PHOTOELECTRIC VS. IONIZATION A REVIEW OF THE LITERATURE *"REVISITED"*

Original paper was presented at 1997 Symposium. This presentation will incorporate findings from recent NIST smoke detector testing.

PART ONE

REVIEW OF SMOKE DETECTOR STUDIES

GENERALLY ACCEPTED OPINION REGARDING DETECTOR STUDIES

"When either ionization or photoelectric smoke detectors are located outside bedrooms and on each level of a house, they provide adequate warning to allow occupants to evacuate through their normal egress routes in most residential fire scenarios". (NIST Review of Detector Studies, Fire Journal 1993.)

"In the 1990's, reports surfaced that some privately funded testing had shown delayed response from smoke alarms using ion-type sensors to smoldering fires, <u>While detailed reports were never published in the open literature,</u> these persistent reports were the cause of some concern." (From recent NIST Study.)

HISTORICAL DETECTOR STUDIES
(ITALICIZED STUDIES WERE NOT IN NIST SURVEY)

TESTING AGENCY	YEAR	COMMENTS
National Research Council of Canada	1962	This was a study (no testing) that just used judgement to est effectiveness of detectors.
Los Angeles Fire Dept.	1960	This used heat detectors and older photoelectric technology
Bloomington MN Fire Dept.	1969	Remote smoke detectors better than nearby heat detectors. Older technology..
According to the NIST Study, published in Fire Journal, The smoke detectors used in the next test were *"significantly improved over those used in prior test and were essentially equal to that of current devices."* (I do not consider this to be accurate.)		
Japan Housing Corp	1974	Smoke detectors better than heat detectors.
Factory Mutual Apartment Study*	1974	Ion good for flaming bad for smoldering Photo good for smoldering bad for flaming
Indiana Dunes	1976	Smoke Detectors better than heat detectors and one detector per level desireable
Massachusetts Analysis of Dunes	1976	A smoke detector per level will provide 3 minutes of escape time 89% of the time.

HISTORICAL DETECTOR STUDIES

(ITALICIZED STUDIES WERE NOT IN NIST SURVEY)

TESTING AGENCY	YEAR	COMMENTS
Edmonton Fire Dept.	*1976 (N/I)*	***Both ion and photo provide considerable life safety. In smoldering ion may go off too late.***
Minneapolis Fire Dept.*-3	**1978**	**Both Ion and Photo gave good early warning if smoke could reach detector.**
Australian Dept. of Housing and Const.*-3	**1979**	**All Smoke detectors adequate and smokes better than heats for flaming fires.**
Modern furnitue, containing plastics used in all studies after this point. Modern furniture was used in some of the previous studies, i.e. FM.		
CAL CHIEFS LA Fire*-3	1978	**Smoke detectors more reliable than heat detectors. NIST analysis concluded both types of smoke detectors adequate.** ***(Modern furn used, LAFD and IAFC Reps favor photo-electrics based on the results.)***
Fire Research ion (Great Britain)	*1978 (N/I)*	***Both ion and photo respond rapidly to flaming. Ion was not adequate in smoldering***
Smoldering Fire – Aust. (Fire Tech)	*1986 (N/I)*	***Photoelectric detectors provided adequate escape time for most fires. Ionization generally were inadequate.***

N/I means prior to 1991 but, not included in NIST Study.

HISTORICAL DETECTOR STUDIES

(ITALICIZED STUDIES WERE NOT IN NIST SURVEY)

TESTING AGENCY	YEAR	COMMENTS
Norwegian Fire Research Lab Study	*1993*	*There are reasons to indicate ions are inadequate for smoldering fires. Ion only 15-20 secs better than photo in flaming fires. Advantage only beneficial under extraordinary circumstances.*
Smoke Alarms In Typical Dwelling Fire Research (GB)	*1997 (Pt 1)*	*Ion cannot be guaranteed to detect smoldering fire. Ion better at flaming and difference could be critical. (smolder > 30 m)*
Practical Comparison of Alarms Fire Research (GB)	*1997 (Pt 2)*	*Both Ion and Photo Adequate (In Pt 2 the "smoldering fire" appeared to smolder for a shorter period than in Pt 1*
Simplex Study- 12th International Detection Conference	*2001*	*Ion detector only slightly better for flaming. Photo provides clear advantage over ion if most likely danger is from smoldering fires*
KEMANO FIRE STUDIES NRC-Canada	*2002*	*Both Ion and Photo appeared to be adequate. (Fire appeared to smolder for less than 15 mins.*

SUMMARY OF HISTORICAL STUDIES

- **All the studies that utilized synthetic material and smoldering scenarios that lasted more than 30 minutes concluded that ionization detectors were not providing adequate warning. (7 studies over 3 decades in 4 different countries.)**
- **No study that utilized the photoelectric detectors with “open designs” similar to current photoelectric detectors showed photoelectric detectors providing inadequate warning.**

NIST VS. HISTORY?

***"A report from the Commerce Department's National Institute of Standards and Technology (NIST) today stated that both types of commercially available home smoke alarms (also called smoke "detectors") consistently provide people enough time to escape most residential fires."* - NIST Press Release**

THIS WOULD APPEAR TO CONTRADICT PREVIOUS SIMILAR TESTS (I.E. TEST THAT SMOLDERED MODERN FURN. >30 MINS) THAT FOUND ION INADEQUATE FOR SMOLDERING,

- DOES IT?

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

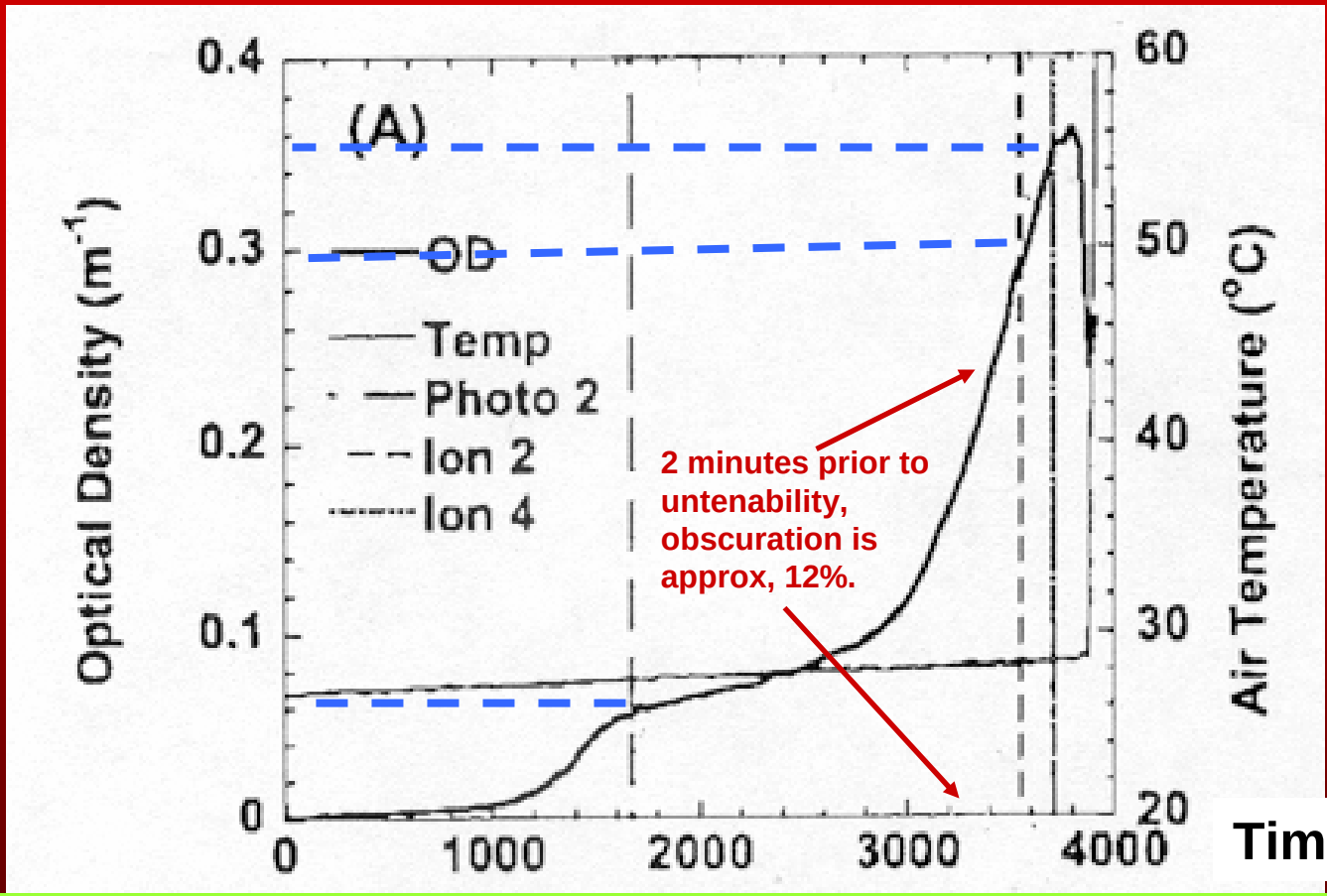
Smoldering fires in living room were the #1 fatal scenario.

