UL 217

STANDARD FOR SAFETY

Smoke Alarms

UL Standard for Safety for Smoke Alarms, UL 217

Eighth Edition, Dated October 30, 2015

SUMMARY OF TOPICS

The following revisions are being issued to ANSI/UL 217, the Standard for Smoke Alarms:

1. Updates to Polyurethane Flaming and Smoldering and Cooking Nuisance Tests

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The requirements are substantially in accordance with Proposal(s) on this subject dated October 7, 2016.

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OCTOBER 30, 2015
(Title Page Reprinted: November 23, 2016)

ANSI/UL 217-2016

UL 217

Standard for Smoke Alarms

Prior to the seventh edition, the previous editions were entitled Standard for Single and Multiple Station Smoke Alarms.

First Edition – January, 1976
Second Edition – October, 1978
Third Edition – October, 1985
Fourth Edition – May, 1993
Fifth Edition – February, 1997
Sixth Edition – August, 2006
Seventh Edition – June, 2015

Eighth Edition

October 30, 2015

This ANSI/UL Standard for Safety consists of the Eighth Edition including revisions through November 23, 2016.

The most recent designation of ANSI/UL 217 as an American National Standard (ANSI) occurred on November 23, 2016. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, or Title Page information.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 These requirements cover electrically operated single and multiple station smoke alarms intended for open area protection in indoor locations and portable smoke alarms used as ″travel″ alarms in accordance with:

a) National Fire Alarm and Signaling Code, NFPA 72;

b) Standard for Recreational Vehicles, NFPA 501C, for smoke alarms intended for use in recreational vehicles;

c) For smoke alarms intended for use in recreational boats:

1) Fire Protection Standard for Pleasure and Commercial Motor Craft, NFPA 302,

2) AC and DC Electrical Systems on Boats, ABYC E-11, and

3) The applicable regulations of the United States Coast Guard.

1.2 A single station smoke alarm (e.g. ionization-type, photoelectric-type, smoke alarm with supplementary heat detection type, combination smoke type, multi-criteria type), as defined by these requirements, is a self-contained fire alarm device that consists of an assembly of electrical components including a smoke sensor/ chamber, alarm sounding appliance, and provision for connection to a power supply source, either by splice leads, terminals, a cord and plug arrangement or containing integral batteries to detect one or more products of combustion. The products of combustion may consist of visible as well as invisible smoke particles, gases, heat, radiant energy, and water vapor. Additional functionality such as, a supplemental heat detector, terminals for connection to a remote audible signaling appliance (device) or accessory, and an integral transmitter to energize a remote audible signaling appliance (device) is permitted to be incorporated as part of the smoke alarm assembly.

1.3 Smoke-alarms not intended for interconnection are defined as single-station type.

1.4 Multiple station units are single station smoke alarms that are:

a) Interconnected so that actuation of one results in alarm sounding by all interconnected smoke alarms, or

b) Smoke alarms that are connected to remote heat detectors or heat alarms (thermostats).

1.5 These requirements, where applicable, also cover all remote accessories that are to be connected.

1.6 This standard does not cover the following:

a) Smoke detectors of the non-self-contained type that are intended for connection to a household or industrial system control unit. These are included in the Standard for Smoke Detectors for Fire Protective Signaling Systems, UL 268;

b) Mechanically operated single and multiple station fire alarm devices that are specified in the Standard for Single and Multiple Station Heat Alarms, UL 539;

c) Heat detectors – except for the requirements in the Fire Test (smoke alarm with heat detection) – Section 71) incorporated as part of a single station smoke alarm assembly whose requirements are covered in the Standard for Heat Detectors for Fire Alarm Signaling Systems, UL 521 and/or when part of a multi-criteria smoke alarm.

d) An accessory that is provided with a means to transmit alarm signals to a constantly attended, remote monitoring location. Any accessory capable of transmitting these types of signals is covered by the requirements in the Standard for Household Fire-Warning Sytem Units, UL 985;

e) A gas and vapor detector or sensor incorporated as a part of a smoke alarm assembly and covered by the Standard for Single and Multiple Station Carbon Monoxide Alarms, UL 2034, except when part of a multi-criteria smoke alarm.

2 Assembly

2.1 A smoke alarm shall be so constructed that it will be reliable and sufficiently durable for its intended installation and use.

2.2 A component of a smoke alarm shall comply with the requirements for that component, except that such requirements may be modified if appropriate for the particular application.

2.3 Unless specifically indicated, the construction requirements specified for a smoke alarm shall also apply to any remote accessories with which it is to be employed.

3 Components

3.1 Except as indicated in 2.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components used in the products covered by this standard.

3.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

4 Units of Measurement

4.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

5 Undated References

5.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

6 Glossary

6.1 For the purpose of this standard the following definitions apply.

6.2 BROILING – The fresh-frozen hamburger cooking process used to cook the fresh-frozen hamburger in the oven of an electric range.

6.3 COMBINATION SMOKE ALARM – A smoke alarm that employs more than one smoke detecting principle in one unit. The sensor output signals are individually evaluated but not combined to determine when an alarm signal is warranted.

6.4 COMPONENT, LIMITED-LIFE – A component which is likely to fail during the anticipated service life of a smoke alarm and be periodically replaced and the failure of which is monitored, when failure of the component affects the intended operation, gas and/or smoke sensitivity, or both. Typical examples of such components include incandescent lamps, electronic tube heaters, and functional heating elements.

6.5 COMPONENT, RELIABLE – A component that is not expected to fail or be periodically replaced and is not monitored. A reliable component shall have a predicted failure rate of 2.5 or less failures per million hours as determined for a ″Ground Fixed″ (GF) environment by Military Standardization Handbook, MIL-HDBK 217, or equivalent (see Appendix D).

6.6 CONFORMAL COATING – A protective covering applied on a printed-wiring board capable of conforming to the configuration of objects coated, used to increase the dielectric voltage-withstand capability between conductors and/or to protect against environmental conditions. Conformal coatings may be used on printed wiring boards where electrical spacing's are insufficient between uninsulated live parts of opposite polarity or between such parts and accessible dead-metal parts.

6.7 DRIFT COMPENSATION – A feature of a smoke alarm that monitors and automatically adjusts the smoke alarm's smoke sensitivity, example: to the gradual build-up of contaminants in the sensing chamber or degradation of the sensor component(s).

6.8 END-OF-LIFE-SIGNAL – An audible signal, differing from the alarm signal, intended to indicate that the device has reached the end of its useful life and should be replaced. It is permitted for the audible component of the signal to be of the same format as a trouble signal, provided a visual indicator is employed to differentiate between the end-of-life and other trouble conditions.

6.9 FIRMWARE – For the purpose of this Standard, software programs residing permanently on a microprocessor or in a nonvolatile memory chip within smoke alarm and accessory devices.

6.10 GAS SENSITIVITY – Relative degree of response of gas sensor(s) that are used within the multi-criteria smoke alarm as defined by the manufacturer and verified by the tests required in this Standard.

6.11 HEAT ALARM, SINGLE STATION – A self-contained fire alarm system comprising of a heat alarm, an alarm sounding device, and a stored energy source (wound spring) incorporated in one integral package.

6.12 HEAT DETECTOR – A device that detects an abnormal high temperature or rate of temperature rise.

6.13 LOW BATTERY TROUBLE POINT – Any combination of battery voltage and series resistance that results in an audible trouble signal from a battery-operated detector.

6.14 MULTI-CRITERIA SMOKE ALARM – An alarm comprised of a smoke sensor plus one or more additional sensors such as heat, radiant energy, fire gases or smoke that operates on different principles. Each sensor in the set is separately monitored for the presence or absence of physical stimuli. The individual signal from each sensor is mathematically evaluated together with the signals from the other sensor(s) to determine when a smoke alarm signal is warranted. Aside from this smoke alarm signal, the smoke alarm may generate other independent alarm signals such as but not limited to a CO alarm, heat alarm, or a flame alarm for which each alarm type complies with the applicable standard

6.15 PRODUCTION GAS SENSITIVITY – A gas sensitivity range equal to or less than the sensitivity limits determined by the applicable tests required in this Standard. This range is used to verify sensitivity calibration in Section 91.

6.16 PRODUCTION SMOKE SENSITIVITY – A smoke sensitivity range established by the tests in this Standard within the limits outlined in Table 37.1, Visible smoke obscuration limits (gray smoke) and Table 37.2, Measuring ionization chamber (MIC) measurement, for single criteria smoke alarms. For multi-criteria smoke alarms, smoke sensitivity limits may be provided by the manufacturer.

6.17 RISK OF ELECTRIC SHOCK – A risk of electric shock is determined to exist at any part when:

a) The potential between the part and earth ground or any other accessible part is more than 42.4 volt peak and

b) The continuous current flow through a 1500 ohm resistor connected across the potential exceeds 0.5 milliampere.

6.18 RISK OF FIRE – A risk of fire is determined to exist at any point in a circuit where:

a) The open circuit voltage is more than 42.4 volt peak, and the energy available to the circuit under any condition of load, including short circuit, results in a current of 8 amperes or more after 1 minute of operation, or

b) A power of more than 15 watts is deliverable into an external resistor connected between the two points.

6.19 SMOKE ALARM ACTIVATION – An audible signal that lasts at least 5 seconds.

6.20 SMOKE ALARM SENSITIVITY – Relative degree of response of a smoke sensor in a smoke alarm as measured in percent/m obscuration (percent/ft. obscuration). A high sensitivity denotes response to a lower concentration of smoke than a low sensitivity under identical smoke build-up conditions.

6.21 SMOKE ALARM SIGNAL – An audible signal intended to indicate an emergency fire condition.

6.22 SMOKE ALARM WITH SUPPLEMENTARY HEAT DETECTION – A smoke alarm that responds to excessive concentrations of smoke or heat in compliance with 17.6, Supplementary heat sensor, and Section 71, Fire Test – Smoke Alarm with Heat Detection, but are not fully compliant to the Standard for Single and Multiple Station Heat Alarms, UL 539. The sensor output signals are individually evaluated but not combined to determine when an alarm signal is warranted.

6.23 SMOKE SENSITIVITY – Relative degree of response of a smoke sensor in a smoke alarm as measured in percent/ft. obscuration (percent/m obscuration). A high sensitivity denotes response to a lower concentration of smoke than a low sensitivity under identical smoke build-up conditions.

6.24 SMOKE SENSOR/CHAMBER – Components of a smoke alarm that sense particulate.

6.25 SPECIFIED LIFETIME – For purposes of this standard, specified lifetime will be referred to as "lifetime." A continuous period of time specified by the manufacturer, during which the alarm meets the requirements of this standard. The manufacturer will specify the start date of the period as either the date of manufacturer or the fully assembled unit in its final enclosure, or the date the unit is placed into service.

6.26 TRANSCEIVER – A device capable of transmitting and receiving wireless signals.

6.27 TROUBLE SIGNAL – A visible or audible signal intended to indicate a fault or trouble condition.

6.28 VOLTAGE CLASSIFICATION – Unless otherwise indicated, all voltage and current values specified in this standard are rms:

a) Extra-Low-Voltage Circuit – A circuit that has an AC voltage of not more than 30-volts alternating current (AC) (42.4 volts peak) and maximum power of 100 volt-amperes, such as supplied by a Class 2 transformer; or a circuit of not more than 30-volts direct current (DC) supplied by a primary battery; or a circuit supplied by a combination of a transformer and fixed impedance, that as a unit, complies with all the performance requirements of a Class 2 transformer. A circuit that is derived from a supply circuit of more than 30 volts by connecting resistance or impedance, or both, in series with the supply circuit to limit the voltage and current, is not identified as an extra-low-voltage circuit.

b) Hazardous-Voltage Circuit – A circuit having characteristics in excess of those of an extra-low-voltage circuit.

6.29 WATERTIGHT – A product that is constructed to prevent water from entering the enclosure under any condition other than submersion

7 Smoke Alarm Reliability Prediction

7.1 Smoke alarms shall be constructed to a maximum failure rate of 4.0 failures per million hours as calculated by a full part stress analysis prediction as described in Section 2.0 of Military Standardization Handbook, MIL-HDBK 217 or 3.5 failures per million hours as calculated by a simplified parts count reliability prediction as described in Section 3.0 of MIL-HDBK 217, or equivalent. See Appendix D, Reliability Prediction and Criteria for Acceptance. A ″Ground Fixed″ (GF) environment is to be used for all calculations. When actual equivalent data is available from the manufacturer, it is permissible that it be used in lieu of the projected data for the purpose of determining reliability.

7.2 Any component whose failure:

a) Results in energization of an audible trouble signal, or

b) Results in energization of a separate visual indication (orange or yellow), or

c) Results in de-energization of a power-on light, or

d) Does not affect the normal operation, or

e) Is evaluated by specific performance tests included in this standard

is not required to be included in the failure rate calculation. Examples include but are not limited to the audible signal appliance, non-compulsory thermostat, test switch, battery contacts and functional light source (LED or IRLED) that is supervised for light degradation as well as additional failures as specified within this standard and/or as identified by the manufacturer.

7.3 An integral or remote accessory is not required to be included in the reliability prediction except for those components whose failure affects the normal operation of the alarm.

7.4 A reliable light emitting diode (LED) of a single station smoke alarm employing a photocell-light assembly shall have a predicted failure rate of not greater than 2.5 failures per million hours.

7.5 An application specific integrated circuit (ASIC) employed in a smoke alarm shall have a predicted failure rate of not greater than 2.5 failures per million hours. The failure rate is to be determined through evaluation of data in a 3000 hour burn-in test, or equivalent.

7.6 A gas sensor or a gas sensing component supervision system of an alarming device shall be provided with the following:

a) Reliability data developed using the Military Standardization Handbook, MIL-HDBK 217 or equivalent demonstrating a predicted failure rate of not more than 2.5 failures per million hours operation (see 7.5); or

b) Supervision of the predicted failure modes other than for loss of electrical continuity; and

c) If the sensor is automatically and periodically tested for its performance response to the target gas (acceptable proxy gas), and results in a trouble signal when the sensor drifts out of specification, then the sensor can be excluded from the reliability calculation.

7.7 Documentation of the failure modes resulting from aging for the gas sensor in a multi-criteria alarm or the sensing components and identification of failure modes addressed by the supervision system shall be provided. The manufacturer shall submit a test method to render the sensor unresponsive to the test concentrations as specified by the manufacturer if the documentation submitted for the sensor or the sensing components indicates drift in the less sensitive direction. This method shall be used when conducting the Electrical Supervision Test, Section 41. All predicted failure modes shall result in a trouble signal.

7.8 Integral transceiver and related components used for non-supervised, wireless interconnected alarms are required to be included in the reliability prediction.

8 Installation and Operating Instructions

8.1 A copy of the installation and operating instructions, and related schematic wiring diagrams and installation drawings shall be used as a reference in the examination and test of the smoke alarm. For this purpose, a printed edition is not required. The information is to be included in a homeowner's manual. See Markings, Sections 99, General; 100, Package Marking; and Instructions, 101, General.

8.2 The instructions and drawings shall include such directions and information as deemed by the manufacturer to be required for proper installation, testing, maintenance, operation, and use of the smoke alarm.

9 Automatic Drift Compensation for Smoke Sensing

9.1 Where automatic drift compensation of smoke sensitivity is provided and initiated within the smoke alarm, the alarm shall initiate a visual and/or audible trouble condition when drift compensation is no longer capable of making additional adjustments to the smoke sensitivity of the smoke alarm. The trouble signal(s) created when reaching the drift compensation limit shall differ from the low battery signal but may be identical or similar to trouble signals for other supervised conditions. The trouble signal shall be activated when the limit of compensation is reached.

9.2 For alarms with adjustable smoke sensitivity settings, after automatic drift compensation has occurred, the smoke sensitivity of the smoke alarm shall be within 0.5 percent/ft. (1.65 percent/m) obscuration of the initial smoke sensitivity when tested as described in 42.5.1 – 42.5.4.

9.3 For alarms without adjustable smoke sensitivity settings, after automatic drift compensation has occurred the smoke sensitivity of the smoke alarm shall remain within the manufacturer's identified range.

9.4 The compensation shall not adversely affect the operation of the smoke alarm. The summation of compensation steps over a twenty-four hour period shall not change the clean-air reference value by more than 50 percent of the shift necessary to indicate an alarm signal and shall not impact the smoke sensitivity of the smoke alarm as specified in 9.2. Maximum compensation rate of the clean air reference value shall not exceed 5 percent every 2.4 hours.

10 Nonfire Feature

10.1 A nonfire feature, such as carbon monoxide detection, shall be used in common with a single or multiple station smoke alarm or both, or an accessory only when a nonfire feature does not degrade or interfere with operation of the smoke alarm or accessory and complies with all the applicable requirements of this standard. See 7.3 and 38.1.9.

11 Smoke Sensitivity Indicating Means (optional)

11.1 This requirement applies to end product installation smoke alarms that are provided with a means for measuring or indicating the nominal sensitivity or a sensitivity range, as described in 11.2. Removal of a snap-on cover to gain access to the sensitivity control is permissible, only when no hazardous-voltage parts are exposed or are able to be contacted by the user.

11.2 The measuring or indicating instrument may include the use of jacks or terminals for the connection of a meter, visual indicators (such as a change in frequency of a pulsing light visible with the smoke alarm installed), operation of a mechanical device (such as described in 11.3), or any arrangement determined to be equivalent. An instrument used for measuring smoke sensitivity of a smoke alarm shall be provided with the following information and features:

a) The instrument shall have the capability to determine if the smoke alarm is within its production smoke sensitivity range. If the instrument contains a numerical readout, a chart shall be provided with the instrument to indicate the acceptable production smoke sensitivity range of each model of smoke alarm that it is capable of testing. A chart is not required for a numerical readout in units of percent obscuration per ft.

b) Instructions for the instrument shall clearly state the operating temperature range of the instrument.

c) If a warm-up period is required, the instrument shall clearly state this period.

d) The instrument shall include the description of the method used to confirm the calibration of the instrument and the period at which re-calibration is required.

The instrument shall have provision to identify its date of last calibration.

f) The instrument shall have a method of identifying to the user that it is not calibrated, if low batteries, dirty filters, or the like, affect the instrument.

11.3 The test feature of such an alarm shall verify that the smoke sensitivity alarm is within its marked range. Unless it is employed on an alarm that has other means of measuring its smoke sensitivity, the test feature shall consist of either an electrical means or a mechanical device which simulates a specified level of smoke in the sensing chamber.

11.4 The use of a plug-in type alarm assembly that is removed readily for insertion of an adapter connected to metering equipment is permissible. A plug-in type alarm that is removed readily and connected to metering equipment is also permissible.

11.5 An alarm that incorporates a variable smoke sensitivity setting intended to be field adjusted shall have a mechanical stop on the adjusting means for the maximum and minimum settings.

12 Maintenance (Field Cleaning)

12.1 If recommended by the manufacturer, the smoke alarm shall be cleaned without:

a) Degradation of performance when tested in accordance with 85.2, Maintenance (cleaning); and

b) Disturbance of field wiring.

13 Alarm Silencing Feature

13.1 It is not prohibited that each single and multiple station smoke alarm be provided with an automatically resettable alarm silencing means that has a fixed or variable time setting which desensitizes the alarm for a maximum of 15 minutes. Alarm silencing shall not disable the smoke alarm. Sensitivity shall not be reduced to more than 4 percent per ft. of obscuration (37.5pA). Each alarm shall produce a distinctive audible or visible trouble signal while in the silence mode. Following the silenced period, the alarm shall restore automatically to its intended operation. Silencing of one alarm of a multiple station system shall not prevent an alarm operation from the other alarms in the system. See 40.1 and 40.2.

13.2 When a variable adjustment is provided on an alarm to vary the silenced period, the adjustment means shall be provided with a mechanical stop, or the equivalent, so that the maximum 15-minute limitation is not exceeded.

13.3 Smoke alarms powered by a non-replaceable battery shall be provided with a temporary alarm silencing means.

13.4 When single station smoke alarms are configured in a multiple station connection (interconnection of two or more smoke alarms), the smoke alarm that initiates an alarm signal shall be designed to be silenced through a manual operation by physically depressing the alarm silence feature on the initiating alarm.

13.5 As an optional feature, the manufacturer is permitted to include an additional wireless communication remote silencing feature. If included and tested for compliance with the requirements outlined in 13.8, the wireless communication remote silence feature may be activated through a remote device and shall be capable of providing additional instructions for the user to confirm his physical proximity to the initiating smoke alarm. Manufacturers that include a wireless communication remote silencing feature shall include language on their remote device for the user to confirm his physical proximity to the initiating smoke alarm, and that the user verified the presence or absence of smoke/fire at the initiating alarm(s) before silencing the alarm signal using the remote device.

13.6 A multiple-station interconnected smoke alarm that produces an alarm signal (wired, wireless, relay, audible and/or visual) shall be permitted to be silenced by either of the following:

a) By activating the alarm silence feature on any multiple station interconnected smoke alarm, provided the smoke alarm that initiated the alarm signal remains in alarm; or

b) By physically depressing the alarm silence feature on the initiating smoke alarm(s), as noted in 13.1; or

c) By activating the wireless communication remote silencing feature using a remote device.

Exception: In the event that the initiating alarm(s) cannot be silenced per the requirements in 13.1, it is permitted that the smoke alarms providing an alarm signal resulting from the multiple-station interconnect, excluding the initiating alarm(s), be silenced but not exceed the limits defined in 13.1.

13.7 Upon activation of an alarm signal from a smoke alarm in the multiple-station circuit, or reactivation of the alarm signal from the originating smoke alarm, all alarms in the multiple-station interconnect shall re-initiate their alarm signal.

13.8 Smoke alarms with a wireless communication remote device and employing a remote alarm silence feature shall be tested in accordance with one of the following requirements:

a) The remote transmission radio of the smoke alarm shall comply with FCC Part 15.249 and the following frequency and field strength requirements:

1) Frequency range

(i) 2.4 GHz (2.4 GHz – 2.4835 GHz)

(ii) 900 MHz (902 – 928 MHz)

(iii) 5.8 GHz (5725 – 5875 MHz)

2) Field strength

(i) 94 dBuV/m @ 3m

or

b) The remote transmission radio of the smoke alarm shall comply with FCC Part 15.247 and the following frequency and field strength requirements:

1) Frequency range

(i) 2.4 GHz (2.4 GHz – 2.4835 GHz)

(ii) 900 MHz (902 – 928 MHz)

(iii) 5.8 GHz (5725 – 5875 MHz)

2) Field strength

(i) 30 dBm (1 W) (using antennas with directional gains < 6 dBi)

or

c) The manufacturer shall provide a defined test procedure, test frequency and field strength in compliance with FCC regulations that demonstrate the open field (line of sight) transmission range of the smoke alarm does not exceed 984 ft (300 m).

14 Smoke Sensitivity Test Feature

14.1 A smoke alarm shall incorporate means for manual test of its operability and sensitivity by mechanically or electrically simulating a preset level of smoke in the sensing chamber. The test means shall be externally accessible when the unit is installed as intended and shall test the operability of the entire unit with the exception of the trouble indicating part of the circuit, which may be excluded. See 42.7, Smoke sensitivity test feature.

15 Batteries

15.1 General

15.1.1 When a battery or set of batteries is used as the main source of power of a single or multiple station smoke alarm, it shall comply with the requirements of the Battery tests, 85.3.

15.1.2 Batteries included as part of an alarm shall be so located and mounted that terminals of cells are prevented from coming in contact with uninsulated live parts, terminals or adjacent cells, or metal parts of the enclosure as a result of shifting.

15.1.3 A battery compartment intended for use with rechargeable batteries which emit gases during charging shall be provided with vent holes.

15.1.4 Ready access shall be available to the battery compartment to facilitate battery replacement, without damage to the alarm components or disassembly of any part of the alarm, except for a cover or the equivalent. When the battery is capable of powering the alarm for a minimum of 10 years, the battery shall not be user replaceable.

15.1.5 Connections of external wiring to a battery-operated single- or multiple-station smoke alarm, or to a portable accessory, shall not be subjected to stress or motion during battery replacement, servicing, or both. Removal of the alarm or accessory from the mounting support to replace a battery or to service the unit shall occur only when the connected wiring is not subjected to flexing or stress.

15.1.6 A smoke alarm powered by a non-replaceable, ten-year life battery shall be provided with a means of activating the power prior to installation and deactivating the battery at the end of useful battery life. The deactivation means shall require the use of a tool, or equivalent, and shall render the unit resistant to being reinstalled. The deactivation means shall also serve to discharge the battery(ies) completely. Both the activation and deactivation means shall be designed to operate one time only. The installation instructions shall provide the user with information describing this one time operation. See 101.1(p).

15.2 Battery removal indicator

15.2.1 Removal of a battery from a battery-operated (or AC with battery back-up) smoke alarm shall result in a readily apparent and prominent visual indication. The visual indication shall consist of one of the following:

a) A warning flag that is exposed with the battery removed and the cover closed;

b) A hinged cover that is resistant to being closed with the battery removed;

c) A swing-out or pull-out battery compartment that is resistant to being closed unless it has a battery in place;

d) An audible or audible and tactile trouble signal on an AC powered smoke alarm with battery back-up;

e) An arrangement to render the unit resistant to reinstallation; or

f) A local audible, local audible and tactile, or local visual indication at the control panel.

15.2.2 Deactivation of the battery of a smoke alarm that uses a non-replaceable battery with a 10-year minimum battery life shall result in a readily apparent and prominent indication. The indication shall consist of one of the following:

a) A warning flag that is exposed with the battery removed and the cover closed;

b) A hinged cover that is resistant to being closed with the battery removed;

c) A swing-out or pull-out battery compartment that is resistant to being closed unless it has a battery in place;

d) An audible or audible and tactile trouble signal on an AC powered smoke alarm with battery back-up;

e) An arrangement to render the unit resistant to reinstallation; or

f) A local audible, local audible and tactile, or local visual indication at the control panel.

15.2.3 When a warning flag, or equivalent, is employed to comply with the requirement of 15.2.1 or 15.2.2, it shall be marked as required in 99.6.

16 Firmware Update (if provided)

16.1 General

16.1.1 A firmware release level shall identify the firmware of a product. A new release level shall be assigned due to any changes in the firmware.

16.1.2 Program software and code shall not be accessible for modification by the user.

16.2 Firmware update

16.2.1 Products capable of receiving a firmware update shall provide a means of indicating the current firmware version of the unit.

16.2.2 Firmware updates for battery operated units that occur over wireless communication shall not occur when the battery supply has been depleted to the trouble point (refer to 56.2, Battery trouble voltage determination).

16.2.3 Products capable of receiving a firmware update shall be tested and evaluated for the following type of applicable firmware updates when the alarm device is subjected to the specified operating conditions:

a) Authentic Firmware Update:

1) Normal standby condition

2) Abnormal smoke condition

(i) When detecting smoke during a fire event, a software update shall not interfere with alarm detection and signaling.

(ii) When firmware updates are proposed that could alter the alarm threshold or algorithm performance, the alarm (with firmware updates) shall be evaluated in the fire test room to ensure that the revised firmware does not affect the device's alarm thresholds or performance.

3) Fault condition

4) Loss of power

5) Battery trouble signal voltage level

6) Firmware transmission (data) interruption

b) Duplicate firmware version update:

1) Normal standby condition.

c) Corrupt firmware update:

1) Normal standby condition.

d) Unsigned manufacturer firmware update:

1) Normal standby condition.

16.2.4 Successful firmware updates shall occur in 2 seconds or less and result in the alarm operating as intended following the update and comply with all applicable requirements as defined within this Standard.

16.2.5 For products capable of receiving an automatic (no end user interaction) update, such as the use of WiFi, failure to successfully update the firmware shall result in the alarm or accessory reverting back to the previous firmware revision, and the alarm shall operate as originally intended. At a minimum, the test specified in 38.1.3 of the Normal Operation Test shall be conducted. As an alternative, failure to update or revert back to the previous firmware revision shall result in an audible trouble signal.

16.2.6 For products requiring physical interaction to install a firmware update, such as the use of a USB connection, failure to update the firmware shall result in the alarm or accessory reverting back to the previous firmware revision, and the alarm shall operate as originally intended. At a minimum, the test specified in 38.1.3 of the Normal Operation Test shall be conducted. As an alternative, failure to update or revert back to the previous firmware revision shall result in an audible trouble signal. If an audible trouble signal is not provided, failure to update shall be readily apparent to the end user, and alarm signaling shall not be adversely impacted.

16.2.7 Products that are capable of receiving firmware update shall provide a means for the end user to obtain the homeowner's manual for the updated firmware.

CONSTRUCTION

ASSEMBLY

17 General

17.1 Remote accessories

17.1.1 Unless specifically indicated otherwise, the construction requirements specified for a smoke alarm shall apply also for any remote accessories with which it is to be employed.

17.2 Smoke sensitivity adjustment (single criteria)

17.2.1 When a field smoke sensitivity adjustment is provided, it shall be accessible with the alarm installed as intended, marked to indicate the direction of smoke sensitivity (high or low), and shall employ a mechanical stop at both extremes. The smoke sensitivity shall be within the production sensitivity limits indicated in 42.1.1. Removal of a snap-on cover to gain access to the smoke sensitivity control is permissible only when no high-voltage parts are able to be contacted by the user.

17.3 Radioactive materials

17.3.1 The manufacture, importation, distribution, marking, and disposal of smoke alarms containing radioactive material are subject to the safety requirements of local and federal agencies responsible for the control of these materials.

17.3.2 Documentation verifying compliance with regulating agency requirements is required for the smoke alarm.

17.4 Supplementary signaling feature

17.4.1 A supplementary signaling feature, such as a transmitter for remote signaling, included integral with a single or multiple station smoke alarm, is to be compatible with the device(s) with which it is intended to be employed, and the remote signaling device(s) shall be intended for fire alarm application.

17.5 Insect guards

17.5.1 A smoke sensor shall be provided with a screen or equivalent protection (louvers, slots, holes) as a deterrent for entry of insects into the detecting chamber. The maximum opening size shall not exceed 0.05 in. (1.27 mm).

17.5.2 To determine that the maximum opening size has not been exceeded, openings in rigid assemblies shall not permit passage of a 0.051 in. (1.30 mm) diameter rod. For nonrigid openings, such as a screen, ten measurements are to be made at different locations by an optical micrometer; five measurements are to be made in each direction (not on diagonal).

17.6 Supplementary heat sensor

17.6.1 When a heat sensor is provided integral with a non multi-criteria smoke alarm, the temperature rating of the heat sensor shall not be less than 57°C (135°F). The heat sensor shall be connected in the smoke alarm circuit or be intended for connection to a separate circuit.

17.6.2 The temperature rating of a heat sensor shall not be greater than 60°C (140°F), unless the smoke alarm has been investigated and found appropriate for installation at a higher temperature.

17.6.3 A fixed-temperature heat alarm shall operate within the temperature tolerance range according to its rating as specified in the operating temperature test of the Standard for Single and Multiple Station Heat Alarms, UL 539.

18 Servicing and Maintenance Protection

18.1 General

18.1.1 An uninsulated live part of a hazardous voltage circuit and hazardous moving parts that present a risk of injury to persons within the enclosure shall be located, guarded, or enclosed to reduce the risk of unintentional contact by persons performing service functions performed with the equipment energized.

18.1.2 Manual switching devices may be located or oriented with respect to uninsulated live parts or hazardous moving parts so that manipulation of the mechanism can be accomplished in the normal direction of access if uninsulated live parts or hazardous moving parts are not located in front (in the direction of access) of the mechanism, or not located within 5.9 in. (150 mm) of any side or behind the mechanism, unless guarded.

18.1.3 In determining compliance with 18.1.2 only uninsulated live parts in circuits above 30 Vrms shall be considered

18.1.4 An electrical control component, which may require examination, adjustment, servicing, or maintenance while energized (excluding voltage measurements except for jacks or terminals specifically intended for that purpose), shall be located and mounted with respect to other components and with respect to grounded metal parts so that it is accessible for electrical service functions without subjecting persons to the likelihood of shock hazard from adjacent uninsulated live parts or to accident hazard from adjacent hazardous moving parts.

18.1.5 Other arrangements of location of components and/or guarding shall be also acceptable where electrical components are accessible for service as indicated by 17.1.1.

18.1.6 The following are not identified as uninsulated live parts:

a) Coils of controllers, relays, and solenoids, and transformer windings when the coils and windings are provided with appropriate insulating overwraps;

b) Enclosed motor windings;

c) Terminals and splices with suitable insulation; and

d) Insulated wire.

18.1.7 An assembled part intended to be removed during installation shall be protected against damage from normal handling.

18.2 Sharp edges

18.2.1 An edge, or corner of an enclosure, opening, frame, guard, knob, handle, or other similar projection of a smoke alarm shall be smooth and rounded, so as not to result in a cut-type injury when contacted during use or user maintenance.

19 Enclosure

19.1 General

19.1.1 The enclosure of a smoke alarm shall be constructed to resist the abuses encountered in service. The degree of resistance to abuse inherent in the smoke alarm shall preclude total or partial collapse with the attendant reduction of spacings, loosening or displacement of parts, and other serious defects, which alone or in combination result in an increase in the risk of fire, electric shock, or injury to persons.

19.1.2 Enclosures for individual electrical components, outer enclosures, and combinations of the two shall be evaluated in determining compliance with the requirement specified in 19.1.1.

19.1.3 All electrical parts of a smoke-alarm, including a separate power supply, except for plug-in blades, shall be enclosed to provide protection against contact with uninsulated live parts. A separate enclosure for field wiring terminals that will be enclosed by a back box is not required.

19.1.4 There shall be no rear openings in a smoke alarm through which debris or air currents can pass that would affect alarm response.

19.1.5 Following installation as intended there shall not be any openings between the intended mounting surface and the rear of the smoke alarm which allow for sufficient passage of air to affect smoke alarm response from test smoke.

19.1.6 To comply with 19.1.4 and 19.1.5, one of the following methods, or a method determined to be equivalent, shall be used:

a) An elastomeric rubber or neoprene gasket, or the equivalent, interposed between the rear of the alarm and the mounting surface to seal the rear openings and preclude the escape of air from around the edge of the alarm; or

b) Instructions in the installation manual provided to describe the location and method(s) of applying a sealing compound that has been found appropriate for the intended use.

19.1.7 Representative smoke alarms shall be subjected to the Smoke Entry (Stack Effect) Test, Section 45.

19.1.8 The enclosure of a smoke alarm shall be provided with means for mounting in the intended manner. Any fittings, such as brackets or hangers, required for mounting shall be furnished with the smoke alarm. The mounting means shall be accessible without disassembling any operating part of the smoke alarm. The removal of a completely assembled panel, cover, or equivalent, to mount the smoke alarm is not identified as disassembly of an operating part.

19.1.9 If the smoke alarm is intended for permanent connection, the enclosure shall either have provision for the connection of metal-clad cable, conduit, or nonmetallic sheathed cable or have provision for mounting on an outlet box.

19.2 Cast metal enclosures

19.2.1 The thickness of cast metal used for an enclosure shall be as indicated in Table 19.1. Cast metal having a thickness 1/32 in. (0.8 mm) less than that indicated in Table 19.1 shall be employed only when the surface under consideration is curved, ribbed, or otherwise reinforced, or when the shape of the surface, size of the surface, or both, are such that equivalent mechanical strength is determined to be provided.

Table 19.1
Cast-metal enclosures

Use or dimensions of area involved	Minimum thickness			
	Die-cast metal,		Cast metal of other than the die-cast type,	
	in.	(mm)	in.	(mm)
Area of 24 in.^{2} (155 cm^2) or less and having no dimension greater than 6 in. (152 mm)	1/16[a]	(1.6)	1/8	(3.2)
Area greater than 24 in.^{2} (155 cm^2) or having any dimension greater than 6 in. (152 mm)	3/32	(2.4)	1/8	(3.2)
At a threaded conduit hole	1/4	(6.4)	1/4	(6.4)
At an unthreaded conduit hole	1/8	(3.2)	1/8	(3.2)

[a] The area limitation for metal 1/16 in. (1.6 mm) thick is obtained by the provision of reinforcing ribs subdividing a larger area.

19.2.2 If threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, or if an equivalent construction is employed, there shall be not less than 3.5 nor more than 5 threads in the metal, and the construction shall be such that a standard conduit bushing can be properly attached.

19.2.3 When threads for the connection of conduit are tapped only part of the way through a hole in an enclosure wall, there shall be a smooth, rounded inlet hole for the conductors that shall afford protection to the conductors equivalent to that provided by a standard conduit bushing.

19.3 Sheet metal enclosures

19.3.1 The thickness of sheet metal employed for the enclosure of a smoke alarm shall not be less than that indicated in Table 19.2, except that sheet metal of two gage sizes lesser thickness shall be employed only when the surface under consideration is curved, ribbed, or otherwise reinforced, or when the shape of the surface, the size of the surface, or both, are such that equivalent mechanical strength is determined to be provided.

Table 19.2
Sheet metal enclosures

Maximum dimensions of enclosure				Minimum thickness of sheet metal								
Length or width,		Area,		Steel, zinc-coated,			Steel, uncoated,			Brass or aluminum,		
in.	(mm)	in.^{2}	(cm^2)	in.	(mm)	GSG	in.	(mm)	MSG	in.	(mm)	AWG
12	(305)	90	(581)	0.034	(0.86)	20	0.032	(0.81)	20	0.045	(1.14)	16
24	(610)	360	(2322)	0.045	(1.14)	18	0.042	(1.07)	18	0.058	(1.47)	14
48	(1219)	1200	(7742)	0.056	(1.42)	16	0.053	(1.35)	16	0.075	(1.91)	12
60	(1524)	1500	(9678)	0.070	(1.78)	14	0.067	(1.70)	14	0.095	(2.41)	10
Over 60	(1524)	Over 1500	(9678)	0.097	(2.46)	12	0.093	(2.36)	12	0.122	(3.10)	8

19.3.2 At any point where conduit or metal-clad cable is to be attached, sheet metal shall have a thickness not less than 0.032 in. (0.81 mm) when of uncoated steel, not less than 0.034 in. (0.86 mm) when of galvanized steel, and not less than 0.045 in. (1.14 mm) when of nonferrous metal.

19.3.3 A ferrous plate or plug closure for an unused conduit opening or other hole in the enclosure shall have a thickness not less than 0.027 in. (0.69 mm) or 0.032 in. (0.81 mm) nonferrous metal for a hole having a 1-3/8 in. (34.9 mm) diameter maximum dimension.

19.3.4 A closure for a hole larger than 1-3/8 in. (35 mm) diameter shall have a thickness equal to that required for the enclosure of the device or a standard knockout seal shall be used. Such plates or plugs shall be securely mounted. See 25.1, Mounting of components.

19.3.5 A knockout in a sheet metal enclosure shall be secured and shall be capable of being removed without undue deformation of the enclosure.

19.3.6 A knockout shall be provided with a surrounding surface for seating of a conduit bushing and shall be located so that installation of a bushing at any knockout used during installation does not result in spacings between uninsulated live parts and the bushing of less than those indicated in Spacings, Section 36.

19.4 Nonmetallic enclosures

19.4.1 An enclosure or parts of an enclosure of nonmetallic material shall be formed so that operating parts are protected against damage. The mechanical strength of the enclosure shall be at least equivalent to a sheet metal enclosure of the minimum thickness specified in Sheet Metal Enclosures, Table 19.2 or Thickness of Glass Covers, Table 19.3. See also Tests on Polymeric Materials, Section 79.

19.4.2 The continuity of any grounding system intended for a smoke alarm connection shall not rely on the dimensional integrity of the nonmetallic material.

19.4.3 Polymeric material used for an enclosure shall comply with the following requirements:

a) Enclosures containing parts including a risk of fire – minimum flammability rating of 5VA or V-0 and compliance with the 5-in. (127-mm) Flame test, 79.4.

b) Enclosures containing power limited circuits with a voltage not exceeding 30 volts AC, 42.4 volts-peak, or 60 volts DC – minimum flammability rating of:

1) V-2, or

2) HB and successful completion with the 3/4-in. (19-mm) Flame Test, as described in 79.3.

c) Enclosures containing circuits powered by batteries with energy limited to 15 watts – minimum flammability rating of HB.

19.4.4 For 19.4.3, Flammability ratings are defined in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

19.5 Ventilating openings

19.5.1 Ventilating openings in an enclosure, including holes, louvers, and openings protected by means of wire screening, expanded metal, or perforated covers, shall be of such size or shape that no opening will permit passage of a rod having a diameter of 9/64 in. (3.6 mm) for circuits greater than 30 V rms (42.4 V peak). An enclosure for fuses or other overload protective devices and provided with ventilating openings shall afford adequate protection against the emission of flame or molten metal. Openings provided to permit cleaning or openings which may be used to clean internal parts shall be arranged to prevent damage to functional internal components during such cleaning operations. For units equipped with a cover, the requirements of this clause apply with the cover open for circuits greater than 30 V rms (42.4 V peak).

19.5.2 Perforated sheet metal and sheet metal employed for expanded metal mesh shall not be less than 0.042 in. (1 mm) in average thickness, 0.046 in. (1.2 mm) when zinc coated.

19.5.3 When the indentation of the guard enclosure does not alter the clearance between uninsulated live parts and grounded metal so as to reduce spacings below the minimum values required, it is permissible for 0.021 in. (0.5 mm) expanded metal mesh or perforated sheet metal, 0.024 in. (0.6 mm) when zinc coated, to be employed under the following conditions:

a) The exposed mesh on any one side or surface of the product has an area of not more than 72 in.^{2} (465 cm^2) and has no dimension greater than 12 in. (300 mm) or

b) The width of an opening so protected is not greater than 3-1/2 in. (90 mm).

19.5.4 The wires forming a screen employed as a smoke chamber cover shall be not less than 22 AWG for steel and not less than 20 AWG for aluminum.

19.6 Covers

19.6.1 An enclosure cover, other than the type usually employed over the sensing chamber, shall be hinged, sliding, pivoted, or similarly attached when:

a) It provides ready access to fuses or any other overcurrent protective device, the intended protective functioning of which requires renewal, or

b) It is required to periodically open the cover in connection with the intended operation of the smoke alarm.

For the purpose of this requirement, intended operation is identified as operation of a switch for testing or for silencing an audible signal device or operation of any other component of a smoke alarm that requires such action in connection with its intended performance.

Exception: This requirement does not apply to a photoelectric type smoke alarms where the lamp is intended to be periodically replaced, or to the battery replacement aspect of an alarm employing a battery as the main or standby supply.

19.6.2 A cover that is intended to be removed only for periodic cleaning of the sensing chamber or replacement of a lamp shall be secured by any one of the following or equivalent means: snap catch, plug-in or twist action, snap tab with one screw, or two screws.

19.6.3 When a smoke alarm cover is not intended to be removed for cleaning, maintenance, or both, and the smoke alarm is intended to be returned to the factory for servicing, the cover shall be secured so that it cannot be readily removed. Exposed screw slots or nuts, other than a tamper proof type, shall be sealed or covered. See 99.1(s) for marking.

19.6.4 A hinged cover is not required where the only fuse(s) enclosed is intended to provide protection to portions of internal circuits, such as a fuse on a separate printed wiring board or circuit subassembly, to prevent excessive circuit damage resulting from a fault. The use of such a fuse(s) shall be used only when the word ″CAUTION″ and the following or equivalent marking is located on the cover of an alarm employing high-voltage circuits: ″Circuit Fuse(s) Inside – Disconnect Power Prior To Servicing .″

19.6.5 A hinged cover shall be provided with a latch, screw, or catch to hold it closed. An unhinged cover shall be securely held in place by screws or the equivalent.

19.7 Glass panels

19.7.1 Glass covering an enclosure or observation opening shall be held securely in place so that it cannot be displaced in service and shall provide mechanical protection of the enclosed parts. The thickness of a glass cover shall not be less than the applicable value indicated in Table 19.3.

Table 19.3
Thickness of glass covers

Maximum size of opening				Minimum thickness,	
Length or width,		Area,			
in.	(mm)	$in.^2$	(cm^2)	in.	(mm)
4	(102)	16	(103)	1/16	(1.6)
12	(305)	144	(929)	1/8	(3.2)
Over 12	(Over 305)	Over 144	(Over 929)	See footnote a	(See footnote a)

[a] 1/8 in. (3.2 mm) or more, based upon the size, shape, and mounting of the glass panel. A glass panel for an opening having an area greater than 144 $in.^2$ (929 cm^2), or having any dimension greater than 12 in. (305 mm), shall be supported by a continuous groove not less than 3/16 in. (4.8 mm) deep along all four edges of the panel.

19.7.2 A transparent material other than glass employed as a cover over an opening in an enclosure shall have mechanical strength equivalent to that of glass, shall not become a fire hazard or distort, and shall not become less transparent at the temperature to which it may be subjected under normal or abnormal service conditions.

19.7.3 A lens, light filter, or similar part of a smoke alarm shall be constructed of a material the transparency of which is not impaired by the conditions to which it is exposed in service as represented by the performance tests described in Sections 38 (General) – 85 (Conformal Coatings on Printed Wiring Boards).

20 Corrosion Protection

20.1 Iron and steel parts shall be protected against corrosion by enameling, galvanizing, plating, or other means determined to be equivalent.

20.2 The requirement of 20.1 applies to all enclosures, whether of sheet steel or cast iron, and to all springs and other parts upon which proper operation depends. It does not apply to minor parts such as washers, screws, and bolts, when the deterioration of such unprotected parts does not result in noncompliance with this standard, result in a hazardous condition, or impair the operation of the smoke alarm.

20.3 Bearing surfaces shall be of such materials that reduce the risk of binding due to corrosion.

20.4 Metal shall not be used in combinations such as to result in galvanic action that results in deterioration of cabinets or enclosures.

20.5 Hinges and other attachments shall be resistant to corrosion.

20.6 Nonferrous cabinets and enclosures do not require special corrosion protection.

21 Field Wiring Connections

21.1 Permanent connection

21.1.1 A smoke alarm intended for permanent connection shall be provided with wiring terminals or leads for the connection of conductors of at least the size corresponding to the rating of the unit in accordance with the National Electrical Code, ANSI/NFPA 70.

21.2 Field wiring compartment

21.2.1 The field wiring compartment area shall be of sufficient size for completing all field wiring connections as specified by the installation wiring diagram. There shall be space within the compartment to permit the use of a standard conduit bushing on conduit connected to the compartment when a bushing is required for installation.

21.2.2 Protection from sharp edges for internal components in the wiring area and wire insulation shall be provided by insulating or metal barriers having smooth, rounded edges or equivalent means of protection.

21.3 Field wiring terminals (general)

21.3.1 A field-wiring terminal to which field-wiring connections are made shall comply with the requirements in 21.3.2 – 21.3.5 and:

a) The field-wiring requirements in the Standard for Electrical Quick-Connect Terminals, UL 310;

b) The Standard for Wire Connectors, UL 486A-486B;

c) The Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E; or

d) The Standard for Terminal Blocks, UL 1059, rated for field-wiring (FW) Code 2 applications and also suitable for the voltage, current, wire range, and wire type of the intended application.

21.3.2 Nonferrous soldering lugs or solderless (pressure) wire connectors shall be used for 10 AWG (5.3 mm^2) and larger wires. When the connectors or lugs are secured to a plate, the plate thickness shall not be less than 0.050 in. (1.3 mm) thick. Securing screws of plated steel have been determined to meet the requirements.

21.3.3 A wire-binding screw used at a wiring terminal shall not be smaller than No. 8 (4.2 mm) diameter. Plated screws are not prohibited.

Exception: A No. 6 (3.5 mm) diameter screw is appropriate for use for the connection of a 14 AWG (2.1 mm^2) and a No. 4 (2.8 mm) diameter screw is appropriate for use for the connection of a 19 AWG (0.65 mm^2) or smaller conductor.

21.3.4 Terminal plates tapped for wire-binding screws shall:

a) Have not less than two full threads in the metal (the terminal plate metal may be extruded to provide the two full threads) and shall have upturned lugs, clamps, or the equivalent, to hold the wires in position. Other constructions may be used if they provide equivalent thread security of the wire-binding screw.

b) Be of a nonferrous metal not less than 0.050 in. (1.3 mm) thick when used with a No. 8 (4.2 mm) diameter or larger screw, and not less than 0.030 in. (0.76 mm) thick when used with a No. 6 (3.5 mm) diameter or smaller screw.

21.3.5 When two or more conductors are intended to be connected by wrapping under the same screw, a nonferrous intervening metal washer shall be used for each additional conductor. A separator washer is not required when two conductors are separated and intended to be secured under a common clamping plate. When the wires protrude above terminal barriers, the nonferrous separator shall include means, such as upturned tabs or sides, to retain the wire.

21.4 Special field-wiring terminals (qualified application)

21.4.1 of the following terminal configurations are suitable for connection of field wiring when all of the conditions in 21.4.2 are met:

a) Quick-Connect Terminals – Nonferrous, quick-connect (push-type) terminals consisting of male posts permanently secured to the device and provided with compatible, female connectors for connection to field wiring. These require a special tool for crimping of field wires. Mating terminals shall be shipped with the control unit with instructions for their installation;

b) Push-In Terminals – Nonferrous (screwless), push-in terminals of the type used on some switches and receptacles. Solid conductors are pushed into slots containing spring-type contacts. The leads are removable by means of a tool inserted to relieve the spring tension on the conductor. Push-in terminals are not to be used with aluminum conductors. The marking adjacent to the terminal shall indicate that copper conductors only are to be used; and

c) Other Terminals – Other terminal connections are not prohibited when determined to be equivalent to (a) and (b) and are limited to the same restrictions.

21.4.2 Any of the terminal configurations listed in 21.4.1 are appropriate for connection of field wiring provided all of the following indicated conditions are met:

a) When a special tool is required for connection, it shall be provided and its use indicated on the installation wiring diagram by name of the manufacturer and the model number or equivalent;

b) The range of wire sizes shall be indicated on the installation wiring diagram. The minimum permissible wire size to be used shall not be less than 26 AWG (0.13 mm^2) for a jacketed, multi-conductor cable or 18 AWG (0.82 mm^2) for a single conductor wire;

c) The wire size to be used shall be rated for the current-carrying capacity of the circuit application; and

d) The special field-wiring terminal assembly shall comply with the strain relief test as outlined in 80.3.

21.5 Field wiring leads

21.5.1 Power supply leads provided for field connection shall not be less than 6 in. (152 mm) long; shall be provided with strain relief; and shall not be smaller than 18 AWG (0.82 mm^2). The insulation, when of rubber or thermoplastic, shall not be less than 1/32 in. (0.8 mm) thick.

21.5.2 Extra-low voltage leads provided for field connection signaling circuits, such as employed for multiple station interconnection or for connection to remote signaling devices, shall not be smaller than 18 AWG (0.82 mm^2), consisting of stranded copper wire, not more than seven strands, 19 AWG (0.65 mm^2) for two or more conductors, and 22 AWG (0.32 mm^2) for four or more conductors of a multiconductor cable.

21.6 Grounding terminals and leads

21.6.1 Except as permitted by 21.6.9, an equipment-grounding terminal or lead shall be provided in a smoke alarm intended for connection to other than a 30 V rms or less energy limited source of supply (see Primary power supply – battery, 85.3.1) by means of other than metal enclosed wiring system.

21.6.2 The grounding means shall be reliably connected to all exposed dead metal parts which are liable to become energized and all dead metal parts within the enclosure which are exposed to contact during servicing and maintenance.

21.6.3 The surface of an insulated lead intended solely for the connection of an equipment-grounding conductor shall be green, with or without one or more yellow stripes and no other leads visible to the installer, other than grounding conductors, shall be so identified.

21.6.4 A field wiring terminal intended for connection of an equipment grounding conductor shall be plainly identified, such as being marked ″G″, ″GR″, ″Ground″, ″Grounding″, or the equivalent, or by a suitable marking on a wiring diagram provided on the smoke-alarm. The field wiring terminal shall be so located that it is unlikely to be removed during normal servicing of the smoke-alarm.

21.6.5 A field wiring terminal for the connection of an identified supply conductor shall be identified by means of a metallic plated coating substantially white in colour and shall be readily distinguishable from the other terminals, or proper identification of the terminal for the connection of the identified supply conductor shall be clearly shown in some other manner, such as on an attached wiring diagram.

21.6.6 A field wiring lead provided for connection of an identified supply conductor shall be finished to show a white or gray colour and shall be readily distinguishable from other leads and no other leads, other than identified supply conductors, shall be so identified.

21.6.7 A terminal or lead identified for the connection of the identified supply conductor shall not be electrically connected to a single-pole manual switching device which has an off position or to a single-pole over-current (not thermal) protective device.

21.6.8 The grounding means for a cord-connected smoke-alarm shall consist of a separate ground lead integral with the supply cord and terminating in the grounding pin of a parallel blade attachment plug.

21.6.9 An equipment grounding terminal or lead is not required for a smoke-alarm provided with an overall nonmetallic enclosure and cover and which is not intended to be internally serviced or a smoke alarm provided with an overall nonmetallic enclosure and cover and does not employ internal dead-metal parts which may be energized under a fault condition and which can be contacted during servicing.

21.7 Power supply cord

21.7.1 A cord-connected single station smoke alarm accessory shall be provided with not less than 6 ft. (1.83 m) nor more than 20 ft. (6.10 m) of flexible cord and a two or three prong attachment plug of the type and rating for connection to the supply circuit.

21.7.2 The flexible cord shall be minimum 18 AWG (0.82 mm^2) and rated for use at the voltage and ampacity rating of the smoke alarm. Type SP-1, SPT-1, SP-2, SPT-2, SV, SVT, SJ, SJT, SPE-1. SPE-2, SVE, or the equivalent in accordance with the National Electrical Code, ANSI/NFPA 70, are acceptable cord types.

21.7.3 Means shall be provided to prevent the flexible cord from being pushed into the enclosure through the cord-entry hole if such displacement can subject the cord to mechanical damage or to exposure to a temperature higher than that for which the cord is rated, reduce spacings below the minimum acceptable values, or result in damage in internal components.

21.7.4 Where a flexible cord passes through an opening in a wall, barrier, or enclosing case, the edges of the hole shall be smooth and rounded, without burrs, fins, or sharp edges which may damage the cord jacket. The cord as connected to the smoke alarm shall comply with Strain Relief Test, Section 80.

22 Remote Power Supply

22.1 For an alarm that is intended to be connected to a separate remote power supply such as a transformer, the supply cord is not required to be factory wired to the alarm or to the transformer terminals or leads when the installation instructions provided with the unit are explicit regarding the method of connection. The minimum size conductors between the alarm and remote power supply shall not be less than 18 AWG (0.82 mm^2) and shall not be longer than 20 ft. (6.1 m). The interconnecting wiring is to be provided with the alarm and the transformer by the manufacturer.

22.2 Where longer runs of interconnecting wiring are used in an installation, such as in a multiple station configuration, or where several alarms are supplied by a common power supply, the wiring is not required to be provided by the manufacturer. However, the installation wiring diagram or instructions shall be marked to specify that the wiring to be used shall be in accordance with the provisions of Articles 210 and 3003 (B) of the National Electrical Code, ANSI/NFPA 70. In addition, the resistance of the interconnecting wiring shall be a maximum of 10 ohms, unless otherwise specified by the manufacturer.

23 Internal Wiring

23.1 General

23.1.1 The internal wiring of a smoke alarm shall be routed away from moving parts and sharp projections and held in place with clamps, string, ties, or the equivalent, unless the wiring is determined to be rigid enough to retain a shaped form. The internal wiring shall consist of conductors having:

a) Insulation rated for the potential involved;

b) Insulation rated for the temperatures to which they are subjected; and

c) The current-carrying capacity for the service.

23.1.2 Leads or a cable assembly connected to parts mounted on a hinged cover shall be of sufficient length to permit the full opening of the cover without applying stress to the leads or their connections. The leads shall be secured or equivalently arranged to prevent abrasion of insulation and jamming between parts of the enclosure. Wire shall be stranded copper.

23.1.3 When the use of a short length of insulated conductor is not feasible, such as for a short coil lead or the like, electrical insulating tubing shall be used. The tubing shall not be subjected to sharp bends, tension, compression, or repeated flexing and shall not contact sharp edges, projections, or corners. The wall thickness of the tubing shall comply with the requirements for such tubing except that the wall thickness at any point for polyvinyl chloride tubing of 3/8 in. (9.5 mm) diameter or less shall not be less than 0.017 in. (0.43 mm). For insulating tubing of other types the wall thickness shall not be less than that required to at least equal the mechanical strength, dielectric properties, and heat and moisture resistance characteristics of polyvinyl chloride tubing having a wall thickness of 0.017 in. (0.43 mm).

23.1.4 Internal wiring of circuits which operate at different potentials shall be reliably separated by barriers or shall be segregated, unless the conductors of the circuits of lower voltage are provided with insulation equivalent to that required for the highest voltage involved. Segregation of insulated conductors may be accomplished by clamping, routing, or an equivalent means, which ensures permanent separation. See 23.4, Barriers.

23.1.5 Stranded conductors clamped under wire-binding screws or similar parts shall have the individual strands soldered together or be equivalently arranged to provide secure connections.

23.2 Wireways

23.2.1 Wireways shall be smooth and free from sharp edges, burrs, fins, moving parts, and the like which may cause abrasion of the conductor insulation.

23.3 Splices

23.3.1 All splices and connections shall be mechanically secured and bonded electrically. Tack soldering of components is permitted where the construction precludes mechanical security only when 5 samples resist a pull-force of 2 lbs (8.9 N) applied for 3 seconds and the connection is subjected to 100 percent inspection and testing with the same pull force by the manufacturer.

23.3.2 A splice shall be provided with insulation determined to be equivalent to that of the wires involved when permanence of electrical spacings between the splice and uninsulated metal parts is not provided.

23.3.3 Splices shall be located, enclosed, and supported so that flexing, movement, or vibration does not damage the insulation or affect the integrity of the splice.

23.4 Barriers

23.4.1 A metal barrier shall have a thickness at least equal to that required by Table 19.2, as determined by the size of the barrier. A barrier of insulating material shall not be less than 0.028 in. (0.71 mm) thick and shall be thicker when its deformation is readily accomplished so as to defeat its purpose. Any clearance between the edge of a barrier and a compartment wall shall not exceed 1/16 in. (1.6 mm).

23.5 Strain relief

23.5.1 A strain relief means shall be provided for the field leads, battery leads, and all internally connected wires or cords that are subject to movement in conjunction with the installation, operation, or servicing of a smoke alarm to reduce the risk of any mechanical stress being transmitted to internal connections and terminals. Inward movement of the cord or leads provided with a ring-type cord grip shall not damage internal connections or components, or result in a reduction of the electrical spacings required. See the Strain Relief Test, Section 80.

24 Bonding for Grounding

24.1 An exposed non-current-carrying metal part of a smoke alarm operating at more than 30 Vrms that is liable to become energized, shall be reliably bonded to the point of connection of the field-equipment grounding terminal or lead, if provided or required, and to the metal surrounding the knockout, hole, or bushing provided for field power-supply connections. This requirement also applies to a smoke alarm equipped with auxiliary function contacts rated at more than 30 Vrms.

24.2 Except as indicated in 24.3, uninsulated metal parts of electrical enclosures, motor frames and mounting brackets, controller mounting brackets, capacitors, and other electrical components shall be bonded for grounding when it is possible that they be contacted by the user or by a service person in servicing or operating the equipment.

24.3 Metal parts as described below are not required to comply with the requirement specified in 24.2:

a) Adhesive attached metal foil markings, screws, and handles that are located on the outside of the smoke alarm enclosure and isolated from electrical components or wiring by grounded metal parts so that they do not become energized.

b) Isolated metal parts, such as small assembly screws, that are positively separated from wiring and uninsulated live parts.

c) Panels and covers that do not enclose uninsulated live parts when wiring is positively separated from the panel or cover so that it does not become energized.

d) Panels and covers that are insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar material not less than 1/32 in. (0.8 mm) thick and secured in place.

24.4 A bonding conductor shall be of material determined to be capable for use as an electrical conductor. When of ferrous metal, it shall be protected against corrosion by painting, plating, or the equivalent. The conductor shall not be smaller than the maximum size wire employed in the circuit wiring of the component or part. A separate bonding conductor or strap shall be installed in such a manner that it is protected from mechanical damage.

24.5 The bonding shall be by a positive means, such as by clamping, riveting, bolted or screwed connection, brazing, or welding. The bonding connection shall penetrate nonconductive coatings such as paint. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material.

Note 1: A bolted or screwed connection that incorporates a star washer under the screw head is considered acceptable for penetrating non-conductive coatings.

Note 2: Where the bonding means depend upon screw threads, two or more screws or two full threads of a single screw engaging metal are considered acceptable. Metal-to-metal hinge-bearing members for doors or covers may be considered as a means for bonding the door or cover for grounding providing that a multiple bearing, pin-type hinge is employed.

