UL 2034

STANDARD FOR SAFETY

Single and Multiple Station Carbon Monoxide Alarms

UL Standard for Safety for Single and Multiple Station Carbon Monoxide Alarms, UL 2034

Fifth Edition, Dated June 3, 2024

Summary of Topics

This new Fifth Edition of ANSI/UL 2034 dated June 3, 2024 includes Markings revisions.

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated December 15, 2023 and March 22, 2024.

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Standard for Single and Multiple Station Carbon Monoxide Alarms

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The most recent designation of ANSI/UL 2034 as an American National Standard (ANSI) occurred on June 3, 2024. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page. Any other portions of this ANSI/UL standard that were not processed in accordance with ANSI/UL requirements are noted at the beginning of the impacted sections.

Comments or proposals for revisions on any part of the Standard may be submitted to ULSE at any time. Proposals should be submitted via a Proposal Request in ULSE's 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 carbon monoxide (CO) alarms intended for protection in ordinary indoor locations and unconditioned areas, per applicable governing laws, codes, and standards. This includes, but is not limited to, recreational vehicles, mobile homes, commercial vehicles, and recreational boats with enclosed accommodation spaces and cockpit areas.

1.2 Carbon monoxide alarms covered by these requirements are intended to respond to the presence of carbon monoxide from sources such as, but not limited to, exhaust from internal-combustion engines, abnormal operation of fuel-fired appliances, and fireplaces. Carbon monoxide alarms are intended to alarm at carbon monoxide levels below those that cause a loss of ability to react to the dangers of carbon monoxide exposure. See Table 41.1, Part A, Alarm – carbon monoxide concentration and response time.

1.3 Carbon monoxide alarms covered by this standard are not intended to alarm when exposed to long-term, low-level carbon monoxide exposures or slightly higher short-term transient carbon monoxide exposures, possibly caused by air pollution and/or properly installed/maintained fuel-fired appliances and fireplaces. See Table 41.1, Part B, False alarm resistance specifications.

1.4 These requirements, where applicable, also cover all remote accessories that may be connected to or are intended to be employed with a single or multiple station carbon monoxide alarm. See 37.2.1.

1.5 This standard does not cover the following:

a) Single and multiple station smoke alarms that are covered by the Standard for Smoke Alarms, UL 217, or the Standard for Smoke Alarms, ULC-S531.

b) Smoke alarms of the nonself-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 Alarm Systems, UL 268/ULC 529.

c) Mechanically operated single and multiple station fire alarm devices that are specified in the Standard for Smoke Detectors for Fire Alarm Systems, UL 539 / ULC 589, or the Standard for Heat Actuated Fire Detectors for Fire Alarm Systems, ULC-S530.

d) Heat alarms whose requirements are covered in the Standard for Heat Detectors for Fire Protective Signaling Systems, UL 521, or the Standard for Lined Building Protection Fire Hose, ULC-530.

e) Carbon monoxide gas detectors intended for use in hazardous locations as defined in the U.S. Coast Guard Electrical Engineering Regulations.

2 Components

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

2.2 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.

2.3 A component shall be used in accordance with its rating established for the intended conditions of use.

2.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

3 Units of Measurement

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

4 Undated References

4.1 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.

5 Glossary

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

5.2 ALARM, MULTIPLE STATION – A single station alarm that is able to be interconnected with one or more other alarms for common alarm annunciation.

5.3 ALARM SIGNAL – An audible and visual signal intended to indicate a gas concentration in excess of 30 ppm carbon monoxide for thirty days or 70 ppm carbon monoxide for 1 hour. The audible portion of the alarm signal shall be 4 cycles of 100 milliseconds "on"/100 milliseconds "off," then 5 seconds "off." After the initial 4 minutes of the alarm signal, the 5 second "off" period may be changed to 60 seconds±10 percent. This signal shall be repeated until the alarm resets after dissipation of CO or the alarm signal is manually silenced. The visual indicator for alarm shall be located on the face of the unit.

5.4 ALARM, SINGLE STATION – An alarm device consisting of an assembly of electrical and mechanical components including a sensor or sensors, an audible alarm, and an optional visual alarm constructed to detect the presence of carbon monoxide gas. It is powered either from an external source by means of splice leads or a cord and plug arrangement or from an integral battery or batteries. Some devices have terminals for connection to remote audible signaling appliances or accessories. Some also contain an integral transmitter for energizing a remote audible signaling appliance.

5.5 BATTERY TROUBLE LEVEL SIGNAL – Any combination of battery voltage and series resistance that results in an audible trouble signal from a battery-operated alarm.

5.6 CARBON MONOXIDE (CO) – A colorless, odorless, toxic gas.

5.7 CARBOXYHEMOGLOBIN OR CARBONMONOXYHEMOGLOBIN (COHb) – A stable combination of carbon monoxide and hemoglobin formed in the blood when carbon monoxide is inhaled. Percent carboxyhemoglobin indicates the degree to which the oxygen-carrying capacity of the blood is impeded by the uptake of carbon monoxide by the hemoglobin.

5.8 COMMERCIAL VEHICLES – US GVWR (Gross Vehicle Weight Rating) Class 6 – 8 as defined by the United States Code (U.S.C.) Title 49 – Transportation Subtitle VI – Motor Vehicle And Driver Programs, Part B – Commercial.

5.9 COMPONENT, LIMITED LIFE – A component that provides a minimum of one year of service but is expected to periodically fail and be replaced and that is supervised for failure that affects normal operation or sensitivity. Typical examples of such components include incandescent lamps, electronic tube heaters, functional heating elements, and batteries. See also 40.4.1.

5.10 COMPONENT, RELIABLE – A component that is not expected to fail or be periodically replaced and is not supervised. A reliable component shall have a predicted failure rated of 2.5 or less failures per million hours.

5.11 DRIP-PROOF – A product that is constructed, or so protected, so that falling drops of liquid or solid particle striking the enclosure, from 0 – 15° downward from the vertical, do not interfere with the intended operation of the equipment.

5.12 DWELLING UNIT – That structure, area, room, or combination of rooms in which a family (or individual) lives. This is intended to cover the living area only and not common usage areas in multifamily buildings such as corridors, lobbies, and basements.

5.13 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.

5.14 LONG-TERM, LOW-LEVEL CARBON MONOXIDE EXPOSURES – Situations resulting in a carbon monoxide concentration not exceeding 30 ppm for less than 30 days.