ASET – 2 STORY 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.

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'S REASONS WHY CURRNET RESULTS DIFFER FROM 1975

- **Main difference in amount of escape time attributed to (Page 248):**
  - ***1) Different and more conservative tenability criteria***
  - ***2) Fire growth rates significantly faster***
- **In reality, since the obscuration criteria was always the limiting criteria, i.e. the first to be reached, the tenability criteria are essentially the same.**
- **In addition, although the flaming fire starts have an 80% decrease in time to untenability, The smoldering fire only have a 20% decrease and still do not reach untenability for over 50 mins on average**

"REAL" DIFFERENCE IN RESULTS FROM 1975 RESULTS

	1975		CURRENT	
	FLAMING	SMOLDER	FLAMING	SMOLDER
ION	ADEQUATE	ADEQUATE	ADEQUATE	*NOT ADEQUATE*
PHOTO	ADEQUATE	ADEQUATE	ADEQUATE	ADEQUATE

The important result that differs from the 1975 tests is that the ionization detector is not responding adequately to smoldering fires. The best explanation is: ionization detectors may have been de-sensitized over time (definitely since the early 80's) and are relatively poor at detecting the kind of smoke given off by today's furnishings. This possible explanation was never investigated or even discussed by NIST.

PART TWO

REVIEW OF STATISTICS

“Not everything that counts can be counted and not everything that can be counted, counts.” - Albert Einstein

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.**

"Thus the home smoke alarm is credited as the greatest success story in fire safety in the ;last part of the 20th century, because it alone 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 remarkably short time." – NIST Executive Summary

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 without any smoke detectors! (2/3 of total.)**

Data from NFPA Smoke Detector Study 11/04.

TRENDS IN FIRE DEATHS COMPARED TO INCREASE IN DETECTOR USAGE

	65-75	77-87	92-02
Increase in homes with detectors over 10 years	<4% - 10%	22% - 82%	90% - 96%
% decrease in fire deaths per million people, over 10 years	-27% (Residential) National Safety Council	-29% (All) NFPA	-25% (All) NFPA

Fire deaths wee decreasing <u>before</u> widespread use of detectors and continued to decline <u>after</u> "market saturation".

BURN CARE'S CONTRIBUTION TO FIRE DEATH REDUCTION

- **At the time of America Burning (1975) there were 12 full spectrum burn centers. By 1999 there were over 100 burn centers with 25 being full spectrum. On a yearly basis, deaths, once the victim has been placed into the burn care system, have decreased from around 4,000 to 1,000. *(America Burning Recomissioned – 1999)***
- **This reduction may be partially due to the fact that smoke detectors and FF's SCBA allow victims to be rescued earlier. It has been my personal experience that FFs SCBA has made a significant contribution to victims survival rate.**

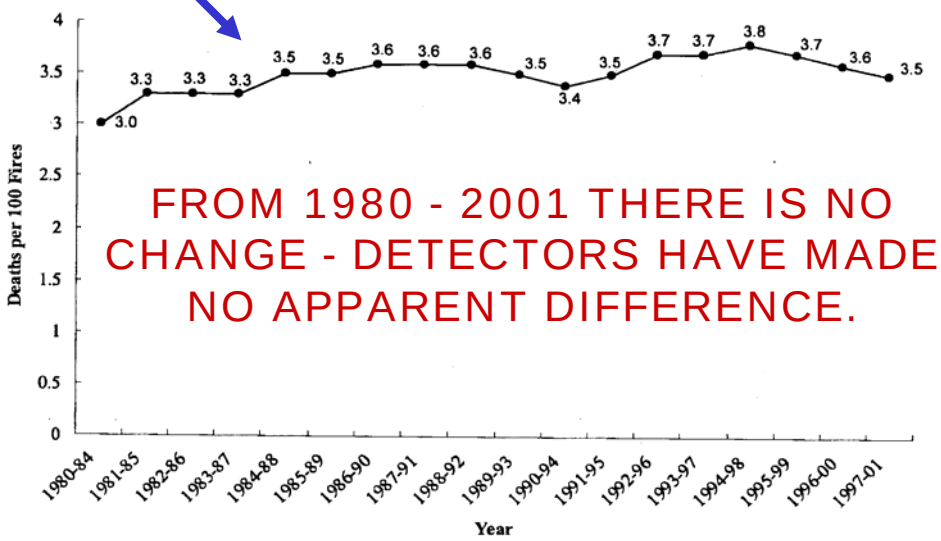
REDUCED SMOKING'S CONTRIBUTION TO FIRE DEATH REDUCTION

- **Stopping smoking can significantly reduce the devastation, injury and cost by fire. 2/3 of all U.S. reductions in fire fatalities related to smoking from 1984 – 1995 were attributed to reductions in cigarette consumption. *(Dr. B. Leistikow, University of California at Davis – Cancer Research Dept.)***
- **The most important part of the smoking-material fire problem-the number of structure fires-has declined by two-thirds, or 66 percent, since 1980, while the number of civilian deaths has dropped by 49 percent from the high in 1981 and 44 percent since tracking began in 1980. However, deaths per 100 smoking-material fires were 66 percent higher in 1995 than they were in 1980. *(John Hall, PhD – "Cigarettes Kill", www.interfire.org - reprinted from NFPA Fire Journal, Jan/Feb 1998)***

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.

Source: NFIRS and NFPA survey

NFPA's EST. BENEFIT OF RES. SMOKE DETECTORS

- **" If a home fire occurs, smoke alarms reduce the risk of death by 40-50%. From 99-01 the reduction in risk for apts. & condos was only 7%**
- **From 1999 an increasing amount of data has been collected in NFIRS Version 5.0.**
- **In 2001 using this new data the NFPA estimated reduction was only 21%.**
  - ***Were the previous estimates, which incorporated assumptions to compensate for incomplete data, overly optimistic?***
  - ***How much of this new, and smaller, reduction is due to characteristic that go along with owning a smoke detector: higher income, newer construction, better evac plans etc?***

% 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 INCREASED 100%

% OF HOMES WITH SMOKE DETECTORS INCREASED 2%

% OF FIRE WITH WORKING SMOKE DETECTORS INCREASED 12%

QUOTES FROM "FIRE IN THE UNITED STATES , 95-01"

- ***"In 39% of fire deaths, an alarm did operate – 10% points higher than in 1998 and <u>30% points higher than in 1988</u>. This is somewhat disturbing since there is a widespread belief that an operating alarm will save lives. In some cases, the alarm may have gone off too late to help the victim, the victim may have been too inebriated or too feeble to react, or the fire may have been too close to the victim. "***

CONCLUSION ON STATISTICS

It appears that a careful review of the available statistics indicates that smoke detectors are not nearly as effective as many people assume. In fact the statistics seem to indicate that there is a "problem" with the smoke detectors that have been used for the past 20 years. I am not saying that they do not work at all. I am saying that they do not appear to work as efficiently as they should. Or as efficiently as they are claimed to be by many experts as well as manufacturers.

