Programs

From Bukowski (NIST) "Debate" in Reno 2005)

- **Los Angeles FD (1963 and 1978)**
- **Bloomington MN FD (1969)**
- **Japan Housing Corp (1974)**
- **FMRC (apartments 1974)**
- **Indiana Dunes (Phase 2, 1976)**
- **Minneapolis MN FD (1978)**
- **Australian Dept. of Housing and Construction (1979)**
- **In all, 10 studies in 4 countries over 20 years involving 206 experiments with real detectors in real homes with real fuels reached consistent conclusions**

Bukowski, R. W., Studies Assess Performance of Residential Detectors, *NFPA Journal*, **87**, 1, pp 48-54, (1993).

QUOTES FROM STUDIES "Overlooked" in NIST Review

- **"Test Series II-A: Test A consisted of a cigarette left burning on a spring filler mattress in the front bedroom. The door to the bedroom was closed. In the first hour and a half, alarms has been turned in from all three of the photoelectric detectors. After 110 minutes, the CO meter had climbed off the scale, indicating dangerous levels of CO throughout the main floor, but it was not until 2 1/2 hours has elapsed, that the ionization detector began to alarm … It also appears that "stale" smoke can reach deleterious states without triggering an ionization detector." - Edmonton Fire Dept., 1976. *(NOT IN NIST REVIEW)***
- **Ionization chamber type detectors, in the room of origin and the corridor, did not, in the smoldering fire tests, provide adequate warning that the escape route was impassable or that conditions in the room were potentially hazardous to life. - GREAT BRITAIN, 1978*. (NOT IN NIST REVIEW)***

QUOTES FROM STUDIES "Overlooked" in NIST Review

- **"This test will show that most photoelectric detectors, operated by battery will detect smoke at about 1.5-3% smoke, which is good. The test will show that the photoelectric detectors operated by household current will activate between 2 and 4 %, which is still good. But, the test also will show that many ionization detectors will not activate until the smoke obscuration reaches 10-20 and sometimes 25%. … Therefore, because of the present state of the art in detecting smoke, the Subcommittee can take no other course but to recommend the installation of photoelectric detectors." - IAFC REPORT, CAL CHIEFS, International Fire Chief Magazine1979. (ANALYSIS NOT IN NIST REVIEW)**
- **A report by the Los Angeles Fire Dept., the agency which conducted the tests recommended photoelectric in bedroom in in all common areas. (ANALYSIS NOT IN NIST REVIEW)**

QUOTES FROM STUDIES
"Overlooked" in NIST Review

- **The NIST Study does quote from another analysis of the CAL Chiefs Report. Unlike the other reports this analysis was published several years after the study was conducted (1983). *"Conclusion 4 – Smoke detectors (ion or phot)) are more reliable than heat detectors as early warning devices for dwelling fires."***
- **The NIST Analysis negelected to mention conclusion 1 which stated, *"Photoelectric detectors provide the best protection against smoke build-up".***

Why is Conclusion 4 more important than Conclusion 1?

QUOTES FROM STUDIES

- **Ionization detectors sited in the hallway generally provide inadequate escape times unless smoke movement into the hallway is slowed down by narrow door openings, causing a slower loss of visibility, or unless they are sited close to the smoke source. - AUSTRALIA, 1986 *(REFERENCED BY NIST BUT NOT DISCUSSED BECAUSE IT DID NOT INCLUDE HEAT DETECTORS. – NO EXPLANATION WS GIVEN AS TO WHY THIS INVALIDATED THE RESULTS)***
- **The ionization detectors detected smoke from a smoldering fire much later than optical (photoelectric) detectors. When the particular conditions during the fire development are taken into consideration there are reasons to indicate that this detection principle would not provide adequate safety during this type of fire. - NORWAY, July*1991 (ALTHOUGH THE ARTICLE WAS PUBLISHED IN 1993, AN ARBITARRY CUT-OFF DATE FOR INCLUSION OF REPORTS WAS JUNE OF 1991 – ONE MONTH BEFORE THIS STUDY WAS PUBLISHED. THIS STUDY COULD HAVE EASILY BEEN ADDED.***