5.15 PPM – Gas concentration in parts per million.

5.16 PRE-ALARM – An optional audible or audible-visual signal above 30 ppm of CO, unique from the trouble and alarm signal, intended to provide an early notification of the detection of carbon monoxide prior to an alarm signal. When the pre-alarm signal occurs, the carbon monoxide alarm emits the unique pre-alarm signal at the indicating carbon monoxide alarm and may also send the pre-alarm signal to a wireless communication remote accessory device. The pre-alarm signal is an optional signal that when implemented does not prohibit the normal operation of the carbon monoxide alarm. When rapid levels of carbon monoxide are detected, the alarm signal takes precedence over the pre-alarm signal.

5.17 QUALIFIED APPLIANCE TECHNICIAN – A person, firm, corporation, or company that either in person, or through a representative, is engaged in and responsible for the installation, testing, servicing, or replacement of heating, ventilation, and air-conditioning (HVAC) equipment, combustion appliances and equipment, and/or gas fireplaces or other decorative combustion equipment.

5.18 SELF-CONTAINED UNIT – An alarm containing an internal battery or batteries.

5.19 SENSITIVITY – The gas concentration versus time at or above which the alarm must initiate or remain in alarm.

5.20 SENSOR – The component or combination of components of the alarm that responds to and in turn provides a usable output signal in the presence of carbon monoxide.

5.21 SHORT-TERM CARBON MONOXIDE EXPOSURE – Situations resulting in a carbon monoxide concentration not exceeding 70 ppm for less than 60 minutes.

5.22 SPECIFIED 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 of the fully assembled unit in its final enclosure, or the date the unit is placed into service.

5.23 SWITCHING DEVICE – A device designed to close and/or open one or more electrical circuits.

5.24 TROUBLE SIGNAL – A visual or audible signal, differing from the alarm signal, intended to indicate a fault or trouble condition, such as an open or shorted condition of a component in the device, an open or ground in the connecting wiring, loss of AC power, or the need for replacement of a limited life component. In a product that includes more than one limited life component, other than the battery, the trouble signal shall be identified by both an audible and visual signal. The audible portion of the trouble signal shall be a single tone pattern consisting of a short "beep" of not more than 0.5 second repeating once every 30 – 60 seconds ±10 percent. This signal shall be repeated until the trouble condition is corrected.

5.25 UNCONDITIONED AREAS – Enclosed spaces without continuous climate controls where an individual spends time and where there is a potential for carbon monoxide buildup. (Examples of unconditioned areas that may include combustible fuel appliances and/or fireplaces include attached and detached garages, crawl spaces, attics, cottages, cabins, etc.)

5.26 WARNING SIGNAL – Except for alarm and trouble signals, no other audible and visual signals shall be used (i.e. warning signals that indicate the presence of CO less than 30 ppm).

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

6 Alarm Reliability Prediction

6.1 Alarm units 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 the Military Standard 217F or 3.5 failures per million hours as calculated by a simplified parts count reliability prediction as described in Section 3.0 of the Military Standard 217B, or equivalent. A "Ground Fixed" (GF) environment is to be used for all calculations. If actual equivalent data is available from the manufacturer, it is usable in lieu of the projected data for the purpose of determining acceptable reliability.

6.2 Any component whose failure results in any of the following is not required to be included in the failure rate calculations:

a) Energization of either an audible trouble signal or energization of a separate visual indication (orange or yellow),

b) De-energization of a power-on light,

c) Does not affect the normal operation, or

d) Is evaluated by specific performance tests included in this standard. Examples include the sensor, audible signal appliance, test switch, and battery contacts.

6.3 An integral or remote accessory, such as an integral transmitter or remote sounding appliance, is not required to be included in the reliability prediction except for those components whose failure affects the normal operation of the alarm.

6.4 A custom integrated circuit (CHIP) employed in an 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 an evaluation of data in a 3000-hour burn-in test, or equivalent. (See Annex A for information on evaluation methods.)

6.5 The carbon monoxide sensor, or a sensing component supervision system, of a CO alarming device shall be either be reliable as required by 6.6 or supervised as required by 6.7.

6.6 If the CO sensor is to be considered reliable, reliability data shall be developed using the Military Standardization Handbook, MIL.217-F or equivalent. The data must indicate a failure rate of not more than 2.5 failures per million hours of operation.

6.7 If the CO sensor is to be considered supervised, failure modes with a likelihood of more than 2.5 failures per million hours of operation, including, but not limited to shorts, opens, and uncompensated sensitivity drift outside of the limits of Table 41.1, must result in a trouble signal as required in Section 40.

6.8 Documentation of the sensor failure modes shall be provided.

6.9 Documentation of the failure modes shall include a description of each failure mode and the circumstances under which it may occur.

6.10 The manufacturer shall submit a test method to render the CO sensor unresponsive to the CO concentrations given in Table 41.1 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 40.

7 Battery Removal Indicator

7.1 Removal of a battery from a battery-operated carbon monoxide alarm shall result in a readily apparent and prominent visual indication. The visual indication shall consist of:

a) A warning flag that will be exposed with the battery removed and the cover closed,

b) A hinged cover that cannot be 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 carbon monoxide 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.

7.2 Deactivation of the battery of a carbon monoxide alarm that uses a non-replaceable battery shall result in a readily apparent and prominent indication. The indication shall consist of one of the following:

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

b) A hinged cover that cannot be 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 carbon monoxide 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.

7.3 If a warning flag, or equivalent, is employed to comply with the requirement of 7.1 or 7.2, it shall be marked as required in 89.7.

8 Alarm Reset/Silence Feature

8.1 Each single and multiple station carbon monoxide alarm shall be designed to be reset/silenced through a manual operation (on the alarm) by physically depressing the alarm reset/silence feature. The operation of the reset/silence feature shall silence the alarm signal and restore the alarm to its normal condition resulting in the alarm once again being able to sense carbon monoxide and alarm within the limits of the Sensitivity Test, Section 41. The alarm signal shall be reenergized within 6 minutes from the time the reset button is operated if the concentration of carbon monoxide surrounding the alarm remains at 70 ppm or greater.

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

8.3 As an optional feature, the manufacturer is permitted to include an additional wireless communication remote reset/silencing feature. If included, and tested for compliance with the requirements outlined in 8.6, the wireless communication remote reset/silence feature may be activated through a remote device. The wireless communication feature shall be capable of providing additional instructions for the user to confirm his physical proximity to the initiating carbon monoxide alarm before resetting/silencing the alarm signal using the remote device.

8.4 A multiple-station interconnected carbon monoxide alarm that produces an alarm signal (wired, wireless, relay, audible and audible-visual) shall be permitted to be reset/silenced by any of the following:

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

b) By physically depressing the alarm reset/silence feature on the initiating carbon monoxide alarm(s), as noted in 8.1; or

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

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

8.6 Carbon monoxide alarms with a wireless communication remote device and employing a remote alarm reset/silence feature shall be tested in accordance with one of the following requirements:

a) The remote transmission radio of the carbon monoxide 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 @ 3 m

or

b) The remote transmission radio of the carbon monoxide 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 carbon monoxide alarm does not exceed 984 feet (300 m).