When talking about a "problem" with detectors, one is actually talking about a problem with "ionization" detectors, 89% of all detectors. (CPSC-1995)

PART THREE

REVIEW OF UL APPROVAL

ORIGIN OF SMOLDERING FIRE TESTS

- **EN54 - Swiss originators, felt that the fires represented pyrolyzed and self-sustained cellulosic smoldering.**
- **Canadian - Developed by ionization manufacturer, no technical justification.**
- **UL217 - Originally Douglas Fir proposed. Problems with repeatability, particularly with challenge to ionization detector, led to abandonment. White Pine selected to mimic cotton mattresses. (This also allowed ion to pass.)**

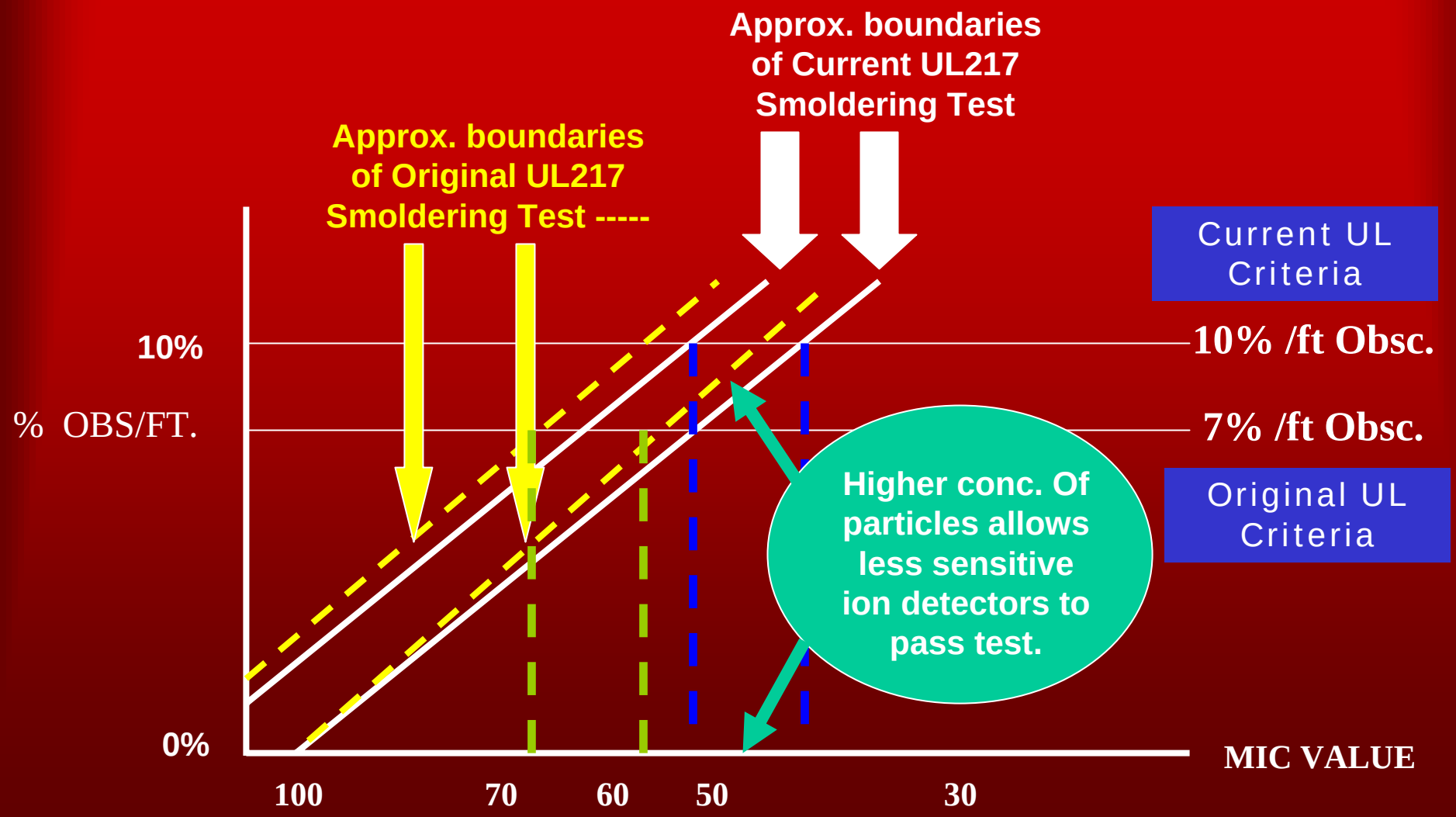
Source: USFA - *Analysis of Fire Detector test Methods/Performance*, 1980.

QUICK HISTORY OF UL217

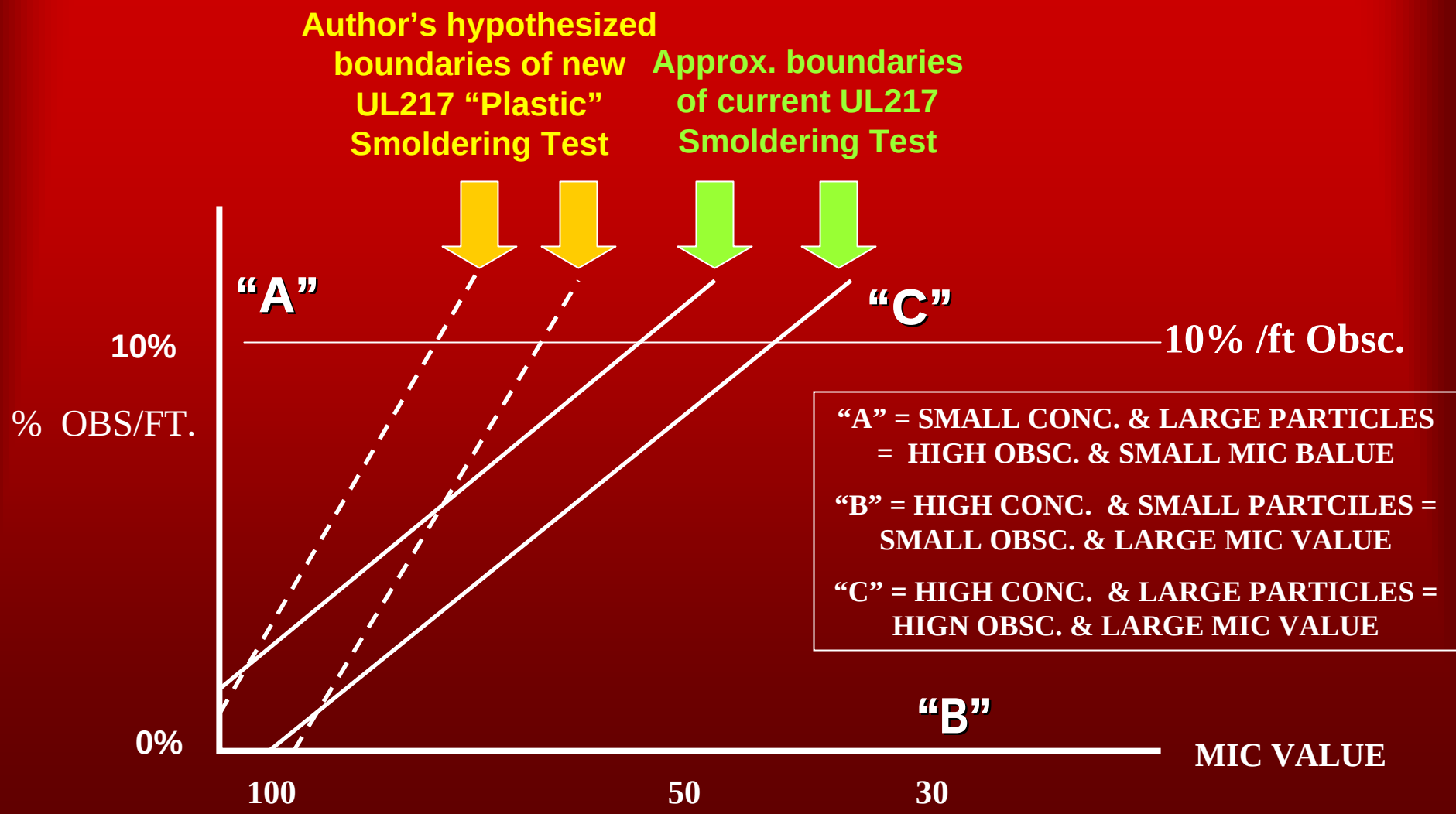
YEAR	EVENT
<1976	2 Standards: UL167 for Ion and UL168 for Photo
1976	UL217 created using 4 flaming fires from UL167. Prod Sens: 0.2-4.0 gray smoke, 0.5 – 10% for black smoke
1979	Smoldering test added – 7% criteria. (Typical ion detector increased in sensitivity in order to pass this new test.)
Early 80's	Massive nuisance alarm problems cause UL to investigate possible desensitization of detectors.
01/84	Minimum sensitivity for gray smoke increased from 0.2% to 0.5%. (Forces increase in ave. sensitivity.)
05/84	Smoldering Profile "shifted" as well as slower build-up. Insect screen. No response <0.5% in Smoldering Test. Max. sens. for black smoke increased from 10% to 13%
87-88	Passing Criteria of Smoldering Test increased from 7% to 10%. (Allowed increase in production sensitivities.)

