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Automatic Sliding Door Sensor Safety Analysis

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Abstract: A female pedestrian wearing black clothing was injured when an automatic sliding door closed on her while she was standing at the right door threshold. An accident reconstruction was performed to document the injury mechanism. Testing of the automatic sliding door revealed presence sensor blind zones in the door threshold that are not identified when performing an American Association of Automatic Door Manufacturers (AAADM) safety check. Alternative presence sensor technologies are explored to prevent pedestrian-door contact events.

Keywords: Automatic Sliding Door, Safety, Sensor

1. Automatic Sliding Door Accident Description

On September 22, 2014, a female pedestrian (62 inches tall and weighing 165 pounds) was injured when she was contacted by an automatic sliding door while standing in the door threshold on the right side of the door opening. The pedestrian, wearing black clothing and using a cane in her right hand, was exiting the building through an interior automatic sliding door shown in Figure 1 with a female surrogate. After the pedestrian stood at the right door threshold for approximately two to four seconds, the automatic sliding door began to close with the right door panel contacting the pedestrian's right shoulder. The pedestrian lost her balance and fell to her left onto the floor in front of the automatic sliding door. After the accident, three separate men tested the automatic sliding door by standing in the threshold and the door did not close on them. When a fourth man of smaller stature than the first three men tested the automatic sliding door by standing in the door threshold, the door closed and contacted the man.

2. Automatic Sliding Door Inspection Following Accident

On the day following the accident, an American Association of Automatic Door Manufacturers (AAADM) certified inspector of power-operated automatic pedestrian doors tested the automatic sliding door at issue by standing in the door threshold with the door closing and contacting the inspector (AAADM, 2006). The inspector determined that the combination motion and presence sensors mounted on the header above the door on the inside and outside of the door were improperly functioning. Both combination motion and presence sensors exhibited a green blinking light, which indicates to the inspector that the sensor is reaching the end of its life cycle. The inspector found nine similar combination motion and presence sensors mounted on automatic sliding doors located in the facility following the accident that exhibited green blinking lights, which coincided with the doors closing on the inspector standing in the door threshold during testing. The manual associated with the combination motion and presence sensor did not indicate the meaning of the green blinking light. Other presence sensors display an orange flashing light when the sensor signals an internal fault (BEA, 2010).

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Figure 1. Automatic Sliding Door (Female Surrogate Holding Cane Standing in Door Threshold).

3. Automatic Sliding Door System Characteristics

The automatic sliding door involved in the accident was installed in the facility in 2008. The automatic sliding door system consisted of combination motion and presence sensors mounted on the door header approximately 102 inches above the floor on both sides of the 8 foot high door and horizontal photo electric beams installed on the non-slide side of the door with the lower beam positioned 24.5 inches above the floor and the upper beam positioned 48.5 inches above floor level. However, the photo electric beams were not wired into the system at the time of the accident. The presence sensor can be adjusted as close as approximately 4 – 5 inches from the face of the door. According to ANSI/BHMA A156.10-2005, a minimum of two photo electric beams on one side of the automatic sliding door are required if overhead presence sensors are installed on each side of the sliding door opening with an inactive area exceeding 3 inches from the face of the door (ANSI/BHMA A156.10, 2005). The automatic sliding door opening is 6 feet wide. The operating instructions for the automatic sliding door indicate that each interruption of a safety device (e.g. light beam) leads to the immediate reversal of a closing motion, or prevents it, and initiates a renewed opening. The door remains open as long as the object remains in the door frame. The external safety is actively tested before the beginning of a closing cycle. On failure of the test, the door remains open. No AAADM safety check label was mounted on the automatic sliding door at the time of the accident as required by AAADM (AAADM, 2006). In addition, the automatic sliding door was not equipped with a sign that instructs users to stand clear of the sliding door travel path as required by ANSI/BHMA A156.10-2011 and AAADM (ANSI/BHMA A156.10, 2011 and AAADM, 2006).

Figure 2. Accident Reconstruction (Female Surrogate at Right Threshold Contacted by Closing Door).

