Smoke Alarm Detection Technology

(Prepared for CALFIRE 3-28-11)

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Agenda

- What is required or recommended?
- Photoelectric Versus Ionization
  - Two Task Groups
  - Final TG Report Findings
    - Combination smoke alarms
    - Nuisance Alarm Criteria
    - Other Reports
    - Escape Scenarios
    - Calculating Tenability
  - Concluding Points

Photo and Ion

- What is required or recommended?
  - NFPA, as an organization, recommends using both technologies in homes
  - NFPA 72 does not generally require the use of one technology over the other
    - Except locations near cooking appliances
  - NFPA 72 does recommend the use of both technologies where there is a desire for a higher level of protection or where individuals need extra time to escape (See A.29.1.1)

Photo and Ion

- What is required or recommended?
  - NFPA 72 requires smoke alarms to be installed in <u>every sleeping room</u>, <u>outside every sleeping area</u>, and <u>on every level</u> (See 29.5.1.1)
    - Many older homes do not have smoke alarms in all of these minimum siting locations
  - NFPA 72 requires all smoke alarms to be interconnected, unless exempted (See 29.5.2.1.1)
    - Smoke alarms are now available with wireless interconnection capability

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Photo and Ion

- What is required or recommended?
  - NFPA 72 restricts the installation of any smoke alarm within 10 feet of a fixed cooking appliance (See 29.8.3.4(4))
    - 6 foot exception for smaller homes or apartments
    - No longer 3 feet from kitchen door (2002 code)
  - NFPA 72 restricts the installation of any smoke alarm within 3 feet of a bathroom door (See 29.8.3.4(5))
    - Both technologies are susceptible

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Photo Versus Ion

- Which is better?
  - This question has had a long history
  - Informal demonstration fire test videos prompted renewed interest
  - The NFPA 72 Technical Committee on Single- and Multiple-Station Smoke Alarms and Household Fire Alarm Systems appointed a task group to review issues of effectiveness
  - Ultimately two task groups worked over a period of about two years

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Two Task Groups

- Task Group on Minimum Performance Requirements for Smoke Alarm Detection Technology – Report dated February 22, 2008.
- Task Group on Smoke Detection Follow-up – Report dated July 1, 2009

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Two Task Groups

- Both task groups reported to the NFPA 72 Technical Committee on Single- and Multiple-Station Alarms and Household Fire Alarm Systems – responsible for Chapter 29 of the 2010 National Fire Alarm and Signaling Code.
- Both reports are available on the NFPA Website at www.nfpa.org under “Safety Information” / “For Consumers” / “Fire Safety Equipment” / “Smoke Alarms” / “Ionization versus Photoelectric”

Two Task Groups

- The first task group reported to the technical committee at their Report on Proposals meeting in January 2008 with the results of their work and recommendations for follow-up work.
- Membership on the first task group included technical committee members and other interested parties

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Two Task Groups

- The second task group reported to the technical committee at their Report on Comments meeting in October 2008 with their draft report.
- Membership on the second task group included technical committee members
  - Other parties declined to participate

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Two Task Groups

- The work of both task groups used the data documented in NIST Technical Note 1455-1 (February 2008), Performance of Home Smoke Alarms – Analysis of the Response of Several Available Technologies in Residential Fire Settings

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Final Report Findings

- The second task group assigned two sub-task groups
  - Sub-TG on Smoke Alarm Installation Strategy
    - Combination smoke alarm performance
    - Nuisance alarm installation criteria
  - Sub-TG on Performance Follow-up
    - Review of other reports
    - Escape scenarios
    - Methods of calculating tenability

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Combination Smoke Alarms

- Photoelectric alarms generally respond faster to smoldering fires than ionization
  - Minutes to tens of minutes (e.g. 1.6 to 40 min)
- Ionization alarms generally respond faster to flaming fires than photoelectric
  - Seconds to tens of seconds (e.g. 20 to 100 sec)
- Time differences depend on fire growth rate
  - Times estimated from SDC 01 thru 15 curves