QUICK HISTORY OF UL217

BOUNDARIES "SHIFTED TO RIGHT AND PASSING CRITERIA CHANGES FROM 7% TO 10%



"SMOKE PROFILE" OF UL 217 SMOLDERING TEST



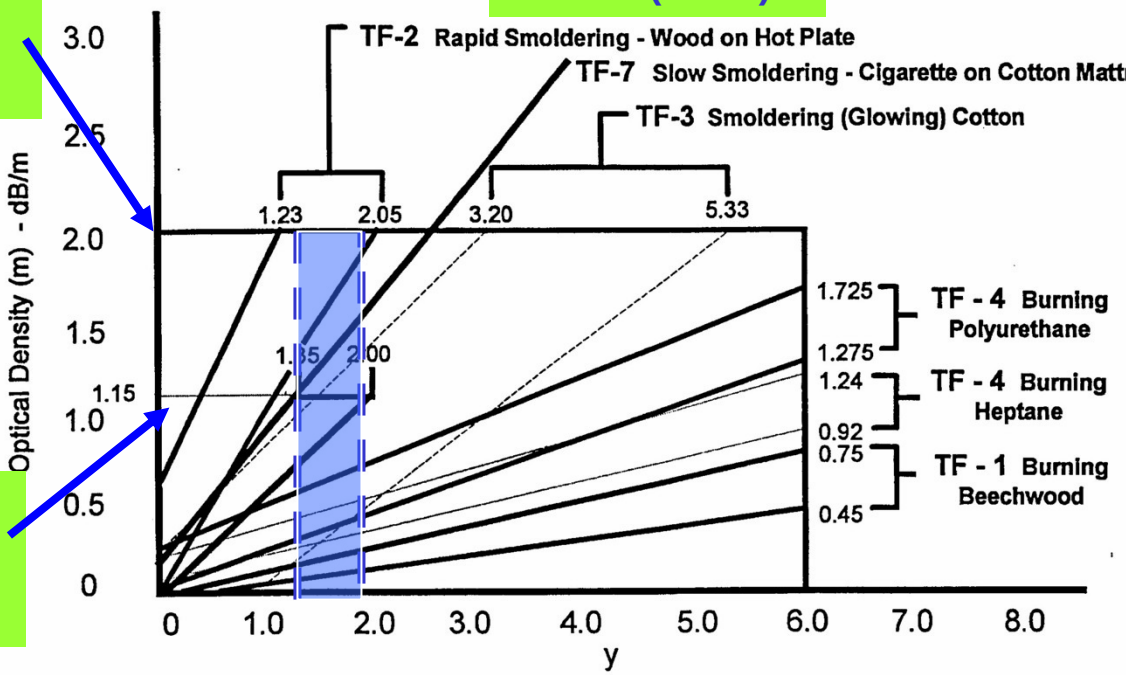
EN54 AND UL217 SMOLDERING COMPARISON

TF-2, EN54 SMOLDERING TEST (FAST)

≅17% OBS/FT

EN54 PASSING CRITERIA

TF-7, UL 217 SMOLDERING TEST (SLOW)



