Underwriters Laboratories Inc.

Report on Project 92NK26482

Fire Detection in Recreational Vessels

OVERVIEW

Since their inception, smoke alarms and smoke detectors have been shown to provide lifesaving performance in homes and buildings. The results of this project demonstrate that this type of performance should also be possible when using these products on board recreational vessels.

The work performed under this project can be broken into two main components, the performance of smoke and environmental tests on smoke alarms and detectors, and the development of an outline of investigation for testing and installation of fire alarm devices on recreational vessels.

Smoke alarms and detectors were subjected to shock, vibration, and salt fog corrosion similar to what they could be expected to encounter in actual use. Smoke tests were also conducted, both in a simulated boat setting, as well as on two derelict vessels.

A draft outline of investigation for the installation, maintenance, and use of fire detection systems on recreational boats was developed. The basics of the draft came from tests and installation guidelines contained in other UL and ABYC Marine Standards. This draft then evolved during the course of this project. The evolution of this draft was aided by reviewing information from other sources, such as the National Fire Alarm Code (NFPA 72), members of the industry advisory group assisting with this project, and results of testing obtained during this project.

Details of the testing performed and of the development of the draft outline of investigation are included on the following pages of this report.

There was a third portion of this project that was part of the initial proposal. This was a literature search of boat fire incidents. This search was not conducted, and the funds originally set aside for this search were not used.

TESTING

Environmental Tests

One of the concerns expressed by industry representatives during the formation of the scope of this investigation was whether or not commercially available products would be capable of withstanding conditions found in the marine environment. To get a feel for how products would fare, three tests were selected from the draft outline of investigation: Vibration, Shock, and Corrosion Resistance.

A number of different smoke detector and smoke alarm models were chosen to be the subjects of these tests. It should be noted that the samples used for these tests were standard, UL Listed, commercially available products intended for installation within a home or building. These test results can be found in Appendix A.

Smoke detectors and alarms were chosen instead of heat detectors and alarms for two main reasons. In numerous studies over the years, smoke detectors have been shown to typically provide earlier warning than heat detectors in the majority of fire situations. As a result, they are the detection types most often used in land based fire detection systems, and the most commonly available type of fire detector. In addition, they are typically a bit less robust than heat detectors. Therefore, it was felt that the environmental conditions would be a bigger challenge for smoke detectors than they would be for heat detectors.

These test results show that a number of commercially available smoke alarms and detectors are capable of meeting these three environmental tests contained in the draft guidelines. While not all of the models that were tested produced acceptable performance, the test results seem to indicate that production of special, marine only smoke detectors and smoke alarms may not be necessary.

It is important to emphasize that any fire alarm device and/or system must be properly maintained if it can be expected to perform its intended function. In spite of some of the positive test results found in this portion of the project, the marine environment is arguably more severe than a typical residential or commercial office environment. Therefore, it may be reasonable to require that maintenance be performed more frequently on fire alarm equipment installed in the marine environment than for the same equipment installed in a more benign environment.

Smoke Tests

There were two completely different types of smoke tests that were conducted during the course of this investigation. In meetings and discussions prior to this project being established, industry representatives expressed interest in looking at the affects of elevated overhead temperatures on performance of smoke detectors. Therefore, the first set of smoke tests was conducted with the intent of determining if smoke detector performance would be adversely affected by temperature extremes between the overhead and the air within the cabin or passageway below.

Following completion of these tests, the general consensus of the advisory committee was that additional testing, on board actual boats, would be beneficial.

Simulated Passageway Tests

These tests involved constructing a simulated passageway and stateroom within the UL Smoke Detector Fire Test Room. The passageway was 32 feet long, with a stateroom off of one end of the passageway. Refer to Appendix B for more details of the layout.

A series of smoke tests was conducted with the overhead of the corridor and stateroom at room temperature, approximately 73^{o}F, to provide baseline readings, and with the temperature of the overhead increased to approximately 170^{o}F. Smoke density

measurements were made at various locations during these tests, and the results of the tests at the two overhead temperatures were compared with each other.

The results were discussed during a meeting of the advisory committee for this project on August 30, 1995. The results show that if the temperature difference between the overhead and air within the compartment is great enough, the performance of overhead mounted smoke detectors can be adversely affected. However, as was pointed out by committee members during the meeting and in follow up conversations with members of the committee, the elevated temperature used during the tests was very high, far exceeding the temperature an actual boat would experience. Also, the committee members pointed out that dimensionally, the simulated passageway was much larger than an actual passageway on even the largest recreational vessel.

Subsequent temperature measurements on board actual vessels during July 1996 showed there to be very little temperature variation between the overhead and the deck of vessels ranging in size from 21 to 110 feet. It was also demonstrated that the living areas within the boats were typically much smaller than similar areas in a house or apartment. With this information in hand, the advisory committee recommended we perform some type of smoke testing on actual boats. While this testing went beyond the original scope of the investigation, it was felt that it could prove quite helpful in developing the installation guidelines.

Smoke Testing on Boats

The purpose of testing smoke detector operation on board actual boats was to evaluate the performance of overhead vs. bulkhead mounted detectors in an actual, rather than theoretical, application. A total of 17 fire tests were performed in the cabin areas of two boats on September 22 and 23, 1997 in Solomons, Maryland. Both of the boats were of wood construction and were upright on dry land. Temperatures during the tests ranged from roughly 45 to 70^{o} F. Details of these tests can be found in Appendix C.

The results of these tests don't show any great difference in performance between overhead and bulkhead mounted smoke detectors.

OUTLINE OF INVESTIGATION

Many of the requirements in the initial draft of the Outline of Investigation were extracted from two main sources. The bulk of the test specifications came from UL Standards for Safety, primarily those covering marine equipment. The second main source was from ABYC Standards, which cover application and installation of a wide range of equipment on recreational vessels.