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Combination Smoke Alarms

- Dual photoelectric/ionization smoke alarms offer the advantage both detection technologies in a single unit
- Concern was raised in the initial report that the performance of dual smoke alarms lagged behind that of smoke alarm using individual technology

Combination Smoke Alarms

- The task group reviewed the further work on dual alarms done by NIST
  - "Performance of Dual Photoelectric/Ionization Smoke Alarms in Full Scale Fire Tests" (based on data from NIST TN 1455)
    - http://fire.nist.gov/bfrlpubs/fire09/PDF/f09006.pdf
  - "Results from a Full-Scale Smoke Alarm Sensitivity Study" (based on additional full-scale fire tests)
    - http://fire.nist.gov/bfrlpubs/fire09/PDF/f09007.pdf

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Combination Smoke Alarms

- The following conclusions were reached:
  - Dual alarms usually respond before ionization alarms in smoldering fires and before photoelectric alarms in flaming fires
  - Dual alarms are not always less sensitive than individual alarms
  - Alarms using an individual technology may or may not respond before a given dual alarm at the same location for any particular fire

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Combination Smoke Alarms

- The following conclusions were reached:
  - Sensitivity of off-the-shelf dual alarms used for comparison were more sensitive than the ionization alarm sensitivities specified in the NIST Home Smoke Alarm report
    - Thus for flaming fires, comparable off-the-shelf dual alarms would not be expected to alarm later than the responses computed for the dual alarms in the NIST Home Smoke Alarm report

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Nuisance Alarm Criteria

- Frequent nuisance alarms can result in occupants disabling smoke alarms
- The task group reviewed available literature on causes for nuisance alarm
  - An extensive review is outlined in the 2008 TG Report with additional review provided in the 2009 TG Report
  - Annex D of the 2009 TG report summarizes the overall findings

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Nuisance Alarm Criteria

- Conclusions
  - Although photoelectric and ionization smoke alarms are both susceptible to cooking activities, ionization is more susceptible
    - <u>Both types should be restricted from placement near cooking appliances</u>
    - Surveys have found that smoke alarms are often installed in kitchens despite precautions in NFPA 72
    - New restrictions on placement in NFPA 72 2010

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Nuisance Alarm Criteria

- Conclusions
  - Placement between 10 and 20 feet from cooking appliances
    - Use photoelectric or alarm silencing means
      - Education on the use of the hush feature
    - Trade-off – locating smoke alarms that use ionization technology in this zone can result in a higher potential for cooking related nuisance alarms than those using photoelectric technology, but can provide an improved response to flaming fires when compliance with minimum siting criteria requires installation of a smoke alarm in this zone

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Nuisance Alarm Criteria

- Conclusions
  - Both photoelectric and ionization smoke alarms are susceptible to bathroom steam
    - Ionization smoke alarms are not more susceptible
    - Photoelectric alarms may be more susceptible
    - Placement more than 10 feet from the bathroom door does not appreciably reduce susceptibility
    - No changes with made to the mandatory requirements regarding the 3 foot restriction from bathroom doors. New annex material was added to suggest placement up to 10 feet away if possible

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Nuisance Alarm Criteria

- Conclusions
  - NFPA 72 -2010
    - Specific requirements related to nuisance alarms from cooking activities and bathroom steam are contained in 29.8.3.4(4) and 29.8.3.4(5) on page 72-159 of the code
    - Detailed explanatory annex material (including installation diagrams) is contained in A.29.8.3.4(4) and A.29.8.3.4(5) on pages 72-259 through 72-262

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Other Reports

- California Fire Chiefs Studies
  - Rodin and Graham, 1979
  - Los Angles Fire Department, 1981
  - Either technology provides acceptable warning
- Norway report
  - Meland and Lonvik, 1991
  - UL listed alarms - either technology provides acceptable warning

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Other Reports

- England Study
  - Kennedy et al
  - Did not use smoke alarms
  - Did not provide correlation between sensor measurements and actual smoke alarms

