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Video Image Detection

COMPARATIVE TESTING OF VARIOUS DETECTION TECHNOLOGIES

SEC Project No. 1810001-000

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February 11, 2010

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Preface

This project was conducted with staff from Schirmer Engineering's Greenbelt, Maryland office and Schirmer Engineering's Corporate office in Glenview, Illinois. The results and findings of this report are relevant to the test conditions and fire/smoke detection products evaluated in these tests. While the data and findings of this report may be relevant to a variety of applications, it should be noted that there may be physical or environmental conditions present in actual applications that could impact the use of any of the technologies addressed in this report.

Additionally, in a number of cases some fire/smoke detectors did not respond or alarm in one or more tests. Such non-responding detectors should not be viewed as a failure or inadequate for their intended purpose. Many of the low-energy fire/smoke sources used are challenging in the higher ceiling environment used in these tests. Nothing in this report should be construed to suggest or imply that any technology addressed in this report is not a suitable or capable means of fire/smoke detection.

For clarifications or questions regarding this report please refer to one of Schirmer's project team members.

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I. INTRODUCTION

Schirmer Engineering Corporation (Schirmer Engineering) was tasked by axonX, LLC (axonX) to witness a series of fire tests in a warehouse environment in which the detection times of various technologies that detect flame and/or smoke are compared. These technologies included air-sampling (aspiration) detection (ASD), projected beam smoke detection, spot type ionization and photoelectric detectors, and video image fire and smoke detection (VID) and linear heat detection. The purpose of these tests was to compare the detection capability of each type of detector for each fire. Additionally, a key objective of the test program for axonX was to identify the relative performance of their VID technology to the variety of technologies used in this program.

In this test series, a total of 63 tests were completed and analyzed. Seven different fire sources were tested at three different fire locations for a total of 21 different fire scenarios. Each fire scenario was tested three times for repeatability, yielding 63 total tests. Although linear heat detection was present in the test room, the fire sources used were not sufficiently large to cause linear heat responses. Consequently, each test had five technologies with six detector events possible, that being an alarm response or non-response for the detector systems present (ASD1, ASD2, beam, ion, photo, VID). The entire test program represented a total of 378 detector system alarm events.

The fire/smoke sources used were derived from the BFPSA *Code of Practice for Category I Aspirating Detection Systems* [1], and UL 268, *Standard for Safety Smoke Detectors for Fire Alarm Systems* [2] fire tests. The fire/smoke sources generally approximated the BFPSA and UL specified sources, including a black smoke emitter, white smoke emitter, overheated smoldering wire fire, UL 268 flammable liquids fire, UL 268 smoldering wood test, UL 268 paper fire, and UL 268 wood crib fire. These fire sources represented a variety of small flaming fires, and slow-growth smoldering fires. The variety of fire/smoke sources and room locations was intended to identify the range and differences in detection performance for the various technologies.

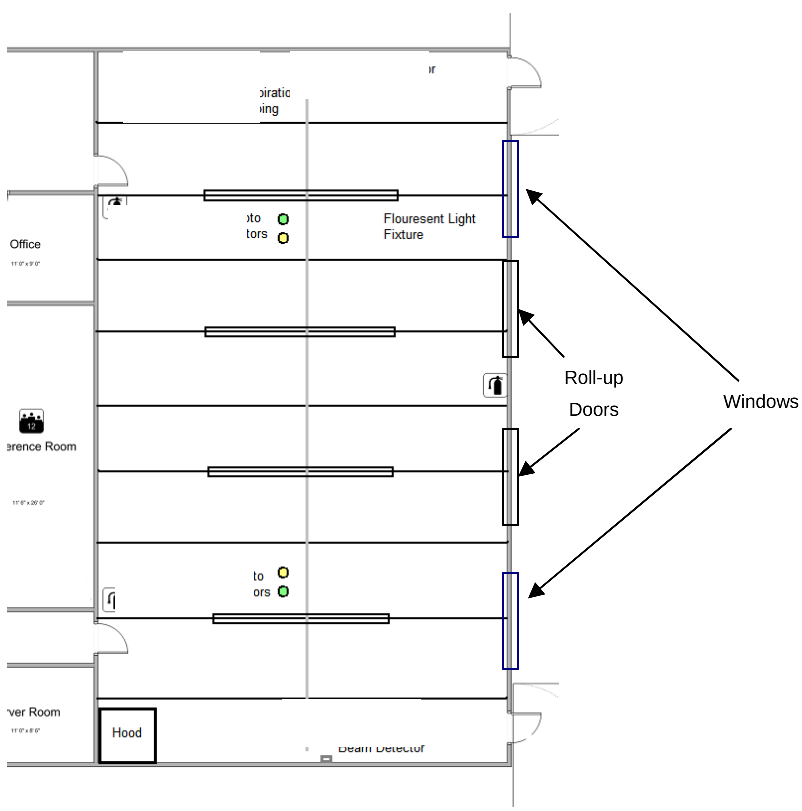
II. TEST SERIES

The test series was conducted in January, 2010 at the axonX facility. An employee of axonX, LLC, and at least one employee of Schirmer Engineering was present to witness and record all test results. Schirmer Engineering tabulated all the data and is responsible for the independent review and analysis of all the data presented in this report.

A. Test Facility

The tests were conducted at axonX headquarters which is located in Sparks, MD. The test space has a length of 59 feet and 7 inches and a width of 34 feet and 10 inches with a height of 18 feet and 1 inch from the concrete floor to ceiling. The space has a total of six doors – two lead to interior office space and the remaining four lead directly to the exterior. Two of the exterior doors are large roll-up loading dock doors. There are also two windows and two skylights within the test facility. During the tests, all of the doors and windows were closed and darkened to outside light to regulate lighting levels and temperature within the facility. A diagram of the facility is shown in Figure 1.

Figure 1: Test Facility



B. Detection Technologies

During the test series, the response times of five detection technologies were evaluated: air-sampling (aspiration) detection (ASD), projected beam smoke detection, ionization spot type detection, photoelectric spot type smoke detection, and video image fire and smoke detection (VID). Although linear heat detection was present in the test room, the fire sources used were not sufficiently large to cause linear heat responses. For this reason the linear heat detection was not considered in the data analysis

An aspirating smoke detection (ASD) system was installed in the testing facility with a single pipe installed on the ceiling along the centerline of the space, approximately 17 feet from each side. There were three air sampling ports in the pipe and locations are shown in Figure 2. The default settings of the ASD contain four levels of alarm: “Alert”, “Action”, “Level 1”, and “Level 2”.

The corresponding obscuration sensitivities of these levels were:

- Alert – 0.08 %/m
- Action – 0.14 %/m
- Fire 1 – 0.2 %/m
- Fire 2 – 2.0 %/m

The Fire 2 alarm setting matches that of the projected beam smoke detector, and spot type smoke detectors and were recorded in each test. Since ASD is used in many settings as additional or supplemental protection, the Fire 1 alarm setting was also noted during the tests. The alert and action times were recorded for the majority of the tests, but were not included in the results as these are considered supervisory settings. Figure 2 shows the location of the ASD sampling ports. Note that all dimensions are in feet.

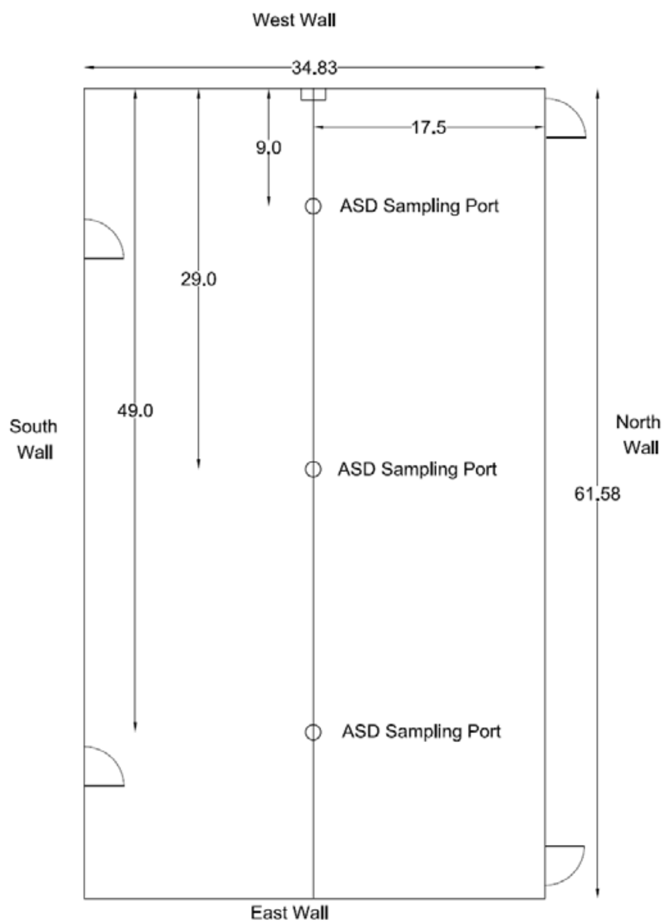


Figure 2: ASD Sampling Port Locations (nts)

One projected beam smoke detector was installed in the test facility at a height of approximately 15 feet. It was located slightly off-center within the space, about 15.5 feet from the exterior wall and 19.5 feet from the interior office wall. The exact location of the beam detector was dictated by the presence of obstructions in the test area including open joist structural members and lighting. The sensitivity of the beam detector was set to “Level 2” which most closely corresponds to that of the spot detection and “Fire 2” alarm of the ASD (2.0%/m). The beam detector Level 2 corresponds to a 30%/span obscuration level or 0.6%/ft or 1.94%/m. Figure 3 shows the location of the beam detector in the test facility. Note that all dimensions are in feet.