9 Voltage Classification

9.1 Unless otherwise indicated, all voltage and current values contained in this standard are rms.

a) Extra-Low-Voltage Circuit – A circuit that has an AC voltage of not more than 30 volts 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 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 considered to be an extra-low-voltage circuit.

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

10 Lifetime

10.1 The unit (including the sensor) shall have a specified lifetime of at least 3 years from the date of manufacture, or from the date the unit is placed into service. The unit reliability shall be estimated with an in-service reliability measurement, see 84.2.2(a). If the manufacturer bases the specified lifetime on the date that the unit is placed into service, this specification shall be substantiated with technical data documenting that performance degradation is not likely to occur prior to the unit being placed into service if the unit 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 unit.

CONSTRUCTION

11 General

11.1 Accessories

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

11.2 Sensitivity adjustment

11.2.1 A field sensitivity adjustment, if provided, shall be accessible with the alarm installed as intended, marked to indicate the direction of sensitivity (high or low), and shall employ a mechanical stop at both extremes. Removal of a snap-on cover to gain access to the sensitivity control is allowable, if no hazardous voltage parts are able to be contacted by the user. Adjustment extremes shall not exceed the values given in Table 41.1.

11.3 Supplementary signaling feature

11.3.1 A supplementary signaling feature, such as a transmitter for remote signaling, included integral with a single or multiple station carbon monoxide 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 acceptable for carbon monoxide alarm application.

12 Service and Maintenance Protection

12.1 General

12.1.1 An uninsulated live part of a hazardous-voltage circuit within the enclosure shall be located, guarded, or enclosed so as to reduce the risk of unintentional contact by persons performing service functions with the equipment energized.

12.1.2 An electrical component which may require examination, replacement, adjustment, servicing, or maintenance with the alarm energized shall be located and mounted with respect to other components and with respect to grounded metal so that it is accessible for such service without subjecting the user to an electric shock from adjacent uninsulated hazardous-voltage live parts.

12.1.3 The following are not considered to be uninsulated live parts:

a) Coils of relays, solenoids, and transformer windings, if the coils and windings are provided with insulating overwraps,

b) Terminals and splices with insulation rated for the intended application, and

c) Insulated wire.

12.2 Sharp edges

12.2.1 An edge, projection or corner of an enclosure, opening, frame, guard, knob, handle, or the like, of a carbon monoxide alarm shall be smooth and rounded, so as not to cause a cut-type injury when contacted during use or user maintenance.

13 Enclosure

13.1 General

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

13.1.2 Enclosures for individual electrical components, outer enclosures, and combinations of the two are to be considered in determining compliance with the requirement of 13.1.1.

13.1.3 All electrical parts of an 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 junction box is not required.

13.1.4 There shall not be rear openings in a carbon monoxide alarm which are permeable to debris or air currents that affect alarm response.

13.1.5 There shall not be openings between the mounting surface to which an alarm is intended to be installed and the rear of the alarm which are permeable to air that affects alarm response.

13.1.6 To comply with 13.1.4 and 13.1.5, one of the following methods, or method determined to be equivalent, shall be used:

a) An elastomeric rubber or neoprene gasket, or the equivalent, may be placed between the rear of the alarm and the mounting surface to seal the rear openings or

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

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

13.1.8 If the unit is intended for permanent connection in a hazardous voltage circuit, 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.

13.1.9 A mounting bracket, or other means provided to secure a detector system to a boat, shall be of a type and located so the installation maintains a fixed relationship to the boat when subjected to the vibration and shock loads of marine service. See 81.2.7 – 81.2.15.

13.1.10 Among the factors taken into consideration when a frame or enclosure for a detector system intended for a boat is judged are:

a) Mechanical strength;

b) Resistance to impact;

c) Moisture-absorptive properties;

d) Combustibility;

e) Resistance to ignition from electrical sources;

f) Resistance to corrosion; and

g) Resistance to distortion at temperatures to which the enclosure is subjected under conditions of normal or abnormal use.

13.1.11 Materials which are to be exposed to moist environments shall not be adversely affected when subjected to the humidity conditioning specified in 81.2.16 and 81.2.17.

13.2 Cast metal enclosures

13.2.1 The thickness of cast metal for an enclosure shall be as indicated in Table 13.1. Cast metal having a thickness 1/32 inch (0.8 mm) less than that indicated in Table 13.1 shall be employed only if the surface under consideration is curved, ribbed, or otherwise reinforced, or if the shape and/or size of the surface is such that equivalent mechanical strength is provided.

Table 13.1
Cast Metal Enclosures

Use, or dimensions of area involved	Minimum thickness			
	Die-cast metal,		Cast metal of other than the die-cast type,	
	inch	(mm)	inch	(mm)
Area of 24 square inches (155 cm^2) or less and having no dimension greater than 6 inches (152 mm)	1/16[a]	(1.6)	1/8	(3.2)
Area greater than 24 square inches (155 cm^2) or having any dimension greater than 6 inches (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 inch (1.6 mm) in thickness is able to be obtained by the provision of reinforcing ribs subdividing a larger area.

13.2.2 If threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, there shall not be less than 3-1/2 nor more than five threads in the metal, and the construction shall be such that a standard conduit bushing is able to be attached.

13.2.3 If threads for the connection of conduit are tapped only part of the way through a hole in an enclosure wall, there shall not be less than 3-1/2 full threads in the metal, and there shall be a smooth, rounded inlet hole for the conductors which shall afford protection to the conductors equivalent to that provided by a standard conduit bushing.

13.3 Sheet metal enclosures

13.3.1 The thickness of sheet metal employed for the enclosure of an alarm shall not be less than that indicated in Table 13.2 unless the surface under consideration is curved, ribbed, or otherwise reinforced, or if the shape or size of the surface is such that equivalent mechanical strength is provided.

Table 13.2
Sheet Metal Enclosures

Maximum dimensions of enclosure				Minimum thickness of sheet metal					
				Steel					
Length or width		Area		Zinc-coated		Uncoated		Brass or aluminum	
inches	(mm)	$inches^2$	(cm^2)	inch	(mm)	inch	(mm)	inch	(mm)
12	(305)	90	(581)	0.034	(0.86)	0.032	(0.81)	0.045	(1.14)
24	(610)	360	(2322)	0.045	(1.14)	0.042	(1.07)	0.058	(1.47)
48	(1219)	1200	(7742)	0.056	(1.42)	0.053	(1.35)	0.075	(1.91)
60	(1524)	1500	(9678)	0.070	(1.78)	0.067	(1.70)	0.095	(2.41)
Over 60	(Over 1524)	Over 1500	(Over 9678)	0.097	(2.46)	0.093	(2.36)	0.122	(3.10)

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

13.3.3 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 or 0.032-inch (0.69 or 0.81-mm) nonferrous metal for a hole having a 1-3/8 inch (34.9 mm) diameter maximum dimension.

