

Inspection, Testing and Maintenance Records: A Window into System Reliability

Steve Carter
Vice President Information Technology and Engineering
Orr Protection Systems, Inc.

Telephone: (502) 244-4507
Fax: (502) 244-4554
e-mail: scarter@orrprotection.com

Introduction

What is the reliability of a fire alarm system? That's certainly an important question that should be answered. However, what is the formula for predicting the reliability of any given fire alarm system? Much has been written on this subject and most have concluded that the factors contributing to the reliability of a system will include things like: the quality level of component manufacturing, competence of the design engineer, proper installation techniques, and a diligent inspection, testing and maintenance program. I want to spend a few minutes exploring just one of those factors today – the inspection, testing and maintenance of systems. I believe, like many of you, that when an appropriate level of inspection, testing and maintenance is taking place - - that this activity will directly contribute to the high level of reliability expected of a fire alarm system. But how does one prescribe this "appropriate" level?

For many years, the leading standard for the inspection, testing and maintenance of fire alarm systems has been found in chapter 10 of NFPA 72, the National Fire Alarm Code. It is here that fire alarm system owners, service contractors, and authorities having jurisdiction will find the requirement for a prescribed frequency of visual inspections, test routines and preventative maintenance activities for all types of components found in a fire alarm system. For example, NFPA 72 prescribes for a common smoke detector that a visual inspection be completed on a semi-annual basis, functional testing on an annual basis and sensitivity testing the first year after installation and every two years after that. In addition to defining the frequency of these required activities, the standard also provides instructions on methods for many of the required testing routines. For example, the method for functional testing of a common smoke detector is for it to be tested in place to ensure smoke entry into the sensing chamber and an alarm response using smoke or listed aerosol. And remember, this particular "functional test" is required to be performed on an annual frequency.

One of the more challenging problems for those on the NFPA 72 – Chapter 10 technical committee has been to find a technical substantiation for prescribing the frequency for an inspection or test or preventative maintenance activity of a particular fire alarm system component. Part of the problem is the lack of historic performance data available to the committee that might be used to measure and ultimately predict the failure rate of a fire alarm system component. Historically, system owners and service contractors have used pen and paper to record the results of these required inspections, tests and maintenance activities. Additionally, these handwritten records have been kept in many different formats. Collecting a population of data from handwritten forms in various formats has made the task of compiling and analyzing data quite difficult. To my knowledge, very few studies have been completed of this nature; therefore, little technical information has been available to the committee that could be used to inform decisions surrounding a change from the current frequencies prescribed by the standard.

Today, an increasing number of fire alarm system owners and service contractors are utilizing software and database driven inspection, test and maintenance recordkeeping systems. These systems may offer us a greater opportunity to study relevant data which may ultimately substantiate the need to preserve or change the existing frequencies required by NFPA 72. The primary factor contributing to this greater opportunity is the utilization of structured data. One aspect of this structured data is the consistent manner of recording the result of the inspection, test or maintenance activity. This result data is tied to pre-defined tasks or events and recorded in a consistent format each and every time an inspection or test is completed. For instance when testing a smoke detector, the result of a functional test might be required to always be recorded as either a Pass or Fail result, while the sensitivity test might be recorded as a Pass or Fail result accompanied by a two-decimal numeric value (%/ft.). Another important aspect of this structured data is the use of master data tables which are referenced for the recording of failure conditions. For instance, after recording a failure result from the visual inspection of a Strobe Light, the software might require the user to select an appropriate failure condition value from a pre-defined pick list of options such as “Broken Lens”. The outcome of this kind of structured data is an opportunity to more quickly and easily analyze inspection, test and maintenance data for fire alarm systems.

NetReport

Orr Protection Systems is a leading fire protection systems contractor who has for over 30 years been designing, installing and servicing many types of systems. However, over the past 7 or 8 years Orr has increased its focus on the inspection, testing and maintenance aspect of the business. This focus has

lead Orr to invest its resources in several areas including technology to support the process of inspection, testing and maintenance recordkeeping. In 2003, Orr began the development of a software and database driven inspection information management system called NetREPORT.

NetREPORT is made up of three primary parts. The first part is the Web Server. The Web Server consists of three key elements: the Component Library, the Client Monitor, and the Route Manger.

The first element, the Component Library, is where the various types of components are setup with the appropriate inspection tasks, testing tasks and maintenance tasks. Up to four service levels may be defined according to the frequency assigned each task. For example, Service Level 1 may require the task to perform a visual inspection of a smoke detector on a semi-annual frequency; however, Service Level 2 may only require this same task annually. Since many different manufacturer and models of devices will share a common inspection, testing and maintenance requirement, Component Templates are used to more quickly assign the appropriate tasks to multiple components. Components in the Component Library are divided into Component Classes. One example of a Component Class is the Detector Class where heat, smoke and flame detector components are added to the library. Each Class contains a reference table listing the available Types of components that may be added to it. For instance, the Notification Appliance Class has Types that include Horn, Bell, Speaker, Strobe, and Horn/Strobe Combination just to name a few. The Component Library also contains a master reference table listing the available Manufacturers. Whenever a new component is added to an existing Component Class, the user is required to enter a Manufacturer and Type from those available in their respective pre-defined pick-lists, but also must enter a Model and Part Number as free-form text. Today, nearly 1,600 different components are in this library that may be used when building a system that will be inspected using the NetREPORT system. One final, but important, aspect of the Component Library is the definition of the failure conditions and repair actions available to be recorded. Again, each Class contains a reference table listing the available Conditions along with a separate listing of the available Actions that are appropriate for components existing in that class. For example, Ground Fault is one of the many failure conditions that are pre-defined and available for the Control Panel Class of components.