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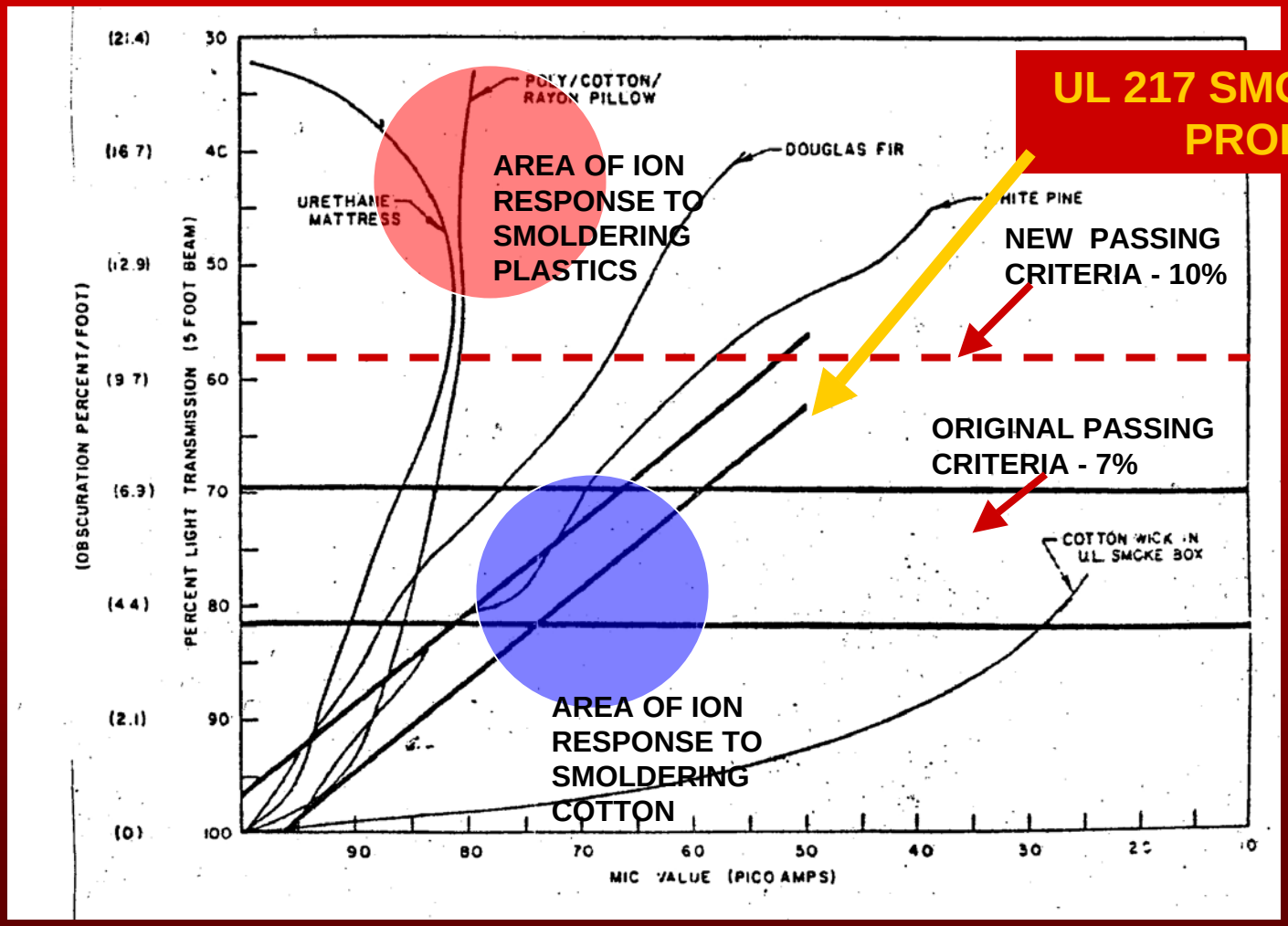
NIST OPINION OF RESULTS HAVE CHANGED OVER TIME