13.3.4 A closure for a hole larger than 1-3/8 inch (34.9 mm) diameter shall have a thickness equal to that required for the enclosure of the device or a standard knockout seal shall be used.

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

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

13.4 Nonmetallic enclosures

13.4.1 An enclosure or parts of an enclosure of nonmetallic material shall have the mechanical strength and durability and be so formed 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 Table 13.2. See also the Tests of Thermoplastic Materials, Section 68.

13.4.2 The continuity of any grounding system to which an alarm is able to be connected shall not rely on the dimensional integrity of the nonmetallic material.

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

a) Enclosure containing parts presenting risk of fire – Minimum flammability rating of V-0, and complies with the performance requirements of the Flammability – 5 Inch Flame Test in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

b) Enclosures containing Class 2 and Class 3 circuits with a voltage not exceeding 30 V AC, 42.4 V-peak, or 60 V DC – Minimum flammability rating of HB, and complies with the performance requirements of the Flammability – 3/4 Inch Flame Test in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

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

13.5 Ventilating openings

13.5.1 Ventilating openings in an enclosure for hazardous-voltage circuits including perforated 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 permits passage of a rod having a diameter of 9/64 inch (3.6 mm). An enclosure for a fuse(s) or other overload protective device provided with ventilating openings shall afford protection against the emission of flame or molten metal. Openings provided to permit cleaning, or openings that are used to clean internal parts, shall be constructed to reduce the risk of damage to functional internal components during such cleaning operations.

13.5.2 Except as noted in 13.5.3, perforated sheet metal employed for expanded metal mesh shall not be less than 0.042 inch (1.07 mm) in average thickness, 0.046 inch (1.17 mm) if zinc coated.

13.5.3 If the indentation of the guard or enclosure does not alter the clearance between uninsulated live parts and grounded metal so as to reduce spacings below the minimum values required, 0.021 inch (0.53 mm) expanded metal mesh or perforated sheet metal, 0.024 inch (0.61 mm) if zinc coated, is able 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 square inches (465 cm^2) and has no dimension greater than 12 inches (305 mm^2) or

b) The width of an opening so protected is not greater than 3-1/2 inches (88.9 mm).

13.5.4 The wires forming a screen protecting hazardous-voltage parts shall not be smaller than 16 AWG (1.3 mm^2) and the screen openings shall not be greater than 1/2 square inch (3.2 cm^2).

13.6 Covers

13.6.1 An enclosure cover 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 necessary to open the cover periodically in connection with the intended operation of the alarm. For the purpose of this requirement, intended operation is considered to be operation of a switch for testing or operation of any other component of an alarm that requires such action in connection with its intended performance. This requirement does not apply to the battery replacement aspect of an alarm employing a battery as the main or standby supply.

13.6.2 A cover that is intended to be removed only for periodic maintenance shall be secured by any one of the following or equivalent means: positive snap catch, plug-in or twist action, snap tab with one screw, or two or more screws.

13.6.3 If an alarm cover is not intended to be removed for cleaning, maintenance, or both, and the 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 tamperproof type, shall be sealed or covered.

Exception: These requirements do not apply if the alarm cover is intended to be removed for cleaning, maintenance, or both, even though the alarm is intended to be returned to the manufacturer for servicing.

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

13.6.5 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 a means determined to be equivalent.

13.7 Transparent panels

13.7.1 Glass covering an enclosure 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 that indicated in Table 13.3.

Table 13.3
Thickness of Glass Covers

Maximum size of opening				Minimum thickness	
Length or width		Area			
inches	(mm)	inches^2	(cm^2)	inch	(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	

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

13.7.2 A transparent material other than glass employed as a cover over an opening in an enclosure shall:

a) Be mechanically equivalent to that of glass;

b) Not distort; or

c) Not become less transparent at the temperature to which it is subjected under normal service conditions.

13.7.3 A lens, light filter, or similar part of a carbon monoxide alarm shall be constructed of a material whose transparency will not be diminished by the conditions to which it will be exposed in service, as represented by the Performance Tests (see Sections 38 – 75) of this standard.

14 Corrosion Protection

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

14.2 The requirement of 14.1 applies to all sheet steel or cast iron enclosures, and to all springs and other parts upon which mechanical operation depends. It does not apply to minor parts, such as washers, screws, and bolts, if the failure of such unprotected parts does not result in a risk of fire or electric shock or injury to persons or impair the operation of the alarm. Parts made of stainless steel, polished or treated if necessary, do not require additional protection. Bearing surfaces shall be of materials that will prevent binding due to corrosion.

14.3 Metal shall not be used in combinations such as to cause galvanic action which will adversely affect cabinets or enclosures.

14.4 Hinges and other attachments shall be resistant to corrosion.

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

POWER SUPPLY

15 Primary Power Supply

15.1 The primary power supply of a single or multiple station carbon monoxide alarm shall be either an electrical power source or a battery or batteries. Connection to the electrical power source, if used, shall be in the form of permanent wiring to terminals or leads in a separate wiring compartment (see also

13.1.8) having provision for the connection of conduit, metal-clad or nonmetallic sheathed cable, or by means of a power-supply cord and a two or three prong attachment plug.

15.2 If 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 volt-amperes. The energy shall be limited by an energy limited transformer having an output rating of 100 volt-amperes or less, or by a transformer plus additional circuitry having characteristics equivalent to those of a Class 2 transformer.

16 Secondary Power Supply (Not Applicable for Commercial Vehicles)

16.1 The use of a secondary power supply is required for all alarms that receive their primary power from a source other than an integral battery or batteries. The secondary power supply, such as a battery, shall have the capacity to supply the maximum intended power to the alarm for 24 hours in the standby condition and thereafter be able to operate the alarm for an alarm signal for at least 12 hours continuously, followed by not less than 7 consecutive days of trouble signal.

16.2 If a battery is employed for the secondary power supply, it shall be of a rechargeable or nonrechargeable 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 nonrechargeable type battery, data on battery life, including discharge curves, shall be provided for the investigation to evaluate battery shelf aging and performance characteristics.

16.3 If a battery is employed as a secondary power supply, the marking on the unit shall include the manufacturer's specified periodic battery replacement instructions.