24.6 Splices shall not be employed in conductors used to bond electrical enclosures or components.

COMPONENTS

25 General

25.1 Mounting of components

25.1.1 All parts of a smoke alarm shall be securely mounted in position and prevented from loosening or turning.

Exception No. 1: It is not required that a switch be prevented from turning when all four of the following conditions are met:

a) The switch is a plunger or other type that does not tend to rotate when operated. A toggle switch is subject to forces that tend to turn the switch during operation of the switch.

b) The switch mounting means is constructed so that it is not loosened by the switch operation.

c) The spacings are not reduced below the minimum required values when the switch rotates.

d) The operation of the switch is by mechanical means rather than by direct contact by persons.

Exception No. 2: A lampholder of the type in which the lamp is not capable of being replaced, such as a neon pilot or indicator light in which the lamp is sealed in a nonremovable jewel, is not required to be prevented from turning when rotation does not reduce spacings below the minimum values required.

25.1.2 Uninsulated live parts shall be secured to the base or mounting surface so that they shall not turn or shift in position when it is possible that such motion results in a reduction of spacings below the acceptable values. Friction between surfaces shall not be used as a means to prevent shifting or turning of live parts. A lock washer applied as intended is permitted.

25.1.3 Uninsulated live parts, for example, field wiring terminals, shall be secured to their supporting surfaces by methods other than friction between surfaces so that they shall not turn or shift in position when such motion results in reduction of spacings below the minimum values required. This may be accomplished by two screws or rivets, by square shoulders or mortices, by a dowel pin, lug, or offset, by a connecting strap or clip fitted into an adjacent part, or by any method determined to be equivalent.

25.2 Operating components

25.2.1 Operating components and assemblies, such as switches, relays, and similar devices, shall be protected by individual protection (ie. dust covers) or dust tight cabinets against fouling by dust or by other material which affect their operation.

25.2.2 Adjusting screws and similar adjustable parts shall not loosen under the conditions of actual use. The use of a lock washer, applied as intended, to reduce the risk of loosening is permitted.

25.2.3 Moving parts shall have sufficient play at bearing surfaces to prevent binding.

25.2.4 Manually operated parts shall have sufficient strength to withstand the stresses to which they will be subjected in operation.

25.2.5 An electromagnetic device shall be reliable and ensure positive electrical and mechanical performance under all conditions of normal operation.

25.3 Current-carrying parts

25.3.1 A current-carrying part shall have adequate mechanical strength and current-carrying capacity for the service, and shall be a metal such as silver, copper or copper alloy, or other material, which will provide equivalent performance.

25.3.2 Bearings, hinges, and the like shall not be acceptable for carrying current between interrelated fixed and moving parts.

26 Bushings

26.1 When a lead or wire harness passes through an opening in a wall, barrier, or enclosing case, there shall be a metal or insulating type bushing, or the equivalent, that shall be substantial, secured in place, and have a smooth, rounded surface to provide support for the wire.

26.2 When the opening is in a phenolic composition or other nonconducting material or in metal of thickness greater than 0.042 in. (1.07 mm) at the opening, a smooth surface having rounded edges is identified as the equivalent of a bushing.

26.3 Ceramic materials and some molded compositions are permissible for insulating bushings. Separate bushings of wood and of hot-molded shellac shall not be used.

26.4 Fiber shall be employed only where:

a) It is not subjected to a temperature higher than 90°C (194°F) under normal operating conditions;

b) The bushing is not less than 1/16 in. (1.6 mm) thick, with a minus tolerance of 1/64 in. (0.4 mm) for manufacturing variations; and

c) It does not deteriorate in normal ambient humidity conditions.

26.5 When a soft rubber bushing or similar material that deteriorates with age is employed in a hole in metal, the hole shall be free from sharp edges, burrs, projections, and other anomalies which cut into the bushing and wire insulation.

26.6 An insulating metal grommet shall be used in lieu of an insulating bushing, only when the insulating material used is not less than 1/32 in. (0.8 mm) thick and completely fills the space between the grommet and the metal in which it is mounted.

27 Electrical Insulating Material

27.1 Material for the mounting of current-carrying parts shall be porcelain, phenolic composition, cold-molded composition, or equivalent material which is suitable for the particular application.

27.2 Polymeric materials shall be used for the sole support of uninsulated live parts only when determined to be equivalent to the materials indicated in 27.1.

27.3 When vulcanized fiber is used for insulating bushings, washers, separators, and barriers, it shall not be the sole support for uninsulated current-carrying parts of other than extra-low-voltage circuits.

27.4 The thickness of a flat sheet of insulating material, such as phenolic composition employed for panel mounting of parts, shall not be less than the applicable value indicated in Table 27.1.

Table 27.1
Thickness of flat sheets of insulating material

Maximum dimensions				Minimum thickness,[a]	
Length or width,		Area,			
in.	(mm)	in.^{2}	(cm^2)	in.	(mm)
6	(152)	36	(232.4)	1/16	(1.6)
12	(305)	144	(928.8)	1/8	(3.2)
24	(610)	360	(2322)	3/8	(9.5)
48	(1219)	1152	(7432)	1/2	(12.7)
48	(1219)	1728	(11148)	5/8	(15.9)
Over 48	(Over 1219)	Over 1728	(Over 11148)	3/4	(19.1)

[a] Material less than the minimum thickness shown shall be used for a panel only when the panel is supported or reinforced to provide equivalent rigidity.

27.5 A terminal block mounted on a metal surface which is capable of being grounded shall be provided with an insulating barrier between the mounting surface and all live parts on the underside of the base to reduce the risk of the parts and the ends of replaceable terminal screws from reducing spacings below the minimum thickness specified in Table 27.1.

27.6 A countersunk sealed part shall be covered with a waterproof insulating compound which does not melt at a temperature 15°C (27°F) higher than the maximum intended operating temperature of the assembly, and not less than 65°C (149°F) in any case. The depth or thickness of sealing compound shall not be less than 1/8 in. (3.2 mm).

28 Lampholders and Lamps

28.1 A smoke-alarm intended to be connected to a utility supply, either directly or via a separate power supply as described in 18.1 shall be provided with a steady ″power-on″ lamp to indicate energization of the unit.

Exception: When pulsed, the lamp shall pulse at least once per minute.

28.2 When a smoke alarm has more than one indicator lamp, lamp colors shall be:

a) A ″power-on″ lamp, white or green;

b) An alarm indicating lamp, red; and

c) A trouble lamp, amber or yellow.

When the ″power-on″ lamp is of a different color it shall be marked to identify the function.

28.3 At least one spare lamp shall be provided in a smoke alarm that employs photocell illuminating lamps that burn out during the service life of a smoke alarm.

28.4 A lampholder and lamp shall be rated for the circuit in which they are employed.

28.5 A lampholder in a hazardous-voltage circuit shall be wired so that the screw shell is connected to an identified neutral (grounded circuit) conductor.

28.6 A lampholder shall be installed so that uninsulated hazardous-voltage circuit live parts are not exposed to contact by persons removing or replacing lamps in service.

29 Photocell Illuminating Lamps and Light Emitting Diodes (LEDs)

29.1 Quality assurance program

29.1.1 Light emitting diode (LED) manufacturer

29.1.1.1 Verification shall be provided by the LED manufacturer to indicate compliance with the following minimum quality assurance program:

a) Lot sample testing of optical efficiency, anode bond, and chip peel tests are performed on diode chips;

b) 100 percent production tests of light output, forward conduction, leakage, and reverse breakdown are performed on the finished LED.

29.1.2 Smoke alarm manufacturer

29.1.2.1 The smoke alarm manufacturer shall conduct the following minimum quality assurance program on the LED lamps:

a) All incoming LEDs, in a de-energized condition, shall be subjected to one of the following stress conditions:

1) Ten cycles of temperature variation from minus 40°C to 85°C (minus 40°F to 185°F) with 30 min at each extreme and 5 min between extremes. Each cycle consists of starting at minus 40°C, going to 85°C, and returning to minus 40°C;

2) Exposure for 48 hours at the LED Manufacturer's maximum recommended storage temperature;

b) Following the stress conditioning, 100 percent inspection tests shall be conducted on the following parameters:

1) Light output;

2) Maximum forward voltage drop at specified forward current;

3) Maximum reverse leakage current at specified reverse voltage.

29.1.2.2 The temperature cycling burn-in and component screening may be conducted by the LED manufacturer if each shipment is accompanied by a certificate of compliance verifying its conduction on that shipment. In this case the smoke alarm manufacturer need only conduct 100 percent inspection for light output.

30 Protective Devices

30.1 Fuseholders, fuses, and circuit breakers shall be rated for the application.

31 Printed Wiring Boards

31.1 The components of a printed wiring board shall be attached securely and the spacings between circuits shall comply with the spacing requirements of Section 36, Spacings, for rigidly clamped assemblies. Also see Table 36.1, Minimum spacings. The board shall be mounted so that deflection of the board during servicing shall not result in damage to the board or in a reduction of electrical spacings below those required in this standard.

32 Switches

32.1 A switch provided as part of a unit shall have a current and voltage rating not less than that of the circuit which it controls when the device is operated under any condition of normal service.

32.2 When a reset switch is provided, it shall be of a self-restoring type.

32.3 An alarm silencing switch or equivalent means shall be provided on a single or multiple station smoke alarm only when its ″off normal″ position is supervised.

33 Transformers and Coils

33.1 A transformer shall be of the two-coil or insulated type.

33.2 A transformer shall meet the requirements of the Standard for Specialty Transformers, UL 506.

33.3 The insulation of coil windings of relays, transformers, and other insulation, shall resist the absorption of moisture.

Exception: An autotransformer shall be used only when the terminal or lead connected to the autotransformer winding that is common to both input and output circuits is identified and the output circuits are located only within the enclosure containing the autotransformer. See 21.6.1 and 21.6.2.

33.4 Film-coated or equivalently insulated wire does not require additional treatment to stop moisture absorption.

34 Dropping Resistors

34.1 A carbon composition resistor shall not be used as a dropping resistor in the hazardous-voltage circuit of a smoke alarm.

35 Power Supplies

35.1 Primary power supply

35.1.1 The primary power supply of a smoke alarm shall be either a utility supply (commercial light and power source) or an integral battery or batteries. Connection to the utility supply (commercial light and power source), when used, shall be in the form of permanent wiring to terminals or leads in a separate wiring compartment having provision for the connection of conduit, metal-clad or nonmetallic sheathed cable, by means of a power-supply cord and attachment-plug, or by means of a separate power supply.

35.1.2 When a separate power supply is provided, it shall have limited output energy consisting of an open circuit voltage not in excess of 30 volts rms, 42.4 volts peak or direct current (DC), and its output capacity shall be limited to a maximum of 100 VA. The energy may be limited by an energy limiting device having an output rating of 100 VA or less or by a transformer plus additional circuitry having characteristics equivalent to those of a 100 VA transformer.

35.2 Secondary power supply

35.2.1 A secondary power supply, such as a battery, shall be provided and have the capacity to supply the maximum intended power to the smoke alarm for no less than 7 days in the standby condition and thereafter be able to operate the smoke alarm for an alarm signal for at least 4 minutes continuously. This capacity shall be measured using a fully charged battery or other applicable rechargeable energy storage media, or a fresh non-rechargeable battery, as appropriate. Refer to 41.5, Battery powered (primary or secondary) smoke alarms. Smoke Alarms consisting of battery primary power shall not be subject to this requirement.

35.2.2 If a battery or set of batteries is employed as the main source of power of a smoke-alarm, it shall meet the requirements of the Battery tests, 85.3.

35.2.3 When a battery is used for the secondary power supply, it shall be of either a rechargeable or non-rechargeable type. For a rechargeable type battery, the maximum charging current, as well as the maximum trickle charging current available, shall not exceed the battery manufacturer's specifications. For a non-rechargeable type battery, data on battery life, including discharge curves, shall be provided for the investigation to evaluate battery shelf aging and performance characteristics.

35.2.4 When a non-rechargeable or rechargeable type battery is used as a secondary power supply, the marking on the unit shall include specified periodic battery replacement instructions.

35.2.5 The discharge condition of a non-rechargeable or rechargeable type battery shall be monitored where a trouble indication, as described in 41.5.3 is obtained. The monitoring shall take place whether the alarm is operating on the primary supply or on the standby supply.

36 Spacings

36.1 Spacings shall be maintained between uninsulated live parts and dead metal parts and between uninsulated live parts of opposite polarity. The spacings shall not be less than those indicated in Table 36.1.

Table 36.1
Minimum spacings

Point of application	Voltage range[f]	Minimum spacings[a,b]			
		Through-air,		Over-surface,	
		in.	(mm)	in.	(mm)
To walls of enclosure					
Cast metal enclosures	0 – 300	1/4	(6.4)	1/4	(6.4)
Sheet metal enclosures	0 – 300	1/2	(12.7)	1/2	(12.7)
Installation wiring terminals					
With barriers	0 – 30	1/8	(3.2)	3/16	(4.8)
	31 – 150	1/8	(3.2)	1/4	(6.4)
	151 – 300	1/4	(6.4)	3/8	(9.5)
Without barriers	0 – 30	3/16	(4.8)	3/16	(4.8)
	31 – 150	1/4	(6.4)	1/4	(6.4)
	151 – 300	1/4	(6.4)	3/8	(9.5)
Rigidly clamped assemblies[c]					
100 volt-amperes maximum[d,e]	0 – 30	1/32	(0.8)	1/32	(0.8)
Over 100 volt-amperes[e]	0 – 30	3/64	(1.2)	3/64	(1.2)

Table 36.1 Continued on Next Page

Table 36.1 Continued

Point of application	Voltage range[f]	Minimum spacings[a,b]			
		Through-air,		Over-surface,	
		in.	(mm)	in.	(mm)
	31 – 150	1/16	(1.6)	1/16	(1.6)
	151 – 300	3/32	(2.4)	3/32	(2.4)
Other parts	0 – 30	1/16	(1.6)	1/8	(3.2)
	31 – 150	1/8	(3.2)	1/4	(6.4)
	151 – 300	1/4	(6.4)	3/8	(9.5)

[a] An insulating liner or barrier of vulcanized fiber, varnished cloth, mica, phenolic composition, or similar material employed where spacings are otherwise insufficient, shall not be less than 0.028 in. (0.71 mm) thick. When a liner or barrier is used that is less than 0.028 in. (0.71 mm), and not less than 0.013 in. (0.33 mm) thick, it shall be used only in conjunction with an air spacing of not less than one-half of the through air spacing required. The liner shall be located so that it is not affected adversely by arcing. When insulating material having a thickness less than that specified is used it shall be found to be appropriate for the particular application.

[b] Measurements are to be made with solid wire of adequate ampacity for the applied load connected to each terminal. In no case is the wire to be smaller than 16 AWG (1.3 mm^2).

[c] Rigidly clamped assemblies include such parts as contact springs on relays or cam switches, printed-wiring boards, and similar assemblies.

[d] Spacings less than those indicated, and not less than 1/64 in. (0.4 mm), are appropriate for the connection of integrated circuits and similar components where the spacing between adjacent connecting wires on the component is less than 1/32 in. (0.8 mm).

[e] When spacings between traces on a printed-wiring board are less than the minimum specified, the boards shall be covered with a conformal coating, and the combination shall be evaluated to the requirements in Conformal Coatings of Printed-Wiring Boards, Section 85.

[f] RMS volts for sinusoidal waveform. The equivalent peak voltage should be used for non-sinusoidal waveforms.

36.2 The spacings between an uninsulated live part and:

a) A wall or cover of a metal enclosure,

b) A fitting for conduit or metal-clad cable, and

c) Any dead-metal part.

36.3 The ″Through Air″ and ″Over Surface″ spacings of Table 36.1 measured at an individual component part shall be judged on the basis of the volt-amperes used and controlled by the individual component. However, the spacing from one component to another, and from any component to the enclosure or to other uninsulated dead metal parts, excluding the component mounting surface, shall be judged on the basis of the maximum voltage and total volt-ampere ratings of all components in the enclosure.

36.4 The spacing requirements specified in Table 36.1 do not apply to the inherent spacings inside motors, except at wiring terminals, nor to inherent spacings for a component provided as part of the smoke alarm. Such spacings are judged on the basis of the requirements for the component. The electrical clearance resulting from the assembly of a component into the complete device, including clearances to dead metal or enclosures, shall be as indicated in Table 36.1.

36.5 The ″To Walls of Enclosure″ spacings of Table 36.1 are not to be applied to an individual enclosure of a component part within an outer enclosure.

36.6 Film-coated or equivalently insulated wire is identified as an uninsulated live part. Enamel is capable of being used as turn-to-turn insulation in coils.

36.7 Spacings on printed-wiring boards which are less than those indicated in Table 36.1 shall be provided with a coating in compliance with Conformal Coatings on Printed-Wiring Boards, Section 85.

PERFORMANCE

37 General

37.1 Test units

37.1.1 Smoke alarms and power supply units that are fully representative of production units shall be used for the tests specified in Sections 38 – 98, unless otherwise specified. The sensitivity setting or range of sensitivities provided on the units for test will define the production smoke sensitivity single and multi-criteria smoke alarms and production gas sensitivity, for multi-criteria smoke alarms.

37.1.2 The devices employed for testing shall be those specified by the wiring diagram of the smoke alarm. When substitute devices are used, they shall produce functions and load conditions equivalent to those obtained with the smoke alarm in service, including devices intended to be used with the smoke alarm. Smoke alarms intended to be energized by a separate power supply, as described in 35.1.2 shall be tested as a combination, and the applicable requirements of the test also applied to the power supply unit. See Section 87, Power Supply Tests.

37.2 Performance of single sensor components of multi-criteria smoke alarms

37.2.1 The performance of single sensor components of a multi-criteria smoke alarm need not comply with the standards specific for those single phenomena smoke alarms.

37.2.2 The performance of the multi-criteria smoke alarm shall meet the requirements of this standard except for the smoke sensitivity limits specified in Tables 37.1 and 37.2. Manufacturers shall provide samples that reflect and information that identifies the combined and discreet maximum and minimum sensitivities of each constituent sensor.

Table 37.1
Visible smoke obscuration limits (gray smoke)

Percent per ft.	(Percent per m)	OD per ft.	(OD per m)
4.0	(12.5)	0.0177	(0.0581)
0.5	(1.6)	0.0022	(0.0072)
Note: Refer to Appendix C for the calculation of obscuration and optical density			

Table 37.2
Measuring ionization chamber (MIC) measurement

93 pA (maximum) – 37.5 pA (minimum)
Note: Refer to Appendix C for the calculation of obscuration and optical density

37.3 Test voltages

37.3.1 Unless otherwise specified, the test voltage for each test shall be as specified in Table 37.3 and at rated frequency.

Table 37.3
Test voltages

Nameplate voltage rating	Test voltage[a]
110 to 120	120
220 to 240	240
Other	Maximum marked nameplate rating
[a] Smoke alarms rated at frequencies other than 60 Hz shall be tested at their rated nameplate voltage and frequency.	

37.4 Test samples and data

37.4.1 The following samples and data are required; the data required in (e) does not have to be in final printed form:

a) At least 28 assembled alarms; 12 preset (as close as intended production calibration permits) to the nominal maximum production sensitivity (most sensitive setting), and 16 preset (as close as intended production calibration permits) to the nominal minimum anticipated production sensitivity (least sensitive setting). Four of the 12 units preset to the maximum sensitivity and four of the 16 preset to the minimum sensitivity shall be calibrated so that the sensitivity of any individual unit does not vary more than 25 percent from any other unit in each setting, and shall establish the maximum and minimum sensitivities to be employed in production. Combination/multi-criteria smoke alarms shall be provided with means for monitoring each principle of operation during the Sensitivity Test, Section 42. Fewer samples are permitted to be submitted for partial investigations based on a limited test program when agreed to by the testing agency.

b) One additional unassembled smoke alarm.

c) Five additional samples of smoke alarms that operate on the photoelectric principle provided with means to reduce the light output as described in 47.2.

d) The monitoring instrument, or reference to a readily available instrument, intended to monitor the sensitivity of each sensor in the multi-criteria smoke alarm.

e) Installation and Operating Instructions, see 8.1 and 8.2 and Instructions, General, Section 101.

f) Where applicable, samples of conformal coated printed-wiring boards, as specified in Conformal Coatings on Printed-Wiring Boards, Section 85.

g) Power supplies, if the smoke-alarms are intended to be employed with specific power supply.

37.4.2 For smoke alarms employing a battery as the main operating supply, 24 additional battery operated smoke alarms for long term battery tests or equivalent test circuit set ups with appropriate measuring facilities to monitor the battery voltage, standby current, and alarm current shall be provided. See the Battery tests, 85.3.

37.4.3 Four battery test setups shall be provided for subjection to each of four environmental conditions. Each set up shall be representative of six smoke alarms and shall include test terminals and switches, limiting resistors, the alarm horn, and batteries. The value of resistors shall represent the normal standby current which is obtained from a complete smoke alarm.

37.4.4 The batteries shall be connected in the test circuit with the same terminal arrangement employed in the smoke alarm. Provision for connection of the actual sounding appliance used in the unit for the periodic and weekly testing shall also be made. See Battery tests, 85.3.

37.5 Component reliability data

37.5.1 Data on smoke alarm components, for example, capacitors, resistors, solid-state devices and the like, shall be provided for evaluation of the components for the intended application. When a military specification is referenced, a copy of the specification is to be provided for review.

37.5.2 The data required by 37.5.1 shall include the following or equivalent information:

a) Component Fault Analysis. Effect of failure, open and short, of capacitors and limited-life components on operation of a smoke alarm;

b) Maximum supplier's ratings for each component as well as the actual maximum operating values (voltage and current) in the smoke alarms;

c) A description of component screening and burn-in test data for solid-state devices (including, but not limited to, relays, semiconductor, integrated circuit) that operate at greater than the limits described in note d of Table 58.1;

d) General description of the smoke alarm manufacturer's quality assurance (QA) program. This data shall include incoming inspection and screening, in-process quality assurance, burn-in data, and testing. This applies to complete and partial assemblies as well as individual components;

e) A general description of the circuit operation under standby, alarm, and trouble conditions;

f) For smoke alarm employing a reliable LED as the photocell illuminating light source, the data shall be as specified in Section 29, Photocell Illuminating Lamps and Light Emitting Diodes (LEDs);

g) General calibration procedure of test instruments employed by the manufacturer in the calibration of a smoke alarm;

h) Amount of derating of components under normal standby and alarm conditions;

i) Component failure rate data at rated values and derated values.

37.6 Accessories

37.6.1 Unless specifically indicated otherwise, the applicable performance requirements of this standard shall also apply to any remote accessories with which it is to be employed – for example, but not limited to:

a) Normal Operation Test, Section 38;

b) Circuit Measurement Test, Section 56;

c) Overvoltage and Undervoltage Tests, Section 57;

d) Temperature Test, Section 58;

e) Jarring Test, Section 61;

f) Overload Tests, Section 69;

g) Endurance Test, Section 70;

h) Variable ambient temperature and humidity test, 88.3;

i) Leakage Current Test, Section 73;

j) Transient Tests, Section 66;

k) Dielectric Voltage-Withstand Test, Section 77;

l) Tests on Polymeric Materials, Section 79;

m) Drop Test, Section 83 (portable appliance only);

n) Audibility Test, Section 84.

37.6.2 Optional accessories used to assist persons with disabilities by enhancing the low frequency or signaling a tactile appliance shall include a source of secondary power equal to that of the smoke and heat alarms that the unit is compatible with.

37.6.3 Detached accessories utilizing a low frequency sound or actuating tactile appliances for Single and Multiple Units shall provide a low frequency sound or visual indication in the event of the following:

a) Loss of primary power,

b) Low energy of the secondary power source, or

c) The accessory unit cannot perform its intended function of enhancing the Smoke or Heat alarms primary low frequency audible sound or operate the tactile appliance.

37.7 Smoke alarm guards

37.7.1 Mechanical smoke alarm guards for use in providing physical protection to an installed smoke alarm shall be subjected to the following tests (in conjunction with the smoke alarm) as applicable:

a) Normal Operation Test, Section 38;

b) Sensitivity Test, Section 42;

c) Velocity-Sensitivity Test, Section 44;

d) Reduction in Light Output Test, Section 47;

e) Fire Tests, Section 51;

f) Smoldering Smoke Test, Section 52;

g) Audibility Test, Section 84.

37.8 Test conditions

37.8.1 The smoke alarm shall be installed in an environment so as to permit accurate monitoring of the conditions in (a) – (e). Unless otherwise specified, the following conditions shall be established and maintained throughout the test:

a) Ambient temperature at 23 ±3°C (73.4 ±5°F) or a higher temperature if specified by the manufacturer,

b) Relative humidity at 50 ±20 percent,

c) Oxygen concentration at 20.9 ±1 percent,

d) Barometric pressure of 101 ±4 kPa of mercury (760 ±30 mm), and

e) Supply voltage, if applicable, adjusted to 100 percent of rated input voltage.

37.9 Tests and analysis

37.9.1 Samples are to be subjected to analysis and tests as specified in Table 37.4 but are not required to be completed in the sequential order unless otherwise noted within the specified clause.

Table 37.4
Smoke alarm tests and analysis

Test title	Applicable test (paragraphs, sections, subsection)	Single criteria	Multi-criteria/combination
Test units	37.1.1 – 37.1.2	X	X
Performance of single sensor components of multi-criteria smoke alarm	37.2.1 – 37.2.2		X
Test voltages, Test samples and data Component reliability data Remote accessories Smoke alarm guards Test conditions	37.3 – 37.8	X	X
General	38.1.1 – 38.1.3, 38.1.6	X	X
General	38.1.4 – 38.1.5		X
Standardized alarm signal, Sensitivity shift criteria	38.2 – 38.3	X	X
Electrical Supervision			
General, Component Failure, Photocell illuminating lamps and light emitting diodes (LEDs), Battery powered (primary or secondary) smoke alarms, Smoke chamber monitoring	41.1 – 41.3, 41.5, 41.7	X	X
End-of-life signal	41.8	X	X
Multi-criteria smoke alarm with gas sensor	41.9		X
Sensitivity Test, General	42.1.1	X	
Sensitivity Test, General	42.1.2	X	X
Combustibles	42.2	X	X
Aerosol generation equipment (alternate method)	42.3	X	X
Test Equipment	42.4	X	X
Test method	42.5	X	X
Uniformity of operation	42.6	X	X
Smoke sensitivity test feature	42.7	X	X
Sensitivity test – gas sensor of a multi-criteria smoke alarm, general	42.8.1		X
Sensitivity test – heat sensor	42.8.2		X
Sensitivity test – sensors other than smoke, gas or heat	42.8.3		X
Directionality Test	43	X	X
Velocity Sensitivity Test – Smoke sensor	44.1	X	X

Table 37.4 Continued on Next Page

Table 37.4 Continued

Test title	Applicable test (paragraphs, sections, subsection)	Single criteria	Multi-criteria/combination
Multi-criteria smoke alarm with gas sensor	44.2		X
Smoke Entry (Stack Effect) Test	45	X	X
Lamp Interchangeability Test (Photoelectric)	46	X	X
Reduction in Light Output Test	47	X	X
Stability Test	48.1 – 48.7	X	X
Stability Tests – Multi-Criteria Smoke Alarms Incorporating Gas Sensor(s)	49		X
Fire Tests	51	X	X
Smoldering Smoke Test	52	X	X
Smoldering Polyurethane Foam Test	53	X	X
Selectivity Test – Multicriteria Smoke Alarms Incorporating Gas Sensor(s)	55		X
Circuit Measurement Test	56	X	X
Overvoltage and Undervoltage Tests	57	X	X
Temperature Test	58	X	X
Vibration Test	59	X	X
Replacement Test, Head and Covers	60	X	X
Jarring Test	61	X	X
Operation in high and low ambients and Effect of shipping and storage	62.1 and 62.2	X	X
Effect of shipping and storage – Multi-criteria smoke alarms incorporating gas sensor(s)	62.3		X
High Humidity, Humidity test	63.1.1 – 63.1.3	X	X
Low humidity [multi-criteria smoke alarms with gas sensors(s)]	63.2		X
Corrosion Test	64	X	X
Alternate Corrosion Test (21-Day)	65	X	X
Transient Tests	66	X	X
Static Discharge Test	67	X	X
Dust Test	68	X	X
Overload Tests	69	X	X
Endurance Test	70	X	X
Fire Test – Smoke Alarm with Heat Detection	71	X	
Fire Test – Smoke Alarm with Supplementary Heat Detection	72	X	
Abnormal Operation Test	74	X	X
Locked Rotor Test	76	X	X

Table 37.4 Continued on Next Page

Table 37.4 Continued

Test title	Applicable test (paragraphs, sections, subsection)	Single criteria	Multi-criteria/combination
Dielectric Voltage-Withstand Test	77	X	X
Polarity Reversal Test	78	X	X
Tests on Polymeric Materials	79	X	X
Strain Relief Test	80	X	X
Non-Compulsory Fire and Smoldering Smoke Tests	81	X	X
Survivability Tests	82	X	X
Drop Test	83	X	X
Audibility Test	84	X	X
Field service tests	85.1, 85.2	X	X
Battery tests	85.3	X	X
Conformal Coatings on Printed Wiring Boards	86	X	X

38 Normal Operation Test

38.1 General

38.1.1 A smoke alarm shall operate for all conditions of its intended performance, at all smoke alarm sensitivity settings, when energized from a source of rated voltage, under all conditions covered both in the installation instructions and in any supplementary information provided by the manufacturer.

38.1.2 The test voltage is to be in accordance with 37.3, Test voltages. The smoke alarm is to be in the standby condition and prepared for its intended signaling operation when it is connected to related devices and circuits.

38.1.3 The introduction of smoke into the detection chamber, such as from a smoldering cotton lamp wick, rope, or equivalent, shall result in the operation of the alarm in its intended manner. See 42.1.1. The alarm signal shall persist for at least 4 minutes under an abnormal level of smoke exceeding the alarm threshold limit.

38.1.4 A smoke alarm that employs a secondary power supply shall operate for alarm signals with the main power de-energized.

38.1.5 A multiple-station smoke alarm shall result in an indication (while in alarm), which will positively identify the actuating unit when installed in a multiple-station mode. When the interconnection wiring is not supervised for opens, shorts, and grounds, no more than 12 smoke alarms or 18 alarms [12 smoke alarms and 6 other (heat, CO, or similar alarms)] shall be specified for interconnection. When the interconnection is supervised, no more than 64 smoke alarms shall be specified for interconnection.

38.1.6 When a heat alarm is provided integral with a single station smoke alarm, or is intended to be connected to a remote initiating device circuit of a multiple station smoke alarm, actuation of the heat alarm shall result in the smoke alarm signal.

38.1.7 No individual sensor of a smoke alarm shall be rendered inoperative by any of the Performance Tests (Sections 37 – 89) of this standard.

38.1.8 If low power wireless transmission between smoke alarms, is used, it shall be in compliance with the requirements outlined in the Standard for Household Fire Warning System Units, UL 985, section titled ″Short Range Radio Frequency Devices.″ The transmission signal of a smoke alarm with integral or remote transmitter to a compatible receiver shall result in an alarm signal, at the receiver, being locked-in for at least 4 minutes. The test is to be conducted at the maximum distance specified by the manufacturer when tested under free-field conditions with no obstructions between the smoke alarm transmitter and receiver units. Refer to 101.1(m) for instructions to be provided. Lock-in of the receiver is not required when the receiving unit audible alarm signal is energized in time sequence and duration with the smoke alarm.

38.1.9 An alarm or accessory that employs one or more non fire alarm features shall operate as follows:

a) The smoke alarm/fire alarm signal shall take precedence or be clearly recognizable over any other signal even when the non fire alarm signal is initiated first.

b) Distinctive signals shall be obtained between the smoke alarm/fire alarm and other non fire alarm functions. The use of a common sounding appliance for the fire alarm and non fire alarm function(s) shall be used only when distinctive signals are obtained. When an audible trouble signal is additionally provided it shall be distinctive from all alarm signals. The trouble signal may be common to all functions employed.

c) Any fault condition of limited life non fire alarm components shall not interfere with the operation and supervision of the smoke alarm. See 41.1.5.

38.1.10 Multiple station smoke alarms interconnected with carbon monoxide alarms shall result in the carbon monoxide audible alarm sounding by all interconnected alarms when the carbon monoxide alarms are the actuating units. Smoke alarms may remain silent if they do not produce the CO alarm signal. Refer to the Standard for Single and Multiple Station Carbon Monoxide Alarms, 2034.

38.1.11 Multiple station smoke alarms interconnected with carbon monoxide alarms shall result in the smoke alarm audible alarm sounding by all interconnected units smoke alarms when the smoke alarms are the actuating units. CO alarms may remain silent if they do not produce the smoke alarm signal.

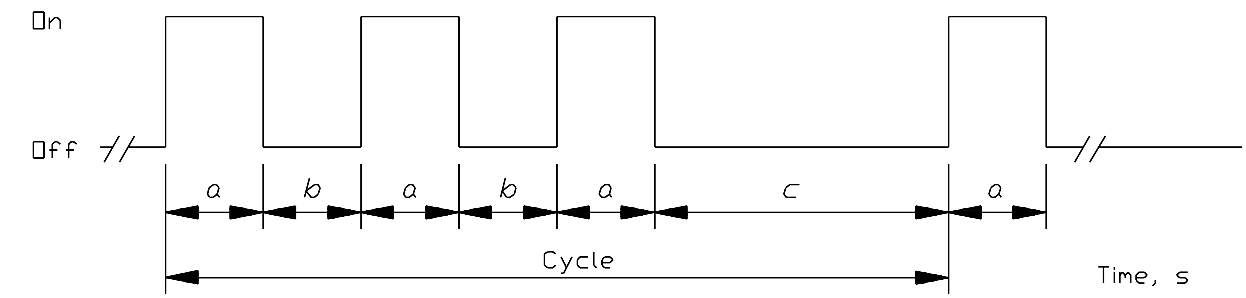
38.1.12 Multiple station smoke alarms interconnected with carbon monoxide alarms or combination smoke alarms and carbon monoxide alarms shall result in a smoke alarm audible signal taking precedence when both types of alarms are activated.

38.1.13 For the multiple station smoke alarm that initiates the smoke alarm signal, the initiating alarm shall be allowed to restore all interconnected units, by operation of the reset button on the actuating unit, to their “Normal Operation” state.

38.2 Standardized alarm signal

38.2.1 A smoke alarm that produces an audible signal which is intended to initiate immediate evacuation from the protected area shall produce the signal in the form of the ″three pulse″ temporal pattern shown in Figure 38.1. Each ON phase shall last 0.5 second ±10 percent followed by an OFF phase of 0.5 second ±10 percent. After the third of these ON phases, there shall be an OFF phase that lasts 1.5 seconds ±10 percent. Where the intended action is not immediate evacuation, the audible signal shall produce an alert signal distinctive from the ″three pulse″ temporal system.

Figure 38.1
Standardized alarm signal temporal pattern



Key

Phase a signal is ″on″ for 0.5 s ± 10 %
Phase b signal is ″off″ for 0.5 s ± 10 %
Phase c signal is ″off″ for 1.5 s ± 10 % (c = a + 2b)
Total cycle lasts for: 4 s ± 10 %

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38.2.2 A voice message shall be permitted to be included with the standardized alarm signal in one or both of the formats noted below.

a) A voice message of 1.5 seconds or less in length shall be permitted to be inserted into any or all of the 1.5 second OFF phases of the temporal pattern.

b) A voice message that exceeds 1.5 seconds but does not exceed 10 seconds in length shall be permitted to be inserted following a minimum of 8 cycles of the initial “three pulse” temporal pattern. This voice message shall be followed by not less than 2 cycles of the “three pulse” temporal pattern. The voice message shall then be permitted to be repeatedly inserted provided that each additional use of the voice message follows at least 2 cycles of the “three pulse” temporal pattern.

c) In Board and Care Occupancies, provisions should be made to allow premise staff to have multiple languages available which reflect the general region.

38.3 Sensitivity shift criteria

38.3.1 During or immediately after performance tests, the sensitivity of the smoke sensor shall not vary more than ±1 percent per ft (±3.3 percent per m) [±0.0045 optical density per ft (±0.014 optical density per m)] obscuration from the value recorded prior to the test. For non-multi-criteria smoke alarms the sensitivity limits shall comply with 42.1.1. Manufacturers shall define acceptable sensitivity shift for non-smoke sensors in multi-criteria smoke alarms.

39 Automatic Drift Compensation for Smoke Sensing

39.1 For products that employ a drift compensation function to automatically shift the alarm threshold to maintain the same overall sensitivity of the smoke alarm, the compensation shall comply with the requirements in 9.1 – 9.4.

39.2 Two samples of each smoke alarm shall be subjected to the conditions described in 39.3. One sample of the smoke alarm shall be set at the maximum production clean air setting and the highest production gain, while the other shall be set at the lowest production clean air setting and the lowest production gain.

39.3 Each smoke alarm shall be subjected to the Sensitivity Test described in Section 42. The product sensitivity setting for the low gain alarm shall be the least (minimum) sensitivity value and the sensitivity setting for the high gain alarm shall be the most (maximum) sensitivity setting. The measured sensitivities shall be within the rated limits for the smoke alarm.

39.4 A contamination or simulated contamination (as defined by the manufacturer) is then to be introduced into each smoke alarm and the smoke alarm allowed to compensate. The process is to be repeated, increasing the contamination or simulated contamination within the smoke alarm, until the smoke alarm is at the point where the maximum amount of compensation has been provided. The Sensitivity Test described in Section 42 is to be repeated. This sensitivity shall be within 0.5 percent/ft. (1.65 percent/m) obscuration of the initial sensitivity measurement for the same smoke alarm. If the sensitivity of the alarm is not adjustable, the sensitivity must remain within the proposed production smoke sensitivity limits.

40 Alarm Silenced Test

40.1 To determine the duration of the alarm silenced period, one single station smoke alarm, in the normal standby condition, is to be placed in the sensitivity test chamber. See the Sensitivity Test, Section 42. The smoke is to be increased until the smoke alarm goes into an alarm condition. The smoke is to be maintained at an abnormal amount for the duration of the test. After the smoke alarm has been in an alarm condition for 1 minute, the silencing means is to be actuated and the time recorded between operation of the silencing means and reactivation of the smoke alarm signal. The maximum time of silencing shall not exceed the time limits specified in 13.2. This test shall be conducted on four individual samples.

40.2 With the maximum number of smoke alarms interconnected in a multiple station configuration, as specified by the installation instructions, one smoke alarm is to be placed into an alarm condition by permitting an abnormal amount of smoke to fill the sensitivity test chamber in accordance with the procedure described in 40.1. The alarm silencing means on that one unit shall be actuated. The time shall be recorded between operation of the silencing means and reactivation of the alarm. During the silenced period, the other smoke alarms in the system are also to be subjected to an abnormal amount of smoke to determine that they are still operational for initiating an alarm. The maximum silenced period shall not exceed the time limits specified in 13.2. This test shall be conducted on four individual samples.

41 Electrical Supervision Test

41.1 General

41.1.1 A single station smoke alarm shall be electrically supervised so that failure of a limited life component, open in an externally connected smoke alarm circuit, or ground fault on any externally connected wiring, which prevents operation for an alarm signal from the smoke alarm, shall result in an audible trouble signal.

41.1.2 The wiring extending between smoke alarms wired in a multiple station configuration shall be electrically supervised and capable of operation as a single station type smoke alarm, or multi-criteria smoke alarm, during the following fault condition; open-circuit, short-circuit, or ground, fault conditions on the interconnect circuit. This includes, but is not limited to short circuit faults between the interconnect conductor(s) and supply conductors if the interconnect circuit is common with the supply circuit. Any fault condition which results in trouble or alarm signal is considered as meeting this requirement. This requirement does not apply to the interconnected wiring of alarms intended to be connected by NFPA 70 Class 1 wiring method.

41.1.3 When an audible trouble signal is required to indicate a fault condition, it shall be produced at least once every minute for a minimum of seven consecutive days. The trouble signal shall be distinctive from the smoke alarm signal.

41.1.4 To determine that a smoke alarm unit complies with the requirements for electrical supervision, the smoke alarm is to be energized in the standby condition, and the type of fault to be detected is then to be introduced. Each fault is to be applied separately, the results noted and the fault removed. The smoke alarm is then to be restored to the standby condition prior to establishing the next fault.

41.1.5 A fault condition (open, ground, or short), of other than the smoke detection circuit of a smoke alarm with a non fire alarm feature shall not prevent alarm signal operation as a smoke alarm. For this test the smoke alarm is to be energized from a rated source of supply in the normal standby condition and the fault is to be applied. With the fault applied the smoke alarm is then to be subjected to an abnormal smoke condition which shall result in an audible smoke alarm.

41.2 Component failure

41.2.1 Failure of a limited life (non-reliable) electronic component, such as opening or shorting of electrolytic capacitors, shall be indicated by an audible trouble or alarm signal; otherwise a reliable component shall be used. The reliable component shall fall within the reliability prediction described 37.5, Component reliability data.

41.3 Photocell illuminating lamps and light emitting diodes (LEDs)

41.3.1 The filament(s) of a photocell illuminating lamp(s), which burn out periodically, shall be electrically monitored to indicate an open circuit fault by an audible trouble signal.

41.3.2 In smoke alarms employing a limited life LED light source, the source shall be monitored for an open, short, or, except as exempted in 41.3.3, 50 percent or greater light degradation, by means of a audible trouble signal. Failure of the light source shall not result in a smoke alarm signal. Energization of the alarm signal for a maximum of 5 seconds prior to the audible trouble signal is acceptable

41.3.3 An audible trouble signal for greater than 50 percent light degradation of a limited life LED is not required when light degradation data is supplied by the LED manufacturer to show that, for the conditions under which it is to be operated, the LED does not reduce to 50 percent light output at the maximum failure rate prediction described in 37.5, Component reliability data.

41.3.4 The sensitivity of a smoke alarm employing a LED as the functional light source shall not be reduced abnormally when either the light output from the LED is reduced to the light level anticipated at the end of the reliability prediction described in 37.5, Component reliability data, or to 50 percent of normal.

41.3.5 An LED employed as the light source of a photoelectric type smoke alarm is not required to be electrically supervised by means of a trouble signal if it is considered to be reliable.

41.3.6 To be considered reliable, an LED shall have a predicted failure rate of less than 0.25 percent/1000 h, (2.5 failures per million hours), and shall comply with the requirements in 41.3.3 and 41.3.4. In addition, the operating conditions of the LED in the smoke-alarm circuit, as well as the diode and smoke-alarm manufacturer's quality assurance (QA) programs, are to be evaluated as to the level of reliability they provide. See Section 29, Photocell Illuminating Lamps and Light Emitting Diodes (LEDs).

41.4 AC or remotely powered units

41.4.1 Failure of the main power supply to an alarm other than those powered from a primary battery shall be indicated by de-energization of a green ″power-on″ lamp.

41.4.2 Neither loss nor restoration of power shall result in an alarm signal under either momentary or extended (at least 1/2 hour) power outage conditions. Momentary energization of the alarm circuit (maximum of 1 second), and energization of the trouble circuit (maximum of 2 minutes), is acceptable. A gradual increase to 110 percent of rated voltage or reduction to 0 volts from rated voltage at a rate of not greater than 5 volts per minute shall not result in energization of the alarm signal for more than 1 second, nor energization of the trouble circuit for more than 2 minutes.

41.4.3 Loss of power to a single unit of a multiple station alarm configuration, while energized in the standby condition, shall not result in a false alarm and shall not prevent the operation of the remaining units for alarm.

41.5 Battery powered (primary or secondary) smoke alarms

41.5.1 A smoke alarm that uses a battery as the main source of supply shall be capable of producing an alarm signal for at least 4 minutes, at the battery voltage at which an audible trouble signal is obtained, followed by 7 days of an audible trouble signal indication. See Section 84, Audibility Test.

41.5.2 To determine compliance with 41.5.1, three samples, powered from primary battery supplies, shall be equipped with batteries which have been depleted to the trouble signal level. The samples are then to be placed in alarm for 4 minutes. Following the 4 minutes of alarm the trouble signal shall persist for at least seven consecutive days. It is possible to deplete a fresh battery by applying a 1 percent or smaller loading factor based on the ampere hour rating of the battery. For example, a 1000 milliampere-hour rated battery is depleted by applying a 10 milliamperes (1 percent load) or less drain continuously until the battery voltage reaches the predetermined test level.

41.5.3 A smoke alarm which uses a battery (or other applicable rechargeable energy storage media) as the secondary source of supply shall be capable of supplying the smoke alarm with a minimum of 7 days of power in the normal standby condition. The smoke alarm shall be capable of producing an alarm signal for at least 4 minutes at the battery voltage at which an audible trouble signal is obtained followed by 7 days of audible trouble signal indication.

41.5.4 To determine compliance with 41.5.3 for smoke alarms whose secondary supply is a battery (or other applicable rechargeable energy storage media), three samples shall be powered from secondary sources of supply (with the primary source of supply disabled) which are fully charged, or in fresh condition (see 35.2, Secondary power supply) and allowed to remain in the normal standby condition for a minimum of 7 days. The samples shall not emit audible low battery trouble signals before the end of the 7 day period. Three samples shall also be equipped with secondary supplies (with the primary source of supply disabled) which have been depleted to the trouble signal level. The samples are then to be placed in alarm for 4 minutes. Following the 4 minutes of alarm the trouble signal shall persist for at least 7 consecutive days. It is possible to deplete a fresh battery by applying a 1 percent or smaller loading factor based on the ampere hour rating of the battery. For example, a 1000 milliampere-hour rated battery is depleted by applying a 10 milliampere (1 percent load) or less drain continuously until the battery voltage reaches the predetermined test level.

41.5.5 A decrease in the battery capacity of a smoke alarm, which uses a battery as the main power supply, to a level where at least a 4-minute alarm signal is not obtainable, shall result in an audible trouble signal. The trouble signal is to be produced at least once each minute for seven consecutive days.

41.6 External wiring

41.6.1 An open or ground fault in the loop wiring connected from a single station smoke alarm to additional remote heat alarms that prevent operation for alarm signals from any of the interconnected alarms, shall not result in an alarm signal and shall result in an audible trouble signal.

Note: It is acceptable for a short or double ground fault in the leads to result in an alarm.

41.6.2 An open, ground fault, or short in any power limited fire protective circuit wiring among multiple station interconnected smoke alarms or any wiring extending to a heat alarm, or remote signaling device is not required to be indicated by a trouble signal when the fault does not prevent operation of any of the interconnected units as a single station smoke alarm. It is acceptable for a ground fault to prevent operation for alarm when the interconnected wiring is to be made in accordance with Class 1 requirements of the National Electrical Code, ANSI/NFPA 70. The installation wiring diagram shall indicate the type of connections to be employed.

41.6.3 An open, ground fault, or short in the power limited fire protection circuit conductors extending between the output of a separate power supply and a smoke alarm, which prevents operation of the smoke alarm, shall result in de-energization of the smoke alarm ″power-on″ light.

41.7 Smoke chamber monitoring

41.7.1 The clean-air condition of a smoke chamber shall be monitored for contamination. A trouble signal shall be indicated at the smoke alarm before the clean-air reference value changes by more than 50 percent of the shift required to place the smoke alarm into the alarm condition.

41.7.2 Two smoke alarms, one set at maximum and one set at minimum sensitivity, shall be used for the test. Each smoke alarm is to have the clean-air reference value in the smoke chamber gradually adjusted over a 48-hour period in increments not exceeding 1/14 of the value required to reach 50 percent of the shift that places the smoke alarm into the alarm condition. The reference value is to be adjusted not more than once each hour.

41.8 End-of-life signal

41.8.1 The smoke alarm shall indicate end-of-life, based on the manufacturer’s specified lifetime (not to exceed 10 years), with an end-of-life signal (see 6.8). It is permitted for the audible component of the signal to be of the same format as a trouble signal, provided a visual indicator is employed to differentiate between the end-of-life and other trouble conditions. The end-of-life signal shall repeat once every 30 – 60 seconds ±10 percent. This signal shall be triggered either by an internal timer or by a self-diagnostic test(s) as follows:

a) For a smoke alarm that employs an internal timer that activates the end-of-life signal, once the maximum specified lifetime is reached, the end-of-life signal shall be initiated. The end-of-life signal can be reset repeatedly for a period not exceeding 72 hours for each period of reset provided that the self-diagnostic test(s) does not result in a trouble signal. The end-of-life signal timer shall not be able to be reset after a maximum of 30 days.

b) The end-of-life signal shall be allowed to be reset prior to the end of 30 days, but shall not be allowed to be reset beyond the maximum of 30 days.

c) For a smoke alarm that employs a signal generated by a self-diagnostic test, the end-of-life signal shall be initiated once the manufacturer specified fault has been identified. The manufacturer shall provide a detailed description of operation associated with the self-diagnostic process/procedure, describe a method to verify the self-diagnostic that results in an end-of-life signal and provide the additional equipment necessary to confirm operation of the end-of-life signal within the timelines specified by the manufacturer not exceeding the limits of this standard.

41.9 Multi-criteria smoke alarm with gas sensor

41.9.1 The gas sensor shall have a specified lifetime of at least 3 years (not to exceed 10 years) from the date of manufacture, or from the date the smoke alarm is placed into service. The smoke alarm reliability shall be estimated with an in-service reliability measurement, see Section 94, Measurement of In-Service Reliability for Multi-criteria Smoke Alarms with Gas Sensor(s). If the manufacturer bases the specified lifetime on the date that the smoke alarm is placed into service, this specification shall be substantiated with technical data documenting that performance degradation is not likely to occur prior to the smoke alarm being placed into service if the smoke alarm is placed into service within 18 months after manufacture. The selection of which basis is employed to define the beginning of specified lifetime may be contingent upon the technology of the sensor used in the smoke alarm.

41.9.2 If the gas sensor has a lifetime of less than 10 years and is field replaceable, the alarm shall produce a gas sensor end-of-life signal that is different from other trouble conditions

41.9.3 The gas sensor end-of-life signal shall be reset upon replacing the field replaceable gas sensor. The end-of-life signal shall only be reset upon replacing the gas sensor with a new gas sensor.

41.9.4 The smoke alarm shall immediately produce a trouble signal if the replaceable gas sensor is removed.

41.9.5 The sensitivity of the smoke alarm shall not be altered upon replacing the gas sensor.

41.9.6 The replaceable gas sensor shall be marked with a date indicating its end-of-life.

42 Sensitivity Test

42.1 Smoke sensor (general)

42.1.1 A single criteria smoke alarm, when calibrated to each end of its production window, shall operate within the limits specified in Table 37.1, Visible smoke obscuration limits (gray smoke), or Table 37.2, Measuring ionization chamber (MIC) measurement, when subjected to a smoldering smoke or aerosol buildup condition using the test equipment described in 42.2 – 42.4 and when subjected to a range of air velocities. The manufacturer shall define the gray smoke/aerosol limits for the smoke sensor in a multi-criteria smoke alarm. The smoke generating method used for this test can be smoldering cotton lamp wick, aerosol generator, or punk sticks. Interchangeability between the methods is acceptable (e.g., conformity assessment testing utilizing a different method than the manufacturer) and shall be so documented in product reports and procedures created to document compliance to this standard. When the smoke alarm employs a variable field adjustable sensitivity setting, test measurements shall be made at maximum and minimum smoke alarm settings as specified in Tables 37.1 or 37.2. The sensitivity measurement is to be made with the smoke alarm located in the air stream in the least and most favorable horizontal positions for smoke entry as determined in the Directionality Test, Section 43.

42.1.2 When a single criteria smoke alarm evaluated for a special application employs sensitivities outside of the range specified in Tables 37.1 or 37.2, it shall have been evaluated using the sensitivities detailed in the smoke alarm's instructions; see 101.3.

42.1.3 When the manufacturer's required production control, inspection and test procedures (see Sections 90, General, and 95, Production-Line Dielectric Voltage-Withstand Tests) include testing in accordance with the Sensitivity test, then all product conformity testing shall use the same smoke generating method (e.g. aerosol, cotton lamp wick, punk stick, or equivalent) as specified in the manufacturer's procedures for the Sensitivity test and all related gray smoke/aerosol testing.

42.1.4 A smoke alarm employing a secondary power supply shall operate within the limits specified in 42.1.1 when operating from the secondary power supply.

42.2 Combustibles

42.2.1 A cotton lamp wick, nominally 1/8 in. (3.2 mm) in diameter, a minimum of 5 in. (127 mm) long and secured by a thin wire inserted through one end, is to be employed as the source of smoke. Prior to use, the wick is to be conditioned at least 72 hours at 45°C (113°F) and 10 percent or less relative humidity. It is then to be stored in a desiccator at room temperature and 10 percent or less relative humidity. The wick end is to be cut square and smoldering initiated by momentarily placing the wick end over a horizontally mounted resistive heater element energized to a dull red color. Upon ignition, it is possible for momentary flaming to occur for 1 second, after which the flame is to be extinguished. The wick is then permitted to smolder a minimum of 30 seconds before being placed in the chamber. The smoldering rate of the wick is to be such that the relationship between the MIC output and the percent light transmission remains within the curves illustrated in Figure 42.1. The visible smoke buildup rate is to be maintained within the limits illustrated in Figure 42.2 outside the test compartment and the smoke permitted to enter through an inverted funnel-pipe arrangement.

Figure 42.1
Sensitivity test limits
Gray smoke – cotton wick/aerosol – 9.8 mpm
Room ambient temperature, 85 percent relative humidity

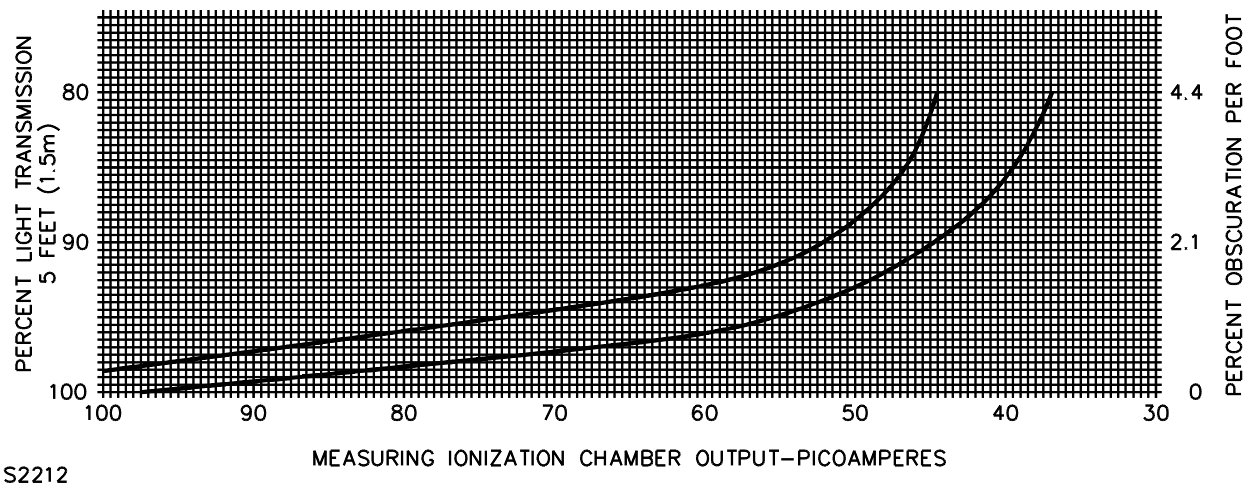

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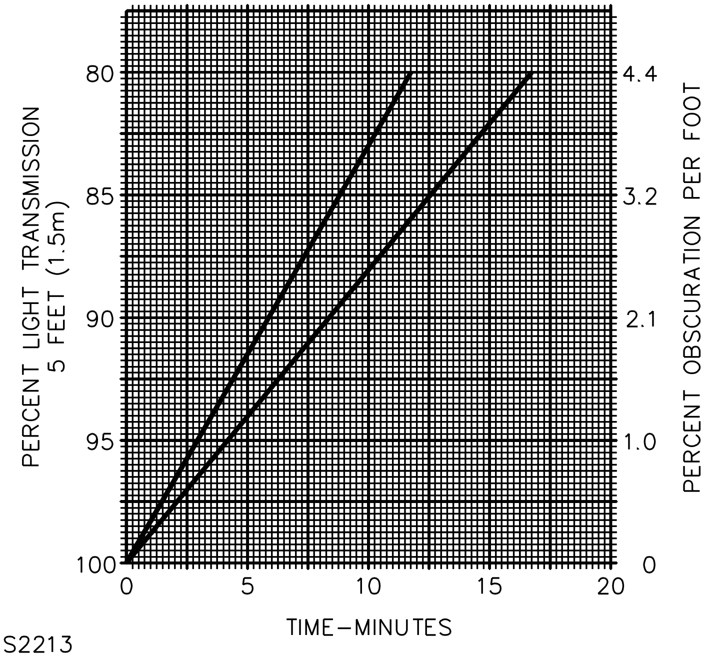
Figure 42.2
Smoke build-up rate – sensitivity test
Gray smoke – cotton wick/aerosol – 9.8 mpm
Room ambient temperature, 85 percent relative humidity



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42.3 Aerosol generation equipment (alternate method)

42.3.1 The equipment used shall generate the buildup rates specified in Figures 42.1 – 42.4.

Figure 42.3
Sensitivity test limits (gray smoke/aerosol)

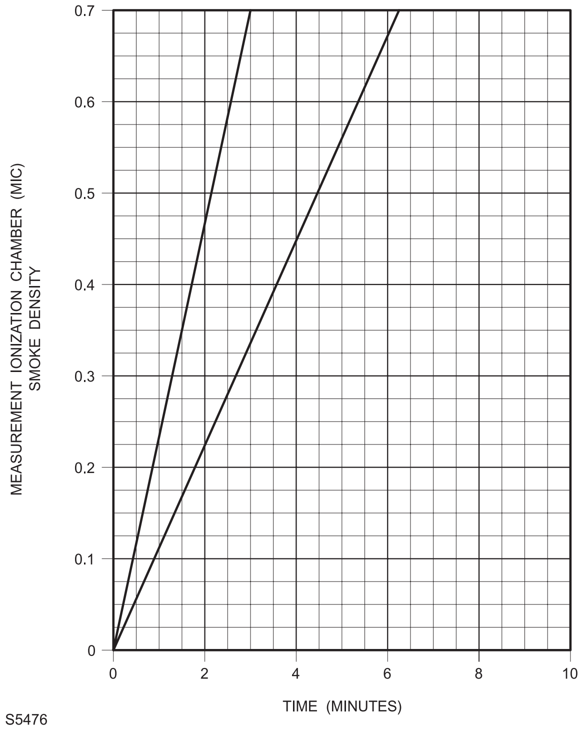

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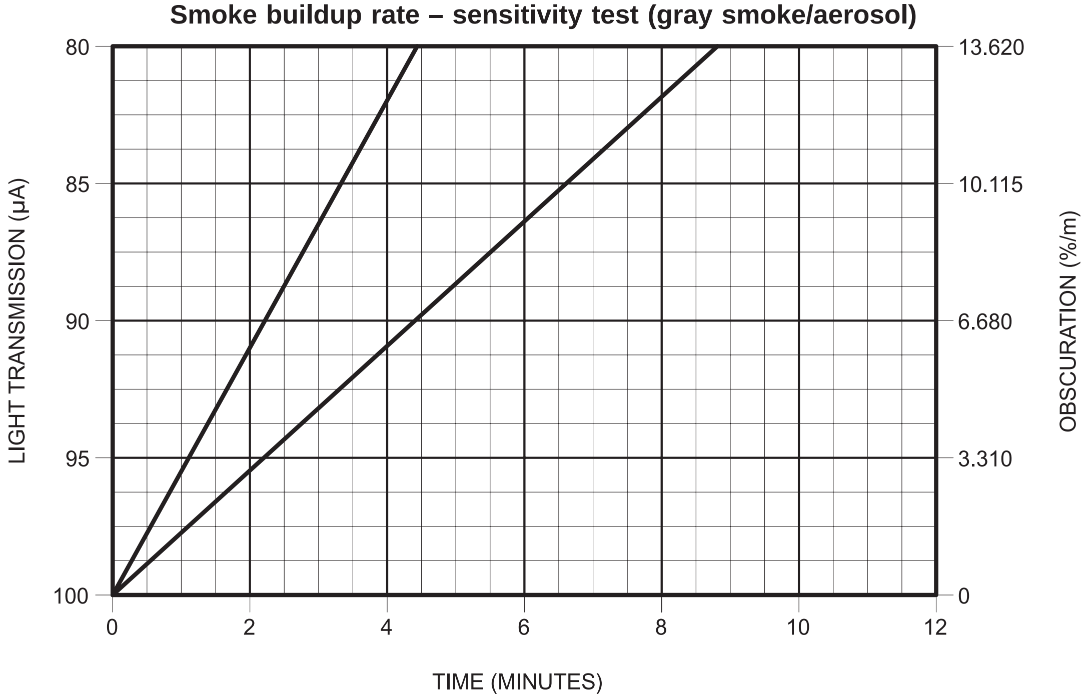
Figure 42.4
Smoke buildup rate – sensitivity test (gray smoke/aerosol)



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42.4 Test equipment

42.4.1 Refer to Appendix B, Typical Sensitivity Smoke Test Chamber Construction, for details on test equipment.

42.5 Test method

42.5.1 Test conditions are defined in 37.8.

42.5.2 A minimum of 12 samples of the smoke alarm, previously energized from a source of supply in accordance with 37.3, Test voltages, for at least 16 hours or for a time interval as specified by the manufacturer, shall be subjected to this test. The smoke alarm under test is to be tested in the least and most favorable horizontal positions of smoke entry. See the Directionality Test, Section 43.