The second key element of the Web Server, the Client Monitor, is the database of systems to be serviced. The Client Monitor is organized into Clients, which are further broken down into Regions (or other groupings). The Client Regions contain multiple Sites (or Buildings) which have Routes (or Fire Protection Systems) inside of them. When a new Site is setup, information is captured and stored

including the address, phone numbers, personnel, notes about site protocol and other site-level information. When a new Route is setup, information is captured and stored including system manufacturer, system type, notes about special equipment required and other route-level information. Each Route must also be assigned an appropriate Service Level according to the obligations of the written service contract. The most important part of adding a new Route is the process of Assetting. Assetting is where each and every unique component of the fire protection system must be added. While this process may be accomplished through the user interface of the web server, it is best performed in the field using the NetREPORT Mobile software loaded on a handheld computer. Assetting involves physically tagging the component with a barcode label containing a unique identifier. This barcode number becomes the unique identifier for the component record along with a 5-part description of its location in the building. The primary step in assetting is the assignment of the appropriate library component according to its manufacturer and model number. It is important to note, that sometimes additional static data called Properties are recorded during assetting. These Properties may be required depending upon the type of component, such as an installation date for Non-Restorable Heat Detectors so that their 15-year replacement cycle may be tracked. Today, over 800 Clients, 6,000 Sites and 12,000 Routes exist in the Client Monitor of the NetREPORT system.

The third, and final, key element of the Web Server is the Route Manager where the Routes due for Service are scheduled assigned to the available Service Technicians. Routes become due according to their assigned Service Level and the corresponding frequencies setup for the component's tasks. Once a route inspection has been assigned to a Service Technician using the Route Manger, it becomes available for download to his or her handheld mobile computer. The Route Manger is also where Service Managers do a final quality review of completed and uploaded route inspections, the final step necessary to create the electronic inspection report.

The second part of the NetREPORT system is the Mobile Computer. Each Service Technician utilizes a handheld mobile computer loaded with NetREPORT Mobile software. This mobile computer communicates over the internet to synchronize data with the Web Server. Assigned route inspections are downloaded from the Web Server to the Mobile Computer. Completed route inspections, are uploaded to the Web Server from the Mobile Computer. Inspection, Testing and Maintenance of Fire Protection Systems are performed and the results are collected for each component using the handheld mobile computer. The results of each task are time and date stamped as the data is entered. Whenever a Failure result is recorded, the software prompts the user to enter a Failure Condition and subsequent

Repair Action to be taken. At the completion of the inspection process, additional information may be recorded including the attendees of a training session, general notes about the inspection and the signature of the system owner or representative.

The third and final part of the NetREPORT system is the Customer Portal known by its users as NetSITE. System owners are granted password protected online access to vital records for all of their fire protection systems. These records of course include historical Inspection, Test and Maintenance Reports but also include System Owner's Manuals, system drawings, and Invoices. The Customer Portal also makes available several specialized reports allowing system owners to quickly analyze inspection recordkeeping data such as failure trends and open follow-up repairs needed.

While NetREPORT certainly may have a few unique characteristics, it is not unlike many other software and database-driven inspection recordkeeping systems in use today. Service Contractors and System Owners receive tremendous value from this technology. Values like code compliance, accuracy, accountability, standardization, and many others. However, I believe this technology also offers tremendous value in its potential to help fire protection professionals to better measure fire protection system reliability. I'd like to spend the remainder of my time sharing a few of the outcomes that were the result of some analysis I performed on a population of data from Orr's NetREPORT system.

Now let me just state up front, when I (along with some help from Kathleen) choose the title of this paper, "...A Window into System Reliability", just understand, I've only barely cracked it open – I didn't come even close to opening it all the way (Ha! Ha!).

The Data and Results

In my research, I choose to analyze a population of data that included exactly four years of inspection, testing and maintenance activity from January 1, 2004 to December 31, 2007. Selected data fields from the component inspection results record table were exported from NetREPORT's Microsoft SQL database to a format readable with Microsoft Excel 2007. In order to make the data more manageable, it was separated according to Component Class. Data from both the Detectors class and the Notification Appliances class were analyzed. Fortunately, the latest version of Microsoft Excel overcame the limitations of previous versions by offering the capability to store greater than 66,000 rows. Microsoft Excel 2007 was chosen because it offered a powerful, yet simple pivot table tool to use for the analysis.

Let's take a look at some of the data from the detectors class. The analysis is broken down into each detector type including photoelectric, ionization, duct (all types), restorable heat, and non-restorable heat. [See Figures 1.1 through 1.6] The data includes the total number of inspections recorded, the number of failures and a calculated failure percentage. The data also includes a breakdown of failure conditions sorted by quantity along with a percentage of that failure against the total. A final piece of data is included comparing the number of failures that were identified by visual inspection versus functional testing.

A few outcomes were evident to me after performing this study of detector data:

- 1.) Overall, Detectors out of their sensitivity range is the number one failure condition. Ionization Smoke Detectors fail sensitivity nearly 7 times more than Photoelectric Detectors.
- 2.) Ionization Detectors seem to fail at approximately twice the rate of Photoelectric Detectors.
- 3.) Overall, failure conditions for Detectors are identified by visual inspections at an equivalent rate to functional testing. Duct detectors are an exception to this rule in that 85% of all failures are identified by testing.

A summary of key data was performed broken down into the major detector categories of All Detectors, All Smoke Detectors, Restorable Heat Detectors and Non-Restorable Heat Detectors. [See Figure 1.7] Summarized data included number of systems, number of components, and annual failure rate. The annual failure rate was calculated using the following simple formula: $[(\text{No. of Failures}/\text{No. of Components})/\text{No. of Years}]$.

Another outcome that was evident to me after this study of detector data:

- 1.) Annual smoke detector testing will identify one failure for every 300 detectors tested. Human influenced failures such as spacing, placement and obstructions have a big impact on this failure rate.

Now, let's quickly take a look at some of the data from the notification appliances class. This analysis is also broken down into appliance type including Horn and Horn/Strobe, Bell and Bell/Strobe, Speaker and Speaker/Strobe, Strobe Only, and all other types (i.e. beacons, air horns, etc.). [See Figures 2.1 through 2.6] This data again includes the total number of inspections recorded, the number of failures and a calculated failure percentage. The data also includes a breakdown of failure conditions sorted by

quantity along with a percentage of failure against the total. The comparison of the number of failures identified by visual inspection versus functional testing has again been included in the data.