16.4 The discharge condition of a non-rechargeable or rechargeable type battery shall be monitored where a trouble indication, as described in 40.1.3, is obtained. The monitoring shall take place whether the alarm is operating on the primary supply or on the standby supply.

17 Batteries

17.1 General

17.1.1 If a battery or set of batteries is employed as the main source of power of a single or multiple station carbon monoxide alarm, it shall meet the requirements of the Battery Tests, Section 66.

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

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

17.1.4 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.

17.1.5 Connections of external wiring to a battery-operated single- or multiple-station carbon monoxide alarm, or to a portable accessory, shall not be subjected to stress or motion during battery replacement and/or servicing. Removal of the alarm or accessory from the mounting support to replace a battery or to service the unit is not allowed unless the connected wiring is not subjected to flexing or stress.

17.1.6 A carbon monoxide alarm powered by a non-replaceable battery shall be provided with a means of activating the power prior to installation and deactivating the battery at the end of the 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 91.1(u).

17.2 Battery connections

17.2.1 Lead or terminal connections to batteries shall be identified with the proper polarity (plus or minus signs), and provided with strain relief. Indicating polarity on the unit adjacent to the battery terminals or leads is not prohibited.

17.2.2 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 pounds (6.6 N) force to each battery contact, or equivalent. The connection shall consist of an unplatted or plated metal which is resistant to the corrosive action of the electrolyte.

17.2.3 Each lead of a clip-lead assembly employed as part of a battery operated alarm shall be a minimum of 26 AWG (0.21 mm^2) stranded wire with a minimum 1/64-inch (0.4-mm) insulation.

18 Supplementary Signaling Circuits

18.1 For a cord-connected or battery operated single station alarm employing a supplementary signaling circuit which is energized from a separate source of supply, the source of energy shall not exceed the energy limits defined in 74.2.1 and 74.2.2.

18.2 For an alarm intended to be connected to a fixed wiring system and employing a separately energized signaling circuit, the source of energy shall not exceed the limits in 74.2.1 unless the connections are made as a Class 1 wiring system as defined in the National Electrical Code, NFPA 70-1996, or in the Canadian Electrical Code, Part 1 (CSA C22.1).

FIELD WIRING

19 Permanent Connection

19.1 General

19.1.1 A single station or multiple station carbon monoxide alarm intended for permanent connection to a hazardous voltage circuit shall be provided with wiring terminals or leads for the connection of conductors of at least the size required by the National Electrical Code, NFPA 70-1996, or the Canadian Electrical Code, Part 1 (CSA C22.1), corresponding to the rating of the unit.

19.2 Field-wiring compartment for hazardous voltage connection

19.2.1 The field-wiring compartment area is to 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 if a bushing is required for installation.

19.2.2 Protection for internal components and wire insulation from sharp edges shall be provided by insulating barriers or metal barriers having smooth rounded edges.

19.3 Field-wiring terminals

19.3.1 Terminal parts to which field connections are to be made shall consist of binding screws with terminal plates having upturned lugs or a means determined to be equivalent to hold the wires in position. Other terminal connections shall not be provided unless determined to be equivalent.

19.3.2 If a wiring-binding screw is employed at a field-wiring terminal, the screw shall not be smaller than a No. 6 (3.5 mm diameter).

19.3.3 Except as noted in 19.3.4, a terminal plate tapped for a wire-binding screw shall be of metal not less than 0.030 inch (0.76 mm) thick and shall not have less than two full threads in the metal.

19.3.4 A terminal plate shall have the metal extruded at the tapped hole for the binding screw so as to provide two full threads. Other constructions shall be employed only if they provide equivalent security.

19.3.5 Wiring terminal assemblies that are used for field connections shall be prevented from turning.

19.4 Field-wiring leads

19.4.1 Power supply leads provided for field connection shall not be less than 6 inches (152 mm) long, provided with strain relief, and shall not be smaller than 18 AWG (0.82 mm^2); and the insulation, if thermoplastic, shall not be less than 1/32 inch (0.8 mm) in thickness.

Exception No. 1: The lead may be less than 6 inches long if it is evident that the use of a longer lead may result in damage to the insulation.

Exception No. 2: Solid copper leads as small as 26 AWG (0.13 mm^2) may be used if:

a) The current does not exceed 1 ampere for lengths up to 2 feet (61 cm) and the current does not exceed 0.4 ampere for lengths up to 10 feet (3.05 m);

b) There are two or more conductors and they are covered by a common jacket or the equivalent;

c) The assembled conductors comply with the requirements of the Strain Relief Test, Section 73; and

d) The installation instructions indicate that the lead cannot be spliced to a conductor larger than 18 AWG.

19.4.2 Leads provided for field connection to power limited signaling circuits, such as employed for multiple station interconnection or for connection to remote signaling devices, shall not be smaller than 16 AWG (1.3 mm^2), for a single conductor, 19 AWG (0.65 mm^2) for two or more conductors, and 26 AWG (0.13 mm^2) for four or more conductors of a multiconductor cable. The conductor shall be solid, bunch tinned stranded, or stranded copper. Stranded copper wire, consisting of not more than seven strands, may be employed only for 18 AWG (0.82 mm^2) and larger conductors.

19.5 Grounded supply terminals and leads

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

19.5.2 A field-wiring lead provided for connection of a neutral supply conductor shall be finished to show a white or gray color and shall be readily distinguishable from other leads. No leads other than neutral conductors, shall be so identified.

19.5.3 A terminal or lead identified for the connection of the neutral supply conductor shall not be electrically connected to a single-pole manual switching device that has an OFF position or to a single-pole overcurrent (not thermal) protective device.

20 Power Supply Cord

20.1 A cord-connected single station carbon monoxide alarm shall be provided with not less than 6 feet (1.83 m) nor more than 20 feet (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.

Exception: The cord may be less than 6 feet in length if it is evident that the use of a longer cord:

a) May result in a risk of fire or electric shock;

b) May result in unintentional contact with moving parts that may cause a risk of injury to persons; and

c) Is not required for the intended operation of the product.

20.2 The flexible cord shall be of Type SP-1, SPT-1, SP-2, SPT-2, SV, SVT, SJ, SJT, SPE, SVE, or equivalent, minimum 18 AWG (0.82 mm^2). It shall be rated for use at the voltage and ampacity rating of the alarm, in accordance with the National Electrical Code, NFPA 70, or the Canadian Electrical Code, Part 1 (CSA C22.1).

20.3 Means shall be provided to prevent the flexible cord from being pushed into the enclosure through the cord-entry hole if such displacement:

a) Subjects the cord to mechanical damage or to exposure to a temperature higher than that for which the cord is rated,

b) Reduces spacings below the minimum acceptable values, or

c) Results in damage in internal components.