42.5.3 The air velocity in the test compartment is to be maintained at 32 ± 2 fpm (0.16 ±0.01 m/s) as measured in front of the middle section of the smoke alarm with a hot wire anemometer, or equivalent air velocity measuring instrument. The velocity measurement is to be made with the smoke alarm removed.

42.5.4 Smoldering cotton lamp wick, or equivalent, producing a gray smoke having an equivalent particle size distribution shall be used as the actuating medium. The rate of smoke build-up shall be uniform and within the limits as specified in 42.2, Combustibles, or 42.3, Aerosol generation equipment (alternate method).

42.5.5 The smoke/aerosol is to be admitted into the test chamber and operation is to be continued until smoke alarm activation as specified in 38.2.1. The MIC/light relationship and the visible smoke buildup rate is to remain within the limits represented by the curves illustrated in the Figures described in 42.2, Combustibles. When the trial-to-trial variation in light transmission alarm is ±0.2 µA or less, only three trials are required to be conducted on each sample. When the variation is greater than ±0.2 µA, five trials shall be performed. The test chamber is to be exhausted between each trial until the MIC and light beam indicate a clear condition. The airflow is to be allowed to stabilize for at least 30 seconds before each test trial.

42.5.6 The final value used for the sensitivity is to be the average of the total number of readings. The following readings shall be recorded for each trial at the moment of actuation:

a) Visible Obscuration (percent light transmission),

b) Measuring Ionization Chamber (MIC) Meter Reading, and

c) Time of test trial.

For combination smoke alarms, the sensitivity of each principle of operation is to be recorded. When a smoke alarm has a variable sensitivity setting, test trials shall be made at the maximum and minimum sensitivity settings.

42.6 Uniformity of operation

42.6.1 The smoke alarms shall be uniform in operation so that the sensitivity (average of three trials) of any one smoke alarm shall be within 25 percent of the overall average of all twenty eight smoke alarms tested in 37.4.1(a), Test samples and data. If a smoke alarm has a variable sensitivity setting, the requirement applies to the end points of the variable range.

42.6.2 The measured average sensitivity of the smoke alarms shall be within 25 percent of the marked sensitivity rating or range of the smoke alarm.

42.7 Smoke sensitivity test feature

42.7.1 A sensitivity test feature shall be provided on a smoke alarm, to simulate either mechanically or electrically a specified level of smoke in the sensing chamber. The test feature shall be accessible from outside the alarm, with the alarm installed as intended

42.7.2 When this test feature is the method used by the manufacturer to comply with the requirements in Smoke Sensitivity Indicating Means, 11.1 and 11.2, the test feature is to have the capability of verifying that the sensitivity of the smoke alarm is within 25 percent of the marked range.

42.7.3 When a sensitivity test feature is provided as an operational test to simulate either mechanically or electrically a specified level of smoke in the sensing chamber, the maximum permissible measured obscuration level using gray smoke/aerosol shall not exceed:

a) 6 percent per ft., or if the marked sensitivity is greater than 4 percent per ft., the test shall provide for a maximum of 2 percent per ft. over the marked range; or

b) 18.4 percent per m, or if the marked sensitivity is greater than 12.5 percent per m, the test shall provide for a maximum of 6.4 percent per m over the marked range.

42.7.4 Four samples, two at maximum and two at minimum sensitivity, shall be subjected to this test. Each sample is to be connected to a rated supply voltage, except that an alarm employing a battery as the main supply shall be tested at the test voltage level (rated or trouble level voltage) that results in the lowest sensitivity measurement. The sensitivity is to be determined by conducting a curve plot of obscuration versus an instrument (meter) reading, or equivalent.

42.8 Sensitivity test – gas sensor of a multi-criteria smoke alarm

42.8.1 General

42.8.1.1 The manufacturer shall provide the sensitivity performance over its operating range/tolerance for the gas sensor(s).

42.8.1.2 The smoke alarm shall be installed in a chamber, having a volume of at least 1 ft^3 (0.0283 m^3) constructed so as to permit accurate monitoring and control of chamber air temperature and humidity and oxygen and target gas concentrations. The following conditions shall be established within the test chamber and maintained throughout the test.

42.8.1.3 Before commencing each measurement, the gas test chamber shall be purged to ensure that the gas concentration is less than 1 ppm.

42.8.1.4 The air velocity in the proximity of the specimen shall be specified by the manufacturer.

42.8.1.5 Connect the specimen to its supply and monitoring equipment and allow it to stabilize for a period of at least 15 minutes, unless otherwise specified by the manufacturer.

42.8.1.6 Increase the gas concentration to the level specified by the manufacturer within 3 minutes after sealing the chamber and maintain this concentration throughout the remainder of the test. Record the:

a) Time to reach the target gas concentration within the test chamber; and

b) Output from the sensor which will be compared to the manufacturer's gas sensor specification.

42.8.2 Sensitivity test – heat sensor

42.8.2.1 Where smoke alarms comply with the Standard for Single and Multiple Station Heat Alarms, UL 539, the response times measured in those tests may be used as the heat response values for the purposes of this standard.

42.8.2.2 Install the specimen for which the temperature response value is being measured in a UL 539 (Standard for Single and Multiple Station Heat Alarms) heat tunnel. The orientation of the specimen, relative to the direction of airflow, shall be the least sensitive one, as determined in the Directionality Test, Section 43, unless otherwise specified in the test procedure.

42.8.2.3 Install the specimen for which the temperature response value is being measured in a UL 539 heat tunnel. The orientation of the specimen, relative to the direction of airflow, shall be the least sensitive one, as determined in the Oven Test of the Standard for Single and Multiple Station Heat Alarms, UL 539, unless otherwise specified in the test procedure.

Note: Depending upon the construction of the alarm, it may be necessary to repeat the oven tests with test samples rotated 90 degrees and 180 degrees from the original test position.

42.8.2.4 Connect the specimen to its supply and indicating equipment, and allow it to stabilize for at least 15 minutes, unless otherwise specified by the manufacturer.

42.8.2.5 Conduct the Oven Test as described in the Standard for Single and Multiple Station Heat Alarms, UL 539, and measure the heat response value as defined by the manufacturer's heat sensor specification.

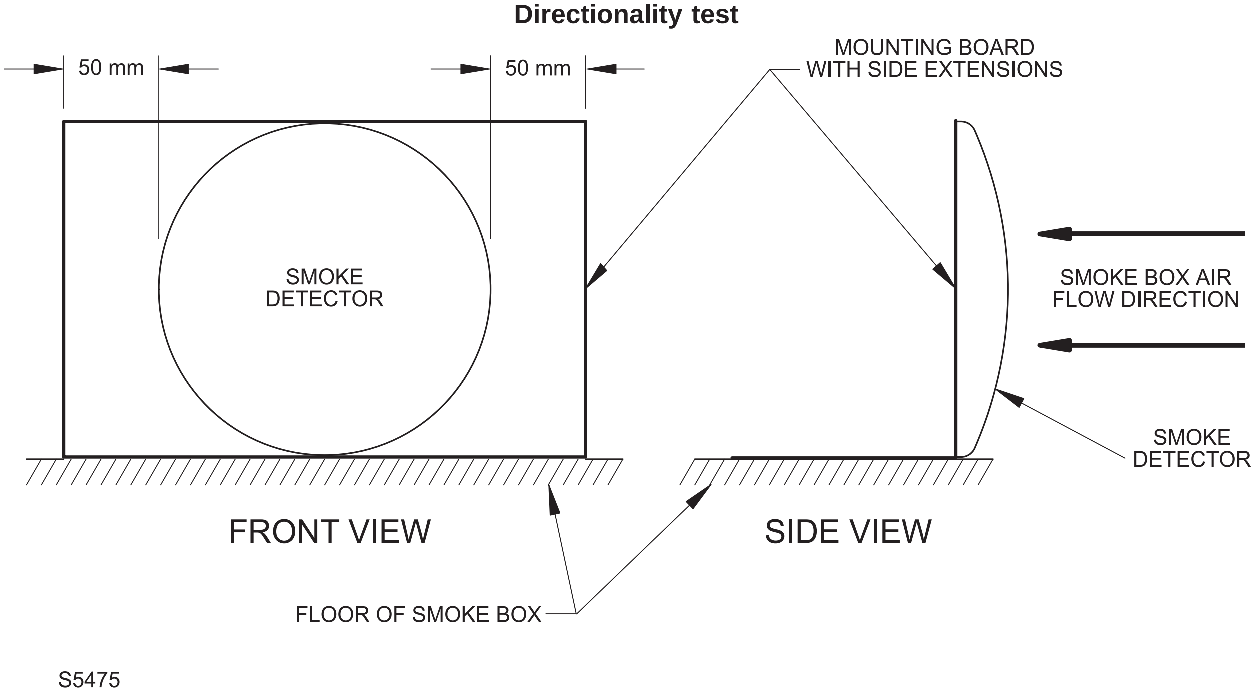
42.8.3 Sensitivity test – sensors other than smoke, gas or heat

42.8.3.1 For sensors other than smoke, gas or heat the manufacturer shall provide a method for measuring the sensor's response acceptable limits.

43 Directionality Test

43.1 The sensitivity of the smoke alarm shall comply with the requirements of Section 42, Sensitivity Test, using gray smoke/aerosol in any orientation with the air flow in the chamber. The smoke alarm is to be tested at an air velocity of 32 ±2 fpm (0.16 ±0.01 m/s) in its least favorable position for smoke entry and at each 90 degree angle from this position. The positions are to include all four compass points with the smoke alarm in a horizontal position with the oncoming air directed to each of four sides and with the smoke alarm positioned on edge with the smoke alarm front facing the oncoming air illustrated in Figure 43.1. The locations of the least and most favorable smoke entry positions for the smoke sensors in the unit shall be marked on all smoke alarms to be used in subsequent tests. See 42.1.1, Stability Test, Section 48, and Stability Tests – Multi-Criteria Smoke Alarms Incorporating Gas Sensor(s), Section 49. The variation of the highest and lowest sensitivity position from the mean shall not exceed 50 percent.

Figure 43.1
Directionality test



43.2 For multi-criteria smoke alarms use the least favorable smoke entry position determined in 43.1 for the measurements used in the Sensitivity Test, Section 42.

43.3 In this test, the air velocity is measured prior to the sample mounted in the chamber and not adjusted during the test. Refer to Figure 43.1, Directionality Test.

43.4 Two samples, one set at the maximum production sensitivity, and one set at the minimum sensitivity, shall be employed for this test.

43.5 A sample to be positioned on edge is to be mounted on a wooden board so that the edge of the sample rests on the mounting platform. The mounting board is to:

a) Extend a maximum of 2 in. (50.8 mm) beyond the vertical sides of the sample; and

b) Have no extension beyond the top edge.

43.6 When the height of a smoke alarm is too great to be accommodated in the platform test area, it is to be located adjacent to the left edge of the mounting platform with the top edge touching the roof of the test compartment and corresponding adjustments made in the location of the velocity measurement. See B1.3 in Appendix B, Typical Sensitivity Smoke Test Chamber Construction.

44 Velocity-Sensitivity Test

44.1 Smoke sensor

44.1.1 The smoke sensitivity of the smoke alarm shall not vary more than 1 percent per ft. (3.3 percent per m) obscuration outside of the production window limits, using gray smoke/aerosol, when tested in accordance with the sensitivity test at air velocities of 32 and 300 fpm (0.16 and 1.52 m/s) ±10 percent. In no case shall the smoke sensitivity of a single criteria smoke alarm exceed the limits specified in 42.1.1 for gray smoke/aerosol.

44.1.2 Two smoke alarms, one at maximum and one at minimum sensitivity, shall be subjected, in turn, to the sensitivity test; first at a velocity of 32 fpm (0.16 m/s), and then at a velocity of 150 fpm (0.76 m/s). At 150 fpm the smoldering rate of the cotton lamp wick, punk stick, aerosol, or equivalent build-up is to be such that the relationship between the MIC output and percent light transmission remains within the limits represented by the curve illustrated in Figure 42.1. The visible smoke buildup rate is to be maintained within the limits illustrated in Figure 42.2.

44.1.3 For this test, the smoke alarms shall be oriented in the least favorable and most favorable positions for smoke entry.

44.2 Multi-criteria smoke alarm with gas sensor

44.2.1 The sensitivity of the gas sensor shall not vary by more than that specified in 38.3.1 when tested at a minimum air velocity of 32 ±2 fpm and 300 fpm ±10 percent (0.16 ±0.1 m/s and 1.52 m/s ±0.1 m/s), or as specified by the manufacturer.

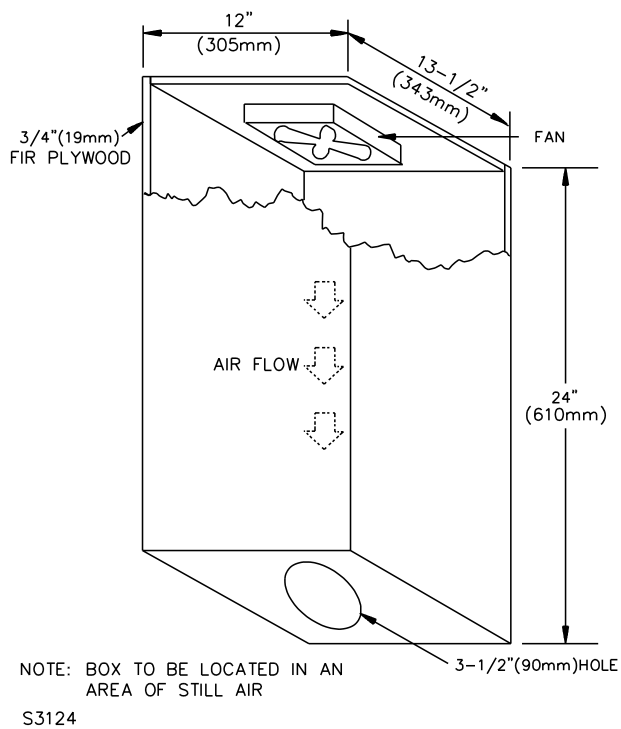
45 Smoke Entry (Stack Effect) Test

45.1 The sensitivity of a smoke sensor as part of a smoke alarm intended to be mounted to an electrical box shall not vary by more than specified in 38.3.1 when subjected to the test conditions described in 45.2 – 45.4, which simulate air passing through an electrical conduit system that is connected to a smoke alarm.

Exception: Battery operated units not intended for connection to an electrical conduit are exempt from this test.

45.2 The test box shown in Figure 45.1 is to be employed. Fan operation is to be adjusted so that the free flow air velocity at the center of the hole in the base is 300 fpm (91.4 mpm). With the hole covered, the fan shall produce a back pressure measuring between 0.012 and 0.015 in. (0.304 and 0.381 mm) (2.99 Pa and 3.74 Pa) of water. The fan is then to be turned off. A smoke alarm is to be installed in accordance with the manufacturer's installation instructions, facing downward and covering the hole in the base of the test box, to simulate installation in a ceiling.

Figure 45.1
Test apparatus for smoke entry (stack effect) test



45.3 The entire test box/smoke alarm assembly is to be placed (alarm side down) in an opening provided in a modified top door of the test chamber described in B1.3 of Appendix B. The smoke alarm shall then be tested for sensitivity while in this position. Two samples shall be tested, one at maximum and one at minimum sensitivity.

45.4 The procedure described in 45.2 and 45.3 is to be repeated on both smoke alarms, except the fan is to be turned on.

46 Lamp Interchangeability Test (Photoelectric)

46.1 The sensitivity of a photoelectric smoke sensor shall vary not more than specified in 38.3.1 from its initial measurement and shall comply with the requirements of the Sensitivity Test, Section 42, when tested with the intended replacement lamps.

46.2 Three samples, set at the minimum smoke sensitivity setting, shall be subjected to the Sensitivity Test, Section 42. The smoke alarms are then to be de-energized, the photocell illuminating lamps replaced, re-energized, and subjected again to the Sensitivity Test.

47 Reduction in Light Output Test

47.1 The sensitivity of a smoke alarm employing an LED as the functional light source shall not be reduced to less than the minimum levels when the light output from the LED is reduced to 50 percent of the intended output or to the light level anticipated at the end of the devices' specified lifetime. The light level anticipated at the end of the devices' specified lifetime shall be determined through manufacturer's testing of the LED. During this determination, the duty cycle and test temperature of the LED under test shall be selected such that the burn-in test length multiplied by the as-tested duty cycle, divided by the end-use duty cycle, and related to the maximum device operating temperature by using the Arrhenius equation (as described in D4.2.1), is equal to or greater than the devices' specified lifetime.

47.2 Five samples, calibrated to the minimum sensitivity, shall be subjected to the Sensitivity Test, Section 42, while connected to a source of rated voltage and frequency. Following this, the light output from the LED is to be reduced to 50 percent of the intended output or to the light level anticipated at the end of the devices' specified lifetime when less than 50 percent light reduction, by reducing the supply voltage to the smoke alarm, or an equivalent method. (The level of reduction of light is to be determined initially by means of a light meter intended for this use, review of curve sheets, or the equivalent.) The samples shall then be subjected to the Fire Tests, Section 51, and the Smoldering Smoke Test, Section 52. In no case shall the single criteria smoke alarm exceed the limits specified by Table 37.1 or 42.1.1.

47.3 A smoke alarm which employs a battery as the main source of power, the test is to be conducted at the worst case sensitivity levels as determined in Section 57, Overvoltage and Undervoltage Tests.

47.4 For smoke alarms equipped with drift compensation, the Sensitivity Test, Section 42, shall be conducted after the samples have been allowed to compensate as defined in 39.4, in response to the light output reduction. The Fire Tests, Section 51, and Smoldering Smoke Test, Section 52, shall be conducted in the operational mode (normal light, or reduced light) that results in the least sensitive smoke alarm as measured in the Sensitivity Test.

48 Stability Test

48.1 There shall be no false alarms of a smoke alarm set at the maximum smoke alarm sensitivity setting when two representative samples are subjected to the test specified in (a) – (f). Different smoke alarms may be employed for each test. A test is not required to be conducted when the principle of operation is such that conducting the test has no possible effect. A smoke alarm for which smoke alarm sensitivity is affected by air velocity is to be tested in the position in which a false alarm is most likely to occur.

a) Operation (with a laminar flow) for 90 days in a relatively clean atmosphere in an air stream having a velocity of 300 ±25 fpm (1.5 ±0.13 m/s) in an ambient of 23 ±2°C (73.4 ±3°F) and 30 – 50 percent relative humidity. For a smoke alarm with a maximum specified installation ambient higher than 38°C refer to 48.7(a).

b) Three plunges from an ambient humidity of 20 ±5 percent relative humidity to an ambient of 93 ±2 percent relative humidity at 23 ±2°C (73.4 ±3°F).

c) Ten cycles of temperature variation between minus 17.8°C (0°F) and plus 66°C (150°F) for extended temperature range; the following formulas shall be applied:

1) Low temperature = (T_{LO} - 0°C) - 17.8°C or (T_{LO} - 32°F) - 0°F

2) High temperature = (T_{HI} - 38°C) + 66°C or (T_{HI} - 100°F) + 150°F

Where T_{LO} and T_{HI} are the respective low and high operating temperatures.

d) Ten cycles of a 2 in. (50.8 mm) change of air pressure starting from 31 – 29 in. ±0.5 in. (787 – 737 mm ±12.7 mm) of mercury.

e) Fifty cycles of momentary (1/2 second) interruption of the smoke alarm power supply at a rate of not more than 6 cycles per minute.

f) Twenty cycles subjected to high light intensity from a distance of 1 ft. (0.3 m), 10 cycles (e.g., 150-watt incandescent lamp), 10 cycles using a 4 light fluorescent fixture (e.g., 40-watt daylight lamps) at a rate of 4 cycles per minute. Each cycle is to consist of 10 seconds of exposure and 5 seconds non-exposure. The peak luminous intensity of the incandescent lamp test shall be 175 candela. The peak luminous intensity of the fluorescent fixture test shall be 424 candela.

48.2 Two smoke alarms, set at the maximum smoke alarm sensitivity setting, shall be mounted in a position of intended use, energized from a source of supply in accordance with 37.3, Test voltages, and subjected to each of the test conditions in 48.1.

48.3 For 48.1(b), the smoke alarm is to be transferred from the 20 percent humidity environment to the 90 percent humidity environment as follows:

a) The smoke alarm is to be first conditioned in the 20 percent humidity environment for at least 1/2-hour.

b) The smoke alarm shall be transferred from the 20 percent humidity environment to the 90 percent humidity environment in less than 5 seconds.

c) The smoke alarm shall remain powered during each transfer and while in the sample conditioning environment.

d) When conducting the transfer of the smoke alarm between conditioning environments, the smoke alarm shall;

1) Be placed in an enclosure that was conditioned in the same environment as the smoke alarm, such as a portable cooler,

2) The enclosure shall be closed, prior to opening the door of the test environment,

3) Then the enclosure containing the smoke alarm shall be transferred between environments.

e) Once the enclosure containing the sample is placed in the 90 percent relative humidity conditioning environment:

1) The target temperature and humidity within the conditioning environment shall be reached within 3 minutes of placing the enclosure, containing the sample, within the conditioning environment.

2) The enclosure shall be opened after the target temperature and humidity within the conditioning environment have been reached.

f) After conditioning the smoke alarm in the 90 percent environment for at least 1/2-hour, the smoke alarm is to be placed in the 20 percent environment, repeating (a) – (f) two additional trials.

48.4 The transfer method noted within 48.3 (a) – (f) may be conducted using an alternate means provided that the smoke alarm is only exposed to the two conditioning environments as noted in paragraph 48.1(b).

48.5 For 48.1(c), the time of cycling from one extreme to the other is to be a maximum of 1 hour and a minimum of 5 minutes and not less than 15 minutes at each temperature level. For 48.1(d), the time of change from one pressure to the other is to be 30 seconds. For 48.1 (e) and (f), the smoke alarm is to be positioned in a plane to permit the maximum entry of light into the chamber. Each cycle is to start at one test condition, changing to the other extreme, and returning to the original test condition.

48.6 The test samples subjected to 48.1 (a) – (f) shall be tested for smoke sensitivity (see the Sensitivity Test, Section 42, following the completion of each test. The response of any smoke alarm, when tested in accordance with the Sensitivity Test shall vary not more than that specified in 38.3.1.

48.7 The tests specified in (a) and (b) are an alternate test method to the 90-day stability test requirement of 48.1(a):

a) A smoke alarm shall operate for its intended signaling performance after being subjected for 90 days to an ambient temperature of 15 degrees below its maximum installation temperature (minimum 38°C). Alternately, the smoke alarm may be subjected to a shorter time period and higher temperature as determined by the following equation:

$$\frac{4 * D_1}{D_2} = e^{-\frac{\Theta}{K}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)}$$

Where:

D_1 *= 90 days,*

D_2 *= proposed time period in days,*

T_1 *= the temperature in Kelvin when testing for 90 days (minimum 23°C)*

T_2 *= temperature in Kelvin when testing for proposed time period in days,*

θ *= 0.65 eV and*

$k = 8.62 \times 10^{-5}$ *eV/K*

allowed by 10 cycles of change of air velocity from 0 to 1.5 ±0.13 m/s. No false alarms shall occur following the aging or during exposure to the air velocity; and

b) Sensitivity measurements recorded before and after the exposures in (a) shall be conducted in accordance with 42.5, Test method. The sensitivity values shall be in accordance with 38.3.1.

49 Stability Tests – Multi-Criteria Smoke Alarms Incorporating Gas Sensor(s)

49.1 Three sets of two representative smoke alarm samples set at the manufacturer's defined gas sensitivity setting shall be subjected to a series of tests as outlined in Sections 42 (Sensitivity), 48 Stability, 55 [Selectivity Test – Multicriteria Smoke Alarms Incorporating Gas Sensor(s)], 62 (Variable Ambient Temperature), and 63 (Humidity).

49.2 The smoke alarms shall be mounted in a position of normal use, energized from a source of supply in accordance with 37.3.1 and subjected to the following tests:

a) Two smoke alarm samples are to be tested sequentially to the following tests:

1) Sensitivity test – gas sensor of a multi-criteria smoke alarm, 42.8,

2) Stability Test, 48.1(c)

3) Selectivity Test – Multicriteria Smoke Alarms Incorporating Gas Sensor(s), Section 55,

4) Operation in high and low ambients, 62.1.

b) Two smoke alarm samples are to be tested according to 62.3, Effect of shipping and storage – multi-criteria smoke alarms incorporating gas sensor(s),

c) Two smoke alarm samples are to be tested according to the Humidity Test, Section 63.

49.3 The gas sensitivity reading shall not in any case exceed the limits specified in 42.8.

50 Stability Tests for Multi-Criteria Smoke Alarms Incorporating CO Gas Sensor(s)

50.1 Two representative multi-criteria smoke alarm samples set at the manufacturer’s defined CO gas sensitivity setting shall be subjected to the following CO gas concentrations and exposure times (absent of smoke or simulated smoke) and shall not produce an alarm signal:

a) Exposure to 30 ±3 ppm of CO for a minimum of 30 days;

b) Exposure to 70 ±5 ppm of CO for a minimum of 60 minutes; and

c) Exposure to an increase in CO of 16 ppm per minute (starting from fresh air) for a minimum of 19 minutes.

50.2 Tests defined in 50.1 shall be conducted using equipment and methods identified in the Sensitivity Test (Section 39) specified in the Standard for Single and Multiple Station Carbon Monoxide Alarms, UL 2034.

51 Fire Tests

51.1 General

51.1.1 Fire test fuel guidelines are provided, but actual fuel amounts used can be varied to the meet the required profiles as specified in Figures 51.1, 51.2, 51.5, and 51.6. , 51.11 – 51.14, and 52.1 – 52.3.

51.1.2 All combustibles shall be ignited with the device as described. The bottom of the container for all combustibles is to be 3 ft. (0.9 m) ±3 in. (7.6 cm) above the floor. Both the paper and wood brand are to be preconditioned in a relative humidity of 50 ±5 percent at a temperature of 23 ±2°C (73.4 ±3°F) for at least 48 hours prior to the test.

51.1.3 Each smoke alarm subjected to the tests specified in 51.2 – 51.4 shall produce the alarm sound for not less than 5 seconds when installed as intended in service and exposed to three types of controlled test fires. The response time of each smoke alarm shall not be more than 4 minutes for each flaming fire type. Different samples may be used for each flaming fire test.

51.1.4 With reference to the requirements of 51.1.1, and in lieu of employing smoke alarms with a pre-calibrated alarm setting, it is not prohibited to employ smoke alarms that are equipped with means to provide an analog output (electrical measurement) of the alarm sensitivity during the course of the test trials. The smoke alarms are then subjected to the Sensitivity Test, Section 42, in the smoke box with the analog output recorded to translate the electrical reading into an obscuration measurement. It is possible to obtain the minimum production sensitivity setting using this type of arrangement without conducting repeat tests after recalibration. This method is also usable for the Smoldering Smoke Test, Section 52.

51.1.5 Smoke alarms shall also be subjected to the following tests:

a) Flaming polyurethane foam test, 51.4,

b) Smoldering polyurethane foam test, section 53,

c) Cooking nuisance test, section 54.

51.2 Paper fire

51.2.1 The following materials and procedures are to be used for the paper fire test. Dimensions and locations of test apparatus are intended for reference only. The smoke produced in this section (Paper Fire) shall have a particle composition that falls within specified profiles and may require the adjustment of the fuel quantity to achieve that result.

51.2.2 The materials and procedures shall be used as follows:

a) Combustible – Shredded newsprint is to be cut in strips as follows:

Width: 0.25 – 0.375 in. (6 – 10 mm)

Length: 1 – 4 in. (25.4 – 102 mm)

Total weight: 1.5 oz (42.6 g)

The paper is to be placed into the receptacle, see (b), with the bottom covered temporarily by a flat plate. The receptacle is to be tamped periodically during the pouring operation until the paper contents are even with the top of the receptacle. The paper is then to be further tamped by hand or by a rod 1 in. (25.4 mm) in diameter until the paper level is 4 in. (102 mm) below the top edge of the receptacle. A hole 1 in. in diameter is to be formed through the center from top to bottom of the paper. The temporary bottom plate is then to be removed and the assembly mounted 3 ft. (0.9 m) above the floor on a 5-in. (127-mm) diameter ring support.

b) Receptacle – To be formed of sheet metal seamed together, with no air gap at the seam (open at both ends). Dimensions are as follows:

Thickness: 0.031 in. ±0.08 in. (0.40 ±2 mm)

Diameter: 4 ±0.08 in. (101 ±2 mm)

Height: 12 ±0.08 in. (300 ±2 mm)

Support flange at the bottom 6 ±0.08 in. (152 ±2 mm). Wire screen of 18 AWG wire, 0.25 in. (6.4 mm) minimum mesh.

c) Point of Ignition – The probe tips of the igniter shall be placed at the bottom center of the receptacle and arcing sustained for up to 5 seconds.

d) Smoke Profile – The test shall be terminated 4 minutes after ignition. All three samples shall respond prior to the termination of the test. Refer to Figure 51.1. Additionally, the following conditions apply:

1) Flame breakthrough is to occur at between 1 and 3 minutes.

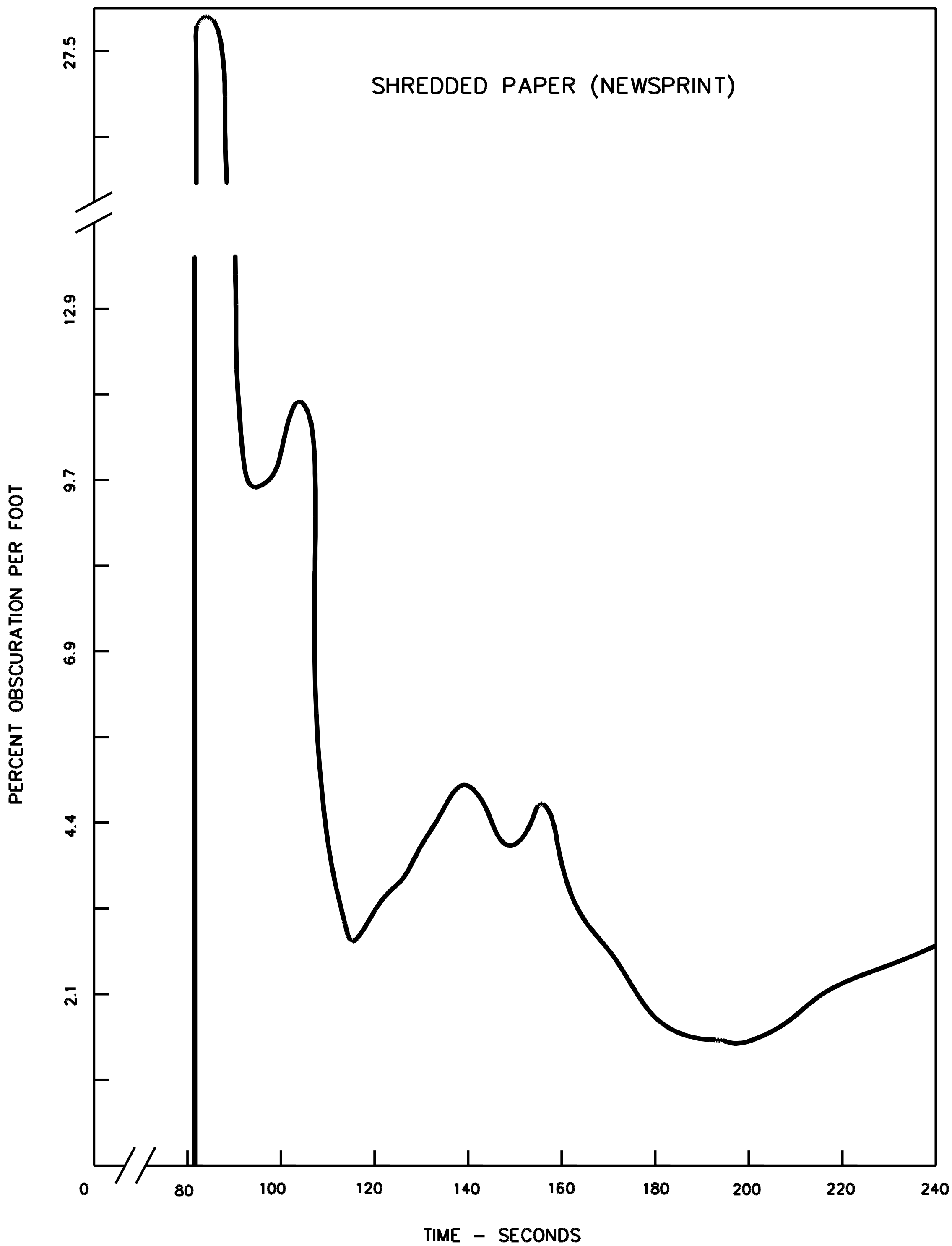
2) The first principle peak is to occur at between 1 and 3 minutes.

3) Smoke shall peak between 0.137 and 0.2 OD/ft. (0.45 and 0.66 OD/m) [27 and 37 percent/ft. obscuration (64.4 and 78.1 percent/m obscuration)] at the ceiling smoke alarm location, and between 0.105 and 0.2 OD/ft. (0.345 and 0.66 OD/m) [21.5 and 37 percent per ft. obscuration (54.8 and 78.1 percent/m obscuration)] at each sidewall location.

4) There is to be between 20 and 40 seconds of 0.018 OD/ft. (0.058 OD/m) [4 percent/ft. (12.56 percent/m) obscuration] or higher obscuration at the ceiling smoke alarm location, and between 10 and 30 seconds of 0.045 OD/ft. (0.15 OD/m) [10 percent/ft. (29.26 percent/m) obscuration] or higher obscuration at the sidewall alarm locations.

5) The secondary peak is not to exceed 0.061 OD/ft. (0.198 OD/m) [13 percent/ft (36.7 percent/m) obscuration] at any smoke alarm location.

Figure 51.1
Shredded paper (newsprint) profile



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51.3 Wood fire

51.3.1 The following materials and procedures shall be used for the wood fire test:

The following materials and procedures shall be used for the wood fire test. Dimensions and locations of test apparatus are intended for reference only. These are variable as long as the correct build up rates are achieved.

a) Combustible[a] – A wood brand formed of three layers of kiln dried fir strips, each strip 3/4 in. (19.1 mm) square in cross section, 6 in. (152 mm) long with six strips in each layer, is to be used. Wood strips are to be nailed or stapled together with adjacent layers at right angles to each other. Overall dimensions of the wood brand are to be 6 by 6 by 2-1/2 in. (152 by 152 by 64 mm). The brand is to be supported on a 5-in. (127-mm) diameter ring support 3 ft. (0.9 m) above the test room floor.

b) Promoter – The wood brand is to be ignited by burning 4 milliliters of denatured alcohol consisting of 190 proof (95 percent) ethanol to which 5 percent methanol is added as a denaturant. The alcohol is to be placed in a 1-1/2 in. (38 mm) diameter, 1-in. (25.4-mm) deep metal container, the bottom of which is to be 3-1/2 in. (89 mm) below the bottom of the wood brand and centered so that the flame does not break through the top of the wood brand. The container is to be supported by a 1/4-in. (6.4-mm) hardware cloth. The alcohol is to be placed in the container no earlier than 30 seconds prior to ignition.

c) Point of Ignition – Ignition is to be by probes in alcohol. Probe tips of the igniter are to be placed as near the container lip as possible without arcing to the sides.

d) Smoke Profile (Refer to Figure 51.2) – For this test the following conditions apply:

1) Smoke buildup shall begin between 80 and 120 seconds at the ceiling alarm location; and between 60 and 120 seconds at each sidewall alarm location.

2) There shall be at least 60 seconds of 0.018 OD/ft. (0.058 OD/m) [4 percent/ft (12.56 percent/m) obscuration] or higher obscuration at all alarm locations.

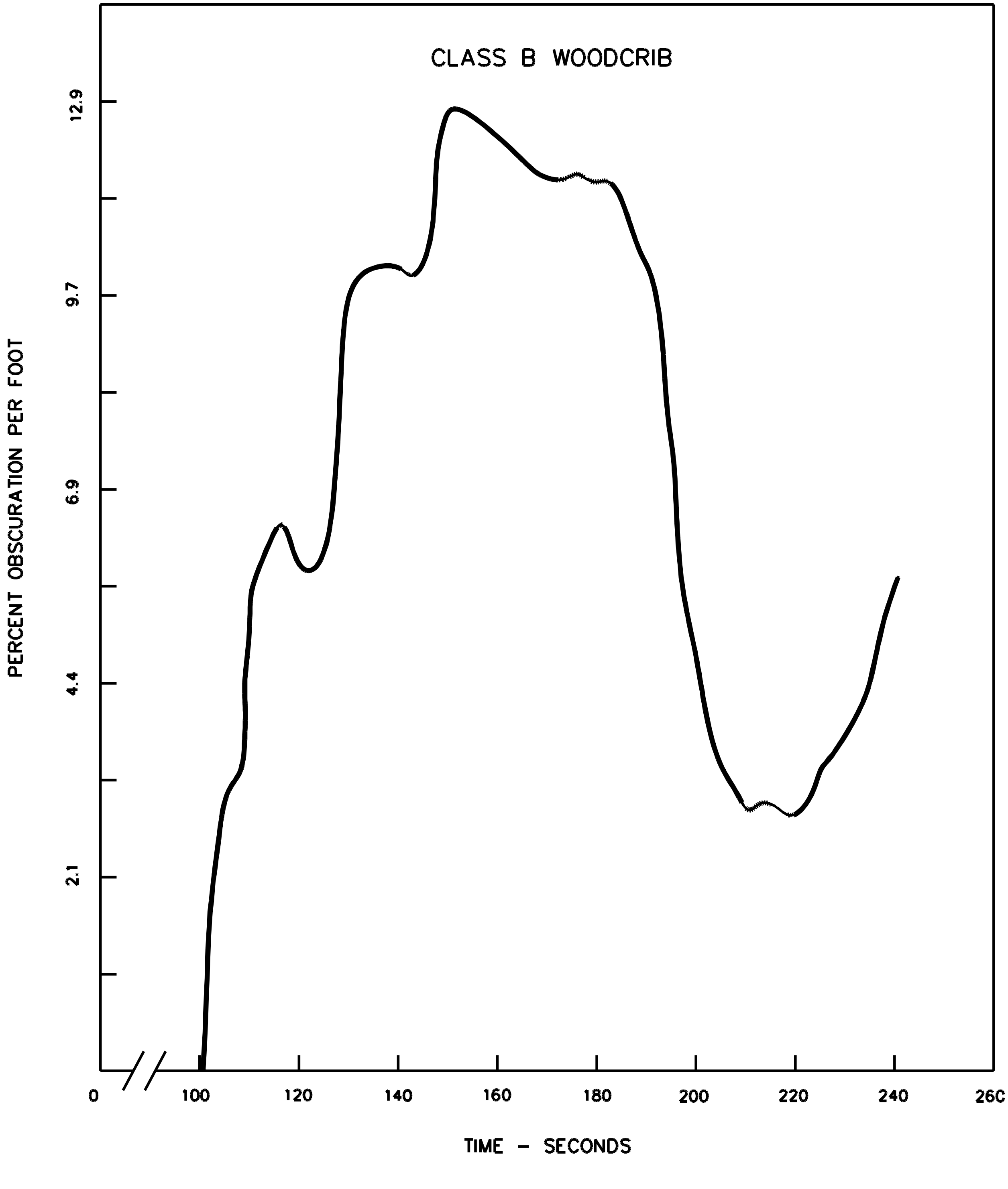
3) Maximum obscuration shall not exceed 0.081 OD/ft. (0.265 OD/m) [17 percent/ft (45.8 percent/m) obscuration] at the ceiling alarm location; and 0.14 OD/ft. (0.46 OD/m) [27.5 percent/ft (66.2 percent/m) obscuration] at either sidewall alarm location.

4) Flame breakthrough shall occur between 150 and 190 seconds.

5) Length of test shall be 4 minutes.

[a] Douglas Fir, S4 (smooth on all sides), clear of knots and holes, weight – 1.05 – 1.32 lbs. per 10 ft. length (0.48 – 0.6 kg per 3.05 m length).

Figure 51.2
Woodcrib profile



S2485B

51.4 Flaming polyurethane foam test

51.4.1 Combustible

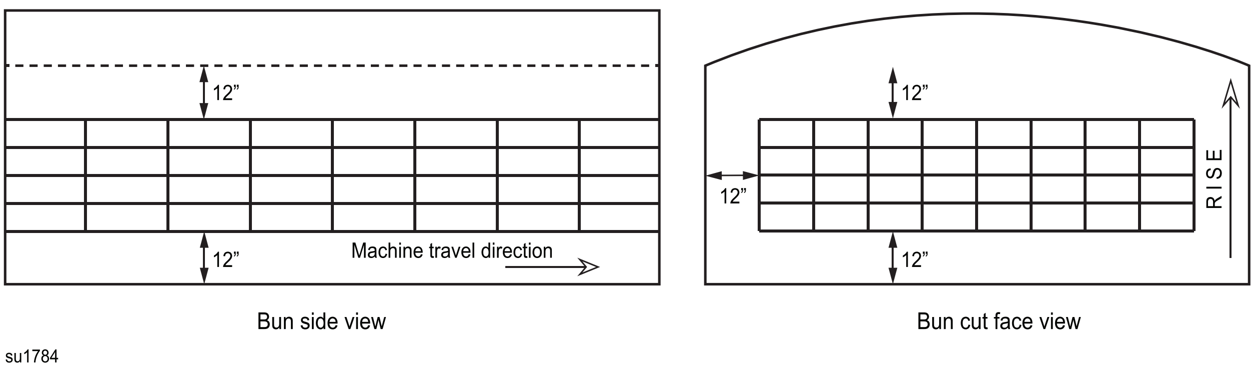
51.4.1.1 Foam specifications

51.4.1.1.1 The foam shall be a pure polypropylene oxide polyol, polyether-based flexible polyurethane foam, produced using an 80/20 TDI blend. It shall not have any colorants or whitening additives nor shall it have any fire retardant additives or post-production fire retardant treatment.

51.4.1.2 Foam physical properties

51.4.1.2.1 Foam test samples shall be cut horizontally with the longest sample dimension parallel to the bun machine direction, not less than 12 in. (30.5 cm) from top and bottom of bun and not less than 12 in. from bun sidewalls as shown in Figure 51.3.

Figure 51.3
Cutting diagrams for foam samples



(Figure courtesy of Polyurethane Foam Association)

51.4.1.2.2 The foam when measured at standard laboratory conditions of 23 ±2°C (73.4±3 °F) and 50 ±5 percent relative humidity shall have the physical properties specified in Table 51.1.

Table 51.1
Foam

Property	Range (average of 5 samples)	
Density	1.80 ±0.05 lb/ft^3	(28.8 ±0.8 kg/m^3)
Indentation Force Deflection (IFD) 25% by ASTM D 3574, Standard Test Methods for Flexible Cellular Materials—Slab, Bonded, and Molded Urethane Foams, Test Method B1	30 ±3 lb/50 sq. in. IFD @ 25%	(4140 ± 414N/m^2) IFD @ 25%

51.4.1.3 Foam combustion properties

51.4.1.3.1 The average of five samples of the polyether foam shall have the burning characteristic properties specified in Table 51.2 when tested by ASTM E 1354, Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter, Cone calorimeter coupled to a particle analyzer based on mobility measurement and a gas analyzer. Test samples shall nominally measure 4 by 4 by 1 in. (100 by 100 by 25 mm). Samples shall be mounted using a horizontal sample holder with edge frame and restraining grid (HEG) and tested at a heat flux of 35 ±0.5 kW/m^2 with piloted ignition.

Table 51.2
Burning properties

Property	Range
Peak HRR	250 ±35 kW/m^2
Effective HOC	25.8 ±1.6 kJ/g
Peak SRR	0.030 ±0.004 m^2/s
Effective Cross Section Area	0.11 ±0.04 m^2/g
Average particle diameter	0.08 ±0.03 micron
Average particle number density ×10^6	3.55 ±1.05 cm^{-3}
CO maximum concentration	170 ±25 ppm
CO_2 maximum concentration	6500 ±1500 ppm
NOTE: Additional conditioning of the foam to ASTM E 1354 conditioning criteria has been found to be beneficial for samples that did not initially meet the requirements listed in 51.4.1.3	

51.4.2 Test procedure

51.4.2.1 Sample dimensions

51.4.2.1.1 The foam test sample shall nominally measure 14.5 by 17.0 by 3.0 in. (368 by 432 by 76 mm). However, the exact quantity of fuel may be adjusted to obtain valid tests.

51.4.2.2 Sample conditioning

51.4.2.2.1 The foam test sample(s) shall be conditioned in air at a temperature 23 ±2°C (73.4 ±3°F) and 50 ±5 percent relative humidity for a minimum of 48 hours prior to testing.

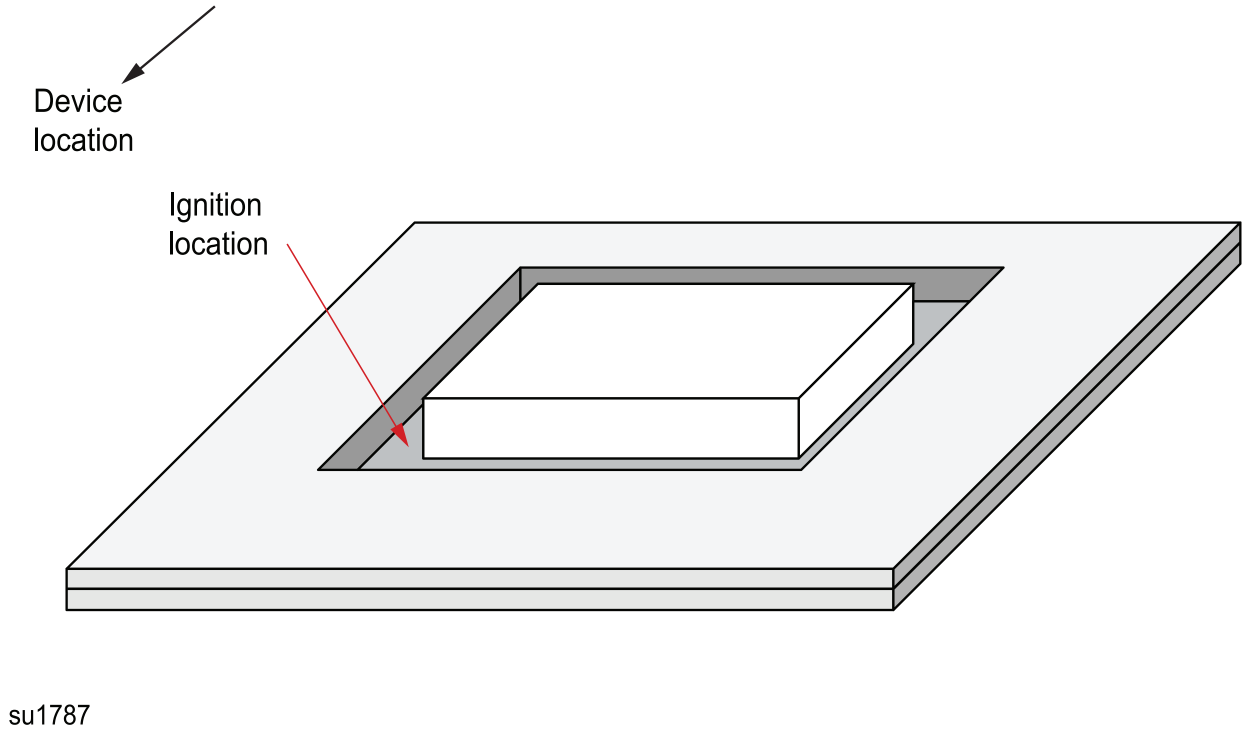
51.4.2.3 Sample arrangement

51.4.2.3.1 Place the foam test sample on a base formed from aluminum foil with the edges folded up approximately 1 inch (25 mm) to provide a melt retention tray. The foil tray is placed on a nominal 5/8 in (16 mm) thick non-combustible tile such that the top of the tile is 2-3/4 in. (70 mm) above the floor such that the long dimension of the sample is perpendicular to the longest dimension of the room. The exact arrangement of the sample may be varied to obtain valid tests.

51.4.2.4 Point of ignition

51.4.2.4.1 Ignite the foam test sample at one of the corners closest to the devices under investigation. The exact position of ignition may be adjusted to obtain a valid test. A small quantity of a clean burning material [e.g., 5 mL (0.17 oz)] of methylated spirit or denatured alcohol) may be used to assist the ignition.

Figure 51.4
Example of sample arrangement and ignition location



51.4.2.5 End-of-test condition

51.4.2.5.1 The end-of-test condition shall be 6 minutes.

51.4.3 Test validity criteria (smoke profile)

51.4.3.1 The development of the fire shall be such that the curves of beam against time and beam against MIC fall within the limits shown in Figures 51.5 and 51.6, respectively.

Figure 51.5
Flaming foam test profile

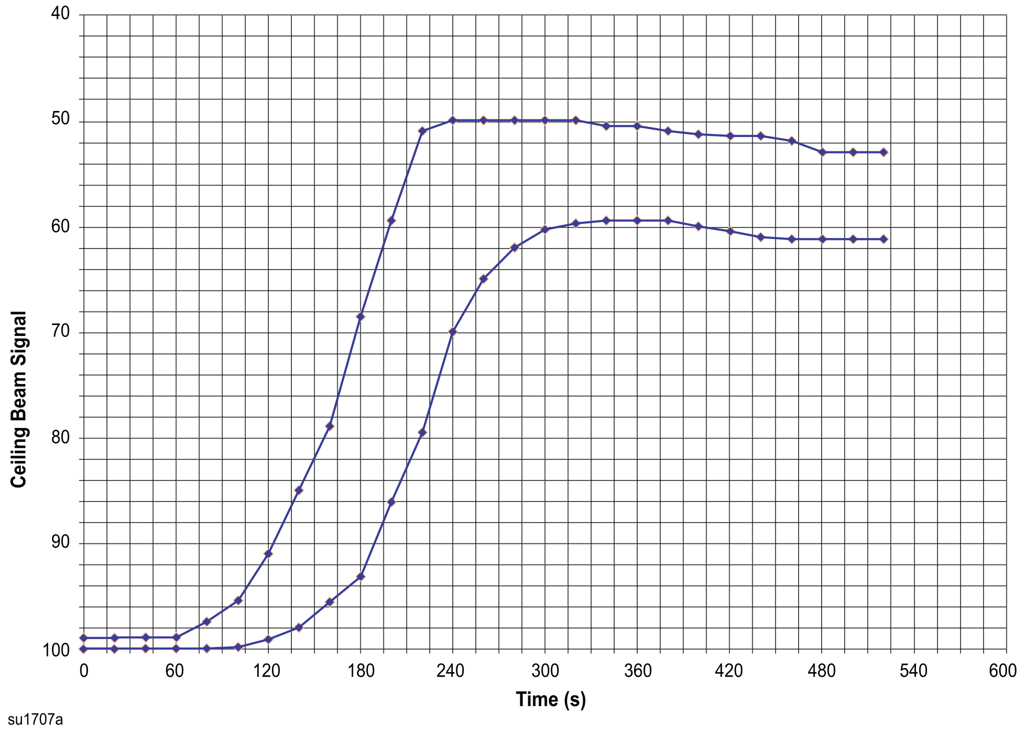
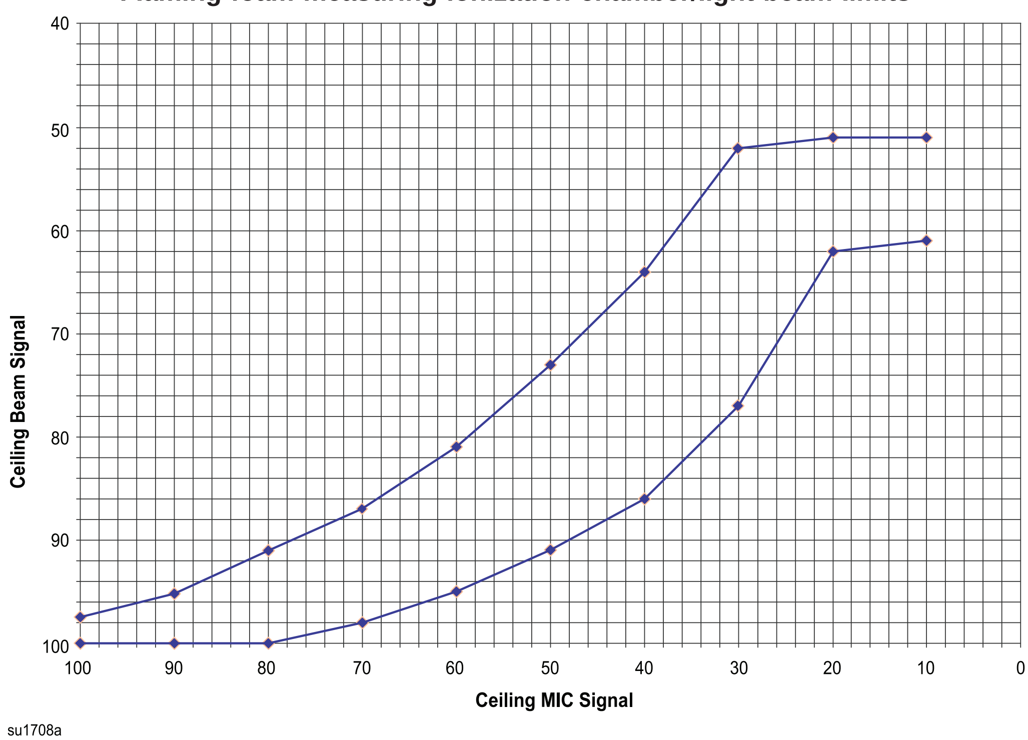


Figure 51.6
Flaming foam measuring ionization chamber/light beam limits



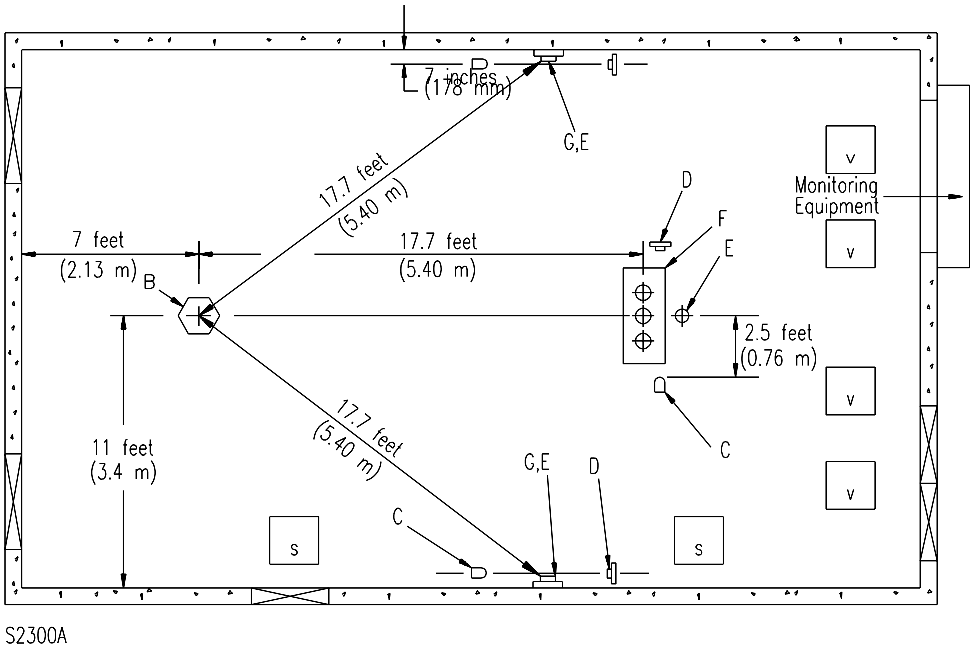
51.4.4 Acceptance criteria

51.4.4.1 All alarms shall produce an alarm signal at or before an obscuration limit of 5%/ft (15.47 percent per meter) [0.0223 OD/foot (0.0730 OD/m)] at each alarm location as measured by the photocell-lamp assembly described in Appendix B1.3 (f) and (m).

51.5 Test method

51.5.1 The fire tests shall be conducted in a room having a smooth ceiling with no physical obstructions. Air movement in the test room is to be minimal. The distance from the base of the combustible to the ceiling shall be 7 ft. (2.1 m). The room is to be provided with a means for the removal of smoke. Heating, humidity, and air conditioning shall be provided for maintaining the room ambient, when required. Specified dimensions are for reference only and are variable as long as the correct smoke build up rates are achieved. For room dimensions see Figure 51.7.

Figure 51.7
Fire test room



A. Fire Test Room Dimensions

1) Length – 36 ft. (11 m)

2) Width – 22 ft. (6.7 m)

3) Ceiling – height 10 ft. (3.0 m) suspended type. Consists of 2 by 4 ft. (0.6 by 1.2 m) by 5/8 in. (15.9 mm) thick incombustible fissured mineral fiber layer in panels.

B. Test Fire

1) 3 ft. (0.91 m) above floor for the Fire Tests, Section 51

2) 8 in. (203 mm) above floor for the Smoldering Smoke Test, Section 52

C. Lamp Assembly – 4 in. (102 mm) below ceiling, 7 in. (178 mm) from each side wall.

D. Photocell Assembly – Spaced 5 ft. (1.5 m) from lamp, photocell center 4 in. (102 mm) below ceiling, 7 in. (178 mm) from each side wall.

E. Measuring Ionization Chamber (MIC) – See 52.9.

F. Test Panel, Ceiling Mounted Alarms – see Figures 51.8 and 51.10.

G. Test Panel, Sidewall Mounted Alarms – see Figures 51.9 and 51.10.

S. Air Supply

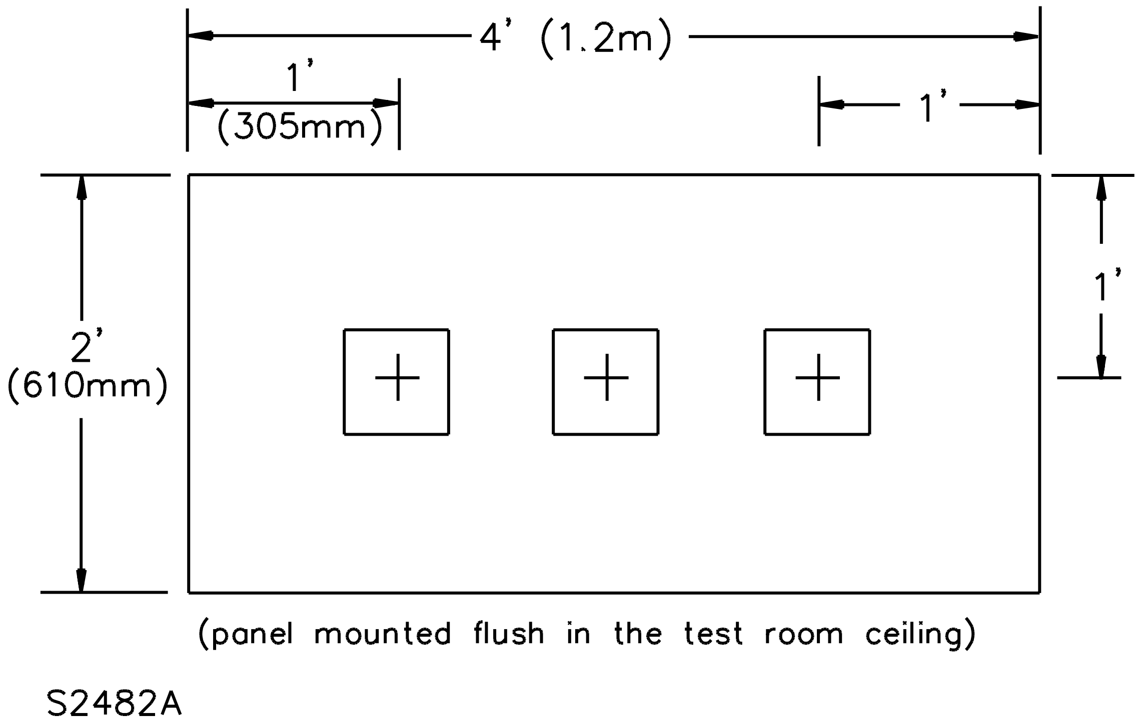
V. Exhaust Vents

51.5.2 The tests shall be conducted at 50 ±10 percent relative humidity in an ambient temperature between 20.0 and 27°C (68 and 81°F). The smoke alarm samples, each adjusted to the minimum smoke alarm sensitivity, shall be energized from a source of supply in accordance with the requirements specified in 37.3, Test voltages.

51.5.3 A smoke alarm intended for flush mounting is to be mounted flush with the mounting base. The ceiling mounted smoke alarms shall be mounted such that the least favorable position of the center sample faces the oncoming smoke flow, with the remaining samples rotated 120 and 240 degrees respectively.