4. Accident Reconstruction

The subject accident was captured by a surveillance camera in the facility. Based upon a review of the surveillance video, an accident reconstruction was performed using a 62 inch tall female surrogate wearing black clothing as illustrated in Figure 2. Figure 2A depicts the female surrogate walking with a cane on the right towards the opening interior automatic sliding door from inside the building with another pedestrian on the left entering the building. In Figure 2B, the female surrogate is standing motionless at the right door threshold with her right hand holding the cane. Figure 2C demonstrates the female surrogate's right side being contacted by the closing automatic sliding door.

5. Presence Sensor Detection Time

The presence detection timer prevents the door from closing during the selected time. This timer refers to how long an object can stay in the presence detection area before the sensor will re-learn the detection pattern. That is, the sensor will learn that the object placed there is a normal part of the detection area, and the door will then close. For the combination motion and presence sensor mounted on the automatic sliding door involved in the accident, the presence sensor detection time can be set at two seconds only for testing. The normal presence sensor detection time can be set at 60 seconds, 180 seconds, or infinity. The factory default setting for the presence sensor detection time is 60 seconds. Following the accident, it was discovered that the presence sensor detection time potentially was set to the two seconds testing setting. The AAADM automatic sliding door safety check involves standing motionless in the threshold for at least 10 seconds (AAADM, 2006). There are commercially available presence sensors for automatic sliding doors that possess a minimum detection time of at least 15 seconds (Optex, 2008) and at least 30 seconds (Optex, 2013), which exceeds the AAADM 10 seconds safety check procedure. One sensor manufacturer instructions state to set the presence timer to infinity for when elderly pass through the door (Optex, 2006).

6. Black Clothing Testing

Testing was conducted on the automatic sliding door involved in the accident to determine if the color of the clothing worn by the injured woman had an effect on the ability of the presence sensor to detect her standing in the door threshold. The literature references sensors that have a lower detection performance of people wearing black clothing, which absorbs infrared light (Optex, 2009 and Preece, 2015). Figure 3 depicts the black clothing test results associated with a female surrogate (62 inches tall and weighing 120 pounds) and a male surrogate (71 inches tall weighing 147 pounds) standing in the automatic sliding door threshold. Figure 3A shows the male surrogate wearing a blue shirt standing at the center door threshold where the door remains open. Figure 3B demonstrates the door closing on the male surrogate wearing a black shirt standing in the same location as in Figure 3A. Figure 3C depicts the female surrogate wearing a blue shirt and black pants standing at the right door threshold where the door holds open. Figure 3D illustrates the door closing on the female surrogate wearing a black shirt and black pants standing in the same location as in Figure 3C.

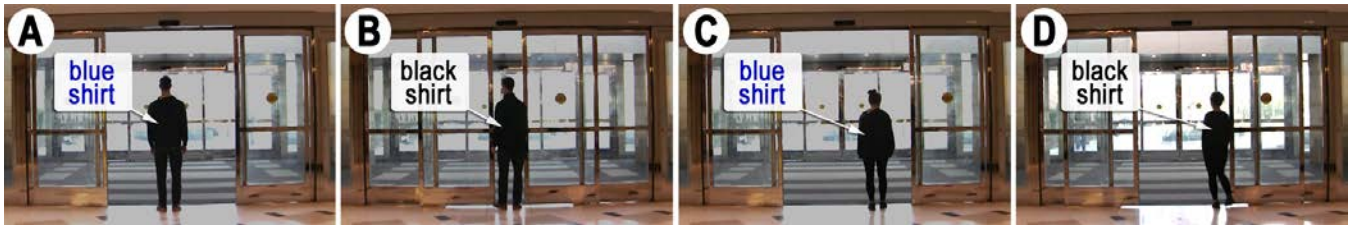

Figure 3. Black Clothing Testing (Surrogates Wearing Black Clothing Contacted by Closing Door).