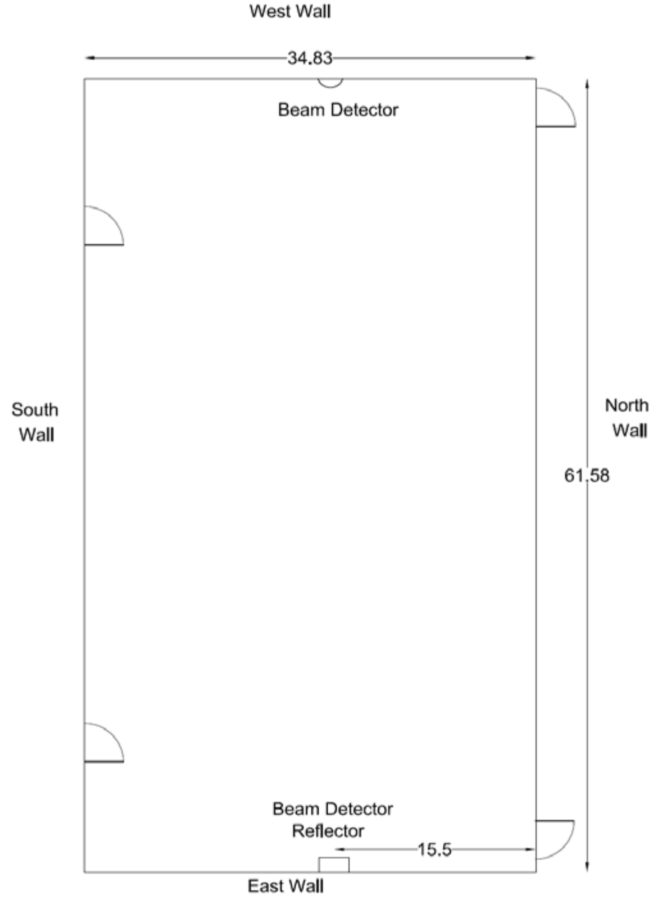


Figure 3: Beam Detector Location (nts)

Two ionization spot type smoke detectors were located adjacent to the ASD piping in the test facility. The first was located approximately 15 feet from the west wall and the second was spaced approximately 30 feet from the first at a distance of 45 feet from the west wall. This spacing is representative of that which would be found in a similar real-world application. The detectors were set to a measuring ionization chamber (MIC) level of 80 which according to the manufacturer and UL 217 test results for cotton wick corresponds to a 0.61%/ft or 1.96%/m obscuration level. Pre-alarm times were also noted for the ionization detectors but were not analyzed in the results as these are considered supervisory settings. The detector locations can be seen in Figure 4. Note that all dimensions are in feet.

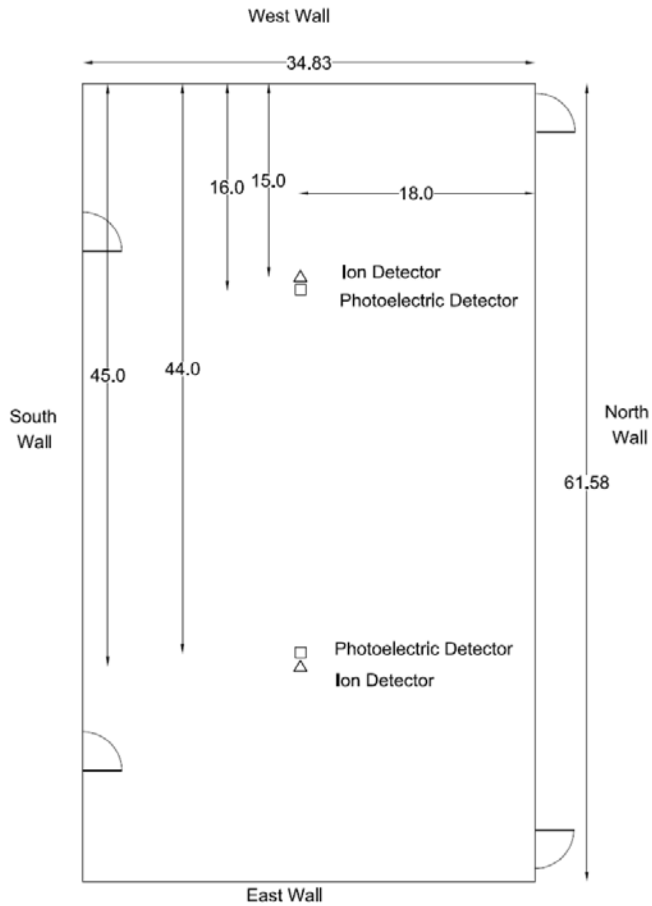


Figure 4: Ionization and Photoelectric Detector Locations (nts)

Two photoelectric spot detectors were located in the test facility, and installed according to manufacturer's instructions. One is located approximately 16 feet from the west wall and the second is spaced approximately 28 feet from the first at a distance of 44 feet from the west wall. The sensitivity of each detector was set to 2.0 % obscuration per meter. Pre-alarm times were also noted for the photoelectric detectors but not analyzed in the results as these are considered supervisory settings. Figure 4 shows the detector locations. Note that all dimensions are in feet.

A linear heat detector was installed in the test facility and run in a U-shaped loop through the testing space. The linear heat detector was located approximately seven feet from the North wall, four feet from the east wall, and eight feet from the south wall. The activation temperature for this detector is 155 degrees Fahrenheit. As anticipated, the linear heat detector did not activate during the test series and is not included in the results or analysis of data. Figure 5 shows the linear heat detector location. Note that all dimensions are in feet.

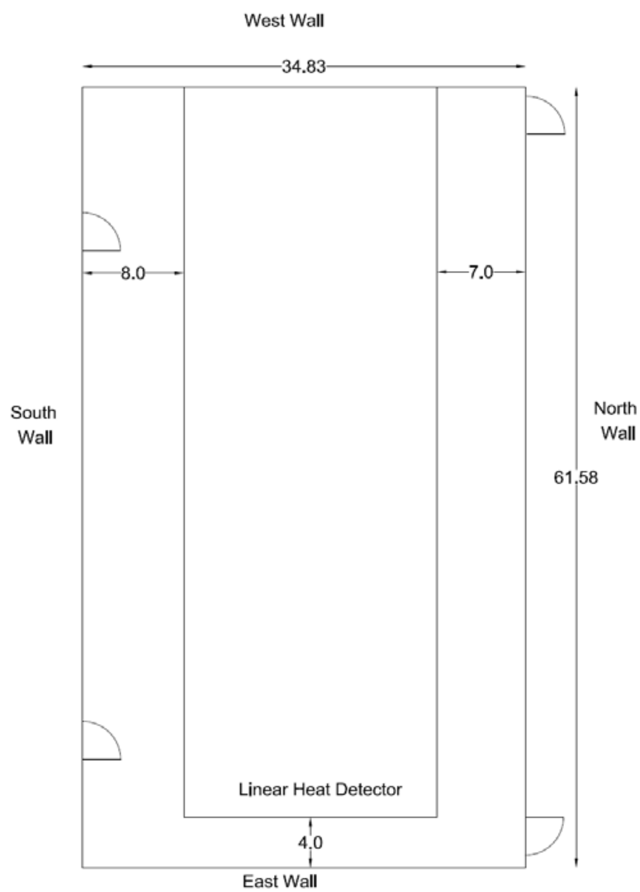


Figure 5: Linear Heat Detector Location (nts)

Two video image fire and smoke detection (VID) cameras were mounted in the test space at opposing corners of the facility. The camera in the East corner was mounted at a height of 13 feet 8 inches, and the camera in the West corner was mounted at a height of 11 feet. The sensitivities of the camera were set to the default "medium" setting with a five second delay for alarm confirmation. Figure 6 shows the location of the two VID detectors. Note that all dimensions are in feet.

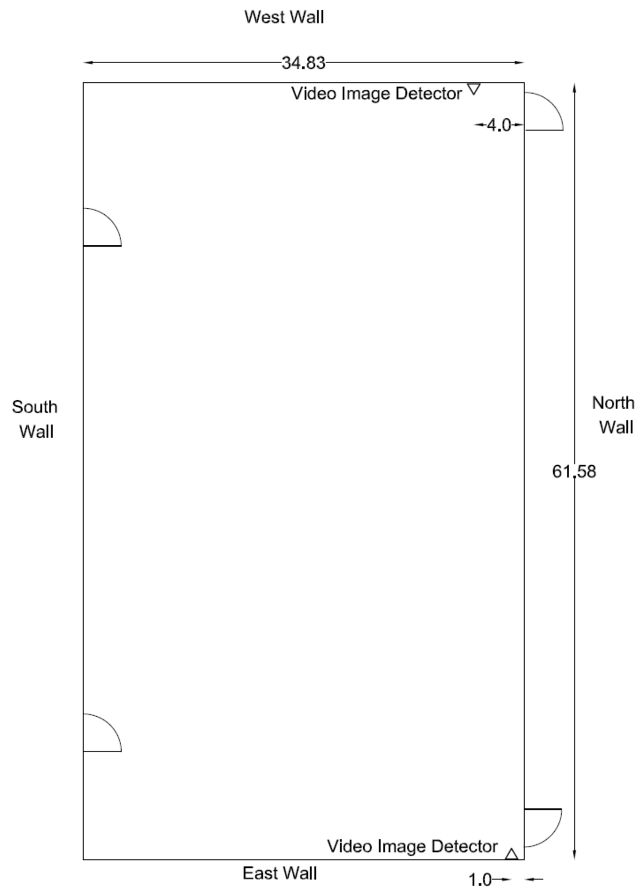


Figure 6: VID location (nts)

With the exception of the video image fire and smoke detection (VID), all detection technologies were monitored by a CyberCat 50 Control Panel [3]. The video detection was monitored using the Signi*Fire* Spyder*Guard* Early Warning/Early Response software [4]. All systems were designed and installed by an approved system distributor (SSI and SPC, respectively). All system detector settings were confirmed and the systems installations visually inspected by Schirmer Engineering before the test series.