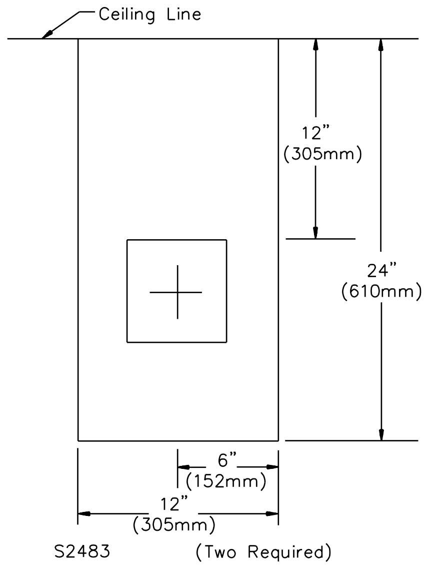
51.5.4 When intended for ceiling mounting only, three smoke alarms shall be tested on a ceiling panel; see Figure 51.8.

Figure 51.8
Ceiling panel size and sample location for ceiling mounting of smoke alarms



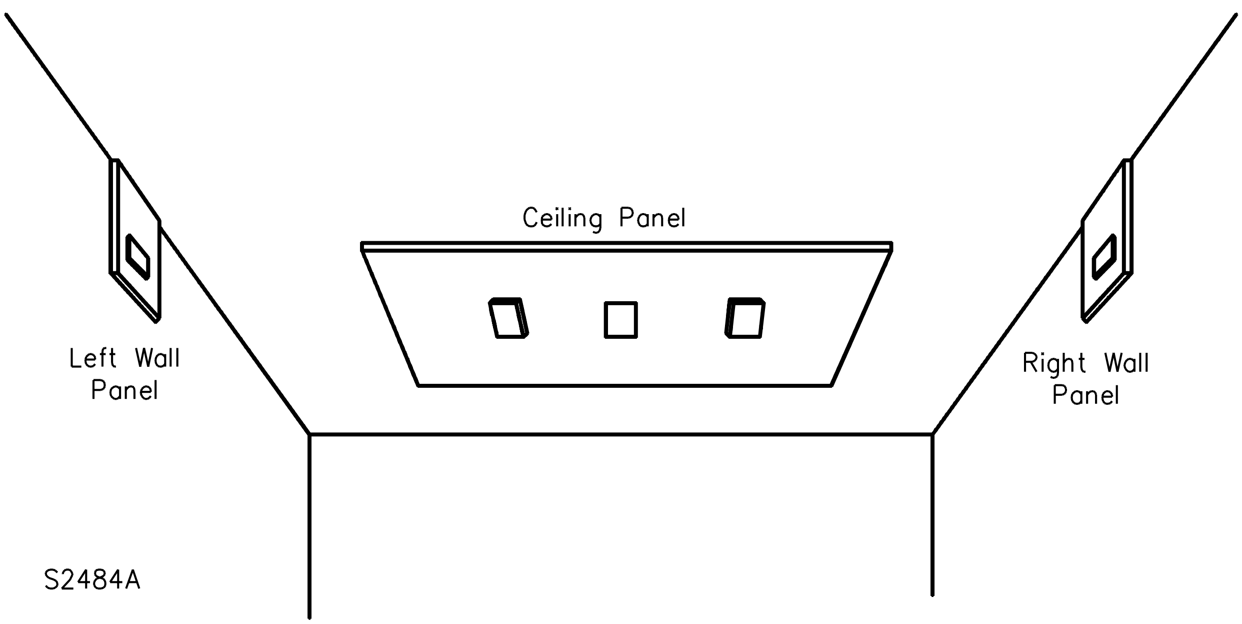
51.5.5 When intended for wall mounting only, two smoke alarms shall be tested, one on each sidewall; see Figure 51.9.

Figure 51.9
Test panel and alarm location for side wall mounted smoke alarms



NOTE – Distance less than 12 in. (305 mm), and not less than 4 in. (102 mm) is permissible only when so specified in the installation instructions.

Figure 51.10
Panel mounting for fire tests



51.5.6 For smoke alarms intended for both wall and ceiling mounting, five smoke alarms shall be tested: three on the ceiling and one on each side wall; see Figures 51.8 – 51.10.

51.5.7 For alarms intended as portable (travel) alarms, two units are to be mounted, one on each side wall, 16 in. (406 mm) from the ceiling to the top of the alarm.

51.5.8 All smoke alarm samples shall respond by generating an alarm signal to the test fire for each combustible. The test time is to start at ignition. The smoke obscuration level at each smoke alarm location is to be monitored by a photocell-light-beam assembly, mounted directly on the ceiling, on each side wall, and spaced 5 ft. (1.5 m) apart. Combination and multi-criteria smoke alarms shall be provided with means for monitoring each principle of operation during testing. Each sensor shall contribute in response, either wholly or partially, to at least one of the test fires in section 51 or to the Smoldering Smoke Test, Section 52, unless the sensor is only used to identify nuisance alarm condition.

51.5.9 To determine the acceptability of each test fire; the smoke profile curves as described in each fire test shall be obtained for the specific combustible. Consult the following test profiles in the following Figures 51.1, 51.2, 51.5, 51.6, and 51.11 – 51.14.

51.5.10 Measuring ionization chambers (MIC) shall be used to measure the relative buildup of particles of combustion during each trial at each smoke alarm location for the wood and paper fires. The MIC utilizes the ionization principle with air drawn through the chamber at a rate of 20 ±3 liters per minute by a regulated vacuum pump. A monitoring head is to be located at each smoke alarm location as shown in Figure 51.7.

51.5.11 Prior to each test, each MIC is to be calibrated in clean air for a value of 100 picoamperes. As the smoke level increases during the test, the meter reading decreases.

51.5.12 To determine the acceptability of the test trial for each combustible and each smoke alarm location, the relationship between the MIC output (ordinate) and the percent light obscuration (abscissa) is to be plotted. The data generated is to remain within the limits represented by the curves illustrated in Figures 51.11 – 51.14 .

Figure 51.11
Paper fire – ceiling location

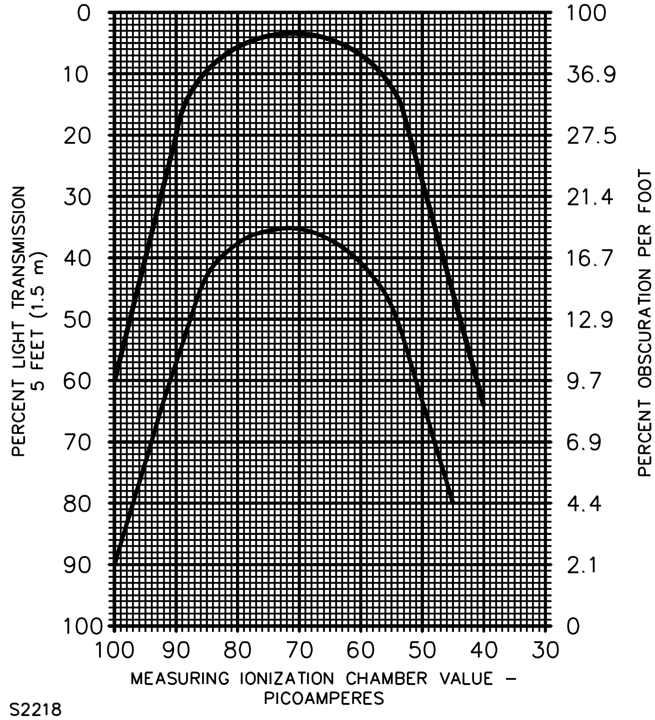


Figure 51.12
Paper fire – wall location

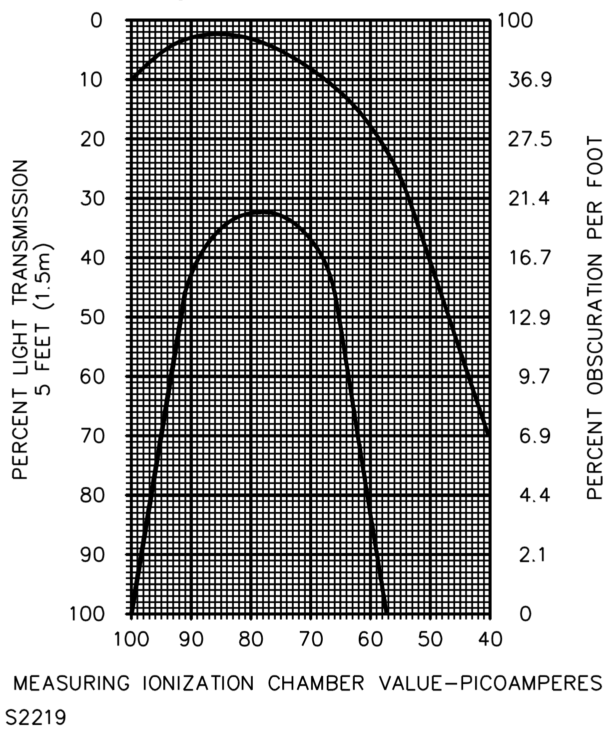
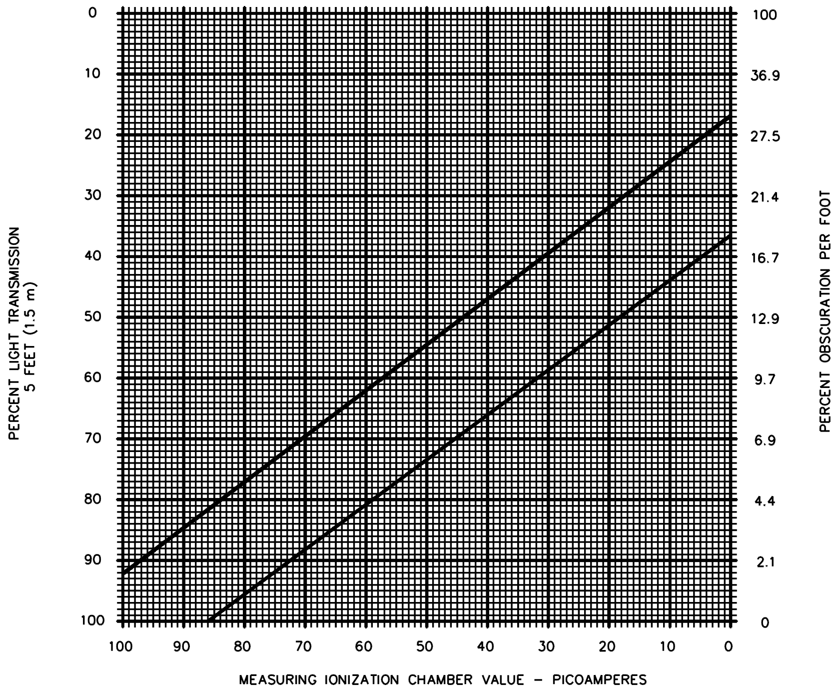
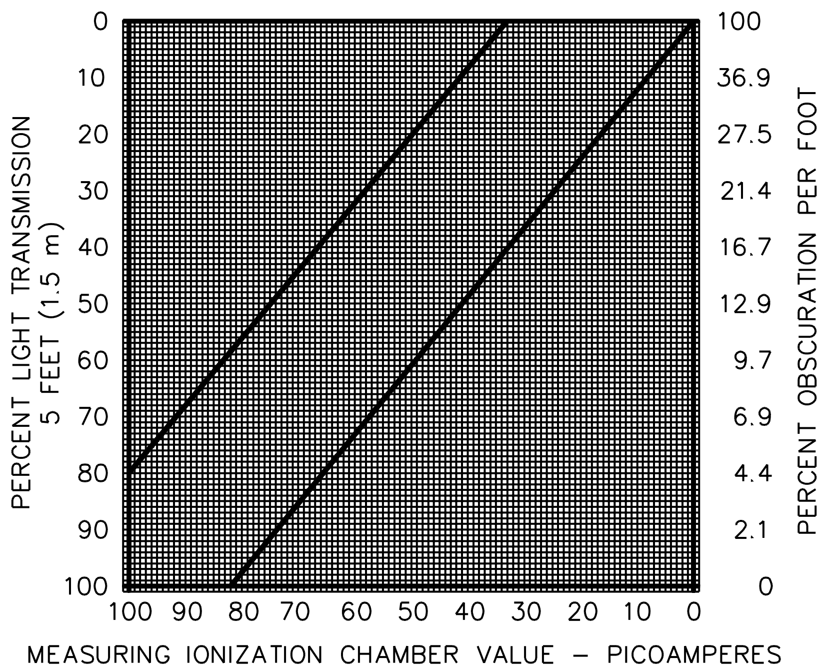


Figure 51.13
Wood fire – ceiling location



S2220

Figure 51.14
Wood fire – wall location



S2221

52 Smoldering Smoke Test

52.1 Each smoke alarm shall produce an alarm sound for not less than 5 seconds when installed as intended in service, and exposed to the following controlled smoldering smoke condition.

52.2 Each smoke alarm shall produce an alarm when installed as intended in service, and exposed to the following controlled smoldering smoke condition.

52.3 Unless specifically indicated otherwise in the alarm installation instructions, the alarms are to be installed in the least favorable position for smoke entry (except where noted in 51.5.3) with respect to the smoldering smoke source as determined by the Directionality Test, Section 43. Smoke alarms adjusted to the minimum smoke alarm sensitivity are to be employed for this test. Alarms shall also comply with the Smoldering Polyurethane Foam test specified in section 53.

52.4 The combustible for this test is to be ponderosa pine sticks (nonresinous, free from knots or pitches) placed on the hotplate. All surfaces of each stick shall be relatively smooth and free from burrs or holes. The grain of the wood is to be parallel to the stick length. Each stick is to be conditioned for not less than 48 hours at 52°C (125°F) in an air-circulating oven. The stick weight is to be 16 ±2 grams (0.56 ±0.07 oz) following the oven conditioning. The following stick configuration has been used for this test:

a) Eight sticks placed in four parallel rows of two sticks each. The two sticks in each row are configured to touch at the 1 by 3/4 in. (25.4 by 19.1 mm) face, with the 3/4 by 3 in. (19.1 by 76.2 mm) face in contact with the hotplate. The rows are arranged such that outermost corner of the end sticks is flush with the edge of the hotplate. The distance between each row is roughly 1/2 in. (12.7 mm).

52.5 The heat source is to be a 240 volt, 1550 watt hotplate[b] having a steel plate 8-1/2 in. (216 mm) diameter by 1/4 in. (6.4 mm) thick, the topmost portion of which is 8 in. (200 mm) above the floor. The temperature of the hotplate is to be monitored by an iron-constantan AWG 30 (0.05 mm^2) (Type J) thermocouple attached to the edge of the steel plate by placing its junction in a hole 0.015 in. (0.38 mm) in diameter and 1/4 in. (6.4 mm) deep and peening over the opening to secure it. The thermocouple is to be connected to a proportioning temperature controller which is able to be precisely set for the specified hotplate temperature. The controller sensitivity is adjusted so that all conditions for this test are met. Once set for a specific temperature, the hotplate shall be maintained at that temperature (as monitored by a temperature measuring meter). Prior to the start of the test, the hotplate temperature is to be 23 ±2°C (73 ±4°F). The initial proportioning controller temperature setting is to be 205°C (401°F). The hotplate and controller then are to be energized and the test time started (T=0). The proportioning controller setting is to be increased to obtain the temperature sequence included in Table 52.1 and Figure 52.1 (the hotplate temperature normally lags the controller setting by 2 minutes during incremental increases). The temperature of the hotplate may require adjustment to achieve the profile described in Figure 52.2

[b] A hotplate for this purpose is Emerson Electric Co., Series PH-400 Chromalox .

Table 52.1
Hotplate temperature

Time (minutes)	Hotplate temperature
0	23 ±2°C (73 ±4°F)
0 – 3	Increased 60.7°C (109°F) per minute to 205°C (401°F)
More than 3	Increased 3.2°C (5.8°F) per minute for remainder of test

Figure 52.1
Hotplate temperature profile (United States only)

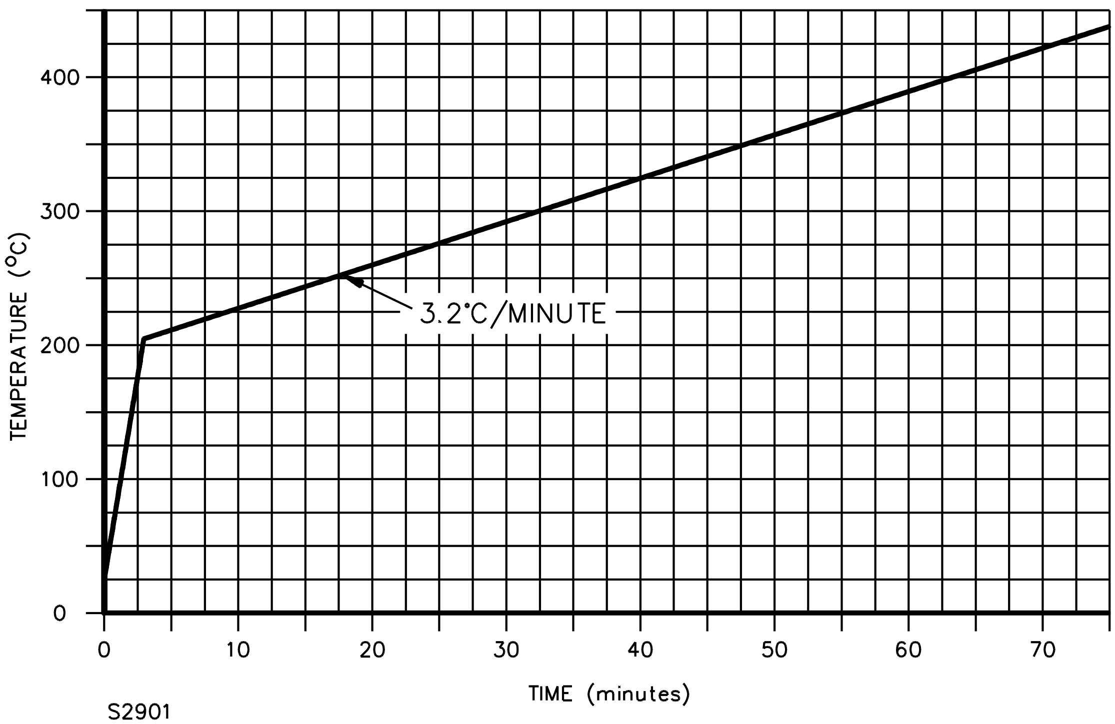
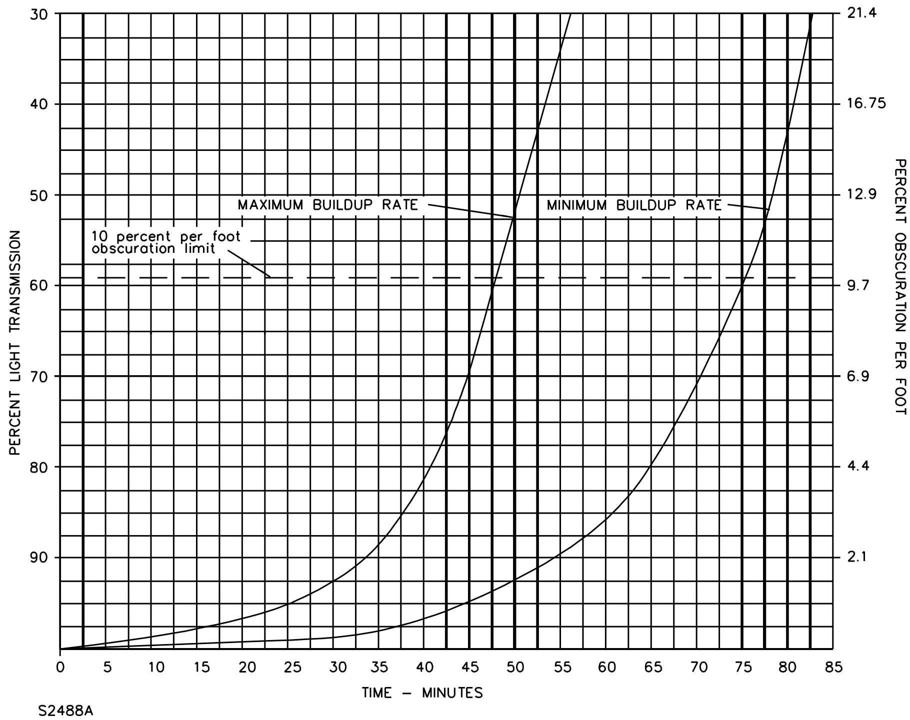


Figure 52.2
Smoldering test profile



52.6 The Smoldering Smoke Test is to be conducted in the same room and ambient conditions and under the same mounting conditions as employed for the Fire Tests. See 51.1 and 51.5. The alarm samples are to be energized from a source of supply in accordance with 37.3.1 except that alarms powered from a battery shall be energized by batteries that are depleted to their trouble signal voltage levels unless the minimum sensitivity is measured at rated battery voltage.

52.7 All smoke alarms shall respond to the test trial before the obscuration levels exceed 10.0 percent per ft. (29.26 percent per m) [0.0458 OD/ft. (0.15 OD/m)] at the smoke alarm location as measured by the photocell-lamp assembly described in Appendix B, Typical Smoke Test Chamber Construction, B1.3 (f) and (m).

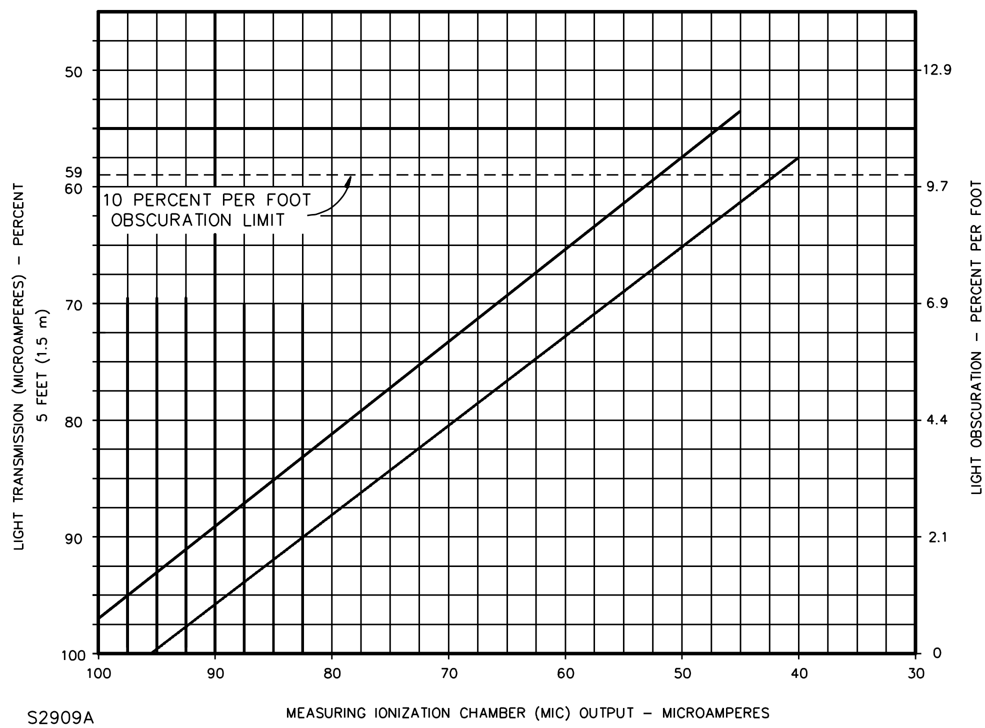
52.8 For this test, the visible smoke buildup rate is to be maintained within the limits illustrated in Figure 52.2. At no time during the test trial shall the buildup rate exceed 5 percent obscuration per minute as measured over the length of the 5 ft. (1.5 m) light beam.

52.9 A Measuring Ionization Chamber (MIC) is to be used to measure the relative buildup of particles of combustion during the test. The MIC utilizes the ionization principle with air drawn through the chamber at a rate of 30 ±3 liters per minute by a regulated vacuum pump. The monitoring head is to be located as shown in Figure 51.7.

52.10 Prior to the test, the MIC is to be calibrated in clean air for a value of 100 picoamperes. As the smoke level increases during the test, the meter reading decreases.

52.11 To determine the acceptability of the test trial, the relationship between the MIC output (ordinate) and the percent light transmission (abscissa) is to be plotted at 1-minute intervals during the test. The points generated are to remain within the curves illustrated in Figure 52.3.

Figure 52.3
Smoldering smoke test measuring ionization chamber/light beam lights



S2909A

53 Smoldering Polyurethane Foam Test

53.1 Combustible

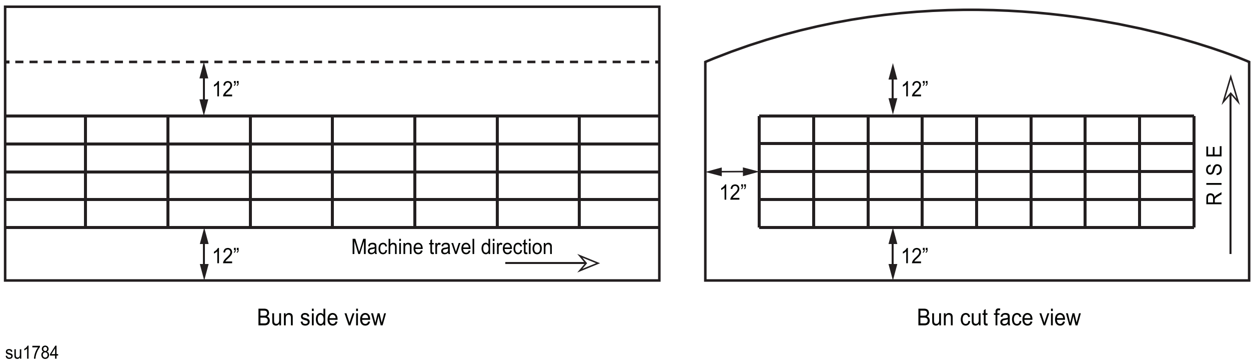
53.1.1 Foam specifications

53.1.1.1 The foam shall be a pure polypropylene oxide polyol, polyether-based flexible polyurethane foam, produced using an 80/20 TDI blend. It shall not have any colorants or whitening additives nor shall it have any fire retardant additives or post-production fire retardant treatment.

53.1.2 Foam physical properties

53.1.2.1 Foam test samples shall be cut horizontally with the longest sample dimension parallel to the bun machine direction, not less than 12 in. (30.5 cm) from top and bottom of bun and not less than 12 in. from bun sidewalls as shown in Figure 53.1.

Figure 53.1
Cutting diagrams for foam samples



(Figure courtesy of Polyurethane Foam Association)

53.1.2.2 The foam when measured at standard laboratory conditions of 23 ±2°C (73.4±3 °F) and 50 ±5 percent relative humidity shall have the physical properties specified in Table 53.1.

Table 53.1
Foam

Property	Range (average of 5 samples)	
Density	1.80 ±0.05 lb/ft^3	(28.8 ±0.80 kg/m^3)
Indentation Force Deflection (IFD) 25% by ASTM D 3574, Standard Test Methods for Flexible Cellular Materials – Slab, Bonded, and Molded Urethane Foams, Test Method B1	30 ±3 lb/50 sq. in. IFD @ 25%	(4140 ± 414N/m^2) IFD @ 25%

53.1.3 Foam combustion properties

53.1.3.1 The average of five samples of the polyether foam shall have the burning characteristic properties specified in Table 53.2 when tested by ASTM E 1354, Standard Test Method for Heat and Visible Smoke Release Rates for Materials and Products Using an Oxygen Consumption Calorimeter, Cone calorimeter coupled to a particle analyzer based on mobility measurement and a gas analyzer. Test samples shall nominally measure 4 by 4 by 1 in. (100 by 100 by 25 mm). Samples shall be mounted using a horizontal sample holder with edge frame and restraining grid (HEG) and tested at a heat flux of 35 ±0.5 kW/m^2 with piloted ignition.

Table 53.2
Burning Properties

Property	Range
Peak HRR	250 ±35 kW/m^2
Effective HOC	25.8 ±1.6 kJ/g
Peak SRR	0.030 ±0.004 m^2/s
Effective Cross Section Area	0.11 ±0.04 m^2/g
Average particle diameter	0.08 ±0.03 micron
Average particle number density $\times 10^6$	3.55 ±1.05 cm^{-3}
CO maximum concentration	170 ±25 ppm
CO_2 maximum concentration	6500 ±1500 ppm
NOTE: Additional conditioning of the foam to ASTM E 1354 conditioning criteria has been found to be beneficial for samples that did not initially meet the requirements listed in 53.1.3	

53.2 Test procedure

53.2.1 Sample dimensions

53.2.1.1 The foam test sample shall nominally measure 14.5 by 17.0 by 4.0 in. (368 by 432 by 101 mm). However, the exact quantity of fuel may be adjusted to obtain valid tests.

53.2.2 Sample conditioning

53.2.2.1 The foam test sample(s) shall be conditioned in air at a temperature 23 ±2°C (73.4 ±3°F) and 50 ±5 percent relative humidity for a minimum of 48 hours prior to testing.

53.2.3 Test method

53.2.3.1 The foam test sample(s) shall smolder without transitioning to open flame. Smoldering may be induced by a number of means including radiant heaters, hot plates, and cartridge heaters.

53.2.4 End of test

53.2.4.1 General

53.2.4.1.1 The test shall be terminated after the smoke alarm has activated or the smoke obscuration has reached the acceptance criteria.

53.2.4.2 Early test termination criterion

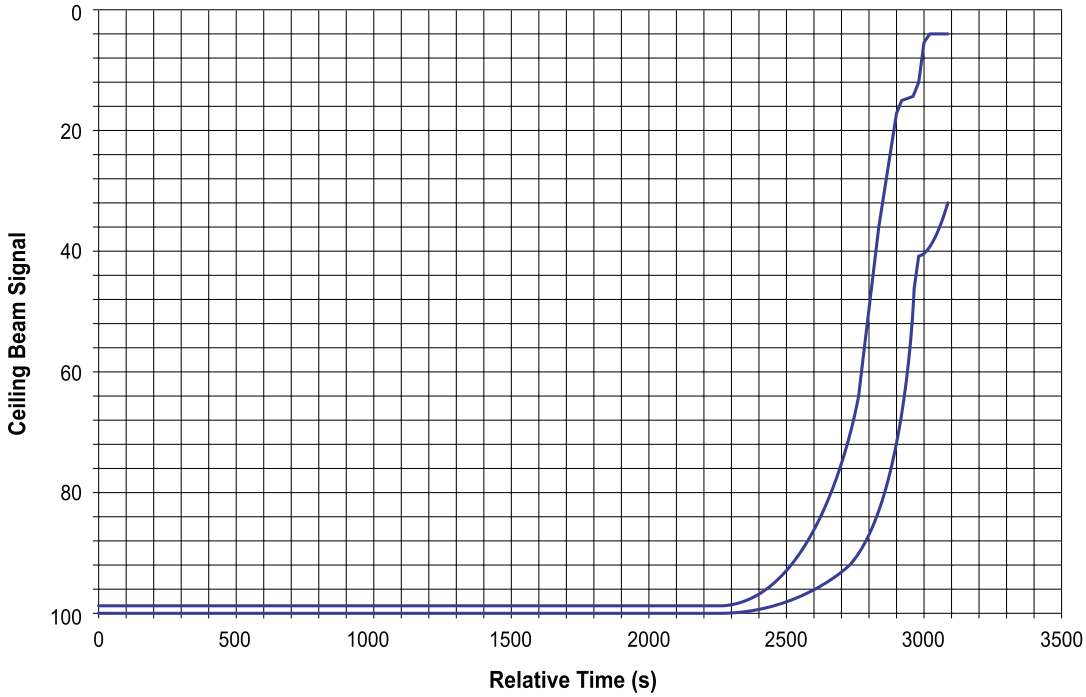
53.2.4.2.1 The test shall be terminated if the foam blocks transition to flaming combustion before the end of the test.

53.3 Test validity criteria (smoke profile)

53.3.1 The test is invalid if the Early test termination criterion, 53.2.4.2, is observed.

53.3.2 The development of the fire shall be such that the curve of beam against time shall fall within the limits shown in Figure 53.2 when time-adjusted such that an obscuration level of 1.0 percent per foot (3.24 percent per meter) [0.0044 OD/foot (0.014 OD/m)] at the alarm location as measured by the photocell-lamp assembly described in Appendix B1.3 (f) and (m) occurs at a reference time of 2500 seconds.

Figure 53.2
Smoldering foam test profile (time-adjusted)



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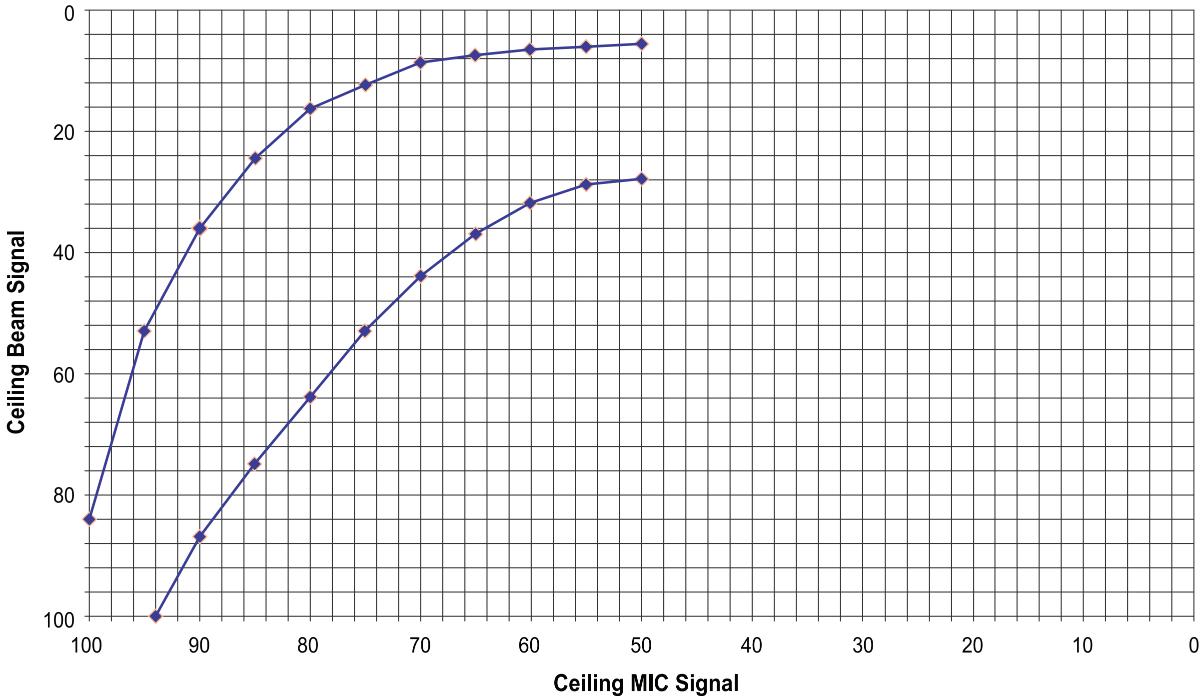
53.3.3 The development of the fire shall be such that the curve of the measured beam against MIC falls within the limits shown in Figure 53.3.

Figure 53.3
Smoldering foam measuring ionization chamber/light beam limits



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53.4 Acceptance criteria

53.4.1 General

53.4.1.1 All alarms shall produce an alarm signal prior to the smoke obscuration exceeding 12.0 percent per foot (34.3 percent per meter) [0.0555 OD/foot (0.182 OD/m)] at each alarm location as measured by the respective photocell-lamp assembly described in Appendix B1.3 (f) and (m).

54 Cooking Nuisance Smoke Test

54.1 Acceptance criteria

54.1.1 Four alarms shall not produce an alarm signal or other notification signal prior to:

a) An obscuration level of 1.5 percent per foot (0.987 percent per meter) [0.0013 OD/foot (0.0043 OD/m)] based on the profile illustrated in Figure 54.4,

b) A MIC value between the range of 59.3 to 49.2 based on the profile illustrated in Figure 54.5 and,

c) The combined acceptance criteria from (a) and (b) as identified in the profile illustrated in Figure 54.6.

54.1.2 The acceptance criteria specified in 54.1.1 shall be based on:

a) The data recorded from the center alarm location as measured by the respective photocell-lamp assembly described in B1.3 (f) and (m) of Appendix B;

b) The OBS vs Time, MIC vs Time, OBS vs MIC, and CO vs OBS profiles shall be within the limits as specified in Figures 54.4 – 54.7;

c) The CO buildup rate in relation to the particle displacement (obscuration (OBS) in %/ft) shall be within the profile as specified in Figure 54.7. The maximum CO limit shall not exceed 4.72 ppm at 1.5 %/ft obscuration; and

d) The requirements outlined in 54.2 through 54.4.6.

54.1.3 The test shall be considered invalid and terminated if more than 5 flashes of a light (similar to a spark) are observed or a flame is observed within the electric range.

54.2 Electric range

54.2.1 An electric range shall be used for this test. The electric range shall consist of electric coils within the range, that are used for broiling, that can be adjusted for operation necessary to achieve the smoke profiles specified in 54.4.6. The electric range shall not be located more than 2 ±0.5 in. (5 ±1.27 cm) from the back wall as noted in Figure 54.1.

54.3 Hamburger mixture and freezing

54.3.1 Each fresh hamburger is to consist of a mixture of 75 percent lean beef and 25 percent suet by weight ground together at least twice in succession. Each fresh hamburger is to be approximately 3/4 in. (19 mm) thick with an approximate diameter of 4 inches (102 mm) before cooking. Overall fresh hamburger size may vary based on templates from the butcher and packaging.

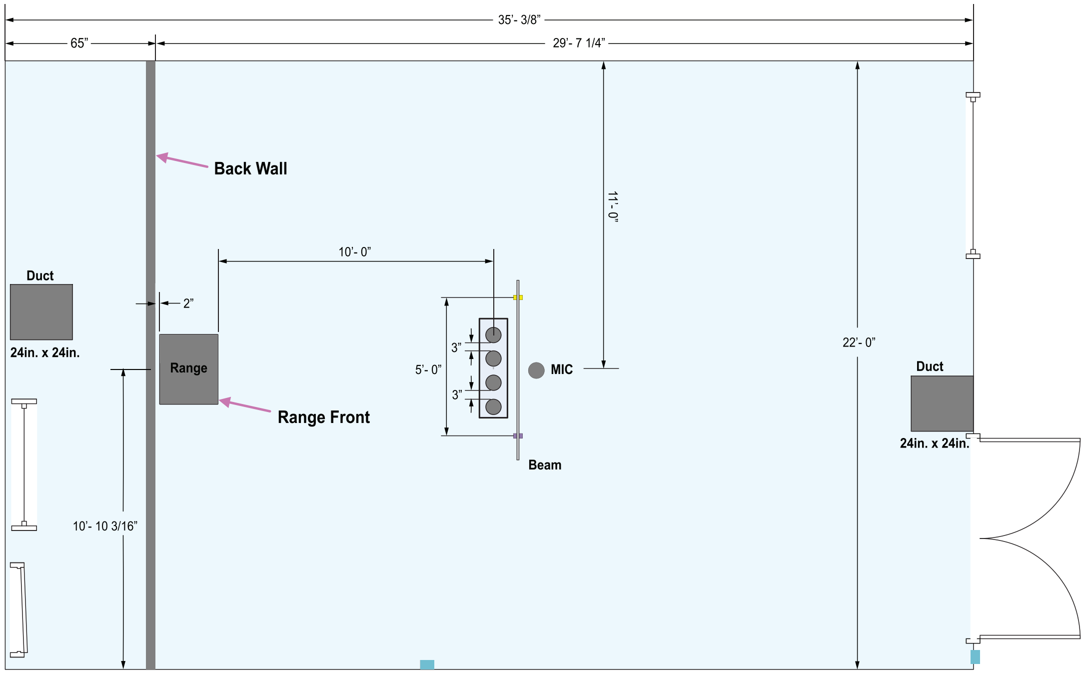
54.3.2 Prior to the hamburger being used for testing, the hamburger shall be frozen in an ambient temperature ranging from minus 20 to minus 25°C (minus 4 to minus 13°F) for at least 72 hours. After freezing, the fresh hamburger specified in 54.3.1, the hamburger used for testing will be referred to as a “fresh-frozen hamburger.″

54.4 Test procedure

54.4.1 Test room

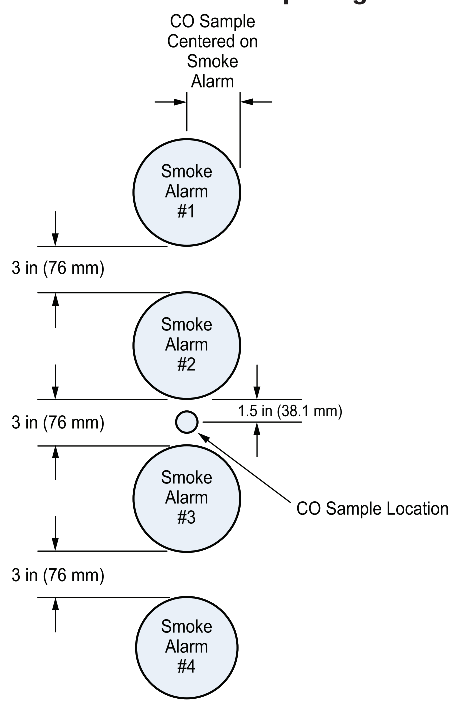
54.4.1.1 The fire test room specified in 51.5 shall be used for this test. The room shall be modified such that the wall closest to the back of the electric range shall be a flat surface that is perpendicular to the ceiling and free of any obstructions that may affect air entrainment. A separate wall placed behind the electric range may be added but shall not reduce the length of the room by more than 65 in. (165 cm). See Figure 54.1, Fire Test Room Electric Range and Smoke Alarm Placement, for placement of the electric range within the room. Also reference Figure 54.2, Smoke Alarm Spacing, for placement of the smoke alarms on the ceiling.

Figure 54.1
Fire test room electric range and smoke alarm placement



su2173b

Figure 54.2
Smoke alarm spacing



su2174c

54.4.1.2 The electric range shall be elevated from the floor so that the top of the cooking surface of the electric range is 60.5 ±1 in. (154 ±2.5 cm) from the ceiling.

54.4.2 Fresh-frozen hamburger placement

54.4.2.1 Two fresh-frozen hamburgers shall be equally spaced on the center of a broiler tray which is equally spaced in the center of a baking rack inside the oven of the electric range. The door to the oven on the electric range shall be closed such that the opening between the “Inside Surface of Range Door” and the “Front Surface” of the oven door of the electric range maintains a gap of 4.5 ±1 in. (11.5 ±2.54 cm). The opening between the “Inside Surface of Range Door” and the “Front Surface” of the oven door of the electric range shall be maintained for the duration of the test. See Figure 54.3, Electric Range Door Opening, for details.

Figure 54.3
Electric range door opening description

su2175

54.4.3 Smoke alarms

54.4.3.1 Four smoke alarms shall be used for this test. Each of these alarms shall be calibrated to the maximum smoke sensitivity anticipated in production and shall be oriented in the most favorable position facing the fire as determined in the Directionality Test.

54.4.3.2 The smoke alarms shall be placed on the ceiling, 120 ±2 in. (304.8 ±5.1 cm) along the ceiling from the horizontal plane of the “Front of Cooktop/Range”. The smoke alarms shall be centered and installed flush to the ceiling.

54.4.3.3 Carbon monoxide shall be measured and recorded and shall not exceed the limit specified in 54.4.6.1 when conducting this test. The CO measuring equipment shall either be range selectable by the user or have auto range capability for measuring up to 10 ppm of carbon monoxide. The sample draw for the CO monitor location shall not exceed 0.12 ft^3/min (3.3 L/min).

54.4.3.4 The carbon monoxide sampling tube shall be centered between the 2nd and 3rd smoke alarm as illustrated in Figure 54.2. The sample tube shall not be larger than the rated 1/4 in (6.4 mm) O.D. tubing, and shall protrude from the ceiling surface 1 ±0.125 in (25.4 ±3.2 mm) into the room from the ceiling surface. Centering of the test samples (alarms) and CO sample tube shall be within ±10% of the specified dimensions illustrated in Figures 54.1 and 54.2.

54.4.3.5 Beam and MIC placement shall be located in the 10-foot location as noted in Figure 54.1, with the same Beam and MIC placement as specified in Figure 51.7, Fire Test Room, items C, D, E and F.

54.4.4 Electric range broiler

54.4.4.1 Full power to the heating coils shall be applied within 1 second from turning on the power. Test power will vary based on the make and model of the electric range used. However, smoke build-up rates shall be within the profile limits specified in 54.4.6.

54.4.5 Test termination

54.4.5.1 The test shall be terminated after the smoke alarm

a) Has activated, or

b) The smoke obscuration has reached the acceptance criteria in 54.1.

54.4.6 Smoke profile criteria

54.4.6.1 The development of the combined smoke and carbon monoxide from a broiling hamburger shall be such that the curve of the measured data falls between the upper and lower limits specified in the figures below:

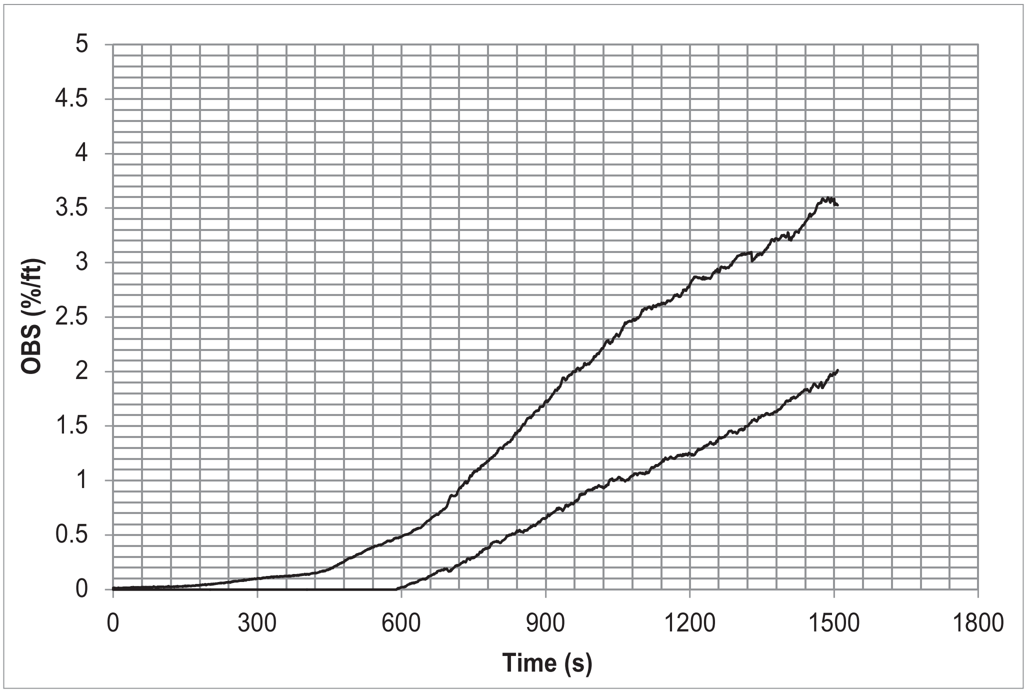
a) Figure 54.4, OBS vs. Time

b) Figure 54.5, MIC vs. Time

c) Figure 54.6, OBS vs. MIC

54.4.6.2 For Figure 54.7, CO vs. OBS, the curve of the measured data may fall between the upper and lower limits but shall not exceed the upper limit specified in the figure.

Figure 54.4
Nuisance alarm test profile (OBS vs Time)



su2176

Figure 54.5
Nuisance alarm test profile (MIC vs Time)

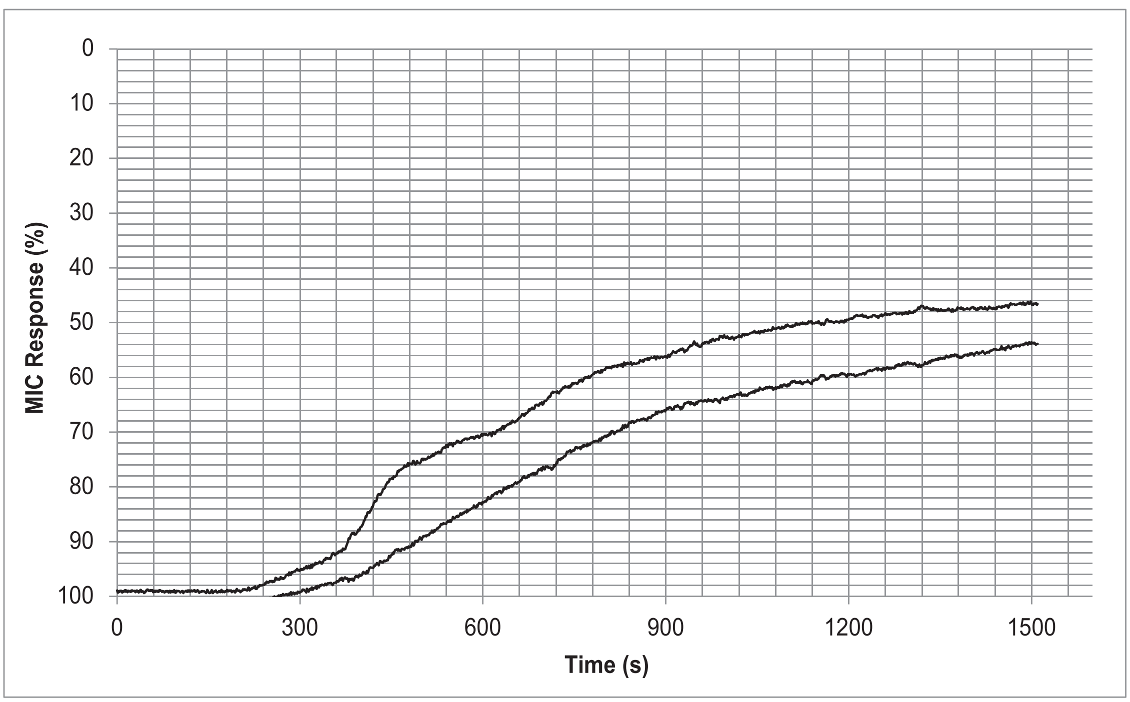


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Figure 54.6
Nuisance alarm test profile (OBS vs MIC)

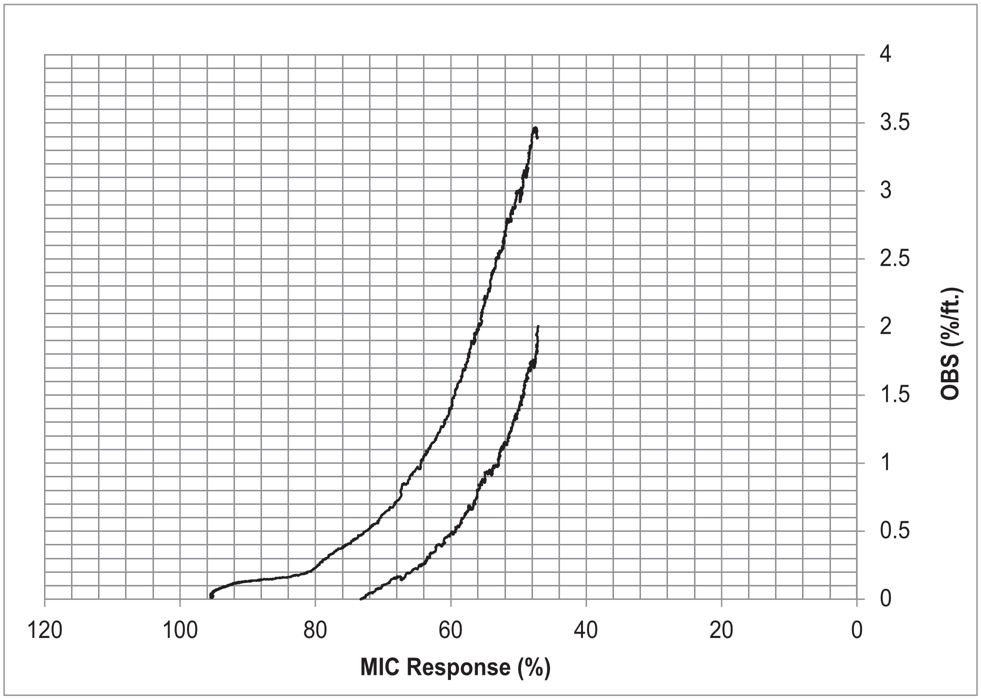

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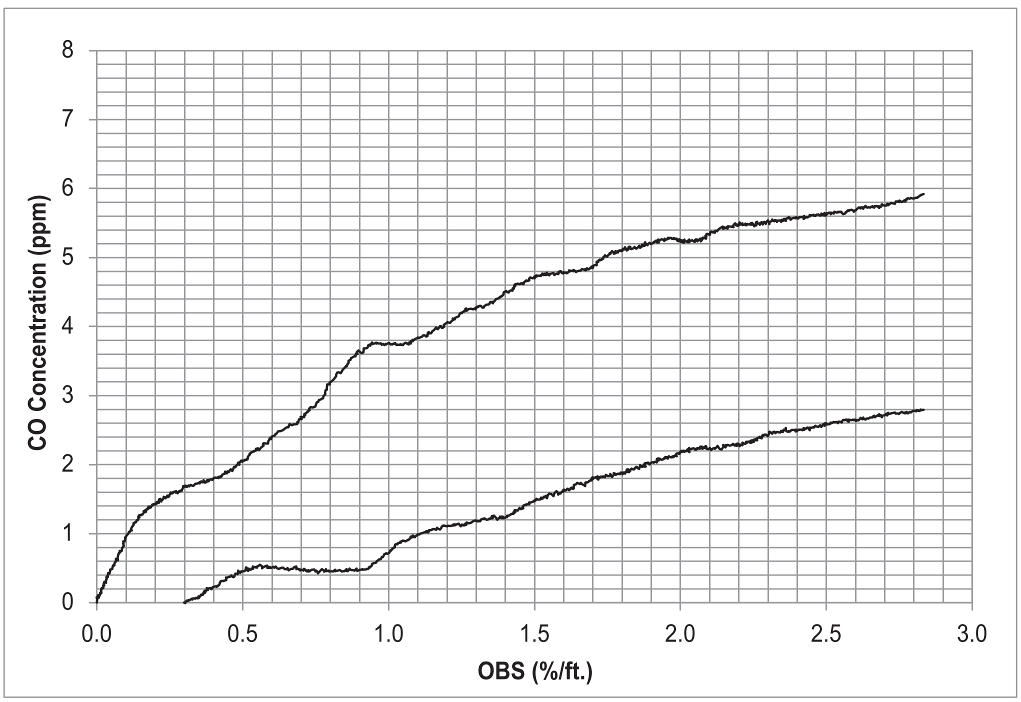
Figure 54.7
Nuisance alarm test profile (CO vs OBS)



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55 Selectivity Test – Multicriteria Smoke Alarms Incorporating Gas Sensor(s)

55.1 The smoke alarm shall not alarm or have its gas sensitivity performance affected when exposed sequentially, as described in 55.2 – 55.6, to the concentrations of gases and vapors shown in Table 55.1. These substances are intended to represent air contaminants found in the vicinity of an installed smoke alarm.

Table 55.1
Gas and vapor concentrations

Substance	Concentration, ppm
Methane	500 ±50
n-Butane	300 ±30
n-Heptane	500 ±50
Ethyl acetate	200 ±20
Isopropyl alcohol	200 ±20
Carbon dioxide	5000 ±500
Ammonia	100 ±10
Ethanol	200 ±20
Toulene	200 ±20
Trichloroethane	200 ±20
Acetone	200 ±20
hexamethyldisiloxane	10 ±3
Hydrogen	30 ±3
Manufacturer Defined Gases	Provided By Manufacturer

55.2 Calculate the interior volume of the test chamber used in 42.8.1.2. From this volume, calculate the amount of each test substance necessary to supply the concentrations given in Table 55.1.

55.3 Ensure that the chamber has been well ventilated with fresh air. Place the smoke alarm in operation inside the chamber and allow it to run for 15 ±5 minutes. Close and seal the chamber to prevent air infiltration.

55.4 Using a syringe or equivalent device, add the calculated amount of the first substance into the chamber at a rate and in a location such that it is well mixed with the air within 30 seconds and does not cause localized high concentrations.

55.5 Allow the smoke alarm to remain in the chamber for 2 hours. Unless specifically designated to detect the gas under test, during the two hours of exposure the smoke alarm shall not produce an alarm signal or aid in the signaling of an alarm when combined with the multi-detection properties of the multi-criteria smoke alarm.

55.6 Resistance to background gases shall be demonstrated by monitoring the appropriate output signal of a multi-criteria smoke alarm and/or the firmware logic that is used to determine the smoke alarm’s alarm condition. The manufacturer shall provide the necessary equipment and/or information to monitor the output signal.

55.7 If the gas under test has not been identified to be integral to the sensitivity performance of the smoke alarm, an output signal from the sensor(s) is permitted for each specific gas and its designated concentration, but shall not result in an alarm signal or result in an increase or decrease of the smoke alarm performance.

55.8 Purge the chamber with clean air to remove all of the test atmosphere. Maintain clean air in the chamber for a recovery time of 16 hours, or as specified by the manufacturer. In no case shall recovery time exceed 16 hours. Reseal the chamber and repeat the test using another substance from Table 55.1 until the smoke alarm has been exposed to all substances. It is not required that exposure to the substances be in any particular order.

55.9 Following each selectivity test gas exposure and recovery, the sensitivity of each sensor shall be assessed in accordance with the 42.2, Combustibles (Sensitivity Tests). Alternatively, the manufacturer may choose to conduct the sensitivity test following the sequential test gas exposure and recovery time for all selectivity gases.

55.10 Following each selectivity test gas exposure and recovery, the gas sensitivity of each sensor shall be assessed in accordance with the 42.7, Smoke sensitivity test feature. Alternatively, the manufacturer may choose to conduct the sensitivity test following the sequential test gas exposure and recovery time for all selectivity gases.

56 Circuit Measurement Test

56.1 General

56.1.1 Except for a battery operated smoke alarm, the input current of a smoke alarm shall not exceed the marked rating of the smoke alarm by more than 10 percent when operated under conditions of intended use and with the smoke alarm connected to a source of supply as specified in 37.3.1. Measurements shall also be made of components such as capacitors to determine that they are being employed within the manufacturer’s ratings.

56.1.2 For each smoke alarm with an external power supply, surge current, start-up time, normal supervisory current, and alarm current shall be measured at the:

a) Smoke alarm’s rated input voltage values and

b) Nominal voltage value.

The measured current values shall be within the rated values.

56.2 Battery trouble voltage determination

56.2.1 An increase in the internal resistance, or a decrease in terminal voltage, of a battery employed as the primary source of power to an smoke alarm shall not impair operation for an alarm signal before a trouble signal is obtained. In addition, any combination of voltage and resistance at which a trouble signal is obtained shall be greater than the battery voltage and resistance combination measured over a 1 year period in the room ambient of the Battery tests, 85.3.

56.2.2 The trouble level of a battery operated smoke alarm shall be determined (using the test circuit in Figure 56.1 and the voltage-resistance curves of Figure 56.2 for each of the following voltages:

a) Rated battery voltage,

b) Trouble level voltage (assuming minimal or no series resistance), and

c) Voltages between rated and trouble level voltage.