During the course of this project, the draft outline was modified by taking in information from other sources. These sources included the text of the National Fire Alarm Code (NFPA 72), members of the industry advisory group, and test results obtained during this

project. The result of this is the modified Outline of Investigation that is included as Appendix D.

While the draft outline can serve as a good starting point for possible future development work on an installation document, there are several areas of the outline that may require additional investigation. Some of these that were identified during the course of this project are:

- Should standby (secondary) power supplies be required?

- Should additional radio frequency transient tests be required to take into account sources of RF energy often present on a boat (from navigational radar, for instance) that aren't typically found in a dry land installation?

- Are the Shock and Vibration Tests needed for this type of application?

- Should maintenance schedules for fire alarm equipment be modified to account for the marine environment?

- Should additional tests be developed to account for sources of nuisance alarms unique to the marine environment such as diesel engine exhaust?

SUMMARY

During the course of this project, testing was conducted to estimate the performance of fire alarm devices when used in a marine environment. A draft outline of investigation for this equipment when it is used on recreational vessels was also developed.

Samples of smoke alarms and smoke detectors were exposed to two types of tests, environmental tests and smoke performance tests. The results of the environmental tests showed present smoke detector technology to be capable of meeting these tentative requirements. It is therefore possible to conclude that manufacturers may not need to produce special marine use smoke detector models.

The smoke testing demonstrated that while an extreme temperature difference between the overhead and the surrounding air can have a detrimental affect on the ability of smoke to reach overhead mounted smoke alarms or detectors, the magnitude of the temperature difference encountered on board actual boats appears to be more in line with that expected within a room in a house. Testing of smoke alarms on two actual boats showed no real difference in performance between overhead and bulkhead mounted alarms.

A draft Outline of Investigation was created using information from UL Standards, ABYC Standards, information from other sources such as the National Fire Alarm Code, members of the Industry Advisory Group, and results of tests conducted during the

course of this project. This outline can serve as the basis for development of a document covering installation of fire detectors on board recreational vessels.

A P P E N D I X A

RESULTS OF SMOKE ALARM AND DETECTOR ENVIRONMENTAL TESTS

SENSITIVITY TEST:

METHOD

Each smoke alarm (detector) was mounted in the approximate center of a wooden enclosure constructed of ¾ in. thick plywood having overall inside dimensions of approximately 67-1/2 in. long by 18-1/4 in. deep by 18-1/8 in. wide.

The enclosure has a centrally located gasketed-hinged top door approximately 33-7/8 in. wide in the top with a 14-1/2 by 24 in. clear plastic window. A 7-in. diameter exhaust port located in the right end centered 4-1/2 in. above the bottom and equipped with a sliding wooden cover is provided.

The interior of the testing enclosure is made of two compartments; the testing platform, and a mixing chamber. The testing platform has approximate dimensions of 41-3/4 by 18 by 7 in. The mixing chamber has approximate inside dimensions of 41-3/4 in. long by 11-1/2 in. high covering the entire 18 in. width of the inside of the outer cabinet.

The smoke density in the chamber was measured by means of a direct current microammeter (0-100 uA) employed with a photoelectric cell used in conjunction with the light from a tungsten filament automotive type lamp energized from a constant current source of provide a light beam of uniform flux density.

Light gray smoke, as generated from the smoldering of a cotton wick, was circulated throughout the compartments by a fan adjusted to provide an air velocity of between 30 and 35 ft/min. Starting with a reading of 100 uA on the meter to indicate a 100 percent clear condition, the smoke density was slowly increased in the test compartment at the rate of approximately 0.2 to 0.4 percent obscuration per foot per minute until the alarm circuit of the smoke alarm (detector) was energized.

The uA readings were converted to percent per foot obscuration readings using the following equation:

$$O_u = [1 - (T_s/T_c)^{1/d}] \, 100$$

0u is the percent obscuration per foot.
T_s is the meter reading with smoke.
T_c is the meter reading with clean air (a value of 100).
d is the distance in feet.

RESULTS

Refer to the data in Table 1. The results of this test both before and after the conditioning tests were used to quantify smoke alarm and detector operability.

VIBRATION TEST:

METHOD

The test samples were mounted on a vibration table using the hardware either supplied or recommended by the manufacturer and mounted in a manner representative of an actual installation in accordance with the manufacturer's instructions.

The samples were subjected to variable frequency vibration along each of three rectilinear axes (horizontal, lateral, and vertical) for four hours in each plane (12 hours total) at a peak-to-peak amplitude of 0.030 in. The frequency of the vibration was varied continuously, at a uniform rate, from 10 to 60 to 10 Hz. every four minutes.

RESULTS

Following the test, the units were checked for operation and smoke sensitivity. Refer to Table 1 for specifics.

SALT SPRAY CORROSION TEST:

METHOD

The apparatus for salt spray (fog) testing consists of a fog chamber with inside measurements of 48 by 30 by 36 inches, a salt solution reservoir, a supply of conditioned compressed air, one dispersion tower constructed in accordance with ASTM designation B117 for producing a salt fog, specimen supports, provision for heating the chamber, and the necessary controls.

The dispersion tower for producing the salt fog is located in the center of the chamber and was supplied with humidified air at a pressure of 17-19 psig so that the salt solution was aspirated as a fine mist or fog into the interior of the chamber.

The salt solution consisted of 20% (by weight) common salt (sodium chloride) in distilled water. The pH value of the collected solution was 6.5 – 7.2 and the specific gravity was 1.036 at 95 degrees F. The temperature of the chamber was maintained at 92 – 97 degrees F throughout the test.

Drops of solution that accumulated on the ceiling or cover of the chamber were diverted from dropping on the specimens and drops of solution that fell from the specimens were not recirculated, but were removed by a drain located at the bottom of the apparatus.