20.4 A smoothly rounded restraining means shall be provided for securing the attachment plug to the receptacle. See the Strain Relief Test, Section 73.

20.5 The power supply cord shall be provided with strain relief means so that a stress on the cord will not be transmitted to terminals, splices, or internal wiring. See the Strain Relief Test, Section 73.

20.6 If a knot in a flexible cord serves as strain relief, a surface against which the knot may bear or with which it may come in contact shall be free from projections, sharp edges, burrs, and fins that may cause abrasion of the insulation on the conductors.

20.7 Clamps of any material (metal or otherwise) are acceptable for use on cords and supply leads without varnished-cloth insulating tubing or the equivalent under the clamp unless the tubing or the equivalent is necessary to prevent the clamp from damaging the cord or supply leads.

21 Equipment Grounding

21.1 General

21.1.1 An equipment grounding terminal or lead, or equivalent, is required for a hazardous-voltage alarm that is intended to be serviced internally and employs internal dead metal parts that become energized under a fault condition.

21.1.2 An equipment grounding terminal or lead is not required for:

a) An extra-low-voltage alarm;

b) A hazardous-voltage alarm provided with an overall nonmetallic enclosure and cover, and that is not intended to be internally serviced; or

c) A hazardous-voltage alarm provided with an overall nonmetallic enclosure and cover, that does not employ internal dead metal parts that become energized under a fault condition and is able to be contacted during servicing.

21.2 Permanently-connected units

21.2.1 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. No other leads visible to the installer, other than grounding conductors, shall be so identified. 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 a means determined to be equivalent, or by a marking on a wiring diagram provided on the alarm. The field-wiring terminal shall be so located that it cannot be removed during servicing of the alarm.

21.3 Cord-connected units

21.3.1 The grounding means for a cord-connected alarm that is intended to be serviced internally shall consist of a separate grounding lead integral with the supply cord and terminating in the grounding pin of a parallel blade attachment plug.

22 Remote Power Supply Leads

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, if 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 feet (6.1 m). The interconnecting wiring is to be provided 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 manufacturer is not required to provide the wiring. 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 Article 725 of the National Electrical Code, NFPA 70, or Section 33 of the Canadian Electrical Code, Part 1 (CSA C22.1). In addition, the resistance of the interconnecting wiring shall be a maximum of 10 ohms, unless otherwise specified by the manufacturer.

INTERNAL WIRING

23 General

23.1 The internal wiring of an alarm shall consist of conductors having insulation rated for the voltage involved and the temperatures to which it shall be subjected, and shall have the mechanical strength and current-carrying capacity for the service. The wiring shall be routed away from moving parts and sharp projections and held in place with clamps, string, ties, or equivalent, unless of sufficient rigidity to retain a shaped form.

23.2 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.

23.3 If the use of a short length of insulated conductor is not feasible, such as for a short coil lead, the use of electrical insulating tubing is not prohibited. 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 conform to the requirements for such tubing, except that the wall thickness at any point for polyvinyl chloride tubing of 3/8 inch (9.5 mm) diameter or less, shall not be less than 0.017 inch (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 inch (0.43 mm).

23.4 Internal wiring of circuits operating at different potentials shall be 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 shall be accomplished by clamping, routing, or equivalent means that provides permanent separation.

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

24 Wireways

24.1 Wireways shall be smooth and free from sharp edges, burrs, fins, and moving parts that cause abrasion of the conductor insulation.

25 Splices

25.1 All splices and connections shall be mechanically secured to preclude shorting to adjacent uninsulated current carrying parts in the event that an improper connection, such as a cold solder joint, is made. Tack soldering is not to be used unless the design precludes mechanical security and five samples resist a pull force of 2 pounds (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.

25.2 A splice shall be provided with insulation equivalent to that of the wires involved, if permanence of electrical spacing between the splice and uninsulated metal parts is not assured.

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

26 Barriers

26.1 A metal barrier shall have a thickness at least equal to that required by Table 13.2, as determined by the size of the barrier. A barrier of insulating material shall not be less than 0.028 inch (0.71 mm) thick and shall be thicker if its deformation may be readily accomplished so as to defeat its purpose. Any clearance between the edge of a barrier and a compartment wall shall not be more than 1/16 inch (1.6 mm).

27 Grounding and Bonding

27.1 An exposed dead metal part that becomes energized by hazardous voltage shall be bonded to the point of connection of the alarm grounding terminal or lead, and to the metal surrounding the knockout, hole, or bushing provided for field power supply connections.

27.2 Except as indicated in 27.3, uninsulated metal parts of electrical enclosures, transformer cores, mounting brackets, capacitors, and other electrical components shall be bonded for grounding if they may be contacted by the user or by a service person servicing or operating the equipment.

27.3 Metal parts as described below, are not required to comply with the requirement of 27.1 and 27.2:

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

b) Isolated metal parts, such as small assembly screws, that cannot come in contact with wiring and uninsulated live parts.

c) Panels or covers that do not enclose uninsulated live parts when they cannot come in contact with wiring which causes them to become energized.

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

27.4 The bonding shall be by a positive means, such as by clamping, riveting, brazing, welding, or making a bolted or screwed connection. 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.

27.5 A bolted or screwed connection that incorporates a star washer or serration under the screwhead is acceptable for penetrating nonconductive coatings as required by 27.4.

27.6 The use of two or more screws, or two full threads engagement of a single screw in metal, complies with 27.4 if the bonding means depends upon screw threads.

27.7 Metal-to-metal hinge bearing members for doors or covers shall not be used as means of bonding the door or cover for grounding unless a multiple bearing-pin type (piano type) hinge is used.

27.8 The size of a copper or aluminum conductor employed to bond an electrical enclosure shall be based on the rating of the branch circuit overcurrent device by which the alarm will be protected. Except as noted below, the size of the conductor shall comply with the applicable requirements for connection of an equipment grounding conductor as specified in Table 250-95 of the National Electrical Code, NFPA 70, and Table 16 of the Canadian Electrical Code, Part 1, CSA C22.1, except that such a conductor need be not larger than one of the power supply conductors.

27.9 A bonding conductor to an electrical component need not be larger than the conductor supplying the component.

27.10 A bonding conductor in an alarm shall have insulation equivalent to that of live conductors, if there is any possibility of accidental contact between the bonding conductor and uninsulated live parts.

27.11 Splices shall not be employed in wire conductors used for bonding.

ELECTRICAL COMPONENTS

28 General

28.1 Mounting of components

28.1.1 A switch, lampholder, attachment-plug receptacle, plug connector, or similar electrical component, and uninsulated live parts shall be mounted securely and shall be prevented from 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 rotate when operated. A toggle switch is considered to be subject to forces that tend to turn the switch during operation of the switch.

b) The means for mounting the switch makes it unlikely that the operation of the switch will loosen it.

c) The spacings are not reduced below the minimum required values if 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 cannot be 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 if rotation cannot reduce spacings below the minimum values required. See Spacings, Section 36.

