Door Position Messaging Strategies
Implications for Detection and Notification

Presented by:
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Motivation

• Public messaging encourages closing of residential bedroom doors
  — UL Firefighter Safety Research Institute (UL FSRI) “Close Before You Doze”
  — Also highlights closing the door when you escape/egress

• Closed doors reduce spread of fire and smoke
  — Increase escape time, particularly out secondary means of escape
  — Increase possibility of Fire Department rescue

• Issues with detection and notification
  — How big are these issues?

• Overall Objective – to provide technical information on these potential issues
  — Should help to inform: How to utilize this information to best “target” or deliver the message, if at all, for maximum effectiveness?

• This study funded through the Fire Protection Research Foundation to examine the issue
Motivation

- NFPA Position (EMAC 2016)

The current message in the 2015 Educational Messages Desk Reference is:

- If you sleep with the bedroom door closed, install smoke alarms inside and outside the bedroom. For the best protection, make sure all smoke alarms are interconnected.

The Committee came to consensus to modify the message to the 2016 Educational Messages Desk Reference:

- A closed door may slow the spread of smoke, heat and fire.
- Install smoke alarms in every sleeping room and outside each separate sleeping area. For the best protection, make sure all smoke alarms are interconnected.
Motivation

- NFPA EMAC still has outstanding questions

Impact educational messaging around this topic. Variables include:

- Will a closed door delay early warning from a smoke alarm located outside the sleeping room?
- Will a single station smoke alarm, installed in the sleeping room with the door closed, provide early warning to a fire outside the sleeping area to allow for safe escape?
- Does a closed sleeping room door impact the use of that door as the primary escape route out of the room?
- What is the impact of a closed door when the fire originates in the sleeping room and no smoke alarm is present in the room?
- About one-quarter of home fire deaths occur from fires that originate in sleeping rooms. How will a closed sleeping room door impact the rates of fatalities?
- Does closing the sleeping room door have the potential to increase risk of injury or death from fire?
- Does a closed sleeping room door have different implications for special populations such as those who have mobility, sensory, or cognitive disabilities?
- Will a closed sleeping room door reduce fatalities in homes if working smoke alarms are not present?

Based on these and other unanswered questions, the Committee recommends additional research to examine these and other variables.
The Problem

- Scenarios of concern from detection and notification perspective:

  **Scenario 1**
  - Bedroom fire

  **Scenario 2**
  - Outside-bedroom fire

  **Fire dynamics/detection concern**
  - Scenario 1
  - Scenario 2

  **Notification/audibility concern**
  - Scenario 1
  - Scenario 2
Current Messaging

- UL FSRI
  - Closeyourdoor.org
- UL FSRI website also includes information on smoke alarms and fire escape plans
  - Both are educational materials from the NFPA
- Many videos from UL FSRI pair the closing bedroom door message with smoke alarm and fire escape planning messaging
- Found instances of smoke alarm messaging being altered or omitted in non-UL FSRI media
Potential Magnitude of the Problem

• NFPA 72, 2007 edition
  – Smoke alarms in sleeping areas, outside sleeping areas (hallways), and on all floors
    • Previously only in hallways outside sleeping areas
  – Interconnection required
    • Due to availability of wireless interconnected smoke alarms
  – Referenced by 2009 edition of the ICC codes
  – Adopted in all 50 states

• Less than 50% have alarms in bedroom
  – Even fewer have them interconnected
The Fire Dynamics/Detection Problem

**Scenario 1**
Bedroom fire

**Scenario 2**
Outside-bedroom fire

Fire dynamics/detection concern

Notification/audibility concern
Fire Dynamics/Detection

- **Approach**
  - Assume non-bedroom origin fires will be first detected by alarm in the hallway (if present) and therefore that is an audibility/notification issue, not a fire dynamics issue
  - For bedroom-origin fires:
    - Analyze fire test data for tests with door open and door closed
    - Analyze both from a hallway alarm and bedroom alarm perspective and determine number of adverse outcomes
    - ASET/RSET analysis (with very conservative tenability criteria)
  - Utilize statistics to determine percentage of residential fires and residential fatalities that may result from closing the bedroom door
Fire Dynamics/Detection

• References considered

NIST Technical Note 1455-1
February 2008 Revision

Performance of Home Smoke Alarms
Analysis of the Response of Several Available Technologies in Residential Fire Settings

Richard W. Buckowski
Richard D. Pascocci
Jason D. Avrill
Thomas G. Cleary
Nelson P. Beynon
William D. Walten
Paul A. Betzke
Erica D. Koshowska

TASK GROUP ON
SMOKE DETECTION FOLLOW-UP
REPORT
Subtask Group 1 - Task Group on Smoke Alarm Installation Strategy
Subtask Group 2 – Task Group on Performance Follow-up

FINAL – July 1, 2009

This report was prepared by the Task Group on Smoke Detection Follow-up, a task group of the NFPA 72 Technical Committee on Single- and Multiple-Station Alarms and Household Fire Alarm Systems (TC). The report is a follow-up to the February 22, 2006 Task Group Report – Minimum Performance Requirements for Smoke Alarm Detection Technology, prepared by the Task Group on Smoke Detection Technology.