10% OBS/FT

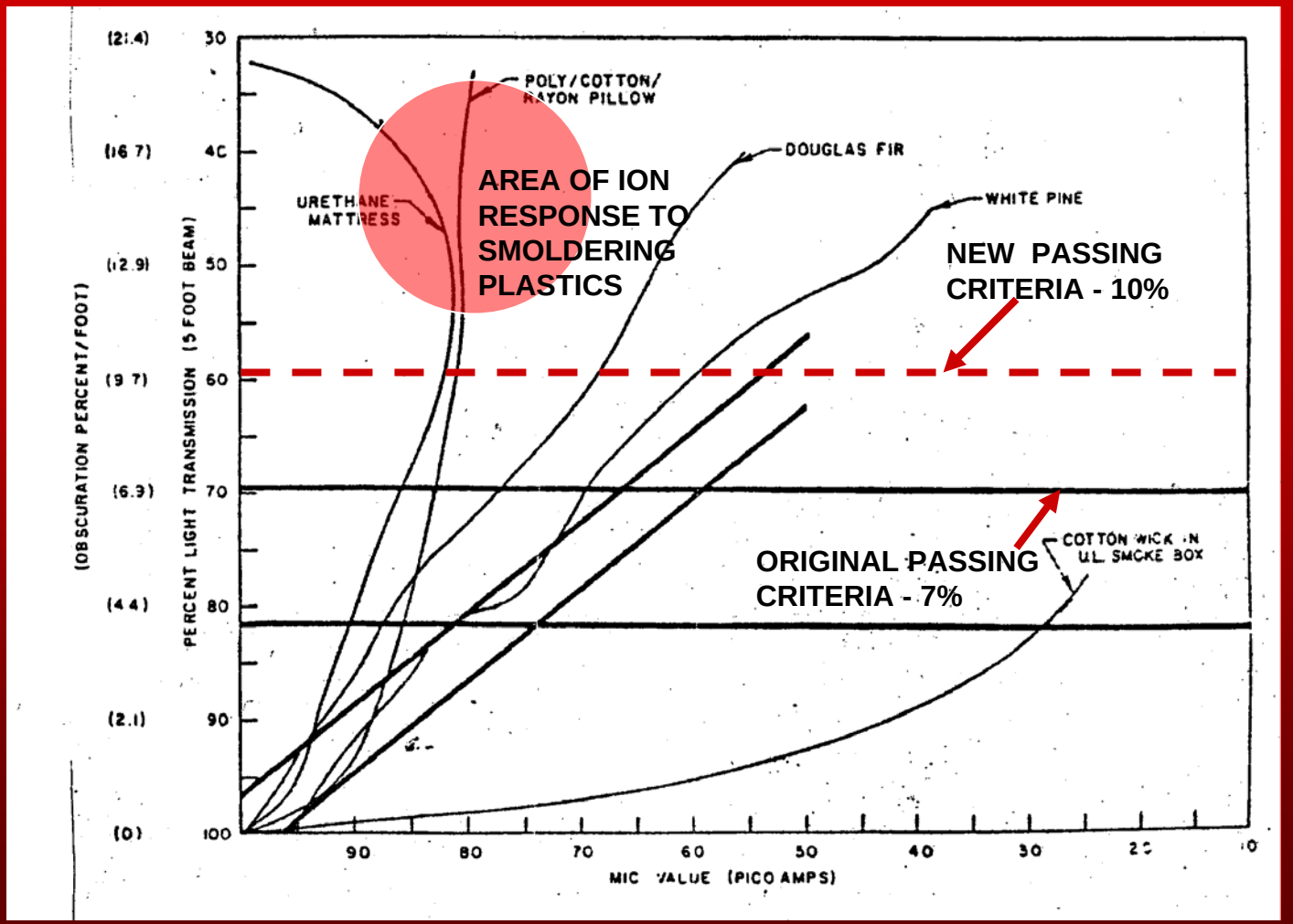
UL PASSING CRITERIA

Figure 1
Composite of ISO Test Fires Profile Curves
m Versus y

NOTE: TF-2 REACHES 10% OBS/FT IN APPROX. 400-650 SECS

NOTE: TF-7 REACHES 10%OBS/FT IN APPROX. 2,700-4,500 SECS

SMOKE PROFILE (MIC VS. OBS.) OF SMOLDERING MATERIAL - SCHUCARD



SMOKE BOX SENSITIVITY VS. RESPONSE TO FUELS (Schucard)

IONIZATION DETECTOR				
SMOKE BOX	WHITE PINE	DOUGLAS FIRE	URETHANE MATTRESS	POLYESTER PILLOW
0.85	6.2	7.7	20.0	NO RESPONSE
*1.1**	*7.4**	NO RECORD	21.6	26.8
*1.3**	*8.9**	11.2	20.0	21.8
1.78	10.4	15.6	NO RESPONSE	26.8
3.7	9.6	18.0	NO RESPONSE	28.4

*** Ionization detectors at these sensitivities would have flunked original UL test at 7% but passed at 10%.**

SUCCESS PREDICTION FROM HARPE AND CHRISTIAN

SMOLDERING FIRE SUCCESS RATE

VS.