Figure 56.1
Test circuit

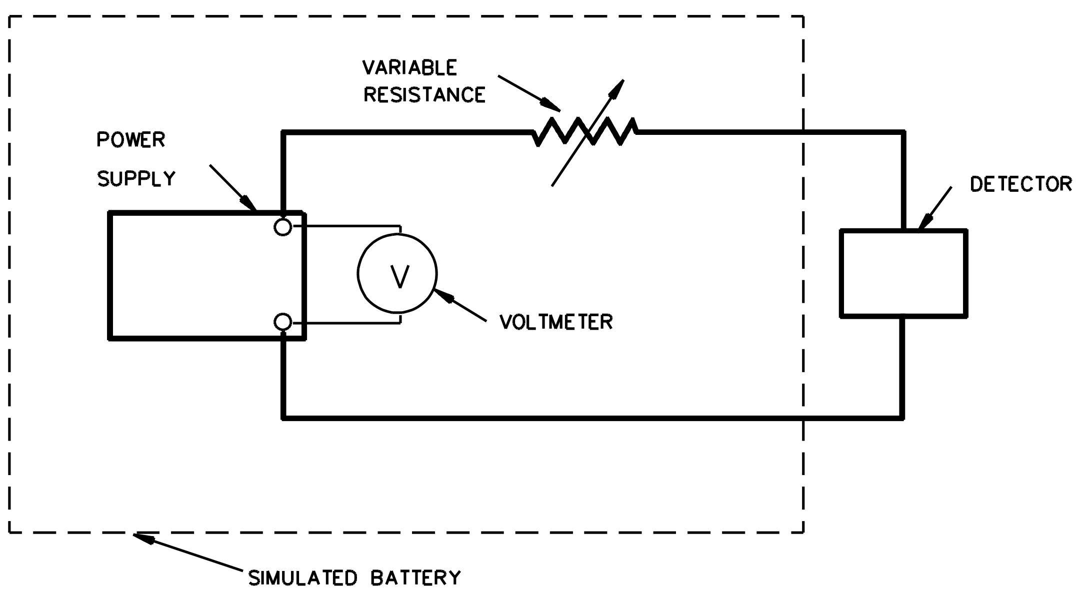

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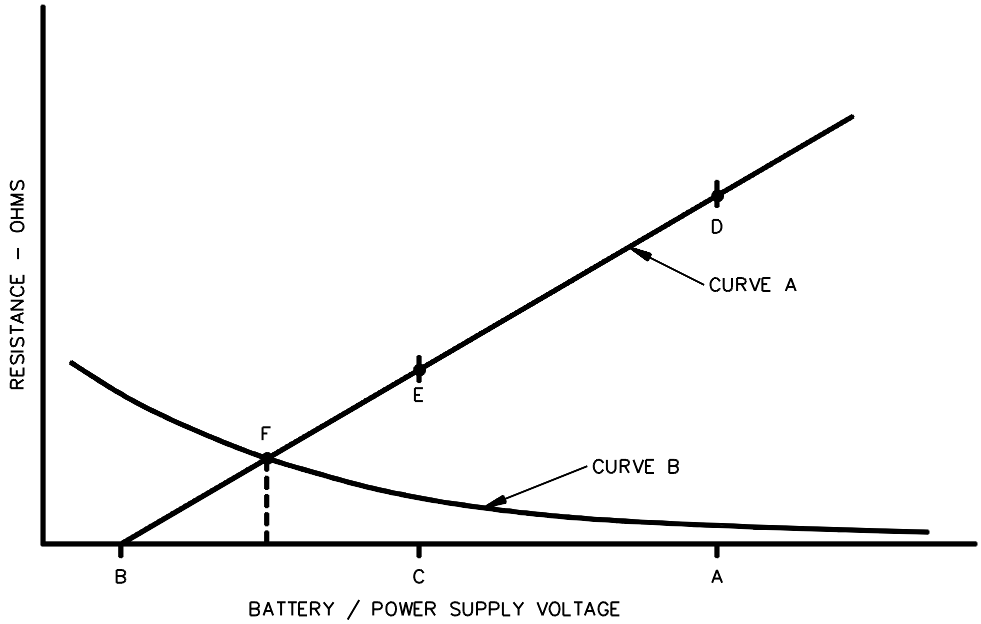
Figure 56.2
Trouble level determination



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56.2.3 To determine compliance with 56.2.1 each of three smoke alarms is to be connected in series with a variable regulated direct current power supply and a variable resistor as illustrated in Figure 56.1. The trouble level is to be determined by the following steps:

a) Rated Battery Voltage – The voltage of the power supply is to be set at the rated battery voltage and the series resistor at 0 ohm. The resistor is to be increased in increments of 0.1 – 10 ohms, at a rate of not more than one increment per minute, until a trouble signal is obtained. The smoke alarm is to be tested for alarm operation at each resistance level and at the trouble level.

b) Trouble Level Voltage – With the variable resistor set at 0 ohm, the voltage of the power supply connected to the smoke alarm is to be reduced in increments of 1/10 volt per minute to the level where the trouble signal is obtained. The smoke alarm is to be tested for alarm operation at each voltage level and at the trouble signal level.

c) Voltage Values Between Rated and Trouble Level Voltages – The voltage of the power supply is to be set at prespecified voltages between the rated battery voltage and the trouble level voltage. The series resistor is then to be increased in increments of 0.1 – 10 ohms, at a rate of not more than one increment per minute, until a trouble signal is obtained. The smoke alarm is to be tested for alarm operation at each resistance and voltage level and at the trouble voltage level. A number of voltage values shall be used to determine the shape of the trouble level curve.

d) Internal Resistance Increase With Constant Terminal Voltage – The voltage of the power supply is to be set at the battery rated voltage (terminal voltage of new battery under normal standby current drain) and the resistance increased from zero ohms until the smoke-alarm trouble signal is obtained. The rate of resistance change prior to the trouble point shall be reduced to a value required to eliminate any error due to any time lag in the trouble circuit of the smoke-alarm.

e) Terminal Voltage Decrease With Constant Internal Resistance – With the variable resistance set at zero ohms, the power supply voltage is to be decreased until the smoke-alarm trouble signal is obtained. The rate of voltage change prior to the trouble point shall be reduced to a value required to eliminate any error due to any time lag in the trouble circuit of the smoke-alarm.

f) Variable Internal Resistance With Variable Terminal Voltage – The test of (a) is to be repeated with the power supply voltage set to values equal to the 25 percent, 50 percent and 75 percent points of the voltage range determined in (b).

56.2.4 To determine that a battery is capable of supplying alarm and trouble signal power to the smoke alarm for at least 1 year under the room ambient condition described in Battery tests, 85.3. Curve A of Figure 56.2 is to be plotted from the data obtained in the measurements described in 56.2.3 and compared to Curve B of Figure 56.2, which is plotted from data generated in the 1 year battery test. The intersection of Curves A and B shall not occur before 1 year and all points of Curve B to the right of point F (extended to the base line), shall be below Curve A.

57 Overvoltage and Undervoltage Tests

57.1 Overvoltage test

57.1.1 A smoke alarm, other than one operating from a main battery power supply, shall operate as intended in the standby condition at maximum and minimum sensitivity settings and perform its intended signaling function, while connected to a supply source of 110 percent of the rated voltage. When a nominal rated voltage value is specified, the overvoltage shall be 110 percent of the rated voltage specified in 37.3, Test voltages. When an operating voltage range is specified, the overvoltage shall be either 110 percent of the high value of the rated voltage range or 110 percent of the rated voltage specified in 37.3, Test voltages, whichever is higher. Three samples are to be subjected to the specified increased voltage in the normal standby condition for at least 16 hours, or until stabilized temperatures have been reached, and then tested for normal signalling operation and sensitivity.

57.1.2 Sensitivity measurements at the increased voltage shall vary not more than specified in 38.3.1. For smoke-alarms intended to be energized from a separate power supply, as described in 35.1, Primary power supply, the overvoltage shall be applied to the input of the power supply.

57.1.3 For alarms intended for connection in a multiple station configuration, the minimum number of alarms specified by the installation instructions are to be interconnected with zero line resistance between alarms and tested for their intended operation.

57.2 Undervoltage test

57.2.1 An alarm shall operate for its intended signaling performance while energized from a supply of 85 percent of the test voltage specified by the manufacturer and while at both maximum and minimum sensitivity settings. For units powered from a primary battery, the test shall be conducted at the battery trouble signal voltage level. Sensitivity measurements at the reduced voltage shall vary not more than specified in 38.3.1 from the readings measured at rated voltage. Refer to Section 84, Audibility Test.

57.2.2 For smoke alarms intended for connection in a multiple station configuration, the maximum number of alarms specified by the installation instructions are to be interconnected with either 10 ohms resistance between alarms, or the maximum resistance specified in the installation instructions, and tested for intended operation.

57.2.3 When the smoke alarm is provided with a standby battery the test is to be conducted at 85 percent of the charged battery voltage. When the standby battery provides a trouble signal requiring replacement at higher than 85 percent of the charged battery voltage, the test is to be conducted at the battery trouble signal voltage level.

57.2.4 For operation at the reduced voltage, three smoke alarms are to be energized from a source of supply in accordance with 37.3.1, following which the voltage is to be reduced to 85 percent of the test voltage specified in 37.3.1 for AC operated smoke alarms, or the battery trouble level voltage for battery operated smoke alarms, and then tested for signaling operation and sensitivity. For units intended to be energized from a separate power supply, as described in 35.1, Primary power supply, the undervoltage shall be applied to the input of the power supply.

58 Temperature Test

58.1 The materials or components employed in a smoke alarm shall not be subjected to a temperature rise greater than the values indicated in Table 58.1, Maximum temperature rises, under any condition of intended operation.

Table 58.1
Maximum temperature rises

Materials and components	Normal standby,		(Signaling) alarm condition,	
	°C	(°F)	°C	(°F)
A. COMPONENTS				
1. Capacitors: [a, b]				
a. Electrolytic types	25	(45)	40	(72)
b. Other types	25	(45)	65	(117)
2. Rectifiers – At any point				
a. Germanium	25	(45)	50	(90)
b. Selenium	25	(45)	50	(90)
c. Silicon				
(i) Maximum 60 percent of rated voltage	50	(90)	75	(135)
(ii) 61 percent or more of rated voltage	25	(45)	75	(135)
3. Relay, solenoid, transformer, and other coils with:				
a. Class 105 insulation system:				
Thermocouple method	25	(45)	65	(117)
Resistance method	35	(63)	75	(135)

Table 58.1 Continued on Next Page

Table 58.1 Continued

Materials and components	Normal standby, °C	(°F)	(Signaling) alarm condition, °C	(°F)
b. Class 130 insulation system:				
Thermocouple method	45	(81)	85	(153)
Resistance method	55	(99)	95	(171)
c. Class 155 insulation system:				
(i) Class 2 transformers:				
Thermocouple method	95	(171)	95	(171)
Resistance method	115	(207)	115	(207)
(ii) Power transformers:				
Thermocouple method	110	(198)	110	(198)
Resistance method	115	(207)	115	(207)
d. Class 180 insulation system:				
(i) Class 2 transformers:				
Thermocouple method	115	(207)	115	(207)
Resistance method	135	(243)	135	(243)
(ii) Power transformers:				
Thermocouple method	125	(225)	125	(225)
Resistance method	135	(243)	135	(243)
4. Resistors:[c]				
a. Carbon	25	(45)	50	(90)
b. Wire wound	50	(90)	125	(225)
c. Other	25	(45)	50	(90)
5. Solid state devices	See footnote d			
6. Other components and materials:				
a. Fiber used as electrical insulation or cord bushings	25	(45)	65	(117)
b. Varnished cloth insulation	25	(45)	60	(108)
c. Thermoplastic materials	Rise based on temperature limit of the material			
d. Phenolic composition used as electrical insulation or as parts whose malfunction or deterioration results in a risk of electric shock, explosion, fire, or injury to persons[e]				
e. Wood or other combustibles	25	(45)	125	(225)
f. Sealing compound	25	(45)	65	(117)
g. Fuses	25	(45)	65	(117)
B. CONDUCTORS				
1. Appliance wiring material[f]	25 °C (45°F) less than the temperature limit of the wire			
2. Flexible cord (for example, SJO, SJT)	35	(63)	35	(63)
3. Conductors of field-wired circuits to be permanently connected to the product	35	(63)	35	(63)
C. GENERAL				
1. All surfaces of the product and surfaces adjacent to or upon which the product is be mounted	65	(117)	65	(17)
2. Surfaces normally contacted by the user in operating the unit (such as control knobs, push buttons, and levers):				
a. Metal	35	(63)	35	(63)
b. Nonmetallic	60	(108)	60	(108)
3. Surfaces subjected to casual contact by the user (such as the enclosure or grille):				

Table 58.1 Continued on Next Page

Table 58.1 Continued

Materials and components	Normal standby,		(Signaling) alarm condition,	
	°C	(°F)	°C	(°F)
a. Metal	45	(81)	45	(81)
b. Nonmetallic	65	(117)	65	(117)

[a] For an electrolytic capacitor which is physically integral with or attached to a motor, the temperature rise on insulating material integral with the capacitor enclosure shall not be more than 65°C (117°F).

[b] It is not prohibited to evaluate a capacitor which operates at a temperature higher than a 65°C (117°F) rise on the basis of its marked temperature rating.

[c] When the temperature rise of a resistor exceeds the values shown the power dissipation shall be 50 percent or less of the manufacturer's rating.

[d] The temperature of a solid-state device (for example, transistor, SCR, integrated circuits), shall not exceed 50 percent of its rating during the normal standby condition. The temperature of a solid-state device shall not exceed 75 percent of its rated temperature under the alarm condition or any other condition of operation which produces the maximum temperature dissipation of its components. For reference purposes 0°C (32°F) shall be identified as 0 percent. For integrated circuits the loading factor shall not exceed 50 percent of its rating under the normal standby condition and 75 percent under any other condition of operation. It is permissible that both solid-state devices and integrated circuits be operated up to the maximum ratings under any one of the following conditions:

1) The integrated circuit (microcircuits) complies with the requirements of MIL-STD.883H..

2) The semiconductor devices comply with the requirements of MIL-STD 750E.

3) A quality-control program is established by the manufacturer consisting of an inspection stress test followed by operation of 100 percent of all components, either on an individual basis, as part of a subassembly, or equivalent.

4) Each assembled production unit is subjected to a burn-in test, under the condition which results in the maximum temperatures, for 24 hours while connected to a source of rated voltage and frequency in an ambient of at least 49°C (120°F) followed by a Normal Operation Test, Section 38.

[e] The limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to compounds which have been investigated and determined to have special heat-resistant properties.

[f] For standard insulated conductors other than those mentioned, reference shall be made to the National Electrical Code, ANSI/NFPA 70, the maximum allowable temperature rise in any case is 25°C (45°F) less than the temperature limit of the wire in question.

58.2 Except as noted in 58.3, all values for temperature rises apply to equipment intended for use in prevailing ambient temperatures that usually are not higher than 23°C (73°F)

58.3 When equipment is intended specifically for use in a prevailing ambient temperature constantly more than 23°C (73°F), the test of the equipment is to be made at the higher ambient temperature, and allowable temperature rises specified in Table 58.1 shall be reduced by the amount of the difference between that higher ambient temperature and 23°C (73°F).

58.4 Temperature measurements on equipment intended for recessed mounting are to be made with the unit installed in an enclosure of nominal 3/4-in. (19.1-mm) wood having clearances of 2 in. (50 mm) on the top, sides and rear, and the front extended to be flush with the smoke alarm cover.

58.5 A temperature is determined to be constant when three successive readings, indicate no change, when taken at not less than 5-minute intervals.

58.6 Temperatures shall be measured by means of thermocouples consisting of 30 AWG (0.06 mm^2) wire. Measuring the temperature of a coil is to be accomplished by either the thermocouple or resistance method. The thermocouple method, however, is not to be employed for a temperature measurement at any point where supplementary thermal insulation is employed.

58.7 Thermocouples consisting of iron and constantan wires and a potentiometer-type indicating instrument shall be used whenever temperature measurements by thermocouples are required. The thermocouples shall be 30 AWG (0.06 mm^2) wire.

58.8 The thermocouple wire is to conform with the requirements for ″special″ thermocouples as listed in ASTM MNL12: Manual on the Use of Thermocouples in Temperature Measurement.

58.9 The temperature of a copper coil winding is to be determined by the resistance method by comparing the resistance of the winding at the temperature to be determined with the resistance at a known temperature by means of the equation:

$$T = \frac{R}{r}(234.5 + t) - 234.5$$

in which:

T is the temperature to be determined in degrees C,

R is the resistance in ohms at the temperature to be determined,

r is the resistance in ohms at the known temperature, and

t is the known temperature in degrees C.

58.10 As it is essential to de-energize the winding before measuring R, the value of R at shutdown is determined by taking several resistance measurements at short intervals, beginning as quickly as possible after the instant of shutdown. A curve of the resistance values and the time is plotted and extrapolated to give the value of R at shutdown.

58.11 The smoke alarm is to be connected to a source of supply as specified in 37.3, Test voltages, and operated under the conditions specified in (a) – (c):

a) STANDBY – (16 hours minimum). Constant temperatures,

b) ALARM – (1 hour), and

c) ALARM – (7 hours or to battery depletion) Abnormal test.

58.12 For test condition 58.11 (c), when the temperature limits are exceeded, there shall be no manifestation of a fire or impending malfunction, and the smoke alarm shall operate as intended following the test.

58.13 The smoke alarm is to be subjected to the Dielectric Voltage-Withstand Test, Section 77, following test 58.11 (b) or (c).

59 Vibration Test

59.1 A smoke alarm shall withstand vibration without breakage or damage to parts. Following the vibration the smoke alarm shall operate for its intended signaling operation.

59.2 To determine compliance with 59.1 following vibration as specified in 59.3, smoke sensitivity measurements using gray smoke/aerosol shall be conducted, in accordance with the Sensitivity Test, Section 42, and shall vary not more than specified in 38.3, Sensitivity shift criteria.

59.3 Two samples, one at the maximum and one at the minimum sensitivity setting, shall be secured in their intended mounting position on a wood mounting board which is to be securely bolted to a variable speed vibration machine having an amplitude of 0.01 in. (0.25 mm). The frequency of vibration is to be varied from 10 to 35 Hz in increments of 5 Hz until a resonant frequency is obtained. The samples then shall be vibrated at the maximum resonant frequency for a period of 1/4 hour. If a resonant frequency can not be achieved, the samples shall be vibrated at 35 Hz for a period of 4 hours.

59.4 For these tests, amplitude is defined as the maximum displacement of sinusoidal motion from a position of rest or 50 percent of the total table displacement. Resonance is defined as the maximum magnification of the applied vibration.

60 Replacement Test, Head and Covers

60.1 A smoke alarm employing a removable head or a cover that is intended to be attached or closed by a snap type action, shall withstand 50 cycles of removal and replacement or opening and closing the cover, and shall comply with the requirements of the Jarring Test, Section 61.

60.2 A smoke alarm is to be installed as intended in service and the cover or head removed and replaced, or opened and closed, as specified by the manufacturer. The unit is then to be subjected to the Jarring Test, Section 61.

61 Jarring Test

61.1 A smoke alarm shall withstand jarring resulting from impact and vibration such as that experienced in service, without causing an alarm or trouble signal, without dislodgment of any parts, and without impairing its subsequent operation.

Exception: Dislodgment of parts is acceptable if the dislodged part(s) does not affect the operation of the unit, and there are no high voltage parts exposed.

61.2 The smoke alarm and associated equipment, if any, shall be mounted in a position of intended use to the centre of a 6 by 4 ft. (1800 by 1200 mm), nominal 3/4 in. thick (nominal 19 mm thick) plywood board which is secured in place at four corners.

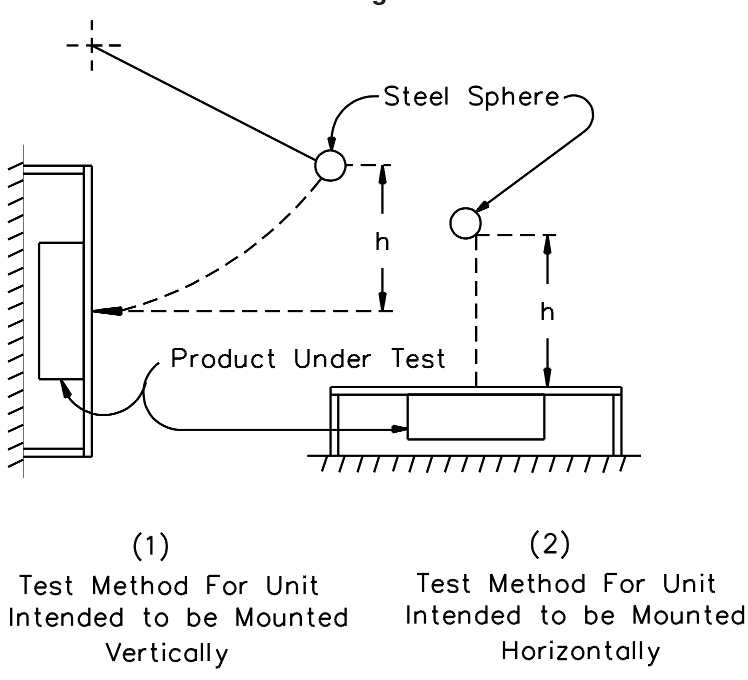
61.3 A 3.94 x 3.94 in. ±10 percent (100 by 100 mm ±10 percent) steel plate, 1/8 in. ±10 percent (3.2 mm ±10 percent) thick, shall be rigidly secured to the center of the reverse side of the board.

61.4 An impact of 3 foot-pounds (4.08 J) shall be applied once to the center of the reverse side of this board by means of a 1.18 lb. (540 g), 2 in. (50 mm) diameter steel sphere either:

a) Swung through a pendulum arc from a height of 2.54 ft. (775 mm) in order to apply 4.08 J of energy; or

b) Dropped from a height of 2.54 ft. (775 mm) to apply 3 foot-pounds (4.08 J) of energy, depending upon the mounting of the equipment (see Figure 61.1).

Figure 61.1
Jarring test



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61.5 The test is to be conducted by supporting the smoke alarm in its intended mounting position and conducting the jarring with the smoke alarm in the standby condition and connected to a rated source of supply in accordance with 37.3.1.

61.6 Following the jarring the smoke alarm shall be tested for sensitivity in accordance with Section 42, Sensitivity Test. Sensitivity measurements shall vary not more than specified in 38.3.

62 Variable Ambient Temperature Tests

62.1 Operation in high and low ambients

62.1.1 The smoke alarm shall operate for its intended performance. For products that identify an installation temperature below 0°C and above 38°C, the following ambient test conditions shall be applied:

a) Relative humidity = 30 to 50 percent;

b) Low temperature = proposed low end environmental ambient temperature (T_{LO})

c) High temperature = (T_{HI} – 38°C) + 49°C or (T_{HI} – 100°F) + 120°F

d) Where T_{LO} and T_{HI} are low and high end operating range respectively.

Otherwise, the smoke alarm shall operate for its intended performance when tested in an ambient temperature of 0° and 49°C (32° and 120° F).

62.1.2 Two smoke alarms, one at maximum and one at minimum sensitivity, are to be maintained at each ambient temperature for a minimum of 3 hours.

62.1.3 The smoke alarms are to be tested for sensitivity while connected to a source of supply in accordance with 37.3, Test voltages.

62.1.4 Sensitivity measurements shall be recorded before and during exposure to each ambient temperature in accordance with the Sensitivity Test, Section 42, except that:

a) The relationship between the MIC output and the percent light transmission remains within the limits represented by the curves illustrated in Figures 62.1 and 62.3 for the 0°C (32°F) and 49°C (120°F) ambient, respectively. The visible smoke buildup rates shall be maintained within the limits illustrated in Figures 62.2 and 62.4 for the 0°C (32°F) and 49°C (120°F) ambient, respectively.

Figure 62.1
Sensitivity test limits
0 °C ambient – gray smoke – cotton wick – 30 fpm

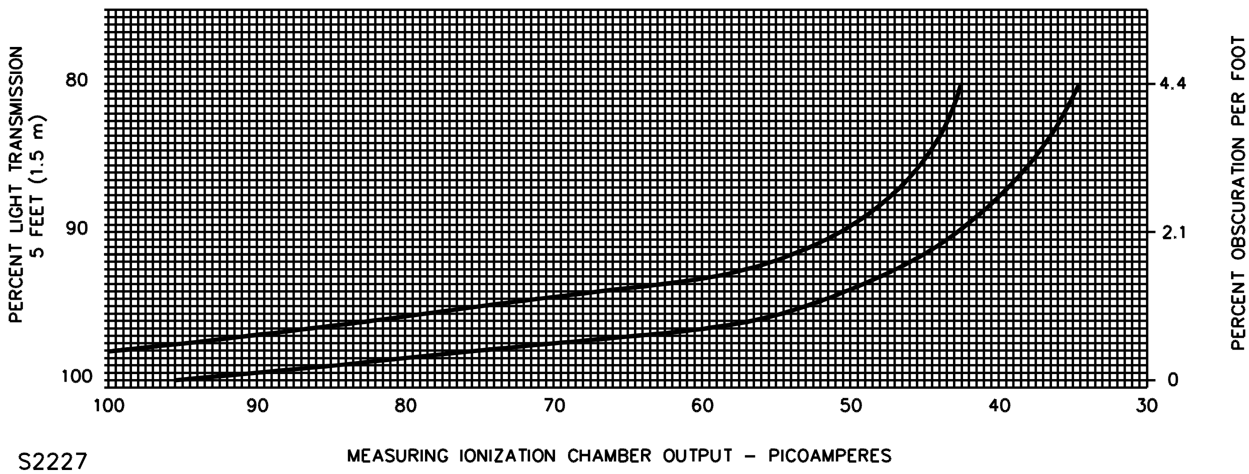


Figure 62.2
Smoke build-up rate – sensitivity test
0°C ambient smoke/aerosol 0.16 ±0.01 m/s (32 ±2 fpm)

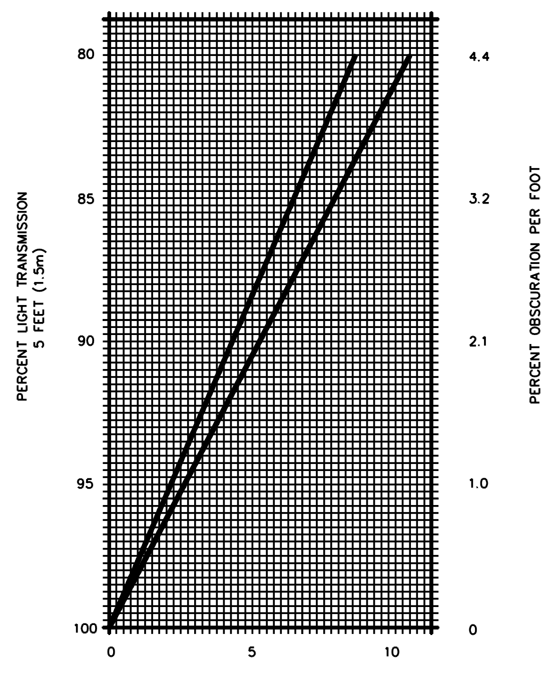
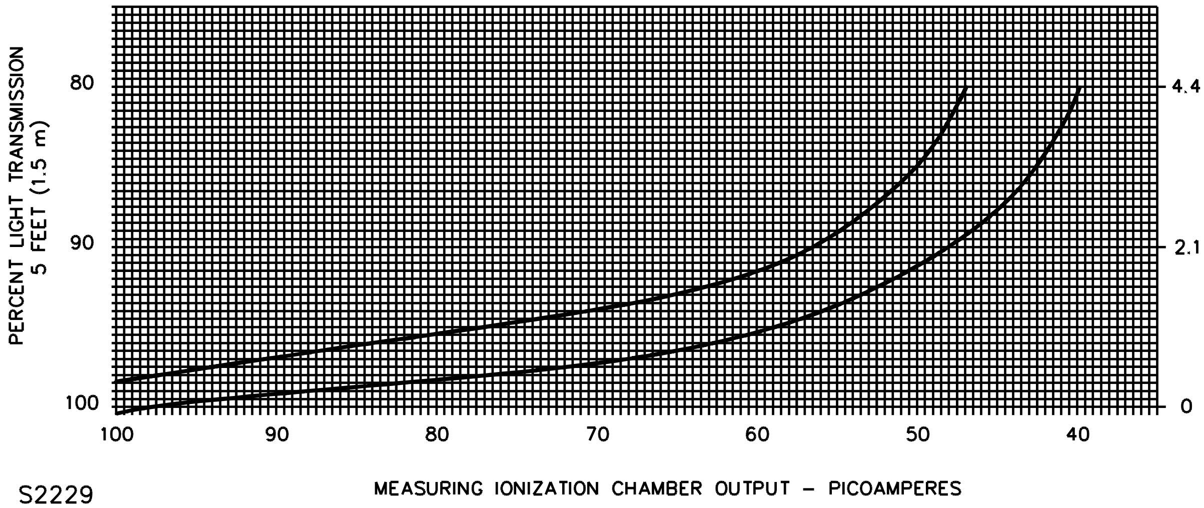
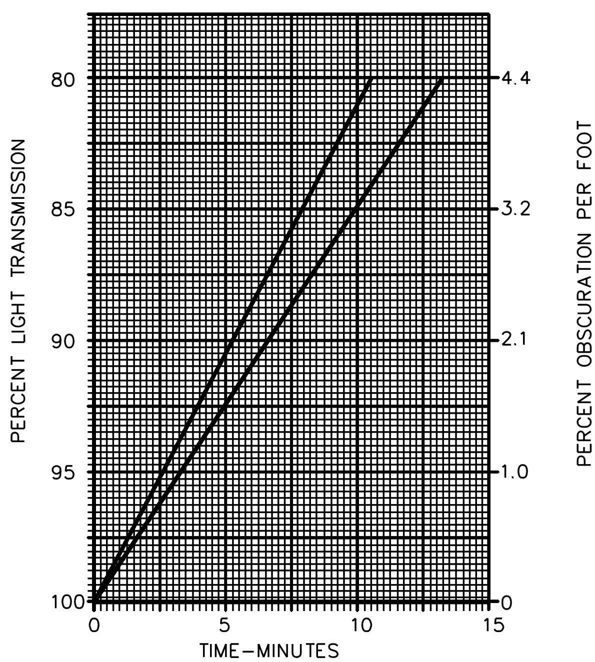


Figure 62.3
Sensitivity test limits
49°C ambient - gray smoke/aerosol 0.16 ±0.01 m/s (32 ±2 fpm)



S2229

Figure 62.4
Smoke build-up rate – sensitivity test
49°C ambient – gray smoke/aerosol 0.16 ±0.01 m/s (32 ±2 fpm)



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62.1.5 For products that identify an installation temperature below 0°C (32°F) and above 38°C (100°F) it is permissible to conduct the sensitivity test at 0°C and 49°C (120°F) after conditioning at the temperatures identified in 62.1.1. When conducting the transfer of the alarm between conditioning environments, the detector shall:

a) Be placed in an enclosure that was conditioned in the same environment as the alarm, such as a portable cooler,

b) The enclosure shall be closed, prior to opening the door of the test environment,

c) Then the enclosure containing the alarm shall be transferred between environments.

62.1.6 Both units shall operate normally in each ambient. Sensitivity measurements shall vary not more than specified in 38.3, Sensitivity shift criteria, and shall be in accordance with Section 42, Sensitivity Test.

62.2 Effect of shipping and storage – (single and multi-criteria smoke alarms)

62.2.1 The smoke sensitivity of a smoke alarm shall not be impaired by exposure to high and low temperatures representative of shipping and storage. The exposure shall not result in warping, cracking or any other physical or electronic damage, which would impair its operation in any way or its suitability for its intended use. The sensitivity of a smoke alarm shall not be impaired by exposure to high and low temperatures representative of shipping and storage. The exposure shall not result in warping, cracking or any other physical or electronic damage, which would impair its operation in any way or its suitability for its intended use.

62.2.2 Two smoke alarms, one at maximum and one at minimum smoke sensitivity, packaged as intended for shipping, shall be subjected, in turn, to a temperature of 70°C (158°F) for a period of 24 hours, allowed to cool to room temperature for at least 1 hour. The same two smoke alarms shall then be exposed to a temperature of minus 40°C (minus 40°F) for at least 3 hours, and then permitted to warm up to room temperature for a minimum of 3 hours. The same smoke alarms are then to be tested for sensitivity using gray smoke/aerosol while connected to a source of rated supply voltage in accordance with 37.3, Test voltages.

62.2.3 Sensitivity measurements shall be recorded, before and after exposure to both ambient conditions, in accordance with the Sensitivity Test, Section 42.

62.2.4 The sensitivity readings using gray smoke/aerosol measured after exposure shall comply with the requirements of the Sensitivity Test, Section 42, and shall vary not more than specified in 38.3, Sensitivity shift criteria.

62.3 Effect of shipping and storage – multi-criteria smoke alarms incorporating gas sensor(s)

62.3.1 The sensitivity of the gas sensor of a multi-criteria smoke alarm shall not be impaired by exposure to high and low temperatures representative of shipping and storage as well as storage in point-of-purchase packaging.

62.3.2 Two smoke alarms, in point of purchase packaging, one at maximum and one at minimum sensitivity, are to be subjected, in turn, to a temperature of 70°C (158°F) at 50 ±30 percent RH for a period of 24 hours, allowed to cool to room temperature for at least 1 hour.The same two smoke alarms shall then be exposed to a temperature of minus 40°C (minus 40°F) for at least 3 hours, and then warmed up to room ambient temperature for at least 3 hours. The same two samples are then to be subjected to 50 ±30 percent RH at 50°C for 45 days, or 50 ±30 percent RH at 55°C for 30 days, or 50 ±30 percent RH at 60°C for 20 days as selected by the manufacturer. The same smoke alarms are then tested for sensitivity per 42.2 while connected to a source of supply in accordance with 37.3.1.

62.3.3 Sensitivity measurements shall be recorded, before and after exposure to the ambient conditions in 62.3.2 and shall be in accordance with 42.8.

63 Humidity Test

63.1 High humidity

63.1.1 Two smoke alarms, one at maximum and one at minimum sensitivity, shall operate for their intended signaling performance when exposed for 168 hours to air having a relative humidity of 93 ±2 percent and a temperature of 40 ±2°C (104 ±4°F) while energized from a source of supply in accordance with 37.3.1. There shall not be false alarms during the exposure.

63.1.2 Gas and smoke sensitivity measurements shall be recorded before and during exposure to the humidity condition in accordance with the Sensitivity Test, Section 42.

63.1.3 The sensitivity values during exposure to the humid atmosphere shall vary not more than specified in Sensitivity shift criteria, 38.3.

63.2 Low humidity [multi-criteria smoke alarms with gas sensor(s)]

63.2.1 Two smoke alarms, one at maximum and one at minimum gas sensitivity, shall operate for their intended signaling performance when exposed for 168 hours to air having a relative humidity of 10 ±3 percent at a temperature of 22 ±3°C (72 ±5°F) while energized from a source of supply in accordance with 37.3.1.

63.2.2 Gas sensitivity measurements shall be recorded before and during exposure to the humidity condition. Gas sensitivity measurements shall not vary more than specified in the Sensitivity shift criteria, 38.3.1.

64 Corrosion Test

64.1 The alarms are to be tested for sensitivity prior to exposure to the corrosive atmospheres. Following the corrosion exposures described in 64.2 and 64.3, the smoke alarms are to be dried in a circulating air oven at a temperature of 40°C (104°F) for at least 24 hours after which the smoke alarms are to be again tested for sensitivity. The sensitivity shall not exceed the limits specified in the Sensitivity Test, Section 42.

64.2 An alarm shall operate as intended after being subjected to the corrosive atmosphere tests described in 64.3 and 64.4. The samples shall be placed in the test chambers that are located in a room having a temperature of 23 ±2 °C (73 ±4°F) and 20 – 50 percent relative humidity. The samples shall be mounted in their intended position of use on a platform 1 in. (25.4 mm) above the bottom. The relative humidity inside the chamber during the test is to be 93 ±2 percent. The samples are not to be energized during these tests.

64.3 Two samples, one at the maximum and one at the minimum sensitivity setting, are to be exposed to a moist hydrogen sulfide-air mixture as specified in 64.2, in a closed glass chamber for 10 days. The concentration of hydrogen sulphide by volume in air saturated with water vapor at room temperature is to be 1000 ±50 PPM (parts per million).

64.4 Two samples, one at maximum and one at minimum sensitivity setting, are to be exposed to a moist carbon dioxide-sulphur dioxide-air mixture as specified in 64.2 in a closed glass chamber for 10 days The concentration of carbon dioxide by volume in air saturated with water vapor at room temperature is to be 10 000 ±500 PPM (parts per million). The concentration of sulphur dioxide by volume in air saturated with water vapor at room temperature is to be 5000 ±250 PPM (parts per million).

64.5 Alarms are to be subjected to the corrosive atmospheres while de-energized so as not to produce an alarm signal. Battery operated alarms are to be tested with the batteries in place, and the leads to the clips disconnected for the same reason. After the exposure the leads are to be reconnected and the Sensitivity Test, Section 42, is to be conducted.

65 Alternate Corrosion Test (21-Day)

65.1 The 21-day corrosion test outlined in 65.2 – 65.4 may be conducted in lieu of the Corrosion Test, Section 64.

65.2 Two alarm samples, one at maximum and one at minimum sensitivity setting, are to be placed in a 200 liter or larger test chamber on a platform approximately 2 in. (50.8 mm) above the bottom of the chamber. The temperature in the chamber shall be maintained at 30 ±2°C (86 ±3°F) and the relative humidity at 70 ±2 percent (measured directly in the chamber). The temperature and humidity are to be checked daily. Because of the corrosive atmosphere a set of wet and dry bulb thermometers shall be used for measurement of relative humidity.

65.3 The following gas mixture in air is to be supplied to the chamber at a rate sufficient to achieve an air exchange in the chamber of about five times per hour, for a period of 3 weeks: 100±10 parts per billion (ppb) (parts per billion = parts per 10^9 by volume) hydrogen sulfide (H_2S) plus 20 ±5 ppb chlorine (Cl_2) plus 200 ±50 ppb nitrogen dioxide (NO_2). The air inside the chamber is to be circulated by a single fan, with flow upwards from the bottom.

65.4 Following this test, the alarms shall comply with the sensitivity requirements of the Sensitivity Test, Section 42.

66 Transient Tests

66.1 General

66.1.1 Two smoke alarms, one at maximum and one at minimum sensitivity:

a) Shall operate for their intended signaling performance,

b) Shall not initiate a smoke alarm signal,

c) Shall not initiate a trouble signal, and

d) The sensitivity shall be in accordance with (Sensitivity Shift Criteria) after being subjected to 500 internally induced transients in 66.2, extraneous transients in 66.3, 500 (hazardous-voltage) supply line transients in 66.6, supply line (extra-low-voltage) circuit transients in 66.7, while energized from a source of supply as specified in Table 37.3, Test voltages, and connected to the devices intended to be used with the alarm. Smoke alarms using a primary battery as a power supply are to be subjected to the extraneous transients test only. When a smoke alarm is intended for multiple-station connection, the transient tests are to be first conducted with an individual smoke alarm, and secondly with two interconnected smoke alarms. The interconnecting wiring shall not exceed 12 in. (300 mm).

66.1.2 Different smoke alarms are to be used for each test. The smoke alarms shall not false alarm for more than 1 second.

66.2 Internally induced transients

66.2.1 The alarm is to be energized in the standby condition from a source of supply as specified in Table 37.3, Test voltages. The supply is to be interrupted a total of 500 cycles for 1 second at a rate of not more than 6 cycles/min. Following the test the alarm is to be operated for its intended signaling performance and the alarm shall be tested for sensitivity. Following this test, the alarm shall comply with the requirements of Section 42, Sensitivity Test, and shall vary not more than specified in 38.3, Sensitivity shift criteria.

66.3 Extraneous transients

66.3.1 A smoke alarm shall not false alarm nor shall its intended operation be impaired when subjected to extraneous transients generated by the devices and appliances described in 66.3.2.

66.3.2 The alarm shall respond to smoke or other aerosol during application of the transient condition.

66.3.3 To determine compliance with 66.3.1, two single and two sets of multiple station smoke alarms are to be energized from a source of rated voltage and frequency and subjected to transients generated from the following devices located 300 mm from the alarm, interconnecting wires, or both. The time of application for condition (b) shall be at least 2 minutes. Conditions (c), (d), and (e) are to be applied for 10 cycles, each application of 2 seconds duration, except the last application shall be of a 2-minute duration. Near the end of the last cycle, an abnormal amount of smoke or other aerosol is to be introduced into the alarm chamber to determine whether the unit is operational for smoke with the transient applied.

a) Energization and transmission of random voice message of transmitter-receiver units in turn, each having a 5 watt output and operating in the following nominal frequencies:

1) 27 megahertz,

2) 150 megahertz,

3) 450 megahertz,

4) 866 megahertz, and

5) 910 megahertz.

A total of six energizations in each of two orientations are to be applied from each transmitter-receiver; five to consist of 5 seconds on and 5 seconds off, followed by one consisting of a single 15-second energization. For this test, the cellular phones are to be in the same room and on the same plane as the alarm under test. The cellular phones are to be positioned to generate a field strength of 20 volts/meter at the power sensing antenna adjacent to the smoke alarm under test. The test is to be conducted with the antenna tip pointed directly at the smoke alarm, and at a right angle to the first position, centered on the alarm.

b) Sequential arc (Jacob's ladder) generated between two 15 in. (381 mm) long, 14 AWG (2.1 mm^2) solid copper conductors attached rigidly in a vertical position to the output terminals of an oil burner ignition transformer or gas tube transformer rated 120 volts, 60 Hz primary; 10,000 volts, 60 Hz, 23 milliamperes secondary. The two wires are to be formed in a taper, starting with an 1/8 in. (3.2 mm) separation at the bottom (adjacent to terminals) and extending to 1-1/4 in. (31.8 mm) at the top.

c) Energization of an electric drill rated 120 volts, 60 Hz, 2.5 amperes.

d) Energization of a soldering gun rated 120 volts, 60 Hz, 2.5 amperes.

e) Energization of a 6-in. (152-mm) diameter solenoid-type vibrating bell[c] with no arc suppression and rated 24 volts DC.

At the conclusion of the test series, the smoke alarm shall comply with the requirements of the Normal Operation Test, Section 38, and the Sensitivity Test, Section 42.

[c]Edwards, Model 439D-6AW, vibrating bell rated 0.075 ampere, 20/24 volt DC or equivalent.

66.4 Surge immunity test (combination wave)

66.4.1 The smoke alarm shall be subjected to the Surge Immunity Test without demonstrating, either during or after testing, any of the following:

a) Emission of flame, molten metal, glowing or flaming particles through any openings (preexisting or created as a result of the test) in the product;

b) Ignition of the enclosure; nor

c) Creation of any opening in the enclosure that results in energized parts becoming accessible.

66.4.1 effective August 4, 2015

66.4.2 The test method is to be conducted in accordance with the testing methods described in IEC 61000-4-5, Electromagnetic Compatibility (EMC) Part 4-5: Testing and Measurements Techniques – Surge Immunity Test. The surges (five positive and five negative) are to be applied at phase angles of 90 and 270 electrical degrees.

66.4.3 The surge impulse test levels in Table 66.1 are to be used (combination 1.2/50 µs, 8/20 µs Voltage/Current surge waveform). A separate smoke alarm shall be used for each surge level.

Table 66.1
Surge impulse levels

Peak voltage (kV)	Peak current (kA)
2	1
4	2
6	3

66.4.4 At the conclusion of the test, the alarm is to comply with the requirements of the Normal Operation Test, Section 38, and the Sensitivity Test, Section 42.

66.5 Surge current test

66.5.1 Each of three previously untested representative devices of the smoke alarm are to be subjected to the Surge Current Test without demonstrating, either during or after testing, any of the following:

a) Emission of flame, molten metal, glowing or flaming particles through any openings (preexisting or created as a result of the test) in the product;

b) Charring, glowing, or flaming of the supporting surface, tissue paper, or cheesecloth;

c) Ignition of the enclosure; nor

d) Creation of any opening in the enclosure that results in energized parts becoming accessible

66.5.2 The smoke alarm is to be mounted on a ceiling surface covered with a double layer of white tissue paper. Each smoke alarm is to be loosely draped with a double layer of cheesecloth. The cheesecloth shall cover openings (for example, ventilation openings) where flame, molten metal, or other particles are not prohibited from being expelled as a result of the test. During this test it is not intended that the cheesecloth be deliberately pushed into any openings.

66.5.3 A permanently-connected smoke alarm shall be connected to a source of supply in accordance with 37.3, Test voltages, and shall be subjected to a surge of 20 kV ±10 percent at 10 kA ±10 percent. The surge shall be a combination 1.2/50 µs, 8/20 µs voltage/current surge waveform. The polarity of the impulses shall be one positive applied at a phase angle of 90 degrees (+0, -15) and one negative applied at a phase angle of 90 degrees (+0, -15).

66.6 Supply line (ring wave surge voltage) transients

66.6.1 An alarm intended to be powered from commercial AC power shall be subject to supply line transients induced directly between the power supply circuit conductors of the alarm under test.

66.6.2 For this test, the product is to be connected to a transient generator capable of producing the Location Category A, 100 kHz Ring Wave transient as defined in ANSI/IEEE C62.41, IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.

66.6.3 Each unit is to be subjected to 500 oscillatory transient pulses induced at an average rate of 3 pulses every minute. Each transient pulse is to be induced 90 degrees into the positive half of the 60 Hz cycle. A total of 250 pulses are to be applied so that the polarity of the transients is positive with reference to earth ground, and the remaining 250 pulses are to be negative with respect to earth ground.

66.6.4 The alarm is to be subjected to 500 oscillatory transient pulses a rate of 6 cycles/min. Each transient pulse is to be induced 90 degrees into the positive half of the 60 Hz cycle.

66.6.5 At the conclusion of the test, the smoke alarm shall comply with the requirements of the Normal Operation Test, Section 38, the requirements of the Sensitivity Test, Section 42, and shall not vary more than the limits specified in 38.3.1.

66.7 Supply line (extra-low-voltage circuit) transients

66.7.1 Each of two extra-low-voltage smoke alarms are to be subjected to 60 transient voltage pulses. The pulses are to be induced into:

a) The alarm circuit intended to be connected to the extra-low-voltage initiating device circuit of a system control unit and

b) The extra-low-voltage power supply circuit of the alarm.

66.7.2 For this test, each circuit is to be subjected to five different transient waveforms having peak voltage levels in the range of 100 to 2400 volts, as delivered into a 200 ohm load. A transient waveform at 2400 volts shall have a pulse rise time of 100 volts per microsecond, a pulse duration of 80 microseconds, and an energy level of 1.2 joules. Other applied transients shall have peak voltages representative of the entire range of 100 to 2400 volts, with pulse durations from 80 to 110 microseconds, and energy levels not less than 0.3 joule or greater than 1.2 joules.

66.7.3 The alarm is to be subjected to 60 transient pulses induced at the rate of six pulses per minute as follows:

a) Twenty pulses (two at each transient voltage level specified in 66.7.2) between each circuit lead or terminal and earth ground, consisting of ten pulses of one polarity, and ten of the opposite polarity (total of 40 pulses) and

b) Twenty pulses (two at each transient voltage level specified in 66.7.2) between any two circuit leads or terminals consisting of ten pulses of one polarity and ten of the opposite polarity.

66.7.4 At the conclusion of the test, the alarm shall comply with the requirements of the Normal Operation Test, Section 38, and the Sensitivity Test, Section 42.

67 Static Discharge Test

67.1 The intended performance of an alarm shall not be impaired or a false alarm obtained, when the alarm is subjected to static electric discharges. Operation of the trouble circuit during this test shall not be considered a malfunction, when the subsequent intended operation is not affected. The test is to be conducted in an ambient temperature of 23 ±3°C (73.4 ±5°F) at a relative humidity of 10 ±5 percent and a barometric pressure of not less than 700 mm of mercury (193.5 kPa). The alarm is permitted to sound for 5 seconds or less during the test.

67.2 Each of two alarms, one at maximum and one at minimum sensitivity, is to be mounted on the underside of a 3/4-in. (18.1-mm) thick plywood panel in its intended mounting position and connected to a source of supply in accordance with 37.1, Test units. When an alarm is intended to be installed on a metal back box, the box is to be connected to earth ground. A 250 picofarad low leakage capacitor, rated 10,000 volts DC, is to be connected to two high voltage, hazardous-voltage insulated leads, 3 ft. (0.9 m) long, stripped 1 in. (25.4 mm) at each end. A 1500 ohm resistor is to be inserted in series with one lead. The end of each lead is to be attached to a 1/2-in. (12.7-mm) diameter metal test probe with a spherical end mounted on an insulating rod. The capacitor is to be charged by touching the ends of the test leads to a source of 10,000 volts DC for at least 2 seconds for each discharge. One probe is to be first touched to the alarm and the other probe then touched to earth ground. An electrostatic voltmeter is to be employed to measure the voltage and is to be removed prior to conducting the discharge.

67.3 Ten discharges are to be applied to different points on the exposed surface of the alarm, recharging the capacitors for each discharge. Five discharges are to be made with one lead connected to earth ground and the other lead probed on the smoke alarm surface followed by five discharges with the polarity reversed. For an alarm intended to be serviced by the consumer, ten additional discharges are to be applied on all internal parts that are able to be contacted during servicing. Discharges inside the smoke alarm are not to be applied when the smoke alarm is not intended to be serviced in the field and is marked to be returned to the factory for servicing.

67.4 Following the discharges, the alarm is to be tested for normal operation and sensitivity. Sensitivity shall be in accordance with the requirements of Section 42, Sensitivity Test, and shall vary not more than specified in 38.3, Sensitivity shift criteria.

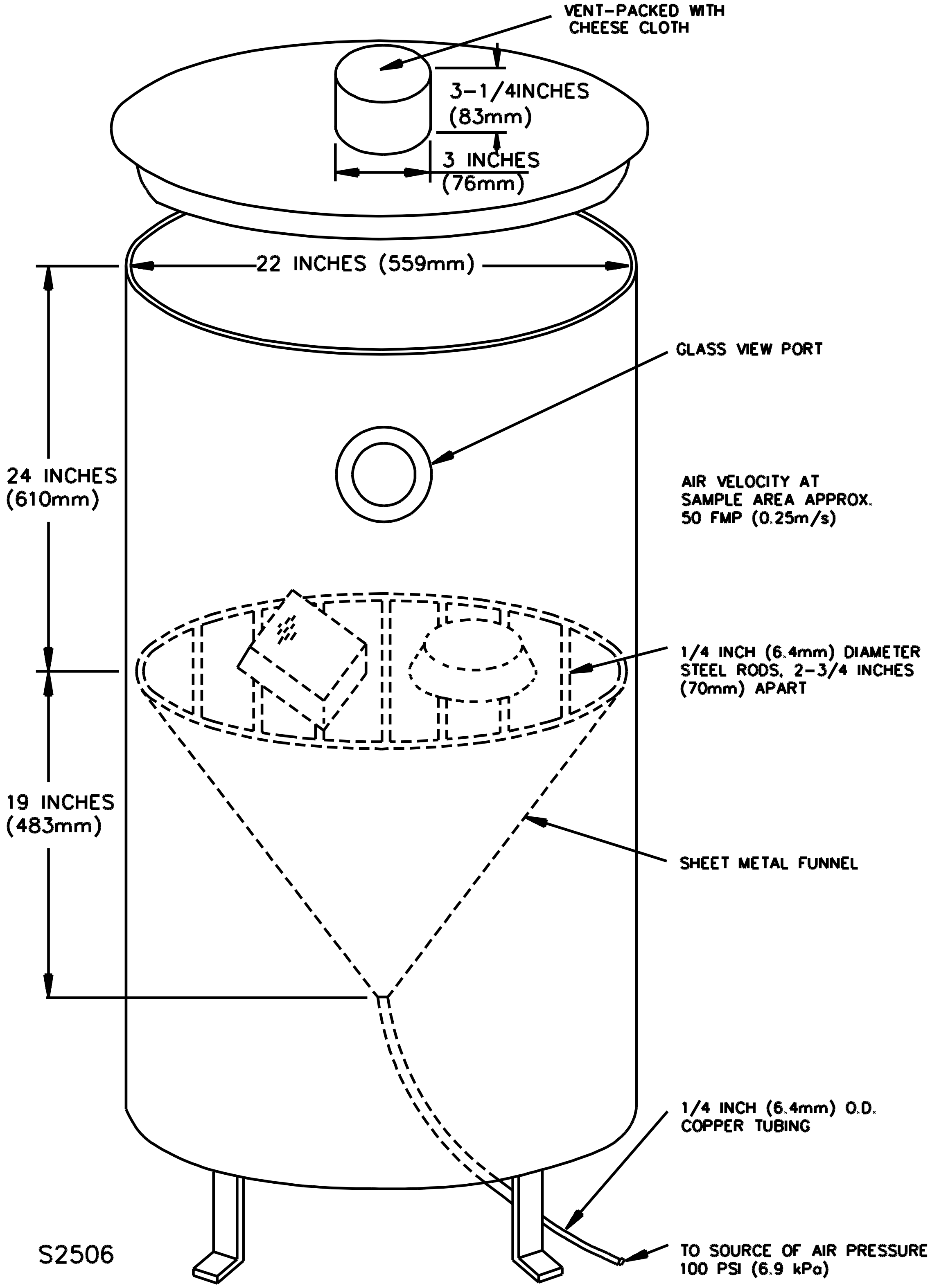
68 Dust Test

68.1 The smoke alarm samples subjected to the Go/no-go field test, 85.1, shall be used for the dust test.

68.2 The smoke sensitivity of a smoke alarm shall be evaluated in conformance with the requirements of 68.2 through 68.4. Energization and operation of the alarm or trouble circuit is permitted.

68.3 To determine compliance with 68.2, two samples, one at maximum and one at minimum smoke sensitivity, are to be placed in the normal mounting positions, de-energized, on metal supports in a chamber having an internal volume of at least 3 ft^3 (0.09 m^3). See Figure 68.1, Dust test chamber, as an example.

Figure 68.1
Dust test chamber



68.4 2.1 ± 0.1 oz. (60 ± 3 g) of cement dust, maintained in an ambient room temperature of 23 ±2°C (73.4 ±3°F) at 20 – 50 percent relative humidity and capable of passing through a 200 mesh screen, are to be circulated for 15 minutes by means of compressed air or a blower so as to completely envelop the sample in the chamber. The air flow is to be maintained at an air velocity of at least 50 fpm (0.25 m/s).

68.5 Following the exposure to dust the smoke alarm is to be removed carefully, mounted in its intended position, energized from a source of supply in accordance with Table 37.3, Test voltages, and tested for smoke sensitivity, using gray smoke/aerosol, unless a trouble signal or false alarm is obtained. Following exposure to dust:

a) Acceptable modes of operation are:

1) Trouble signals;

2) Alarm signals; or

3) Smoke sensitivity measurement which is more sensitive than the least sensitive limit.

b) Failure modes are:

1) Inoperative test switch; or

2) Smoke sensitivity measurements less sensitive than the least sensitive limit.

Refer to manufacturer's published instructions for cleaning or replacement information.

Following this test, the alarm shall comply with the requirements of Section 42, Sensitivity Test, and shall vary not more than specified in 38.3.

69 Overload Tests

69.1 Smoke alarm

69.1.1 A smoke alarm other than that operating from a primary battery shall be capable of operating as intended after being subjected to 50 cycles of alarm signal operation at a rate of not more than 6 cycles per minute with the supply circuit to the smoke alarm at 115 percent of the rated test voltage. Each cycle shall consist of starting with the smoke alarm energized in the standby condition, initiation of an alarm by smoke or equivalent means, and restoration of the smoke alarm to standby.

69.1.2 Rated test loads are to be connected to the output circuits of the smoke alarm that is energized from the smoke alarm power supply. The test loads are to be those devices, as specified by the manufacturer, such as remote indicators, relays, and the like, or their equivalent, intended for connection. When the equivalent load consists of an inductive load, a power factor of 60 percent shall be employed. The rated loads shall be established initially with the smoke alarm connected to a source of supply as specified in 37.3, Test voltages, following which the voltage shall be increased to 115 percent of the smoke alarms stated nominal voltage rating.

69.1.3 A multiple-station type smoke alarm shall be tested while interconnected with the maximum number of units specified and all units supplied by 115 percent of the smoke alarms stated nominal voltage rating.

69.1.4 For direct current rated signaling circuits, an equivalent inductive test load is to have the required DC resistance for the test current and the inductance (calibrated) to obtain a power factor of 60 percent when connected to a 60 Hz potential equal to the rated DC test voltage. When the inductive load has both the required DC resistance and the required inductance, the current measured with the load connected to an AC circuit is equal to 0.6 times the current measured with the load connected to a DC circuit when the voltage of each circuit is the same.

69.2 Separately energized circuits

69.2.1 Separately energized circuits of a smoke alarm, such as dry contacts, shall operate as intended after being subjected for 50 cycles of signal operation at a rate of not more than 6 cycles/min while connected to a source of supply in accordance with the requirements specified in 37.3, Test voltages, with 150 percent rated loads at 60 percent power factor applied to output circuits that do not receive energy from the smoke alarm. There shall be no electrical or mechanical malfunction of the switching circuit.

69.2.2 The test loads shall be adjusted to carry 150 percent of rated current while connected to a separate source of supply as specified in 37.3, Test voltages.

70 Endurance Test

70.1 Smoke alarm

70.1.1 Following the Overload Test – Smoke alarm (69.1), a smoke alarm shall operate as intended after being subjected to 6000 cycles of the complete alarm/test signal operation, at a rate of not more than 10 cycles per minute, with the smoke alarm connected to a source of supply in accordance with Table 37.1, Visible smoke obscuration limits (gray smoke), and with related devices or equivalent loads connected to the output circuits. There shall not be electrical or mechanical failure or evidence of failure of the smoke alarm components. It is acceptable for battery operated units to be connected to an equivalent filtered DC power supply source for this test.

70.1.2 Sensitivity measurements are to be recorded before and after the Endurance Test, in accordance with the Sensitivity Test, Section 42. The sensitivity values shall vary not more than specified in 38.3.

70.2 Separately energized circuits

70.2.1 Following the overload test of separately energized circuits (69.2), the separately energized circuits of a smoke alarm shall operate as intended, when operated for 6000 cycles at a rate of not more than 10 cycles per minute at a 50 percent duty cycle. When an electrical load is involved, the contacts of the device shall be made to make and break the normal current at the voltage specified by 37.3, Test voltages. The load is to represent that which the device is intended to control. The Endurance Tests of the separately energized circuits shall be conducted either separately or in conjunction with the Endurance Test of the smoke alarm. There shall not be electrical or mechanical malfunction of the smoke alarm nor malfunction or welding of any relay contacts.

Exception: When the contact rating is at least twice that of the load controlled, this test is not required.

70.3 Audible signaling appliance

70.3.1 The internal and/or external audible signaling appliance associated with each of two smoke alarms shall operate as intended when the smoke alarms are operated for 8 hours of alternate 5-minute periods of activation and de-activation of the audible alarm signal, followed by 72 hours of continuous activation of the alarm signal. For this test, the smoke alarms shall be connected to a source of rated voltage and frequency. For a battery operated smoke alarm, a filtered DC supply shall be employed that has an output voltage equivalent to the fresh battery voltage. The sound level output following endurance shall meet the requirements of Section 84, Audibility Test.

70.4 Test means

70.4.1 A sensitivity adjustment switch, test means, alarm silencing means, or reset switch provided on a smoke alarm shall operate as intended after being operated for 1500 cycles at the rate of not more than 10 cycles per minute. The time of actuation of a test means is to be long enough to obtain at least 1 test sequence of alarm. For this test one smoke alarm is to be connected to a rated source of supply voltage and frequency. This test shall be conducted either separately or in conjunction with the Endurance Test of the smoke alarm.

71 Fire Test – Smoke Alarm with Heat Detection

71.1 A heat detector, provided as part of a smoke alarm assembly, shall comply with the Standard for Heat Detectors for Fire Protective Signaling Systems, UL 521. It shall be sensitive enough to qualify for at least a 50 ft. (15.2 m) spacing when subjected to the Fire Tests described in UL 521.

71.2 Two samples of the smoke alarm incorporating the heat detector shall be subjected to the Fire Tests described in the Standard for Heat Detectors for Fire Protective Signaling Systems, UL 521, while installed on a 50-ft. (15.2-m) spacing.

72 Fire Test – Smoke Alarm with Supplementary Heat Detection

72.1 The smoke alarm with supplementary heat detection shall comply with:

a) The operation temperature test for a fixed temperature device; and/or

b) The rate of rise test for devices that incorporate a rate of rise feature

as specified in the Standard for Single and Multiple Station Heat Alarms, UL 539

72.2 The smoke alarm with supplementary heat detection shall be sensitive enough to qualify for at least a 50 ft. (15.2 m) spacing when subjected to the Fire Test described in the Standard for Single and Multiple Station Heat Alarms, UL 539.

72.3 Two samples of the smoke alarm incorporating the heat detector shall be subjected to this test.

73 Leakage Current Test

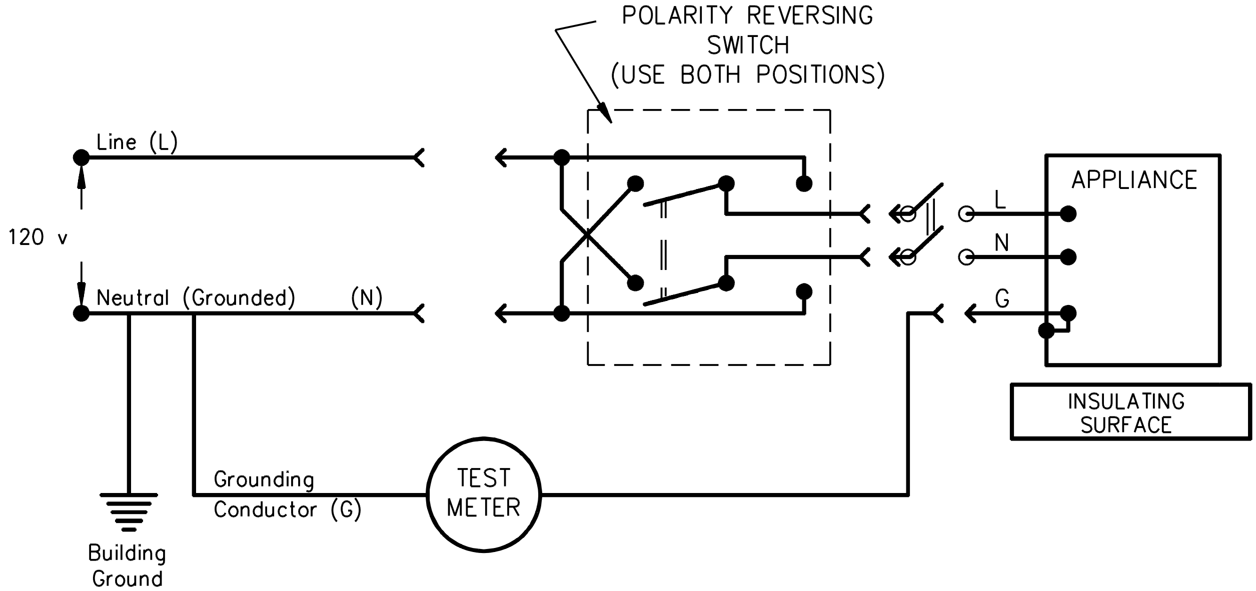
73.1 The leakage current of an alarm not operating from a primary battery shall not exceed 0.5 milliampere, AC or DC, after being subjected to the Humidity Test, Section 63, when measured as follows:

a) Between any exposed surface of an alarm that is contacted by a person and earth ground, and

b) Between any interior parts of an alarm that are contacted by a person during servicing and earth ground.