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Escape Scenarios

- NIST 1455-1 report escape scenarios
  - Assumed individuals were not in the room of fire origin
  - Assumed occupants could escape through alternate means of egress (windows)
  - Not aligned with assumptions in NFPA 72
    - See next slide

Escape Scenarios

- NFPA 72 Purpose and Assumptions

  29.2 (11.2)* Purpose. Fire-warning equipment for residential occupancies shall provide a reliable means to notify the occupants of the presence of a threatening fire and the need to escape to a place of safety before such escape might be impeded by untenable conditions in the normal path of egress.

  29.4.1 (11.4.1) Occupants. The requirements of this chapter shall assume that occupants are not intimate with the ignition and are capable of self-rescue.

  29.4.2.3* (new) The escape route shall be along the normal path of egress for the occupancy.

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Escape Scenarios

- Based on NFPA 72 assumptions, tenability evaluations should assume:
  - Escape through the normal path of egress
  - Individuals can be in the room of fire origin and still not be intimate with ignition
  - Individuals are capable of self-rescue
- Evaluations should further consider individuals that might need assistance in awakening or egress

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Calculating Tenability

- NIST 1455-1 report available safe egress times (ASET) were evaluated as the time from the earliest alarm activation to the time when any tenability limit was reached at any location.
  - The first task group observed that tenability calculated on that basis might produce overly pessimistic results since individuals do not necessarily remain in a given (potentially worst case) location

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Calculating Tenability

- The second task group formulated a revised evaluation model
  - Calculate tenability based on the integrated exposure for the individual as they moved through the assumed escape path
  - Two assumed escape paths will be used
    - Direct escape path (NFPA 72 assumptions)
    - Indirect escape path (additional travel to awaken others and then escape)
    - See next two slide for assumed paths

