Review of Alarm Technologies to Wake Sleeping People who are Deaf or Hard of Hearing

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People with Disabilities in the US

• Approximately **57 million** citizens (18.7 %) are recognized as people with disabilities.
• About **38.3 million citizens** (12.6 %) are recognized as people with severe disabilities.
People with Hearing Loss

• It is estimated that almost 1 out of 100 US citizens over the age of twelve experience hearing loss classified as severe (>60 through 80 dBA) or profound (>80 dBA) hearing loss.
• More than 14 out of 100 US citizens over the age of twelve experience hearing loss to some degree.
• Hearing loss is also more prevalent in older age; as the population ages, hearing loss is likely to increase.
• Commonly used audible alarms are often ineffective at warning people who are deaf and to some extent also people who are hard of hearing.
  – This effect is further enhanced when people are asleep.
The problem

• Traditional fire alarms emit a high-frequency sound to alert the occupants of an imminent threat, which is typically not appropriate for people who are deaf or hard of hearing.

• Research Questions:
  – What are the available alarm technologies for awakening sleeping people who are deaf or hard of hearing?
  – How and when are these technologies effective at awakening people who are deaf or hard of hearing?
  – What regulations, certification and approval processes are these technologies subject to?
Research Goal

• To develop resources on and provide a review of the currently available alternative alarm and detection technologies and their respective characteristics, use cases, regulations and certification and approval processes for the deaf and hard of hearing community.
Methodology

Four Phases of Methodology:
1) Identification 2) Screening 3) Eligibility 4) Inclusion

Relevant information includes:

1. Identified **technologies** to awaken people who are deaf or hard of hearing,
2. The **effectiveness** of these technologies to awaken people who are hard of hearing or deaf,
3. **Negative effects** on other populations from the use of the technology, and
4. **Codes and standards** related to the technologies.
Alarm Technology Landscape

Audible
- High-Frequency Alarm
- Low-Frequency Alarm

Olfactory
- Olfactory Alarm

Tactile
- Air movement
- Bed shaker
- Electric shocks
- Hearing-dog robot
- Heater
- Pager
- Phone under pillow
- Pillow shaker
- Vibrating wristband

Visual
- Strobe Light
Survey: Technology Use by Deaf/Hard of Hearing People

Fixed Strobe Light
Bed Shaker
Pillow Shaker
High-frequency smoke alarm
Overhead lights that rapidly turn on and off
Hearing Dog
Phone under pillow
Low-frequency alarm
Portable strobe light
Vibrating Wristband
Pager
Robotic Hearing-Dog
Air movement
Olfactory Alarm

This is what I use
I have used it, but don't use it anymore
I have heard of it, but have not tried
I have not heard of it
Survey: Recommended Technologies by Support Persons

- Bed Shaker
- Pillow Shaker
- Fixed Strobe Light
- Low-frequency alarm
- Overhead lights that rapidly turn on and off
- Portable strobe light
- High-frequency smoke alarm
- Phone under pillow
- Pager
- Hearing Dog
- Vibrating Wristband
- Robotic Hearing-Dog
- Olfactory Alarm
- Air movement

- This is what I recommend
- I have recommended it before, but don't anymore
- I have heard of it, but have never recommended it
- I have not heard of it
# Audible Alarms

## High Frequency

<table>
<thead>
<tr>
<th>Primary Stimulus</th>
<th>Audible Technology Description</th>
<th>Use/Availability</th>
<th>Effectiveness</th>
<th>Undesirable Consequence</th>
</tr>
</thead>
</table>
|                  | Makes use of a high-frequency sound (>2000 Hz) generally incorporated in smoke detection device. | Widely used. (typically for normal hearing adults) | • **Limited effectiveness** for people with hearing loss.  
• **Not effective** for *deaf people*. | People on autism spectrum may get disoriented. |

## Low Frequency

<table>
<thead>
<tr>
<th>Primary Stimulus</th>
<th>Audible Technology Description</th>
<th>Use/Availability</th>
<th>Effectiveness</th>
<th>Undesirable Consequence</th>
</tr>
</thead>
</table>
|                  | Makes use of a low-frequency sound (around 520 Hz) generally incorporated in smoke detection device. | Available in integrated or standalone devices. | • **Effective** for people with *hearing loss*  
• **Very limited effectiveness** for deaf people | None identified |
## Bed or Pillow Shaker

<table>
<thead>
<tr>
<th>Primary Stimulus</th>
<th>Tactile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>The bed or pillow shaker is most often connected to a device that is to be placed at the bedside table, which detects the sound of a regular smoke alarm and activates the bed/pillow shaker upon detection.</td>
</tr>
<tr>
<td>Description</td>
<td></td>
</tr>
</tbody>
</table>

| Use/Availability | Wide availability from multiple manufacturers  
|                 | Preferred choice when alarm clock functionality is integrated  
|                 | Widely used in deaf and hard of hearing community |

| Effectiveness    | Effective.  
|                 | May be less effective for older people. |

| Consequence      | None identified |

Source: US Fire Administration
Strobe Light

<table>
<thead>
<tr>
<th>Primary Stimulus</th>
<th>Visual</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology Description</strong></td>
<td>Device used to produce regular flashes of light, usually used to accompany audible alarms; particularly in sleeping units. Lights that produce are activated by the fire alarm and flashes. Often hardwired to the fire alarm system.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Use/Availability</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Strobe lights are widely commercially available with many manufacturers globally</td>
<td></td>
</tr>
<tr>
<td>• Sometimes required in public buildings and especially in areas where people are expected to be sleeping.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Effectiveness</th>
<th>Limited effectiveness, but very dependent on installation distance from the occupant.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consequence</td>
<td>Depending on the flashing frequency, it could cause epileptic seizures or disorientation.</td>
</tr>
</tbody>
</table>