All grounding connections to the unit being tested are to be disconnected prior to making the measurement. The leakage current measurement is to be made at the supply connection polarity indicated on the installation wiring diagram by the manufacturer on the smoke alarm and at the same locations with the polarity reversed. See Figure 73.1, Leakage current measurement circuit.

Figure 73.1
Leakage current measurement circuit



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73.2 For this test the alarm is to be de-energized, removed from the humidity environment, placed on a dry insulating surface, and immediately reenergized from a rated source of supply. The leakage measurement then is to be made within 5 minutes of energization while in the standby and alarm conditions. The leakage current value is to be rms values for DC (nonfiltered rectified AC) and sinusoidal waveforms up to 1 kilohertz. For frequencies above 1 kilohertz the leakage current limit is to be the value given multiplied by the frequency in kilohertz up to a maximum multiplier of 100.

73.3 The test meter employed to measure the leakage current is to be an average responding AC milliammeter that indicates the rms value of a pure sine wave, having an error of not greater than 5 percent, and a maximum input impedance of 1000 ohms. For DC measurements, a DC milliammeter, with a maximum impedance of 1000 ohms in the test circuit, is to be employed.

73.4 When a conductive surface other than metal is used for the enclosure or part of the enclosure, the leakage current is to be measured using a metal foil with an area of 4 by 8 in. (10 by 20 cm) placed in contact with the enclosure surface. Where the enclosure surface is less than 4 by 8 in. (10 by 20 cm), the metal foil is to be the same size as the surface. It is not intended that the metal foil be pressed into openings on the smoke alarm during this test and the metal foil should not remain in place long enough to affect the temperature of the sample.

73.5 When an alarm is intended for multiple station connection, leakage currents are to be measured with the maximum number of alarms intended to be interconnected, unless it is established by circuit analysis that the leakage current is independent of interconnection.

74 Abnormal Operation Test

74.1 A smoke alarm shall operate continuously under abnormal (fault) conditions without resulting in a risk of fire.

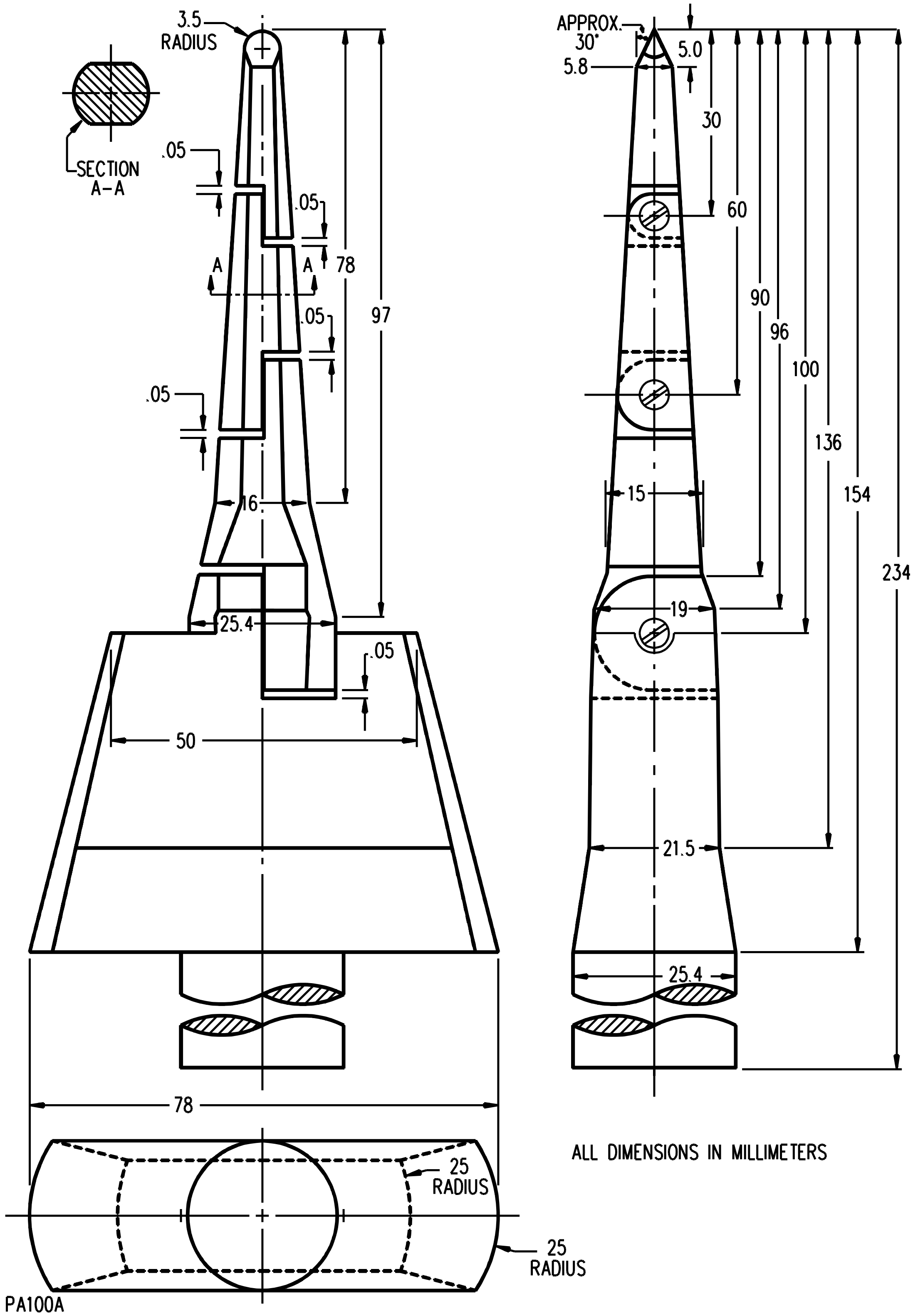
74.2 The smoke alarm is to be operated under the most severe abnormal circuit fault conditions encountered in service while connected to a source of supply as specified in Table 37.3, Test voltages. There shall not be emission of flame or molten metal, or any other manifestation of a fire.

74.3 During this test, the fault condition is to be maintained continuously until constant temperatures are attained, or burnout occurs, when the fault condition does not result in the operation of an overload protective device. The shorting of an electrolytic capacitor(s) and operation in the alarm condition for more than 1 hour represents typical abnormal conditions. See 41.2 and 66.1.1.

75 Electric Shock Current Test

75.1 If the open circuit potential between any part that may be contacted by the probe shown in Figure 75.1 either during normal operation or during operator servicing (servicing as defined in the operating or installation instruction) and either earth ground or any other exposed accessible part, exceeds 42.4 volts peak, then the part shall comply with the requirements of 75.2 and 75.4.

Figure 75.1
Articulated probe



75.2 The continuous current flow through a 500-ohm resistor shall not exceed the values specified in Table 75.1, Maximum current during operator servicing, when the resistor is connected between any part that is exposed only during operator servicing and either earth ground or any other exposed accessible part.

Table 75.1
Maximum current during operator servicing

Frequency, hertz[a]	Maximum current through a 500-ohm resistor, milliamperes peak
0 – 100	7.1
500	9.4
1000	11.0
2000	14.1
3000	17.3
4000	19.6
5000	22.0
6000	25.1
7000 or more	27.5

[a] Linear interpolation between adjacent values may be used to determine the maximum allowable current corresponding to frequencies not shown. The table applies to repetitive nonsinusoidal or sinusoidal waveforms.

75.3 The duration of a transient current flowing through a 500-ohm resistor connected as described in 75.2 shall not exceed the following:

a) The value determined by the following equation:

$$T \le \left(\frac{20\sqrt{2}}{I}\right)^{1.43}$$

in which:

T is the interval, in seconds, between the time that the instantaneous value of the current first exceeds 7.1 milliamperes and the time that the current falls below 7.1 milliamperes for the last time;

I is the peak current in milliamperes; and

b) 809 milliamperes, regardless of duration.

The interval between occurrences shall be equal to or greater than 60 seconds if the current is repetitive. Typical calculated values of maximum acceptable transient current duration are shown in Table 75.2, Maximum transient current duration.

Table 75.2
Maximum transient current duration

Maximum peak current (I) through 500-ohm resistor, milliamperes	Maximum duration (T) of waveform containing excursions greater than 7.1 milliamperes peak, seconds
7.1	7.22
8.5	5.58
10.0	4.42
12.5	3.21
15.0	2.48
17.5	1.99
20.0	1.64
22.5	1.39
25.0	1.19
30.0	0.919
40.0	0.609
50.0	0.443
60.0	0.341
70.0	0.274
80.0	0.226
90.0	0.191
100.0	0.164
150.0	0.092
200.0	0.061
250.0	0.044
300.0	0.034
350.0	0.027
400.0	0.023
450.0	0.019
500.0	0.016
600.0	0.013
700.0	0.010
809.0	0.0083

75.4 The maximum capacitance between the terminals of a capacitor that is accessible during operator servicing shall comply with the following equations:

$$C = \frac{88{,}400}{E^{1.43}(Ln\ E - 1.26)} \quad for\ \ 42.4 \leq E \leq 400$$

$$C = 35{,}288 E^{-1.5364} \quad for\ \ 400 \leq E \leq 1000$$

in which:

C is the maximum capacitance of the capacitor in microfarads and

E is the potential in volts across the capacitor prior to discharge; E is to be measured 5 seconds after the capacitor terminals are made accessible, such as by the removal or opening of an interlocked cover, or the like.

Typical calculated values of maximum capacitance in microfarads are shown in Table 75.3, Electric shock – stored energy.

Table 75.3
Electric shock – stored energy

Potential across capacitance prior to discharge, volts	Maximum capacitance, microfarads
1000	0.868
900	1.02
800	1.22
700	1.50
600	1.90
500	2.52
400	3.55
380	3.86
360	4.22
340	4.64
320	5.13
300	5.71
280	6.40
260	7.24
240	8.27
220	9.56
200	11.2
180	13.4
160	16.3
140	20.5
120	26.7
100	36.5

Table 75.3 Continued on Next Page

Table 75.3 Continued

Potential across capacitance prior to discharge, volts	Maximum capacitance, microfarads
90	43.8
80	53.8
70	68.0
60	89.4
50	124.00
45	150.00
42.4	169.00

75.5 With reference to the requirements in 75.2 and 75.3, the current is to be measured while the resistor is connected between ground and each accessible part individually or all accessible parts collectively if the parts are simultaneously accessible. The current also is to be measured while the resistor is connected between one part or group of parts and another part or group of parts, if the parts are simultaneously accessible.

75.6 With reference to the requirements in 75.5, parts are considered to be simultaneously accessible if they can be contacted by one or both hands of a person at the same time. For the purpose of these requirements, one hand is to be considered to be able to contact parts simultaneously if the parts are within a 4- by 8-in. (102- by 203-mm) rectangle; and two hands of a person are considered to be able to contact parts simultaneously if the parts are not more than 6 ft. (1.83 m) apart.

75.7 Electric shock current refers to all currents, including capacitively coupled currents.

75.8 If the product has a direct-current rating, measurements are to be made with the product connected in turn to each side of a 3-wire, direct current supply circuit.

75.9 Current measurements are to be made with any operating control, or adjustable control that is subject to user operation, in all operating positions, and either with or without a vacuum tube, separable connector, or similar component in place. These measurements are to be made with controls placed in the position that causes maximum current flow.

76 Locked Rotor Test

76.1 Motors

76.1.1 A motor used in a smoke alarm that complies with the Standard for Overheating Protection for Motors, UL 2111, or one that is an impedance-protected motor complying with the requirements for such motors comply with these requirements without the necessity of further tests

76.2 Thermal or overcurrent protection

76.2.1 When the rotor of the motor is locked, the maximum temperature on a Class A insulated motor winding shall be 200°C (392°F) during the first hour of operation and 175°C (347°F) thereafter. After the first hour of operation, the average temperature, found by taking the arithmetic mean of the maximum temperatures and the arithmetic mean of the minimum temperatures, shall not exceed 150°C (302°F).

76.2.2 Temperatures shall be measured by thermocouples on the surface of coils of the motor. The test of a manually reset device is to be continued for four operations of the protective device, with the device being reset as quickly as possible after it has opened. For an automatically reset device, the locked-rotor test is to be continued for 72 hours unless the smoke alarm includes other controls (such as a timer) that limits the duration of the operation to a shorter interval. During the test, the motor is to be connected to a source of supply as specified in 37.3.1.

76.2.3 An automatic-reset thermal protector of a motor shall perform as intended when operated for 15 days (unless the smoke alarm includes other controls, such as a timer, which positively and reliably limits the operation to a shorter interval, or unless the device permanently opens the circuit prior to the expiration of that period), with the rotor of the motor locked, and with the motor connected to a supply circuit having a voltage of 100 – 110 percent of the rated voltage of the motor. There shall not be permanent damage to the motor (including excessive deterioration of the insulation), and, in a situation where the device permanently opens the circuit, it shall do so without grounding to the motor frame, damaging the motor, or resulting in a risk of fire. A manual-reset thermal protector of a motor shall interrupt for 50 operations, without damage to itself, the locked-rotor current of the motor.

76.2.4 There shall not be any ignition of cotton surrounding the enclosure of a thermal protector of a motor when three samples of the device are subjected to limited short-circuit currents. For a motor rated at 1/2 horsepower (373 W output) or less, and 250 volts or less, the current is to be 200 amperes. For a motor having other ratings, and not more than 1 horsepower (746 W output), it is to be 1000 amperes. The power factor of the test circuit is to be 0.9 – 1.0, and the circuit capacity is to be measured without the device in the circuit. A nonrenewable cartridge fuse is to be connected in series with the device under test. The fuse rating is to be not less than four times the rated current of the smoke alarm except that the fuse rating is not to be less than 20 amperes for a smoke alarm rated 150 volts or more, and not more than 600 volts. The test on one sample is to be made by closing the device on the short circuit.

76.3 Impedance protection

76.3.1 When operated under locked-rotor conditions for 15 days:

a) A motor shall not attain a temperature of more than 150°C (302°F) during the first 72 hours of operation;

b) The motor winding shall not burn out or become grounded to the frame, nor shall there be any evidence of excessive deterioration of insulation; and

c) The supply-circuit fuses shall not open. The supply-circuit fuses shall not open.

Exception: The test does not have to be continued longer than required for the windings of the motor (of either the open or totally enclosed type) to reach constant temperature, when this constant temperature is not more than 100°C (212°F).

76.3.2 During the test, a motor having a nominal rating of 115 volts is to be connected to a circuit having a voltage of 120 volts, and a motor having a nominal rating of 230 volts is to be connected to a circuit having a voltage of 240 volts. A motor having any other voltage rating is to be connected to a circuit having a voltage of 100 – 105 percent of the voltage rating of the motor.

76.3.3 To determine that a motor complies with the requirements of 76.3.1, temperature readings shall be taken as follows:

a) For a totally enclosed motor – a motor whose outer metal enclosure is complete – the temperature is to be measured by means of a thermocouple on the enclosure.

b) For any other motor, the temperature is to be measured by means of a thermocouple on the integrally applied insulation of the winding under the coil wrap, when present.

c) When the coil is encapsulated, the winding temperature is to be determined by the resistance method.

76.3.4 The rotor of the motor is to be locked in a stationary position. The motor is to be mounted on wood or other thermal insulating material determined to be equivalent. Blades or other motor attachments shall be removed from the motor. Integral mounting brackets shall be left in place. The frame of the motor is to be connected to ground by means of a solid conductor (that is, with no fuse in the grounding conductor). A 30-amp time-delay fuse is to be connected in each ungrounded conductor of the supply cord.

76.3.5 At the conclusion of the first 72 hours of the Locked Rotor Test, the motor shall withstand the Dielectric Voltage-Withstand Test, Section 77.

76.3.6 At the conclusion of the 15-day test, a potential of twice the marked rated voltage of the motor is to be applied between the windings and the frame to determine whether or not the winding has become grounded.

77 Dielectric Voltage-Withstand Test

77.1 A smoke alarm shall withstand for 1 minute, without breakdown, the application of a sinusoidal AC potential of a frequency within the range of 40 – 70 Hz, or a DC potential, between hazardous-voltage live parts and exposed dead metal parts, and between live parts of hazardous- and extra-low-voltage circuits. The test potential is to be:

a) For a smoke alarm rated 30 volts AC rms (42.4 volts DC or AC peak) or less – 500 volts (707 volts, when a DC potential is used).

b) For a smoke alarm rated between 31 and 150 volts AC rms – 1000 volts (1414 volts, when a DC potential is used).

c) For a smoke alarm rated more than 150 volts AC rms – 1000 volts plus twice the rated voltage (1414 plus 2.828 times the rated AC rms voltage, when a DC potential is used).

77.2 Any reference or component grounds shall be disconnected prior to the test applications.

77.3 When the charging current through a capacitor or capacitor-type filter connected across the line, or from line to earth ground, is sufficient to prevent maintaining the specified AC test potential, it is permissible to test the capacitors and capacitor-type filters using a DC potential in accordance with 77.1.

77.4 The test potential is to be obtained from any convenient source having sufficient capacity to maintain the specified voltage. The output voltage of the test apparatus is to be monitored. Starting at zero, the applied potential is to be increased at a rate of 200 volts per minute until the required test value is reached and is to be held at that value for 1 minute.

77.5 When there is the possibility of short circuit or damage to a printed-wiring assembly or other electronic-circuit component by application of the test potential, the component is to be removed, disconnected, or otherwise rendered inoperative before the test. It is permissible to test a representative subassembly instead of an entire unit.

78 Polarity Reversal Test

78.1 A smoke alarm shall operate as intended after being connected in each polarity. While energized under either polarity, the alarm shall comply with the requirements of the Electric Shock Current Test, Section 75. This includes high-voltage cord connected and fixed wiring (splice lead) types, battery types (main or standby), and multiple station interconnection leads. Each polarity is to be applied for at least 24 hours on all units unless a trouble signal or alarm signal is obtained. For battery operated alarms intended to be connected by a polarized clip assembly the reverse polarity is to be applied for a minimum of 1 second. A trouble or alarm signal is to be permitted under any incorrect polarity applied. A maximum 1-second alarm is permitted when the correct polarity is connected.

78.2 Two samples are to be subjected to this test. Sensitivity measurements prior to and following the test are to be made in accordance with the Sensitivity Test, Section 42. Measurements following the polarity reversal shall vary not more than specified in 38.3, Sensitivity shift criteria.

79 Tests on Polymeric Materials

79.1 General

79.1.1 Polymeric materials intended for the sole support of current-carrying parts or as an enclosure of a smoke alarm shall be subjected to the tests specified in 79.2 – 79.4. When possible, a complete smoke alarm is to be used.

79.2 Temperature test

79.2.1 There shall not be warping that impairs intended operation or exposes hazardous-voltage uninsulated current-carrying parts when representative samples of a polymeric material are in a circulating-air oven for the number of days associated with the test temperature per the equation below, and at a relative humidity of 0 – 10 percent.

$$t_{test\text{-}time} = t_{real\text{-}time} / 2^{(T_{oven} - T_{installation})/10}$$

Where $t_{real\ time}$ *= 257 days,*

T_{oven} *= oven temperature (70°C minimum)*

$T_{installation}$ *= maximum installation temperature (as specified by the manufacturer)*

For example, for a smoke alarm with a maximum installation ambient temperature of 38°C (100°F), tested at an oven temperature of 90°C (194°F), the calculation below would apply:

$\mathbf{t}_{test\text{-}time} = 257/2^{(90-38)/10}$

$\mathbf{t}_{test\text{-}time}$ = 7 days

79.2.2 Three representative samples shall be mounted on supports as intended in service and placed in the oven. Following the aging period indicated in 79.2.1, the samples shall be viewed (while in the oven) for distortion, removed, permitted to cool to room temperature, and then reexamined for compliance with the requirements of 79.2.1. The smoke alarm cover shall be allowed to fall off only when hazardous-voltage parts are not exposed, operation for smoke detection is not affected, and the cover is able to be replaced as intended. Smoke sensitivity measurements, using gray smoke/aerosol, conducted in the event of questionable distortion, shall not vary more than specified in 38.3.1.

79.3 Flame test – 3/4-in. (19 mm)

79.3.1 When equipment is tested as described in 79.3.2 – 79.3.6, the material shall not flame for more than 1 minute after two 30-second applications of a test flame, with an interval of 1 minute between applications of the flame. The sample shall not be completely consumed.

Exception: Parts that are molded from materials that are classed as 5VA, 5VB, V-0, or V-2 are not required to be subjected to the flammability test described in 79.3.2 – 79.3.6.

79.3.2 Three samples of the equipment shall be placed in a forced draft circulating air oven maintained at a uniform temperature not less than 10°C (18°F) higher than the maximum temperature of the material measured under normal operating conditions, and not less than 70°C (158°F) in any case. The samples are to remain in the oven for 7 days. After cooling to room temperature for a minimum of 4 hours, the samples shall be tested as described in 79.3.3 – 79.3.6.

Exception: It is permissible that the test be conducted on only three unconditioned test samples when both of the following conditions are met:

a) The material does not exhibit a reduction in its flame-resistance properties as a result of long-term thermal aging and

b) The thermal-aging program used for such determination included specimens having a thickness equal to or less than the wall thickness of the polymeric part.

79.3.3 Three samples of the part shall be subjected to the flame test described in 79.3.5. In the performance of the test, the equipment is to be supported in its normal operating position in a draft free location. Nonpolymeric portions are not to be removed and insofar as possible, the internal mechanism of the equipment is to be in place. The flame is to be applied to an inside surface of the sample at a location judged ignitable because of its proximity to a source of ignition. Each sample shall be tested with the flame applied to a different location.

Exception: It is permissible that the test be conducted on only three unconditioned test samples when both of the following conditions are met:

a) The material does not exhibit a reduction in its flame-resistance properties as a result of long-term thermal aging and

b) The thermal-aging program used for such determination included specimens having a thickness equal to or less than the wall thickness of the polymeric part.

79.3.4 With reference to 79.3.3, the sections most ignitable shall be identified as those adjacent to coil windings, splices, open-type switches, or arcing parts.

79.3.5 The flame of a Bunsen or Tirrill burner having a tube with a length of 3.94 ±0.39 in. (100 ±10 mm) and an inside diameter of 0.374 ±0.12 in. (9.5 ±0.3 mm) is to be adjusted to have a 3/4-in. (19-mm) height of yellow flame with no blue cone. Two 30-second applications of the tip of the flame shall be made to each section of the equipment chosen as indicated in 79.3.4, with 1 minute intervals between the applications. A supply of technical-grade methane gas is to be used with a regulator and meter for uniform gas flow.

Exception: Natural gas having a heat content of 1000 Btu/ft^3 (37 MJ/m^3) at 23°C (73°F) has been found to provide similar results and is permissible for use.

79.3.6 When one sample from a set of three does not comply with 79.3.1, an additional set of three samples shall be tested. All samples from the second set shall comply with 79.3.1.

79.4 Flame test – 5-in. (127 mm)

79.4.1 When equipment is tested as described in 79.4.2 – 79.4.5, all of the following results shall be obtained:

a) The material shall not continue to burn for more than 1 minute after the fifth 5-second application of the test flame, with an interval of 5 seconds between applications of the flame;

b) Flaming drops or flaming or glowing particles that ignite surgical cotton 12 in. (305 mm) below the test specimen shall not be emitted by the test sample at any time during the test; and

c) The material shall not be destroyed in the area of the test flame to such an extent that the integrity of the part is affected with regard to containment of fire or exposure of high voltage parts.

79.4.2 Three samples of the complete equipment or three test specimens of the part thereof shall be subjected to this test. Consideration is to be given to leaving in place components and other parts that influence the performance. The test samples shall be conditioned in a full draft circulating air oven for 7 days at 10°C (18°F) greater than the maximum use temperature and not less than 70°C (158°F) in any case. Prior to testing, the samples shall be conditioned for a minimum of 40 hours at 23.0 ±2.0°C (73.4 ±3.6°F) and 50 ±5 percent relative humidity. The flame is to be applied to an inside surface of the sample at a location judged to be ignitable because of its proximity to a source of ignition. When more than one part is near a source of ignition, each sample shall be tested with the flame applied to a different location.

Exception: The test be shall be conducted on only three unconditioned test samples only when both of the following conditions are met:

a) The material does not exhibit a reduction in its flame-resistance properties as a result of long-term thermal aging and

b) The thermal-aging program used for such determination included specimens having a thickness equal to or less than the wall thickness of the polymeric part.

79.4.3 The three samples are to result in the performance described in 79.4.1. When one sample does not comply, the test is to be repeated on a set of three new samples with the flame applied under the same conditions as for the unsuccessful sample. All the new specimens shall comply with 79.4.1.

79.4.4 The Bunsen or Tirrill burner with a tube length of 3.94 ±0.39 in. (100 ±10 mm) and an inside diameter of 0.374 ±0.12 in. (9.5 ±0.3 mm), is to be placed remote from the specimen, ignited, and adjusted so that the burner flame is 5 in. (127 mm) and the height of the inner blue cone is 1-1/2 in. (38 mm). The tube is not to be equipped with end attachments, such as a stabilizer.

79.4.5 When a complete enclosure is used to conduct the flame test, the sample is to be mounted as intended in service, providing it does not impair the flame testing, in a draft-free test chamber, enclosure, or laboratory hood. A layer of surgical cotton is to be located 12 in. (305 mm) below the point of application of the test flame. The 5 in. (127 mm) flame is to be applied to any portion of the interior of the part judged as ignitable (by its proximity to live or arcing parts, coils, or wiring) at an angle of 20 degrees in so far as possible from the vertical so that the tip of the blue cone touches the specimen. The test flame is to be applied to three different locations on each of the three samples tested. A supply of technical-grade methane gas is to be used with a regulator and meter for uniform gas flow.

Exception No. 1: It is permissible that the flame be applied to the outside of an enclosure when the equipment is of the encapsulated type or of such size that the flame cannot be applied inside.

Exception No. 2: Natural gas having a heat content of 1000 Btu/ft^3 (37 MJ/m^3) at 23°C (73°F) has been found to provide similar results and is permissible for use.

79.4.6 The flame is to be applied for 5 seconds and removed for 5 seconds. The operation is to be repeated until the specimen has been subjected to five applications of the test flame.

80 Strain Relief Test

80.1 General

80.1.1 A cord or lead that relies upon a thermoplastic enclosure or part for strain relief is to be subjected to the applicable tests specified in 80.2 and 80.3 following exposure to the temperature conditioning test described in 79.2.1.

80.2 Power-supply cord

80.2.1 When tested in accordance with 80.2.2, the strain relief means provided on the flexible cord shall withstand for 1 minute, without displacement, a pull of 35 pounds-force (156 N) applied to the cord with the connections within the alarm disconnected.

80.2.2 A 35 pound-mass (15.9 kg) weight is to be suspended on the cord and supported by the alarm so that the strain relief means are stressed from any angle that the construction of the alarm permits. The strain relief does not comply when, at the point of disconnection of the conductors, there is such movement of the cord as to indicate that stress has resulted on the connections.

80.3 Strain relief (special field-wiring terminals)

80.3.1 To determine suitability as a field-wiring connection in compliance with 21.4.1 and 21.4.2, representative samples shall comply with all of the tests specified in 80.3.2 and 80.3.3.

80.3.2 A terminal connection shall withstand the application of a straight pull of 5 lbs. (22.2 N), applied for 1 minute to the wire in the direction which would most likely result in pullout, without separating from the terminal.

80.3.3 Six samples of the terminal are to be connected to the wire sizes with which they are intended to be used, in accordance with the manufacturer's instructions. When a special tool is required to assemble the connection, it is to be used. Each sample is to be subjected to a gradually increasing pull on the wire until the test pull of 5 lbs. (22.2 N) is reached and maintained at 5 lbs. (22.2 N) for 1 minute.

80.4 Battery connections

80.4.1 Lead or terminal connections to batteries shall be identified with the proper polarity, (plus or minus signs), and provided with strain relief. It is not prohibited for the polarity to be indicated on the unit adjacent to the battery terminals or leads.

80.4.2 Connections to battery terminals shall be either by a lead terminating in a positive snap action type of clip, or a fixed butt-type connection which applies a minimum of 1.5 lbs. (6.6 N) force to each battery contact, or equivalent. The connection shall consist of an unplated or plated metal which is resistant to the corrosive action of the electrolyte.

80.4.3 Each lead of a clip-lead assembly used as part of a battery operated alarm shall be a minimum of AWG 22 (0.32 mm^2) stranded wire with a minimum 1/64 in. (0.4 mm) insulation.

81 Non-Compulsory Fire and Smoldering Smoke Tests

81.1 When the smoke alarm sensitivity of smoke alarms subjected to any one of the following tests exceeds the maximum sensitivity change permitted for that particular test then the same samples, adjusted to the minimum sensitivity settings, shall comply with the Fire Tests, Section 51, and the Smoldering Smoke Test, Section 52.

a) Lamp Interchangeability Test (Photoelectric), Section 46,

b) Reduction in Light Output Test, Section 47,

c) Overvoltage test, 57.1,

d) Undervoltage test, 57.2,

e) Vibration Test, Section 59,

f) Jarring Test, Section 61,

g) Corrosion Test, Section 64, and

h) Dust Test, Section 68.

81.2 For the tests specified in 81.1 (c) and (d), the supply voltage to the smoke alarms in the Fire Tests, Section 51, and the Smoldering Smoke Test, Section 52, is to be at the voltage indicated for the applicable tests.

82 Survivability Tests

82.1 Two samples of the smoke alarm shall be exposed to a temperature of 121 ±2°C (250 ±4°F) for a period of 4 minutes. The units shall be removed from the test chamber and allowed to return to room temperature. The units are then to be subjected to the Audibility Test, Section 84, (when applicable) and the Sensitivity Test, Section 42.

82.2 Following conditioning, the samples shall be capable of producing an audible output (when applicable) of 85 dBA at 10 ft. (3.05 m), and the sensitivity of each smoke alarm shall not vary by more than specified in 38.3, Sensitivity shift criteria.

83 Drop Test

83.1 This test is to be conducted only on smoke alarms intended for transient use, such as a travel alarm, and is not to be conducted on alarms intended for stationary installation.

83.2 An alarm shall withstand five drops from a height of 7 ft. (2.1 m) onto a tiled concrete floor without exposure of internal high-voltage parts and without affecting its intended operation and sensitivity. The sample is to be held so that each impact with the floor is at a different location on the alarm. Dislodgement of parts is not prohibited when:

a) The dislodged part does not affect operation or sensitivity of the unit,

b) The dislodged part is replaceable (such as a cover),

c) There are no high-voltage parts exposed, and

d) The condition is visually obvious.

83.3 Each of two alarms is to be raised to a height of 7 ft. (2.1 m) and permitted to drop five times onto a concrete floor covered with a 1/8 in. (3.2 mm) thick uncushioned vinyl tile. Following the drops, the unit is to be examined for damage and tested for sensitivity. Sensitivity measurements, recorded after the drop test, shall vary not more than specified in 38.3.1.

84 Audibility Test

84.1 General

84.1.1 Except as permitted in 84.2.1, the alarm sounding appliance, either integral with the smoke alarm or intended to be connected separately, shall be capable of providing for at least 4 minutes, a sound output equivalent to that of an omnidirectional source with an A-weighted sound pressure level of at least 85 decibels (dB) at 10 ft. (3.05 m) with two reflecting planes assumed. To determine compliance with this paragraph the method described in 84.2.1 – 84.3.2 is to be employed. It is appropriate for alarms to be tested with the horn duty cycle specified in 38.2 defeated and emitting a continuous tone. In addition, the signal format of a low frequency alarm shall conform to the description in 84.5.

84.2 Sound output measurement

84.2.1 The sound power output of the alarm shall be measured in a reverberation room using procedures outlined in ANSI ASA Standard S12.51 (Acoustics Determination of Sound Power Levels of Noise Sources using Sound Pressure Precision Method for Reverberation Rooms). The sound power in each 1/3 octave band shall be determined using the comparison method. The A-weighing factor shall be added to each 1/3 octave band. The total power is to be determined on the basis of actual power. The total power is then to be converted to an equivalent sound pressure level for a radius or 10 ft. (3.05 m) using the following formula:

$$Lp = Lw - 20Log10\ R - 0.6$$

Where:

Lp is converted sound pressure level,

Lw is the sound power level measured in the reverberation room, and

R is the radius for the converted sound pressure level (10 ft.).

An additional 6 dB is to be added to allow for two reflecting planes.

84.2.2 Each alarm is to be mounted to a 3/4 in. (19.1 mm) plywood board measuring 2 by 2 ft. (610 by 610 mm), supported in a vertical plane, and positioned at an angle of 45 degrees to the walls of the reverberation room.

84.2.3 For this test a AC powered alarm is to be energized from a source of rated voltage and frequency. A battery powered alarm is to be energized from batteries under each of the following conditions along the trouble signal level curve illustrated in Figure 56.2, Trouble level determination, or equivalent:

a) Nondischarged battery (a battery with some unknown shelf life, such as those purchased at a retail outlet) with enough added resistance to obtain a trouble signal (Point D of Figure 56.2), or the maximum resistance for the particular battery based on documented data, whichever is less.

b) Battery depleted to the trouble signal level voltage, no added resistance The equivalent of a battery shall be identified as a voltage source with a series resistance adjusted to a level at which a trouble signal is obtained during the normal standby condition. The resistance and voltages used are to be those that were determined during the Circuit Measurement Test, Section 56.

84.2.4 At least two samples shall be tested. Units intended for multiple-station connection shall also be tested interconnected as multiple-stations with the maximum line resistance as defined in 57.2.2. For AC powered units employing a nonrechargeable standby battery, the measurement shall be made with the smoke alarm connected to a rated AC voltage source, and then with the AC power de-energized and energy obtained from a standby battery depleted to 85 percent of rated battery voltage, or at the voltage level at which a trouble signal is obtained. For an AC unit employing a rechargeable standby battery, the measurement is to be made using a fully recharged battery.

84.3 Alarm duration test

84.3.1 An alarm sounding appliance of an alarm powered by a primary or secondary battery that has been discharged to the trouble level condition shall provide the equivalent of 85 dBA minimum at 10 ft. (3.05 m) for 1 minute of continuous alarm operation and shall provide at least 82 dBA up to 4 minutes of alarm operation.

84.3.2 To determine compliance with 84.3.1, a measurement shall be made under the following conditions. The ambient noise level is to be at least 10 dB below the measured level produced by the signaling appliance. The alarm is to be mounted 1 ft. (302 mm) from the microphone placed in a direct line with the alarm. The alarm is then to be energized in the alarm condition and the sound output is to be measured at 1 minute intervals, using a sound level meter employing the A-weighting network. A maximum of 3 dB decrease from the original 1 minute reading, after 4 minutes shall determine compliance for a battery operated alarm that is providing a trouble signal.

84.4 Supplementary remote sounding appliances

84.4.1 The sound output of a supplementary remote sounding appliance, intended to be installed in the same room as a user (such as a bedroom), shall not be less than 85 dB unless the appliance is marked with the following, or equivalent, text to indicate the specific use:

"THIS UNIT IS TO BE INSTALLED IN A ROOM OCCUPIED FOR SLEEPING."

Under no circumstances is the sound output to be less than 75 dBA. The alarm signal format shall also comply with the requirement in 84.5.

84.5 Low frequency alarm signal format

84.5.1 A low frequency alarm shall have a fundamental frequency of 520 (F1) Hz ±10 percent, with subsequent harmonic frequencies occurring at 1560 (F3), 2600 (F5) and 3640 (F7) Hz ±10 percent as determined by a Fast Fourier Transform (FFT) analysis of the audible alarm signal.

84.5.2 The spectral analyses shall be performed in a reverberant room per the test setup as described in 84.2.2. The FFT measurement shall be a 30 second spectrum averaging of a 12.8 (kHz) frequency span of 2 (Hz) resolution, non-weighted.

84.5.3 The maximum sound pressure level (dB) of any frequency within the FFT measurement shall be at least 5 dB less than the F1 sound pressure level (dB). The minimum sound pressure level (dB) of the odd harmonics shall not be less than 20 dBA for F3, 30 dBA for F5 and 50 dBA for F7 of the fundamental F1 level.

85 Field Service Tests (If recommended by the manufacturer)

85.1 Go/no-go field test

85.1.1 Go/no-go field test (gas sensors used in multi-criteria smoke alarms)

85.1.1.1 Where the smoke and gas sensor can be tested independent of the other sensors, Section 68, Dust Test shall apply.

85.1.1.2 Two smoke alarms shall be energized with their rated voltage and operate at their intended signaling performance. The smoke alarms shall be subjected to X number of the manufacturer's recommended go/no-go field test. The number of go/no-go field tests is determined using the following calculation:

$$X=(A \times B)2.5$$

in which:

A = Sensor life (years based on shortest sensor lifespan) as stated by the manufacturer.

B = The number of tests the sensor is to be subject to annually (as required by NFPA 72 or as recommended by the manufacturer, whichever is worst case).

X = Number of go/no-go test gas concentration exposures the product is to be subject to.

The samples shall go into an alarm condition including a change of state of the alarm relay after successful gas entry into the sensing cell. The alarm shall be reset either mechanically, electrically, or by the smoke alarm remaining in fresh air for a period of time specified by the manufacturer. Following the reset period, this sequence of go/no-go field tests is to be repeated "X" number of trials. Following "X" number of go/no-go test gas exposures, the smoke alarms shall comply with 42.8, Sensitivity test – gas sensor of a multi-criteria smoke alarm, and 85.1.2, Go/no-go field test (for the smoke sensor).

85.1.1.3 The samples shall indicate a successful gas entry into the sensing cell via a measurement means provided by the manufacturer. The alarm shall be reset either mechanically, electrically, or by the smoke alarm remaining in fresh air for a period of time specified by the manufacturer. Following the reset period, this sequence of go/no-go field tests is to be repeated "X" number of trials. Following "X" number of go/no-go test gas exposures, the smoke alarms shall comply with 42.8, Sensitivity test – gas sensor of a multi-criteria smoke alarm, and 85.1.2, Go/no-go field test (for the smoke sensor).

85.1.2 Go/no-go field test (for the smoke sensor)

85.1.2.1 Two smoke alarms, one at maximum and one at minimum sensitivity, shall operate at their intended signaling performance, and each smoke alarm's sensitivity shall not shift by more than specified in 38.3, Sensitivity shift criteria, after being subjected to 50 alarm and restoration cycles of the manufacturer's specified go/no-go field test method for smoke entry. The samples are to be energized with rated voltage and subjected to the go/no-go test at a rate of not more than one field test per 30 minutes.

Note: Where smoke entry into the smoke alarm is not applicable the manufacturer's specified test method shall be utilized.

85.1.2.2 Following the successful completion of the go/no-go field test these samples shall be subjected to the Dust Test, Section 68.

85.2 Maintenance (cleaning)

85.2.1 Single criteria or multi-criteria smoke alarms intended to be cleaned in the field, two smoke alarms, one at maximum and one at minimum sensitivity, shall operate for their intended signaling performance, and each smoke alarm's sensitivity shall not shift by more than specified in 38.3, Sensitivity shift criteria, after being subjected to 50 cycles of the manufacturer's specified field cleaning procedure. The other sensor(s) of a multi-criteria smoke alarm need not be tested for sensitivity if only the smoke sensor is cleaned.

85.3 Battery tests

85.3.1 Primary power supply – battery

85.3.1.1 Where a replaceable battery is employed as the main source of power of a smoke alarm, it shall provide power to the unit under intended ambient conditions for at least 1 year (or whatever longer period specified by the manufacturer) in the standby condition, including novelty and weekly alarm testing, and then operate the alarm for a minimum of 4 minutes of alarm, followed by 7 days of trouble signal. See 41.5. The alarm sound level shall be at least 85 dBA at the end of the 4 min alarm period when tested in accordance with the Audibility Test, Section 84, and the Battery trouble voltage determination, 56.2.

85.3.1.2 Where a non-replaceable battery is employed as the main source of power, it shall provide power to the unit under intended ambient conditions for at least 10 years in the standby condition, including novelty and weekly testing, and then operate the alarm for a minimum of 4 minutes of alarm, followed by 7 days of trouble signal.

85.3.1.3 Six samples of the battery, or sets of batteries when more than one battery is used for primary power, shall be tested under each of the following ambient conditions for a minimum of 1 year while connected to the smoke alarm or a simulated load to which the battery is to supply power:

a) A room ambient temperature of 23 ±2°C (73.4 ±3.6°F), 30 – 50 percent relative humidity, and 760 mm Hg;

b) High temperature of = (T_{HI} − 38°C) + 45°C or (T_{HI} − 100°F) + 113°F;

c) Low temperature of = (T_{LO} − 0°C) or (T_{LO} − 32°F), and

d) Temperature = (T_{HI} − 38°C) + 30°C or (T_{HI} − 100°F) + 86°F, and 85 ±5 percent relative humidity and;

e) Where T_{LO} and T_{HI} are the respective low and high end operating temperatures.

85.3.1.4 For the test, either alarm samples or test loads simulating a maximum standby current drain are to be employed. The alarm load is to be the audible appliance intended to be used in the smoke alarm or an appropriate load simulating maximum alarm conditions. The batteries are to be tested in the mounting clips employed in the alarm.

85.3.1.5 Terminals or jacks are to be provided on each test means to facilitate measurement of battery voltage, standby, and alarm currents. The measuring means is to be separated from the battery test means by a wiring harness or equivalent at least 3 ft (0.9 m) long.

85.3.1.6 Prior to placing the battery test setups in the various ambient conditions, each battery is to be subjected to 25 cycles of alarm representing novelty testing. Each cycle is to consist of 5 seconds of alarm and at least 5 minutes between each application.

85.3.1.7 During the course of the test, the battery voltage and current in standby and alarm condition are to be recorded periodically. The alarm voltage is to be recorded 3 seconds after energization. The standby voltage and current are to be recorded prior to the alarm measurements. The smoke alarm is to be placed into an alarm condition weekly. The duration of the weekly alarm test signal is to be 3 seconds.

85.3.1.8 For batteries rated longer than one year, at the end of the specified test period, all batteries shall have a capacity capable of operating the alarm signal for a minimum of 4 minutes, followed by 7 days of trouble signal. To obtain the trouble signal level it is sometimes required to continue the test with the standby current drain for longer than the test period. Batteries shall be subjected to the conditions described in 85.3.1.3 (b), (c), and (d) for the test period unless the alarm is marked to indicate the battery limitations for the condition involved. In no case shall the length of conditioning be less than one year.

85.3.1.9 For batteries rated for one year only, at the end of the specified test period (1 year) all batteries shall have a capacity capable of operating the alarm signal for a minimum of 4 minutes, followed by 7 days of trouble signal. To obtain the trouble signal level it is sometimes required to continue the test with the standby current drain for longer than 1 year. Batteries shall be subjected to the conditions described in 85.3.1.3 (b), (c), and (d) for a minimum of 1 year unless the alarm is marked to indicate the battery limitations for the condition involved. In no case shall the length of conditioning be less than 6 months.

86 Conformal Coatings on Printed Wiring Boards

86.1 General

86.1.1 Conformal coatings are for use only on printed wiring boards where the acceptability of the combination has been investigated for flammability in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, and the dielectric property after environmental, humidity, and thermal conditioning in accordance with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E.

86.2 Low voltage printed wiring boards

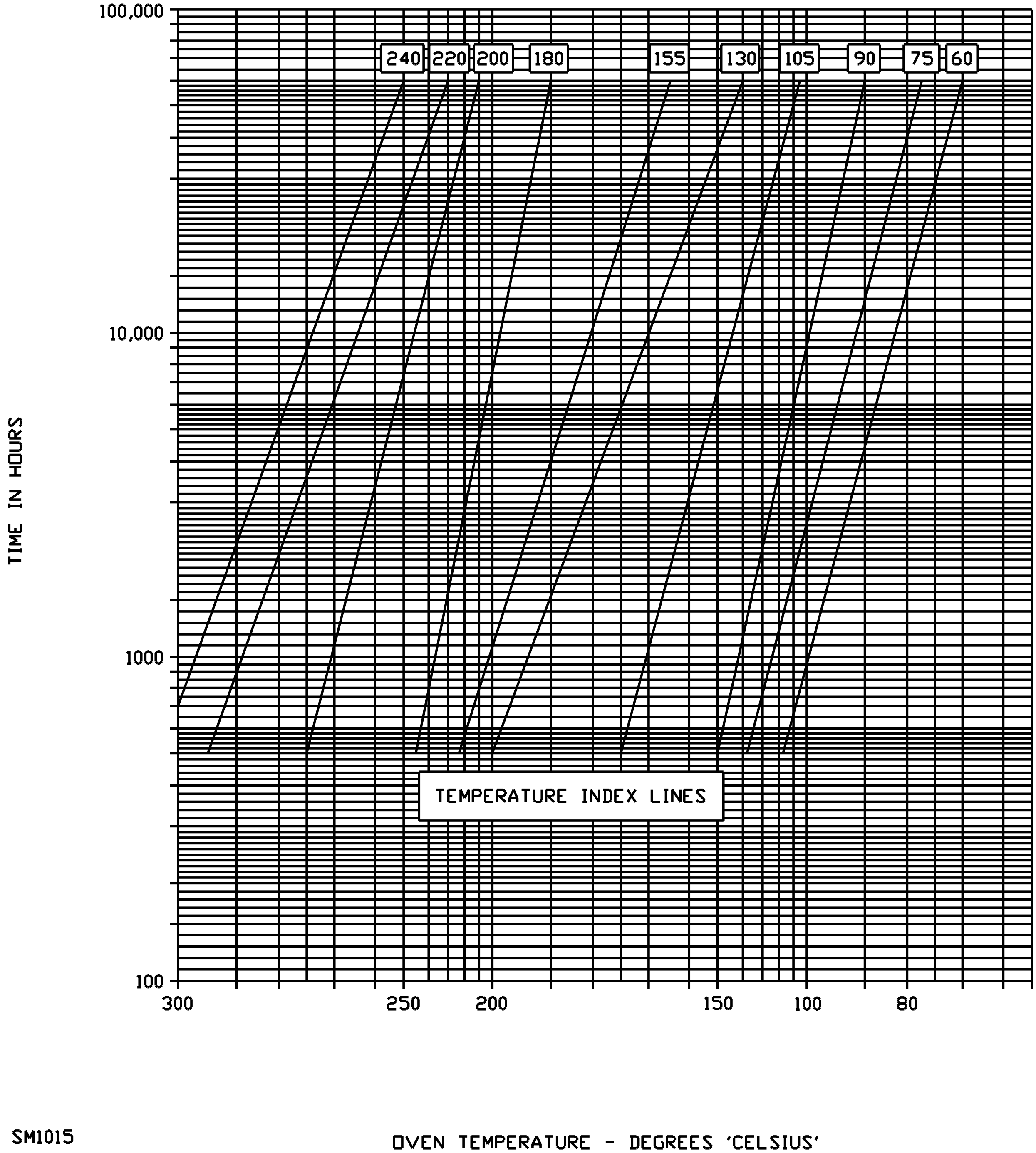
86.2.1 The following test program is to be utilized to determine the acceptability of a conformal coating in lieu of full electrical spacings for circuits at potential of 30 volts rms or less.

86.2.2 Eight samples of the printed wiring board, without electrical components installed, and coated with the conformal coating, shall be subjected to this test. Test leads shall be attached to the printed wiring (prior to the application of the coating) so as to allow for convenient application of the specified test potential.

86.2.3 Four specimens shall be conditioned to room ambient by exposure to ambient air at a temperature of 23 ±2°C (73, minus 3, +4°F) and 50 ±5 percent relative humidity for not less than 24 hours. Following the conditioning, the four samples shall be subjected to the Dielectric Voltage-Withstand Test, Section 77, for the 0 – 30 volt range. There shall be no indication of dielectric breakdown as a result of the test. All specimens shall be smooth, homogeneous, and free of heat deformation such as bubbles and pin holes, as determined by visual examination.

86.2.4 Four samples shall be exposed to ambient air at a temperature chosen from the applicable temperature index line shown in Figure 86.1 corresponding to the ″in service″ operating temperature of the coating. The aging temperature chosen from the index line shall correspond to not less than 1000 hours of exposure. It is permissible for any value of temperature to be chosen when it corresponds to no fewer than 300 hours of exposure. The samples are then to be subjected to the Dielectric Voltage-Withstand Test, Section 77. All specimens shall be smooth, homogeneous, and free of defects such as bubbles and pin holes, as determined by visual examination. There shall not be crazing, chipping, or other visual evidence of deterioration or separation of the coating from the board after conditioning. There shall not be indication of a dielectric breakdown.

Figure 86.1
Aging time versus aging temperature



86.2.5 As an option to the use of conformal coating for circuits at a potential of 30 volts rms (42.4 V DC or AC peak) or less and less than 100 volt-amperes, four samples of the printed wiring board shall be subjected to the following tests. The samples shall be conditioned in the environment described in the Humidity Test, Section 63. Following the conditioning, the four samples shall be subjected to the Dielectric Voltage-Withstand Test, Section 77, for the 0 – 30 volt range. There shall not be indication of dielectric breakdown as a result of the test.

86.3 High voltage printed wiring boards

86.3.1 The following test program is to be utilized to determine the acceptability of a conformal coating in lieu of full electrical spacing for circuits at potential greater than 30 volts rms. The coating shall not be less than 0.008 in. (0.2 mm) thick.

86.3.2 Three samples of the printed wiring board without electrical components installed, and coated with the conformal coating, shall be subjected to this test. Test leads shall be attached to the printed wiring (prior to the application of the coating) so as to allow for convenient application of the specified test potential. Each sample shall be subjected to a 5,000 volts AC Dielectric Voltage-Withstand Test potential for one minute:

a) The test shall be performed between tracks on the printed wiring board;

b) A 7-day heating-cooling cycling period, each cycle consisting of 4 hours ″on″ at 105 ±2°C (221 ±4°F) followed by 4 hours ″off″ at 25 ±2°C (77 ±4°F);

c) A 7-day oven conditioning period of 100 ±2°C (212 ±4 °F);

d) A 7-day oven conditioning period at 85 percent relative humidity at 65°C (149°F); and

e) A Dielectric Voltage-Withstand Test potential at 2,500 volts AC repeated 10 times.

There shall not be peeling or other deterioration of the coating material as a result of the conditioning.

86.3.3 A sample of the coated printed wiring board, equipped with test leads, without electrical components installed, shall be subjected to this test. The sample shall be subjected to an atmosphere having a relative humidity of 93 ±2 percent at a temperature of 32 ±2°C (89, minus 3, +4°F) for a period of 24 hours followed by a 500 volts Dielectric Voltage-Withstand Test with the sample maintained in the conditioning atmosphere. There shall be no indication of a dielectric breakdown.

87 Power Supply Tests

87.1 General

87.1.1 If a separate power supply, as described in Section 22 (Remote Power Supply) is used to provide energy to one or more smoke-alarms, it shall be subjected to the tests of 88.2 and 88.3 and meet the requirements of the following test:

a) Circuit Measurement Test, Section 56;

b) Overvoltage and Undervoltage Tests, Section 57;

c) Temperature Test, Section 58;

d) Jarring Test, Section 61;

e) Variable ambient temperature and humidity test, 88.3;

f) Transients Tests, Section 66;

g) Overload Tests, Section 69;

h) Endurance Test, Section 70;

i) Leakage Current Test, Section 73; and

j) Tests on Polymeric Materials, Section 79.

87.2 VA Capacity

87.2.1 The VA output capacity of a power supply shall not exceed 100 VA and shall not be more than 30 V rms (42.4 V peak).

87.2.2 To determine compliance with 87.2.1, a variable resistive load shall be connected to the output circuit. With the sample connected to a rated source of supply, the load resistor is to be varied between open circuit to short circuit conditions in such a manner that the elapsed time is between 1.5 and 2.5 min. Voltage and current measurements are recorded over the range and the maximum VA is calculated. If an interchangeable type over-current protective device is provided, it shall be shunted out during the test.

87.3 Burnout test

87.3.1 There shall be no damage to the enclosure, charring or burning of the cheesecloth, nor emission of flame or molten metal when a sample is operated under the conditions described in 88.3.2. While still hot from the burnout test, the power supply is to be subjected to and comply with the requirements of the Leakage Current Test, Section 73; and Dielectric Voltage-Withstand Test, Section 77.

87.3.2 With the output shorted, the supply circuit of the sample is to be connected to a rated source of voltage and frequency with the enclosure grounded and operated for a least 7 hours or until burnout occurs. A single layer of mercerized cotton cheesecloth is to be loosely draped over the device during the test. If accessible, interchangeable type over-current protective devices are provided, they are to be shunted out, but inaccessible over-current protective devices are to remain in the circuit.

88 Smoke Alarms for Use in Recreational Vehicles (RV)

88.1 General

88.1.1 A single criteria smoke alarm intended for use in recreational vehicles shall comply with the requirements specified in 89.1 – 89.6, in addition to the requirements specified in Sections 1 – 88 and 91 – 102, inclusive.

88.1.2 A multi-criteria smoke alarm with gas sensor intended for use in recreational vehicles shall comply with the requirements specified in Sections 1 – 88 and 91 – 102, inclusive.

88.1.3 All batteries included with smoke alarms intended for use in recreational vehicles shall at a minimum have a published operational specification range of minus 20°C to 60°C (minus 4°F to 140°F). Recommended replacement batteries shall also meet the temperature range.

88.2 Marking

88.2.1 In addition to the applicable requirements in Markings, Section 99, General, a single criteria or multicriteria smoke alarm for use in a Recreational Vehicle shall be permanently and legibly marked with the following information. The markings shall be in contrasting color, finish or equivalent, in letters at least 3/64 in. (1.2 mm) high. Items (f) and (g) shall be readily visible after installation:

a) Manufacturer's or private labeler's name or identifying symbol;

b) Model, type, or catalog designation;

c) Date of manufacture (in code is not prohibited);

d) Electrical rating in volts and amperes;

e) Reference to owner's manual;

f) The type of product, such as "RV Smoke Alarm" or "RV Multi-criteria Smoke Alarm", or equivalent. It is not prohibited that this marking be incorporated in (g); and

g) Identification of switches and light indicators.

88.3 Variable ambient temperature and humidity test

88.3.1 There shall be no false alarms or adverse change in performance when two units, one at maximum and one at minimum sensitivity, are subjected, in turn, to each of the following conditions:

a) Thirty days in air at 66 ±3°C (150 ±6°F).

b) At least 72 hours at minus 40 ±2°C (minus 40 ±4°F).

c) Ten days in 93 ±2 percent humidity at 61 ±2°C (142 ±4°F).

88.3.2 Sensitivity measurements, recorded in the environmental chamber smoke box, shall not vary more than specified in 38.3, Sensitivity shift criteria. During the sensitivity measurement, the environmental chamber is to be as close as possible to the test conditions specified in 88.3.1, condition (a) to be conducted at 49°C, condition (b) to be conducted at 0°C, and condition (c) to be conducted at 40°C, 93 percent relative humidity, respectively.

88.3.3 Gas sensitivity measurements, recorded in the environmental chamber, shall not vary more than specified in 42.8, Sensitivity test – gas sensor of a multi-criteria smoke alarm.

88.3.4 During each test condition, the alarm is to be connected to a source of rated voltage or battery.

88.3.5 The tests in 88.3.1 shall be done sequentially on the same two samples, and using the same battery samples for all three environments. The tests shall be conducted using each battery model specified in the marking or the installation instructions.

88.4 Corrosion (Salt spray) test

88.4.1 A smoke alarm shall operate as intended and shall not false alarm after exposure for 48 hours to a salt spray in accordance with the procedure specified in the Standard for Salt Spray (Fog) Testing, ASTM B117.

88.4.2 Two alarms, one at maximum and one at minimum sensitivity, are to be subjected to the salt spray while in a de-energized condition. Following the exposure, the samples are to be removed, dried for at least 24 hours in an air circulating oven or air dried for at least 48 hours, and then subjected to the Sensitivity Test, Section 42.

88.4.3 It is not prohibited for sensitivity measurements following the exposure to vary by more than specified in 38.3, Sensitivity shift criteria, in the direction of high sensitivity under the following conditions:

a) The smoke alarm does not false alarm and

b) The sensitivity does not vary more than specified in 38.3.1 in the direction of low sensitivity.

In any case, the sensitivity shall not exceed the limits specified in the Sensitivity Test, Section 42.

88.5 Vibration test

88.5.1 After vibration in accordance with 88.5.2, a smoke alarm shall not false alarm nor be adversely damaged. Sensitivity measurements shall not be greater than specified in 38.3 in the direction of low sensitivity, measurements greater than specified in 38.3 in the direction of high sensitivity are not prohibited. In no case shall the measurements exceed the limits specified in the Sensitivity Test, Section 42.

88.5.2 Two smoke alarms, one at maximum and one at minimum sensitivity, are to be subjected to vibration for 120 hours in accordance with the Vibration Test, Section 59. Sensitivity measurements are to be recorded before and after the test.

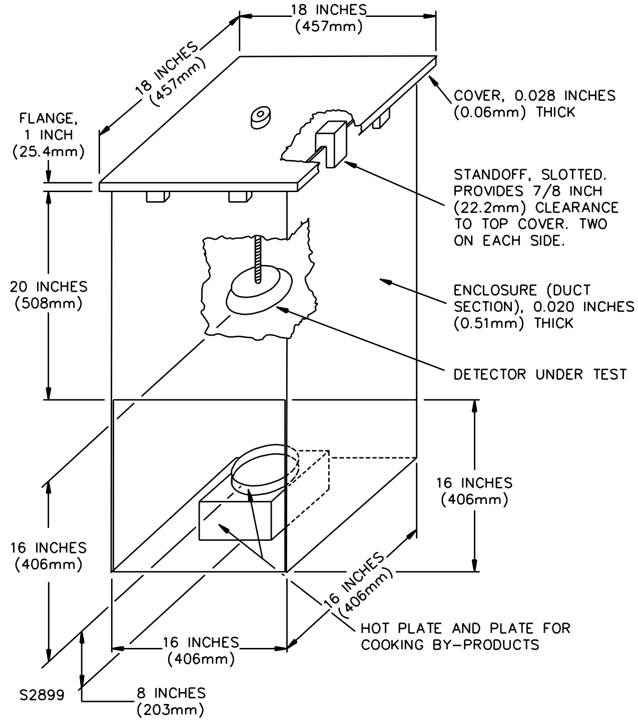
88.6 Contamination test (Cooking by-products)

88.6.1 After exposure in accordance with 88.6.2 – 88.6.5, a smoke alarm shall not false alarm or otherwise be adversely affected. Sensitivity measurements following the exposure shall not be greater than specified in 38.3 in the direction of low sensitivity, (measurements greater than specified in 38.3 in the direction of high sensitivity are not prohibited). In no case shall measurements exceed the limits of the Sensitivity Test, Section 42.

88.6.2 Two samples are to be subjected to the vaporization of a mixture of 50 grams of animal fat (lard), 50 grams of vegetable fat (Crisco), and 100 grams of beef gravy (Franco-American). The mixture is to be placed in an 8 in. (203 mm) diameter aluminum plate that is heated on an 8-1/2 in. (216 mm) diameter hotplate located on the bottom center of a galvanized sheet metal enclosure.

88.6.3 The enclosure is to measure 3 ft (914 mm) high, 16 in. (406 mm) square and have an open top and a 16 in. square opening at the bottom of one side. A sheet metal cover, 18 in. (457 mm) square, with 1 in. (25 mm) flanges, is to be supported at the enclosure top by 7/8 in. (20 mm) high standoffs. See Figure 88.1.

Figure 88.1
Contamination test (cooking by-products)



88.6.4 The alarm under test is to be supported on the end of a threaded 1/4 in. (61 mm) steel rod positioned so that the exposed face of the alarm is 12 in. (304 mm) below the enclosure cover and 16 in. (406 mm) above the aluminum plate. The alarm is not to be energized during the test.