28.1.2 Uninsulated live parts shall be so secured to the base or mounting surface that they will be prevented from turning or shifting in position, if such motion may result in a reduction of spacings. Friction between surfaces is not acceptable as a means to prevent shifting or turning of live parts, but a properly applied lock washer may be accepted.

28.1.3 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 will be prevented from turning or shifting in position if such motion results in reduction of spacings below the minimum values required. This shall be accomplished by two screws or rivets; by square shoulders or mortises; by a dowel pin, lug, or offset; by a connecting strap or clip fitted into an adjacent part; or by some other equivalent method.

28.2 Operating components

28.2.1 Operating components and assemblies, such as switches, relays, and similar devices, shall be protected by individual dust covers or dust tight cabinets, against fouling by dust or by other material that impairs their operation.

28.2.2 Adjusting screws and similar adjustable parts shall be prevented from loosening under the conditions of actual use. A properly applied lock washer is one method of preventing loosening.

28.3 Current-carrying parts

28.3.1 Bearings, hinges, and similar items shall not be used for current carrying parts.

28.4 Electrical insulating material

28.4.1 Material for the mounting of uninsulated live parts shall be porcelain, phenolic composition, cold-molded composition, or equivalent material.

28.4.2 Vulcanized fiber is suitable for insulating bushings, washers, separators, and barriers, but not as the sole support for uninsulated live parts of other than extra-low-voltage circuits.

28.4.3 Polymeric materials shall not be used for the sole support of uninsulated live parts unless they are determined to be equivalent to the materials indicated in 28.4.1.

28.4.4 A flat sheet of insulating material, such as phenolic composition employed for panel-mounting of parts, shall not be less than 1/16 inch (1.6 mm) thick. Material less than 1/16 inch in thickness shall not be employed unless the panel is supported or reinforced to provide equivalent rigidity.

28.4.5 When a terminal block mounted on a metal surface is grounded it shall be provided with an insulating barrier between the mounting surface and all uninsulated live parts on the underside of the base unless the parts are staked, upset, sealed, or equivalently prevented from loosening so as to prevent the parts and the ends of replaceable terminal screws from coming in contact with the supporting surface or reducing spacings below the minimum values required.

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

29 Bushings

29.1 If 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 a means determined to be equivalent, which shall be substantial, secured in place, and have a smooth rounded surface.

29.2 If the opening is in a phenolic composition or other nonconducting material, or in metal of thickness greater than 0.042 inch (1.07 mm), a smooth surface having rounded edges is considered to be the equivalent of a bushing.

29.3 Ceramic materials and some molded compositions are suitable for insulating bushings, but separate bushings of wood and hot-molded shellac shall not be used.

29.4 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 inch (1.6 mm) in thickness, with a minus tolerance of 1/64 inch (0.4 mm) for manufacturing variations, and

c) It is not affected adversely by ordinary ambient humidity conditions.

29.5 If 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, and other projections that cut into the bushing and wire insulation.

29.6 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 inch (0.8 mm) in thickness and fills completely the space between the grommet and the metal in which it is mounted.

30 Lampholders and Lamps

30.1 A single and/or multiple station carbon monoxide alarm intended to be connected to an alternating current (ac) power source shall be provided with a "power-on" lamp to indicate energization of the unit.

30.2 If more than one lamp is provided on the alarm, the "power-on" lamp shall be white or green, an alarm indicating lamp shall be red, and a trouble lamp shall be amber or yellow.

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

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

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

30.6 A lamp or equivalent means, such as a distinctive audible signal indication, shall be provided on an alarm intended for multiple-station interconnection to identify the unit from which the alarm was initiated.

31 Protective Devices

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

32 Printed-Wiring Boards

32.1 The components of a printed-wiring board shall be secured in place and the spacings between circuits shall comply with the spacings requirements for rigidly clamped assemblies (Table 36.1). The board shall be mounted so that deflection of the board during servicing shall not result in damage to the board or risk of fire or electric shock.

32.2 A printed-wiring board shall comply with the requirements in the Standard for Printed Wiring Boards, UL 796, and shall be mounted so that moisture does not accumulate on the board.

33 Switches

33.1 A switch shall have a current and voltage rating not less than that of the circuit which it controls. There shall be no power switches provided with an alarm.

33.2 If a reset switch is provided, it shall be of a self-restoring (momentary) type.

34 Transformers and Coils

34.1 A transformer shall be of the two-coil or isolated-winding type.

Exception: It is not prohibited that an autotransformer be employed in an alarm intended for permanent connection only, when the terminal or lead connected to the autotransformer winding which is common to both input and output circuits is identified, and that the output circuits are located only within the enclosure containing the autotransformer. See 19.5.1 and 19.5.2.

34.2 The insulation of coil windings of relays, transformers and the like shall be such as to resist the absorption of moisture.

34.3 Film-coated or equivalently insulated wire is not required to be given additional treatment to prevent moisture absorption.

35 Dropping Resistors

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

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.

36.2 The spacings between an uninsulated live part and a wall or cover of a metal enclosure; fitting for conduit or metal-clad cable; and any dead metal part shall not be less than that indicated in Table 36.1.

36.3 The "Through air" and "Over surface" spacings of Table 36.1 measured at an individual component part are to be judged on the basis of the volt-amperes used and controlled by the individual component. However, the spacings 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-amperes rating of all components in the enclosure.

36.4 The spacing requirements in Table 36.1 do not apply to the inherent spacings inside motors, except at wiring terminals, or to the inherent spacings of a component provided as part of the 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 those indicated in Table 36.1.

36.5 The "To wall 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 Enameled or equivalently insulated wire is to be considered an uninsulated live part, but enamel is acceptable as turn-to-turn insulation in coils.

Table 36.1
Minimum Spacings

Point of application	Voltage range	Minimum spacings[a,b]			
		Through air		Over surface	
		inch	(mm)	inch	(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]	0 – 30	1/32	(0.8)	1/32	(0.8)
Over 100 volt-amperes	0 – 30	3/64	(1.2)	3/64	(1.2)
	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 will otherwise be insufficient shall not be less than 0.028 inch (0.71 mm) thick; except that a liner or barrier not less than 0.013 inch (0.33 mm) thick is usable 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. Insulating material having a thickness less than that specified shall be used only if it is approved for the particular application.

[b] Measurements are to be made with solid wire of acceptable 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 the like.

