Direct Visual Signaling as a Means for Occupant Notification in Large Spaces
Research Project

Technical report

Prepared by

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FOREWORD

In April of 2005, the Fire Protection Research Foundation's Detection and Alarm Research Council identified the need for a study of direct visual signaling as a means for occupant notification in large spaces. This need was based on the promise shown by some previous limited testing that demonstrated the potential for direct signaling for notification and a request from the NFPA 72 Technical Committee on Notification Appliances for Fire Alarm Systems for additional data to substantiate the addition of text to the Annex explaining possible direct signaling effects in large spaces. The project was initiated in July of 2005.

The Research Foundation expresses gratitude to the report author, Robert Schifiliti, P.E., the Project Technical Panel: Bob Boyer, Dan Grosch, Dave Lowrey, Harry Massey, Jeff Klein, Lee Richardson, Paul Patty, Ray Grill, and Rein Haus, and the project sponsors: GE Security, Honeywell, Siemens Building Technologies, SimplexGrinnell, Wheelock Inc., National Electrical Manufacturers Association, and the Automatic Fire Alarm Association for their support.

The content, opinions and conclusions contained in this report are solely those of the author.

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Sponsors

Automatic Fire Alarm Association

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Siemens Building Technologies

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Direct Visual Signaling as a Means for Occupant Notification in Large Spaces

An Engineering Study Sponsored by the Fire Protection Research Foundation

Principle Investigator:
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1. EXECUTIVE SUMMARY

The requirements for the installation and performance of visible signaling in NFPA 72, the *National Fire Alarm Code*, are based on occupants being alerted by indirect signaling effects[1]. That is, they are alerted by the illumination of their surroundings, not necessarily by direct viewing of the signaling appliance.

The testing that led to the requirements in NFPA 72 was limited to classroom and office type spaces[2]. The methodology was never tested in large, well lit spaces such as warehouses, large "super stores", etc. Nevertheless, because strobes are required by other codes in these spaces, the installation and performance requirements of NFPA 72 are being enforced despite the lack of any technical foundation. In some cases, authorities are imposing their own requirements such as not allowing ceiling mounted appliances. The Annex of NFPA 72 states that there may be more efficient methods of visible signaling in large spaces such as warehouses and distribution centers.

NFPA 72 permits a performance based design approach that actually exceeds the prescriptive requirements for visible signaling[3]. Ad hoc testing in a large home supply store showed that such an approach may be effective, but not necessarily for the same reasons that it works in smaller spaces. The tests showed that high ambient light levels resulted in little or no *indirect* signaling effect in some parts of the space. The signal-to-noise ratio produced by the operating strobes was low in many locations. However, with strobes located over the aisles or unobstructed by stock, *direct* signaling and some indirect signaling was achieved.

As a result of that test, a proposal was submitted to the NFPA 72 Technical Committee on Notification Appliances for Fire Alarm Systems to add text to the Annex explaining possible direct signaling effects in large spaces. The committee accepted the proposal but requested that additional data be gathered and added in the form of a Comment on the Report on Proposals[4]. A proposal for limited research and testing was submitted to the Fire Protection Research Foundation. The proposal was accepted and the project was funded.

Tests were conducted in three different warehouse type stores. The results show that it is possible to have effective occupant notification by strobes installed per the requirements of the performance-based section of NFPA 72. Occupant alerting is achieved by a combination of direct and indirect signaling. The tests highlighted additional factors that designers, installers and owners should consider in order to increase the effectiveness of systems in large spaces. As a direct result of this project, the NFPA 72 Technical Committee on Notification Appliances drafted a Committee Comment revising the Annex text regarding visible signaling in large spaces to incorporate ideas and concepts found in the testing.

2. INTRODUCTION

The NFPA 72 Technical Committee on Notification Appliances recognized that the effectiveness of the prescriptive and the performance based requirements for visible appliances had not been tested in large volume spaces. The Fire Protection Research Foundation was asked to consider sponsoring a project to address some of the committee's concerns[5].