A couple of outcomes were evident to me after performing this study of notification appliance data:

- 1.) The top failure condition for Notification Appliances is the device not functioning far beyond any other condition reported.
- 2.) The identification of a failure condition as the result of functionally testing Notification Appliances is six times that of those found from a visual inspection.

Both of these outcomes lead me to believe there continues to be significant value in testing these devices as part of an inspection, testing and maintenance program.

A summary of key data was again performed on the notification appliance data. The key data was summarized for same six categories of appliances as with the other data. [See Figure 2.7] Summarized data again included the number of systems, number of components and annual failure rate.

One other outcome that was evident to me after this study of notification appliance data:

- 1.) The overall failure rate of Notification Appliances is slightly higher (40% higher) than that of Detectors.

I believe that several other classes of components would also be worthy of this same type of analysis. Studying the results of categories such as Control Panel Equipment, Other Initiating Devices, Extinguishing Equipment and Air Sampling Smoke Detectors might also produce interesting outcomes. Orr's NetREPORT system offers a fairly significant population of data in each of these four categories that could also be studied.

Several aspects of my analysis are less than perfect. First, the number of systems was not static over the four year period. A greater number of systems were inspected in the fourth year than in the first year. A better data set would include a static population of systems inspected over a several year period. Second, the data set included systems of all Service Levels. In other words, results from detectors that were functionally tested on a semi-annual frequency were mixed with detectors that were only tested on an annual frequency. Understanding the impact of frequency on the results might necessitate analyzing different service levels separately. Third, the data available did not contain the installation date of the component. I believe that one important element of a reliability study is the understanding

of a components age on its failure rate. The age of the component was not a factor considered in my analysis. And I am certain that there are probably other imperfections in both the data set and the method of analysis used.

Next Steps

So what are the next steps? I believe the time is right for further study of this type of inspection, test and maintenance data. All of us could benefit from having a better understanding and a more accurate measurement of the reliability of fire protection systems. While I have attempted to “crack open a window” into one important aspect of system reliability, much greater outcomes can be expected if a proper research project was accomplished using the type of data readily available from recordkeeping software systems like NetREPORT. I believe that acting on the opportunity to study such data would go a long way towards helping the writers of NFPA 72, the National Fire Alarm Code, to demonstrate the appropriateness of the required frequencies for the inspection, testing and maintenance of various fire alarm system components.

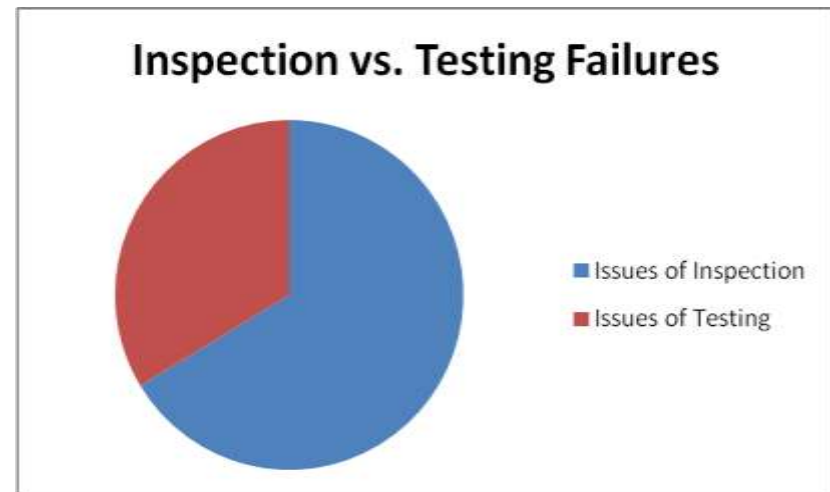
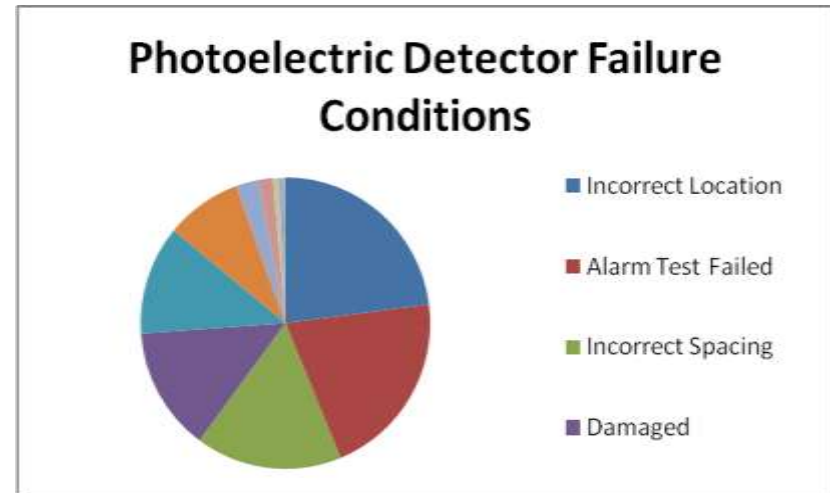
[Figure 1.1] Photoelectric Smoke Detectors

Total Inspections	No. Failed	% Failed
107,318	436	0.41%

Failure Conditions	No.	%
Incorrect Location	100	22.94%
Alarm Test Failed	91	20.87%
Incorrect Spacing	71	16.28%
Damaged	60	13.76%
Failed Sensitivity	53	12.16%
Obstructed	37	8.49%
Excessively Dirty	11	2.52%
Missing or Removed	7	1.61%
Aux. Annunciation Device Failed	3	0.69%
External Residue	2	0.46%
LED Not Illuminated	1	0.23%

Inspection vs. Testing Comparison	No.	%
Issues of Inspection	289	66.28%
Issues of Testing	147	33.72%