Important Note about this Report: This report presents the findings of the Task Group on Smoke Detection Follow-up, which was formed to follow-up on evaluations of an early Task Group on the effectiveness of ionization and photoelectric smoke alarms. This report is advisory only. The information and findings provided in this report do not necessarily reflect the official positions of the Technical Committee on Single- and Multiple-Station Alarms and Household Fire Alarm Systems. The findings of this report do not automatically become adopted as a part of NFPA 72, the National Fire Alarm Code. Changes to NFPA 72 only occur as a result of being processed under NFPA Regulations Governing Committee Projects. The processing of revisions for the 2010 edition of NFPA 72 has been ongoing, subject to the development of this report and will continue in accordance with NFPA regulations under the following schedule:

- Technical Committee Report on Proposals Meeting – April 22-25, 2008
- Comment Closing – August 28, 2009
- Technical Committee Report on Comments Meeting – October 20-24, 2009
- Technical Committee Report on Comments Meeting – January 8-9, 2010
- Report on Comments Posted – February 24, 2009
- Intent to Make Motion Closing Date – April 3, 2009
- NFPA Association Meeting – June 7-11, 2009
- Standard Council Review – August 5, 2010
Fire Dynamics/Detection

Indirect Escape Route from Bedroom 1 – Bedroom 1 Fires

This section corresponds to Table 2.2a in the report.

Figure A.3 – Indirect Escape Route from Bedroom 1

- Smoke alarm response
- Primary gas analysis
- Temperature
- Smoke obscuration
- Path of occupant traveling to awaken another occupant
- Path of occupant where FED was calculated


- Ionization Alert
- Photoelectric Alert

<table>
<thead>
<tr>
<th>Ignition</th>
<th>Time to alarm - Ionization</th>
<th>Travel Segment 1</th>
<th>Bedroom #1</th>
<th>3.5</th>
<th>11.5</th>
<th>87</th>
<th>5</th>
<th>92</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Segment 2</td>
<td>Hallway to Bedroom #5</td>
<td>2.5</td>
<td>8.2</td>
<td>0</td>
<td>3</td>
<td>3</td>
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<td>6</td>
<td>19.7</td>
<td>5</td>
<td>8</td>
<td>13</td>
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<td>Travel Segment 4</td>
<td>Hallway to front door ext</td>
<td>2.5</td>
<td>8.2</td>
<td>0</td>
<td>3</td>
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<tr>
<td>Travel Segment 5</td>
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<td>Travel Segment 6</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td></td>
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<td>Travel Segment 7</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td><strong>TOTALS</strong></td>
<td></td>
<td>14.5</td>
<td>47.6</td>
<td>92</td>
<td>19</td>
<td>111</td>
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</tr>
</tbody>
</table>
• Compared ASET to RSET

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

<table>
<thead>
<tr>
<th>Flame and Door Status</th>
<th>Alarms Provides Sufficient Safe Egress Time</th>
<th>Direct Escape</th>
<th>Smoke</th>
<th>Heat</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flaming door open</td>
<td>ION Y Y Y</td>
<td>Photo</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>SDC 5</td>
<td>ION Y Y Y</td>
<td>Photo</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>SDC 7</td>
<td>ION Y Y Y</td>
<td>Photo</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>SDC 8</td>
<td>ION Y Y Y</td>
<td>Photo</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>SDC 38</td>
<td>ION Y Y Y</td>
<td>Photo</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>SDC 39</td>
<td>ION Y Y Y</td>
<td>Photo</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>SDC 40</td>
<td>ION Y Y Y</td>
<td>Photo</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

Smoldering door closed

<table>
<thead>
<tr>
<th>Flame and Door Status</th>
<th>Alarms Provides Sufficient Safe Egress Time</th>
<th>Direct Escape</th>
<th>Smoke</th>
<th>Heat</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoldering door closed</td>
<td>ION - N Y</td>
<td>Photo</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>SDC 14</td>
<td>ION - N Y</td>
<td>Photo</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>SDC 15</td>
<td>ION - N N</td>
<td>Photo</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>