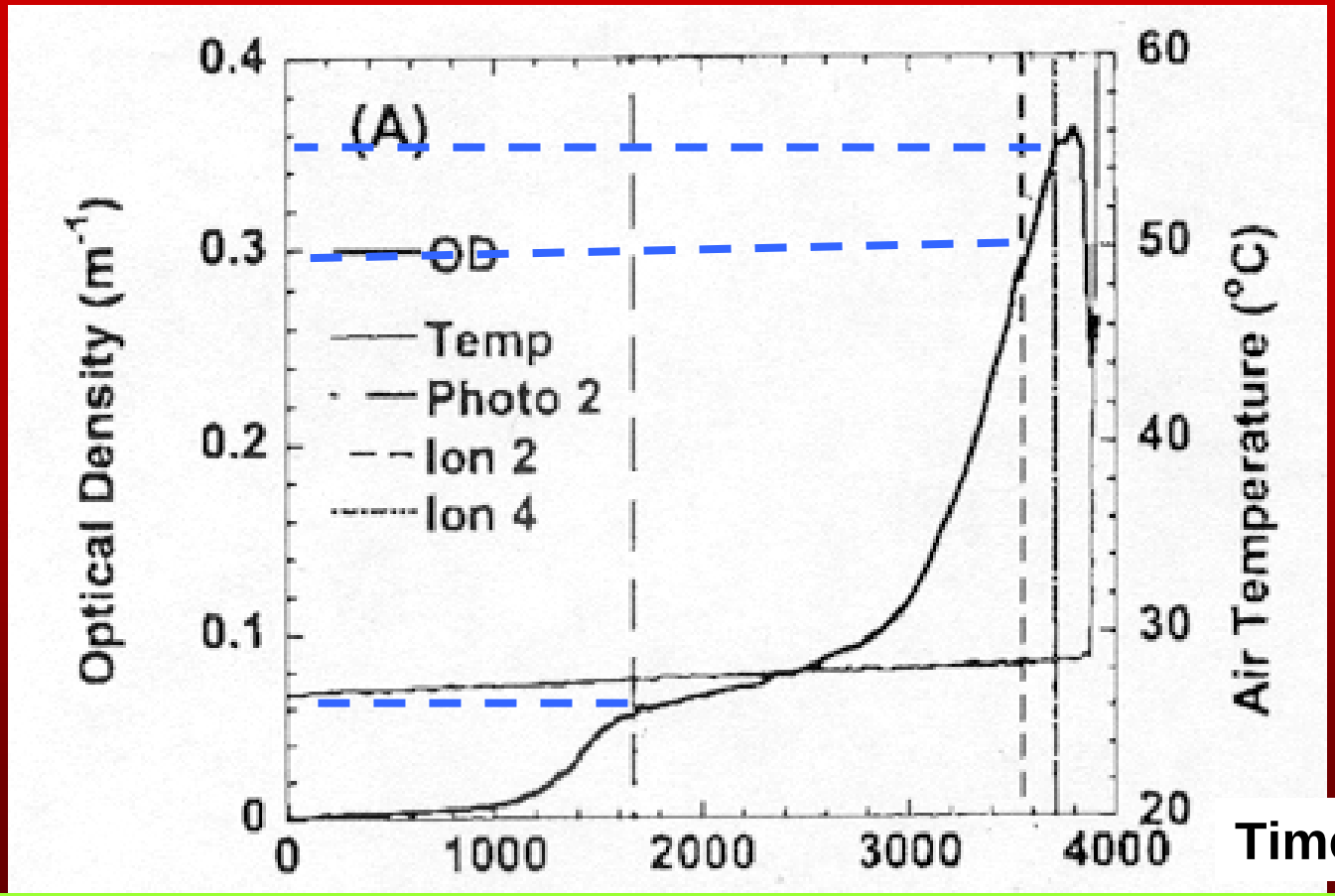
5/7/2002	PRELIMINARY ANALYSIS	ION FAIL IN SOME SMOLDERING TESTS
12/2003	FINAL REPORT	EITHER TYPE PROVIDE NECESSARY ESCAPE TIME
03/2006	NIST RESPONSE TO QUESTIONS TABLE ONE*	PHOTOS FAIL 6/12 FLAMING & ?? 5/12 SMOLDERING ?? IONS FAIL 10/12 SMOLDERING & O/12 FLAMING
03/2006	NIST RESPONSE TO QUESTIONS TABLE TWO	PHOTOS GOOD FOR SMOLDERING & OK FOR FLAMING IONS GOOD FOR FLAMING & < 2MIN ASET 40% IN SMOLDERING