Photoelectric Smoke Detectors



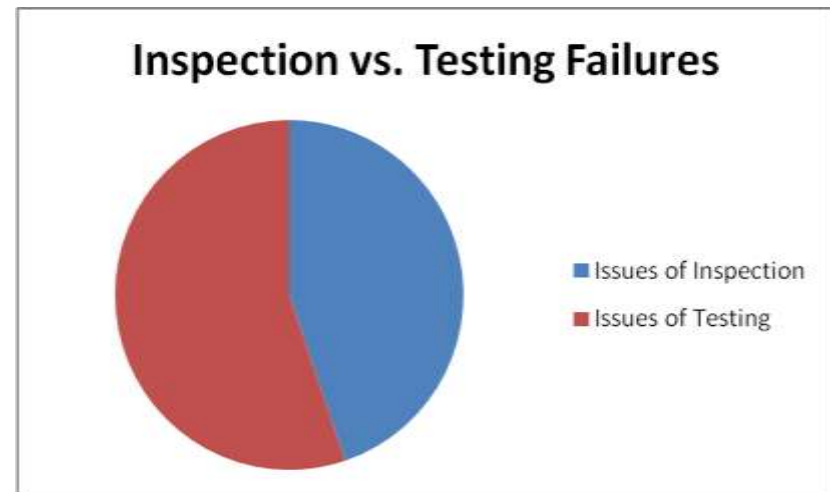
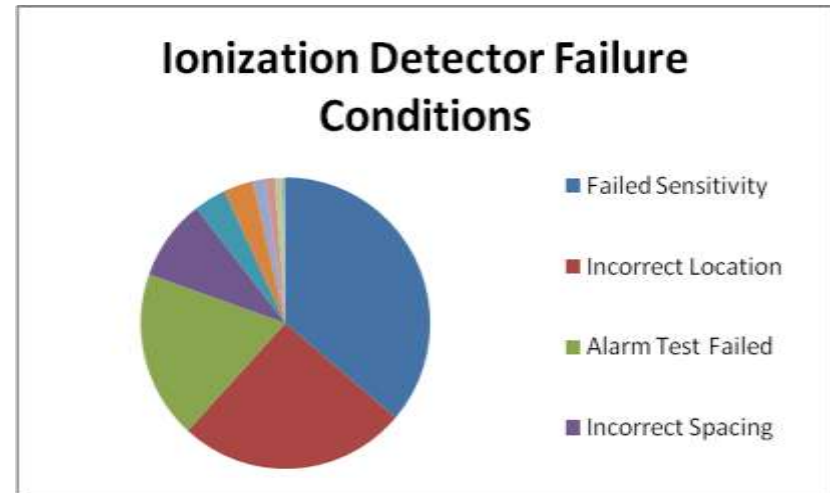
[Figure 1.2] Ionization Smoke Detectors

Total Inspections	No. Failed	% Failed
68,113	609	0.89%

Condition	No.	%
Failed Sensitivity	221	36.29%
Incorrect Location	155	25.45%
Alarm Test Failed	114	18.72%
Incorrect Spacing	55	9.03%
Missing or Removed	22	3.61%
Damaged	20	3.28%
LED not illuminated	8	1.31%
Excessively Dirty	7	1.15%
Obstructed	5	0.82%
Aux. Annunciation Device Fail	1	0.16%
Painted	1	0.16%

Inspection vs. Testing Comparison	No.	%
Issues of Inspection	273	44.83%
Issues of Testing	336	55.17%

Ionization Smoke Detectors



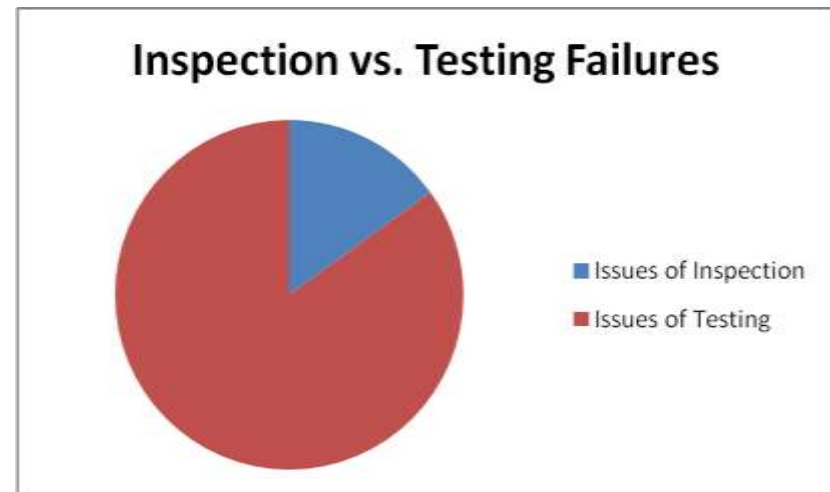
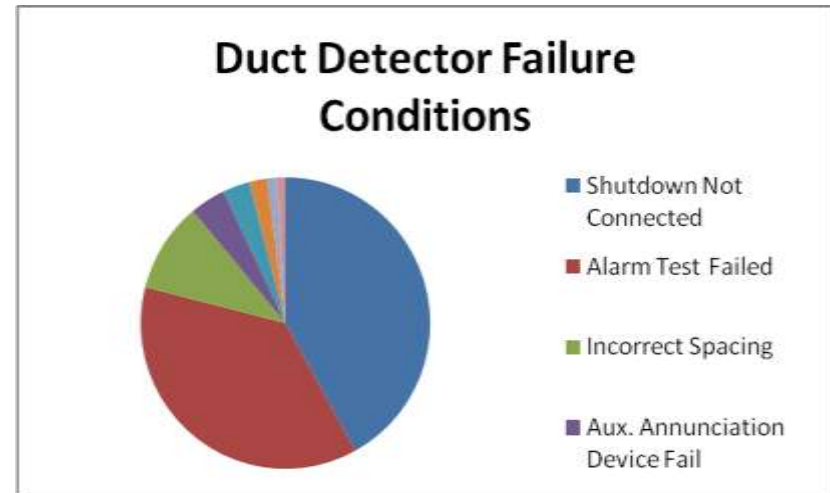
[Figure 1.3] Duct Smoke Detectors (All Types)