A two-phased research initiative was proposed. This project represents only Phase 1. In Phase 1, testing was done in large warehouse stores to test the hypothesis that the current performance based approach provides sufficient direct alerting of occupants. The principle goal of this project was to test the effectiveness of strobe systems in large volume spaces designed and installed using the performance based approach of NFPA 72, 2002. A secondary goal was to understand if occupant alerting was the result of direct or indirect signaling. The main objective was to draft text for inclusion in the Annex of the 2007 edition of NFPA 72 that would provide designers, installers and authorities some guidance on how to configure systems to provide effective alerting in these challenging spaces.

Phase 2, if approved and funded, will be a separate project. Phase 2 will extend testing to other large spaces such as malls and atria. The principle goal of Phase 2 is to test the performance based methods in more challenging visual environments. A second goal is to gather sufficient data to permit drafting of code text permitting or limiting the performance based approach as an acceptable method of occupant notification in large volume spaces. This may potentially move Annex text on suggested design and installation issues into the body of the code. Phase 2 may also consider other visible signaling methods or performance criteria.

This project (Phase 1) was intentionally designed for quick, but meaningful results. The project began in mid July 2005 and needed to be substantially complete by the end of October to provide feedback to the code committee. The project did not seek to define all variables and their required parameters for success. Instead, the systems were studied as a whole to determine if they were effective. Engineering analysis of the tests resulted in the identification of several variables that affect the success of the systems in alerting occupants. This allowed some information on design and installation practices to be proposed for inclusion in NFPA 72.

The Fire Protection Research Foundation formed a Project Technical Panel to monitor project progress, review and comment on any interim or draft reports and to release the final project report. The Project Technical Panel consisted of:

Robert Boyer	GE Security
Ray Grill	Arup Fire (Chair of the NFPA 72 NAS TC)
Dan Grosch	Underwriters Laboratories, Inc.
Rein Haus	Wheelock, Inc.
Jeffrey Klein	System Sensor, Inc.
David Lowry	Boulder Fire Department
Issac Papier	Honeywell Life Safety
Jack Poole	Poole Consulting Services, Inc.
Lee Richardson	National Fire Protection Association, NFPA 72 Liaison

3. PROJECT PARTNERS

The Fire Protection Research Foundation is the principle sponsor for this project. They have provided a grant to R.P. Schifiliti Associates, Inc. to conduct tests, draft code language and write a report.

One of the principle goals for this project was a quick turn-around and a second was low cost. To achieve these goals the help of other organizations was solicited. Project Partners were solicited to provide facilities for testing, technicians to assist in the tests and other services necessary to move the project forward. Several Project Partners have provided in-kind donations of time, facilities and services. In addition to the corporate support, several individuals within these companies have been instrumental in setting up and conducting the strobe tests.

TVA Fire & Life Safety, Inc. offers comprehensive fire protection, life safety, security, engineering, risk management, and loss control services to Fortune 500 companies including Home Depot and Wal*Mart stores. They donated time and assisted in setting up tests at Home Depot locations. In addition, they provided engineering information about the installed systems and coordinated technicians from FMG for conducting the tests at the Home Depot test sites.

The Home Depot is the world's largest home improvement retailer and second largest retailer in the United States. They donated the use of their stores as test sites.

Fire Materials Group (FMG) provides professionally managed fire and life safety services. They provide fire alarm inspection, testing and maintenance services for the Home Depot. FMG donated the services of their technicians for conducting tests at Home Depot locations.

Wal-Mart Stores, Inc. is the world's largest retailer. They have donated time and permitted testing in their stores. Wal-Mart Security Services donated time and assisted in setting up testing at the Kissimmee, FL test location. They have also provided Wal-Mart fire alarm technicians for conducting tests.

American Sign Language Interpreting Services (ASL Services) is a nationwide company dedicated to providing the highest quality of professional and ethical Sign Language services at reasonable prices to the community in accordance with the communication preferences of the Deaf and Hard of Hearing persons they serve. ASL provided the services of an interpreter during the testing in Kissimmee, Fl.