The test samples were mounted in the salt fog chamber in a manner representative of their end use installation. One sample was mounted on the roof of the interior of the chamber. Two samples were mounted vertically, one on each of two opposite sides of the chamber.

RESULTS

Following the test, the units were tested for operation and smoke sensitivity. Refer to Table 1 for specifics.

SHOCK TEST:

METHOD

The test samples were mounted on a shock machine in the same manner as the Vibration Test. The units were subjected to 5000 shock impacts of 10g acceleration and having a shock duration of 20 – 25 ms as measured at the bases of the half-sine envelope. The acceleration and shock pulse duration is to be measured by an accelerometer on a test machine platform on an axis parallel to the action of motion.

RESULTS

Following the test, the units were tested for operation and smoke sensitivity. Refer to Table 1 for specifics.

TABLE 1

SUMMARY OF SENSITIVITY BEFORE AND AFTER CONDITIONING TESTS

Sensitivity, Percent Per Foot Obscuration

Sample	Initial	After Vibration	After Salt Spray	After Shock
A2	1.15	-	-	0.88
A4	1.13	1.00	No Power	-
A5	1.06	1.02	Constant Alarm	-
A6	1.13	1.00	0.79	0.71
B7	1.19	0.98	-	0.98
C8	0.79	0.75	-	0.85
D12	1.02	0.63	Constant Alarm	-
D13	0.83	0.65	0.67	False Alarm
D14	0.83	0.73	0.51	0.83
E3	2.97	-	-	No Alarm
E4	2.64	2.50	Constant Alarm	-
E5	2.93	2.66	Constant Alarm	-
E6	2.81	2.61	0.92	1.38

F4	3.18	2.88	Constant Alarm	-
F5	3.18	2.95	Constant Alarm	-
F6	3.50	3.27	No Operation	-
G3	3.11	-	-	False Alarm
G4	2.77	2.39	2.09	2.19
G5	3.40	3.11	3.29	3.24
G6	3.38	-	2.72	-
H1	1.00	-	-	0.96
H2	1.02	-	1.02	-
H3	1.17	-	-	0.83
H4	1.04	0.94	0.81	1.21
H5	1.05	1.13	0.94	-

Samples A2-A6 and D12-D14 were ionization smoke alarms.
Samples E3-E6 were photoelectric smoke alarms.
Samples F4-F6 and G3-G6 were photoelectric system type smoke detectors.
Samples H1-H5 were ionization system type smoke detectors.

Notes

- Indicates test not performed on that specific sample.

A P P E N D I X B

SIMULATED PASSAGEWAY TESTS

The smoldering smoke and fire tests were conducted in a passageway 32-ft long, with a room (simulating a stateroom) on one end of the passageway. Refer to Figure 1 for a drawing of the passageway. The test fires were started in the center of the room and the smoke build-up was monitored using light beams and Measuring Ionization Chambers (MIC) located 9 ft, 2 in. and 28 ft from the closed end of the passageway.

To determine the effect of smoke stratification caused by an elevated overhead temperature, the tests were conducted with the overhead at room temperature (73^{o}F) and at a temperature of 170^{o}F. In all, a total of 11 smoldering and 19 flaming fires were conducted. Charts 1 through 6 provide examples of smoke level build-ups for tests conducted at both temperatures. These 6 were considered as being representative of the 30 tests that were conducted.

The test data shows there was generally less smoke available near the overhead when its temperature was elevated to 170^{o}F as compared to the amount of smoke available when the test was conducted at 73^{o}F.

A P P E N D I X C

RESULTS OF FIRE TESTS CONDUCTED ONBOARD TWO BOATS

The following is a summary of 17 smoke detector fire tests performed in the cabin areas of two boats. The first, "Maverick," was roughly 45 feet long and laid out as shown in Figure 1. The second, a Cruis-A-Long, was roughly 32 feet long with an internal configuration shown in Figure 2. Both boats were of wood construction and were upright on dry land during the tests. Temperatures during the tests ranged from roughly 45 to 70^{o}F.

The main purpose of these tests was to compare the response of smoke detectors installed on the overhead and on a nearby bulkhead. Four single station, battery operated smoke alarms were used in these tests. Two of the units were ionization type, while the other two were photoelectric type. Details of the tests are included below. Tests 1 through 10 were conducted on Maverick, which had a layout as shown in Figure 1. The stateroom door was open during all tests.

Tests 1 through 7 were run with the smoke alarms located in the bow cabin. The fires were started in a metal bucket located approximately 54 inches from the open door of the cabin for tests 1 through 3, and 42 inches from the door for tests 4 through 7. The overhead mounted alarms were roughly on line with the right edge of the doorway, while the bulkhead alarms were just inside the doorway on the right.

Test 8 was conducted with two of the smoke alarms mounted on the overhead of the salon roughly 16 inches from the rear bulkhead, and the other two mounted on the rear bulkhead as shown in Figure 2. The fire was located in the galley area, even with the range, and roughly 2 feet from the center of the steps leading to the salon.

Test 9 was conducted with two of the smoke alarms mounted on the overhead in the aft part of the salon, as per Test 8, and the other two mounted on the overhead above the helm. The fire was located in the same location as Test 8.

Test 10 was conducted with two of the alarms mounted on the overhead above the helm, and the other two on the overhead of the bow cabin. The fire was located approximately 124 inches aft from the bow smoke alarm location.

Tests 11 through 17 were conducted on the Cruis-A-Long, which had an interior layout as shown in Figure 2. Tests 11 through 14 were run using the metal bucket and cotton cloth used in many of the preceding fires.

Tests 15 through 17 were conducted using an electric toaster and slices of white bread. The toaster was repeatedly cycled as necessary to create smoke.