Total Inspections	No. Failed	% Failed
6,657	100	1.50%

Condition	No.	%
Shutdown Not Connected	42	42.00%
Alarm Test Failed	37	37.00%
Incorrect Spacing	10	10.00%
Aux. Annunciation Device Fail	4	4.00%
Missing or Removed	3	3.00%
Failed Sensitivity	2	2.00%
Damaged	1	1.00%
LED not illuminated	1	1.00%

Inspection vs. Testing Comparison	No.	%
Issues of Inspection	15	15.00%
Issues of Testing	85	85.00%

Duct Smoke Detectors (All Types)



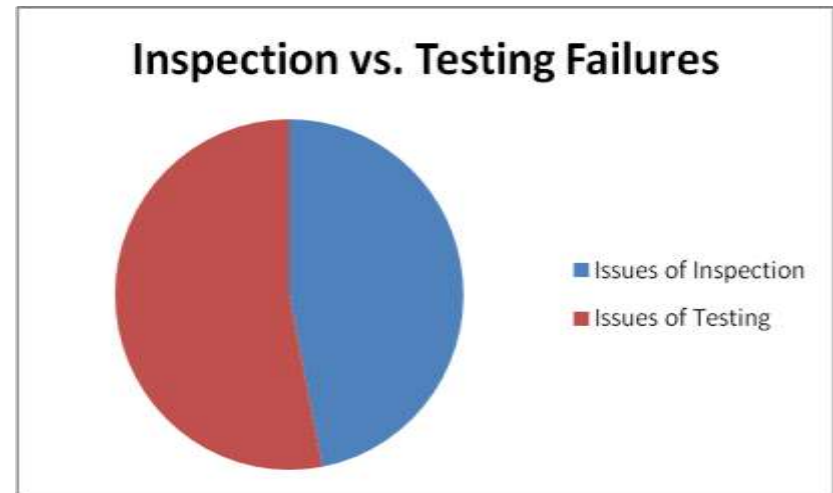
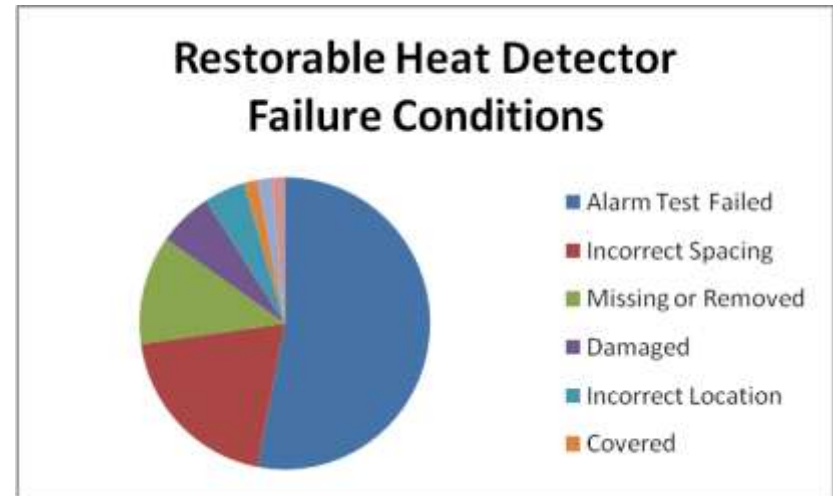
[Figure 1.4] Restorable Heat Detectors

Total Inspections	No. Failed	% Failed
13,415	66	0.49%

Condition	No.	%
Alarm Test Failed	35	53.03%
Incorrect Spacing	13	19.70%
Missing or Removed	8	12.12%
Damaged	4	6.06%
Incorrect Location	3	4.55%
Covered	1	1.52%
Excessively Dirty	1	1.52%
Painted	1	1.52%

Inspection vs. Testing		
Comparison	No.	%
Issues of Inspection	31	46.97%
Issues of Testing	35	53.03%

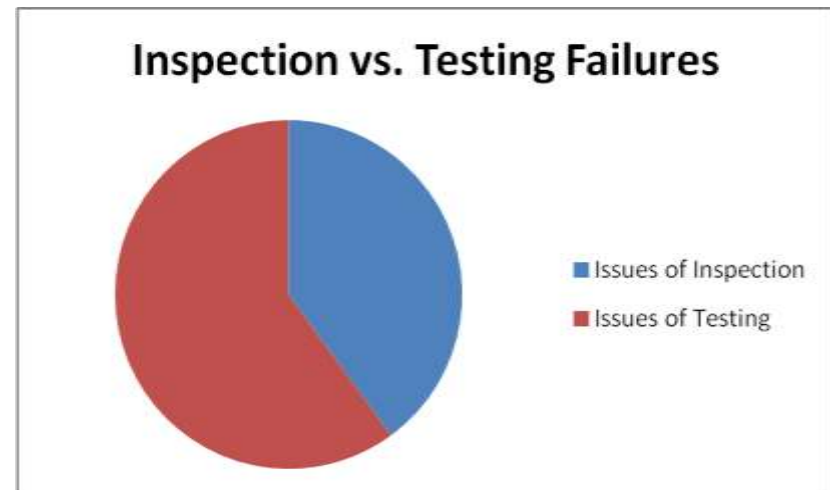
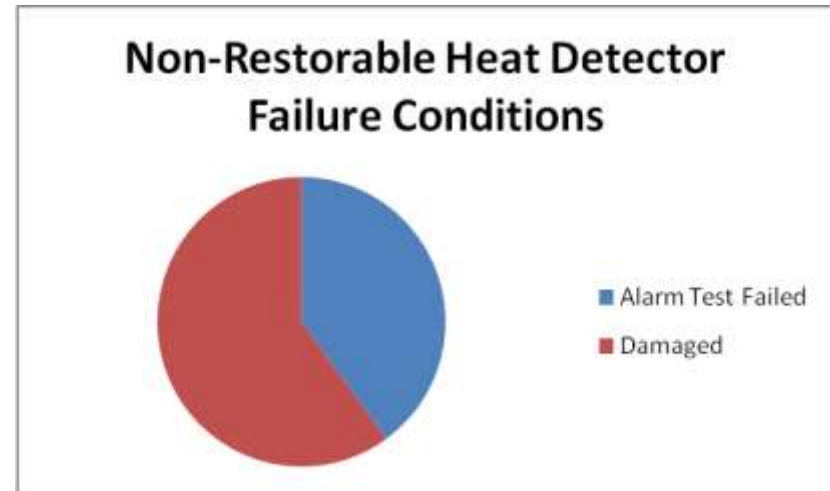
Restorable Heat Detectors