4. TEST PLAN

The test plan began with the development of a detailed *Test Protocol*. A copy of the protocol is reproduced in Section 14 to this report. The protocol was used as a checklist for each test. In summary, participants were solicited and asked to walk around the store. The fire alarm system was then activated. Pre and post test surveys were used to gather data.

For each site, information was gathered concerning the design and installation of the strobe alerting system. Ceiling heights were either obtained from plans or measured. The mounting height of strobes, relative to the floor, the ceiling and lighting fixtures was measured. Stock heights, aisle widths and rack widths were measured in several locations. Ambient light measurements were taken throughout the stores.

At each test location a reception/gathering point for participants was established outside, in front of the main entrance to the store. Refreshments were provided for the participants. Because the project used human test subjects, an Informed Consent Form was required. Section 15 contains a copy of the *Participant Information Sheet & Consent Form*. As each person arrived, they were given a numbered nametag. Their participant number was used on all forms as the means of tracking the participant. Each person was asked to read, initial and sign a consent form. The form was checked for completeness and the person was asked if the had any questions, which were then answered.

A tool was developed to gather pertinent information about the test participants. A blank copy of the *Participant Survey – Pre-Test* is included as Section 16. After completing the Consent Form, they were given the Pre-Test Survey to complete. Each survey form was checked to determine if there were any conditions that might be cause for a person to not participate. (None were noted for any of the tests.)

Test participants were each given a small note card with instructions and reminders about what they were to do during the tests. A copy of the card is reproduced in Section 17. The group was given verbal instructions and asked to enter the store and go "shopping".

The store's paging systems were used to make verbal announcements that a test was in progress. After participants had been in the store for 10 to 20 minutes, the fire alarm system was activated. The group returned to the gathering point where they were given a Post-Test survey (*Participant Survey – Post-Test*, Section 18). Each Post-Test Survey was checked for completeness and, if necessary, questions were asked and the form marked for clarity or completeness.

After all forms had been gathered a group discussion was initiated to gather addition feedback and information. The group discussions were valuable in getting qualitative information about the pros and cons for each test scenario. This was particularly valuable for participants that took part in more than one test.

5. TEST LOCATIONS

The first two test sites were Home Depot stores located in Reading, MA and Danvers, MA. Invitations to participate were sent to members of the NFPA Technical Committee, NFPA staff, members and affiliates of the New England Chapter of the Society of Fire Protection Engineers and several deaf and hard-of-hearing organizations, including Self Help for the Hard of Hearing (SHHH).

A third test was planned for a Home Depot in Plaistow, NH and a fourth was planned for a Wal*Mart in Plymouth, MA. Both tests were cancelled after receiving only a few responses from persons invited to participate. A test was then scheduled to coincide with the NFPA 72 Report on Comments meeting taking place in Orlando, Fl.

Because the tests were taking place in businesses that were already occupied and open for business, the owners required testing to be done during early morning hours (6:30 – 7:30 AM) when there were few public customers in the stores. While this limited the ability to include "walk-in" participants, it did minimize the "Cry Wolf Syndrome" impact of the testing[6]. The early test time also affected the ability to get participants. In some cases it helped to get persons to come before or on their way to work. However, the time probably caused some people to decline participation.

Lighting in each of the locations was provided by fluorescent lamps. The Wal*Mart store also had skylights. The Illuminating Engineering Society of North America (IESNA) defines these spaces as "High Activity Spaces" with minimal sales assistance and products that are easily recognizable[7]. The recommended lighting level varies with the specific use of the space. IESNA recommends the following levels:

Area	Level	
	lux	ft-candles
Circulation	323	30
Merchandise	1,076	100
Feature displays	5,382	500

Lighting levels for all three locations were within the range for general circulation and merchandise areas. The highest levels were found in the carpet and lighting displays of the two Home Depot stores. Ranges were on the order of 431 – 1937 lux (40 – 180 ft-candles).

5.1. Home Depot, Reading, MA

The test at this location took place on August 24, 2005. There were 13 participants. The fire alarm system at this location was designed and installed to permit the audible signal to be disabled separate from the visible signals. This allowed the strobe lights to be activated without any audible signal.