*** THIS IS ONLY REPORT THAT EVER FOUND PHOTOS FAILING IN SMOLDERING FIRES. WHY DOES NIST THINK THIS MAKES SENSE?**

SMOKE PROFILE (MIC VS. OBS.) OF SMOLDERING MATERIAL - SCHUCARD (COMPARED TO UL 217)



NIST - SMOLDERING LIVING ROOM FIRE - TEST 34



Photo(3-4% O/ft), Ion 2 - (17-19% O/ft), Ion 3 - (20-22% O/ft)

NIST SMOKE ALARM STUDY, 2004
ASET - MANUFACTURED HOME
(PAGE 242, TABLE 27)

	PHOTO	ION
FLAMING		
Living Room	85	142
Bedroom	58	93
Bedroom(Door Closed	451	898
SMOLDERING		
Living Room	172	-43
Bedroom	1091	82
COOKING		
Kitchen	575	821

Smoldering fires in living room were the #1 fatal scenario.

NIST SMOKE ALARM STUDY, 2004
ASET - MANUFACTURED HOME
(PAGE 243, TABLE 28)

	PHOTO	ION
FLAMING		
Living Room	108	152
Bedroom	---	374
Bedroom(Door Closed	3416	3438
SMOLDERING		
Living Room	3298	16
Living Room (AC on)	2772	-54
Bedroom	135	135
COOKING		
Kitchen	952	278

Smoldering fires in living room were the #1 fatal scenario.

MULTIPLE SOURCES? FOR "FLAMING FIRES" AS BIGGEST CONCERN (75%).

NIST Q/A 2007 references PPFC Report (USFA) → **PPFC* references 2000 PPoint Presentation by John Hall (NFPA).**
**** Written by J Hall***

NIST Smoke Alarm Report (2004) references CPSC Analysis → **CPSC Analysis done by John Hall (NFPA)**

NFPA Smoke Alarm Report

(04/07 Ahrens) → **2005 PPoint Presentation by John Hall (NFPA).**

WHAT IS A SMOLDERING FIRE?
(John Hall – NASFM/Reno NV 2005

- **Fires with no extent of flame beyond the first item ignited account for at most 3% of fire deaths. This is an upper bound on deaths associated with fires that <u>only smolder</u>.**
- **Roughly 25-30% of home fire deaths involve fires estimated to have an <u>initial smoldering phase</u>. This estimate includes all cigarette fires and some/most electrical wiring fires.**

The fact that smoldering fires are only a small part of the overall fire problem seems to be the "official" opinion of the NFPA, USFA, NIST etc. - JF

IMPORTANCE OF SMOLDERING FIRES

- **According to "Fire In The US 1983-1990 (USFA)" fire deaths tend to peak late at night and in the early morning hours, such as when fires caused by dropped smoking materials have been smoldering for several hours.[i20]**
- **In a 1979 study of fatal fires, the NFPA found that, "two-thirds of the deaths in one and two fatality fires resulted from fires between the hours of 8pm and 8 am. Moreover, most of these deaths occurred in fire that gained large head starts - over 40 minutes for 38% of such deaths - before discovery.[i21]**
- **Delayed discovery, typically associated with fires that occur at night when everyone is asleep, also tends to be a characteristic of the smoldering fire caused by discarded smoking material. These smoldering fires are the leading causes of US fire fatalities and detectors are ideally designed to deal with them.**

"A Decade of Detectors", Fire Journal 09/85, John Hall.

WHAT CHANGED?

IF SMOLDERING FIRES HAVE DECREASED THEN THE % OF FATAL FIRES AT NIGHT SHOULD HAVE DECREASED?

	AVERAGE 1971 – 1978 (NFPA)	1996 (USFA)	2001 (USFA
8 AM – 8 PM (DAYTIME)	31.2%	35%	33%
8 PM – 8 AM (NIGHTTIME)	68.8%	65%	67%

This does not appear to support a change in opinion, regarding flaming/smoldering fires, from the 80's and 90's

HAVE THE "CAUSES" OF FIRES CHANGED DRAMATICALLY?