C. Source Fires

Seven different source fires were conducted in the test series. They ranged from slow, smoldering fires to flaming fires. The sources were derived from similar tests in BFPSA

Appendix A [1] and UL 268 [2] fire tests. The “UL” designation refers to tests conducted similar to UL 268. The fire sources include:

- Black Smoke Emitter
- Flammable Liquids (UL)
- Overheated Smoldering Wire
- Smoldering Wood (UL)
- Tamped Paper (UL)
- White Smoke Emitter
- Wood Crib (UL)

The black and white smoke emitters have a similar consistency to those used in the BFPSA report. The white smoke emitter produces smoke for approximately 3 minutes with a total smoke volume of 1,200 ft^3. The black smoke emitter produces smoke for approximately 4 minutes with a total smoke volume of 1,200 ft^3. Both smoke emitters are lit using a butane lighter and the smoke emitters are permitted to burn until self-extinguishment. Figure 7 shows both the black and white smoke emitters used in the test series.

Black Smoke Emitter

White Smoke Emitter

Figure 7: Smoke Emitters

The flammable liquids fire consisted of a mixture of fifty percent toluene and fifty percent heptane in a round metal receptacle. The container consists of 0.025 inch stainless steel, with a diameter of 6 ¼ inches and a depth of 1 ¼ inches. The liquid mixture was lit with a Butane lighter and permitted to burn until self extinguished. Figure 8 shows the receptacle for the flammable liquids fire and resulting flame.

Figure 8: UL 268 Flammable Liquids Fire

The overheated smoldering wire used a fire source similar to that used in the BFPSA report. A bundle consisting of six 9 inch Romex Type NM-B 14/3 cables with ground non-metallic sheathing was wrapped around a Vulcan 500 heating element that was energized to 75% of its 120 VAC capacity. The heating element was energized for twenty minutes and then the power disconnected. Figure 9 includes a picture of the smoldering wire bundle (close-up and smoldering mode).

Figure 9: Overheated Smoldering Wire Bundle

The UL 268 smoldering wood test consisted of ten wood sticks (nonresinous and free from knots or pitches) placed in a spoke pattern on a hot plate so that each stick is located 36 degrees from the others. Each stick is 3 x 1 x 3/4 inches and placed flush with the edge of the hotplate. The hotplate used for these tests was the Emerson Electric Co. Series PH-400 Chromolax. The temperature of the hot plate was monitored by a proportioning temperature controller and adhered to the following schedule:

Time (minutes)	Hotplate Temperature
0	23°C +/- 2°C (73° F +/- 4°F)
0-3	Increased 60.7°C (109°F) per minute to 205°C (401°F)
More than 3	Increased 3.2°C (5.8°F) per minute for the remainder of the test

The wood sticks remain on the hotplate for a total of 75 minutes before the hot plate is de-energized and the wood sticks then removed. Figures 10 and 11 depict the smoldering wood test arrangement.

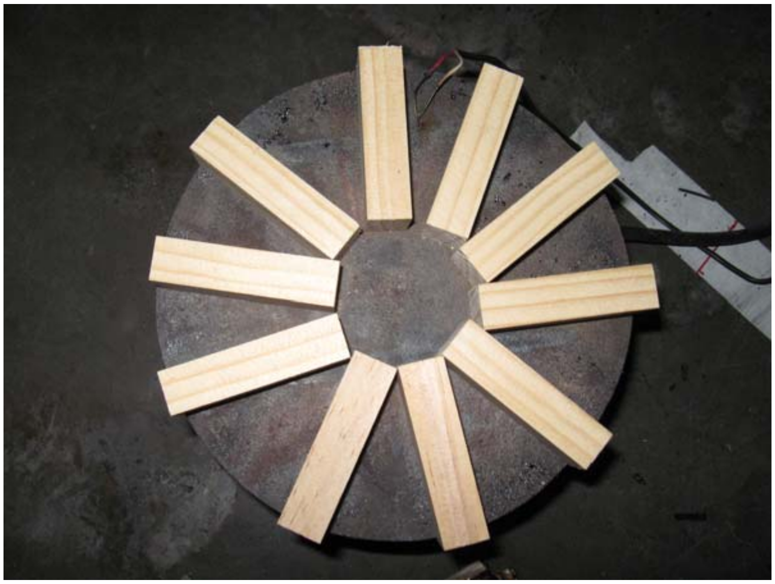


Figure 10: Aerial View of UL 268 Smoldering Wood Configuration

Figure 11: Elevation View of UL 268 Smoldering Wood Configuration

The UL 268 tamped paper fire consists of shredded newspaper in strips ¼ to 3/8 inch wide and 1-4 inches long. Approximately 3 ounces of newspaper strips are placed in a large sheet metal container with a height of 12 inches. The paper is tamped with a rod until the newspaper strips are approximately 4 inches below the container opening. A hole with a 1 inch diameter is formed in the middle of the receptacle to prevent air circulation. The assembly is lit using a butane lighter and permitted to burn until extinguished. Figures 12 and 13 include pictures of the UL 268 tamped paper fire set-up.

Figure 12: Aerial View of UL 268 Tamped Paper

Figure 13: Elevation View of UL 268 Tamped Paper

The UL 268 wood crib fire used a wood crib with dimensions of 6 x 6 x 2½ inches. The wood crib was supported on a ring stand approximately 9 inches off of the test room floor. A container with 10 milliliters of rubbing alcohol was placed approximately 3½ inches below the center of the wood crib. The rubbing alcohol was first ignited which then allowed for ignition of the wood crib. The test continued until the wood crib was extinguished. Figure 14 shows the UL 268 wood crib fire configuration and flaming mode.

Figure 14: UL 268 Wood Crib Fire Configuration & Fire

D. Fire Locations

There are three different fire locations used in the test series. The first location (Location 1) was in the center of the test area and considered an open floor plan test. The second location (Location 2) was an obstructed location. The third location (Location 3) was in the corner of the test area.

Location 1 was a general open test location and located along the centerline of the room as indicated in the blue lines of Figure 15. Within the blue-lined area the exact fire/smoke source location was varied by moving the location to one of three spots within the blue-lined area during the test series.

Figure 15: Location 1

All seven sources were first tested directly below the ionization and photoelectric detectors, approximately 15 feet from the west wall, as shown in Figure 16. The second round of tests at Location 1 was tested directly below the ASD port as shown in Figure 16, approximately 9 feet from the west wall. The final round of tests at Location 1 was tested in the middle of the spot detectors and ASD port approximately 12.5 feet from the west wall. All three locations are on the centerline of the room and unobstructed from any of the detection devices. The shaded area in Figure 16 demonstrates Location 1 for the test series.

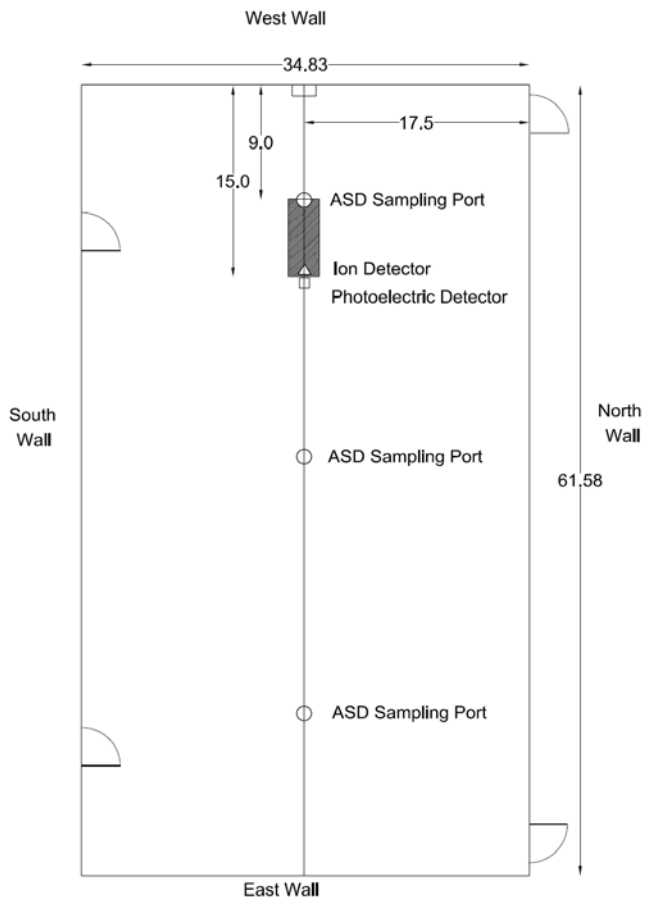


Figure 16: Test Location 1 (nts)

The variations at Location 1 were performed in order to observe if there were any significant effects in detector responses due to locating the fire/smoke sources directly under the spot detectors verses directly under the ASD port. Some differences were observed but generally the results showed that the detector responses were reasonably consistent for any position within the blue-lined area (see Figure 15) marking Location 1.

Location 2 is similar to that in a storage warehouse. The fire/smoke sources were placed between two rows of racks as shown in Figure 17, along the centerline of the room. Each row consists of 4 racks with dimensions of 2 x 3 x 7 feet. The racks are filled with boxes to effectively obstruct the fuel source from the cameras. The fuel was located directly between the spot detection and ASD sampling port. The small shaded square in Figure 17 shows Location 2 for the test series.