Table 1 is a summary of relevant building and environmental information. Table 2 summarizes information about the strobe light system.

Nominal ceiling height:	27 ft
Nominal height to top of storage:	16 ft
Range of ambient light level:	538 – 1,937 lux 50 – 180 ft-candles
Ceiling configuration:	Metal deck (white/gray) on I beams. All utilities exposed.

Table 1 - Building Information

Strobe location:	Mounted below the ceiling, 23 ft above the floor at the same level as the fluorescent light fixtures.
Strobe spacing:	Varies. Nominal 45 - 48 ft spacing in open areas and in aisles.
Strobe intensity:	75 cd. eff. per drawings (one unit found to be only 15 cd eff.)

Table 2 - System Information

The strobes at this location are located below the ceiling, at about the same level of the hanging fluorescent lights. The original design called for the strobes to be located over the aisles, between racks. Within each aisle, the strobes are spaced approximately 45 to 48 ft. Rack spacing varies with most 16 ft on center and some as much as 30 ft on center. Thus, strobe coverage might be 45 ft x 16 ft in order to provide a line of strobes in each rack aisle. However, after the system was installed, the rack layout was altered resulting in many lines of strobes not falling directly over an aisle.

The strobes at this location are the multi-candela type that is field adjustable. After the test it was found that at least one strobe was never changed from the nominal 15 cd eff. out-of-the-box setting.

Photo 1 shows a picture of a typical rack aisle with a strobe located directly overhead. A close-up of the strobe in Photo 2 shows the ceiling configuration and the location of the strobe relative to the building lights and structural steel.

Photo 1 - Strobe Over Aisle (Reading, MA)

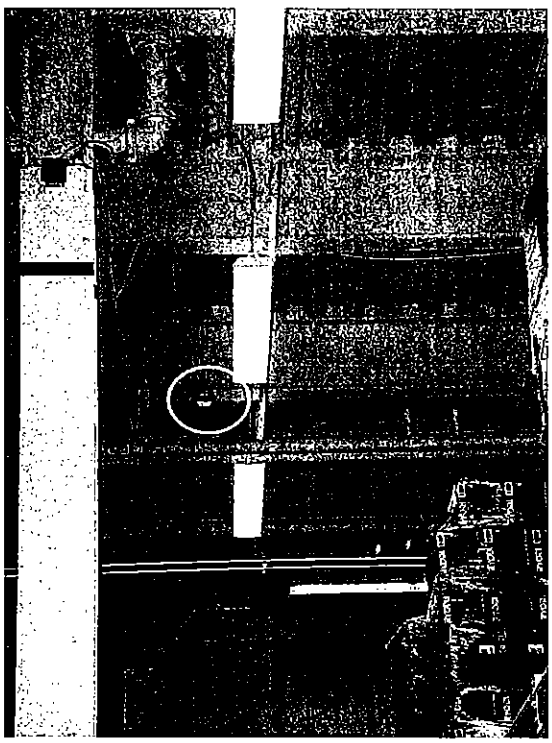

Photo 2 - Close-up of Strobe (Reading, MA)

5.2. Home Depot, Danvers, MA

The test at this location took place on August 25, 2005. There were 12 participants, eight of whom also participated in the Reading test. The fire alarm system at this location did not permit the audible signal to be disabled separate from the visible signals.

Table 3 is a summary of relevant building and environmental information. Table 4 summarizes information about the strobe light system.

Nominal ceiling height:	21.5 ft
Nominal height to top of storage:	16 ft
Range of ambient light level:	431 – 1,722 lux 40 – 160 ft-candles
Ceiling configuration:	Suspended acoustical tiles (white) with recessed fluorescent light fixtures. Most utilities hidden above the suspended ceiling.

Table 3 - Building Information

Strobe location:	Mounted on the ceiling, 21.5 ft above the floor.
Strobe spacing:	48 ft spacing in open areas and in aisles.
Strobe intensity:	115 cd. eff.