Table 2.1b – Bedroom 1 Fires, Indirect Escape Scenarios from Bedroom 1

<table>
<thead>
<tr>
<th>Flame and Door Status</th>
<th>Alarms Provides Sufficient Safe Egress Time</th>
<th>Indirect Escape</th>
<th>Smoke</th>
<th>Heat</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flaming door open</td>
<td>ION Y Y Y</td>
<td>Photo Y Y Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>SDC 5</td>
<td>ION Y Y Y</td>
<td>Photo Y Y Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>SDC 7</td>
<td>ION Y Y Y</td>
<td>Photo Y Y Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>SDC 8</td>
<td>ION Y Y Y</td>
<td>Photo Y Y Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>SDC 38</td>
<td>ION Y Y Y</td>
<td>Photo Y Y Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>SDC 39</td>
<td>ION Y Y Y</td>
<td>Photo Y Y Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>SDC 40</td>
<td>ION Y Y Y</td>
<td>Photo Y Y Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
</tbody>
</table>

Smoldering door closed

<table>
<thead>
<tr>
<th>Flame and Door Status</th>
<th>Alarms Provides Sufficient Safe Egress Time</th>
<th>Indirect Escape</th>
<th>Smoke</th>
<th>Heat</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoldering door closed</td>
<td>ION - N N</td>
<td>Photo Y Y Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>SDC 14</td>
<td>ION - N N</td>
<td>Photo Y Y Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>SDC 15</td>
<td>ION - N N</td>
<td>Photo Y Y Y</td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
</tbody>
</table>

No smoke measurement in room of origin

Test stopped before escape times were attained

No ionization alarms available in bedrooms or corridors.
Fire Dynamics/Detection

- **Bedroom door closed**
  - 66.7% success rate if an alarm in the bedroom
  - 0.0% success rate if no alarm in the bedroom (i.e. alarm only in hallway)

- **Bedroom door open**
  - 96.6% success rate if an alarm in the bedroom
  - 96.6% success rate if no alarm in the bedroom (i.e. alarm only in hallway)
Fire Dynamics/Detection

• For bedroom-origin fires
  — If you have an alarm in the bedroom, closing the bedroom door will result in a drop of successful escapes from bedroom fires from 96.6% to 66.7%
    • A change of 29.9%
  — If you do not have an alarm in the bedroom, closing the bedroom door will result in a drop of successful escapes from bedroom fires from 96.6% to 0.0%
    • A change of 96.6%
## Fire Dynamics/Detection

- **Adverse outcomes – fires standpoint – 0.6 – 0.9%**

<table>
<thead>
<tr>
<th>Pharmacology with only a maxwell alarm</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residences with only a hallway alarm</td>
<td>37.0%</td>
<td>52.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in failure rate due to closed door for an alarm in the hallway only</td>
<td>96.6%</td>
<td>96.6%</td>
<td>35.7%</td>
<td>50.2%</td>
</tr>
<tr>
<td>Residences with an alarm in the bedroom</td>
<td>31.0%</td>
<td>43.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change in failure rate due to closed door for an alarm in the bedroom</td>
<td>29.9%</td>
<td>29.9%</td>
<td>9.3%</td>
<td>12.9%</td>
</tr>
<tr>
<td><strong>SUM</strong></td>
<td>45.0%</td>
<td>63.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of fires that have a bedroom origin</td>
<td>7.0%</td>
<td>7.0%</td>
<td>3.2%</td>
<td>4.4%</td>
</tr>
<tr>
<td>Percentage of fires that occur at night</td>
<td>20.0%</td>
<td>20.0%</td>
<td>0.6%</td>
<td>0.9%</td>
</tr>
</tbody>
</table>

- **Adverse outcomes - fatalities standpoint – 2.2 - 3.2%**
• Closed bedroom door may help contain the fire (compartmentalization) reducing flashover and spread beyond bedroom
  — May be a benefit for other occupants in the structure
• Smoke alarm sensing technology/testing will soon be changing
  — Incorporation of nuisance rejection and flaming/smoldering PU foam testing
    • Are the results still valid?
    • Cost?
    • More alarms disabled or less?
• Is there a secondary means of escape out of the bedroom?
  — Benefit of closing a bedroom door may be limited in high-rise residences or other occupancies where the secondary means of escape is not present or unavailable
The Notification/Audibility Problem

- But what if you do not have an alarm inside and outside the bedroom and interconnected?