Two smoke alarms for Tests 11 and 12 were mounted on the overhead of the open compartment in the bow, which was approximately 51 inches above the deck of main

compartment. The other two smoke alarms were mounted on the bulkhead at the front of the bow compartment. The fire was on the deck of the galley compartment, 36 inches from the aft compartment door, which was closed.

Test 13 was conducted in a similar fashion to Tests 11 and 12, except the two bulkhead mounted smoke alarms were moved to the angled walls on both the port and starboard sides of the bow compartment.

Test 14 was run with the sidewall smoke alarms in the same location as Test 13. However, the other two alarms were moved from the bow compartment overhead to a location on the dinette bulkhead, 4 inches from the overhead. The position of the fire was also changed to be centered 6 feet from the aft compartment door.

The smoke alarm locations for Test 15 were the same as for Test 14. The smoke source was changed to be plain white bread heated in a toaster. The toaster had to be cycled several times to char the bread enough to create smoke. The toaster was located on the top of the range, a distance of 90 inches from the aft bulkhead of the compartment.

Test 16 was similar to 15, with the exception that the toaster was located on the deck of the compartment by the range.

Test 17 was similar to 16, except the toaster location was changed to the open door of the range, 16 inches above the compartment deck.

Smoke Alarm Response, Seconds (NR designates no response)

Test (position)	1i, Ion type	2i, Ion type	1p, Photo type	2p, Photo type
1 (F1)	20 (b)	20 (d)	100 (c)	100 (a)
2 (F1)	41 (b)	50 (d)	178 (c)	165 (a)
3 (F1)	55 (b)	125 (d)	144 (c)	110 (a)
4 (F2)	281 (b)	560 (d)	482 (c)	560 (a)
5 (F2)	519 (b)	330 (d)	541 (c)	558 (a)
6 (F2)	719 (a)	NR (c)	NR (d)	648 (b)
7 (F2)	180 (a)	120 (c)	139 (d)	210 (b)
8 (F3)	678 (g)	905 (i)	665 (h)	677 (j)
9 (F3)	983 (g)	595 (f)	914 (h)	937 (e)
10 (F4)	570 (a)	680 (f)	773 (b)	773 (e)
11 (F5)	443 (l)	560 (m)	406 (k)	241 (n)
12 (F5)	563 (l)	523 (m)	614 (k)	499 (n)
13 (F5)	263 (p)	360 (m)	162 (o)	402 (n)
14 (F6)	NR (p)	216 (r)	NR (o)	261 (q)
15 (F7)	NR (p)	70 (r)	NR (o)	348 (q)
16 (F8)	26 (p)	260 (r)	398 (o)	600 (q)
17 (F9)	218 (p)	180 (r)	351 (o)	360 (q)

Test	Notes
1	Newsprint used as a combustible. Ignited with match and punk stick. Fire was fast flaming with little visible smoke produced.
2	Newsprint and punk used to start fire, then pieces of cotton were added to create more visible smoke.
3	Newsprint used to start, then wet cloth was added later. This generated more visible smoke and slowed the rate of fire growth.
4	Cotton cloth was ignited with a match, then wet cloth was added to slow the rate of fire buildup and provide more visible smoke.
5	Same as 4.
6	Same as 4, but very little flame was permitted and the result was a slow, smoldering type of fire.
7	A piece of cloth of unknown composition was used. Its appearance was different than the previously used all cotton cloth. When ignited, it produced black smoke as it burned. It was allowed to burn rather than smolder.
8	Cotton cloth was used smothered with wet cotton as in previous trials. This resulted in a good smoldering fire with very little open flame.
9	This test began in a similar manner to Test 8, but newsprint was added during the test. This resulted in flaming occurring late in the test.
10	Smoldering cotton, similar to Test 8.
11	Smoldering cotton, similar to Test 8.
12	Smoldering cotton, dining area windows open, flaming occurred early.
13	Smoldering cotton, similar to Test 8.
14	Smoldering cotton, dinette windows open.
15	Thick smoke layer near overhead, relatively little smoke near the deck.
16	Similar to Test 15 except smoke layer was more evenly distributed throughout the cabin. It was not as concentrated near the overhead.
17	Similar to Test 16.

BOATFIR1

A P P E N D I X D

OUTLINE OF INVESTIGATION

FOR THE INSTALLATION, MAINTENANCE

AND USE OF

AUTOMATIC FIRE DETECTION AND WARNING SYSTEMS

ON RECREATIONAL BOATS

TABLE OF CONTENTS

Guidelines for the Installation, Maintenance

And Use of

Automatic Fire Detection and Warning Systems,

And Single and/or Multiple Station Smoke or Heat Alarms

On Recreational Boats

GENERAL

1. SCOPE

1.1 These guidelines cover the selection, installation, operation and maintenance of fire detection and warning systems and single and/or multiple station smoke or heat alarms if installed on recreational boats.

1.2 These guidelines do not cover fire suppression systems or subsystems, or systems designed to notify remote locations. See ABYC A-4 (Fire Fighting Systems)

1.3 These systems utilize only manual, smoke, and heat detecting initiating devices, or single and/or multiple station smoke or heat alarms.

2. GENERAL

2.1 All system equipment and smoke or heat alarms must comply with Appendix A where applicable. Depending upon the size of the vessel and the number of interior compartments, engineering judgment shall be used to determine whether to employ single and/or multiple station alarms, or a fire alarm system.

2.2 A fire alarm system shall have a master control station, which monitors all systems' functions. The master control station shall be located so that it is plainly visible and accessible to the crew. The master control station shall provide audible and visual indication of an alarm or trouble condition. A master control station is not required for single and/or multiple station alarms.