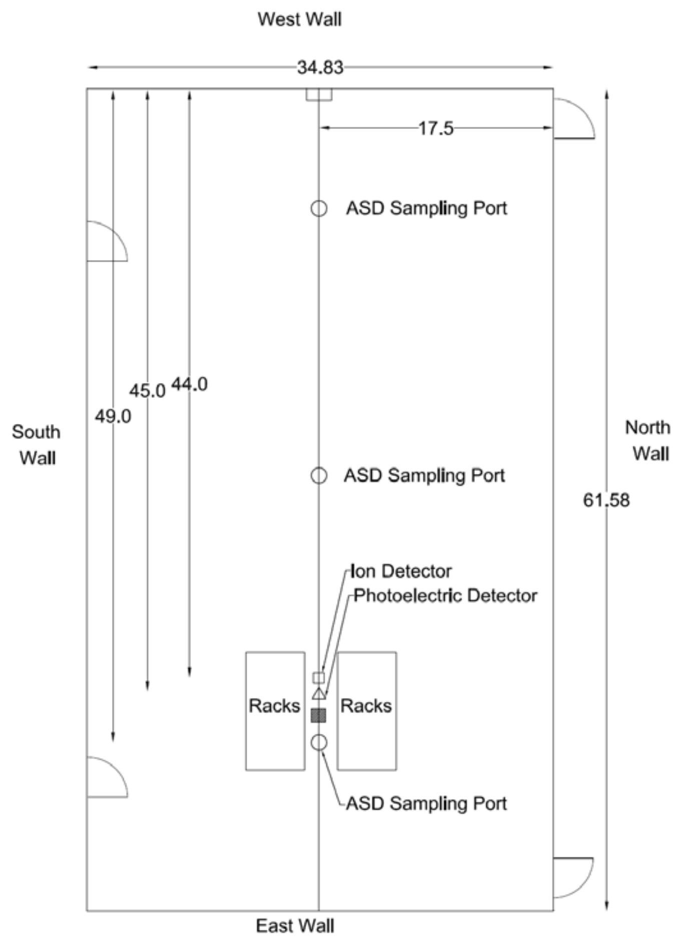


Figure 17: Test Location 2 (nts)

Location 3 was in the corner of the test space, approximately 5 feet from the north wall and 5 feet from the east wall. Location 3 was in the blind spot of one of the cameras (VID #2), and as far as possible in the test space from camera VID #1. Location 3 was located approximately 24 feet from the spot detection and 21 feet from the ASD detection. The small shaded square in Figure 18 shows the approximate location of Test Location 3.

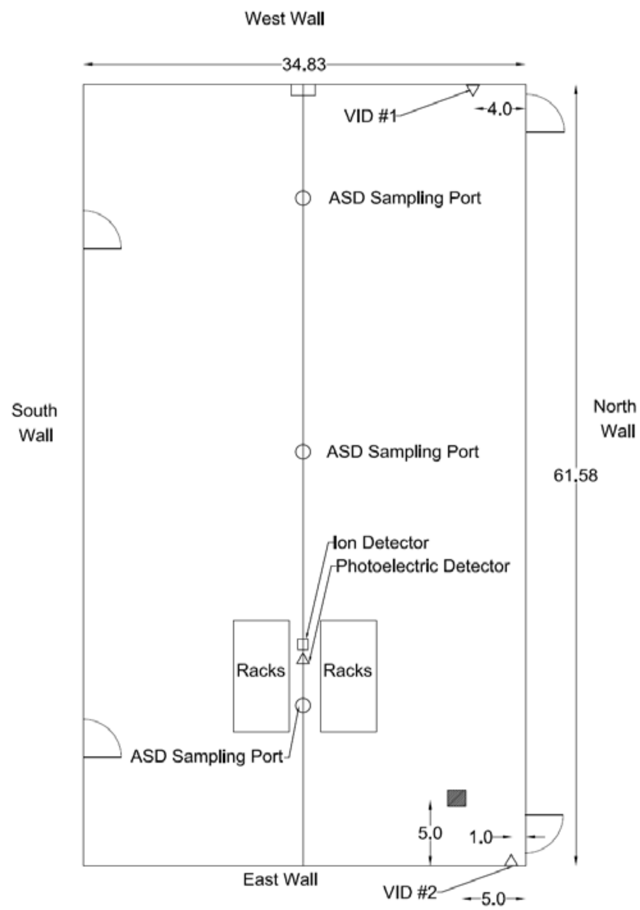


Figure 18: Test Location 3 (nts)

E. Test Procedure

A total of 63 tests were initially planned for the test series and a test matrix is provided as Figure 19. Each fire source was tested in each of the three locations a total of three times. Due to an observed error in one of the UL tamped paper tests, the original Test #8 had to be repeated as Test #64.

Before each test, all exhaust fans and heaters were powered off. The time, temperature, and ASD ambient level for the testing space were recorded. The video detection interface time and fire alarm panel time were synchronized and recorded. Time for the test began once the fuel was ignited. After a fuel source was completed either due to self-extinguishment or removal of power as outlined in the Fire Sources section, the test was continued an additional ten minutes to allow time for later detector responses. Once ten minutes was elapsed, the test was recorded as complete and the exhaust for the space initiated. The final temperature in the testing space was recorded. Results were obtained from the CyberCat 50 control panel [3] and Signi*Fire* Spyder*Guard* Early Warning/Early Response software [4] for the detection times. The next test was conducted after the space was exhausted and the ASD sensor condition returned to a reading of 0.04%/m or less.

Test Number	Source	Location
1	black smoke emitter	1
2	overheated smoldering wire	1
3	UL smoldering wood	1
4	white smoke emitter	1
5	UL flammable liquids	1
6	white smoke emitter	1
7	UL flammable liquids	1
8*	UL tamped paper	2
9	wood crib	2
10	UL smoldering wood	2
11	white smoke emitter	3
12	wood crib	3
13	UL flammable liquids	2
14	black smoke emitter	3
15	wood crib	1
16	UL tamped paper	1
17	white smoke emitter	2
18	overheated smoldering wire	2
19	UL smoldering wood	3
20	UL flammable liquids	3
21	black smoke emitter	2
22	overheated smoldering wire	3
23	overheated smoldering wire	1
24	UL tamped paper	3
25	wood crib	1
26	UL tamped paper	1
27	UL smoldering wood	1
28	wood crib	2
29	black smoke emitter	1
30	overheated smoldering wire	2
31	UL tamped paper	2
32	UL flammable liquids	2
33	white smoke emitter	2
34	UL smoldering wood	2
35	white smoke emitter	3
36	wood crib	3
37	UL flammable liquids	3
38	overheated smoldering wire	3
39	black smoke emitter	2
40	UL tamped paper	3
41	wood crib	1
42	UL smoldering wood	3
43	UL tamped paper	1
44	white smoke emitter	1
45	overheated smoldering wire	1
46	black smoke emitter	3
47	UL smoldering wood	1
48	UL flammable liquids	1
49	black smoke emitter	1
50	UL smoldering wood	2
51	wood crib	2
52	white smoke emitter	2
53	UL tamped paper	2
54	overheated smoldering wire	2
55	black smoke emitter	2
56	UL smoldering wood	3
57	wood crib	3
58	overheated smoldering wire	3
59	UL tamped paper	3
60	UL flammable liquids	2
61	white smoke emitter	3
62	UL flammable liquids	3
63	UL tamped paper	2
64*	black smoke emitter	3

Figure 19: Test Matrix

***** Test 8 was errant test and repeated as Test 64

III. TEST RESULTS AND ANALYSIS

A total of 63 tests were completed during the test series. (Test #8 was excluded due to an error in the testing procedure and was repeated as Test #64.) This involved performing three tests with each of seven smoke/fire sources at three different locations. Repeated smoke source tests were key to the overall tests series for obtaining data that showed repeatability and that could be averaged at each location for all five detector technologies tested. However, in a number of the tests one or more detector technologies did not respond or register an alarm condition and consequently in these cases, only one or 2 data response times are available in lieu of a 3-trial average response time. The following several pages contain summaries of the test results. These summaries provide the following information.

- For each smoke/fire source used, a graph is provided to compare the response times of the five detector technologies tested and described as follows:
  - Air Sampling Detection – ASD1, ASD2, (Fire Alarm 1 and 2 responses)
  - Photoelectric Beam – Beam
  - Ionization Spot – Ion
  - Photoelectric Spot – Photo
  - Video Image Detection – VID
- A table listing the detector activations with respect to each smoke/fire source location. This table also identifies any detector technology that did not respond.
- Comments and observations of the results shown in the graphs and tables.

Following the summaries of each set of smoke/fire source tests are several graphs that compare each detector technology to the entire data set of all 63 tests. Each test had five technologies with six detector events possible, that being an alarm response (with associated time) or non-response for the detector systems present (ASD1, ASD2, beam, ion, photo, VID). The entire test program represented a total of 378 detector system events. Figure 27 provides a graphical comparison of average VID detection responses to all data points for the five detector technologies tested, including two response levels (Fire Alarm 1 and Fire Alarm 2) for the ASD technology. Figure 28 isolates the data for the shorter time frame (0-800s) tests. The data shows the total range of response times (based on averages of each detector type) for all detectors in each series of smoke source tests. Overlaid on the total response range is the range of average VID responses which fall within the total range of detector responses. Figure 29 is a comprehensive comparison of each individual detector technology relative to the entire data set or all 378 detector system events. The X-axis in Figure 29 notes in the fire/smoke source labels the locations (e.g. NR-L1, L2, or L3) for which no detector response was achieved (i.e. NR = No Response).

Review of Black Smoke Emitter Tests

In the graph each bar represents the average response time calculated from three repeated trials at one of three different locations with a black smoke emitter (9 trials total). All detectors indicated were operational in each of the nine trials.