[Figure 1.5] Non-restorable Heat Detectors

Total Inspections	No. Failed	% Failed
1,505	5	0.33%
Condition	No.	%
Alarm Test Failed	2	40.00%
Damaged	3	60.00%
Inspection vs. Testing Comparison		
Comparison	No.	%
Issues of Inspection	2	40.00%
Issues of Testing	3	60.00%

Non-restorable Heat Detectors



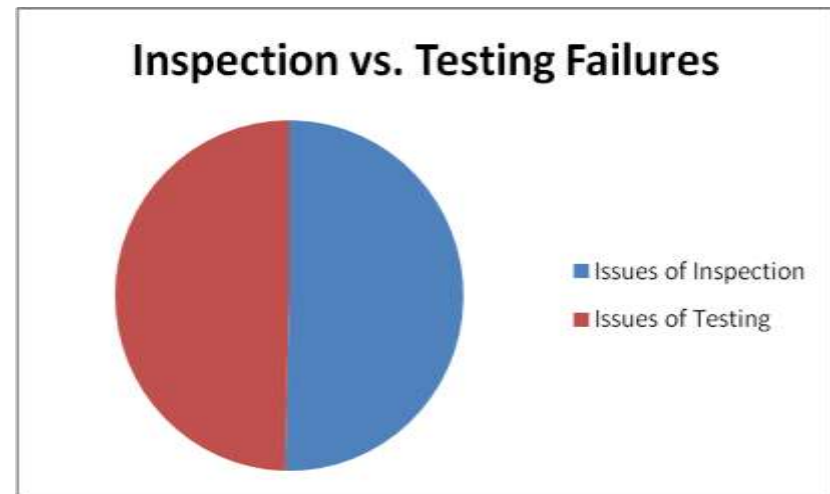
[Figure 1.6] All Smoke Detectors

Total Inspections	No. Failed	% Failed
182,088	1,145	0.63%

Condition	No.	%
Failed Sensitivity	276	24.10%
Incorrect Location	255	22.27%
Alarm Test Failed	242	21.14%
Incorrect Spacing	136	11.88%
Damaged	81	7.07%
Obstructed	42	3.67%
Shutdown Not Connected	42	3.67%
Missing or Removed	32	2.79%
Excessively Dirty	18	1.57%
LED Not Illuminated	10	0.87%
Aux. Annunciation Device Failed	8	0.70%
External Residue	2	0.17%
Painted	1	0.09%

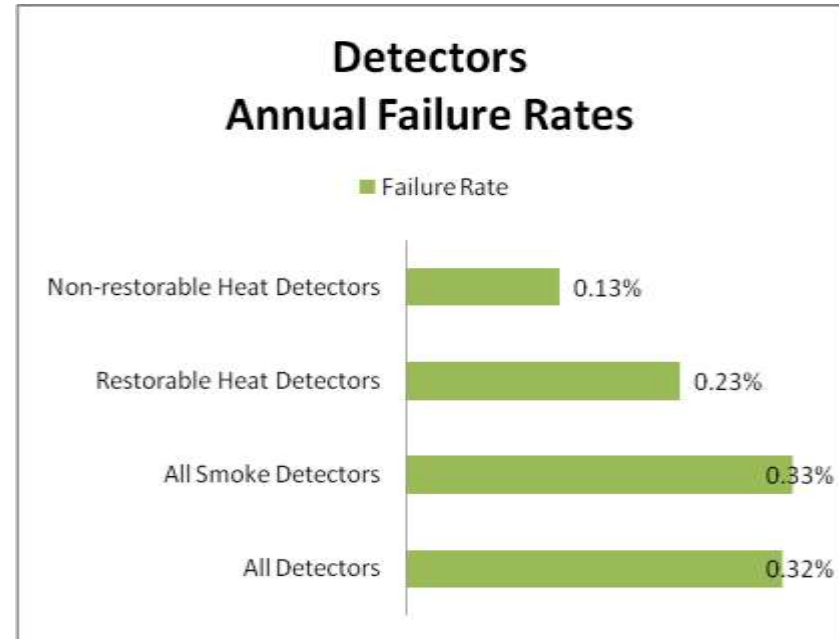
Inspection vs. Testing Comparison	No.	%
Issues of Inspection	577	50.39%
Issues of Testing	568	49.61%

All Smoke Detectors



[Figure 1.7] Detectors – Key Data Summary

Key Data Summary:	No. of Systems	No. of Components	Failure Rate
All Detectors	3,986	94,123	0.32%
All Smoke Detectors	3,856	86,161	0.33%
Restorable Heat Detectors	815	7,026	0.23%
Non-restorable Heat Detectors	268	948	0.13%



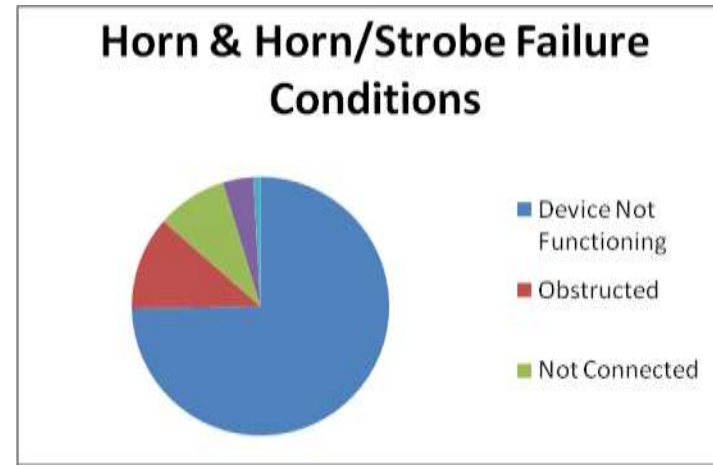
[Figure 2.1] Horn & Horn/Strobe Notification Appliances