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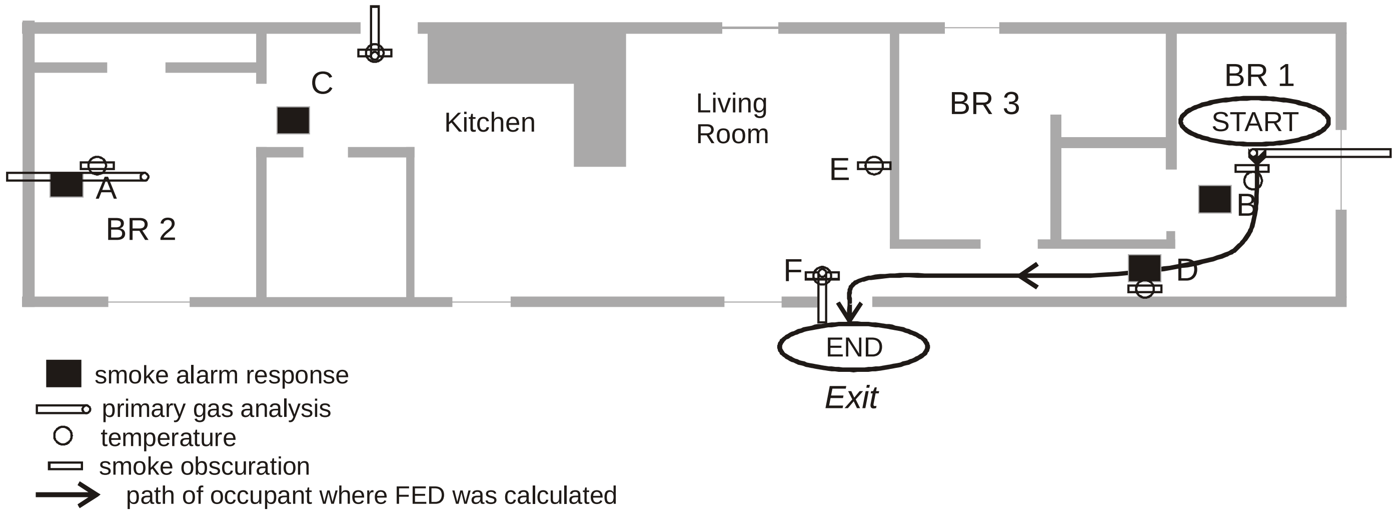
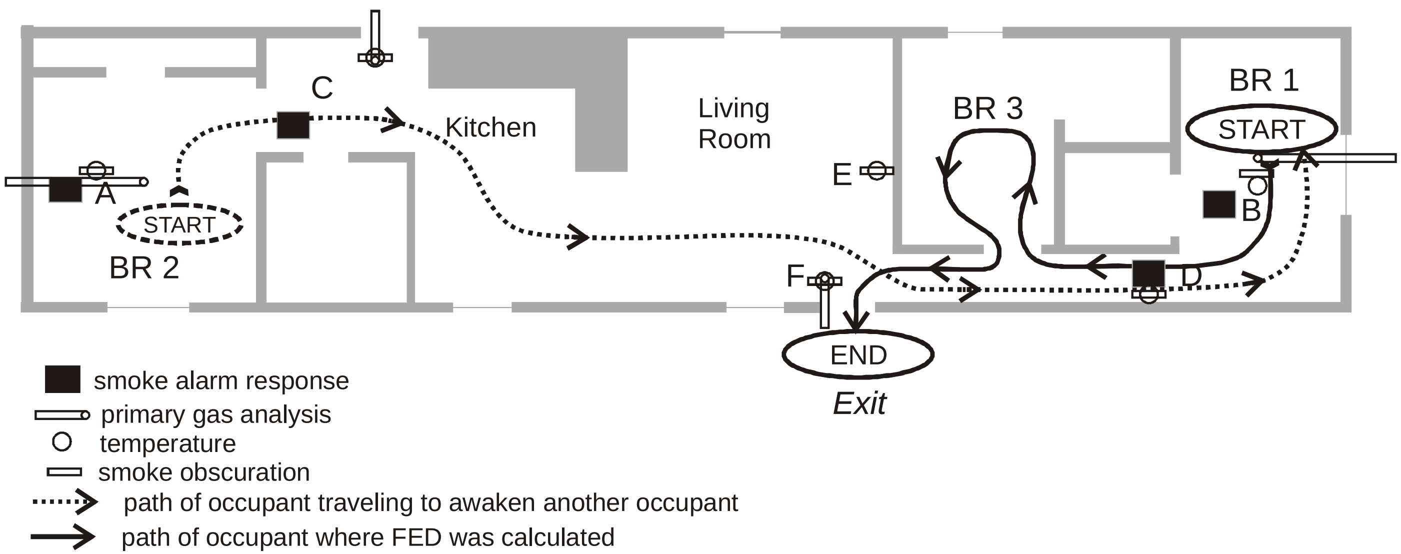
Direct Escape Path – Bedroom 1 – Fire in BR 1