%OBS/FT

AT TIME OF DET. ACTIVATION

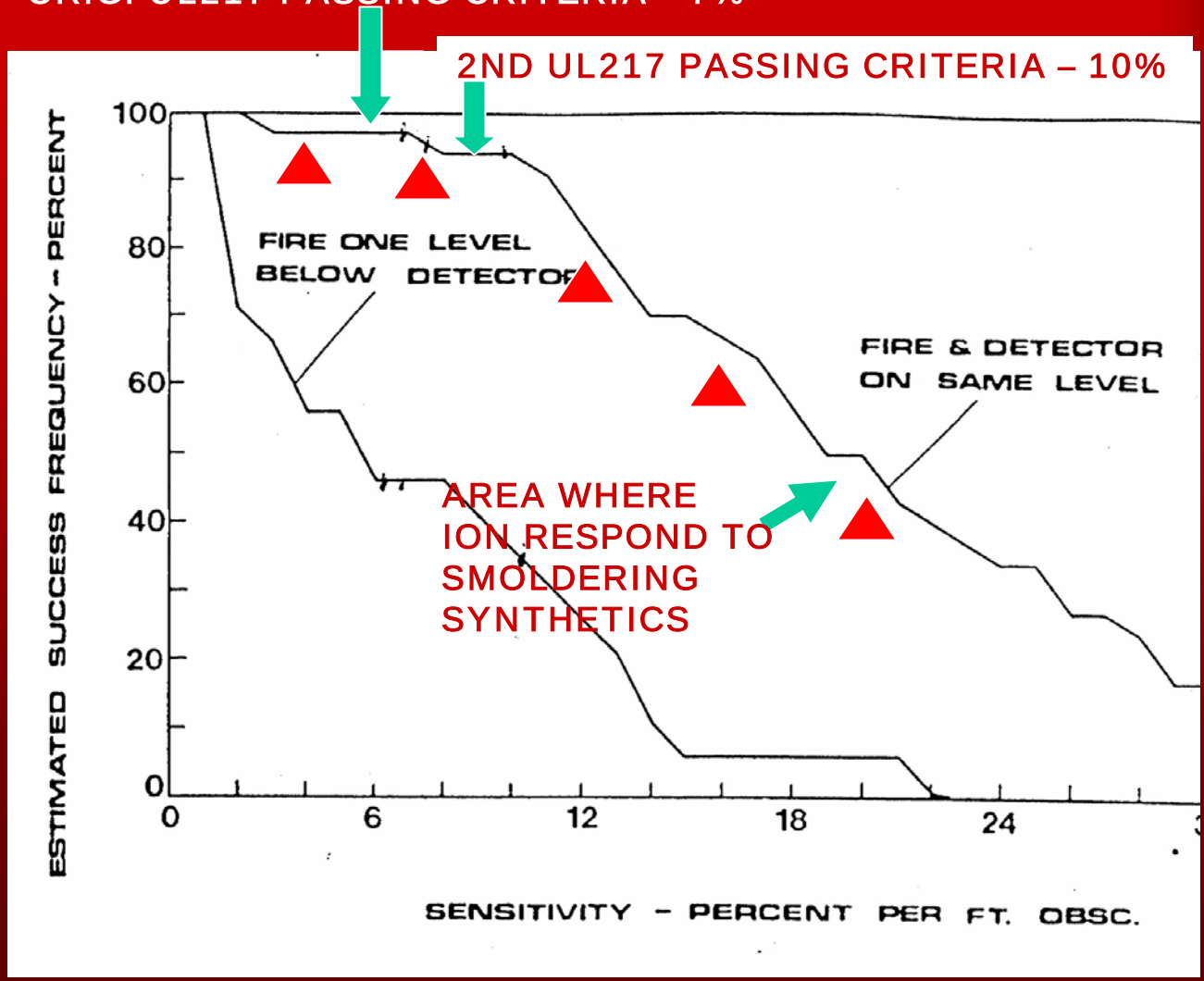
4% OBS/FT – 98%

8% OBS/FT – 97%

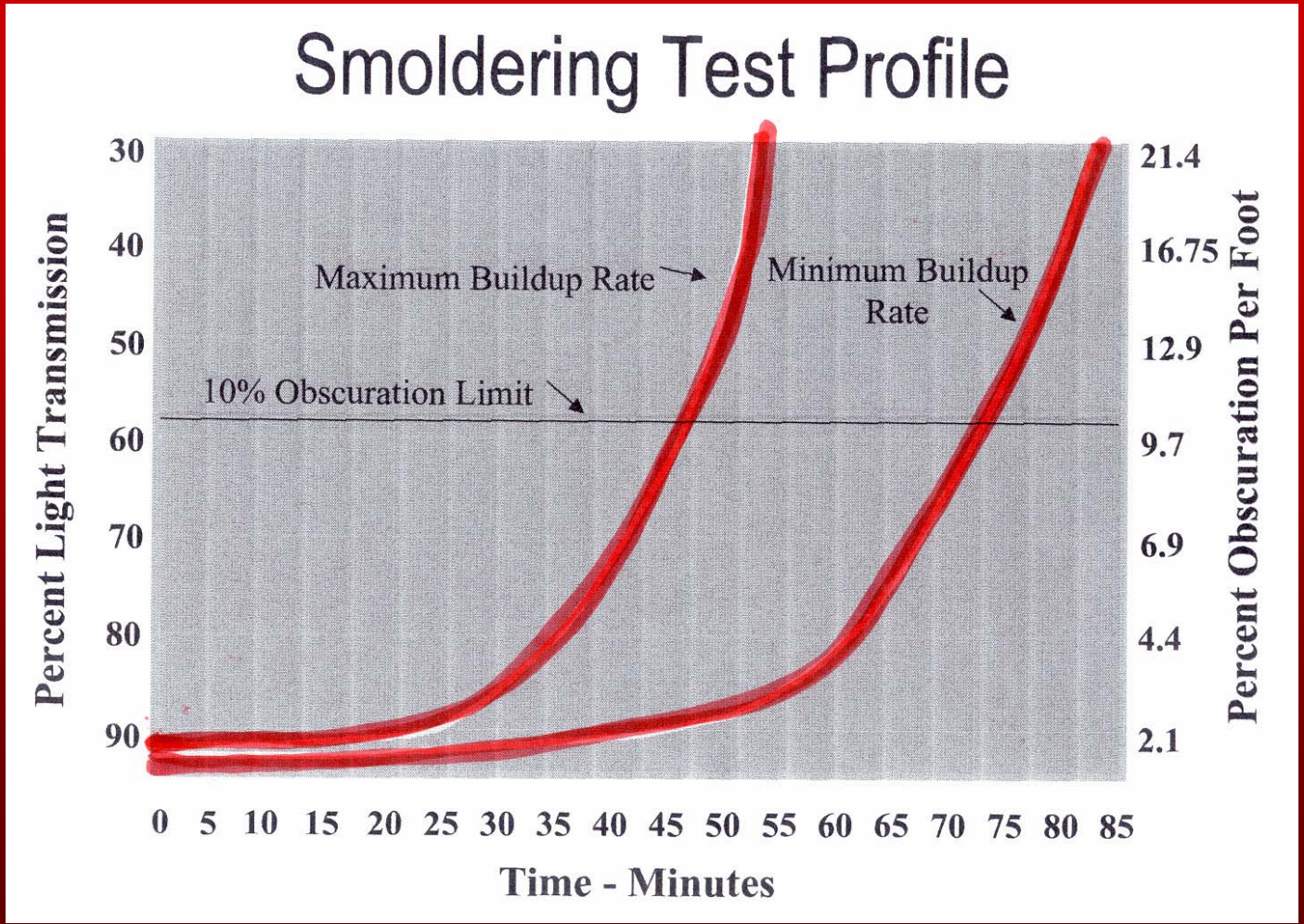
12% OBS/FT – 80%

16% OBS/FT – 65%

20% OBS/FT – 45%



FROM UL FIRE COUNCIL 2004 (Paul Patty's Presentation)



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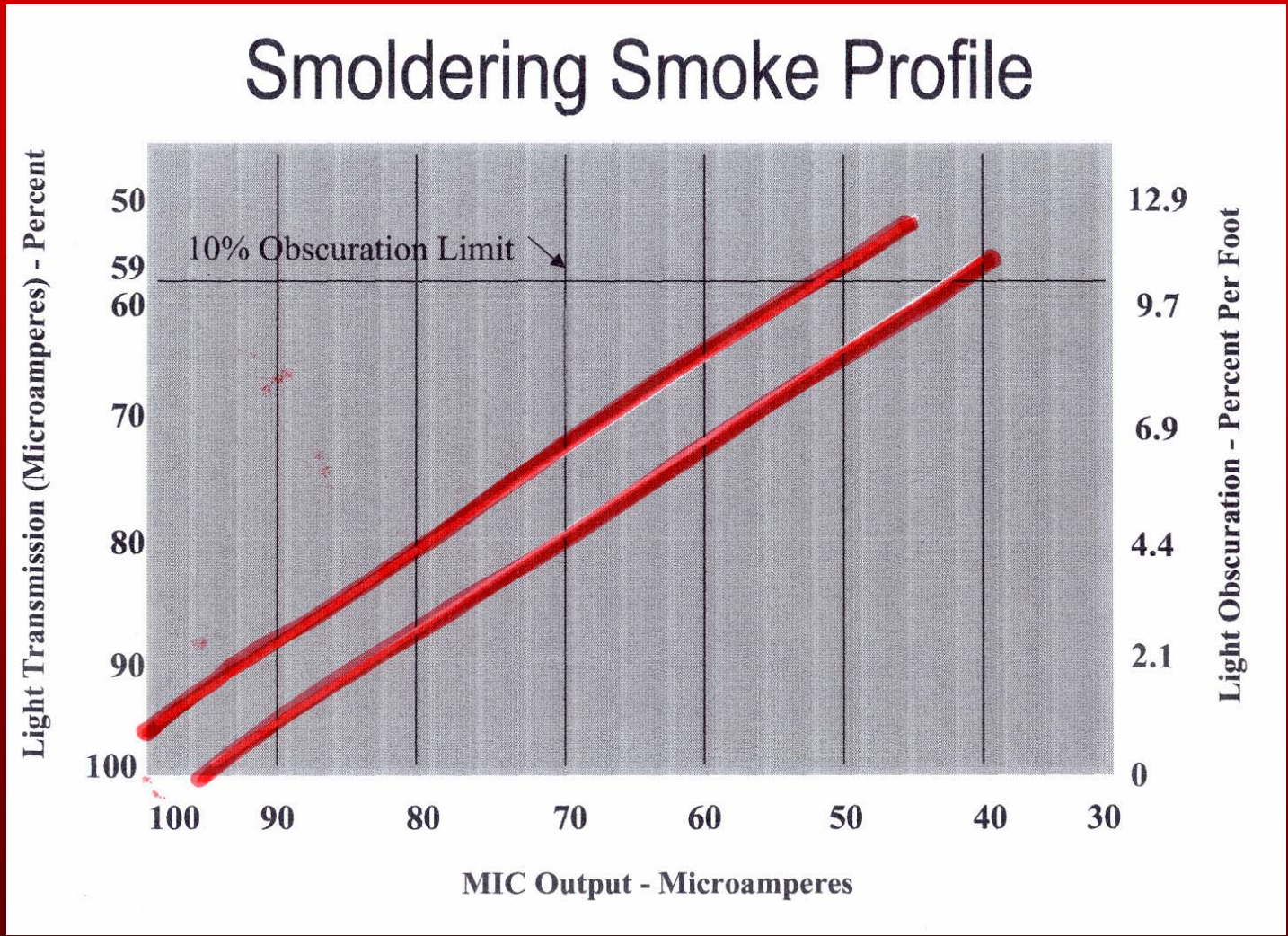