Total Inspections	No. Failed	% Failed
33,191	340	1.02%

Condition	No.	%
Device Not Functioning	254	74.71%
Obstructed	40	11.76%
Not Connected	30	8.82%
Damaged	13	3.82%
Missing or Removed	3	0.88%

Inspection vs. Testing Comparison	No.	%
Issues of Inspection	56	16.47%
Issues of Testing	284	83.53%

Horn and Horn/Strobe Notification Appliances



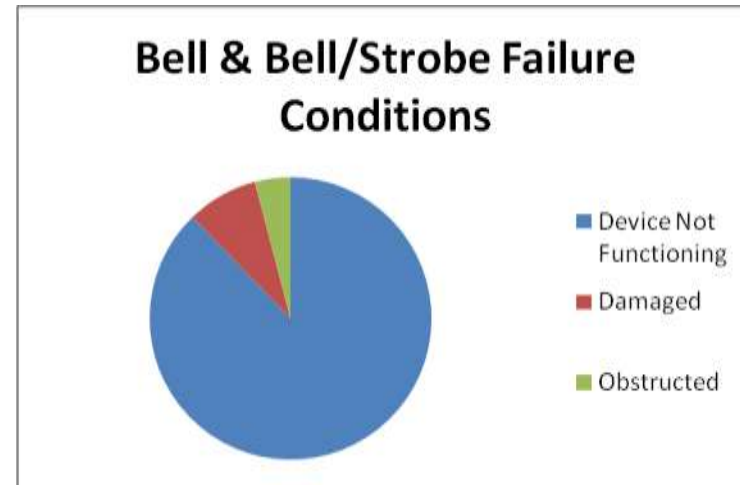
[Figure 2.2] Bell & Bell/Strobe Notification Appliances

Total Inspections	No. Failed	% Failed
9,190	49	0.53%

Condition	No.	%
Device Not Functioning	43	87.76%
Damaged	4	8.16%
Obstructed	2	4.08%
Not Connected	0	0.00%
Missing or Removed	0	0.00%

Inspection vs. Testing Comparison	No.	%
Issues of Inspection	6	12.24%
Issues of Testing	43	87.76%

Bell and Bell/Strobe Notification Appliances



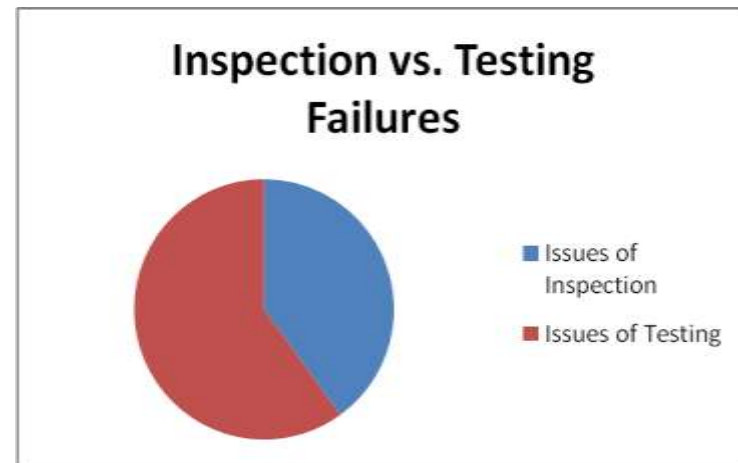
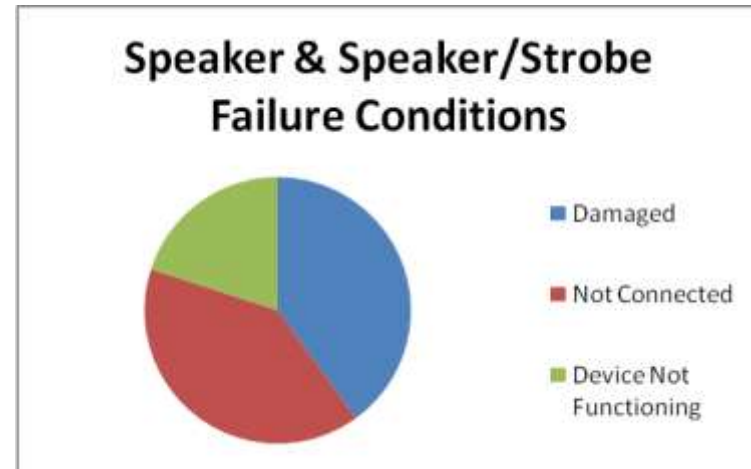
[Figure 2.3] Speaker & Speaker/Strobe Notification Appliances

Total Inspections	No. Failed	% Failed
2,901	5	0.17%

Condition	No.	%
Damaged	2	40.00%
Not Connected	2	40.00%
Device Not Functioning	1	20.00%
Obstructed	0	0.00%
Missing or Removed	0	0.00%

Inspection vs. Testing Comparison	No.	%
Issues of Inspection	2	40.00%
Issues of Testing	3	60.00%

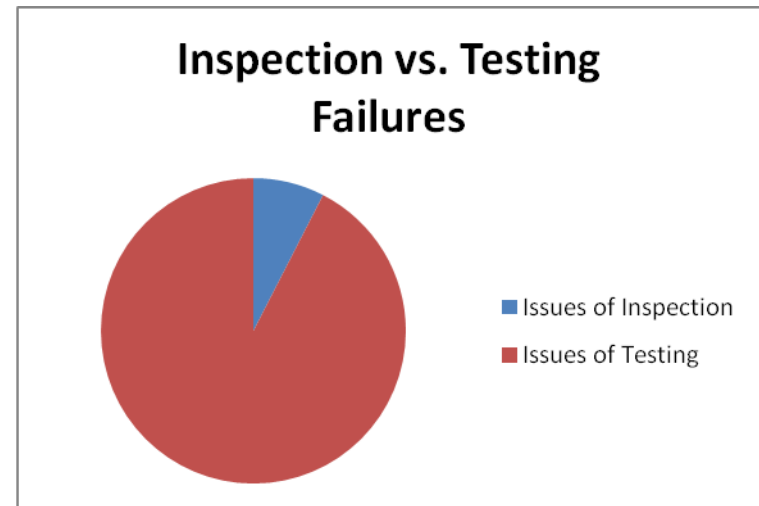
Speaker and Speaker/Strobe Notification Appliances