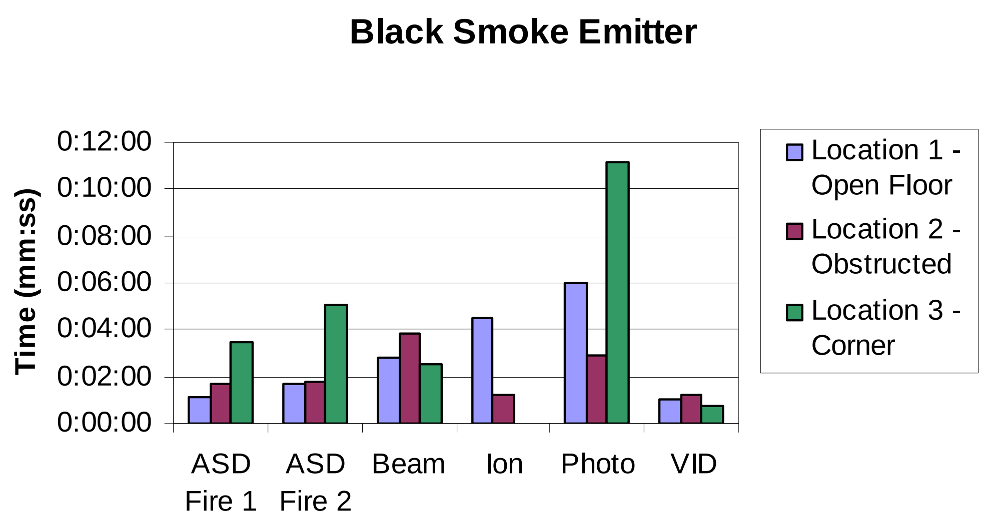


Figure 20

Table 1 lists, in order, the detector activations by location and identifies any detector type that did not respond in all three trials for the respective smoke source location.

TABLE 1 – Summary of Detector Operations Using Black Smoke Emitter		
Smoke Source Location	**Order of Activation**	**No Activations**
Location 1 – Open Floor	VID, ASD1, ASD2, BEAM, ION, PHOTO	----
Location 2 – Obstructed	VID, ION, ASD1, ASD2, PHOTO, BEAM	----
Location 3 – Room Corner	VID, BEAM, ASD1, ASD2, PHOTO	ION

<u>Comments / Observations</u>

For all the black smoke emitter tests the average detector responses ranged from 48 s to 670 s. The VID detectors were consistently the first detector to respond in approximately 60 s after the start of the test followed closely by the ASD1 alarm level in Locations 1 and 2 and the ionization detector at Location 2. The beam detector provided responses in the range of 155 to 232 s for the three locations. For those tests conducted with the smoke source at Location 1 (room corner) there is an observed longer time to detection for ASD1 and ASD2 (206-303 s), photoelectric spot detectors (670 s), and no responses were observed for the ionization detectors in the corner scenarios. In comparison the VID appeared unaffected by the room corner location and responded 15 s faster than noted for the Location 1 and 2 scenarios.

Review of White Smoke Emitter Tests

In the graph each bar represents the average response time calculated from three repeated trials at one of three different locations with a white smoke emitter (9 trials total). All detectors indicated were operational in each of the nine trials.

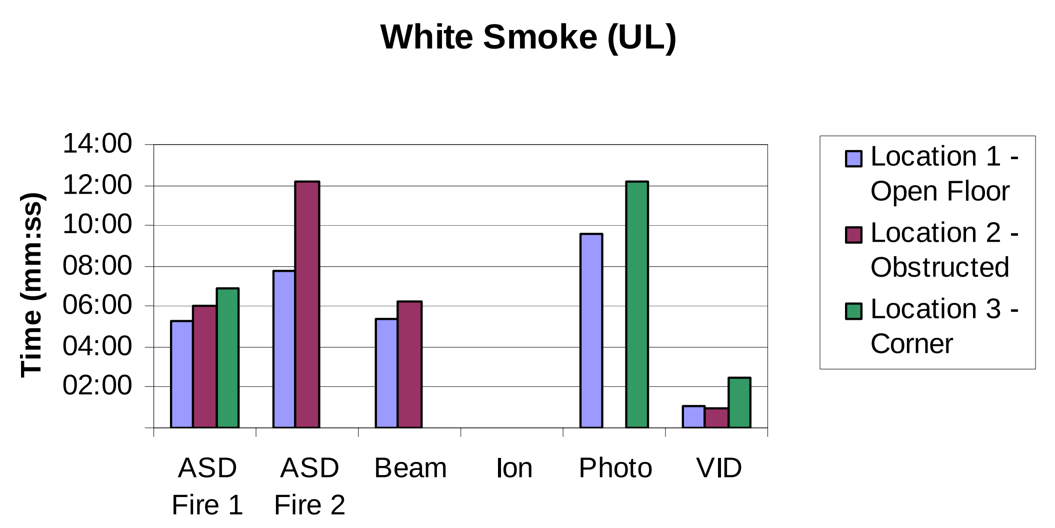


Figure 21

Table 1 lists, in order, the detector activations by location and identifies any detector type that did not respond in all three trials for the respective smoke source location.

TABLE 2 – Summary of Detector Operations Using White Smoke Emitter		
Smoke Source Location	**Order of Activation**	**No Activations**
Location 1 – Open Floor	VID, ASD1, ASD2, BEAM, PHOTO	ION
Location 2 – Obstructed	VID, ASD1, BEAM, ASD2,	ION, PHOTO
Location 3 – Room Corner	VID, ASD1, PHOTO	ION, ASD2, BEAM

Comments / Observations

For all the white smoke emitter tests the average detector responses ranged from 61 s to 733 s. The VID detectors were consistently the first detector to respond in approximately 60 s – 150 s after the start of any test followed by the ASD1 alarm level (315 -363 s) in Locations 1 and 2 and the beam detector (326 -374 s) at Locations 1and 2. The photoelectric detectors provided responses in the range of 573 to 729 s for Locations 1 and 3, respectively; and did not respond for the Location 2 scenarios. For those tests conducted with the smoke source in Location 3 (room corner) there is an observed longer time to detection than in the Location 1 and 2 scenarios. The ionization spot detectors did not respond in any of the nine trials with white smoke. Table 2 notes those additional scenarios where the ASD2, photoelectric and beam detectors did not activate.

Review of Wood Crib Tests

In the graph each bar represents the average response time calculated from three repeated trials at one of three different locations using a wood crib fire (9 trials). All detectors indicated were operational in each of the nine trials.

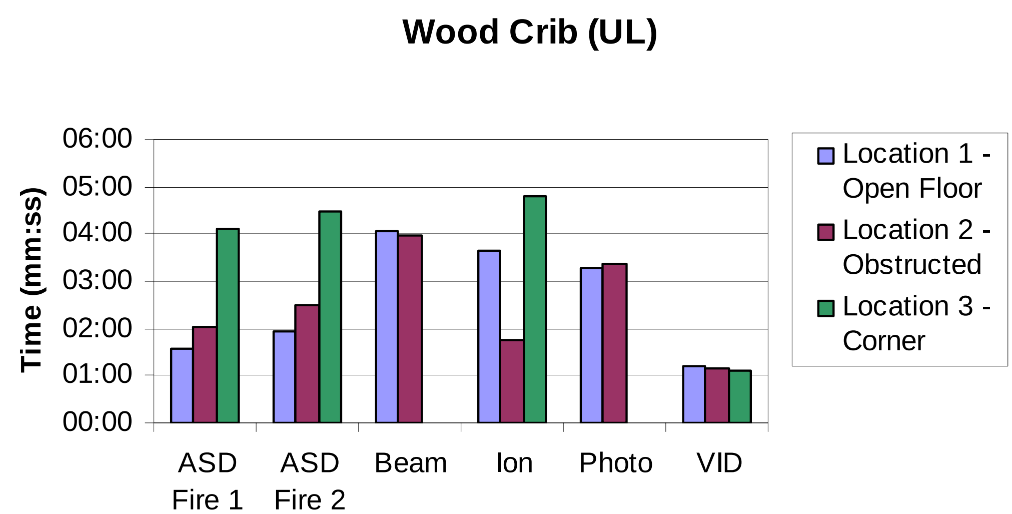


Figure 22

Table 3 lists, in order, the detector activations by location and identifies any detector type that did not respond in all three trials for the respective smoke source location.

TABLE 2 – Summary of Detector Operations Using Wood Crib Fire		
Smoke Source Location	**Order of Activation**	**No Activations**
Location 1 – Open Floor	VID, ASD1, ASD2, PHOTO, ION, BEAM	----
Location 2 – Obstructed	VID, ION, ASD1, ASD2, PHOTO, BEAM	----
Location 3 – Room Corner	VID, ASD1, ASD2, ION	PHOTO, BEAM

<u>Comments / Observations</u>

For all the wood crib tests the average detector responses ranged from 66 s to 288 s. The VID detectors were consistently the first detector to respond in approximately 66 – 72 s after the start of any test followed by the ASD1 alarm level (94 -122 s) in Locations 1 and 2 and the ionization detector (104 s) at Location 2. The photoelectric and beam detectors activated approximately in the range of 196 -238 s for Locations 1 and 2; however, no response was achieved for the Location 3 (room corner) scenarios with the photoelectric or beam detectors.

Review of Tamped Paper Fire Tests (Smoldering then flaming)

In the graph each bar represents the average response time calculated from three repeated trials at one of three different locations using a tamped paper fire (9 trials). All detectors indicated were operational in each of the nine trials.