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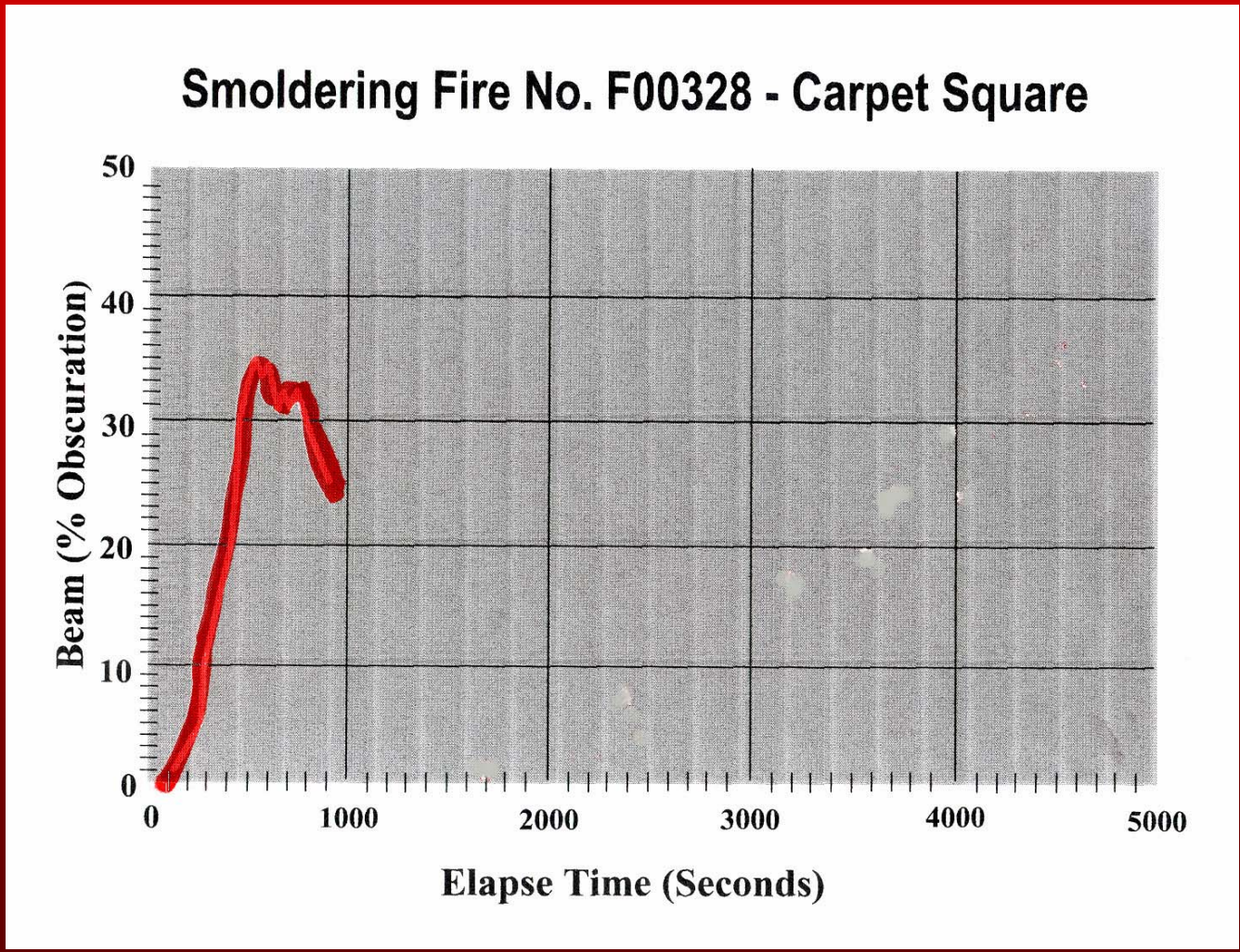
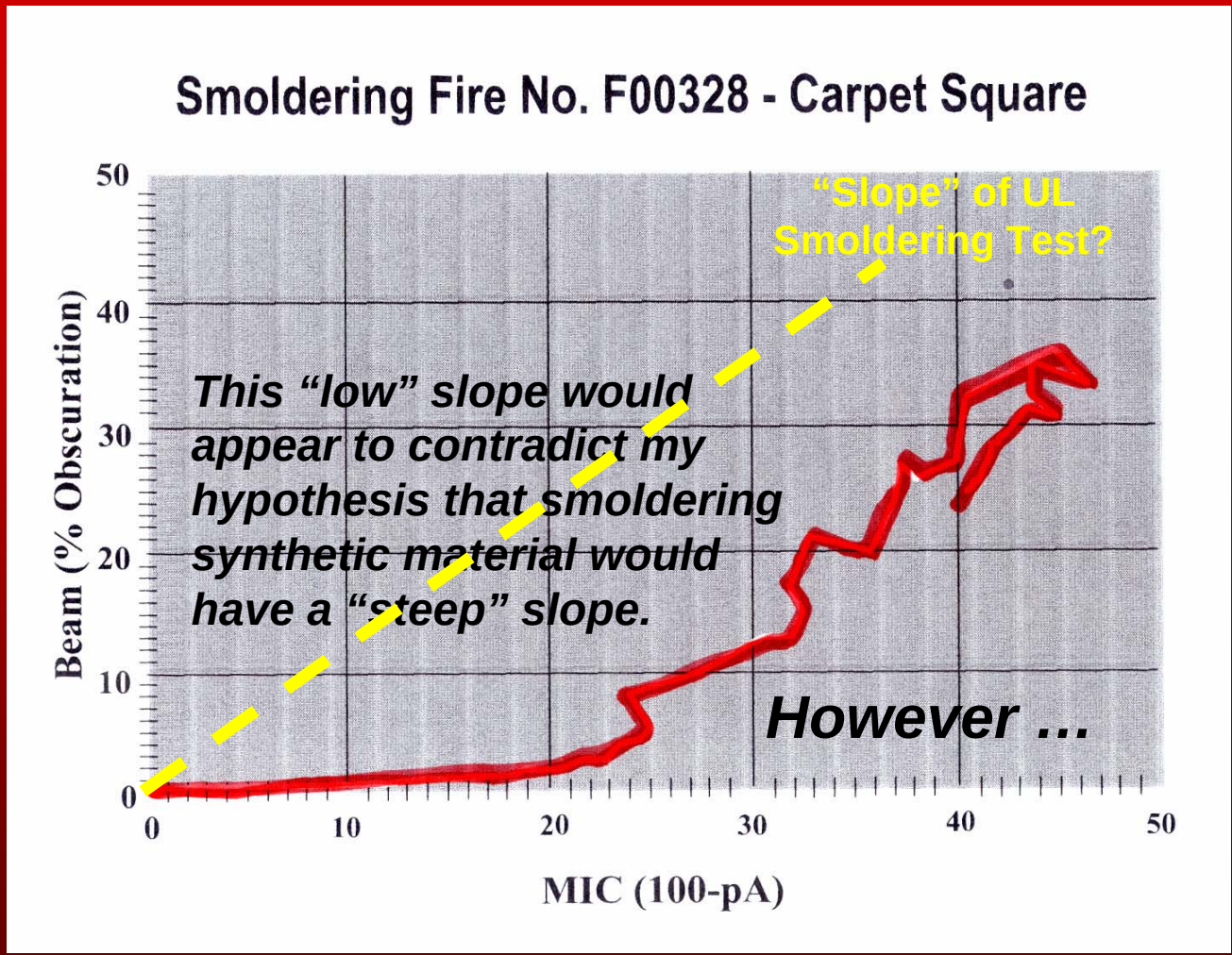
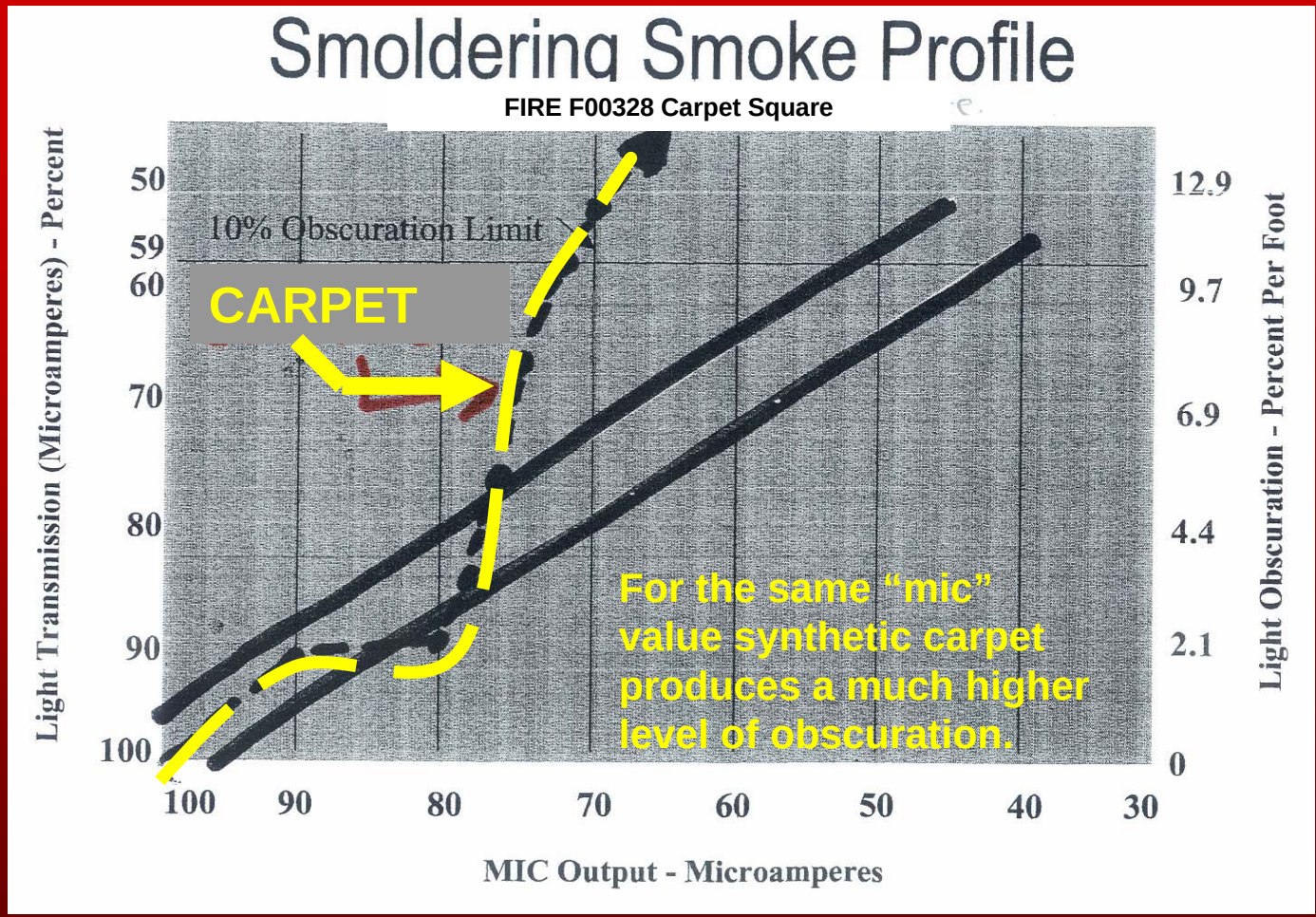