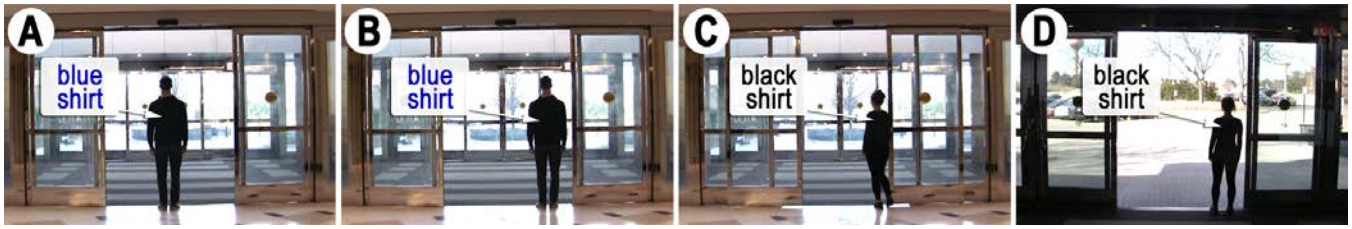

Figure 4. Automatic Sliding Door Safety Check (Surrogates Standing Motionless in Door Threshold).

7. Automatic Sliding Door Safety Check

The automatic sliding door literature contains various methods to perform door safety checks. The AAADM Automatic Sliding Door Owner's Manual indicates to crouch motionless in the threshold for at least 10 seconds to check the safety zone and the door should not close (AAADM, 2010). The AAADM Safety Information Label states to stand motionless on the threshold for at least 10 seconds and the door should not close (AAADM, 2006). The operating instructions for the automatic sliding door involved in the accident state to check the door by approaching the door and passing through it slowly with a short pause time (approximately 5 seconds) before arriving at the door. The automatic sliding door operating instructions indicate that body parts must not be used for functional tests if insufficient space is available. AAADM states that the automatic sliding door safety checks should be performed daily whereas the automatic sliding door operating instructions indicate that the door operator system must be checked for proper functioning at least once every three months. The safety check procedures described by AAADM for automatic sliding doors do not specify where the person should stand, what color clothing the person should wear, and the stature of the person performing the testing.

Frames A, B, and C of Figure 4 show the results of performing a safety check on the automatic sliding door involved in the accident in accordance with the AAADM Safety Information label. Figure 4A illustrates the male surrogate wearing a blue shirt standing in the center accident door threshold where the door remains open. Figure 4B depicts the male surrogate wearing a blue shirt standing at the right accident door threshold where the door holds open. Figure 4C illustrates the female surrogate wearing a black shirt and black pants standing at the right accident door threshold where the door closes on the surrogate. Figure 4D shows the female surrogate wearing a black shirt and black pants standing at the right door threshold of another door in the facility equipped with a different model presence sensor than the sensor mounted on the accident door where the door remains open. This test program results demonstrate that performing the door safety check according to AAADM guidelines in the center door threshold with passing results can still result in a pedestrian being contacted by the same door.

8. Automatic Sliding Door Sensor Header Testing

After the accident, the AAADM inspector found that the header above the automatic sliding door to be in a closed position as shown in Figure 5A. Testing was performed with the door header opened in two separate positions (11/16 inch gap shown in Figure 5B and 15/16 inch gap depicted in Figure 5C) to analyze the performance effects on the type of combination motion and presence sensor involved in the accident. Results indicate that the automatic sliding door started to open when the female surrogate shown in Figure 4 was 43 inches from the door face with the door header closed. The

automatic sliding door opened when the female surrogate was 66 inches from the door face with the door header open 11/16 inch. The automatic sliding door opened when the female surrogate was 70 inches from the door face with the door header open 15/16 inch.

Figure 5. Automatic Sliding Door Sensor Header Testing.

Testing of the presence sensor was also performed with the door header in the same three positions as previously described. There was no noticeable difference in the performance of the automatic sliding door presence sensor in the three door header positions (closed, 11/16 inch open, and 15/16 inch open). The male surrogate wearing a blue shirt standing at the center door threshold was not contacted by the automatic sliding door with the header in the two open positions. The automatic sliding door closed on the female surrogate wearing a black shirt and black pants standing at the right door threshold with the header in the two open positions.

9. Alternative Automatic Sliding Door Presence Sensors

The combination motion and presence sensor model mounted on the automatic sliding door involved in the accident was available as early as 2002. Various alternative automatic sliding door presence sensor technologies are explored as follows.