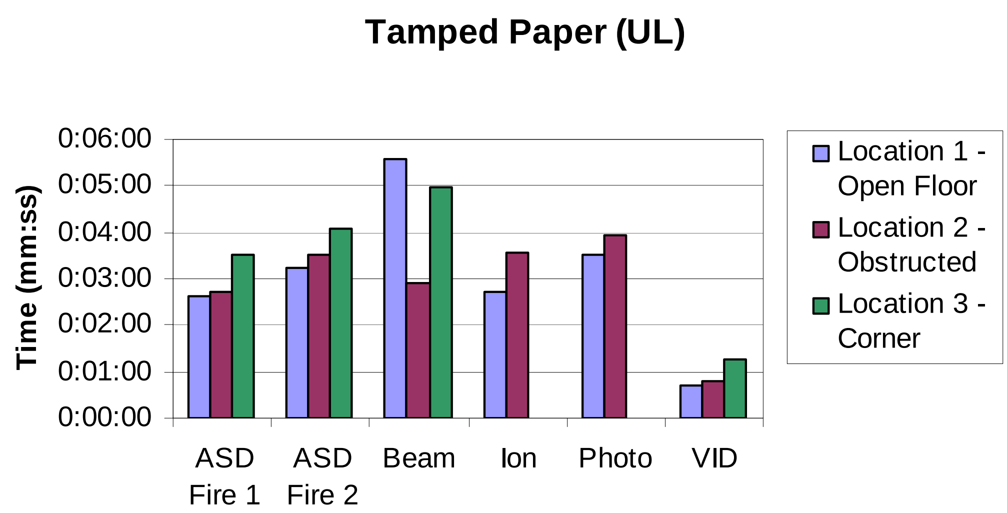


Figure 23

Table 4 lists, in order, the detector activations by location and identifies any detector type that did not respond in all three trials for the respective smoke source location.

TABLE 4 – Summary of Detector Operations Using Tamped Paper Fire		
Smoke Source Location	**Order of Activation**	**No Activations**
Location 1 – Open Floor	VID, ASD1, ION ASD2, PHOTO, BEAM	----
Location 2 – Obstructed	VID, ASD1, BEAM, ASD2, ION,PHOTO,	----
Location 3 – Room Corner	VID, ASD1, ASD2, BEAM	ION, PHOTO

<u>Comments / Observations</u>

For all the tamped paper fire tests the average detector responses ranged from 42 s to 336s. The VID detectors were consistently the first detector to respond in approximately 42 – 75 s after the start of any test. This was followed by the ASD1 alarm level (158 s), ionization (164s), ASD2 (195s) and photoelectric (212s) at Locations 1; and ASD1 alarm level (163 s), beam (176s) ASD2 (212s), ionization (213s), and photoelectric (237s) at Location 2. The beam detector showed the longest activation times of 336s and 298s for Locations 1 and 3, respectively. No response was achieved for the Location 3 (room corner) scenarios with the photoelectric or ionization detectors.

Review of Flammable Liquid Fire (UL-based, ~ 20kW)

In the graph each bar represents the average response time calculated from three repeated trials at one of three different locations using a flammable liquid fire (9 trials). All detectors indicated were operational in each of the nine trials.

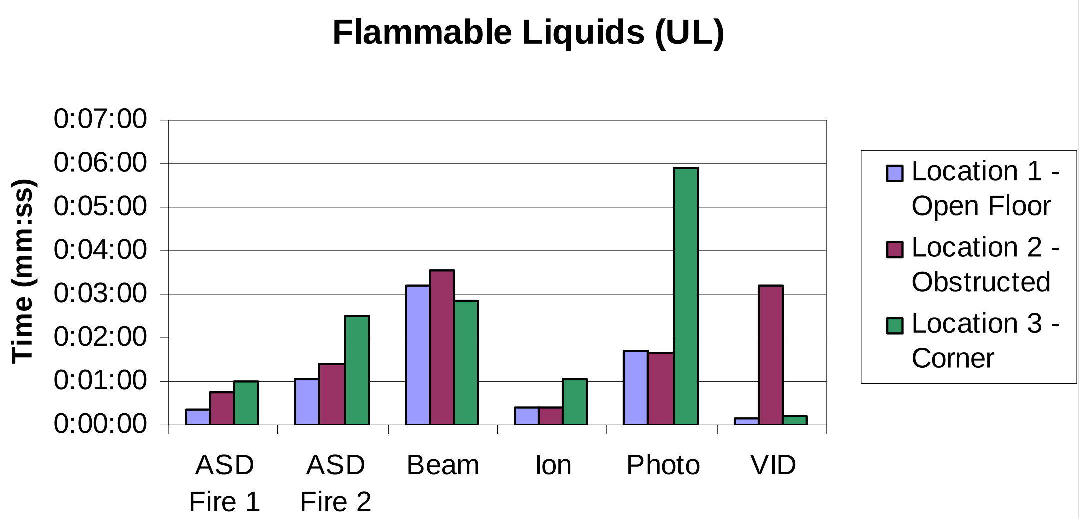


Figure 24

Table 5 lists, in order, the detector activations by location and identifies any detector type that did not respond in all three trials for the respective smoke source location.

TABLE 5 – Summary of Detector Operations Using Flammable Liquid Fire		
Smoke Source Location	**Order of Activation**	**No Activations**
Location 1 – Open Floor	VID, ASD1, ION, ASD2, PHOTO, BEAM	----
Location 2 – Obstructed	ION, ASD1, ASD2, PHOTO,VID, BEAM,	----
Location 3 – Room Corner	VID, ASD1, ION, ASD2, BEAM, PHOTO	----

<u>Comments / Observations</u>

For all the flammable liquid fire tests the average detector responses ranged from 9 s to 355s (photoelectric time). The VID detectors were the first detector to respond in only 2 of 3 locations. Location 1 and 3 tests showed fast average VID activation times of 9 and 11 s after the start of any test. These activations were due to the VID's flame detection algorithm. Conversely, the Location 2 tests showed a relatively long VID time (191s) compared to the ASD, ION and photoelectric detectors (23s – 99s). At Location 2 the VID response (191s) was comparable to that of the beam detector (214s). This was followed by the ASD1 alarm level (158 s), ionization (164s), ASD2 (195s) and photoelectric (212s) at Locations 1; and ASD1 alarm level (163 s), beam (176s) ASD2 (212s), ionization (213s), and photoelectric (237s) at Location 2. The beam detector showed consistently longer activation times in the range of 170s - 214s.

Review of Overheated Smoldering Wire

In the graph each bar represents the average response time calculated from three repeated trials at one of three different locations using an overheated smoldering wire (9 trials). All detectors indicated were operational in each of the nine trials.

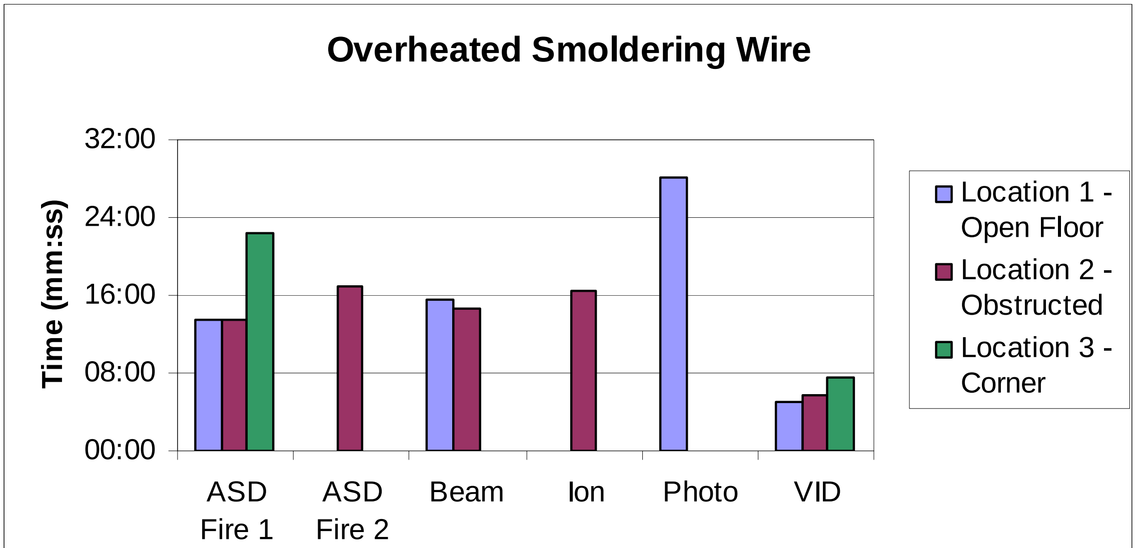


Figure 25

Table 6 lists, in order, the detector activations by location and identifies any detector type that did not respond in all three trials for the respective smoke source location.

TABLE 6 – Summary of Detector Operations Using an Overheated Smoldering Wire		
Smoke Source Location	**Order of Activation**	**No Activations**
Location 1 – Open Floor	VID, ASD1, BEAM, PHOTO,	ASD2, ION
Location 2 – Obstructed	VID, ASD1, BEAM, ION, ASD2	PHOTO
Location 3 – Room Corner	VID, ASD1	ION, ASD2, BEAM, PHOTO

<u>Comments / Observations</u>

This smoldering test series required a relatively long time frame to reach detection thresholds for the five technologies tested. For all the overheated smoldering wire tests the average detector responses ranged from 298s to 1687s. The VID detectors were consistently the first detector to respond in approximately 300 – 455 s after the start of any test. This was followed by the ASD1 alarm level (811 s), and the beam (939s) at Locations 1; and ASD1 alarm level (805 s), beam (875s), ionization (987s), and ASD2 (1016s), at Location 2. For the Location 3 (room corner) scenarios only the VID (455s) and ASD1 (1339s) detection responded. Three of the technologies (photo, ion, beam) and the ASD2 alarm level did not respond in one or more locations as noted in Table 6.

