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Spot And Aspirated Laser Smoke Detection In Telecommunications Facilities

ABSTRACT

Full-scale, in-situ comparison tests of spot and aspirated laser detection systems in an active telephone exchange were conducted to compare the response times of spot and aspirated smoke detection systems when exposed to a variety of smoke sources and ventilation conditions. The paper discusses the performance of multiple systems varying in detector type, detector spacing and detector locations (i.e., mounted on the ceiling versus on return air grills).

1.0 Introduction

With the continuing advances in technology and the use of high value electrical equipment, the need for very early warning fire detection (VEWFD) has increased [1]. The increased use of VEWFD systems has resulted in more system options being available to the user. Currently, the two primary types of VEWFD systems are aspirated (air sampling) smoke detectors and laser-based spot-type smoke detectors. Also available are the standard photoelectric and ionization detectors set to very high sensitivities. Besides having several technologies to choose from, system designers must address the varying complexities of using these systems in diverse applications, such as semiconductor and telecommunication facilities, with little validation or test data.

Full-scale, in-situ comparison tests of spot and aspirated laser detection systems in an active telephone exchange were conducted to compare the response times of spot and aspirated laser smoke detection systems when exposed to a variety of smoke sources and ventilation conditions. The paper discusses the performance of multiple systems varying in detector type, detector spacing and detector locations (i.e., mounted on the

ceiling versus on return air grills). The work provides data intended to guide system designers in the selection and use of very early warning smoke detection systems.

2.0 Experiments

Reference 2 provides details of the experimental setup and procedure. The test space was one entire floor of a three-story building, 30.5 m (100 ft) wide, 54.9 m (180 ft) long (1672 m^2 (18,000 ft^2)) 4.7 m (15.5 ft) high (Figure 1). The exchange was an active facility, which continued to operate throughout the course of the test program. The facility housed a DMS switching system, which covered approximately 223 m^2 (2400 ft^2) of the south end of the building (designated the DMS equipment area), and a main frame and transmission equipment that covers approximately 30 percent of the remaining open floor space (designated the toll/frame area). Except for three small rooms on the periphery (total ~ 67.8 m^2 (730 ft^2) the test area was not subdivided, allowing free transport of gas/smoke throughout the entire space.

The test facility was maintained at normal conditions between 22.2 °C and 22.7 °C (72 and 73 °-F) and 45% relative humidity. Conditions in the test area were maintained via two independent ventilation systems: 1) a recirculation system with three pre-packaged fan/coil cooling units which served the DMS equipment area and 2) the general building HVAC which primarily served the larger toll/frame area. The layout of both systems is shown in Figure 2. The recirculation system serving the DMS equipment area consisted of three air conditioning units sharing a common discharge ductwork (AC1, AC-2, and AC-3 in Figure 2). This system provided the bulk of the airflow through the switch equipment. Compared to the toll/frame area, the airflow velocity in the DMS equipment area was high. Two ventilation conditions were investigated. The first condition consisted of all three recirculation units and the general HVAC unit operating (i.e., normal operation at 12.2 and 5.9 m^3/s (25844 and 12618 cfm), respectively). The second condition consisted of shutting down two of the three recirculation AC units in the DMS area yielding a supply flow rate of 2.9 m^3/s (6,224 cfm) from the remaining