Table 4 - System Information

The strobes at this location are located on a suspended acoustical tile ceiling at the same level of the building's fluorescent lights. The design and installation resulted in most strobes being located over the aisles, between racks. Within each aisle, the strobes are spaced approximately 48 ft. Rack spacing varies with most 16 ft on center and some as much as 30 ft on center. Thus, strobe coverage might be as low as 48 ft x 16 ft in order to provide a line of strobes in each rack aisle.

Photo 3 shows lines of strobes on the ceiling. Photo 4 shows an aisle with strobes directly overhead. Photo 5 is a close-up of a strobe on the suspended ceiling.

Photo 3 - Lines of Strobes

Photo 4 - Strobes Over Aisle

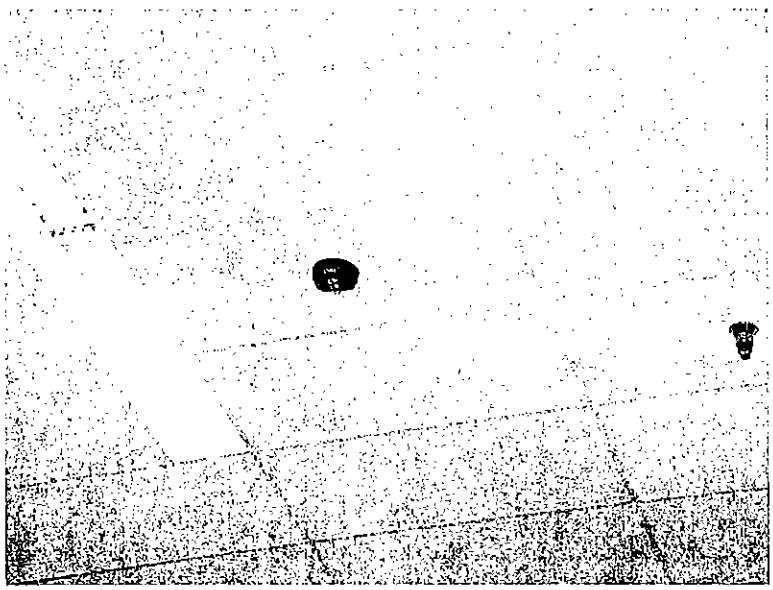

Photo 5 - Close-up of Strobe (Danvers, MA)

5.3. Wal*Mart, Kissimmee, FL

The test at this location took place on October 28, 2005. There were 22 participants. Two participants had also taken part in both the Reading and Danvers tests. This test coincided with the Report on Proposals meetings of the NFPA 72 Technical Committees. The participants were all Technical Committee members and included almost all members of the Notification Appliances Committee.

The fire alarm system at this location was designed and installed to permit the audible signal to be disabled separate from the visible signals. However, the manner in which this is effected results in a single audible chirp when the system was activated. After that first chirp, the audible signals stop and the strobes continued to operate.

Table 5 is a summary of relevant building and environmental information. Table 6 summarizes information about the strobe light system.

Nominal ceiling height:	16 – 21 ft
Nominal height to top of storage:	9 ft
Range of ambient light level:	510 – 1,265 lux (47 – 114 ft-candles)
Ceiling configuration:	Metal deck (white) on bar joist on trusses. All utilities exposed.

Table 5 - Building Information

Strobe location:	Mounted below the ceiling on the bottom chord of the bar joists, approximately 15 – 20 ft above the floor.
Strobe spacing:	45 ft x 45 ft
Strobe intensity:	115 cd. eff.

Table 6 - System Information

The strobes at this location are located on the bottom of the bar joists supporting the ceiling/roof. The florescent light fixtures are approximately 8 - 12 in. below the bar joists. The design and installation resulted in strobes being located over most of the main aisle and circulation areas. However, not every merchandise aisle has a row of strobes overhead. Typically, the strobes are over the main aisles and over every third to fifth stock aisle.

Photo 6 shows the ceiling configuration with strobe lights located on the bottoms of the bar joists.