Review of Smoldering Wood

In the graph each bar represents the average response time calculated from three repeated trials at one of three different locations using a smoldering wood source (9 trials). All detectors indicated were operational in each of the nine trials.

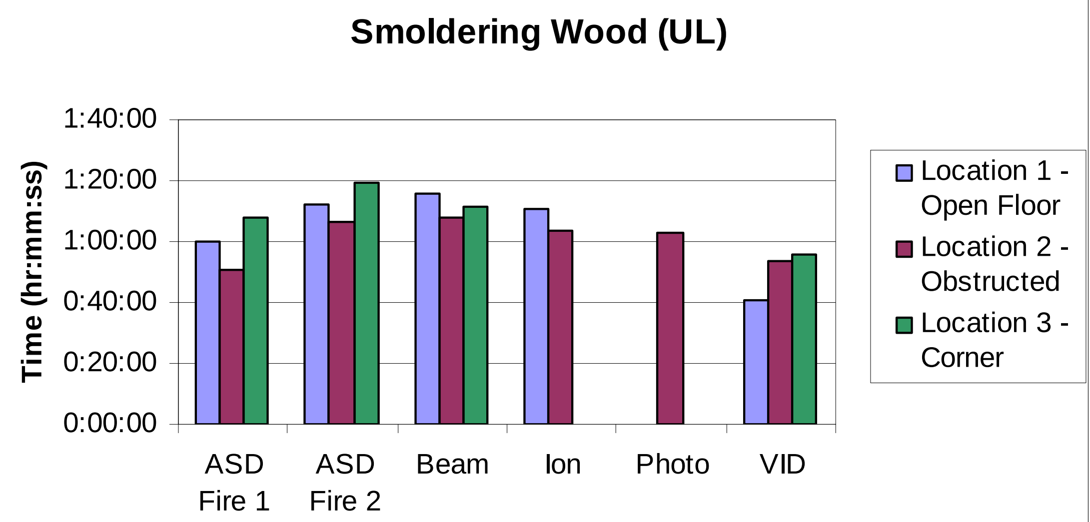


Figure 26

Table 7 lists, in order, the detector activations by location and identifies any detector type that did not respond in all three trials for the respective smoke source location.

TABLE 7 – Summary of Detector Operations Using a Smoldering Wood Source		
Smoke Source Location	**Order of Activation**	**No Activations**
Location 1 – Open Floor	VID, ASD1, ION, ASD2, BEAM	PHOTO
Location 2 – Obstructed	ASD1, VID, PHOTO, ION, ASD2, BEAM	
Location 3 – Room Corner	VID, ASD1, BEAM, ASD2	ION, PHOTO

<u>Comments / Observations</u>

This smoldering test series compared to all the previous test series required a very long time frame to reach detection thresholds for the five technologies tested. For all the smoldering wood source tests the average detector responses ranged from 41 to 80 minutes. The VID detectors were the first detector to respond in only 2 of 3 locations – Location 1(41 min.) and Location 3 (55 min.) For comparison ASD1 responded to Location 1 scenarios in 60 Min. and Location 2 scenarios at 51 min. All other responses are occurring in the range between 60 – 80 minutes. The ionization detectors did not respond in Location 3 (room corner) scenarios. The photoelectric detectors failed to respond in Location 1 and 3 Scenarios.

Figure 27 provides a graphical comparison of average VID detection responses to all data points for the five detector technologies tested, including two response levels (Fire Alarm 1 and Fire Alarm 2) for the ASD technology. Figure 28 isolates the data for the shorter time frame (0-800s) tests. The data shows the total range of response times (based on averages of each detector type) for all detectors in each series of smoke source tests. Overlaid on the total response range is the range of average VID responses which falls within the total range of detector responses. Figure X shows that the average VID responses were among the earliest detector activations. However, in the case of the flammable liquid tests, the range is relatively wide due to a longer time for detection of the view-obstructed flame in Location 2 scenarios. Yet, the VID showed capabilities for the flammable liquid fire in the middle of the response range for all detectors. All other detector comparisons are provided in Figure 29.

Figure 27

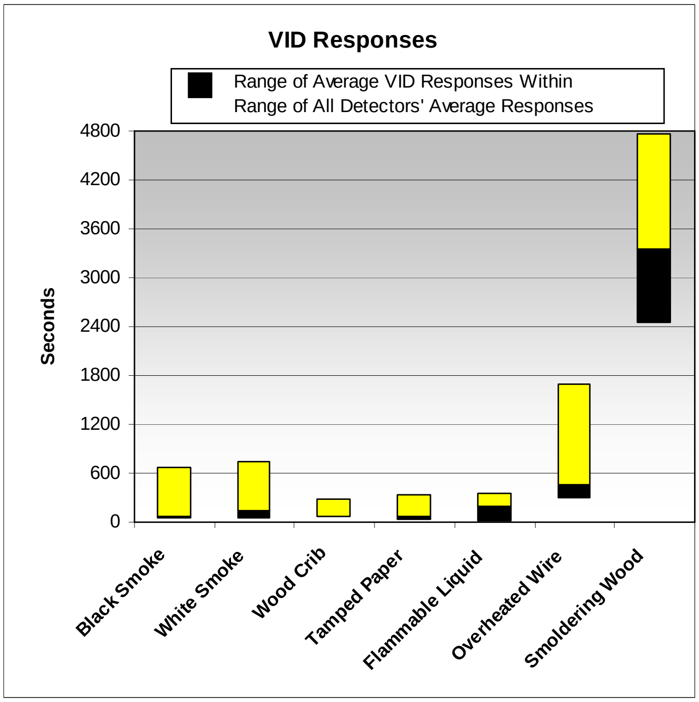
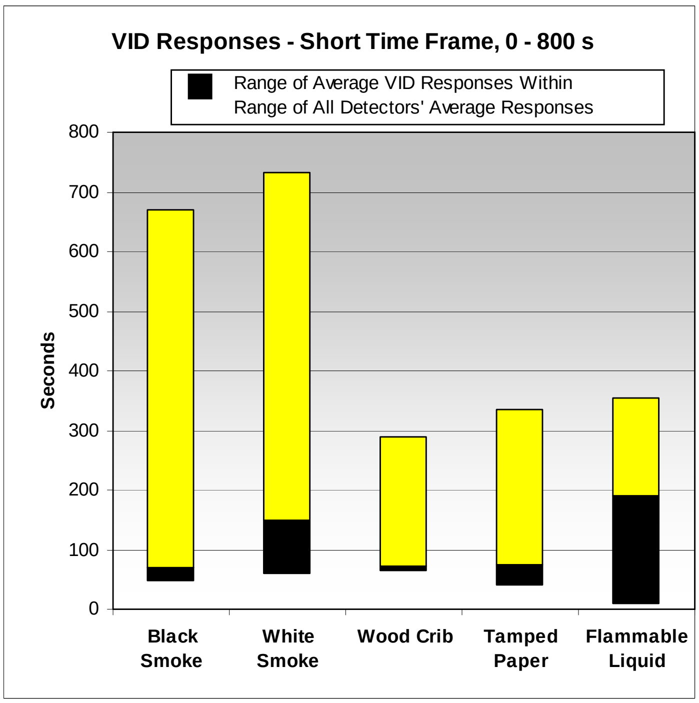