Indirect Escape Path – Bedroom 1 – Fire in BR 1



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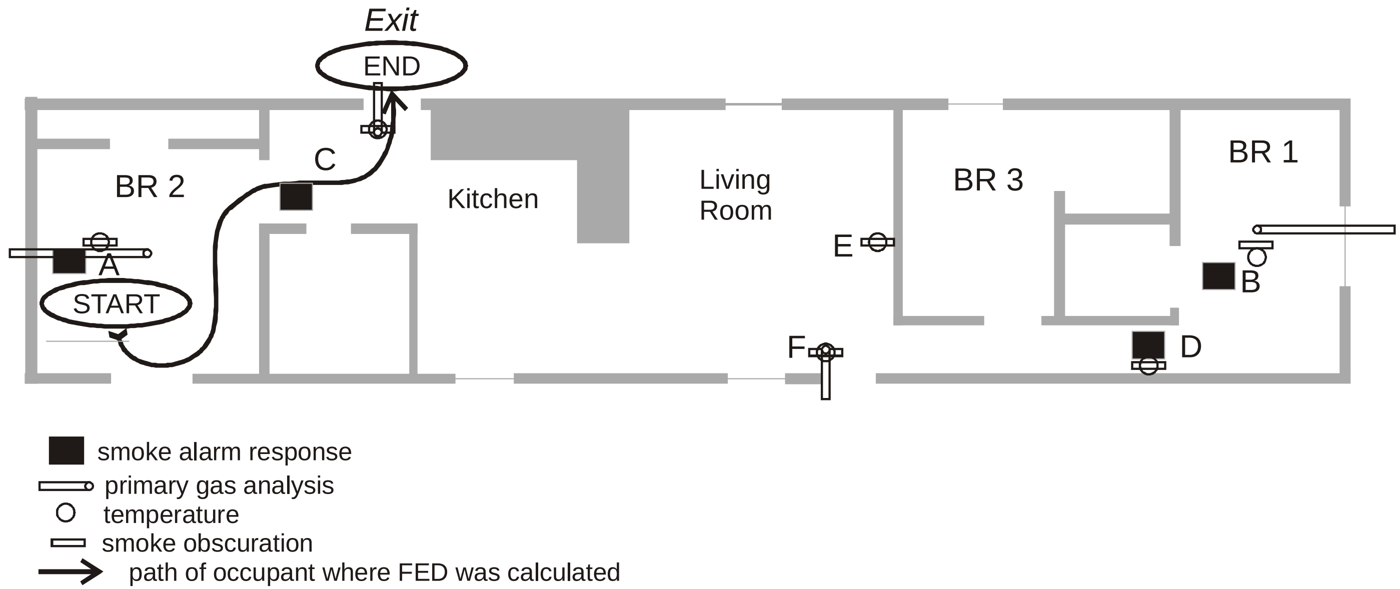
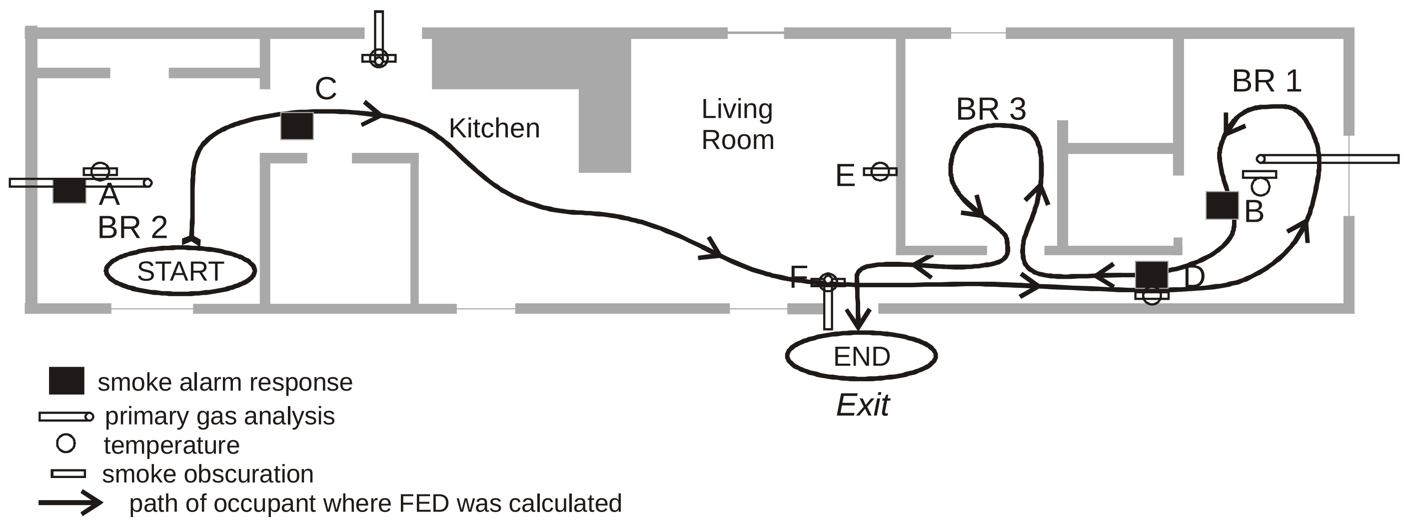
Direct Escape Path – Bedroom 2 – Fire in LR or Kit