2.3 Supplementary functions, including the notification of authorities beyond the vessel, is permitted but shall not interfere with the performance requirements of this Standard.

2.4 A marine fire detection and warning system may consist of appropriate combinations of the following: smoke detectors, heat detectors, manual initiating devices, graphic annunciator panels, control units and interconnecting wiring. Specific applications of these devices are covered by other paragraphs of this outline.

2.5 The use of a graphic annunciator panel or panels shall be based upon the complexity of the boat's compartment layout.

2.6 All wiring practices shall comply with the requirements of ABYC E-8, AC Electrical Systems, and E-9, DC Electrical Systems as applicable.

2.7 Audible alarm and trouble signals shall be audible everywhere on the boat except engine compartments. Where an engine compartment can be occupied, then an audible and visible signal shall be provided in the compartment. This audibility consideration is one of the main factors in determining whether to use a fire alarm system, or single and/or multiple station alarms. External horns will be permitted.

2.8 Intensity of the audible alarm shall be determined in accordance with Section 8-1.4.1.6 of Chapter 8 of NFPA 72.

2.9 The colors for visible signals at the master control station system monitors shall be as follows:

Alarm - Red
Trouble - Yellow
Power "On" - Green

2.10 Any failure in the annunciator panel of these systems, if applicable, must not affect the operation of the system other than the annunciator panel itself.

2.11 An audible and visible trouble indication shall be present at the master control station in the event of primary power loss and/or low primary power voltage.

2.12 A manual pull station for alarm shall be present at the master control location and any remote status or control station.

3. DEFINITIONS

3.1 Alarm Signal - An audible and visual signal indicating the presence of smoke, heat rise, or fire.

3.2 (Graphic) Annunciator (Panel) - A unit containing one or more indicator lamps, alphanumeric displays, or other equivalent means in which each indication provides status information about a circuit, condition, or location.

3.3 Emergency Plan - A defined sequence of events intended to allow crew and passengers to properly and safely handle the emergency indicated by the system.

3.4 Fire Alarm System - A system or portion of a combination system consisting of components and circuits arranged to monitor and annunciate the status of fire alarm or supervisory signal-initiating devices and to initiate the appropriate response to those signals.

3.5 Heat Alarm - A self-contained device that contains all of the components for detecting an abnormal heat build up and providing an audible alarm signal.

3.6 Heat Detector - A device that detects abnormally high temperatures or rate-of-temperature rise.

3.7 Initiating Device - A system component that originates transmission of a change of state condition, such as in a smoke detector, manual fire alarm box, or supervisory switch.

3.8 Manual Fire Alarm Box (Manual Pull Station) - A manually operated device used to initiate an alarm signal.

3.9 Marine Fire Detection and Fire Warning System - A system of devices that produces an audible and visual alarm signal in the vessel for the purpose of notifying the occupants of the presence of a fire, smoke or heat rise such that they may take appropriate action.

3.10 Multiple Station Smoke (Heat) Alarm - A single station alarm capable of being interconnected to one or more additional alarms so that the actuation of one causes the appropriate alarm signal to operate in all interconnected alarms.

3.11 Notification Appliance - A fire alarm system component such as a bell, horn, speaker, light, or text display that provides audible, tactile, or visible outputs, or any combination thereof.

3.12 Recreational Vessel - A vessel being manufactured or operated primarily for pleasure.

3.13 Single Station Smoke (Heat) Alarm - A detector comprising an assembly incorporating a smoke (heat) sensor, control components, and an alarm notification appliance in one unit operated from a power source either located in the unit or obtained at the point of installation.

3.14 Smoke Alarm - A self-contained device that contains all of the components for detecting smoke and providing an audible alarm signal.

3.15 Smoke Detector - A device that detects visible or invisible particles of combustion.

3.16 Trouble Signal - An audible and visible indication distinctive from the alarm signal warning of a malfunction or failure of the system/wiring or power.

3.17 Master Control Station - A system control panel located in the vessels main bridge area intended to provide the most complete control and feedback for system operation.

4. POWER SUPPLIES

4.1 An indicator shall be provided to indicate that the system (or alarm) is powered.

4.2 The system (and smoke and heat alarms) shall employ a backup battery capable of operating the system (alarm) for at least 24 hours in the normal condition, followed by not less than 4 minutes of alarm, in the event of primary power failure.

Exception 1: Smoke alarms and heat alarms are permitted to be powered by a monitored battery primary source. A backup source shall not be required.

Exception 2: A detector and a wireless transmitter that serves only that detector shall be permitted to be powered from a monitored battery primary (main) source when part of a listed, monitored low power radio (wireless) system. A backup source shall not be required.

4.3 The overcurrent protection device for the system shall not serve any other circuit.

4.4 Marine Fire Detection and warning equipment shall not have an "on/off" switch other than the manual lever on the system's circuit breaker. If a fuse is used to protect the system, the "on/off" switch shall be placed in a location that would preclude the possibility of the system being turned off inadvertently.

4.5 Neither loss nor restoration of primary power shall cause an alarm signal, but shall cause an audible trouble signal.

4.6 If wired into the vessels DC electrical system, a Marine Fire Detection and Warning System shall meet the following requirements:

(a) All system power requirements are met for at least 30 days in ready mode, including weekly testing.
(b) All system power requirements in alarm or trouble mode for at least 5 days.

5. EQUIPMENT AND SUBSYSTEMS PERFORMANCE

5.2 The failure of any short life components which render the system inoperative shall be readily apparent to the crew of the vessel without the need for test. This requires an audible and/or visible trouble signal.

5.3 Fixed temperature heat detectors (and heat alarms) shall have a temperature rating at least 25°F (14° C) above the normal ambient and shall not exceed 50°F (28°C) higher than the maximum anticipated ambient temperature in the room or space where installed.