Figure 28



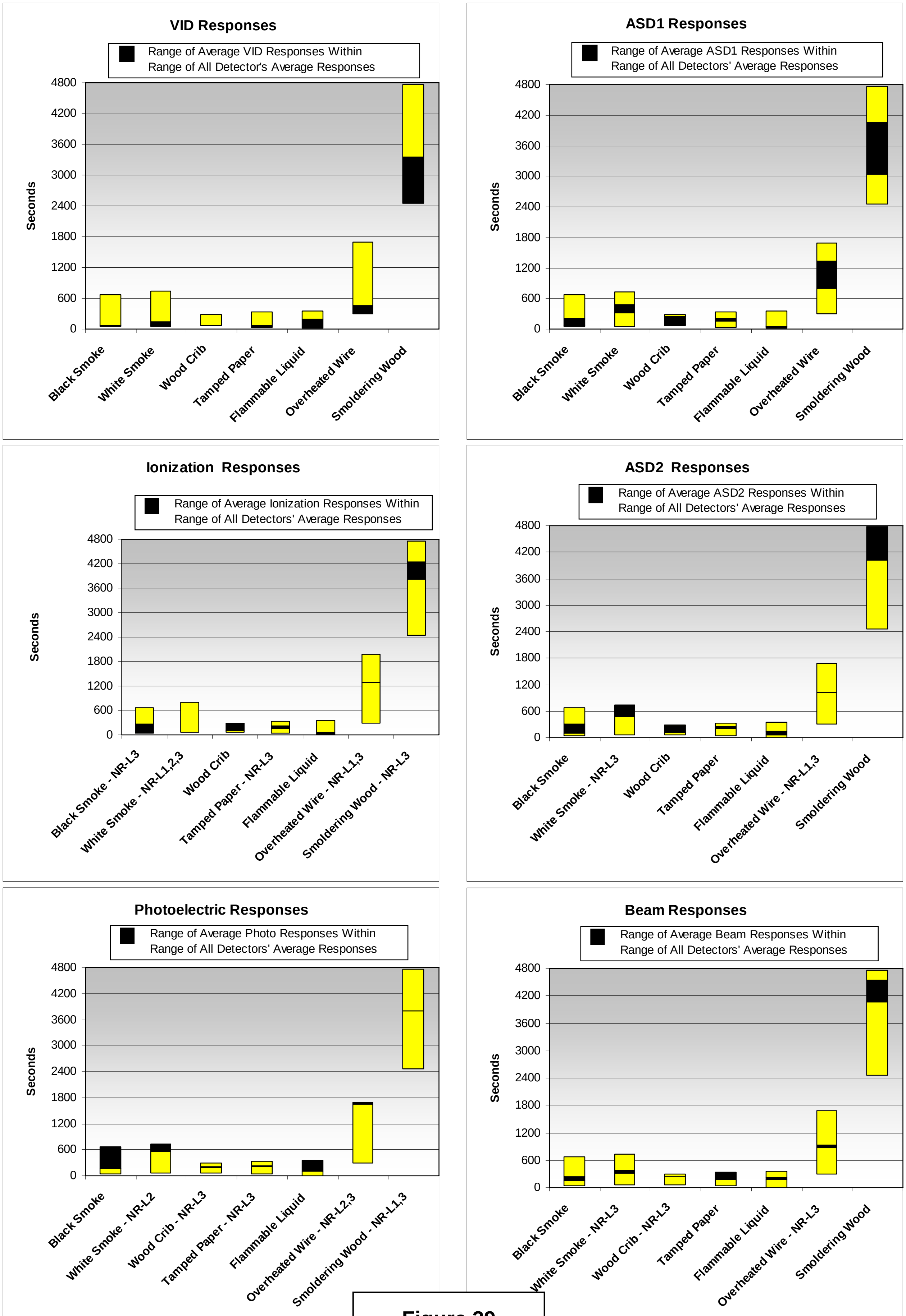

VID Responses
Range of Average VID Responses Within
Range of All Detector's Average Responses
Seconds
4800
4200
3600
3000
2400
1800
1200
600
0
Black Smoke
White Smoke
Wood Crib
Tamped Paper
Flammable Liquid
Overheated Wire
Smoldering Wood
ASD1 Responses
Range of Average ASD1 Responses Within
Range of All Detectors' Average Responses
Seconds
Black Smoke
White Smoke
Wood Crib
Tamped Paper
Flammable Liquid
Overheated Wire
Smoldering Wood
Ionization Responses
Range of Average Ionization Responses Within
Range of All Detectors' Average Responses
Seconds
Black Smoke - NR-L3
White Smoke - NR-L1,2,3
Wood Crib
Tamped Paper - NR-L3
Flammable Liquid
Overheated Wire - NR-L1,3
Smoldering Wood - NR-L3
ASD2 Responses
Range of Average ASD2 Responses Within
Range of All Detectors' Average Responses
Seconds
Black Smoke
White Smoke - NR-L3
Wood Crib
Tamped Paper
Flammable Liquid
Overheated Wire - NR-L1,3
Smoldering Wood
Photoelectric Responses
Range of Average Photo Responses Within
Range of All Detectors' Average Responses
Seconds
Black Smoke
White Smoke - NR-L2
Wood Crib - NR-L3
Tamped Paper - NR-L3
Flammable Liquid
Overheated Wire - NR-L2,3
Smoldering Wood - NR-L1,3
Beam Responses
Range of Average Beam Responses Within
Range of All Detectors' Average Responses
Seconds
Black Smoke
White Smoke - NR-L3
Wood Crib - NR-L3
Tamped Paper
Flammable Liquid
Overheated Wire - NR-L3
Smoldering Wood

Figure 29

IV. GENERAL FINDINGS AND CONCLUSIONS

Schirmer Engineering witnessed a series of fire tests in a warehouse environment and collected the detection times of various technologies that detect flame and/or smoke. These technologies included air-sampling (aspiration) detection (ASD), projected beam smoke detection, spot type ionization and photoelectric detectors, and video image fire and smoke detection (VID). The purpose of these tests was to capture data on the performance of the various technologies and provide a review and analysis of the response data for each type of detector for a number of fire scenarios that varied by location within the warehouse setting and varied by fire/smoke source. A key objective of the test program for axonX was to identify the performance of their VID technology relative to the other technologies tested.

In this test series, 63 tests were completed and analyzed. Seven different fire/smoke sources were tested at three different fire locations for a total of 21 different fire scenarios. Each fire scenario was tested three times for repeatability, yielding 63 total tests. Each test had five technologies with six detector events possible, that being an alarm response or non-response for the detector systems present (ASD1, ASD2, beam, ion, photo, VID). The entire test program represented a total of 378 detector system alarm events. The fire/smoke sources utilized were derived from the BFPSA *Code of Practice for Category I Aspirating Detection Systems* [1], and UL 268, *Standard for Safety Smoke Detectors for Fire Alarm Systems* [2] fire tests. The fire/smoke sources generally approximated the BFPSA and UL specified sources, including a black smoke emitter, white smoke emitter, overheated smoldering wire fire, UL 268 flammable liquids fire, UL 268 smoldering wood test, UL 268 paper fire, and UL 268 wood crib fire.

The variety of fires and locations used in these 63 tests provided sufficient data to demonstrate the relative performance of the five technologies. The following summarizes the general findings and specific conclusions regarding the performance of the VID technology in this series of tests.

1. **Chemical Smoke Candles** – The chemical smoke candles provide a comparison between the extremes of black and white smoke sources. For any of the three testing locations in the test room, the VID technology responded first in all black smoke tests with average response times in the range of 48 to 71 seconds. The ASD1, ASD2, beam and ionization detectors followed with average responses in the range of 69 to 303 seconds for the three test locations. For the white smoke trials, the range of average VID responses was 61 to 150

seconds. The ASD1 fire alarm responses and beam detectors followed in the white smoke tests in the range of 315 to 475 seconds.

2. **Real Fire Sources** – Three fire sources compared the detectors' abilities to respond to actual, real fuel sources: wood crib, tamped paper and flammable liquid. With the exception of the obstructed flammable liquid scenarios, the VID average responses occurred in the range of 9 to 75 seconds. The low-end value represents the flammable liquid responses in the unobstructed flammable liquid scenarios. If these rapidly detected flammable liquid scenarios are excluded, the average VID responses for the wood crib and tamped paper are in the range of 42 to 75 seconds. By comparison (wood crib and tamped paper scenarios) the next responding detector was the ASD1 fire alarm setting at 94 seconds and the ionization detector at 104 seconds. All other detectors' average operations were in the range of 94 to 336 seconds for the wood cribs and tamped paper tests.

   For the flammable liquid scenarios, several detectors responded relatively early. Again the average VID responses were 9 to 11 seconds for unobstructed scenarios, but significantly longer for the obstructed scenario, 191 seconds. By comparison, the ASD1 and ionization average responses were in the range of 22 to 64 seconds for all three fire/smoke source locations including the obstructed locations. These results show that the VID technology lags the ASD and ionization technology in the flammable liquid scenarios when the camera view is obstructed. However, it is also noted that the VID performance in the obstructed flammable liquid scenario was comparable to the beam detector –191 seconds for the VID and 214 seconds for the beam detector.

3. **Smoldering Fires** – The overheated wire and smoldering wood tests are very low energy fire/smoke sources that resulted in much longer times for detector response than occurred with the chemical smoke candles or the flaming fire sources. For all the overheated smoldering wire scenarios, the VID responded first with an average response in the range of 298 to 455 seconds. The next responding detectors were the ASD1, beam, ionization and ASD2 detectors in the range of 805 to 1016 seconds. However, it is also noted that three of the technologies (photo, ion, beam) and the ASD2 alarm level did not show any response in one or more of the room scenarios. Generally, the most challenging location proved to be when the smoldering wire test was located in the corner of the room, removed and off-center from the ceiling mounted detectors.

   The smoldering wood test series when compared to all the previous test series required the longest time frame to reach detection thresholds. For all the smoldering wood source tests, the average detector responses ranged from 41 to 80 minutes. The VID detectors were the first detector type to respond in 2 of 3 locations, with average response times of 41 to 55 minutes for all scenarios. By comparison, the next responding detector was the ASD1 alarm responding to the smoldering wood scenarios in 51 to 67 minutes. All other detectors' responses occurred in the range between 60 and 80 minutes. The ionization and photoelectric detectors failed to respond in three scenarios.

4. **VID Overall Performance** – The VID technology performance in the 63 tests demonstrates that the VID is comparable to all other technologies tested and in this warehouse test series, generally exhibited the earliest alarm responses. The VID technology consistently provided the shortest detection times for all fuel sources in all locations except two scenarios. One exception was the flammable liquids fire in Location 2 (obstructed case) where the VID response was comparable to the beam detection (191s for VID, versus 214s for beam). The second exception was the smoldering wood scenario at Location 2 where the VID response was comparable to the ASD1 response (3354s for VID, versus 3035s for ASD1). Only the VID and ASD1 alarm level consistently responded to every fire/smoke source at every location tested in all 63 tests. This is in contrast to the fact that the ASD2 alarm level, beam, ionization and photoelectric detectors exhibited not even one response in a combined total of 63 detector events (21 potential detector alarms x 3 repeated tests) out of a possible 378 detector events.

The data and findings of this report may be relevant to a variety of applications, however, it should be noted that there may be physical or environmental conditions present in actual applications that could impact, positively or negatively, the use of any of the technologies addressed in this report. Additionally, in a number of cases some detector systems did not respond or alarm in one or more tests. Such non-responding detectors should not be viewed as a failure or inadequate for their intended purpose. Many of the low-energy fire/smoke sources used are challenging in the higher ceiling environment used in these tests. Nothing in this report should be construed to suggest or imply that any technology addressed in this report is not a suitable or capable means of fire/smoke detection.

V. REFERENCES

[1] BFPSA, *Code of Practice for Category 1 Aspirating Detection Systems, Appendix A,* British Fire Protection Systems Association, Ltd., May, 2003.

[2] UL 268, *Standard for Safety Smoke Detectors for Fire Alarm Systems*, Underwriters Laboratory, August, 2009.

[3] CyberCat 50 Intelligent Fire Alarm System, Fike.

[4] Signi*Fire* Spyder*Guard* Early Warning/Early Response, Fike.