88.6.5 Each sample is to be subjected to five complete vaporization exposures. Following the fifth exposure, each sample is to be removed, permitted to cool for at least 3 hours, and then tested for sensitivity as specified in the Sensitivity Test, Section 42.

89 Smoke Alarms for Use on Recreational Boats

89.1 General

89.1.1 A smoke alarm intended for use in recreational boats shall comply with requirements specified in 89.1 – 89.6, in addition to the requirements specified in 1 – 88 and 91 – 102, inclusive.

89.1.2 These requirements apply to the construction and performance characteristics for single station self contained battery operated alarms as well as alarms powered by the vessels installed DC system. These alarms may be used in stand alone operation or as part of an integrated multiple device system when installed.

89.1.3 All batteries included with smoke alarms intended for use in recreational boats shall at a minimum have a published operational specification range of minus 20°C to 60°C (minus 4°F to 140°F). Recommended replacement batteries shall also meet the temperature range.

89.1.4 Sample requirements for single criteria smoke alarm are defined in Table 89.1, Samples for performance tests (Recreational boats).

Table 89.1
Samples for performance tests (Recreational boats)

Number of samples[a]	Test
3	Sensitivity Test, Section 42
3	Operation tests following conditioning, Section 89.2
3	Abnormal Operation Test, Section 74
1	Salt-spray corrosion test, Section 89.4
3	Overvoltage and Undervoltage Tests, Section 57
3	Survivability Tests, Section 82
3	Audibility Test, Section 84

[a] The same 3 samples are to be used for each test. When only 1 sample is required it shall be any one of the previously tested samples.

89.1.5 Sample requirements for multi-criteria smoke alarms with gas sensor are defined in Table 89.2, Samples for performance tests (Recreational boats multi-criteria smoke alarm with gas sensor).

89.1.6 During each test condition the same battery samples shall be used for all of the test conditions. The tests shall be conducted during each battery model specified in the markings or the installation instructions.

Table 89.2
Samples for performance tests (Recreational boats multi-criteria smoke alarm with gas sensor)

Number of samples[a]	Test
3	Sensitivity Test, Section 42
3	Operation tests following conditioning, Section 89.2
3	Abnormal Operation Test, Section 74
1	Watertightness Test, Section 89.3
1	Salt-spray corrosion test, Section 89.4
3	Overvoltage and Undervoltage Tests, Section 57
3	Survivability Tests, Section 82
3	Audibility Test, Section 84

[a] The same 3 samples are to be used for each test. When only 1 sample is required it shall be any one of the previously tested samples.

89.2 Operational tests following conditioning

89.2.1 Immediately following each test condition, an alarm shall operate in accordance with the levels specified in Sensitivity Test, Section 42. When specified by the manufacturer, it is not prohibited that the alarm be warmed up prior to a test or sensitivity check.

89.2.2 The same samples are to be used for each of the conditions in this section. The samples are to be energized (except for humidity) during each exposure. The three samples are to be placed in an air circulating oven maintained at 70 ±2°C (158 ±4°F) for 24 hours.

89.2.3 Immediately following the conditioning specified for high temperature and the sensitivity test, the same alarms are to be placed in a cold chamber maintained at minus 30 ±2°C (minus 22 ±4°F) for 24 hours.

89.2.4 The same three alarms used in the temperature tests are to be used in the vibration test as specified in Section 59. The alarms, including all components, are to be mounted on a vibration table so as to simulate as closely as possible an actual installation on a boat in accordance with the device manufacturer's installation instructions. The means used for such mounting shall be rigid enough to reduce resonant frequencies of the mounting means. The vibration table is to produce vibration frequencies and amplitude specified as follows: The alarms are to be subjected to a variable frequency vibration along each of the three rectilinear orientation axes (horizontal, lateral, and vertical) for 4 hours in each plane (12 hours total) at peak to peak amplitude of 0.015 ±0.001 in. (0.40 ±0.05 mm). The frequency of vibration is to be continuously varied, at a uniform rate, from 10 to 60 to 10 Hz every 4 minutes.

89.2.5 For this test, peak to peak amplitude is defined as the maximum displacement of sinusoidal motion (total machine displacement).

89.2.6 The same three alarms are to be mounted on a shock machine in the same manner as described in the vibration conditioning. The samples are to be subjected to 5000 shock impacts of 10 g acceleration (98 m/s^2) and having a shock duration of 20 – 25 milliseconds as measured at the base of the half-sine shock envelope.

89.2.7 The machine used for this conditioning is to be of the automatic cycling type capable of producing a half sine shock pulse at the acceleration level and duration specified. The acceleration and shock pulse duration is to be measured by a piezoelectric accelerometer mounted on the test machine platform on an axis parallel to the axis of motion.

89.2.8 The test samples are to be mounted so that the center of gravity of the sample is as close as possible to the geometric center of the machine platform.

89.2.9 Following the vibration and shock conditioning, the same three alarms are to be used for the humidity conditioning. The alarms are to be subjected to air at a relative humidity of 90 ±5 percent and a temperature of 40 ±2°C (104 ±4°F) for 96 hours. The alarms are not to be energized during this condition.

89.2.10 Immediately following the above conditioning, the alarms are to be subjected to air at a relative humidity of 30 ±5 percent and a temperature of 23 ±3°C (73 ±5°F) for 96 hours. The alarms are not to be energized during this conditioning.

89.2.11 Multi-criteria smoke alarms with gas sensor will conduct the Stability Test for recreational boat approval; the following substitutions are to be made:

a) Thirty days in air at 66 ±3°C (150 ±6°F).

b) At least 72 hours at minus 40 ±2°C (minus 40 ±4°F).

c) Ten days in 93 ±2 percent humidity at 61 ±2°C (142 ±4°F).

89.2.12 Smoke sensitivity measurements, recorded in the environmental chamber smoke box, shall not vary more than specified in 38.3, Sensitivity shift criteria. During the sensitivity measurement, the environmental chamber is to be as close as possible to the test conditions specified in 89.2.11, condition (a) to be conducted at 49°C, condition (b) to be conducted at 0°C, and condition (c) to be conducted at 40°C, 93 percent relative humidity, respectively.

89.2.13 Gas sensitivity measurements, recorded in the environmental chamber, shall not vary more than specified in 42.8, Sensitivity test – gas sensor of a multi-criteria smoke alarm.

89.3 Watertightness Test

89.3.1 A smoke alarm marked ″Watertight″ is to be tested as specified in 89.3.2. There shall be no evidence of water leakage so as to reach energized parts. No false alarms shall be generated and the alarm shall operate as intended.

89.3.2 One sample smoke alarm from the humidity conditioning is to be used for this test. The assembly is to be mounted in accordance with the manufacturer's installation instructions and energized. A solid stream of water from a nozzle not less than 1 in. (25.4 mm) in diameter and a flow rate of 65 gallons per minute (3 psig), measured at the nozzle, is to be directed at the enclosure in all directions from a distance of 10 ft. (3.1 m) for 5 minutes.

89.3.3 Any water on the exterior of the enclosure is to be removed with a cloth and the enclosure then opened and examined for any evidence of leakage.

89.3.4 An alarm that complies with this test shall be marked in accordance with 89.5.4. See also 89.5.5.

89.4 Salt-spray Corrosion Test

89.4.1 Following the tests in 89.2, Operational Tests Following Conditioning, two sample smoke alarms shall operate as intended and their mounting means shall show no signs of structural deformation after exposure for 48 hours to a salt spray in accordance with the procedure specified in the Standard for Salt Spray (Fog) Testing, ASTM B117. To determine compliance with this test, an alarm is to be subjected to the Sensitivity Test, Section 42.

89.4.2 A smoke alarm is to be mounted in accordance with the manufacturer's installation instructions and subjected to the salt spray while in a de-energized condition. Following the exposure, the samples are to be removed and air dried for 48 hours at 23 ±3°C (73 ±5°F) in a de-energized condition.

89.5 Marking

89.5.1 In addition to the applicable requirements in Section 89, a smoke alarm for use in a Recreational Boat shall be permanently and legibly marked with the following information. The markings shall be in a contrasting color, finish, or equivalent, in letters at least 3/64 in. (1.2 mm) high. Items (f) and (g) shall be readily visible after installation:

a) Manufacturer's or private labeler's name or identifying symbol;

b) Model, type, or catalog designation;

c) Date of manufacture (in code is not prohibited);

d) Electrical rating in volts and amperes;

e) Reference to owner's manual;

f) The type of product, such as ″Marine Smoke Alarm,″ or ″Marine Multicriteria Smoke Alarm" equivalent. It is not prohibited that this marking be incorporated in (g); and

g) Identification of switches and light indicators.

89.5.2 When a manufacturer uses one light to indicate more than one condition, a key to interpret the signals shall be provided on the face of the alarm.

89.5.3 When a manufacturer produces an alarm at more than one factory, each such assembly shall have a distinctive marking to identify it as the product of a particular factory.

89.5.4 An alarm that complies with the requirements in the Watertightness test, 89.3, shall be marked ″Watertight.″

89.5.5 An alarm not marked in accordance with 89.5.4 shall be marked ″For enclosed spaces only,″ or the equivalent.

89.6 Operating and installation instructions

89.6.1 Each alarm shall be provided with installation and operating instructions that include the following information:

a) Typical installation drawing layouts for the smoke alarm(s) indicating appropriate locations and wiring methods. Locations where alarm installations are not appropriate shall also be included;

b) Description of the operation, testing, and proper maintenance procedures for the alarm(s) including the warm-up period (including time), when applicable;

c) Replacement parts, such as lamps or batteries, shall be identified in the instructions by a part number, manufacturer's model number, or the equivalent, and information on where to obtain the part;

d) Description of the various conditions in which the alarm becomes ineffective or contaminated. Test the alarm when a possibility of one of these conditions has existed;

e) In addition to the conditions described in (d), and to reduce the risk of nuisance tripping of the alarm circuit, the instructions shall state that accommodation spaces are to be well ventilated when household cleaning supplies or similar contaminates are used;

f) Information regarding the alarm and an indication where false alarms are to be anticipated;

g) Identification of the owner's manual or instruction sheet by number or equivalent;

h) An indication that the device shall not be installed in locations where temperature, moisture, and/or ultraviolet light affect the operation, unless the alarm is intended and tested for installation in these areas;

i) The name and address of the company to whom the alarm is to be sent for servicing;

j) The word ″WARNING″, and the following or equivalent text: ″TO REDUCE THE RISK OF CARBON MONOXIDE POISONING, TEST ALARM OPERATION WHEN NOT IN USE FOR 10 DAYS OR MORE;″

k) The word ″CAUTION″ and the following or equivalent: ″The alarm only indicates the presence of carbon monoxide gas at the sensor. Carbon monoxide gas may be present in other areas;″

l) The instructions shall also state that individuals with medical problems consider using detection devices with lower COHb alarming capabilities; and

m) A statement shall be provided to specify that the alarm, including a sensor, is not to be located within 5 ft. (1.5 m) of any cooking appliance.

89.6.2 The instructions shall be incorporated on the outside of the alarm, on a separate sheet, or as part of a manual. When not included directly on the alarm, the instructions or manual shall be referenced in the marking information on the alarm.

89.6.3 The material shipped with the alarm, including the package, instructions, or user's manual, shall not include information contrary to that specified in 89.6.1, such as manufacturer's claims on the operation of the alarm which have not been substantiated by the performance tests included in this standard.

MANUFACTURING AND PRODUCTION

90 General

90.1 To verify compliance with the requirements of this section, the manufacturer shall provide the necessary production control, inspection, and tests. The program shall include at least the tests specified in Sections 91 – 96.1 conducted on 100 percent of the production unless otherwise specified.

90.2 A record of accepted smoke alarms, and the smoke alarm serial number or date code, or equivalent identification is to be maintained.

91 Sensitivity Calibration Tests

91.1 The smoke sensitivity of each single or multi-criteria smoke alarm is to be checked, following the warm-up period specified by the manufacturer and using appropriate instruments, to determine that the sensitivity level is within the marked rating including tolerance, which is within the smoke alarm's specified limits. The test equipment is to verify the value or range of sensitivities marked on the smoke alarm. The value of instrument reading is to be convertible to percent per m (percent per ft.) obscuration.

91.2 For multicriteria smoke alarms, the sensitivity of each sensor shall be verified according to the manufacturer's specification for each sensor following the warm-up period specified by the manufacturer. The limits shall be as specified by the manufacturer. The limits shall be as specified by the manufacturer and verified by Section 42, Sensitivity Test.

91.3 For the warm-up period, the smoke alarms shall be energized from a source of supply as specified in Table 37.3, Test voltages. In cases where the smoke alarm sensitivity is not within the manufacturer's specifications, the smoke alarm is to be corrected and retested. When a retested sample is still outside the specifications, it is to be rejected.

91.4 A warm-up period is not required when the smoke alarm components, except for a photocell illuminating lamp, are operated at not more than 25 percent of the component manufacturer's power or temperature rating, whichever is appropriate, in the standby condition or when the individual components are burned-in prior to assembly.

91.5 A warm-up period is required for those smoke alarms or individual components operating at more than 25 percent of rating whose characteristics are variable during initial warm-up, such as solid-state devices, lamp filaments, and resistors, that affect smoke alarm sensitivity.

92 Smoke Tests

92.1 A minimum of two samples from each day's production shall be subjected to a test to determine response from smoke. A smoke test chamber, equivalent to the test compartment described in Appendix B with at least one of the measuring instruments to record the smoke level, shall be employed in conjunction with a smoke generating source, such as a smouldering cotton wick, punk sticks, aerosol generator or equivalent means.

93 Photocell Illuminating Lamp Test

93.1 The manufacturer is to provide facilities for measurement of all the photocell illuminating lamps used in production smoke test chambers (where applicable), including any replacement lamps that are provided, to determine that the illumination output is uniform and within the specifications for the intended use.

94 Measurement of In-Service Reliability for Multi-criteria Smoke Alarms with Gas Sensor(s)

94.1 Required in-service reliability

94.1.1 Reliability for Supervised Failures: The cumulative supervised failures over the specified lifetime of a multi-criteria smoke alarm shall not exceed 23 percent at a 90 percent confidence level.

94.1.2 Reliability for Unsupervised Failures: The cumulative unsupervised failures over the specified lifetime of a multi-criteria smoke alarm shall not exceed 14.6 percent at a 90 percent confidence level.

94.2 Sample frequency and sample size

94.2.1 In-service reliability shall be estimated by subjecting a suitable sample of devices to the Sensitivity Test of Section 42 or Section 42.8, Sensitivity test – gas sensor of a multi-criteria smoke alarm, at the manufacturer's specified gas concentrations.

94.2.2 Reliability information on devices shall be collected quarterly using any of the following methods:

a) Life cycle testing at the manufacturer's facility,

b) Testing of devices installed in the field, or

c) Laboratory testing of devices bought back from customers.

94.2.3 Prior to testing, devices shall be installed and operated in an actual or simulated intended environment for a period of sufficient duration to predict the average failure rate of the overall population over the devices' specified lifetime. During the installation period the alarms shall be tested and an upper bound on their failure rate at a 90 percent confidence level shall be determined at quarterly intervals. It is not prohibited that installation times of less than the devices' specified lifetime, but not less than 3000 hours, be used in this analysis, taking into account any other measurements that might be available demonstrating the applicability of the shorter installation period for estimating failure rates averaged over the devices' specified lifetime. The data from the shorter installation period shall be replaced with data from progressively longer durations, up to the devices' specified lifetime, as it becomes available. When no data is available to demonstrate the applicability of the shorter duration data it is still usable.

94.2.4 The sample size for tests shall be determined according to widely accepted procedures for statistical quality control, as summarized in Appendix E. A statistically significant sample of representative devices shall be randomly chosen to estimate the required in-service reliability at the required confidence level.

94.3 Test results and record keeping

94.3.1 The manufacturer shall maintain data and records of all tests performed to evaluate devices' conformance to the required in-service reliability.

95 Production Line Dielectric Voltage-Withstand Tests

95.1 When the alarm employs high-voltage and low-voltage circuits, the test is to be conducted with the low-voltage circuit connected to the cabinet, chassis, or other dead metal parts so that the potential that is applied between the high-voltage live parts and dead metal parts is applied simultaneously between high-voltage live parts and low-voltage circuits.

95.2 A printed-wiring assembly or other electronic-circuit component that is damaged or short-circuited, by application of the test potential, is to be removed, disconnected, or otherwise rendered inoperative before the test. It is not prohibited for a representative subassembly to be tested instead of an entire unit.

95.3 A 500 volt-amperes or larger transformer, the output voltage of which is able to be varied, is to be used to determine compliance with 95.1. A 500 volt-amperes or larger transformer is not required when the high potential testing equipment used is such that it maintains the specified high potential voltage at the equipment for the duration of the tests.

95.4 The test equipment used for this test is to include a visible indication of application of the test potential and an audible or visible indication, or both, of breakdown. In the event of breakdown, manual reset of an external switch is to be required, or an automatic reject of the unit under test is to result. Other arrangements are to be evaluated and accepted when found to achieve the results contemplated.

95.5 Where the charging current through a capacitor or capacitor-type filter connected across the line, or from line to earth ground, is enough to prevent maintaining the specified AC test potential, the alarm is to be tested using a DC test potential in accordance with 96.1.

96 Production Line Grounding Continuity Tests

96.1 The manufacturer shall test each alarm that has a power-supply cord terminating in an attachment-plug employing a grounding pin to verify electrical continuity between the device and the grounding blade of the attachment-plug.

96.2 For this test, the manufacturer is to employ a resistance-indicating instrument with leads and terminals which determine the grounding circuit continuity.

96.3 When an investigation of the alarm has shown all exposed dead metal parts that become energized and all dead metal parts within the enclosure that are exposed to contact during servicing to be acceptably bonded to the frame and enclosure of the alarm, a test that determines the electrical continuity between the grounding blade and the frame or enclosure is satisfactory.

97 Battery Quality Assurance

97.1 When batteries are employed in a smoke-alarm, the smoke-alarm manufacturer shall conduct a quality assurance programme on the batteries to determine the operational capability. The battery quality assurance may be conducted by the battery manufacturer if each shipment is accompanied by a certificate of compliance verifying the condition on that shipment.

98 Smoke Alarm Shipment

98.1 The battery intended to be employed with the alarm shall be shipped from the factory with the alarm in the same package. To prevent unnecessary drain during shipment and storage, the battery shall not be connected in the alarm. One or both polarities of the battery shall be physically disconnected from the circuitry of the smoke alarm such that no battery capacity is used to provide standby, sleep, or other power to the alarm.

98.2 A nonrechargeable standby battery of an AC operated accessory to a single- or multiple-station smoke alarm is not required to be shipped with the unit when instructions on the unit specify the battery to be used by model number and manufacturer, as well as a source of purchase. A rechargeable standby battery shall be shipped with the unit in which it is to be employed.

MARKING

99 General

99.1 A smoke alarm shall be permanently marked with the following information unless specifically indicated that it appears on the installation wiring diagram. The marking shall be in a contrasting color, finish, or equivalent. Unless the letter height is specified, all markings shall be at least 3/64 in. (1.2 mm) high.

a) Name or identifying symbol and address of the manufacturer or vendor.

b) Model number and date of manufacture. The date of manufacture shall be non-coded and in the format YEAR (in 4 digits), MONTH (in letters), DATE (in 2 digits) located on the outside of the smoke alarm.

c) A multi-criteria smoke alarm shall be marked, “Multi-Criteria Smoke Alarm.”

d) Electrical rating, in volts, amperes, or watts, and frequency. Not required for battery operated alarms.

e) Correct mounting position when a unit is intended to be mounted in a definite position. This information may appear in the installation instructions.

f) Identification of lights, switches, meters, and similar devices regarding their function unless their function is obvious.

g) Maximum rating of fuse in each fuseholder and temperature rating of supplementary heat detector, when provided, in degrees Fahrenheit and Celsius.

h) Identification of spare lamps and batteries by part number, manufacturer's model number or equivalent. Located adjacent to the component.

i) Reference to an installation diagram and/or owner's manual.

j) For a smoke alarm that employs a radioactive material, the following information shall be indicated directly on the exterior of the unit:

i) The statement ″CONTAINS RADIOACTIVE MATERIAL,″

ii) Name or Radionuclide and quantity (no abbreviations), and

iii) The statement, ″U.S. NRC License No. XXX.″ (XXX – No. of License) or the name of the Licensee.

k) An alarm shall be marked on the outer surface of the enclosure with the following or equivalent notice: ″Do Not Paint.″ The letters shall not be less than 1/8 in. (3.2 mm) high and shall be located so as to be readily visible after the alarm is mounted in its intended manner.

l) The following or equivalent qualifying statement on a battery-operated alarm where battery operation, under other than normal room ambient temperature conditions during the long term (minimum 1 year) battery tests in 85.3, is less than 1 year:

″CONSTANT EXPOSURES TO HIGH OR LOW TEMPERATURES OR HIGH HUMIDITY MAY REDUCE BATTERY LIFE.″

m) Distinction between alarm, end-of-life and trouble signals.

n) For battery operated alarms employing replaceable batteries, reference to a source for battery replacement. (It is permissible for this to appear in the homeowner's manual.)

o) For a battery operated alarm employing replaceable batteries, the word ″WARNING″, and the following or equivalent marking shall be included on the unit: ″Use Only Batteries Specified In Marking. Use Of A Different Battery Will Have A Detrimental Effect On Smoke Alarm Operation.″ . The letter height shall be a minimum of 1/8 in. (3.2 mm) for ″WARNING″ and 3/64 in. (1.2 mm) for the rest of the notice.

p) For a smoke alarm employing a nonrechargeable standby battery, the marking information described in 35.2.1 and 35.2.4 shall be in letters not less than 1/8 in. (3.2 mm) high.

q) Test instructions and frequency. Not less than once per week for battery-powered alarms and not less than once per month for other than battery-powered alarms.

r) Maintenance instructions, such as cleaning, lamp and battery replacement.

s) Units intended to be returned to the manufacturer for servicing shall be marked as follows on the outside of the alarm: ″RETURN TO (+) FOR SERVICING,″ or equivalent. It is permissible for units on which the cover is removable, and that are also intended to be returned to the manufacturer for servicing, to have the marking on the inside of the alarm.

(+)Name and address of manufacturer or supplier.

t) The smoke sensitivity setting for a smoke alarm having a fixed setting. For an alarm which is intended to be adjusted in the field, the range of sensitivity shall be indicated. The marked sensitivity shall be indicated as a percent per ft. obscuration level. The marking shall include a nominal value plus tolerance. For an alarm that is capable of receiving a firmware update, and the sensitivity production range is impacted by the content of the firmware update (such as a new smoke algorithm), a means of indicating the current certified sensitivity or sensitivity range for the current firmware version of the unit shall be provided.

u) For a battery-operated smoke alarm employing a non-replaceable 10-year battery, a statement indicating that the unit is sealed, with no serviceable parts, and that the maintenance and testing specified elsewhere on the marking must be performed.

v) For a battery-operated smoke alarm employing a non-replaceable 10-year battery, a description of how to use the deactivation feature and indication that once deactivated the smoke alarm is incapable of being reactivated and must be replaced.

w) A smoke alarm guard shall be permanently marked with the following information in a contrasting color, finish, or equivalent:

i) Name or identifying symbol of the manufacturer or private labeler,

ii) Model number and

iii) A statement indicating that the guard is only to be used with smoke alarms specified in the installation instructions of the guard or smoke alarm.

x) The smoke alarm shall be marked with the following or equivalent, “Replace after X years”. X = Lifetime of the product that identifies when the end-of-life signal will be initiated, but shall not exceed 10 years.

99.2 Information required to appear directly on the alarm shall be readily visible after installation. Except for 99.1(k), the removal or opening of an enclosure cover not requiring a tool, or an equivalent arrangement to view the marking is not prohibited.

99.3 When markings are placed on the base (bottom) of an alarm intended for permanent installation, the word ″CAUTION″ and the following or equivalent marking in letters 1/8 in. (3.2 mm) high is to be provided on the outside or inside of the alarm: ″Additional marking on back. Disconnect power.″

99.4 Additional marking requirements are specified by 19.6.4, 41.9.6, 84.4.1, 88.2, 89.5, 89.6.1 (j) and (k).

99.5 For manufacturers producing alarms at more than one factory, each such assembly shall have a distinctive marking to identify each subassembly as the product of a particular factory.

99.6 With regard to the requirement in 15.2, Battery removal indicator, a warning flag shall be marked with the word ″WARNING″ and the following or equivalent text such as ″Smoke Alarm is Non-Operational.″ or ″NO BATTERY.″ The letter height shall be a minimum of 3/8 in. (9.5 mm) unless it is in a contrasting color, visible from 6 ft. (1.83 m).

Exception: Not required for supervised RF detectors.

100 Packaging Marking

100.1 The smallest point-of-sale carton in which a smoke alarm employing a radionuclide is packaged shall be permanently marked on the exterior with the following information. Each letter shall be at least 1.2 mm (3/64 in.) high and shall be in a contrasting color or finish with respect to the background, or the equivalent:

a) Name of radionuclide and quantity (no abbreviations).

b) The statement, ″U.S. NRC License No. XXX″ (XXX – No. of License) or the name of the Licensee.

c) The following or equivalent statement:

″THIS SMOKE ALARM CONTAINS RADIOACTIVE MATERIAL AND HAS BEEN MANUFACTURED IN COMPLIANCE WITH U.S. NRC SAFETY CRITERIA IN 10 CFR 32.27. THE PURCHASER IS EXEMPT FROM ANY REGULATORY REQUIREMENT.″

INSTRUCTIONS

101 General

101.1 Each single and multiple station smoke alarm shall be provided with installation instructions which shall include the following information:

a) Typical installation drawing layouts for the unit(s) indicating recommended locations and wiring methods which shall be in accordance with the applicable requirements outlined in the following:

1) National Electrical Code, NFPA 70, Wiring Methods and Materials;

2) National Fire Alarm and Signaling Code, NFPA 72, Single- and Multiple-Station Alarms and Household Fire Alarm Systems. Locations where smoke alarm installations are not recommended shall also be included.

b) Description of the operation, testing, and proper maintenance procedures for the unit(s). The frequency of testing shall be in accordance with NFPA 72, Inspection, Testing, and Maintenance.

c) Replacement parts, such as lamps or batteries, shall be identified in the instructions by a part number, manufacturer’s model number, or the equivalent, and information included as to where a homeowner is able to obtain the part.

d) The following text:

″For your information, the National Fire Alarm and Signaling Code, NFPA 72, reads as follows:″

″29.5.1 *Required Detection.″

*29.5.1.1 Where required by applicable laws, codes, or standards for a specific type of occupancy, approved single- and multiple-station smoke alarms shall be installed as follows:

(1) *In all sleeping rooms and guest rooms

(2) *Outside of each separate dwelling unit sleeping area, within 21 ft (6.4 m) of any door to a sleeping room, the distance measured along a path of travel

(3) On every level of a dwelling unit, including basements

(4) On every level of a residential board and care occupancy (small facility), including basements and excluding crawl spaces and unfinished attics

(5) *In the living area(s) of a guest suite

(6) In the living area(s) of a residential board and care occupancy

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e) Description of the various situations against which the smoke alarm may not be effective, for example:

1) Fires where the victim is intimate with a flaming initiated fire; for example, when a person’s clothes catch fire while cooking;

2) Fires where the smoke is prevented from reaching the smoke alarm due to a closed door or other obstruction;

3) Incendiary fires where the fire grows so rapidly that an occupant’s egress is blocked even with properly located smoke alarms.

f) More detailed information on the alarm, end-of-life and trouble signals and an indication where false alarms or trouble signals would be anticipated. The end-of-life information shall include details on how long the unit may be expected to last and shall indicate if the end-of-life is based on the date the unit was manufactured or the date that the user places the unit into service.

g) Identification of the homeowner's manual or instruction sheet by number or equivalent.

h) An indication that the device shall not be installed in locations where the normal ambient temperature is below 4.4°C (40°F) or exceeds 37.8°C (100°F), unless the alarm has been determined to be capable of being used at installation points with higher or lower ambient temperatures.

i) Reference to a source(s) of power limited cable for multiple station interconnection or connection of supplementary devices.

j) The manufacturer shall either provide information on an evacuation plan or include a copy of a separate booklet, or equivalent, which is published by the National Fire Protection Association, National Fire Prevention and Control Administration, or an equivalent agency. When the manufacturer provides information on an evacuation plan, it shall be in accordance with published information available from the National Fire Protection Association.

k) The following information:

1) Name and address of manufacturer or vendor.

2) Model number.

3) Electrical rating in volts, amperes or watts, and frequency. Not required for battery operated alarms.

4) Temperature rating of heat detector, when provided.

5) Test instructions and frequency.

6) Maintenance instructions such as cleaning and lamp and battery replacement.

7) Name and address of firm to whom alarm is to be sent for servicing.

8) The following notice: THIS EQUIPMENT SHOULD BE INSTALLED IN ACCORDANCE WITH THE NATIONAL FIRE PROTECTION ASSOCIATION'S STANDARD 72 (National Fire Protection Association, Batterymarch Park, Quincy, MA 02269).

l) For multiple station alarms, identify the manufacturer and model number of compatible alarms and accessories, such as, but not limited to smoke-alarms, heat alarms, carbon monoxide alarms, signalling devices and/or switching modules.

m) For smoke alarm-transmitters intended to be installed with compatible audible signal receiver units, instructions shall include the limitations of use in typical single level and multilevel dwelling units as well as in apartment buildings where it is possible that adjacent apartments have similar systems.

n) For alarms also recognized for installation in recreational vehicles, the word ″WARNING,″ and the following or equivalent text: ″TEST SMOKE ALARM OPERATION AFTER VEHICLE HAS BEEN IN STORAGE, BEFORE EACH TRIP, AND AT LEAST ONCE PER WEEK DURING USE″. An identical marking is to be provided by the recreational vehicle manufacturer that shall be permanent and located, visibly, within 24 in. (610 mm) of the smoke alarm.

o) Smoke alarms are not to be used with smoke alarm guards unless the combination has been evaluated and found suitable for that purpose.

p) For alarms powered by a non-replaceable battery, the instructions shall provide a description of the proper use of the battery activation and deactivation features. This information shall specify that each feature is intended for one time use only.

q) An indication that current studies have shown smoke alarms may not awaken all sleeping individuals, and that it is the responsibility of individuals in the household that are capable of assisting others to provide assistance to those who may not be awakened by the alarm sound, or to those who may be incapable of safely evacuating the area unassisted.

101.2 It is not prohibited that the instructions be incorporated on the outside of the unit, on a separate sheet, or as part of a manual. When not included directly on the device, the instructions or manual shall be referenced in the marking information on the unit.

101.3 The material shipped with the alarm, including the package, instructions, or user's manual, shall not include information other than that specified in 101.1, such as manufacturer's claims on the operation of the alarm which have not been substantiated by the performance tests included in this standard, or that are not covered in Household Fire Warning Equipment provisions of NFPA 72, or other applicable NFPA standards of the National Fire Protection Association. The package shall also include the end-of-life information described in 101.1(f).

101.4 For smoke alarms for use on recreational boats, the smoke alarm installation instructions shall include the following or equivalent:

a) The smoke alarm is intended to be installed in enclosed accommodation compartments where smoke from undetected fire may accumulate.

b) The instructions shall indicate that the devices shall be wired in accordance with Fire Protection Standard for Pleasure and Commercial Motor Craft, NFPA 302, and AC and DC Electrical Systems on Boats, ABYC E-11, and applicable regulations of the United States Coast Guard.

101.5 For multiple-station interconnected smoke alarms with alarm silencing means, other than physically depressing the silence button, the silencing of the initiating alarm shall describe the following:

a) An example and information detailing the alarm information as communicated to the user;

b) As described in 13.5 all operating instructions shall include detailed information for the user to confirm that he has checked for the presence or absence of smoke at the initiating alarm before activating the silence feature;

c) As described in 13.5, all wireless communication remote device notifications shall include a means for the user to confirm that he has checked for the presence or absence of smoke at the initiating alarm before activating the silence feature.

102 Installation Instructions – Wiring Diagram

102.1 All smoke alarms

102.1.1 Installation instructions, including an installation wiring diagram, shall be packaged with each smoke alarm (head with integral base) illustrating the field connections to be made. For smoke alarms that consist of separable heads and bases, the instructions and diagram shall be packaged with the base. It is permissible for the instructions to be attached to the smoke alarm (head with integral base) or separable base. When not attached, the instructions shall be referenced in the smoke alarm (head with integral base) or base marking. Where devices are packaged in bulk (multiple devices in one single package) and not intended for individual resale, a minimum of one set installation instructions and drawings shall be provided.

102.1.2 The installation wiring diagram shall show a pictorial view of the installation terminals or leads to which field connections shall be made as specified in (a) – (c):

a) Monitored connections (identified incoming and outgoing leads) to the initiating device circuit of a control unit and power supply circuit. See Figure 102.1 for examples.

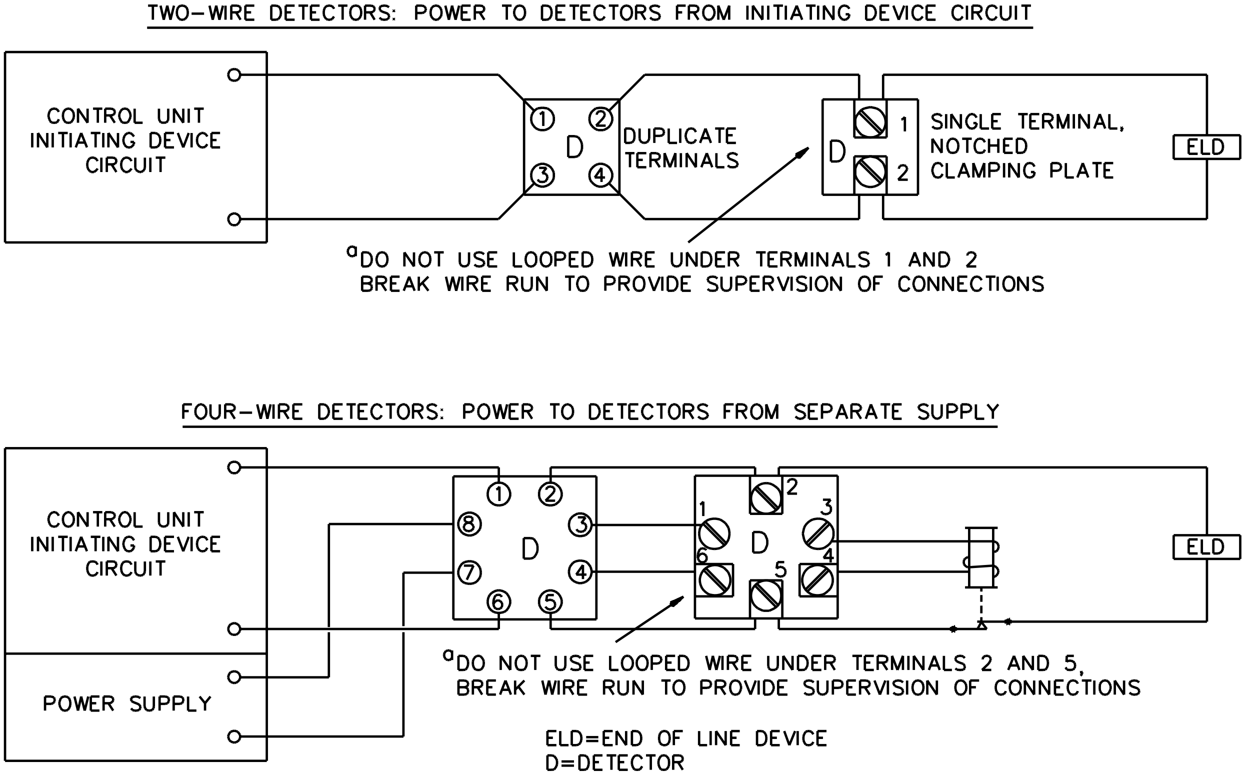
b) The terminal numbers or position (if distinctive) on the smoke alarm (head with integral base) or separable base shall agree with the numbers or position on the drawing.

c) When duplicate terminals are not provided to facilitate monitoring of the installation wiring connections, and there is no provision to prevent looping an unbroken wire around or under a terminal, the word ″CAUTION″ and the following or equivalent text in letters not less than 2.38 mm (3/32 in.) high shall be included on the installation drawing: ″FOR SYSTEM MONITORING – FOR TERMINALS ___ AND ___, DO NOT USE LOOPED WIRE UNDER TERMINALS. BREAK WIRE RUN TO PROVIDE MONITORING OF CONNECTIONS.″ The blanks shall contain the applicable terminal identification.

d) For a smoke alarm intended only for releasing device service, a typical connection shall be shown.

e) Initiating Device Circuit – For open area smoke alarms intended to be connected only to the initiating device circuit of a fire alarm system control unit, at least two smoke alarms shall be shown connected to a typical initiating device circuit.

Figure 102.1
Sample installation drawing for monitored connection of smoke alarms



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102.1.3 Instructions (diagram) not attached to the smoke alarm (head with integral base) or separable base shall be marked with the name or identifying symbol of the manufacturer or private labeler, smoke alarm or separable base model number, issue number and date, or equivalent.

102.1.4 Installation instructions for a separable base shall include reference to all smoke alarm heads with which it is employed, by name of manufacturer and model number, or equivalent.

102.1.5 When a technical bulletin or engineering drawing is separate from the installation instructions, the instructions shall reference the issue number or date of the bulletin.

102.1.6 When other technical literature is required for installation or determination of compatibility between equipment, the instructions shall reference and identify the technical literature and its source. A copy of such literature shall be provided for review.

102.1.7 The instructions shall include the following statement: ″Smoke alarms are not to be used with smoke alarm guards unless the combination has been evaluated and found suitable for that purpose.″

102.2 Four-wire detectors

102.2.1 The marking information specified in (a) and (b) shall appear on the installation wiring diagram for the applicable circuit to which field connections are made:

a) Supply Circuit – Voltage, current or watts, and frequency.

b) Supplementary Circuits – Voltage, current or watts.

102.2.2 Units rated in minimum and maximum voltage (or current) limits shall be marked with those ratings.

102.3 Two-wire detectors

102.3.1 The instructions for two-wire detectors shall either include or provide reference to other identifiable literature and its source that contains the following information:

a) Name of manufacturer, model number(s) of compatible control unit(s), and compatibility identification marker.

b) Name or model number of any plug-in zone module, zone card, or zone panel, when more than one is available.

c) Identification of any other part of the control unit, such as specific wiring terminal numbers, or reference to the control unit installation wiring diagram by issue number and date, or any other variables requiring programming which are a factor in determining compatibility.

d) The maximum number of smoke alarms that are intended to be connected to each initiating device circuit of the control unit. This includes any smoke alarms that employ an integral component, such as a relay or sounder, that consumes power during an alarm condition.

e) Minimum and maximum rated operating voltage.

f) Maximum rated normal standby current.

g) Minimum and maximum rated alarm current and impedance.

h) Minimum current and voltage required for intended operation of integral components, such as a relay or sounder.

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APPENDIX A

Standards for Components

Standards under which components of the products covered by this standard are evaluated include the following:

Title of Standard − UL Standard Designation

Flexible Cords and Cables – UL 62
Fuseholders – Part 1: General Requirements – UL 4248-1
Printed-Wiring Boards – UL 796
Switches, General-Use Snap – UL 20
Transformers, Specialty – UL 506
Tubing, Extruded Insulating – UL 224
Wire Connectors – UL 486A-486B
Wires and Cables, Thermoplastic-Insulated – UL 83
Wires and Cables, Thermoset-Insulated – UL 44

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APPENDIX B – TYPICAL SENSITIVITY SMOKE TEST CHAMBER CONSTRUCTION

B1 Construction

B1.1 The visible smoke/aerosol obscuration (optical density) in the test compartment is to be measured by means of a DC type microammeter having a maximum internal resistance of 100 ohms and full scale reading of 100 mA used with a barrier type selenium photovoltaic cell, enclosed in a hermetically sealed case.[a] An equivalent meter consists of a digital voltmeter having a minimum input impedance of 10 megohms in parallel with a 100 ohms resistance, and a 500 ohms potentiometer. The meter and cell shall be used in conjunction with the light produced by a tungsten filament automotive type lamp (such as a prefocused spotlight bulb) energized from a constant current source at half rated voltage to provide a light beam of uniform flux density. The photoelectric cell and lamp shall be spaced 1.524 m (5.0 ft.) apart. Refer to Appendix C for equations to be used.

B1.2 A measuring ionization chamber (MIC)[b] is to be used to measure the relative buildup of particles of combustion during each trial. The MIC utilizes the ionization principle with air drawn through the chamber at a rate of 25 ±5 liters per minute by a regulated vacuum pump.

B1.3 A typical test chamber consists of the following items. When other chamber configurations are used they shall provide a homogeneous smoke/aerosol mix and a laminar air flow across the smoke alarm, adjustable from 0.16 to 0.76 m/s [30 to 150 feet per minute (fpm)].

a) Outer Cabinet – Constructed of 19.1-mm (3/4-in.) exterior grade plywood, and having overall inside dimensions of 1.67 m (65-3/4 in.) length by 464 mm (18-1/4 in.) depth by 460 mm (18-1/8 in.) width. Has a centrally located gasketed hinged top door 860 mm (33-7/8 in.) wide in the top with a 368 by 610-mm (14-1/2 by 24-in.) clear plastic window. A 6.4-mm (1/4-in.) diameter hole is located in the window center for air flow measurement. Box is provided with a 178-mm (7-in.) diameter exhaust port in the right end, centered 114 mm (4-1/2 in.) above the bottom and employed with a sliding or hinged wooden cover.

b) Inner Compartment – Constructed of 19.1-mm (3/4-in.) plywood, having inside dimensions of 1.06 m (41-3/4 in.) length by 292 mm (11-1/2 in.) height covering the entire width of the inside of the outer cabinet. The left end has a 102-mm (4-in.) diameter hole for the 30 – 35 fpm circulating fan centered 114 mm (4-1/2 in.) from the side and 98 mm (3-7/8 in.) from the bottom rear corner, a 146-mm (5-3/4-in.) diameter hole for the 150 fpm circulating fan centered 96.1 mm (3-7/8 in.) above the bottom, and a 102-mm (4-in.) diameter hole for the light beam centered 76.2 mm (3 in.) in either direction from the top back corner. The right end is the same as the left end except that it has one additional 102-mm (4-in.) diameter hole centered 76.2 mm (3 in.) in either direction from the top front corner. Nominal 15.9-mm (5/8-in.) molding strips are used to secure the end pieces and the top. All interior surfaces are painted with a flat black paint.

c) Circulating Fan 91 mpm (300 fpm)[c] – sized sufficient to obtain 91 mpm (300 fpm). The fan, located on either side of the opening, is connected to a motor controller (autotransformer) or equivalent to adjust speed.

[a] A meter intended for this purpose is Weston Instrument, Model 622, in conjunction with a Weston Instrument, Model 594 RR Photronic Cell.or equivalent.

[b] One MIC suitable for this purpose is Electronikcentralen, Horsholm Denmark, Type EC 23095 measuring ionization chamber.

[c] A fan intended for this purpose is Model 7600, by Pamoter, (Papst-Motoren GMBH & Co., KG) rated 115 volts, 60 Hz; or equivalent.

d) Circulating Fan 9 – 10.7 mpm (30 – 35 fpm)[d] – sized sufficient to obtain 9 – 10.7 mpm (30 – 35 fpm). The fan is connected to a regulated DC power supply.

e) Exhaust Fan – Same as (c), except speed not adjustable.

f) Photocell[e] – Selenium barrier layer type, 1.5-in. (38-mm) diameter for active area. Photovoltaic cell active material is sealed against environment and mounted on a 3/4-in. (19.1-mm) plywood bracket 5 in. (127 mm) behind a panel that has a 2-1/2-in. (63.1-mm) diameter hole to limit the detection of forward-scattered light. Photocell has a 25 percent maximum deviation from true linearity at 200 ft.-candles (2152 lm/m^2) with a 200 ohm load resistance, and has a sensitivity of 4.4 ±0.3 microamperes per ft.-candle (0.416 ±0.046 microamperes per lm/m^2) flowing through a 200 ohm load (meter resistance or other). The photocell (in use) is loaded with a nominal 100 ohm,1 percent load, trimmed with a 10,000 ohm, ten turn potentiometer placed across the loaded photocell in a configuration which has negligible affect on the total photocell load regardless of the potentiometer setting and is nominally illuminated at 22 ft.-candles (236.7 lm/m^2). Spectral response peak is between 530 and 580 nanometer with 30 percent sensitivity response at 350 and 660 nanometer.

g) Airstream Deflector – Constructed of sheet aluminum, 457 mm (18 in.) wide by 394 mm (15-1/2 in.) long, secured at each end by screws to two 19.1-mm (3/4-in.) thick plywood sections; each section is to be 219 mm (8-5/8 in.) high, 235-mm (9-1/4 in.) long (adjacent to top of test box) with a 254-mm (10-in.) radius curved section to which the deflecting plate is to be attached. The plate is to extend 25.4 mm (1 in.) beyond the upper edge and 15.9 mm (5/8 in.) beyond the lower edge. Each plywood cutout is to be secured to the side wall of the test compartment.

h) Airstream Straightener[f] – Constructed of aluminum honeycomb, nominal 6.4 mm (1/4 in.) cell size; overall dimensions shall be 178 by 457 by 76 mm (7 by 18 by 3 in.). When an equivalent honeycomb is employed the cell size length-to-diameter ratio shall be greater than 10.

i) Screen – Constructed of screening material of 0.3-mm (0.01-in.) aluminum wire, having nominal 1.6 mm (1/16 in.) square openings, 460.0 mm (18-1/8 in.) long by 178 mm (7 in.) wide. To be wedged adjacent to airstream straightener.

j) Monitoring Head[g] – Measuring Ionization Chamber (MIC) mounted on backwall adjacent to test sample area 25-mm (1-in.) above test platform. Employed with (q).

k) Smoke Alarm Under Test – Located in center on inner compartment top. Positioned to rest on back or inverted and suspended from the box cover. Samples spaced at least 51 mm (2 in.) from the nearest edge of monitoring head. Located so that least favorable position for smoke/ aerosol entry faces oncoming airflow.

[d] Rotron, Model MD24B2, or equivalent.

[e] A photocell intended for this purpose is Model 594 RR, by Huygen Corporation

[f] Expanded Commercial Grade Honeycomb 1/4 CGH – 5.2 N, American Cyanamid Company, is intended for this purpose.

[g] An instrument intended for this application is manufactured by Electronikcentralen, Horsholm, Denmark, MIC Type EC 23095, and Measuring Ionization Chamber (MIC) Type EC 23095 and control equipment.

l) Outlets – 120 volt receptacles for test samples, controlled by an autotransformer on the control cabinet.

m) Lamp – Extra-low-voltage automotive spotlight, Type 4515 or equivalent, rated at 6 volts DC, and mounted on 19.1-mm (3/4-in.) plywood bracket 102 mm (4 in.) from the side wall in line with the photocell. The distance from the lamp (lens face) to photocell is to be exactly 1.52 m (5 ft.). The lamp is to be operated from a voltage regulated supply at 2.40 volts. Exact specifications: the lamp voltage is to be adjusted to a level that yields a lamp color temperature of 2373 ±50 Kelvin. At that level, the photocell current is to be 100 ±25 microamperes into 100 ohms. The lamp is not to result in random meter fluctuations.

n) Combustible Holder and Screen (32 fpm velocity) – Steel cylinder open on both ends, having 76.2-mm (3-in.) diameter by 152.4-mm (6-in.) height with 3.2-mm (1/8-in.) diameter holes on 7.1-mm (9/32-in.) centers. Smaller 0.8-mm (1/32-in.) diameter holes spaced 2.4-mm (3/32-in.) on centers are arranged in 7.1-mm (9/32-in.) squares around each larger hole. Wick is held vertically by a wire in the center of and is supported by the screen. Combustible is cotton lamp wick with the smoldering end pointing downward so as to extend 127 mm (5 in.) into screen.

o) Combustible Holder and Screen (300 fpm velocity) – Same overall dimensions as holder for 9.75 mpm (32 fpm) velocity except 5-3/4 in. high, fabricated from solid sheet metal with a 13 by 48 mm (1/2 by 1-7/8 in.) rectangular opening at top for insertion of wick and a 5 mm (3/16 in.) diameter hole on side 25 mm (1 in.) from bottom. See Figure B1.

p) Meter Assembly – Digital microampere assembly consisting of a voltmeter having a minimum impedance of 10 megohms (clear air condition is indicated as 10 millivolts), and a trim potentiometer for adjustment of the meter. Connected directly to photocell. An analog direct current microammeter, having a maximum impedance of 100 ohms and a linearity of 1 percent or better over a range of 50 – 100 microamperes, is also permissible for use.

q) Control Cabinet – Cabinet for mounting timers, switches, variable autotransformer for varying supply voltage to outlets (l), and potentiometer for speed control of circulating fan (c).

r) Monitoring Head Meter[i] – High impedance meter 100 picoamperes full scale. Employed with (j) and (t).

s) Air Diffuser – Same type of screening material as described in (i). To be wedged between the underside of the air stream straightener and the deflector at 45-degree angle with the vertical.

t) Control Equipment (Monitoring Head) – Consists of a suction control unit employed with a vacuum pump and an amplifier with power supply. Employed with (j) and (q).

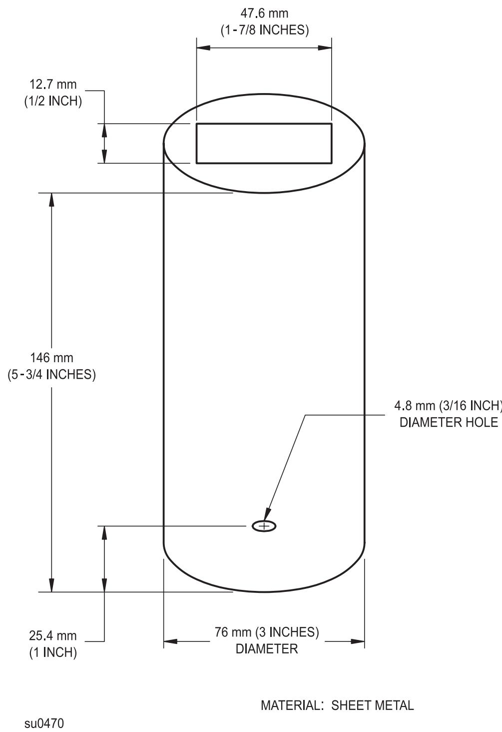
u) Recorder[i] – X-Y plotter. Records buildup of visible smoke versus MIC output.

[h] Fluke, Model 8022A, multimeter or equivalent.

[i] Heath, Model SR-207, rated 120 volts, 50/60 cycles, 35 watts.

v) Velometer[j] – Velocity measuring instrument with probe sensor. Probe inserted through hole in plastic window to measure air flow 25.4 mm (1 in.) above platform.

Figure B1
Wick holder 300 fpm (91 mpm)



[j] Alnor Instrument Co., Type 8500 or equivalent.

APPENDIX C – OBSCURATION CALCULATIONS

C1 Equations For Calculation Of Obscuration And Optical Density

C1.1 At any distance, the percent obscuration per meter or per ft. shall be:

$$O_u = \left[1 - \left(\frac{T_s}{T_c}\right)^{\frac{1}{d}}\right]100$$

in which:

O_u is percent obscuration per meter (or per ft.),

T_s is smoke/aerosol density meter reading with smoke,

T_c is smoke/aerosol density meter reading with clear air, and

d is distance in meters (or ft.).

C1.2 The percent obscuration of light for the full length beam at any distance shall be:

$$O_d = \left[1 - \frac{T_s}{T_c}\right] 100$$

in which:

O_d is percent obscuration at distance d,

T_s is smoke/aerosol density meter reading with smoke, and

T_c is smoke/aerosol density meter reading with clear air.

C1.3 The percent transmission of light for the full length beam at any distance shall be:

$$T_d = \left[\frac{T_s}{T_c}\right]100$$

in which:

T_d is percent transmission at distance d,

T_s is smoke/aerosol density meter reading with smoke, and

T_c is smoke/aerosol density meter reading with clear air.

C1.4 When the percent obscuration per meter or per ft. is known, the percent obscuration for the full length of any longer beam is determined by the following:

$$O_d = \left[1 - \left(1 - \frac{O_u}{100}\right)^d\right]100$$

in which:

O_d is percent obscuration at distance d,

O_u is percent obscuration per meter (or per ft.), and

d is distance in meters (or ft.).

C1.5 At any distance, the total optical density shall be:

$$OD_t = Log_{10}\left(\frac{T_c}{T_s}\right)$$

in which:

OD_t is optical density,

T_c is smoke/aerosol density meter reading with clear air, and

T_s is smoke/aerosol density meter reading with smoke.

C1.6 At any distance, the optical density per meter or per ft. shall be:

$$OD = \frac{Log_{10}\left(\frac{T_c}{T_s}\right)}{d}$$

in which:

OD is optical density per meter (or per ft.),

T_c is smoke/aerosol density meter reading with clear air,

T_s is smoke/aerosol density meter reading with smoke, and

d is distance in meters (ft.).

Obscuration – optical density chart Based on a 5-ft. (1.52-m) light beam

Light transmission (meter reading), microamperes	Obscuration (O_u)		Total obscuration O_d	Optical density (OD)		Total optical density, OD_t
	Percent per ft.	Percent per meter		Per ft.	Per meter	
100.0	0.000	0.000	0.000	0.0000	0.0000	0.0000
99.5	0.100	0.328	0.500	0.0004	0.0014	0.0022
99.0	0.201	0.657	1.000	0.0009	0.0029	0.0044
98.5	0.302	0.987	1.500	0.0013	0.0043	0.0066
98.0	0.403	1.317	2.000	0.0018	0.0058	0.0088
97.5	0.505	1.648	2.500	0.0022	0.0072	0.0110
97.0	0.607	1.979	3.000	0.0027	0.0087	0.0132
96.5	0.710	2.311	3.500	0.0031	0.0102	0.0155
96.0	0.813	2.643	4.000	0.0036	0.0116	0.0177
95.5	0.917	2.976	4.500	0.0040	0.0131	0.0200
95.0	1.021	3.310	5.000	0.0045	0.0146	0.0223
94.5	1.125	3.644	5.500	0.0049	0.0161	0.0246
94.0	1.230	3.979	6.000	0.0054	0.0176	0.0269
93.5	1.335	4.314	6.500	0.0058	0.0192	0.0292
93.0	1.441	4.650	7.000	0.0063	0.0207	0.0315
92.5	1.547	4.987	7.500	0.0068	0.0222	0.0339
92.0	1.654	5.324	8.000	0.0072	0.0238	0.0362
91.5	1.761	5.662	8.500	0.0077	0.0253	0.0386
91.0	1.869	6.001	9.000	0.0082	0.0269	0.0410
90.5	1.977	6.340	9.500	0.0087	0.0285	0.0434
90.0	2.085	6.680	10.00	0.0092	0.0300	0.0458
89.5	2.194	7.020	10.50	0.0096	0.0316	0.0482
89.0	2.304	7.362	11.00	0.0101	0.0332	0.0506
88.5	2.414	7.703	11.50	0.0106	0.0348	0.0531
88.0	2.524	8.046	12.00	0.0111	0.0364	0.0555
87.5	2.635	8.389	12.50	0.0116	0.0381	0.0580
87.0	2.747	8.733	13.00	0.0121	0.0397	0.0605
86.5	2.859	9.077	13.50	0.0126	0.0413	0.0630
86.0	2.971	9.423	14.00	0.0131	0.0430	0.0655
85.5	3.085	9.768	14.50	0.0136	0.0446	0.0680
85.0	3.198	10.12	15.00	0.0141	0.0463	0.0706
84.5	3.312	10.46	15.50	0.0146	0.0480	0.0732
84.0	3.427	10.81	16.00	0.0152	0.0497	0.0757
83.5	3.542	11.16	16.50	0.0157	0.0514	0.0783
83.0	3.658	11.51	17.00	0.0162	0.0531	0.0809
82.5	3.774	11.86	17.50	0.0167	0.0548	0.0836
82.0	3.891	12.21	18.00	0.0172	0.0566	0.0862
81.5	4.009	12.56	18.50	0.0178	0.0583	0.0889
81.0	4.127	12.91	19.0	0.0183	0.0600	0.0915
80.5	4.246	13.27	19.50	0.0188	0.0618	0.0942
80.0	4.365	13.62	20.00	0.0194	0.0636	0.0969
79.5	4.48	13.48	20.5	0.0199	0.0654	0.0996
79.0	4.61	14.33	21.0	0.0204	0.0672	0.1023
78.5	4.73	14.64	21.5	0.0210	0.0690	0.1051
78.0	4.85	15.04	22.0	0.0215	0.0708	0.1079

Obscuration – optical density chart Based on a 5-ft. (1.52-m) light beam Continued on Next Page

Obscuration – optical density chart Based on a 5-ft. (1.52-m) light beam Continued

Light transmission (meter reading), microamperes	Obscuration (O_u)		Total obscuration O_d	Optical density (OD)		Total optical density, OD_t
	Percent per ft.	Percent per meter		Per ft.	Per meter	
77.5	4.97	15.40	22.5	0.0221	0.0726	0.1107
77.0	5.09	15.76	23.0	0.0227	0.0745	0.1135
76.5	5.22	16.12	23.5	0.0232	0.0763	0.1163
76.0	5.34	16.48	24.0	0.0238	0.0782	0.1191
75.5	5.47	16.84	24.5	0.0244	0.0801	0.1220
75.0	5.59	17.20	25.0	0.0249	0.0820	0.1249
74.5	5.72	17.56	25.5	0.0255	0.0839	0.1278
74.0	5.84	17.93	26.0	0.0261	0.0858	0.1307
73.5	5.97	18.29	26.5	0.0267	0.0877	0.1337
73.0	6.10	18.66	27.0	0.0273	0.0897	0.1366
72.5	6.23	19.02	27.5	0.0279	0.0916	0.1396
72.0	6.36	19.39	28.0	0.0285	0.0936	0.1426
71.5	6.49	19.76	28.5	0.0291	0.0956	0.1456
71.0	6.62	20.13	29.0	0.0297	0.0976	0.1487
70.5	6.75	20.50	29.5	0.0303	0.0996	0.1518
70.0	6.89	20.87	30.0	0.0309	0.1016	0.1549
69.5	7.02	21.24	30.5	0.0316	0.1037	0.1580
69.0	7.15	21.61	31.0	0.0322	0.1057	0.1611
68.5	7.29	21.98	31.5	0.0328	0.1078	0.1643
68.0	7.42	22.36	32.0	0.0335	0.1099	0.1674
67.5	7.56	22.73	32.5	0.0341	0.1120	0.1707
67.0	7.70	23.11	33.0	0.0347	0.1141	0.1739
66.5	7.84	23.49	33.5	0.0354	0.1163	0.1771
66.0	7.97	23.86	34.0	0.0360	0.1184	0.1804
65.5	8.11	24.24	34.5	0.0367	0.1206	0.1837
65.0	8.25	24.62	35.0	0.0374	0.1228	0.1870
64.5	8.40	25.00	35.5	0.0380	0.1250	0.1904
64.0	8.54	25.39	36.0	0.0387	0.1272	0.1938
63.5	8.68	25.77	36.5	0.0394	0.1294	0.1972
63.0	8.83	26.15	37.0	0.0401	0.1317	0.2006
62.5	8.97	26.54	37.5	0.0408	0.1339	0.2041
62.0	9.12	26.92	38.0	0.0415	0.1362	0.2076
61.5	9.26	27.31	38.5	0.0422	0.1385	0.2111
61.0	9.41	27.70	39.0	0.0429	0.1409	0.2146
60.5	9.56	28.09	39.5	0.0436	0.1432	0.2182
60.0	9.71	28.48	40.0	0.0443	0.1456	0.2218
59.5	9.86	28.87	40.5	0.0451	0.1480	0.2254
59.0	10.01	29.26	41.0	0.0458	0.1504	0.2291

NOTE – See C1.1.

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APPENDIX D – RELIABILITY PREDICTION AND CRITERIA FOR ACCEPTANCE

INSTRUCTIONS FOR DETERMINING A RELIABILITY PREDICTION OF ELECTRONIC COMPONENTS AND MICROELECTRIC CIRCUITS

D1 Methods Of Determining Failure Rate

D1.1 PARTS COUNT METHOD – When using this method the failure rate is to be determined as follows:

a) Employ generic failure rate from the table among Tables D1.1 – D1.6 that most closely approximates the component employed.

b) Determine the quality factor multiplier for each component from Table D1.7 – D1.9.

c) Multiply the generic failure rate by its associated quality factor multiplier to obtain the final failure rate for the component. See sample calculation, Table D1.10.

Mil-specification numbers in Tables D1.4 and D1.5 are provided for reference only to determine general component type.

Table D1.1
Generic failure rate for standard bipolar digital devices (TTL and DTL) in failures per million hours

Circuit complexity	Failure rate
1 to 20 gates[a]	0.029
21 to 50 gates	0.062
51 to 100 gates	0.094
101 to 500 gates	0.38
Greater than 500 gates	6.0
Memories, less than or equal to 1000 bits	0.30
Memories, 1001 to 4000 bits	0.70
Memories, 4001 to 8000 bits	1.2

[a] Assume 1 gate is equivalent to four transistors.