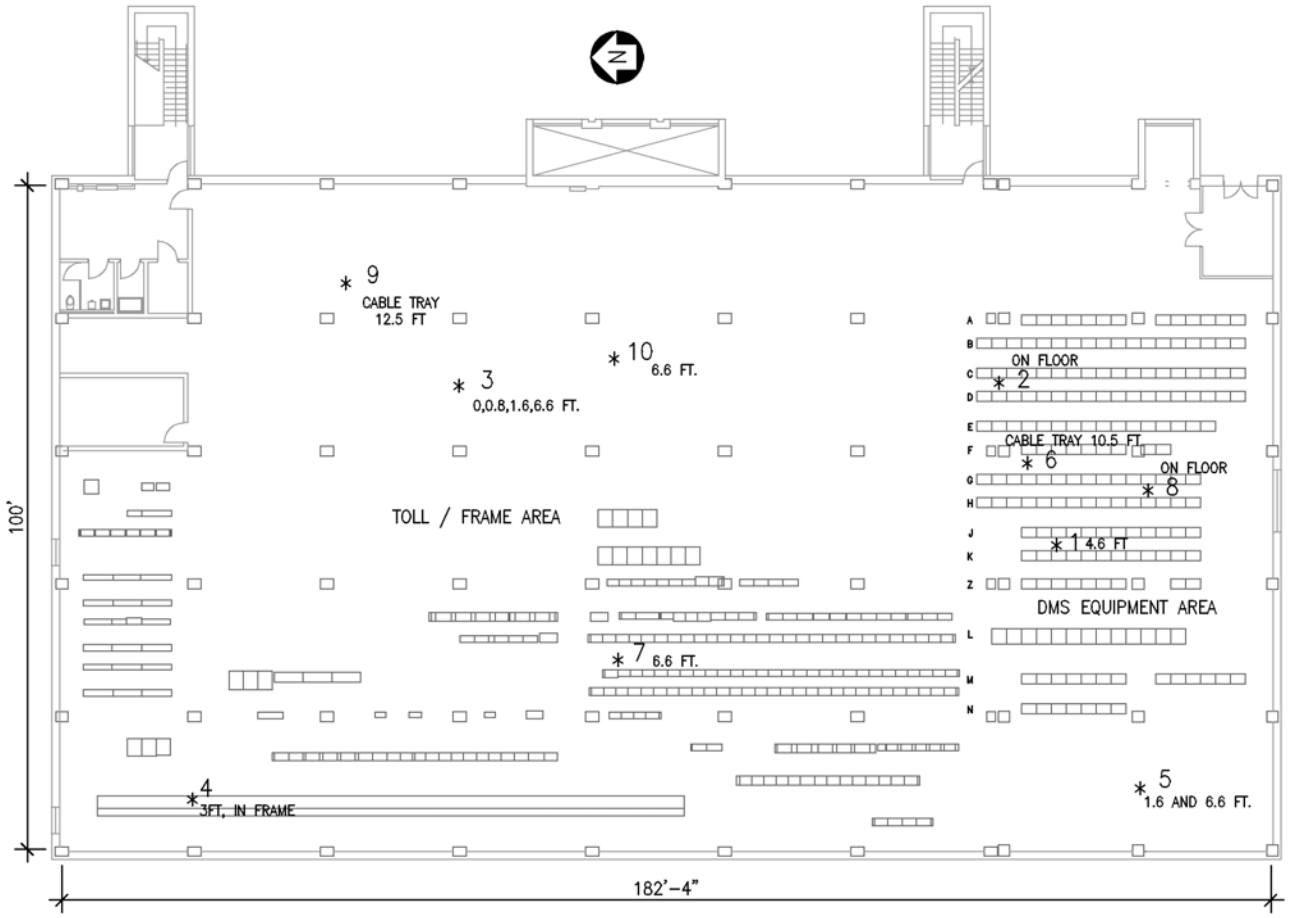

Figure 1 – Test Site with Smoke Source Locations and Equipment Layout

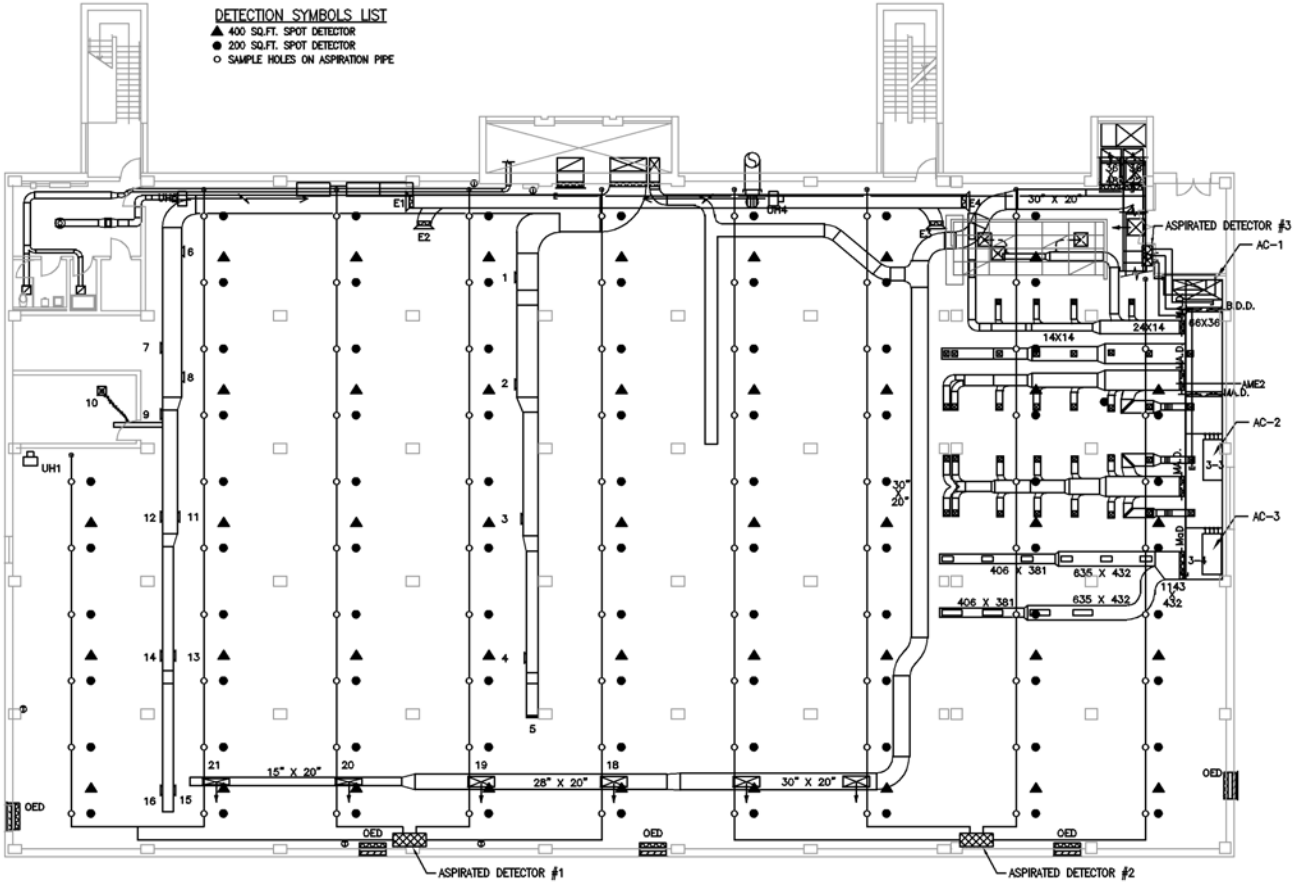

Figure 2 – Drawing of Device Locations and the Layout of the Ventilation Systems

AC unit (AC1) and the normal 5.9 m^3/s (12618 cfm) from the general HVAC supply. Two different types of commercially available laser based smoke detectors were evaluated in this test program: 1) spot type and 2) aspirated. Both types utilized the light scattering principal for smoke detection. The detector layouts were typical of that used in the telecommunication industry [3] and was driven by the 6.1 m x 6.1 m (20 ft x 20 ft) column spacing (bay) in the facility, which is typical of North American telecom buildings. Figure 2 shows the locations of the detection systems. All systems were designed and installed according to standard practices and commissioned by manufacturer authorized personnel.

The spot detection systems consisted of VIEW detectors (LPX-751) installed at ceiling level at both 18.6 m^2 (200 sq ft) (hereinafter referred to as "200 SF") and 37.2 m^2 (400 sq ft) (hereinafter referred to as "400 SF") spacing. Spot detectors were also mounted over the return grills of the ventilation systems (designated as Spot Returns). The 200 SF detectors covered regions 3 m x 6 m (10 ft by 20 ft). The 400 SF detectors covered areas that measured 6 x 6 m (20 by 20 ft), corresponding to the coverage areas of the two closest 200 SF detectors. All of the detectors (including the aspiration system) were installed using four circuits and were monitored by two Notifier panels. The Notifier AFP-400 and AFP-300 control panels were programmed using the Veri•Fire 400™ Programming Utility, revision 3.51. VIEW detector sensitivity levels were fixed at the beginning of the test program to Pre-Alarm setting #4 (0.05 %/ft) and Alarm setting #3 (0.10 %/ft). The Cooperating Multi-Detector Sensing feature was enabled independently for the 200 SF and the 400 SF View systems using condition C, which involves two adjacent detectors. Alarm verification was not used.