FROM UL FIRE COUNCIL 2004 (Paul Patty's Presentation)



Note: MIC Scale "reversed" and Obscuration Scale "compressed".

CARPET PROFILE - REDRAWN (Using Same Scale as UL217)



QUES: DOES UL HAVE DATA ON OTHER SYNTHETIC MATERIAL?

WHAT % OBS/FT DID ION AND PHOTO RESPOND IN THIS TEST?

PART FOUR

CONCLUSION
AND RECCOMENDATIONS

ARE WE MAKING THE LOGICAL ERROR OF "CIRCULAR REASONING"

A **Original approval tests were justified because "everyone knows SD work". (Therefore the test boundaries were set to the limit that let common detectors pass.)**

A supports B  **B supports A**

B **Manufacturers now say the proof that their detectors are effective is that they pass the UL Tests.**

C **We know smoke detectors are effective because deaths have decreased since their introduction.**

C supports D  **D supports C**

D **We know that most of the reduction is due to smoke detectors because they are effective.**

TESTING RECOMMENDATIONS

- **Add a "2nd Generation" smoldering test, as implied by Harpe and Christian, the designers of the original UL217 Smoldering Test. The smoke profile, (mic vs. obscuration) of this test should "mimic" the kind of smoke given off by today's furnishings, i.e. plastic-based furniture. (The boundaries of this profile will probably be steeper than the current boundaries.)**
- **The growth rate should approximate the growth rate of the smoldering fires in the recent NIST tests. They should reach 10% obs/ft in approximately 45-60 minutes**

DETECTOR INSTALLATION RECCOMENDATIONS (NEW)

- **MASS BLDG CODE**
  - *At least one detector per level (outside bedroom area).*
  - *More than one required if level > 1,200 ft^2 in area*
  - *1 detector per bedroom.*
  - *Battery back-up.*
  - *Interconnected.*
  - *Photoelectric if within 20 ft of kitchen or bathroom.*

- **MY PROPOSAL**
  - *At least one detector per level (outside bedroom area).*
  - *1 detector per bedroom.*
  - *If any room exceeds 300 ft^2 then a detector is required in that room,*
  - *Enough detectors so that any door to a room, that does not have a detector, is within 15 ft. of a detector.*
  - *Battery back-up.*
  - *Interconnected.*
  - *<u>All detectors should contain a photoelectric operating mechanism.</u>*

CODES & UL TESTS SHOULD RECOGNIZE CONSUMER REALITIES (EXISTING)

- **We cannot rely on the free market since we do not have an educated consumer. (Since they do not recognize benefits they often decide purely on cost.)**
  - ***Most studies, as well as NFPA 72, recognize the inappropriateness of ionization detectors near kitchens, yet manufacturers are still advertising ion detectors as useful in "every room", even "kitchens". How is a consumer supposed to critique this type of message? How many read the appendices of NFPA 72?***
  - ***Due to information, incorrect in my opinion, that states both types of detectors are equally effective, why would a consumer choose a photoelectric detector over an ionization detector. How many consumers, or even fire chiefs, will read anything more than the NIST Press Release.***
  - ***Except for large retailers, such as Home Depot or Lowes, many stores do not even carry photos due to low consumer demand. Consumers are not even aware they exists.***

SOME MISC. COMMENTS

- **Why do we allow ionization detectors to be installed in sprinkled residential occupancies? *(The only hazard left is a smoldering fire.)***
- **IF UL217 (Residential) and UL268 (Commercial) Standards use the same fire tests, why does UL72 have spacing limitations for commercial detectors, approx. 22 ft max to combustible, but not residential?**
  - ***Indiana Dunes Researchers recommended 2 detectors in long hallways. In 1980 USFA Researchers recommended 30 ft spacing of detectors in corridors - max. 15 ft to combustible.***
- **UL Canada uses a 7% obs./ft. passing criteria. Does this mean Canadian detectors are more sensitive? Do they have more nuisance alarms?**

SHOULD PEOPLE SLEEP WITH BEDROOM DOORS CLOSED?

- **NIST takes the position that their testing re-inforces the recommendation for people to sleep with their bedrooms doors closed.**
  - ***However, this only becomes a factor if smoke detectors do not sound in time. In addition, if the exitway is blocked, and they cannot escape out a window or be rescued then eventually they will die.***
  - ***A recent CPSC Study indicates that closing the bedroom door increase the probability that the detector will not be heard.***

Therefore, NIST is giving advice that benefits people without working detectors, or ionization detectors in smoldering fires, and NIST is giving advice that endangers people with working detectors.

SUGGESTIONS FOR FC MEMBERS

- **Take sample "off-the-shelf" detectors from Europe, Canada, and America. Run all of them through each test to see if results differ.**
- **Encourage fires to be investigated for *"cause of deaths and injuries"* as well as *"cause and origin".***
  - ***Try to determine if it was smoldering or flaming.***
  - ***Check COhB of victims. High level often supports smoldering scenario. High levels could explain inappropriate behavior.***
  - ***Collect detector determine type and whether or not it had power. Try to estimate if audibility was an issue.***
  - ***If detector disabled, determine if it was too close to nuisance source.***
  - ***Take into account distance of fire from detector.***
  - ***NOTIFY UL OF ANY PROBLEMS DISCOVERED.***

FINAL THOUGHTS

If I am right, by switching from ion to photo technology, (or by developing a smoldering test that represents synthetic material) smoke detectors can finally realize their full potential and fire deaths can be reduced by hundreds of lives per year.

I would appreciate any information that supports, or more importantly contradicts, my opinions to be sent to me as soon as possible.

Thank you.

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