[Figure 2.4] Strobe Only Notification Appliances

Total Inspections	No. Failed	% Failed
17,030	159	0.93%
Condition		
Condition	No.	%
Device Not Functioning	124	77.99%
Not Connected	23	14.47%
Damaged	6	3.77%
Obstructed	6	3.77%
Missing or Removed	0	0.00%
Inspection vs. Testing Comparison		
Inspection vs. Testing Comparison	No.	%
Issues of Inspection	12	7.55%
Issues of Testing	147	92.45%

Strobe Only Notification Appliances



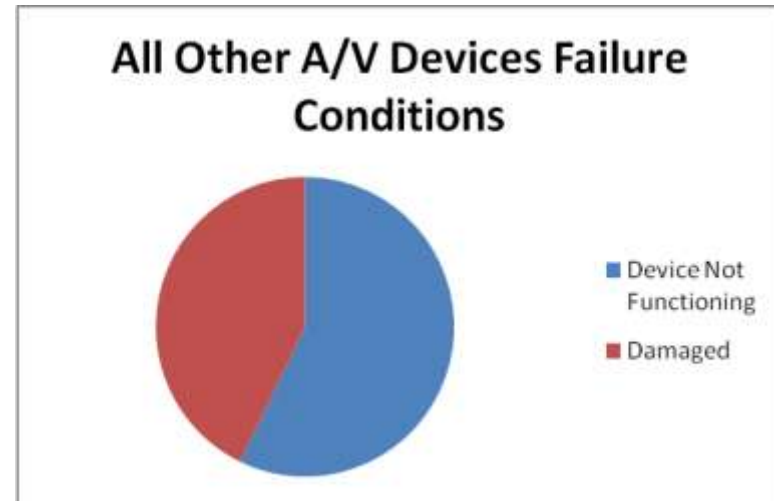
[Figure 2.5] All Other Notification Appliances

Total Inspections	No. Failed	% Failed
321	7	2.18%

Condition	No.	%
Device Not Functioning	4	57.14%
Damaged	3	42.86%
Not Connected	0	0.00%
Obstructed	0	0.00%
Missing or Removed	0	0.00%

Inspection vs. Testing Comparison	No.	%
Issues of Inspection	3	42.86%
Issues of Testing	4	57.14%

All Other Notification Appliances (Beacons, Air Horns, etc.)



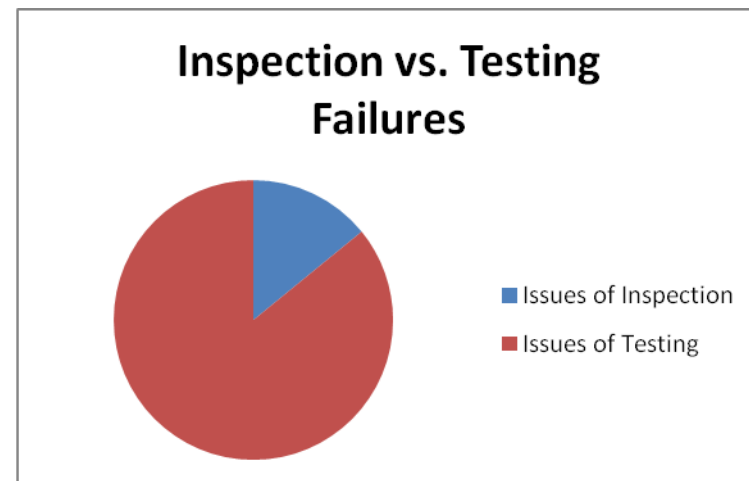
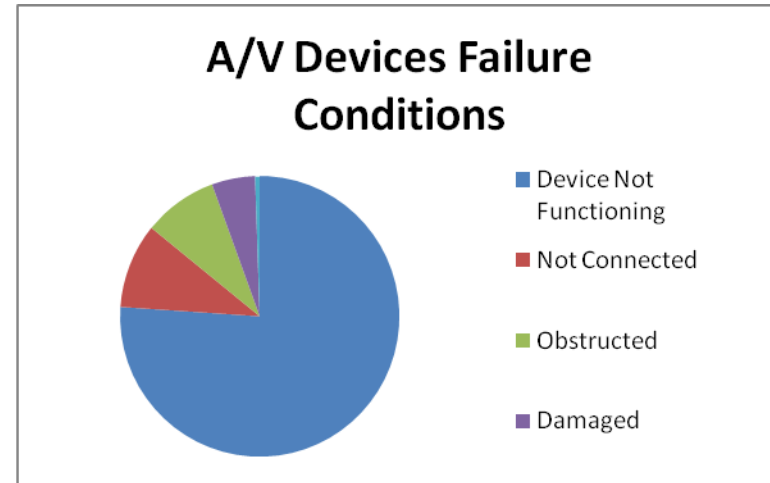
[Figure 2.6] All Notification Appliances

Total Inspections	No. Failed	% Failed
62,633	560	0.89%

Condition	No.	%
Device Not Functioning	426	76.07%
Not Connected	55	9.82%
Obstructed	48	8.57%
Damaged	28	5.00%
Missing or Removed	3	0.54%

Inspection vs. Testing Comparison	No.	%
Issues of Inspection	79	14.11%
Issues of Testing	481	85.89%

All Notification Appliances



[Figure 2.7] Notification Appliances – Key Data Summary

Key Data Summary:	No. of Systems	No. of Components	Failure Rate
All Notification Appliances	3,470	30,610	0.46%
Horn & Horn/Strobe	3,118	16,929	0.50%
Bell & Bell/Strobe	1,627	3,739	0.33%
Speaker & Speaker Strobe	22	1,296	0.10%
Strobe Only	1,577	8,456	0.47%
All Other	79	204	0.86%