The layout and installation of the air aspirated smoke detection systems were performed in conformance with current industry practice, as embodied in Reference 3. The aspirated systems consisted of three VESDA LaserPlus detectors installed to cover three regions of the test space: 1) the 929 m^2 (10,000 ft^2) of space at the north end of the space (toll/frame area); 2) the remaining 743 m^2 (8,000 ft^2) at the south end of the space (DMS equipment area); and 3) the return air inlets. The VESDA systems (1, 2 and 3) were numbered according to the designations described. The detector settings

corresponded to typical sensitivity levels used in telecommunication facilities: Alert was 0.0125 %/ft, Action was 0.022 %/ft, and Fire1 was 0.03 %/ft. No delay settings were used.

Five smoke sources were evaluated in this study, based on an understanding of past fire incidents in the targeted occupancies (telecommunications and data processing) as well as an understanding of the equipment and materials used in these occupancies that may become either the source of ignition energy, or first fuels for a fire [4-8]. The smoke sources consisted of the following:

1. Overheat of BSI 6266 wire samples,
2. Overheat of Bell Canada wire samples,
3. Mixture of potassium chlorate and lactose (BSI 6266 test [7]),
4. Internal printed wire board (PWB) failure [8], and
5. Conductive heating test of an EPDM insulated cable [8].

The smoke sources were evaluated at ten different locations throughout the test facility, as well as at various heights (e.g., floor level, 2 m (6.6 ft) and 3.8 m (12.5 ft) high). Figure 1 shows the smoke source locations. Some source locations were selected to specifically evaluate the effect of various ventilation conditions (e.g., high airflow in the DMS and relatively still air zones) and geometric considerations (e.g., obstructions due to duct work or cable trays). Three locations (7, 9 and 10) were randomly selected.

3.0 Results And Analysis

In total, fifty-six (56) tests were conducted, encompassing variations in source type, source location, and ventilation conditions. Nineteen (19) BSI wire tests were conducted, ten (10) Bell wire tests, twenty (20) chlorate/lactose tests, five (5) PWB tests, and two (2) conductive heating tests. In thirteen of the tests, the smoke sources were either of such small size and duration or in a hard to detect location that no system reached a detection threshold. Of the remaining 43 tests in which at least one system reached a detection threshold, various analyses were conducted to compare the response performance of the different detection systems evaluated.

The analyses of response times was conducted based on two criteria. The first criterion is the time of first response. This time refers to the first time at which any detector within a system reaches any prealarm or alarm criteria. For the aspirated detectors, alarm condition "Alert" was always first even if "Fire1" was attained during the test. Spot detection systems sometimes transitioned directly from normal conditions to "Alarm" without signaling a "Prealarm" condition first. The time of first response criterion provides data from which one can assess the earliest possible notification provided by a detection system in response to a smoke source.

The second criterion used for evaluating system performance was the time to full alarm, either "Alarm" for the spot or "Fire1" for the aspirated systems. Depending on the end user and the particular facility application, an alarm condition may be the significant criteria for evaluating a detection system. As the results show, comparison of detection systems based on the two evaluation criteria can vary with respect to which system provides faster or more complete detection capabilities.

Results were evaluated for five different systems, defined as follows: (a) 200 SF Spot, (b) 400 SF Spot, (c) Spot Returns, (d) Aspirated Ceiling (1 and 2), and (e) Aspirated Returns (3). Using these five systems allowed results of key components of both the spot-type and the aspirated detection systems to be evaluated. Current practices would dictate that a ceiling mounted spot-type detection system (200 SF or 400 SF) would be the primary alternative to the AT&T specification of an aspirated system installed at the ceiling and at air return grills (i.e., full aspirated system1, 2 and 3). The above system categories allow for such comparisons to be made while also evaluating other combinations, such as the benefits of including spot or aspirated detection at the air returns.