FIRE TYPE	1987	1991	1996	2001
Super Fast Flaming Arson, Open Flame, Intimate	32.0	36.0	28.5	36.25
Fast Flaming Cooking, ½ Heat, ½ Appliance, all "Other"	18.7	22.5	25.25	22.75
Smoldering Smoking, Electrical, ½ Heat, ½ Appliance	47.3	41.5	46.25	41.0
Smoldering as % on non-"Super Fast"*	**71.5%**	**65%**	**65%**	**64.5%**

*** It is unlikely detectors could help in these "Super Fast" scenarios so why account for them when discussing smoke detectors?**

JOHN HALL'S QUOTE TO NFPA TAK FORCE (10/2007)

- **Many, <u>perhaps most</u>, fatal fires involve an initial smoldering period followed by an open-flaming period.**

MASS DATA

	SMOLDER-ING	FLAMING	FAST FLAMING	UN-KNOWN
	Photo 30 Mins Faster	Ion 50 Secs Faster	Alarm No Help	
2003	13	2	15	14
2004	9	2	11	9
2005	13	2	8	11
TO-TALS	35	6*	34	34

- ***Smoldering Fires are 85% of fires were alarm can help.***
- **** Of the 6 Faming Fires – 3 impaired at least 2 awake. It is unlikely the extra 50 seconds by ion critical.***

WHAT DO STATISTICS SHOW?

DO THEY REDUCE RISK BY 50%?

ARE THEY RESPONSIBLE FOR 50% REDUCTION IN FATALITIES?

DO DETECTORS PROVIDE 40-50% LESS RISK?

COMPARISONS OF ESTIMATES (NFPA METHOD)

		SMOKE DETECTOR PRESENT	SMOKE DETECTOR ABSENT	REDUCTION IN RISK
RISK (NUMBER DEATHS/ 100 FIRES) NFPA ASSUMPT'S *BUILT IN*	NFPA AVE (99-01) NFIRS V4.0 & V 5.0 (ADJ)	0.65	1.13	43%
	NFPA (2001) NFIRS V4.0 & V 5.0 (ADJ)	0.86	1.13	24%
**********				
RISK (NUMBER DEATHS/ 100 FIRES) *MORE SPECIFIC DATA*	USFA – 2001 (NFIRS V 5.0)	0.772	1.044	26%
	NFPA AVE (99-01) NFIRS V 5.0	1.12	1.21	7.0%
	U.K. (94-97)	0.785	0.767	-2.3%
	U.K.(FROM NFPA) (99-01)	0.63	0.68	-7.0%

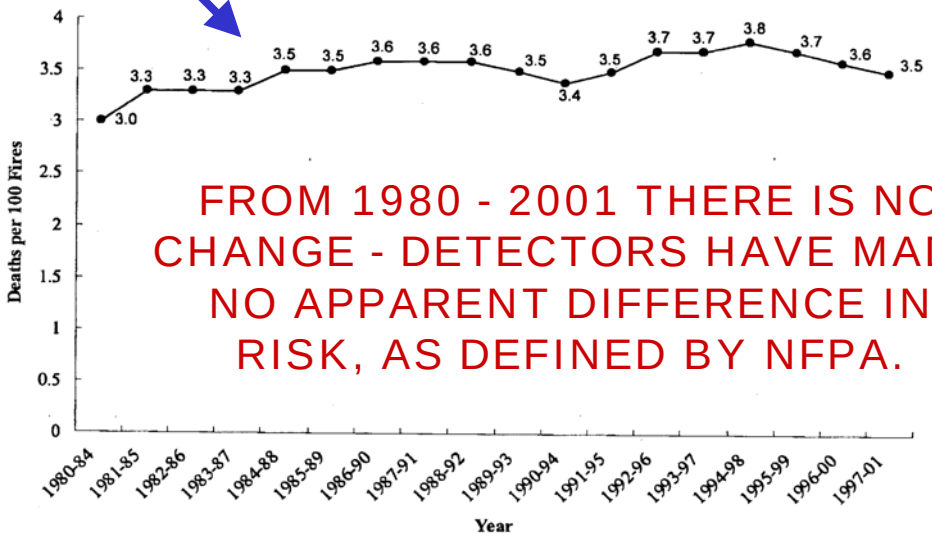
NFPA 2007 Deaths/100 Fires)

- **NFPA used to say that having a smoke alarm reduced deaths by 50%. Now they say having a <u>working</u> smoke alarm reduces deaths by 50%.**
- **For ALL Fires 49% reduction**
  - ***0.55 with alarm, 1.13 without alarm***
- **For NON-CONFINED Fires - 30% reduction**
  - ***1.19 with alarm, 1.65 without alarm***
- **For NON-CONFINED Fires (Old system) – 20% more**
  - ***1.70 with alarm, 1.4 without alarm***

SMOKING DEATHS PER 100 FIRES - 5 YEAR ROLLING AVERAGES

This trend should have signaled a problem by the mid 80's.