5.4 All equipment must remain fully operational at temperatures between -10°C and +60°C, and at humidities of up to 93% RH. Heat detectors with operating temperatures of 50°C or less need not be fully operational at 50°C.

5.5 All equipment must withstand storage temperatures between -30°C and +82°C.

5.6 All alarm-sounding devices shall comply with the audibility requirements of NFPA 72, Section 8-1.4.1.6.

5.7 The control equipment shall "latch" or "lock in" on an alarm condition. Smoke detectors, heat detectors, smoke alarms, and heat alarms need not "lock in."

5.8 An alarm silencing switch or audible trouble silencing switch shall be provided at the master control station and its silenced position shall be indicated by a readily apparent visual signal.

5.9 When powered from the vessel's battery, the system must be capable of operation from a DC power supply whose voltage may be within 85 percent and 125 percent of nominal battery voltage.

6. WIRING AND INTERCONNECTION SUPERVISION

6.1 This Standard requires supervised circuits on systems such that a break in the wiring will not cause an alarm signal, but will cause an audible trouble signal using either a close loop detector circuit or normally open contact detectors with

end-of-line resistors or equivalent. Supervision of the interconnecting circuitry of single and multiple station smoke and heat alarms is not required.

7. WIRING METHODS AND MATERIALS

7.1 See ABYC E-8, E-9.

8. DETECTOR (ALARM) LOCATIONS

8.1 General - This paragraph establishes the guidelines for locating smoke and heat detectors (and smoke and heat alarms) within spaces aboard vessels (if installed).

8.2 Heat Detectors (Alarms) – Consideration should be given to installing heat detectors (alarms) in areas not provided with smoke detectors (alarms), where there are significant risks of fire. Locations such as galleys, engine rooms, other machinery spaces, and laundry facilities should be considered.

(a) Spot-type heat detectors shall be located on the overhead not less than 4 in. (100 mm) from the bulkhead or on the side bulkheads between 4 in. (100 mm) and 12 in. (300 mm) from the overhead.

(b) For overhead spacing, one of the following rules shall apply:

(1) The distance between detectors (alarms) shall not exceed their Listed spacing and there shall be detectors (alarms) within a distance of one-half the listed spacing, measured at a right angle, from all bulkheads, or partitions extending to within 18 in. (460 mm) of the overhead.

(2) All points on the overhead shall have a detector (alarm) within a distance equal to 0.7 times the listed spacing. This will be useful in calculating locations in companionways or irregular areas.

(3) For irregular shaped areas, the spacing between detectors (alarms) may be greater than the listed spacing, provided the maximum spacing from a detector (alarm) to the furthest point of a side bulkhead or corner within its zone of protection is not greater than 0.7 times the listed spacing.

(4) The spacing of heat detectors (alarms), when measured at right angles to repeating solid joist-like overhead projections exceeding 4 in. in height, shall not exceed 50 percent of the smooth overhead spacing allowable under (1) above.

8.3 Smoke Detectors – Consideration should be given to installing smoke detectors (alarms) on board the vessel. If installed, they should be in accordance with the following guidelines.

(a) Consideration should be given to installing smoke detectors (alarms) where they can monitor all sleeping accommodations. In smaller vessels, with generally open interiors, a single smoke detector (alarm) can be employed.
(b) Consideration should be given to installing smoke detectors (alarms) in passageways outside of sleeping areas and other accommodation spaces, i.e. salons and pilot houses.
(c) Smoke detectors (alarms) shall be located in the overhead not less than 4 in. (100 mm) from the bulkhead to the near edge of the detector (alarm), or if on a bulkhead, between 4 in. and 12 in. (100 mm and 300 mm) down from the overhead to the top of the detector (alarm) or as recommended by the manufacturer.
(d) Detectors (alarms) located 20 feet or less from a cooking appliance shall not be of the ionization type.
(e) Detectors (alarms) that may be exposed to diesel engine exhaust shall not be of the ionization type.

9. INSTALLATION

9.1 All equipment shall be installed in accordance with the manufacturer's instructions.

9.2 All installed marine fire detection and warning equipment shall be mounted so as to be supported independently of its attachment to wires.

9.3 The installer shall provide the boat owner with:

(a) Information describing the operation, method and frequency of testing, and proper maintenance of the equipment.
(b) Printed information to inform the owner where they may obtain repair or replacement service and where and how parts requiring regular replacement (such as batteries or bulbs) may be obtained.
(c) Any necessary wiring diagram.

10. MAINTENANCE

10.1 General - The frequency and procedure for tests and inspections on systems shall be formulated by the boat manufacturer using as a basis NFPA 72, Chapter 8. The resulting maintenance manual shall be provided with each vessel employing such a system upon delivery.

PERFORMANCE

General - Completely installed and operational Marine Fire Detection and Warning Systems and Smoke and Heat Alarms shall be subjected to the tests described in Paragraphs 11 and 12, where appropriate.

11. INITIATING DEVICE ON-LINE VERIFICATION TEST

11.1 Each initiating device shall properly cause the system to enter an alarm condition with appropriate stimuli.

11.3 To verify compliance with Paragraph 11.1, each initiating device shall be tripped, an alarm should be present and any annunciator will be indicating the appropriate location of the initiating device.

13. MARKING

General - All Marine Fire Detection and Warning Systems shall be marked as indicated in Paragraphs 13.1 and 13.2.

13.1 The dedicated overcurrent protection device used for the system shall be plainly marked nearby as follows or equivalent:

(a) Electrical rating
(b) "Fire detection and warning system"
(c) "Do not connect non-fire warning system equipment to this fuse or breaker."