Indirect Escape Path – Bedroom 2 – Fire in LR or Kit



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Calculating Tenability

- Tenability Conditions (heat and gas)
  - Evaluated using equations from ISO 13571:2007, Life Threatening Components of Fires – Guidelines on the Estimation of Time Available for Escape Using Fire Data
  - Convective heat – 0.30 FED
  - Toxic gas (CO and HCN) – 0.30 FED

Calculating Tenability

- Tenability Conditions (heat and gas)
  - FED is fractional effective dose
    - An FED of 1 corresponds to the median value of distribution of human responses – one-half the population more susceptible and one-half less susceptible
    - A FED of 0.3 was used to address the more susceptible occupants of the population
  - Refer to the February 22, 2008 Task Group Report for more detailed presentation

Calculating Tenability

- Tenability Conditions (smoke obscuration)
  - Reduced visibility was not considered an incapacitating condition but was included in the evaluations
    - Some have assumed that occupants will abandon efforts to escape when visibility is reduced even if not overcome by heat or gas
    - What reduced visibility will produce this effect?

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Calculating Tenability

- Tenability Conditions (smoke obscuration)
  - An optical density (OD) of 0.22 OD/m was suggested by Jin for safe escape for occupants familiar with a public building
  - An OD of 0.25 OD/m was assumed in the NIST 1455-1 report
  - An OD of 0.43 OD/m was assumed by the task group for residential occupants very familiar with their surroundings
    - Basis in the February 22, 2008 Task Group Report

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Calculating Tenability

- Tenability Conditions (smoke obscuration)
  - A value of 0.22 OD/m is estimated to correspond to about 13 ft assuming light reflecting situations (as opposed to light emitting situations)
  - A value of 0.43 OD/m is estimated to correspond to about 6.6 ft assuming light reflecting situations
  - Measurements were taken 5 ft above the floor

Calculating Tenability

- Results of evaluations (July 1, 2009 TG Report)
  - Direct escape cases - Tables 2.1a and 2.1b
  - 24 cases total
    - Cases SDC 34, 39 & 40 were not included in my summary for heat, gas and visibility (testing anomalies) – leaves 21
    - Cases SDC 9 & 14 were not included in my summary for visibility (no visibility data) – leaves 19

Table 2.1a – Bedroom 1 Fires, Direct Escape Scenarios from Bedroom 1

Fire In Bedroom				
		Alarm provides sufficient safe egress time		
Flaming		Direct Escape		
Door open		Smoke	Heat	Gas
SDC 5	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 7	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 38	ION	Y	Y	Y
	PHOTO	N	Y	Y
SDC 39[2]	ION	-	-	-
	PHOTO	N	-	-
Smoldering door closed				
SDC 14[1]	ION	-	N	Y
	PHOTO	-	Y	Y
Flaming door closed				
SDC 9[1]	ION	-	Y	Y
	PHOTO	-	Y	Y
SDC 36	ION	Y	Y	Y
	PHOTO	Y	Y	Y
Smoldering door open				
SDC 4	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 6	ION	N	Y	Y
	PHOTO	Y	Y	Y
SDC 8	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 37	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 40[3]	ION	-	-	-
	PHOTO	Y	Y	Y

[1]No smoke measurement in room of origin
[2]Test stopped before escapes times were attained
[3]No ionization alarms available in bedrooms or corridors

Table 2.1b – Living Room and Kitchen Fires, Direct Escape Scenarios from Bedroom 2