D1.2 PARTS STRESS ANALYSIS METHOD[a] – The failure rate is calculated using the procedure in MIL HDBK 217. Calculations and supporting data on rating of components for the determination is required for review. See also Table D1.11 and Figure D1.1 for equations and tabulation sheets.

[a] When a MIL-Spec component is required in a smoke alarm and does not employ a specific marking to that effect, the smoke alarm manufacturer shall provide documentation to verify that the component is Mil-Spec graded. It is permissible for the documentation to be in the form of a shipping order, invoice, or equivalent, provided by the component supplier.

Table D1.2
Generic failure rate for standard bipolar beam lead and ECL, bipolar and MOS linear, and all other MOS devices in failure per million hours

Circuit complexity	Failure rate
1 to 20 gates[a]	0.048
21 to 50 gates	0.19
51 to 100 gates	0.31
101 to 500 gates	1.4
Greater than 500 gates	23
Linear, less than or equal to 32 transistors	0.052
Linear, 33 to 100 transistors	0.12
Memories, less than or equal to 1000 bits	1.2
Memories, 1001 to 4000 bits	2.7
Memories, 4001 to 8000 bits	4.5

[a] Assume 1 gate is equivalent to four transistors.

D1.3 SCREENING BURN-IN METHOD – This method is required for the evaluation of application specific integrated circuits (ASIC) although it is in some instances also applied to other components of a smoke alarm, including generic ″chips.″ The evaluation is to consist of a burn-in test program to determine the numerical failure rate coupled with a minimum quality assurance screening program for all production units. See Sections D2 – D4.

D1.4 PUBLISHED RELIABILITY DATA – It is permissible that this method be employed for the evaluation of generic integrated circuit ″chips″ as well as any other component of a smoke alarm, except for an application specific ″chip.″ The evaluation is derived by the use of generic failure rate data from industry and military publications on component reliability based on field accumulated data. Examples of such publications include Micro-Circuit Device Reliability, Linear/Interface Data and Micro-Circuit Device Reliability, and Digital Generic Data. Devices evaluated by this method shall conform to the identification program in D2.3, and minimum screening program of Table D3.1.

Table D1.3
Generic failure rate for discrete semiconductors in failures per million hours

Part type	Failure rate
Transistors	
Silicon NPN	0.18
Silicon PNP	0.29
GePNP	0.41
GeNPN	1.1
FET	0.52
UJT, PUT[a]	1.7
Diodes	
Silicon, general purpose	0.12
Germanium, general purpose	0.26
Zener and avalanche	0.16
Thyrister	0.16
Silicon microwave detector	2.2
Ge microwave detector	5.6
Silicon microwave mixer	3.0
Ge microwave mixer	10.0

Table D1.3 Continued on Next Page

Table D1.3 Continued

Part type	Failure rate
Varactor, step	1.5
[a] When the construction of the device is comparable to that of a thyrister, it is permissible to assign a lower failure rate (0.16 failures/10^6 hrs).	

Table D1.4
Generic failure rate for resistors in failures per million hours

Resistors, fixed			Failure rate
Construction	Style	Mil-R-Spec. (reference only)	
Composition	RCR	39008	0.002
Composition	RC	11	0.01
Film	RLR	39017	0.015
Film	RL	22684	0.075
Film	RNR	55182	0.017
Film	RN	10509	0.017
Film, power	RD	11804	0.96
Wire wound, accurate	RBR	39005	0.056
Wire wound, accurate	RB	93	0.28
Wire wound, power	RWR	39007	0.033
Wire wound, power	RW	26	0.17
Wire wound, chassis mount	RER	39009	0.062
Wire wound, chassis mount	RE	18546	0.31
Resistors, variable			
Wire wound, trimmer	RTR	39015	0.066
Wire wound, trimmer	RT	27208	0.33
Wire wound, precision	RR	1293419	2.7
Wire wound, semi-precision	RA	39002	2.3
Wire wound, semi-precision	RK	22	2.3
Wire wound, power	RP	22097	2.3
Non-wire wound, trimmer	RJ	94	4.6
Composition (common pot)	RV		
Factory preset and sealed			0.46
Field variable			3.7

Table D1.5
Generic failure rate for capacitors in failures per million hours

Dielectric	Style	Mil-C-Spec. (reference only)	Failure rate
Paper/plastic	CHR	39022	0.0006
Paper/plastic	CPV	14157	0.0006
Paper/plastic	CQR	19978	0.0006
Paper/plastic	CQ	19978	0.006
Mica	CMR	39001	0.0032
Mica	CM	5	0.032
Mica	CB	10950	0.58
Glass	CYR	23269	0.011
Ceramic	CKR	39014	0.022
Ceramic	CK	11015	0.22
Tantalum, solid	CSR	39003	0.026
Tantalum, nonsolid	CLR	39006	0.034
Tantalum, nonsolid	CL	3965	0.34
Aluminum, oxide	CU	39018	0.23
Aluminum,			
dry electrolyte	CE	62	0.41
ceramic, variable	CV	81	1.1
piston, variable	PC	14409	0.11

Table D1.6
Generic failure rate for miscellaneous parts in failure per million hours

Part type	Failure rate
Pulse transformers	0.0027
Audio transformers	0.0066
Power transformer and filters	0.021
RF transformers and coils	0.022
Connectors	0.45
Connections	
Solder, reflow lap to printed circuit boards	0.00012
Solder, wave to printed circuit boards	0.00044
Other hand solder connections (for example, wire to terminal board)	0.0044
Crimps	0.0073
Weld	0.002
Wirewraps	0.0000037
Coaxial connectors	0.63
Toggle switches	0.57
Push button switches	0.38
Sensitive switches	0.90
Rotary switches	1.4
General purpose relays	0.30
High current relay	1.0
Latching relays	0.29
Reed relays	0.26
Meters and bimetal	5.7
Two sided printed wiring boards	0.0024
Multilayer printed wiring board	0.30

Table D1.6 Continued on Next Page

Table D1.6 Continued

Part type	Failure rate
Quartz crystals	0.20
Thermistor	
Bead	0.10
Disc	0.31
Fuses	0.10
Neon lamps	0.20
Photocells	0.02
Light emitting diodes (LED)	
General use (indicator light)	0.20
Light source of photoelectric detectors	2.50[a]

[a] This is the maximum value permitted and is based on the failure rate at half light output. LED's having projected lower failure rates at half light output are usually employed. The reliability is to be evaluated on data supplied by LED manufacturer.

Table D1.7
Quality factors for Tables D1.1 and D1.2

Quality level or screen class	Description	Quality factor
A	Mil-M-38510, Class A	0.5
B	Mil-M-38510, Class B	1
B-1	Mil-Std-883A, Method 5004, Class B	2.5
B-2	Supplier equivalent of Mil-Std-883A, Method 5004, Class B	5
C	Mil-M-38510, Class C	8
D	Commercial (or non-mil standard) part with no screening beyond the manufacturer's regular quality assurance practices	75
E	Screening procedure per Table D3.1	8

Table D1.8
Quality factor for Table D1.3

Part class	Quality factor
JANTXV	0.1
JANTX	0.2
JAN	1.0
Commercial grade	1.0

Table D1.9
Quality factor for Tables D1.4 and D1.5

Failure rate level established reliability parts)	Quality factor
L	1.5
M	1.0
P	0.3
R	0.1
S	0.01
Note – For nonestablished reliability parts the quality factor equals 1.5. The quality factor for all miscellaneous parts equal 1.0.	

Table D1.10
Component reliability prediction – parts count method sample calculation

Component	Generic failure rate (A)	Qualify factor multiplier (B)	Failure rate[a], failures/10^6 hrs. A times B
Composition resistor	0.01	1	0.01
Composition resistor	0.01	1	0.01
Composition resistor	0.01	1	0.01
Film resistor	0.075	1	0.075
Film resistor	0.075	1	0.075
Wire wound resistor, power	0.17	1	0.17
Capacitor, plastic	0.006	1	0.006
Capacitor, plastic	0.006	1	0.006
Capacitor, tantalum, solid	0.026	1	0.026
Capacitor, dri electrolyte	0.41	1	0.41
Transistor, silicon NPN	0.18	0.3	0.06
Transistor, silicon NPN	0.18	0.3	0.06
Thyrister (SCR)	0.16	1	0.16
Diode, silicon	0.12	1	0.12
Diode, silicon	0.12	1	0.12
Relay, reed	0.26	1	0.26
Relay, general purpose	0.30	1	0.30
Connector	0.45	1	0.45
Printed wiring board	0.0024	1	0.0024
Switch, push button	0.38	1	0.38
Potentiometer, factory preset	0.46	1	0.46
LED (indicator lamp)	0.20	1	0.20
[a] Failure rate for individual components shall not exceed 2.5 failures per million hours.			

Figure D1.1
Tabulation sheet

DEVICE	EQUATION	λ_b	π_Q	π_E	π_A	π_{S2}	π_C	π_R	π_V	π_{TAPS}	π_{SR}	π_{CV}	π_F	π_N	π_{CYC}	π_L	π_P	λ_{CYC}	λ_P

λ_P = Failure rate for Component – Failures/10^6hours
(Sum of numbers for that Component)

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Table D1.11
Parts stress analysis method references

Type device	Applicable equation	MIL-HDBK- 217 9/20/74 page reference
Monolithic bipolar and MOS digital SSI/MSI		
Devices < 100 gates or 400 transistors	$\pi = \pi;_L \pi_Q (C_1 \pi_T + C_2 \pi_E)$	2.1.1-1
Monolithic bipolar and MOS linear devices	$\lambda_p = \pi_L \pi_Q (C_1 \pi_{T2} + C_2 \pi_E)$	2.1.2-1
Monolithic bipolar and MOS digital LSI		
Devices < 100 gates or 400 transistors	$\lambda_p = \pi_L \pi_Q (C_1 \pi_T + C_2 \pi_E)$	2.1.3-1
Monolithic MOS and bipolar memories	$\lambda_p = \pi_L \pi_Q (C_1 \pi_T + C_2 \pi_E)$	2.1.4-1
Hybrid devices	$\lambda_p = \lambda_b (\pi_T \times \pi_E \times \pi_Q \times \pi_F)$	2.1.7-1
Transistors, group I general purposes	$\lambda_p = \lambda_b (\pi_E \times (_A \times \pi_Q \times \pi_{S2} \times \pi_C)$	2.2.1-1
Transistors, group II field effect transistors	$\lambda_p = \lambda_b (\pi_E \times (_A \times \pi_Q \times \pi_C)$	2.2.2-1
Transistors, group III unijunction	$\lambda_p = \lambda_b \times \pi_E \times \pi_Q$	2.2.3-1
Diodes, group IV general purpose	$\lambda_p = \lambda_b (\pi_E \times \pi_Q \times (_A \times \pi_{S2} \times \pi_C)$	2.2.4-1
Diodes, group V zeners	$\lambda_p = \lambda_b (\pi_E \times (_A \times \pi_Q)$	2.2.5-1
Diodes, group VI thyristers	$\lambda_p = \lambda_b \times \pi_Q \times \pi_E$	2.2.6-1
Diodes, group VII microwave detectors and mixers	$\lambda_p = \lambda_b \times \pi_E \times \pi_Q$	2.2.7-1
Diodes, group VIII varactor step recovery tunnel	$\lambda_p = \lambda_b \times \pi_E \times \pi_Q$	2.2.8-1
RCR and RC insulated fixed composition	$\lambda_p = \lambda_b \times (\pi_E \times \pi_R \times \pi_Q)$	2.5.1-1
RLR, RL, RNR, RN, fixed film insulated	$\lambda_p = \lambda_b \times (\pi_E \times \pi_R \times \pi_Q)$	2.5.2-1
RD/P power film	$\lambda_p = \lambda_b \times (\pi_E \times \pi_R \times \pi_Q)$	2.5.2-5
RBR and RB, fixed wire wound	$\lambda_p = \lambda_b \times (\pi_E \times \pi_R \times \pi_Q)$	2.5.3-1
RWR and RW power type, fixed wire wound	$\lambda_p = \lambda_b \times (\pi_E \times \pi_R \times \pi_Q)$	2.5.3-3
fixed wire wound	$\lambda_p = \lambda_b \times (\pi_E \times \pi_R \times \pi_Q)$	2.5.3-5
RTH bead and disc type thermistors	Read Direct from Table	2.5.4-1
RTR and RT variable lead screw activated, wire wound	$\lambda_p = \lambda_b \times (\pi_E \times \pi_R \times \pi_Q \times \pi_V)$	2.5.5-1
RR precision wire wound potentiometers	$\lambda_p = \lambda_b \times \pi_{TAPS} \times \pi_Q (\pi_R \times \pi_V \times \pi_C \times \pi_E)$	2.5.5-3
RA and RK (not ER) semi-precision wire wound potentiometers	$\lambda_p = \lambda_b \times \pi_{TAPS} (\pi_R \times \pi_V \times \pi_Q \times \pi_E)$	2.5.5-7
RP high power wound potentiometers	$\lambda_p = \lambda_b \times \pi_{TAPS} \times \pi_Q (\pi_R \times \pi_V \times \pi_C \times (_E)$	2.5.5-13
RJ non-wire wound trimmers	$\lambda_p = \lambda_b \times \pi_{TAPS} (\pi_R \times \pi_V \times \pi_Q \times (_E)$	2.5.6-1
RV composition potentiometers	$\lambda_p = \lambda_b \times \pi_{TAPS} (\pi_R \times \pi_V \times \pi_Q \times (_E)$	2.5.6-5
CPV paper and plastic film, est. rel.	$\lambda_p = \lambda_b (\pi_E \times \pi_Q)$	2.6.1-1
CHR metallized paper, est. rel.		
CQ & CQR paper and plastic film, ER & NON-ER		
CM mica molded, CMR mica dipped, est. rel.	$\lambda_p = \lambda_b (\pi_E \times \pi_Q)$	2.6.2-1
CB button mica	$\lambda_p = \lambda_b (\pi_E) (\pi_Q)$	2.6.2-3
CYR glass capacitors, est. rel.	$\lambda_p = \lambda_b (\pi_E \times \pi_{CV} \times \pi_Q)$	2.6.3-1
CK ceramic, general purpose, CKR ceramic, general purpose, est. rel.	$\lambda_p = \lambda_b (\pi_E \times \pi_Q)$	2.6.4-1
CC ceramic, temperature compensating	$\lambda_p = \lambda_b (\pi_E) (\pi_Q)$	2.6.4-5
CSR solid tantalum electrolytic, est. rel.	$\lambda_p = \lambda_b (\pi_E \times \pi_{SR} \times \pi_Q)$	2.6.5-1
CLR nonsolid tantalum, est. rel., CL nonsolid tantalum, NON est. rel.	$\lambda_p = \lambda_b (\pi_E \times \pi_Q)$	2.6.5-3
CU aluminum, oxide electrolytic	$\lambda_p = \lambda_b (\pi_E) \times \pi_Q$	2.6.6-1
CE aluminum, dry electrolyte	$\lambda_p = \lambda_b (\pi_E) \times \pi_Q$	2.6.6-3
CV variable, ceramic capacitors	$\lambda_p = \lambda_b (\pi_E) \times \pi_Q$	2.6.7-1

Table D1.11 Continued on Next Page

Table D1.11 Continued

Type device	Applicable equation	MIL-HDBK- 217 9/20/74 page reference
PC variable, piston type tubular trimmer	$\lambda_p = \lambda_b\ (\pi_E) \times \pi_Q$	2.6.8-1
Transformers	$\lambda_p = \lambda_b\ (\pi_E \times \pi_F)$	2.7-1
Motors high speed	$\lambda_p =(\lambda_E + \lambda_W)\ (_E$	2.8.1-1
Blowers	$\lambda_p = \lambda_E + \lambda_W$	2.8.2-1
Relays	$\lambda_p = \lambda_b\ (\pi_E \times \pi_C \times \pi_{CYC} \times \pi_F)$	2.9-1
Switches, snap-action toggle or pushbutton	$\lambda_p = \lambda_b\ (\pi_E \times \pi_C \times \pi_{CYC})$	2.10-1
Basic sensitive switches	$\lambda_p = \lambda_b\ (\pi_E \times \pi_{CYC})$	2.10-2
Rotary, ceramic or glass wafer silver alloy contacts	$\lambda_p = \lambda_b\ (\pi_E \times \pi_{CYC})$	2.10-3
Connectors	$\lambda_p = \lambda_b\ (\pi_E \times \lambda_p) + N\pi_{CYC}$	2-11-1
Note – π_Q multiplier same as for JAN Class C when Table D3.1 screening is conducted.		

CRITERIA FOR ACCEPTANCE OF MICROELECTRONIC DEVICES

D2 General

D2.1 The evaluation and criteria for acceptance of microelectronic devices consists of a two part procedure:

a) Part I consists of a quality assurance screening program, either by the component vendor or smoke alarm manufacturer, to assure uniformity of production and

b) Part II includes a determination of failure rate for the device supplemented by a one time burn-in test.

D2.2 Although this program is oriented primarily to application specific integrated circuits (″chips″), it is also applied for other microelectronic devices.

D2.3 Components that comply with the requirements of this program shall be distinctively marked for identification purposes. The smoke alarm manufacturer shall maintain on file, accessible to an inspector, copies of the purchase and shipping orders for all smoke alarms and ″chips″ so that a tally of smoke alarms shipped is able to be compared to the quantity of screened devices procured from the component vendor.

D3 Part I – Quality Assurance Screening Program

D3.1 A minimum screening program (see Table D3.1) is to be established by the component manufacturer (vendor).

D3.2 The test methods and conditions referenced in Table D3.1 are based on the most current revisions to MIL-STD-883B dated July 31, 1977.

D4 Part II – Determination of Failure Rate Number Supplemented by Burn-In Test

D4.1 General

D4.1.1 The objective of this part is to determine a numerical failure rate for the device. The method employs Arrehenius calculations and activation energy tables to correlate elevated temperature operation to a failure rate at 38°C (100°F) (maximum installation ambient temperature of the smoke alarm).

Table D3.1
Minimum screening programs

Hermetic packages	
1. Internal visual (Method 2010.1 condition B modified) ____________________	100 percent[a]
2. Bond strength (Method 2011) ____________________	Sample basis[a]
3. Stabilization bake (Method 1008C, 150 °C, 24 hours) ____________________	100 percent[b]
4. Temperature cycling (Method 1010C, minus 55 °C to 150 °C, 10 cycles ____________________	100 percent[e]
5. Seal (fine leak, Method 1014B, 5×10^{-8} cc/Sec) ____________________	100 percent[c]
6. Seal (gross leak – Method 1014B fluorocarbon) ____________________	100 percent
7. Functional electrical, 25 °C ____________________	100 percent
8. External visual, Method 2009 ____________________	100 percent
9. Quality conformance ____________________	AQL 1.5 percent per MIL-STD 105 Level II
A. Functional electrical, 25 °C	
B. Temperature cycling (Method 1010C, minus 55 °C to 125 °C, 10 cycles)	
C. Seal (Fine leak, Method 1014B 5×10^{-8} cc/Sec)[d]	
D. External visual, Method 2009	
Plastic packages	
1. Internal visual (Method 2010.1 condition B modified) ____________________	100 percent[a]
2. Bond strength (Method 2011) ____________________	Sample basis[a]
3. Temperature cycling (Method 1010C, minus 55 °C to 125 °C, 10 cycles ____________________	100 percent[e, f]
4. Functional electrical test, 25 °C ____________________	100 percent
5. External visual, Method 2009 ____________________	100 percent
6. Quality conformance ____________________	AQL 1.5 percent per MIL-STD 105 Level II
A. Functional electrical test, 25 °C	
B. Temperature cycling (Method 1010C, minus 55 °C to 125 °C, 10 cycles)	
C. External visual, Method 2009	

[a] Modified procedures or sample lot sizes shall be submitted for review.
[b] The stabilization bake shall not be required only when the production process includes equivalent conditioning.
[c] Shall be reduced to 1.5 percent AQL only when the vendor's first lot of 25,000 units shows statistical justification.

Table D3.1 Continued on Next Page

Table D3.1 Continued

Hermetic packages
[d] Shall not be required only when justified by the reject rate in item 5.
[e] It is permissible to substitute either condition B or C of thermal shock Method 1011.1.
[f] Shall not be required only when the sample lot used in the burn-in test is subjected to 100 cycles of the temperature cycling and no devices fail as a result of the temperature cycling. The manufacturer shall then perform an annual audit of the device package type. It is permissible for this audit to be in the form of choosing samples from the same package type and subjecting them to the Temperature Cycling or Thermal Shock (Method 1010C or 1011.1, Conditions B or C, MIL-STD-883D . Records shall be maintained for inspection. (MIL-STD-883D). Records shall be maintained for inspection.

D4.2 Determination sequence

D4.2.1 The following step-by-step procedure is to be employed in determining the failure rate number:

a) Estimate numerical failure rate.

b) Choose test temperature for acceptance test.

c) Using chosen test temperature, refer to curves in Figure D4.1 to determine related test time for initial conditional acceptance and final acceptance.

d) Using the equation in D4.5 and the initial conditioning test time determined in (c), calculate the failure rate of the device for conditional acceptance.

e) Sample lot size to be used in temperature test is determined from Tables D4.1 and D4.2. This table lists initial sample lot sizes based on expected failure rates in percent per 1000 hours at a 60 percent confidence level and number of devices that fail during the test, the latter listed as accept numbers. When a different temperature is employed, it is permissible for lot sizes to be derived from a table of Summation of Terms of Poisson's Exponential Binomial Limit[b] at a 60 percent confidence level.

f) Using the Arrenhenius equation and the final test time determined in (c), calculate the failure rate of the device for final acceptance.

[b] Reliability Handbook by W. Grant Ireson.

D4.3 Test calculations and procedures

D4.3.1 Figure D4.1 illustrates basic curves which represent burn-in test conditions for a device of 1000 hours for initial conditional acceptance and is continued to 3000 hours for final acceptance when tested at an elevated temperature of 125 °C (257°F).

D4.3.2 It is permissible to increase or decrease the elevated test temperature and related time periods (using the illustrated curves). The minimum temperature for the burn-in test shall be not less than 100 °C (212°F).

D4.3.3 The following examples illustrate the use of the curves in Figure D4.1 for calculations of final and initial conditional acceptance at temperatures other than 125 °C (257°F):

a) Example 1 – Assuming a test temperature of 150 °C (302°F):

 1) Time for Initial Conditional Acceptance – 167 hours (using Curve A) and

 2) Time for Final Acceptance – 650 hours (using Curve B).

b) Example 2 – Assuming a test temperature of 100 °C (212°F):

 1) Time for Initial Conditional Acceptance – 5700 hours (using Curve A) and

 2) Time for Final Acceptance – 25,000 hours (using Curve B).

D4.4 Test conditions

D4.4.1 Sockets or other mounting means shall be provided to make firm electrical contact to the terminals of devices under test in the specified circuit configuration. The mounting means shall be constructed so that they do not remove internally dissipated heat from the device by conduction, other than that removed through the device terminals and the required electrical contacts, which shall be maintained at or above the specified ambient temperature. The apparatus is to provide for maintaining the specified biases at the terminal of the device under test and, when specified, monitoring of the input excitation.

D4.4.2 Power supplies and current-setting resistors shall be capable of maintaining the specified operating conditions throughout the testing period with intended variations in their source voltages and ambient temperatures. The test equipment is preferably to be arranged so that only natural convection cooling of the devices occur. When test conditions result in significant power dissipation, the test apparatus is to be arranged so as to result in the average power dissipation for each device whether devices are tested individually or in a group. The test circuits do not have to compensate for intended variations in individual device characteristics and shall be arranged so that the existence of failed or excessed (for example, open or short) devices in a group does not negate the effect of the test for other devices in the group.

Figure D4.1
Time-temperature regression and allowable time limits for test condition

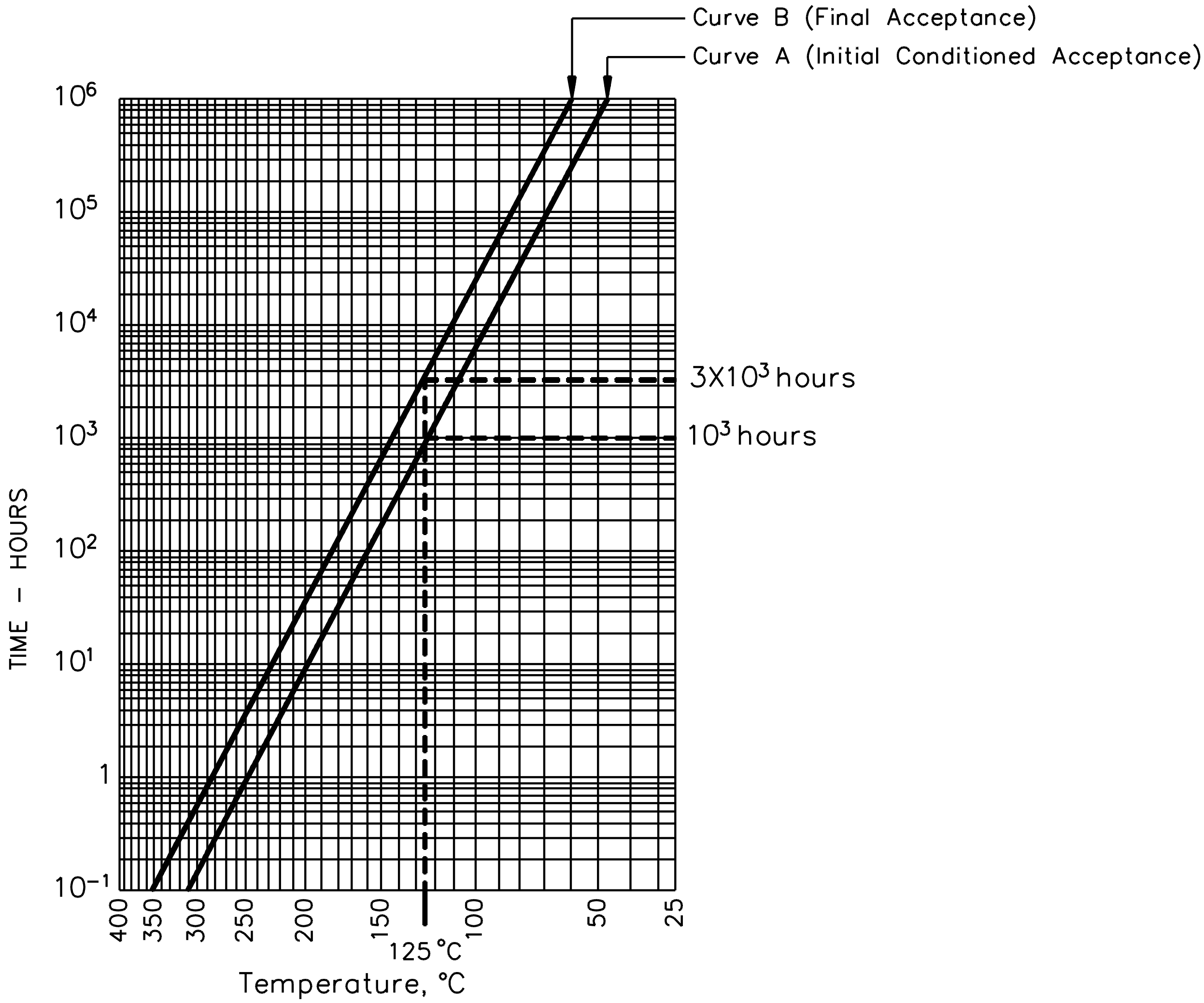

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Table D4.1
Sample lot size for burn-in test

Accept number (C)	Failure rate – percent per 1000 hours									
	20.00	18.00	15.00	12.00	10.00	8.00	7.00	6.00	5.00	4.00
0	5	5	6	8	9	12	13	16	19	23
1	11	12	15	18	22	27	31	36	44	54
2	15	17	21	26	31	39	44	52	62	77
3	20	22	27	34	40	50	58	67	81	101
4	27	30	36	45	54	67	77	89	107	134
5	32	35	42	53	63	79	90	105	126	158
6	36	40	48	60	73	91	104	121	145	181
7	41	45	54	68	81	101	116	135	162	203
8	45	50	60	76	91	113	129	151	181	227
9	50	56	67	84	100	125	143	167	200	251
10	60	67	80	100	120	150	171	200	240	300
11	65	72	86	108	129	162	185	216	259	324
12	70	77	93	116	139	174	199	232	278	348
13	74	83	99	124	149	186	212	248	297	372
14	77	85	102	128	153	192	219	255	307	383
15	82	91	109	136	163	204	233	272	326	408

Table D4.2
Sample lot size for burn-in test

Accept number (C)	Failure rate – percent per 1000 hours								
	3.00	2.00	1.50	1.00	0.70	0.30	0.20	0.15	0.10
0	31	47	62	93	133	311	466	622	933
1	73	109	145	218	311	725	1088	1451	2176
2	103	155	206	309	442	1031	1547	2062	3093
3	134	201	268	403	575	1342	2013	2684	4026
4	179	268	358	536	766	1788	2682	3576	5364
5	210	315	420	631	901	2102	3153	4204	6307
6	242	363	484	726	1037	2419	3629	4838	7257
7	270	405	540	810	1158	2701	4052	5403	8104
8	302	453	604	906	1295	3021	4531	6042	9063
9	334	501	668	1002	1432	3342	5012	6683	10025
10	399	599	799	1198	1712	3994	5991	7988	11982
11	431	647	863	1294	1849	4314	6472	8629	12943
12	464	696	927	1391	1987	4637	6956	9275	13912
13	496	744	991	1487	2124	4957	7435	9913	14870
14	511	766	1022	1533	2190	5109	7663	10218	15327
15	543	815	1087	1630	2329	5434	8151	10868	16302

D4.5 Failure rate number calculation

D4.5.1 The following equation is to be used in determining the initial conditional and final failure rates for the device in concert with the burn-in test:

Extrapolations are made from the chosen elevated test temperature to the 38°C (100°F) smoke alarm operating condition by use of the Arrehenius Equation:

$$\lambda = A\, e^{\left(\frac{-E}{KT}\right)}$$

in which:

λ is failure rate per million hours,

A is constant,

e is the base of natural logarithim (2.7183),

E is activation energy in electron volts (ev) (varies between 0.65 ev to 1.1 ev for a large number of integrated circuits). A value of 0.65 ev is to be used unless documentation is provided which justifies using a different value,

K is Boltzman's constant (8.62×10^{-5} ev/°K), and

T is absolute temperature in degrees Kelvin.

Example:

A. Numerical failure rate λ_2 = 0.1 Failure per 10^6 hours.

B. Test ambient temperature is 125 °C (257°F).

C. Required test time from Figure D4.1 for conditional acceptance is 1000 hours and for final acceptance is 3000 hours.

D. Using the equation in D4.5.1 and assuming an Activation Energy (E) of 0.65 ev, the following calculations are performed:

$$\lambda_1 = A_e^{\left(\frac{-E}{KT}\right)} \quad for\ 125°C$$

$$\lambda_2 = A_e^{\left(\frac{-E}{KT}\right)} \quad for\ 38°C$$

Then

$$\frac{\lambda_1}{\lambda_2} = \ln^{-1}\left[\frac{-E}{K}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)\right]$$

in which:

λ_2 *is 0.1 Failure per* 10^6 *hours*

E is 0.65 ev

T_1 *is 398°K*

T_2 *is 311°K*

K is 8.62×10^{-5} *ev/°K*

Then

$$\lambda_1 = \lambda_2 \ \ln^{-1}\left[\frac{-0.65}{8.62 \times 10^{-5}}\left(\frac{1}{398} - \frac{1}{311}\right)\right]$$

in which:

λ^1 *is 20* $\times$ *10^{-6} failure/hour.*

λ_1 *is 20 failures/10^6 hours.*

λ_1 *is 0.02 failure/1000 hours.*

λ_1 *is 2.0 percent/1000 hours.*

E. Referring to Tables D4.1 and D4.2, the following sample lot size for the appropriate accept number (C - the number of failures or less) is used at the conditional acceptance point (1000 hours). For 2.0 percent/1000 hours:

C = 0 N = 47

C = 1 N = 109

C = 2 N = 155

From the equation and TablesD4.1 and D4.2, with no failures from a sample lot size of 47 at a test ambient of 125°C, the failure rate is 0.1 Failure/10^6 hours at the conditional acceptance point of 1000 hours. It is possible that the failure rate be less at the final acceptance point of 3000 hours.

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APPENDIX E – Sample Size Determination for In Service Reliability Testing of Multicriteria Smoke Alarms Consisting of Gas Detection

E1 General

The objective of this Appendix is to assist manufacturers of multi-criteria smoke alarm with gas sensor in identifying sample sizes for testing under Section 94, Measurement of In-Service Reliability for Multi-criteria Smoke Alarms with Gas Sensor(s). This discussion is a summary of the material provided in the GRI report ″Test Protocols for Residential Carbon Monoxide Alarm, Phase 1″ (GRI-96/0055), Section 6, ″Target Reliabilities and the Number of Units Tested″.

This program requires that smoke alarms must adhere to an upper bound on their cumulative failure rate over a presumptive three year lifetime. Briefly, it requires that the cumulative supervised failures over the specified lifetime of a multi-criteria smoke alarm shall not exceed 23 percent at a 90 percent confidence level.

or the cumulative unsupervised failures over the specified lifetime of a multi-criteria smoke alarm shall not exceed 14.6 percent at a 90 percent confidence level Compliance must be verified through quarterly testing that continues for a minimum period of 3 years. This reliability procedure must be re-initiated whenever there is a significant change in the design or manufacturing.

Table E1 places into perspective the consequences of various failure rates.

Table E1
Field consequences of various mean-times-between-failure (MTBF)

MTBF (hours)	Failures per month (percent/month)	Portion of field units in failure[a]	Cumulative lifetime failures[b]
500,000	0.15 percent	2.6 percent	5.1 percent
250,000	0.29 percent	5.1 percent	10.0 percent
166,667[c]	0.44 percent	7.5 percent	14.6 percent
100,000[d]	0.73 percent	12.1 percent	23.1 percent
50,000	1.45 percent	22.2 percent	40.9 percent
20,000	3.58 percent	44.4 percent	73.1 percent

[a] The portion of field units in failure at any time, making the ideal assumptions of a uniform distribution in the age of detectors , their continuous replacement at the end of a 3 year lifetime, and an average age of installed units of only 18 months. The failed portion is given by the average of the integral of equation 3 over the interval of Δt = (0, 3 years). It is approximately one-half of the cumulative portion failed over the detector ’ entire lifetime, given directly by equation 3.

[b] Assuming a lifetime of 3 years.

[c] The reliability limit for unsupervised failures.

[d] The reliability limit for supervised failures

Mean-time-between-failure (MTBF) is estimated by tallying the failures in a sample over time. To develop the mathematical basis for the calculation of MTBF first express the assumption of a constant failure rate as an equation. For a fixed number of devices under test, NDUT, the rate at which the number of failures, Nf, increases over time is given by the quotient of the number of unfailed devices at any given time and the MTBF as:

Equation 1

$$d/dt\ Nf(t) = N_{DUT} - N_f(t)/MTBF$$

If, instead of using a fixed number of devices, failed devices are replaced so that the number of unfailed devices under test, No, remains constant during the test, then the rate of failure is constant and given by:

Equation 2

$d/dt\ N_f(t) = N_o/MTBF$

We can solve these differential equations to find the number of accumulated failures after time Δt as:

Equation 3

$N_f/N_{DUT} = 1 - \exp[-\Delta t/MTBF]$ and

Equation 4

$N_f/N_o = \Delta t/MTBF$

Because it is impractical to promptly replace failed devices during the test time, the more generally useful expression is Equation 3. This equation is used to estimate the number of expected failures from a known MTBF. For example, using a MTFB of 166,667 hours, the portion of smoke alarms failing over the course of a presumptive 3 year lifetime (Δt = 26,298 hours) would be 14.6 percent. Consequently, if there were 100 devices under test there would be approximately 15 failures.

In reliability testing the MTBF should be estimated from the number of failures observed in a test. Equation 3 for the MTBF sample above, can be solved:

Equation 5

$MTBF_S = -\Delta t/\ln[1 - N_{fS}/N_{DUT}]$

in which N_{fS} is the actual number of failures observed in time Δt out of the number of devices in the sample N_{DUT}, and ln is the natural logarithm.

Equation 5 is the fundamental equation to use to estimate the MTBF when a cumulative test time and number of failures are known. It is easily applied when there is a single cohort of devices all held for the same amount of time. However, it is difficult to apply if different numbers of devices are held for different lengths of time. In that case Equation 5 may be approximated with a more easily applied form as:

Equation 6

$MTBF_S = \alpha\ \Delta t\ (N_{DUT}/N_{fS})$

in which α is a parameter adjusted to make Equation 6 agree with Equation 5 at a particular cumulative failure rate. For the lifetime cumulative failure rates for supervised and unsupervised failures allowed by this Standard, the best values for α are 0.878 and 0.925, respectively; i.e.

Equation 7

supervised failures: $MTBF_S = 0.878 * \Delta t * (N_{DUT}/N_{fS})$

Equation 8

unsupervised failures: $MTBF_S = 0.925 * \Delta t * (N_{DUT}/N_{fS})$

These approximations work well over a wide range of accumulated failures, but for fewer accumulated failures than the maximum allowed they slightly underestimate the MTBF, while for greater accumulated failures they slightly overestimate it.

These approximations are used because they can be easily extended to account for devices held for different amounts of time. For different numbers of units held for different times a total device time is computed as:

Equation 9

$$T_{DUT} = \sum_i \Delta t_i N_{DUT\ i}$$

and a total number of failures as

Equation 10

$$N_{fs} = \sum_i N_{fs\ i}$$

in which the index, i, pertains to different samples of devices held for different amounts of time. Using these definitions, Equations 7 and 8 become:

Equation 11

$$\text{for supervised failures: } MTBF_S = 0.878 \frac{\sum_i \Delta t_i N_{DUT\ i}}{\sum_i N_{f\ S\ i}}$$

and

Equation 12

$$\text{for unsupervised failures: } MTBF_S = 0.925 \frac{\sum_i \Delta t_i N_{DUT\ i}}{\sum_i N_{f\ S\ i}}$$

For example, if 100 alarms are held for a first quarter, and in addition to these 50 more alarms are held for a second quarter, the total device time is given by equation 9 as:

T_{DUT} = 100 * 2 + 50 * 1 = 250 device-quarters or

T_{DUT} = 100 * 2 * 2191.5 + 50 * 2191.5 = 547,875 device-hours.

If at the end of the first quarter the 100 alarms are tested and two unsupervised failures detected, and at the end of the second quarter 148 alarms are tested (all 150 minus the two that had already failed) an additional unsupervised failure detected, then the total number of unsupervised failures would be N_{fS} = 3.

The observed $MTBF_S$ for the test is computed using Equation 12 as:

$MTBF_S$ = 0.925 * 547,875/3 = 168,928 hours.

The number of failures observed will fluctuate from sample to sample about an ideal average with a standard deviation (called the counting error) roughly equal to the square root of the ideal average. Consequently, if a different number of sample devices had been drawn and tested a somewhat different number of failure, N_{fS}, would have been observed. The mean time between failure at 90 percent confidence level should be predicted. This $MTBF_{90}$ is not based solely on the observed number of failures, but on the upper limit on the number of failures at 90 percent confidence level. Consequently, in Equations 11 and 12 replace N_{fSi} with N_{f90i} from Table E2 as:

Equation 13

$$\text{for supervised failures: } MTBF_{90} = 0.878 \frac{\sum_i \Delta t_i N_{DUT\ i}}{\sum_i N_{f\ 90\ i}}$$

and

Equation 14

$$\text{for unsupervised failures: } MTBF_{90} = 0.925 \frac{\sum_i \Delta t_i N_{DUT\ i}}{\sum_i N_{f\ 90\ i}}$$

where N_{f90} is the upper limit on N_{fS} at the 90 percent confidence level, as determined from Table E2, and the index i pertains to different cohorts of devices held in operating condition for different lengths of time.

Table E2
Upper bound on the expected number of failures at a 90 percent confidence level, based on the number of failures observed

Failures observed N_{fS}	Upper bound $N_{f\ 90}$
0	2.30
1	3.89
2	5.32
3	6.68
4	8.00
5	9.28
6	10.54
7	11.77
8	13.00
9	14.21
10	15.14
11	16.60
12	17.78
13	18.96
14	20.13
15	21.30
20	27.05
30	38.33
40	49.39
50	60.35
100	114.06
N_{fS}>100	N_{fS} + 0.82 + 1.28✔ (N_{fS} + 0.41)

Continuing the above example, if of the 150 alarms held for a total device time of 547,875 device-hours there were three observed unsupervised failures, the upper limit on the number of failures is found from Table E2 to be 6.68 failures. The $MTBF_{90}$ is computed as:

$MTBF_{90}$ = 0.925 * 547,875/6.68 = 75,866 hours.

Given a sample of operating devices, the length of time they have been operating, and the number of failures observed, Equations 13 and 14 allow the computation of their $MTBF_{90}$. However the minimum sample size to be tested must be determined. The goal is to estimate the alarms' lifetime failure rate in the minimum elapsed time possible (one-quarter) and then to successively refine that estimation as the alarms are held in operating condition for longer periods of time, up to their minimum lifetime of 3 years. Consequently, the minimum device time required to estimate the failure rate at 90 percent confidence level in one quarter must be computed.

Assuming no failures are observed in the sample, the minimum device time required is calculated from Equations 13 and 14 using the target $MTBF_{90}$ and the minimum upper limit on the number of failures, N_{f90}, of 2.30 as:

Equation 15

for supervised failures:

$T_{DUT} = N_{f90} MTBF_{90}/0.878$

$T_{DUT} = 2.3 * 100{,}000/0.878 = 261{,}959$

from which

Equation 16

$N_{DUT} = T_{DUT}/\Delta t = 119.5$

and

for unsupervised failures:

Equation 17

$T_{DUT} = N_{f90}\ MTBF_{90}/0.925$

$T_{DUT} = 2.3 * 166{,}667/0.925 = 414{,}415$

from which:

Equation 18

$N_{DUT} = T_{DUT}/\Delta t = 189.1$

In order to verify that the mean-time-between-failure is at least 166,667 hours at 90 percent confidence level 190 (rounded up from 189.1) devices must be operated continuously for one quarter, at the end of which they are to be tested and found to have no failures. Because the device-time required for unsupervised failures is greater than that for unsupervised failures the greater number of units must be used. Only 120 units are required for testing for supervised failures.

The results of calculations of Equations 15 – 18 for observed failures from 1 to 100 are presented in the ″In-Service reliability sampling plan″, see Table E3.

Table E3
In-Service Reliability Sampling Plan

Number of failures allowed [a]	Number allowed for an increase in device time [b]	Minimum device time for required $MTBF_{90}$			
		Supervised failures		Unsupervised failures	
		Device-hours	Device-quarters	Device-hours	Device-quarters
0	2	262,000	120	414,000	190
1	3	443,000	203	701,000	320
2	5	606,000	277	959,000	438
3	6	761,000	348	1,204,000	550
4	8	911,000	416	1,441,000	658
5	9	1,057,000	483	1,672,000	763
6	10	1,200,000	548	1,899,000	867
7	11	1,341,000	612	2,121,000	968
8	13	1,481,000	676	2,342,000	1,069
9	14	1,618,000	739	2,560,000	1,169
10	15	1,755,000	801	2,777,00	1,267
11	16	1,891,000	863	2,991,000	1,365
12	17	2,025,000	925	3,204,000	1,462
13	18	2,159,000	986	3,416,000	1,559
14	20	2,293,000	1,047	3,627,000	1,655
15	21	2,426,000	1,107	3,838,000	1,752
20	27	3,081,000	1,406	4,874,000	2,224
30	38	4,366,000	1,993	6,906,000	3,152
40	49	5,625,000	2,567	8,899,000	4,061
50	60	6,874,000	3,317	10,874,000	4,962
100	114	12,991,000	5,928	20,551,000	9,378

[a] The number of failures allowed at the cumulative device time that demonstrates compliance with a minimum MTBF of 100,000 hours for supervised failures or 166,667 hours for unsupervised failures at a 90 percent confidence level.

[b] The number of failures beyond which it is unlikely that compliance will be demonstrated even if the device time of the test is increased. For an observed number of failures greater than the ″number of failures allowed″ and less than or equal to the ″number allowed for an increase in device time″, it is likely that compliance will eventually be demonstrated if the device time is increased sufficiently.

If no failures are observed the devices are considered in-compliance and the entire sample need not be held for a second quarter. It is required that, for the next quarter's test, a cumulative device time of 190 device-quarters be maintained while maximizing the age of the sample of retained devices. Consequently only the following must be retained for the second quarter:

$N_{DUT} = T_{DUT}/\Delta t$ = 190 device-quarters/2 quarters = 95 devices

In fact, as long as no failures are observed the number of retained devices may continue to be reduced on a schedule given by:

Equation 19

$N_{DUT} = T_{DUT}/\Delta t$

in which T_{DUT} is given in device-quarters from Table E3 and Δt is given in quarters. Quarter by quarter the number of devices retained may continue to be reduced. As this is done a constant cumulative device-time is maintained, but the age of the retained devices steadily increased toward their specified lifetime, providing an increasingly more realistic measure of lifetime reliability. As long as no failures are encountered only 16 devices need be retained by the end of the three years.

It is not necessary to reduce the size of the retained sample. In fact, more accurate measures of device reliability will be made by retaining as many devices as possible. In addition, having more retained devices than the minimum required simplifies further testing if more failures are observed.

If a failure is observed when testing at the end of the first quarter the device time may be increased.

For example, if one unsupervised failure is observed in testing 190 devices, in accordance with Table E3, if one failure is observed the required device time increases to 320 device-quarters. In accordance with Equation 19 at least 320/2 = 160 devices must be retained. By the end of the second quarter there will be 160 devices, all having been held for the entire two quarters. If, when all retained devices are tested at the end of the second quarter, no other failures are observed, then compliance with the required $MTBF_{90}$ has been demonstrated. The test may then be continued with a constant device time of 320 device-quarters, reducing the number of devices retained to 320/3 = 107 for the third quarter and further reducing the number quarter by quarter if desired. If, however, more failures had been observed, the device time would again be increased for the third quarter.

For another example, in a test of 190 devices for one quarter no unsupervised failures occur and one supervised failure occurs. From Table E3 it is found that the minimum number of device-quarters required while allowing zero unsupervised failures is 190, and the minimum number required while allowing one supervised failure is 203. Therefore it is required that the device time be increased to the greater of these, to 203 device-quarters. A minimum of 203/2 = 102 devices must be retained for the second quarter. In the case where no additional failures occur during the second quarter compliance with the required $MTBF_{90}$ will have been shown for both supervised and unsupervised failures.

In some cases it will not be possible to increase the device time simply by retaining devices; additional devices may need to be added to the sample. For example, in cases where only the minimum number of devices, 190, are tested in the first quarter, and two unsupervised failures occur, then, according to Table E3, in the next quarter 438 device-quarters are needed. When held for an additional quarter the original 190 devices can account for only 380 of those device-quarters. Unless a larger sample was initially drawn and operated in a simulated residential environment, 58 newly manufactured additional devices must be added. The sample now contains devices of mixed age, and its cumulative device time is calculated using Equation 9.

If at any time the tested sample is augmented with new devices, reliability tests should be continued for longer than the 3 year lifetime, until the average age of the sample of devices achieves the 3 year lifetime.

If compliance cannot be shown in a particular quarter due to too many observed failures, increasing the device time of the test is no guarantee that compliance can be demonstrated in the next quarter. If the population failure rate is too great, more failures are likely to become apparent in tests at the greater device times. There is a level of observed failures for each device time that signals the unlikelihood of demonstrating compliance even if the device time is increased. This number of failures is the number that results in a calculation (using Equations 11 and 12) of a $MTBF_S$ of less than the required minimum $MTBF_{90}$. The number of failures allowing for an increase in test time if compliance is not achieved is also tabulated in Table E3.

If, in the first quarter, 190 devices are tested and four unsupervised failures are found it is pointless to continue into the second quarter by increasing the test time. This is because the number of failures exceeds the ″Number allowed for an increase in device time″ from Table E3. The devices should be deemed not-in-compliance. The observed sample mean-time-between-failure, $MTBF_S$, is given by equation 12 as:

$MTBF_S$ = 0.925 * 414,000/4 = 95,700 hours.

This time is less than the target $MTBF_{90}$, indicating that it is unlikely that an increase in the device time will demonstrate compliance.

E2 Procedure

All data pertaining to the sampling procedure and test results must be recorded on a controlled test sheet and maintained in a file for future reference.

A minimum of 190 packaged, market-ready devices is initially selected for testing. These are serialized, placed in a simulated residential environment, and powered up. At the manufacturer's discretion devices may be installed in actual residences. The devices must be continuously monitored so that false alarms or supervised failures are recorded. The history of each device, including time of power-up and times of supervised failures, must be logged.

At the conclusion of each quarterly period the devices are tested to the sensitivity test, and the number of supervised and unsupervised failures, and the total device time tallied. The sample mean-time-between-failure, $MTBF_S$, and the lower limit on the mean-time-between-failure at 90 percent confidence level, $MTBF_{90}$, must be computed using Equations 11 – 14. The numbers of observed failures are compared to the values in Table E3 to determine whether the devices are in compliance, and whether the total device time should be increased for the next quarter.

For successive quarters, devices should be retained or augmented on a schedule that results in a total device time chosen from Table E3 using the observed failures of the prior quarter.

If the number of observed failures is less than or equal to the ″Number of failures allowed″ in Table E3, the devices are deemed to be in-compliance for the quarter, otherwise they are not-in-compliance for the quarter.

If the number of failures observed is greater than the ″Number of failures allowed″ in Table E3, but not greater than the ″Number allowed for an increase in device time″, then either the total sample size may be increased in an effort to demonstrate compliance at a greater device time in the next quarter, or the manufacturer may forfeit compliance. If for the greater device time the number of observed failures remains in this interval, the device time may be increased again for the next quarter.

If for any quarter the number of observed failures is greater than the ″Number allowed for an increase in device time″ in Table E3 (or, equivalently, the observed sample $MTBF_S$ is less than the target $MTBF_{90}$ for either supervised or unsupervised failures), it is recommended that the device time not be increased further, and that the devices be deemed to be not-in-compliance.

If the devices are not-in-compliance corrective action must be taken to determine the cause of the failure rate. Underwriters Laboratories must be notified and approve an action plan to reduce the failure rate. The action plan should include the diagnostic tests, disposition, redesign or rework done to the failed model. Depending on the action plan the reliability testing may need to be restarted.

As long as the devices remain in-compliance and the model is produced, quarterly testing should be continued.

E3 Statistical Derivation of Table E2

Assuring in-service reliability makes use of a statistical table that provides an upper limit on the number of estimated failures at a 90 percent confidence level given an observed number of failures (Table E2). Table E4 provides a derivation for the values of Table E2.

Because it is generally not feasible to test the entire population of manufactured units, statistical methods for sampling and testing fewer units are used. Each of these tests can be considered a binomial experiment in which the outcome is classified as either a ″pass″ or a ″failure″. Tests of each sampled unit are assumed to be independent of the outcome of tests of other units, and the probability of failure of each unit is assumed to be the same. Using a tally of observed failures from the sample, an upper bound on the entire population's failure rate is found at a chosen confidence level.

Statistically assessing the failure rate places a lower bound on the number of units required for testing. The number of units needed for testing is estimated as follows: In a large population of devices there will be some fraction, F, that will fail a test of any particular characteristic. Call F the ″population failure rate″. The goal of any particular test is to establish an upper bound on F at a given confidence level) eg, 60 percent, 80 percent, or 90 percent) by testing a smaller sub-population, or sample, of only N_{DUT} units. However, the sample size, N_{DUT}, must be sufficiently large to confidently place an upper bound on the failure rate. The number of units expected to fail a test, N_f, is given by the size of the sub-population or sample tested times the population failure rate as:

Equation 20

$$N_f = N_{DUT}F$$

Although N_f is the expected number of failures, the actual number of failures, N_{fS}, observed in any particular sample of N_{DUT} units may be more or less. There is approximately a 50 percent chance that the observed failures would be more numerous than the expected number and a 50 percent chance that they would be less numerous. In fact, any number of failures from 0 to N_{DUT} might be observed but with different probabilities.

The actual population failure rate cannot be known. There is no statistical universe of values from which the failure rate is drawn. There is only a single population failure rate, the correct one, and it cannot really be measured by testing only a sample.

However, if the probability of observing the actual number of failures, N_{fS}, is too small it can be concluded that the population failure rate under consideration is ″unlikely″ to be the correct one. The number of failures should not be too improbable for the correct assumption of population failure rate. Moreover, a likely upper bound on the correct population failure rate can be established by asking the question ″Assuming that if the population failure rate were to equal a certain upper bound, what is the probability of observing more than the actual number of failures?″ If that probability is great, then there can be confidence that the population failure rate is truly less than the hypothetical upper bound.

In other words, it is possible to identify the probability of observing more than the actual number of failures in a sample given an upper bound on the population failure rate as the likelihood of the true population failure rate's being less than the upper bound given the actual number of failures. This is as close to a notion of a ″probability that a population failure rate is correct″ as can be obtained. Although this definition of likelihood is entirely based on intuition, and has no formal mathematical basis in and of itself, it is the basis of many extremely useful methods of statistics.

So, assuming a particular population failure rate, F, it is possible to identify the cumulative probability of observing more than an actual number of failures as the likelihood of, or confidence level for, being correct when using that assumed value as an upper bound on the true population failure rate. This identification is the core assumption for statistical assessment of failure rate. Consequently, if the expected number of failures given an assumed failure rate of F were actually to be observed, that is, if N_{fS} were to equal N_f, then the test would have established that the failure rate is truly less than or equal to F with only about 50 percent confidence. If the observed number of failures were found to be much less than the number expected from a particular assumed failure rate, then there would be high confidence that the actual failure rate is less than or equal to the assumed failure rate. The assumed failure rate could then be used as an upper bound on the actual failure rate with great confidence.

To establish an upper bound on the failure rate, consider the probability distribution for observing differing numbers of failures given a particular population failure rate. This distribution is given by the binomial probability distribution. The probability of observing a particular number, N_{fS}, or fewer failures, $P(\leq N_{fS})$, is given by one minus the cumulative binomial probability for observing more than N_{fS} failures with a probability of F each in a sub-population of D_{NUT} units, and is related to the incomplete beta function as:

Equation 21

$$P(\leq N_{fS}) = 1 - [N_{DUT}!/J!\ (N_{DUT} - j)!]\ F^j\ (1 - F)^{NDUT}{}_{-j} = 1 - I_F(N_{fS} + 1, N_{DUT} - N_{fS})$$

where

$I_f\ (N_{fS} + 1, N_{DUT} - N_{fS})$ is the incomplete beta function.

Tabulations of the incomplete beta function are not as commonly available as those of the gamma or chi-squared functions so it is preferable to approximate the above in terms of those distributions. This may be done by assuming that the number of observed failures is much less than the total number of units tested, $N_{fS} << N_{DUT}$, generally a good assumption, so that the Poisson distribution may be used as an approximation for the binomial distribution. The probability that the number of observed failures, N_{fS}, is equal to or fewer than the expected number, N_f, is given by the cumulative Poisson distribution function, $P(N_{fS} \leq N_f)$, which in turn is given by the complement of the incomplete gamma function, often called GAMMAQ, or the chi-squared function as:

Equation 22

$$P(N_{fS} \leq N_f) = \mathrm{GAMMAQ}(N_{fS} + 1, N_f) = P\chi^2(2N_f, 2N_{fS}+2).$$

This probability equals one minus the confidence that the failure rate is actually less than or equal to the value responsible for the expected number of failures, N_f. In the above equation $P\chi^2(2N_f,2N_{fS}+2)$ represents the probability that an observed chi-squared, $\chi 2$, will exceed a value of 2_{Nf} by chance for $2\ N_{fS} + 2$ degrees of freedom. Note that the standard interpretation of this distribution in terms of chi-squared and degrees of freedom is not particularly meaningful in this application. Rather the chi-squared distribution is used for its availability; it is the most widely tabulated form of the gamma function. Even so, the chi-squared distribution is usually tabulated not as probability as a function of squared error, $P\chi^2$, but rather as reduced-chi-squared as a function of probability, $\chi^2{}_v$, (where reduced-chi-squared, $\chi^2{}_v$, is χ^2 divided by the number of degrees of freedom). Recast in these terms, Equation 22 becomes:

Equation 23

$$N_{DUT}F = N_fC\ (N_{fS} + 1)\ \chi^2{}_v\ (1 - C, 2N_{fS} + 2)$$

Thus the failure rate is bounded for a given confidence level as:

Equation 24

$F \le (N_{fS} + 1)\ \chi^2_v\ (1 - C,\ 2N_{fS} + 2)/N_{DUT}$

where:

N_{DUT} is the number of units undergoing test;

F is the hypothesized population failure rate;

N_{fS} is the actual number of failures observed in a test of N_{DUT} units;

C is the degree of confidence in the bound on the failure rate; and

$\chi^2_v\ (1 - C,\ 2N_{fS} + 2)$ is the reduced chi-squared distribution at a significance of 1 − C and a number of degrees of freedom $v = 2N_{fS} + 2$.

In a manner similar to that of the derivation above, a lower bound on the population failure rate can also be established, given the observed number of failures. This is done by assuming a particular population failure rate, F, and identifying the probability of observing fewer than the actual number of failures as the likelihood of, or confidence level for being correct when using the assumed value as a lower bound on the true population failure rate. In this case a lower bound is found for the population failure rate as:

Equation 25

$F \geq N_{fS}\chi^2_v\ (C,\ 2N_{fS})/N_{DUT}$

Knowing this lower bound is generally less useful than knowing the upper bound, but it is useful for estimating minimum failure rates from field data.

Using these equations, Table E4 lists upper and lower bounds on the expected number of failures, $N_f = N_{DUT}F$, at various confidence levels and numbers of failures observed after testing any sample size. As expected, at the 50 percent confidence level these bounds are approximately the actual numbers of failures observed. Also, for any number of failures observed the upper bound on the expected number increases with increasing confidence level.

Table E4
Upper and lower bounds on the expected number of failures at various confidence levels given an observed number of failures

Number of failures observed	Confidence level (CL) Upper bound/lower bound					
	99 percent	95 percent	90 percent	80 percent	60 percent	50 percent
0	4.6/0.0	3.0/0.0	2.3/0.0	1.6/0.0	0.92/0.0	0.69/0.0
1	6.6/0.01	4.7/0.05	3.9/0.11	3.0/0.22	2.0/0.15	1.7/0.69
2	8.4/0.15	6.3/0.36	5.3/0.53	4.3/0.82	3.1/1.4	2.7/1.7
3	10/0.44	7.8/0.82	6.7/1.1	5.5/1.5	4.2/2.3	3.7/2.7
4	12/0.82	9.2/1.4	8.0/1.7	6.7/2.3	5.2/3.2	4.7/3.7
5	13/1.3	11/2.0	9.3/2.4	7.9/3.1	6.3/4.2	5.7/4.7
6	15/1.8	12/2.6	11/3.2	9.1/3.9	7.3/5.1	6.7/5.7
8	17/2.9	14/4.0	13/4.7	11/5.6	9.4/7.0	8.7/7.7
10	20/4.1	17/5.4	15/6.2	14/7.3	12/8.9	10.7/9.7
15	27/7.5	23/9.2	21/10	19/12	17/14	15.7/14.7
20	33/11	29/13	27/15	25/16	22/19	20.7/19.7
50	69/35	63/39	60/41	57/44	52/48	50.7/49.7
100	126/78	118/84	114/87	109/92	103/97	101/99.7
N_{fS}>100	N_{fS} + /-2.33✔N_{fS}	N_{fS} + /-1.65✔N_{fS}	N_{fS} + /-1.28✔N_{fS}	N_{fS} + /-0.84✔N_{fS}	N_{fS} + /-0.25✔N_{fS}	N_{fS} /N_{fS}

The final row of the table, for N_{fS} > 100, is found by approximating the Poisson distribution with a Gaussian distribution. In this case the obtained upper bound is:

Equation 26

$N_{fS} + \beta^2/2 + \beta$✔$(\beta^2/4 + N_{fS})$

the lower bound is:

Equation 27

$N_{fS} + \beta^2/2 - \beta$✔$(\beta^2/4 + N_{fS})$

where β is the number of standard deviations from the mean of a Gaussian distribution, the integral of which is equal to the confidence level (i.e., β=0.0, 0.25, 0.84, 1.28, 1.65, and 2.33 for CL = 50, 60, 80, 90, 95, and 99 percent). If N_{fS} is great enough that the standard deviations of the distributions at the lower and upper bounds are comparable, then these bounds are simplified to N_{fS} +/- β ✔ N_{fS} as shown in the table.

The values of Table E2 are taken from the upper bounds at the 90 percent confidence level of Table E4.

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