13.2 A label at the master control station shall indicate the location of the system circuit breaker or fuse.

APPENDIX A

SUPPLEMENTAL GUIDELINES FOR EQUIPMENT FOR USE IN

MARINE FIRE DETECTION AND WARNING SYSTEMS

INTRODUCTION

1. SCOPE

These supplemental guidelines cover the equipment intended for use in Fire Detection and Warning Systems installed on recreational boats. These guidelines do not cover equipment intended for use in fire suppression systems, or equipment used to notify authorities or other personnel not located on the vessel.

These guidelines are intended primarily to cover smoke and heat detectors (alarms) and their associated equipment such as control units, annunciator panels and the like.

These guidelines cover equipment mounted in the interior of the vessel in areas protected from direct spray, and dripping water.

Exception: Audible and visible alarm equipment such as horns or lamps which may be mounted on the exterior of the vessel to notify personnel on deck or in the immediate vicinity of the vessel of an alarm condition.

CONSTRUCTION

2. GENERAL

The equipment for use in Marine Fire Detection and Warning Systems as intended by this Standard shall comply with the basic requirements of the appropriate UL Standard. Standards listed in Appendix B are considered to be incorporated by reference.

All wiring practices shall comply with the requirements of Title 33, Code of Federal Regulations, Part 183, Subpar. I, Electrical Systems.

Wiring practices shall comply with the requirements of ABYC E-8, AC Electrical Systems, and E-9, DC Electrical Systems, as applicable.

All equipment shall be corrosion resistant and capable of proper operation in high humidity environments. See Corrosion Resistance Test, Section 7.

Unless specifically stated otherwise, all equipment shall be capable of proper operation from temperatures ranging from -10 C (14 F) to 60 C (140 F). See Operational Temperature Tests, Section 12.

All equipment shall be capable of withstanding storage temperatures from -30°C (-22°F) to 82°C (180°F). See Storage Temperature Tests, Section 11.

Smoke and heat detectors (alarms) shall be so constructed so that condensate shall not accumulate on an internal or external surface when mounted in an end use orientation.

An externally mounted audible horn shall comply with the requirements of UL 464, Audible Signal Appliances, and shall also comply with requirements of the Moisture Resistance Test, Section 13.

3. WIRING

(This section reserved.)

4. MOUNTING MEANS

All components shall be provided with the necessary mounting hardware capable of providing secure mounting that can withstand the anticipated vibration and mechanical shock for the environment in which it is used. Hardware, which is considered to be commonly available such as bolts, screws, etc., and is not provided with the equipment, shall be specified by the manufacturer as to the type appropriate for the application.

5. ENVIRONMENTAL CONSIDERATIONS

If a detector (alarm) is for use in an area requiring a temperature rating greater than the required under Section 12, Operation Temperature Test, the appropriate tests shall be repeated in accordance with the basic Standard at the higher temperature.

If a detector (alarm) is for use in an area requiring a velocity rating greater than that required under the basic UL Standard, the appropriate tests shall be repeated in accordance with the basic Standard to determine suitability at the higher velocity rating.

Heat detectors (alarms) for use in engine rooms or machinery spaces shall be of the combination fixed temperature/rate of rise type with a minimum alarm temperature rating of 70°C.

PERFORMANCE

6. GENERAL

All equipment for use in Marine Fire Protection and Warning Systems must comply with the requirements of the appropriate UL Standard in addition to the performance requirements of Sections 7 through 13.

The performance tests outlined in this Standard may be considered as preconditioning tests to the normal performance tests which are required by the basic UL Standard. If these tests are not performed as preconditioning test, then the necessary operational or calibration tests are to be conducted on the equipment following the exposure to these tests to determine that the equipment still functions as intended.

Equipment shall be subjected to each of the performance tests described herein and still meet the requirements of the basic UL Standard. This is to be determined by conducting the appropriate operation and/or sensitivity calibration tests as deemed necessary, following these performance tests, to verify proper operation on each sample, which is subjected to the tests in this section. Except for smoke or heat detectors (alarms), one sample of equipment is to be subjected to each test.

For tests involving a heat or smoke detector (alarm), three samples of each detector (alarm) shall be used, and all three shall be required to comply with the requirements of the basic Standard after completing the Performance Test in this Standard.

Equipment that is intended only for use on vessels 65 feet and over need not comply with the requirements of Section 9, Vibration Test, and Section 10, Shock Test. This equipment shall be marked that it is not intended for use on vessels less than 65 feet.

The same samples may be used for all the tests in this section, or separate samples may be used for each of the tests in this section with the following exceptions:

Exception No. 1: The vibration and shock tests shall be performed on the same samples.

Exception No. 2: The Storage Temperature Test and the Operation Temperature Test shall be performed on the same samples.

Note that each piece of equipment subjected to performance tests in this section must be subsequently subjected to the necessary operation and/or calibration tests to determine that the equipment still functions as intended without increased risk of fire, shock, or injury to persons.

7. CORROSION RESISTANCE TEST

The equipment shall perform as intended following the tests described below. The equipment shall be energized and tested to determine normal operation within 1 hour of being removed from the chamber.

The sample is to be placed in a salt fog chamber and subjected to the salt fog in accordance with ASTM B-117 for a duration of 48 hours. The equipment is to be placed in a salt chamber in a manner representative of its end use installation.

Smoke and heat detectors (alarms) shall be mounted in a test fixture as described below. The fixture is a box approximately 2 by 2 by 2 ft. One detector (alarm) shall be mounted on the roof of the interior of the box, and the other two detectors (alarms) mounted on vertical sides opposite of one another. On the two remaining sides, a circular hole approximately 12 in. in diameter will be cut to allow the salt fog to enter the box. This will be more representative of an actual installation than simply placing the detectors (alarms) in the chamber by themselves.

The equipment is to be energized during the entire test at nominal supply voltage.