Fire in Living room				
		Alarm provides sufficient safe egress time		
		Direct Escape		
Smoldering		Smoke	Heat	Gas
SDC 1	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 11	ION	N	Y	Y
	PHOTO	N	Y	Y
SDC 31	ION	N	Y	Y
	PHOTO	N	Y	Y
SDC 34[1]	ION	-	-	-
	PHOTO	-	-	-
Flaming				
SDC 2	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 10	ION	Y	Y	Y
	PHOTO	N	Y	Y
SDC 12	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 13	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 15	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 33	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 35	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 41	ION	Y	Y	Y
	PHOTO	Y	Y	Y

[1]Test stopped before escapes times were attained

Calculating Tenability

- Results of evaluations
  - Direct escape - heat and gas exposure
    - In all 21 cases with both photoelectric and ionization alarms present sufficient safe egress time was provided
    - In 20 out of 21 cases both the photoelectric and ionization alarms individually provided sufficient safe egress time
    - In 1 smoldering fire case the ionization alarm did not provide sufficient safe egress time – exceeded heat exposure FED (bedroom door closed)

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Calculating Tenability

- Results of evaluations
  - Direct escape - smoke obscuration
    - In 17 out of 19 cases with both photoelectric and ionization alarms present sufficient safe egress time was provided
    - In 14 out 19 cases both the photoelectric and ionization alarms individually provided sufficient safe egress time
    - Continued next slide

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Calculating Tenability

- Results of evaluations
  - Direct escape - smoke obscuration
    - In 2 flaming fire cases, the photoelectric alarms did not provide sufficient safe egress time
    - In 1 smoldering fire case, the ionization alarm did not provide sufficient safe egress time
    - In 2 smoldering fire cases, neither the photoelectric or ionization alarm provided sufficient safe egress time

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Calculating Tenability

- Results of evaluations (July 1, 2009 TG Report)
  - Indirect escape cases - Tables 2.2a and 2.2b
  - 24 cases total
    - Cases SDC 33, 34, 35, 39 & 40 were not included in my summary for heat, gas and visibility (testing anomalies) – leaves 19
    - Cases SDC 9 & 14 were not included in my summary for visibility (no visibility data) – leaves 17

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Table 2.2a – Bedroom 1 Fires, Indirect Escape Scenarios from Bedroom 1

Fire In Bedroom				
		Alarm provides sufficient safe egress time		
Flaming		Indirect Escape		
Door open		**Smoke**	**Heat**	**Gas**
SDC 5	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 7	ION	Y	Y	Y
	PHOTO	N	Y	Y
SDC 38	ION	Y	Y	Y
	PHOTO	N	Y	Y
SDC 39[2]	ION	-	-	-
	PHOTO	N	-	-
Smoldering door closed				
SDC 14[1]	ION	-	N	N
	PHOTO	-	Y	Y
Flaming door closed				
SDC 9[1]	ION	-	Y	Y
	PHOTO	-	N	Y
SDC 36	ION	N	Y	Y
	PHOTO	N	N	Y
Smoldering door open				
SDC 4	ION	N	Y	Y
	PHOTO	Y	Y	Y
SDC 6	ION	N	Y	Y
	PHOTO	N	Y	Y
SDC 8	ION	N	Y	Y
	PHOTO	Y	Y	Y
SDC 37	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 40[3]	ION	-	-	-
	PHOTO	Y	Y	Y

[1]No smoke measurement in room of origin
[2]Test stopped before escapes times were attained
[3]No ionization alarms available in bedrooms or corridors

Table 2.2b – Living Room and Kitchen Fires, Indirect Escape Scenarios from Bedroom 2

Fire in Living room				
		Alarm provides sufficient safe egress time		
		Indirect Escape		
Smoldering		**Smoke**	**Heat**	**Gas**
SDC 1	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 11	ION	N	Y	Y
	PHOTO	N	Y	Y
SDC 31	ION	N	Y	Y
	PHOTO	N	Y	Y
SDC 34[1]	ION	-	-	-
	PHOTO	-	-	-
Flaming				
SDC 2	ION	Y	Y	Y
	PHOTO	N	Y	Y
SDC 10	ION	N	Y	Y
	PHOTO	N	N	N
SDC 12	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 13	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 15	ION	Y	Y	Y
	PHOTO	Y	Y	Y
SDC 33	ION	Y	Y	Y
	PHOTO[1]	-	-	-
SDC 35	ION	Y	Y	Y
	PHOTO[1]	-	-	-
SDC 41	ION	Y	Y	Y
	PHOTO	Y	Y	Y