9.1 Ceiling-Mounted Presence Sensors

Ceiling-mounted presence sensors provide alternative position and performance compared to header-mounted presence sensors for automatic sliding doors. One ceiling-mounted door presence sensor allows for adjustment to within one inch of the moving face of the door (Optex, 2007). Another ceiling-mounted presence sensor produces a 36 spot safety curtain, combined with advanced door learn technology to protect pedestrians in front of and between the moving door leaves. This presence sensor has a self-monitoring control function that holds the door open when the self-monitoring determines that the sensor has malfunctioned (Hotron, 2014). An additional ceiling-mounted presence sensor possesses visible spots to verify the position of the infrared curtain (BEA, 2014).

9.2 Through the Threshold Presence Sensors

An example of through the threshold sensor technology is an infrared and microwave combination sensor designed for automatic sliding doors that offers presence detection in the threshold when the door is in the open position (Optex, 2014). Once the area is cleared, the sensor will ignore the door panels and allow the door to safely close. The manual for this sensor states to inform the building owner/operator to contact your installer or service engineer when the operation indicator blinks green. Another presence sensor tracks any object while in the infrared presence zone as well as in the threshold area. (Besam, 2007). The focused active infrared (safety zone) remains active even during the closing cycle of the door. Before every closing cycle, this presence sensor is questioned by the door control microprocessor to assure the sensor is functioning properly. If the sensor does not reply per pre-programmed operational settings, the doors are prevented from closing. An additional overhead threshold safety sensor is mounted directly above the door opening and senses presence in the threshold zone (Stanley, 2012). The zone covers the full width of the door opening and extends approximately 10 inches on either side of the threshold.

9.3 Sensor Audible Warning

A variety of audible warning technologies are available to alert the pedestrian regarding the status of the automatic sliding door. For example, the patent literature describes a vocal warning issued by the automatic door system to protect a person who stops in the doorway (Ikeuchi, 2004). A further patent presents both a visual and an audible warning of an automatic door about to open, while opening, when opened, about to close, and while closing (Finn, 2013).

Another sensor possesses a voice warning feature that delivers a voice message to anyone entering the protected area (Optex, 2000). A bed occupancy detector for beds in nursing homes and elderly care environments sounds an alarm when the patient leaves the bed (Optex, 2009). The sensor is based on vision technology and utilizes infrared light for detection assistance in dark conditions. In 2009, Underwriters Laboratories (UL) began requiring an end-of-life warning to alert homeowners when their carbon monoxide (CO) alarm has reached the end of its useful life. Kidde has included this audible warning feature in all of its CO alarms since 2001 (Kidde, 2016). When the CO alarm nears its end of life, it will beep two times every 30 seconds.

10. Conclusions

Results of the safety analysis determined that a series of factors combined to cause the automatic sliding door accident. The combination motion and presence sensor mounted on the door header exhibited erratic behavior and possessed blind spots in detecting the presence of a 62 inch tall female wearing black clothing standing at the right door threshold where the injured woman was positioned at the time of her accident. This sensor displayed a green blinking light indicating the sensor is reaching its end of useful life, which was not communicated to the facility owner. The automatic sliding door installer failed to wire the two door threshold photo electric beams into the system and also failed to install the required safety decals on the door in accordance with the applicable ANSI safety standards. In addition, the automatic sliding door system was not configured according to the door manufacturer's specifications to hold the door open upon sensor failure. Testing of the automatic sliding door sensors revealed that they were not adjusted properly. Following the accident, it was discovered that the presence sensor detection time potentially was set to the two seconds testing setting instead of the 60 seconds factory default setting for normal presence sensing operation. The building owner was not adequately notified about the proper method for performing a safety check for the automatic sliding door. Testing of the automatic sliding door shows that the door is capable of closing on a female surrogate wearing black clothing standing at the right door threshold immediately after the door satisfactorily passes an AAADM door safety check. Technically and economically feasible alternative automatic sliding door sensor technology is available to prevent similar accidents from occurring in the future.

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