An example of results for selected system comparisons have been summarized below. Table 1 shows a summary of the comparisons between the 200 SF Spot system and the full Aspiration (1, 2, and 3) system based on time to first response and time to alarm results. The "Total Number of Tests" reported in the table represents the number of tests in which at least one of the systems being compared responded according to the

criterion being evaluated. As can be seen in Table 1, the 200 SF Spot system responded to more sources when evaluated according to either the time to first response or time to alarm criterion. The table also shows the number of tests in which each system responded faster than the other. The Aspirated (1, 2, and 3) system was first to respond in more tests (26 v. 17) than the 200 SF Spot system when compared according to the time to first response, but the 200 SF Spot system alarmed first in more tests (19 v. 13) when evaluated according to the time to alarm. For most system comparisons, excluding the cases in which one system did not respond, the difference in response times were generally within one to two minutes. Table 2 presents a similar summary of the comparisons between the 400 SF Spot system and the full Aspiration (1, 2, and 3)

Table 1 – Comparison of First Response and Alarm Results for the 200 SF Spot and the Aspirated (Zones 1, 2, & 3) Detection Systems.

FIRST RESPONSE	
Total Number of Tests Where System Achieved Either Pre-Alarm or Alarm	**43**
Number of times Aspirated system responded	34
Number of times 200 SF Spot system responded	40
Number of times Aspirated system responded first	26
Number of times 200 SF Spot system responded first	17
ALARM	
Total Number of Tests Where System Reached Alarm	**32**
Number of times Aspirated system alarmed	19
Number of times 200 SF Spot system alarmed	29
Number of times Aspirated system alarmed first	13
Number of times 200 SF Spot system alarmed first	19

Table 2 – Comparison of First Response and Alarm Results for the 400 SF Spot and the Aspirated (Zones 1, 2, & 3) Detection Systems.

FIRST RESPONSE	
Total Number of Tests Where System Achieved Either Pre-Alarm or Alarm	**39**
Number of times Aspirated system responded	34
Number of times 400 SF Spot system responded	31
Number of times Aspirated system responded first	28
Number of times 400 SF Spot system responded first	11
ALARM	
Total Number of Tests Where System Reached Alarm	**24**
Number of times Aspirated system alarmed	19
Number of times 400 SF Spot system alarmed	15
Number of times Aspirated system alarmed first	17
Number of times 400 SF Spot system alarmed first	7

system. Several observations regarding system response relative to smoke source type

and location can be made based on the test results. The aspirated detection systems (both ceiling and return detectors) were unable to detect most of the BSI wire tests. Considering all three aspirated detectors, only 6 of 19 BSI wire tests were detected. In comparison, the 200 SF Spot system responded in 13 tests and the 400 SF Spot system responded in 8 tests. All detection systems were unable to detect a majority of the Bell wire tests. Evaluating the detector responses when sorted per source location revealed that smoke from source Location 4 (the frame, which consists of horizontal racks of wire) was not detectable by either the spot or the aspirated return detectors. Except primarily for one PWB test, smoke from Location 9 was not detected by any of the systems. Location 9 was in the toll/Frame area on top of a cable tray and subject to high airflows.

Based on the criteria of time to full alarm, few alarm conditions were reached by any detection system for the Bell wire tests (4 of 10 tests). The Spot Return detectors reached alarm conditions in only 5 of all 53 tests reported. The Aspirated system (1, 2 and 3) and the 400 SF Spot system only reached alarm level in 3 of the 19 BSI wire tests. The 200 SF Spot system alarmed in 10 BSI wire tests.

A review of the response times showed that there is considerable variability in the alarm times from a given detection system due to changes in source type and location. Even for tests in which conditions were nominally the same, response times varied by up to a minute. For example, four lactose/chlorate tests were conducted in the same location with no changes in ventilation. The 200 SF Spot system and the ceiling and return aspirated systems had times to first response that varied by up to 48 to 72 seconds between tests. On a percentage basis with respect to the times to respond, these time differences represent roughly 30 to 70 percent variability. These differences may be partially attributable to the way in which the lactose/chlorate burned, but they also illustrate the variability that can be obtained due to subtle and imperceptible differences in events, such as ventilation conditions.