Figure 4. Trend in Civilian Deaths per 100 U.S. Smoking-Material Home Fires (Five-Year Rolling Averages)



FROM 1980 - 2001 THERE IS NO CHANGE - DETECTORS HAVE MADE NO APPARENT DIFFERENCE IN RISK, AS DEFINED BY NFPA.

Source: NFIRS and NFPA survey

% OF FATAL FIRES WERE SMOKE DETECTOR OPERATES

	% 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>

REASONS FOR INCREASE (?) – POST 1990

- **According to USFA – There was no increase, it was only 23% n 2004 (11/05*). Of Course they did not account for "unknowns."***
- **According to Chairman of NFPA 72 – Fires are growing faster according to NIST. Due to increase in synthetic material. *Of course neither the Chairman or NIST ever bothered to point out that the switchover to synthetics was pretty much complete by 1990 so it cannot affect #'s post 1990.***
- **According to NFPA – Fires with working alarms increased so fatal firs with working alarms increased. *Of course they never took into account that more participation in NFIRS and changes in coding caused increase in reported fires.***

MOST LIKELY REASON FOR POST 1990 INREASE IN FATALITIES WERE ALARM OPERATES TO LATE

- **When Smoldering Test added to UL217 – ion sensitivity increased causing nuisance problem.**
- **In 1986 UL changes Standard to force manufacturers to make less sensitive alarms by 1988,**
- **1986-1987 UL changes smoldering test making it easier for ion to pass. (Original designers warned that it should be made more robust not less.)**
- **These “de-sensitized” ion alarms introduced in late 80’s which co-incided with increase. (They could be contributing to 20-25% of all fatalities.)**

SMOKE DETECTORS – FIRESAFETY'S GREATEST SUCCES STORY - NIST

- **Smoke detector usage rose from 10% in 1975 to 95% in 2000 while home fire deaths cut in ½.**

"The home smoke alarm is credited as the greatest success story in fire safety in the last part of the 20th cent., because <u>it alone</u> represented a highly effective fire safety technology with leverage on most of the fire death problem that went from token usage to nearly universal usage in a short time." – NIST, 2004.

HOWEVER -

HOW MUCH OF REDUCTION IN FIRE DEATHS IS DUE TO DETECTORS?

- **In the late 70's approximately 6,200 people dies per year in homes.**
- **According to the NFPA:**
  - ***If no one had detectors residential fatalities = 4,230.***
  - ***If everyone had detectors resid fatalities = 2,430.***
  - ***Actual ave for 1999-2001 = 3,140 fatalities per year.***
- **According to the NFPA, fatalities would have decreased by approx 2,000 people per year <u>without any smoke detectors</u>! (2/3 of total.)**

Data from NFPA Smoke Detector Study 11/04.

REDUCTION ANALYSIS CONT'D

- **Numbers on previous slide obtained from:**
  - ***Total number of fires in 2001 380,000 (3,800, "100's")***
  - ***No Detector "risk" = 1,1 (Therefore 1.1 * 3,300 = 4,230)***
  - ***Detector Present Risk = .65 (Therefore .65 * 3,800 = 2,430)***
  - ***Risk, when present and operated, = 0.54 and risk when present and did not operate = 0.93. Having a smoke detector that does not operate is safer than not having one? ("socioeconomic/construction) factor.***
  - ***If you took away smoke detectors from entire "risk averse" population that currently has them it is unlikely risk would stay at level of "risk accepting" population. If one assume as risk of .0 instead of 1,1 then -***

TOTAL REDUCTION WITHOUT ANY SMOKE DETECTORS WOULD EQUAL 2,400 (6,200 - 1.0 * 3,800),

<u>5/6THS OF TOTAL REDUCTION</u>.