[1]Test stopped before escapes times were attained

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Calculating Tenability

- Results of evaluations
  - Indirect escape - heat and gas exposure
    - In all 19 cases with both photoelectric and ionization alarms present sufficient safe egress time was provided
    - In 15 out of 19 cases both the photoelectric and ionization alarms individually provided sufficient safe egress time
    - Continued next slide

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Calculating Tenability

- Results of evaluations
  - Indirect escape - heat and gas exposure
    - In 2 flaming fire cases, the photoelectric alarm did not provide sufficient safe egress time – exceeded heat exposure FED (bedroom door closed)
    - In 1 flaming fire case, the photoelectric alarm did not provide sufficient safe egress time – exceeded heat and gas exposure FED
    - In 1 smoldering fire case, the ionization alarm did not provide sufficient safe egress time – exceeded heat and gas exposure FED (bedroom door closed)

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Calculating Tenability

- Results of evaluations
  - Indirect escape - smoke obscuration
    - In 12 out of the 17 cases with both photoelectric and ionization alarms present sufficient safe egress time was provided
    - In 7 out 17 cases both the photoelectric and ionization alarms individually provided sufficient safe egress time
    - Continued next slide

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Calculating Tenability

- Results of evaluations
  - Indirect escape - smoke obscuration
    - In 3 flaming fire cases, the photoelectric alarms did not provide sufficient safe egress time
    - In 2 flaming fire cases, neither the photoelectric or ionization alarm provided sufficient safe egress time
    - In 2 smoldering fire cases, the ionization alarm did not provide sufficient safe egress time
    - In 3 smoldering fire cases, neither the photoelectric or ionization alarm provided sufficient safe egress time

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Calculating Tenability

- Results of evaluations
  - TG majority consensus
    - The response to <u>direct escape</u> scenarios was adequate for either technology
      - Possible exception: fires in bedrooms with doors closed
    - Neither technology appears to offer an advantage for nonspecific fires
    - For <u>indirect escape</u> scenarios the use of both technologies is a definite benefit and is recommended
      - Where more time is needed to awaken and/or assist others

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Calculating Tenability

- Results of evaluations
  - TG minority opinion
    - Annex C of final TG report
    - Recommended requiring both technologies in bedrooms
      - Bedroom locations benefit most from using both technologies
      - Photoelectric only 67%, ionization only 71%, both 92%
      - Assumes both direct and indirect cases, smoke, heat & gas
    - Improvement using both technologies in other locations not significant

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Concluding Points

- Exclusion of ionization technology
  - The need for protection from both smoldering and flaming fires is fundamental
  - Excluding ionization technology ignores the benefits of using of both types together
    - Photo and ion individually or combination photo/ion

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Concluding Points

- Restricting ionization technology within 20 ft of kitchen doors
  - Basis for 20 ft from kitchen door?
  - Ignores the benefits of using both technologies together beyond 20 ft of cooking appliances

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Concluding Points

- Restricting ionization technology within 20 ft of bathroom doors
  - Basis for 20 ft from bathroom door?
  - Photoelectric technology is not less susceptible to bathroom steam
  - There is little benefit of restricting either type beyond 10 feet of bathroom doors
  - Ignores the benefits of using both types together in most bedrooms

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Concluding Points

- Smoke alarm installations
  - All homes (regardless of age) should have smoke alarms installed in the minimum siting locations prescribed in NFPA 72
    - Outside each sleeping area
    - On every level
    - Inside every sleeping room
  - All home smoke alarms should be interconnected
    - Especially important for larger homes

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Thank you