Image Source: US Fire Administration
## Summary of Technologies and Respective Effectiveness

<table>
<thead>
<tr>
<th>Technologies</th>
<th>Suggested relative effectiveness</th>
<th>Relative strength of evidence</th>
<th>Field of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-frequency alarm</td>
<td>MEDIUM</td>
<td>VERY STRONG</td>
<td>Not suitable for deaf</td>
</tr>
<tr>
<td>Low-frequency alarm</td>
<td>HIGH</td>
<td>VERY STRONG</td>
<td>Less suitable for deaf</td>
</tr>
<tr>
<td>Olfactory alarm</td>
<td>LOW</td>
<td>MEDIUM</td>
<td>Maybe less suitable for deaf</td>
</tr>
<tr>
<td>Air movement</td>
<td>MEDIUM</td>
<td>LOW</td>
<td>Maybe less suitable for children</td>
</tr>
<tr>
<td>Bed shaker</td>
<td>HIGH</td>
<td>MEDIUM</td>
<td>Maybe less suitable for elderly</td>
</tr>
<tr>
<td>Electric shocks</td>
<td>N/A</td>
<td>VERY LOW</td>
<td>Not applicable as notification technology due to ethical reasons</td>
</tr>
<tr>
<td>Hearing-dog robot</td>
<td>HIGH</td>
<td>LOW</td>
<td>-</td>
</tr>
<tr>
<td>Heater</td>
<td>LOW</td>
<td>VERY LOW</td>
<td>Not applicable as notification technology due to slow reaction time</td>
</tr>
<tr>
<td>Pager</td>
<td>LOW</td>
<td>VERY LOW</td>
<td>-</td>
</tr>
<tr>
<td>Phone under pillow</td>
<td>HIGH</td>
<td>VERY LOW</td>
<td>-</td>
</tr>
<tr>
<td>Pillow shaker</td>
<td>HIGH</td>
<td>MEDIUM</td>
<td>Maybe less suitable for elderly</td>
</tr>
<tr>
<td>Vibrating wristband</td>
<td>MEDIUM</td>
<td>VERY LOW</td>
<td>-</td>
</tr>
<tr>
<td>Strobes</td>
<td>LOW</td>
<td>STRONG</td>
<td>-</td>
</tr>
</tbody>
</table>
Review of Applicable Codes & Standards
Based on international review of codes & standards, only the following technologies are recognized in regulatory documents:

- High frequency alarms (14 standards)
- Low frequency alarms (12 standards)
- Bed/Pillow Shakers (5 standards)
- Strobe Lights (9 standards)
- Air movement devices (1 standard)
The literature concludes that:

- **High frequency-smoke alarms** are **inefficient** in waking people who are deaf and hard of hearing and other vulnerable populations.
- **Low-frequency audible alarms** are **effective** for people who are hard of hearing and for older age groups.
- The recommendation of **strobes** as an alternative alarm technology for awakening people who are deaf or hard of hearing **should be re-evaluated**.
- **Bed/pillow shakers** could be **effective** for people who are hard of hearing or deaf.
Summary Observations

Key takeaways from the survey:

- People who are deaf/hard of hearing do not necessarily commonly use the devices showing strongest effectiveness.

- Support persons and fire safety experts may be recommending technologies that have been proven ineffective in the literature, in some cases.

- Majority of survey respondents who were deaf or hard of hearing indicated they rely on hotel/lodging establishments to provide an appropriate alarm technology for them
  - Additional study on what devices are provided in these establishments may be needed
Next Steps

Outreach & Advocacy:
- Information campaigns are needed towards these target groups (e.g., caregivers, fire & life safety experts, and deaf and hard of hearing community)

Research:
- Experimental research investigating how vibrations transmit when installed in different configurations/locations in a bed is deemed necessary.
- New technologies, such as wearable devices, should be further investigated to establish their effectiveness in waking up people who are deaf or hard of hearing

Standards:
- A usable standard for alarm technologies incorporating tactile signals is needed.
Detection and signaling

Detection and signaling technologies are at the vanguard of SMART and connected solutions to building life safety problems. Our research informs the performance of these systems and characterizes the environments that they respond to.

To learn about older reports, you can:
- see a list of reports, or search and download from the NFPA Library & Archives catalog
- contact the library at +1 617 084-7440

You can also browse NFPA workshop and symposium proceedings on this topic.

Latest report

Review of Alarm Technologies for Deaf and Hard of Hearing Populations

This FFRF report reviews the currently available alarm technologies for the deaf and hard of hearing community and identifies their respective characteristics, use cases, regulations and approval processes.

Download the report.

Download the report at: www.nfpa.org/foundation
Thank You!

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