TRENDS IN FIRE DEATHS VS. INCREASE IN DETECTOR USAGE

	51-71 (20 YEARS)	65-75 (10 YEARS)	77-87 (10 YEARS)	92-02 (10 YEARS)
INCREASE IN HOMES WITH DETECTORS OVER	0%-<4%	<4%-10%	22%-82%	90%-96%
% DECREASE IN FIRE DEATHS PER MILLION PEOPLE	-26.0% NFPA ESTIMATES HB – 14TH ED..	-27% (Residential) National Safety Council	-29% (All) NFPA	-25% (All) NFPA

FIRE DEATHS WERE DECREASING <u>BEFORE</u> WIDESPREAD USE OF DETECTORS AND CONTINUED TO DECLINE <u>AFTER</u> "MARKET SATURATION".

POTENTIAL BENEFITS OF SWITCHING TO PHOTOELECTRIC DETECTORS

- **Photolelectric detectors might reduce by 1/2 the # of people dying in fires, when the detector works. (This would be a 20% reduction.)**
- **Photelectric detectors might reduce the number of disabled detectors due to nuisance alarms. (Assume problem reduced by 1/4 - 5% reduction)**
- **It seems reasonable to assume that switching from ionization to photoelectric technology <u>could save 800 lives (.25 * 3,200) per year!</u>**

This number could be higher, if # of fatalities that occur when no smoke detector present is over-estimated. (Many Chief's assume that if occupants died then the smoke detector wasn't there - good PR opportunity.

DO CHIEF'S MAKE MISTAKEN ASSUMPTIONS ABOUT DETECTORS?

- **Boston Globe (BG), 10/05/04 - Blaze, reported at 1:33 a.m., kills 5 in duplex, Dennis MA. A smoke detector without a battery was found in unoccupied side of duplex. No smoke detector found in charred side.**
- **Boston Herald (BH), 10/05/04 - Fire officials said there were no working smoke detectors in the fire apt. and fire may have raged for an hour. Officials focusing on smoking. At some point the parents awoke and tried to rescue the children.**
- **Cape Cod Times (CCT), 10/06/04 - State Fire Marshal said that the lack of working smoke detectors "contributed to this terrible tragedy". Fire Marshal used the fire as a "teaching moment".**

MISTAKEN ASSUMPTIONS CONT.

- ***HOWEVER ….*** **In April, the Realty Company produced an affidavit/rental agreement that indicated detectors were there in April. The Realty Co. blamed tenants for disabling detector. Newspaper does an article on nuisance alarms and reminds people to check their detectors. (No mention of photo lower susceptibility to nuisance alarms.) - CCT 10/06/04**
- ***HOWEVER ….*** **A friend said she heard detectors go off at a Birthday party in August, due to cooking. She could not imagine them disabling detector because they were so protective of children. - CCT 10/06/04. Victims' father said, "a few days before fire they went off because of cooking." - CCT 10/07/04**

ISN'T IT LIKELY THAT THIS WAS A SMOLDERING FIRE WITH ION DETECTORS THAT WENT OFF TOO LATE?

MISTAKEN ASSUMPTIONS CONT.

- **CAUSE OF FATAL MIAMI UNIVERSITY FIRE DETERMINED - Smoking materials, alcohol and disabled alarms were factors.**
  - ***"Disabled smoke alarms, careless disposal of smoking materials and alcohol are factors that we have seen in other fatal fires," reported Ed Comeau, the director of the Center. "It is important that students learn the steps they can take to protect themselves, their friends and roommates from fire." Some of these steps include:***
    - **Install smoke alarms and ensure that they are working at all times.**
    - **If a smoke alarm is being activated needlessly, such as by cooking or steam from a shower, relocate the smoke alarm instead of disabling it.**

ACTUALLY THERE WAS A WORKING IONIZATION DET IN THE HALLWAY NEAR THE ROOM OF ORIGIN. INVESTIGATORS BELIEVE THIS WAS A SMOLDERING FIRE AND THAT THIS DETECTOR ALERTED A STUDENT IN AN ADJACENT BEDROOM. WHEN HE OPENED THE BEDROOM DOOR, SHORTLY AFTER THE DETECTOR WENT OFF, THE SMOKE WAS TOO THICK TO EXIT THROUGH THE HALLWAY. (ACCORDING TO NIST WOULDN'T A PHOTOELECTRIC PROBABLY HAVE OPERATED 30-40 MINUTES SOONER

END