4.0 Conclusions

Based on the analyses of the detection system response times, the following conclusions were reached:

1. The 200 SF Spot detection system (ceiling mounted detectors) and the full Aspiration (1, 2 and 3) system (ceiling and return air grills) performed comparably. Each system demonstrated relative performance advantages depending on the criteria of performance. Considering the time to first response, the Aspiration system responded sooner in a majority of tests (26 v. 17); however, the 200 SF Spot system detected a greater number of sources (40 v. 34). Based on the time to alarm results, the 200 SF Spot system provided more responses (29 v. 19) than the aspiration system. The spot detection system also alarmed first in more tests (19 v. 13). Even though neither system was clearly superior in response time compared to the other, due to the high sensitivity of these systems, it is expected that they respond faster and to more incipient fires than conventional, standard sensitivity smoke detection systems.

2. The 400 SF Spot system provided a decreased level of performance (i.e., ability to detect the smoke sources and reach alarm points) compared to the 200 SF Spot system. Consequently, the performance of the 400 SF Spot system was also not as good as that of the full Aspirated (1, 2 and 3) system. However, the performance of the 400 SF Spot and the Ceiling Aspirated (1 and 2) systems were more comparable. Comparing the 400 SF Spot versus the full Aspiration (1, 2 and 3) system, the Aspirated system was able to respond (34 v. 31) and alarm (19 v. 15) to more fires than the 400 SF Spot system. Similarly, the full Aspirated system responded faster than the 400 SF Spot system when evaluated according to either the time to first response or time to alarm criterion (28 v. 11 and 17 v. 7, respectively).

   The Ceiling Aspirated and the 400 SF Spot systems detected approximately the same number of sources when evaluated according to either the time to first response (31 v. 31) or time to alarm criterion (14 v. 15). The Ceiling Aspirated system typically responded and alarmed first (26 v. 11 and 13 v. 8, respectively),

typically ranging from 2 to 80 seconds faster than the 400 SF Spot system. The time difference was less than 60 seconds for the majority of the tests. Depending on the facility and the end-user requirements, these time differences may not be considered significant for the incipient-type sources evaluated.

3. There was no clear performance difference between the spot detectors and the aspirated detectors used at the return grills in these tests. The Aspirated Returns system and the Spot Return detectors provide approximately the same capability to respond and alarm to a fire (25 v. 29 and 10 v. 7, respectively). Depending on the criterion used for evaluation (time to first response or time to alarm), both systems were shown to respond faster than the other.

4. The inclusion of the spot detectors at the return air grills with the 200 SF Spot ceiling system provided little improvement in detection performance compared to the 200 SF Spot ceiling system used alone. Considering the time to first response, the Spot Returns detected fewer tests (25 v. 40 out of 43) and were slower to respond in most tests (4 v. 39) than the 200 SF Spot system. Based on the time to alarm results, the Spot Returns system also provided fewer alarms (7 v. 29 out of 31) and alarmed slower in most tests (2 v. 29) than the 200 SF Spot system. The biggest contribution provided by the Return detectors was the detection of 3 additional fires that were not detected by the 200 SF system.

5. The Aspirated 3 detector installed at the air handler return grills provided a small increase in detection capability for the full Aspirated system (1, 2 and 3) compared to the Ceiling Aspirated (1 and 2) system used alone. Considering the time to first response, the Aspirated Returns system detected fewer tests (25 v. 31 out of 34) and were slower to respond in most tests (7 v. 27) than the Ceiling Aspirated system. Based on the time to alarm results, the Aspirated system at the air returns also provided fewer alarms (10 v. 14 out of 19) and alarmed slower in the majority of tests (7 v. 12) than the Ceiling Aspirated system. All of the five tests, in which the ceiling system did not alarm and the return system did, were at a single source location close to the air returns.

6. The results reported in this test series, with respect to the value of return air

intake detection, are counter to general practices and recommendations in the telecommunications industry [1,3]. HVAC practices in the telecommunications industry vary with different airflow patterns and volumetric flow rates depending on the heat loads imposed by the telecommunications equipment present in the room and the design concept used. The differences observed in this study may be attributed to the fact that the general practices were based on studies in which the HVAC systems consisted of a single return point and higher airflow rates.

5.0 References

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