**Scenario 1**
Bedroom fire

**Scenario 2**
Outside-bedroom fire

Fire dynamics/detection concern

Notification/audibility concern
Notification/Audibility

• Approach
  – Consider a scenario with alarm as far as allowed by code from the bedroom
  – Utilize calculations
    • Halliwell and Sultan (1986)
  – Assess drop in sound pressure level of alarm due to closed door in context of awakening studies and code requirements (75 dBA at pillow)
  – Determine from fire statistics the number of estimated adverse outcomes from closing a bedroom door
notify/Audibility

• Audibility scenario
  — 12’x11’ bedroom
  — 4’ wide corridor
  — Hollow core interior door
  — Varying alarm distance down corridor
  — Varying sound pressure level of the alarm (85-90 dBA @ 10’)

Slide 19
85 dBA @ 10 feet – closed door results
- Under 75 dBA at the pillow when alarm just outside the closed door
- Drops to 64 dBA at maximum allowed distance from the door per NFPA 72 (21 feet)
Bruck and Ball, 2005

High frequency alarm
- 72.5 dBA average mean awakening
- 17.8 dBA standard deviation

Assuming a normal distribution
- 55.6% awaken to 75 dBA (current code requirement)
- 31.6% awaken to 64 dBA (worst case calculation)
- Difference of 24%

Fig. 5. Comparison of the mean dBA levels of different alarms required to awaken young adults under different blood alcohol content conditions (n=12) [10].
• Using statistics on prevalence of fires and fatalities as well as alarm setups:
  — Adverse outcomes – fires standpoint – 1.9 - 3.1%
  — Adverse outcomes – fatalities standpoint – 3.5%
• Alcohol/Drugs
  — Bruck et al., 2007
    • Alcohol reduces waking effectiveness
    • Low frequency more effective

• Low Frequency Alarms
  — ICC considering low frequency alarms for all residences
    • May be just for bedrooms but may end up everywhere
  — Low frequency alarms significantly more likely to awaken,
    even normal hearing subjects
    • 50-100% more awakening at any given dBA level
  — Attenuation is less as well
  — May offset most or all of the door attenuation
    • But battery power issues may result in lesser sound pressure levels for
      See FPRF report by Josh Dinaburg, Jensen Hughes

• Accessory Devices
Benefit of a Closed Door

- Additional benefit added – fires standpoint – 18.6%
  - 93% of non-bedroom origin fires and 20% of fires occur at night
- Additional benefit added – fatalities standpoint – 39.3%

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of fatalities that result from non-bedroom fires</td>
<td>77.0%</td>
<td>77.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of fatalities that occur at night</td>
<td>51.0%</td>
<td>51.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Running total</td>
<td></td>
<td></td>
<td>39.3%</td>
<td>39.3%</td>
</tr>
</tbody>
</table>

- Compared with adverse outcomes from detection and notification, there is a societal benefit from closing the bedroom door at night on a purely technical basis.
Benefit of a Closed Door – Additional Considerations

• Closing doors while escaping will also likely provide a benefit
  — Even if not while sleeping
  — Still provides the compartmentalization

• Could be a few human behavior issues with closing a bedroom door as well
  — False sense of security? – lack of additional fire cues
    • Leads to delayed escape due to lack of urgency from lack of smoke
    • Leads to desire to investigate instead of escape due to lack of smoke
    • Leads to desire to grab belongings
  — May be dealt with through current messaging
    • Upon hearing a smoke alarm, leave the residence and then call 911
    • Have an escape plan and practice it
What Is Not Addressed? – Message Effectiveness

• Workshop on Door Messaging – July 9th, 2019
• Development, delivery, and impact of educational messages
  – How many messages can people handle? – fire escape plan/smoke alarm battery changing/etc.
  – Does fire safety messaging need to focus? On what?
    • 40% of fatalities with no alarm
    • 17% with disabled alarm
  – Or does getting someone’s attention with a bedroom door message create an opportunity?
    • Now tell them about the benefit of smoke alarms too?
  – Does the no-cost nature of closing the bedroom door help or hurt the message?
    • Pro – no $ needed to implement
    • Con – occupants may only close the bedroom door and not install smoke alarms, which does require $
Findings

• Closing your bedroom door at night has merit
  — Potential of preventing significant number of residential fatalities by closing the door (>25%)
  — Closing doors when escaping has merit as well

• Compare with (very conservatively):
  — <5% of all residential fires may have an adverse outcome from closing the door
  — <10% of all residential fatalities that may result from closing the door

• The concerns over the detection and notification aspects should not prevent delivering the closed bedroom door message
  — Closing the bedroom door creates a societal fire safety benefit on a purely technical basis
  — Though adverse outcomes are non-zero – there will be some

• The educational-based aspects of the problem, though, warrant further consideration
Upcoming Report

- Final report – early fall
- Workshop summary will be available
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