Drops of solution accumulating on the ceiling or cover of the chamber or test fixture are to be diverted from dropping on the samples, and drops of the solution falling from samples are not to be recirculated but are to be removed by a drain located at the bottom of the apparatus.

8. DRIP PROOF TEST

All equipment shall comply with the requirements of the Drip Proof Test.

Exception: products that are mounted such that they are not subject to dripping water.

The equipment is to be energized and mounted in accordance with the manufacturer's instructions beneath a drip pan that produces both splashing and dripping and that extends beyond all exposed sides of the enclosure. The bottom of the drip pan is to be equipped with uniformly distributed spouts; one spout for each 20 $in.^2$ of pan area. Each spout is to drip water at a rate of 20 drops per minute. The enclosure is to be subjected to continuously dripping water for 30 minutes.

The equipment is to be oriented from 0-15 degrees from the vertical during the test.

9. VIBRATION TEST

Equipment shall operate as intended following the Vibration Test in the following paragraph.

The equipment is to be mounted on a vibration table using the hardware supplied or recommended by the manufacturer and mounted in a manner representative of an actual installation in accordance with the manufacturer's instructions.

The equipment is to be subjected to variable frequency vibration along each of three rectilinear orientation axes (horizontal, lateral, and vertical) for 4 hours in each plane (12 hours total) at a peak-to-peak amplitude of 0.030 in. The frequency of vibration is to be continuously varied, at a uniform rate, from 10 to 60 to 10 Hz every 4 minutes.

10. SHOCK TEST

The equipment used in the Vibration Test shall be mounted on a shock machine in the same manner as described in the Vibration Test above. The shock machine is to produce repeated shock pulses as specified below.

The equipment is to be subjected to 5000 shock impacts of 10 g acceleration and having a shock duration of 20-25 milliseconds as measured at the bases of the half-sine shock envelope. The acceleration and shock pulse duration is to be measured by an accelerometer mounted on the test machine platform on an axis parallel to the axis of motion.

11. STORAGE TEMPERATURE TESTS

All equipment shall be subjected to the following temperature cycling, and then tested to determine that the equipment operates normally within 2 hours of being removed from the test temperature and placed in ambient of 72 ± 5°F.

Non-energized, conduct the following cycles:

24 hours at -30°C
24 hours at 82°C
24 hours at -30°C
24 hours at 82°C

12. OPERATIONAL TEMPERATURE TEST

The equipment subjected to the Storage Temperature Test shall be subjected to the Operational Temperature Test described below.

All equipment shall be subjected to 24 hours of exposure to a temperature of -10 C (14 F). The equipment shall be energized at the intended supply voltage during the exposure period. Following the 24-hour exposure, the equipment shall operate normally while still exposed to the test temperature of -10 C.

The above procedure is to be repeated on the same sample equipment while exposed to a temperature of 60°C (140°F).

13. MOISTURE RESISTANCE TEST

Any externally mounted equipment, such as horns or visual signals, shall be subjected to the test below. Water shall not enter a compartment that houses wiring, wiring devices or any other compartment that could impair the intended operation of the device.

The device should be mounted in a manner in accordance with manufacturer's instructions and in a manner representative of its intended use.

The device is to be subjected to a solid stream of water from a nozzle not less than 1 in. in diameter and under a pressure of 15 lb/in. at the nozzle. The stream of water is to be directed at the enclosure from a distance of 10 ft for 5 minutes from various angles.

At the end of the test, the device is to be energized at nominal rated voltage and operated as intended. If the device operated properly, then any water on the exterior of the enclosure is to be removed with a cloth and the enclosure opened and examined for evidence of leakage.

14. INSTALLATION MANUAL

Each piece of equipment shall be provided with a manual that details installation instructions, equipment specifications, and instructions for proper maintenance and testing. Equipment must contain any special considerations with regard to specific applications. Any information that is related only to marine installations shall be provided in area of the instructions clearly marked in such a manner as to indicate that this information relates only to marine installations.

The manual should specifically contain the following information in addition to that required by the basic UL Standard:

1. Equipment shall be installed in accordance with the requirements of Title 33, Code of Federal Regulations, Part 183, Subpart I, Electrical Systems.

2. Wiring practices shall comply with the requirements of ABYC E-8, AC Electrical Systems, and E-9, DC Electrical Systems, as applicable.

3. This equipment is intended for installation in interior spaces protected from spray and dripping water.

   Exception: Externally mounted equipment, which complies with the Moisture Resistance do not require the above statement.

4. Specifications for detectors (alarms) must include the maximum and minimum temperature ratings for proper operation and storage.

5. Specifications for detectors (alarms) must include maximum air velocity ratings.

6. This equipment is intended for use only with other equipment, which has been evaluated for Marine Applications in accordance with this Standard.

15. MARKING

In addition to the marking required by the basic Standard, the following shall apply:

Any external equipment, which has complied with the Moisture Resistance Test, may be marked "Moisture Resistant" or equivalent.

APPENDIX B

STANDARDS FOR COMPONENTS

Standards under which components of the products covered by this Standard are judged include the following:

Title of Standard	UL Standard Designation
Standards for Safety	
Audible Signal Appliances	UL 464
Cables for Power Limited Fire-Protective-Signaling Circuits	UL 1424
Cables for Boats	UL 1426
Control Units for Fire-Protective Signaling Systems	UL 864
Heat Detectors for Fire-Protective Signaling Systems	UL 521
Manually Actuated Signaling Boxes for Use With Fire-Protective Signaling Systems	UL 38
Single and Multiple Station Smoke Detectors	UL 217
Smoke Detectors for Fire-Protective Signaling Systems	UL 268
Visual Signaling Appliances	UL 1638
Signaling Devices for the Hearing Impaired	UL 1971

Underwriters Laboratories Inc.

Report on Project 92NK26482

Fire Detection in Recreational Vessels