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

PERFORMANCE

37 General

37.1 Test units and data

37.1.1 Alarms that are fully representative of production units are to be used for all tests. The range of sensitivities (ppm CO), regardless of time, which can lead to an alarm signal shall be provided for the samples. This range will define the production sensitivity.

37.1.2 The following samples are to be provided for testing:

a) At least 15 assembled alarms.

b) One additional unassembled alarm.

c) Installation and operating instructions (see 92.1 and 92.2 and Section 91).

d) For alarms employing a battery as the main operating supply, 24 additional battery operated 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. Each set-up, if provided, is to be representative of six alarms and is to include test terminals and switches, limiting resistors, the alarm horn, and batteries. The value of resistors is to represent the normal standby current which is obtained from a complete alarm.

37.1.3 The batteries are to be connected in the test circuit with the same terminal arrangement employed in the alarm. Provision for connection of the actual sounding appliance used in the alarm for random and weekly testing is also to be made. (See the Battery Tests, Section 66.)

37.1.4 Before, during, and after the tests specified in Sections 41, 42, 44, 50, and 51 of this Standard, all alarm samples shall remain operational without the need to replace any component or portion of the alarm. These same alarms may be used in subsequent tests.

37.1.5 The accessory devices such as horns or lights employed for testing are to be those specified by the wiring diagram of the alarm. Substitute devices shall be used only if they produce functions and load conditions equivalent to those obtained with the devices intended to be used with the alarm in service.

37.2 Accessories

37.2.1 Accessories for use with single and multiple station carbon monoxide alarms are to be subjected – but not necessarily limited– to the following tests as applicable:

a) Normal Operation Test, Section 38;

b) Circuit Measurement Test, Section 39;

c) Temperature Test, Section 47;

d) Overload Test, Section 48;

e) Endurance Test, Section 49;

f) Variable Ambient Temperature Test, Section 50;

g) Humidity Test, Section 51;

h) Leakage Current Test, Section 52;

i) Transient Tests, Section 53;

j) Dielectric Voltage-Withstand Test, Section 56;

k) Overvoltage Test, Section 58;

l) Undervoltage Test, Section 59;

m) Jarring Test, Section 64;

n) Audibility Test, Section 67;

o) Tests of Thermoplastic Materials, Section 68; and

p) Drop Test, Section 75 (portable appliance only).

37.3 Test voltages

37.3.1 Unless otherwise specified, the test voltage at rated frequency for each test is to be as follows:

Voltage, nameplate	Alarm rated test voltage
110 to 120	120
220 to 240	240
Other	Marked rating

37.3.2 The following samples are to be provided for testing:

a) At least 15 assembled alarms – 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 alarm.

c) Installation and Operating Instructions (see 92.1 and 92.2 and Section 91).

d) For alarms employing a battery as the main operating supply, 24 additional battery operated 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. Each set up, if provided, shall be representative of six 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 would be obtained from a complete alarm.

37.3.3 The batteries shall be connected in the test circuit with the same terminal arrangement employed in the alarm. Provision for connection of the actual sounding appliance used in the alarm for random and weekly testing shall also be made. (See the Battery Tests, Section 66.)

37.4 Component reliability data

37.4.1 Data on alarm components, such as capacitors, resistors, solid state devices, and the like, shall be provided for evaluation of the reliability of the components for the intended application. If a Military Standard is referenced, a copy of the specification is to be provided for review.

37.4.2 The data required by 37.4.1 shall include the following or equivalent information:

a) Component and overall alarm reliability analysis per Military Standard 217F, described in 6.1.

b) Component vendor's reliability and life expectancy data. This includes failure rate data at rated values and derated values. The latter data is required only where the derating values form the basis of reliability.

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

d) Component Fault Analysis – Effect of failure, open and short, of capacitors and limited-life components on operation of an alarm.

e) Maximum vendor's ratings for each component as well as the actual maximum operating values (voltage and current) in the alarms.

f) A description of component screening and burn-in test data for solid-state devices or integrated circuits which operate at greater than the limits described in note (b) of Table 47.1.

g) General calibration procedure of test instruments employed by the manufacturer in the calibration of an alarm.

h) A general description of the circuit operation under standby, alarm, and trouble conditions.

i) A description of the carbon monoxide test chamber, including drawings and operation procedure, to be used by a manufacturer in conducting the factory calibration tests.

38 Normal Operation Test

38.1 An alarm shall operate for all conditions of its intended performance, at all 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.

38.2 The test voltage is to be in accordance with 37.3.1. The alarm is to be in the standby condition and prepared for its intended signaling operation when it is connected to related devices and circuits.

38.3 The maintenance of approximately 600 ppm of carbon monoxide in the alarm chamber shall result in the operation of the alarm in its intended manner for at least 12 hours.

38.4 A single station carbon monoxide alarm that employs a secondary power supply shall meet the requirements of this standard with the main power de-energized.

38.5 For multiple station configurations, the operation of one alarm shall result in the alarm signal of all connected alarms being energized and the alarm that initiated the alarm signal shall be identified. See 30.6.

38.6 Operation for alarm of a single-station carbon monoxide alarm with integral transmitter that is energized by an initial pulse(s) shall result in an alarm signal with a duration of at least 12 hours at a compatible receiving unit located at the maximum distance specified by the manufacturer, when tested under free-field conditions with no obstructions between the alarm transmitter and receiver units. Refer to 91.1(i) for instructions to be provided. A manual reset of the receiver is not required if the receiving unit audible alarm signal is energized in time sequence and duration with the alarm.

38.7 When a manual test switch is operated it shall cause all visual and audible indicators to be operated.

38.8 Any indicator of CO concentration shall be accurate to within plus or minus 30% of the indicated amount and display the gas concentration for all Sensitivity tests specified in Table 41.1 and pre/post Sensitivity tests within this standard. No indication shall be given for CO concentrations less than 30 ppm. The indicator shall comply with the in-service reliability requirements of 84.1.2. Testing shall be performed at 70, 150, and 400 ppm and the test data shall be part of the in-service reliability measurement program. For the purposes of these requirements, an indicator of CO concentration shall be either an integral component of a CO alarm or a remote indication provided at an external device, such as a remote receiver or a mobile device, i.e. smart phone.

39 Circuit Measurement Test

39.1 Current input

39.1.1 Except for a battery operated alarm, the input current of a single or multiple station carbon monoxide alarm shall not exceed the marked rating by more than 10 percent when the alarm is connected to a source of supply in accordance with 37.3.1 and operated under the conditions of intended use (standby and alarm).

39.2 Battery trouble voltage determination

39.2.1 An increase in the internal resistance, or a decrease in terminal voltage, of a battery employed as the primary or secondary source of power to an 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 12 month period in the room ambient condition of the Battery Tests, Section 66.

39.2.2 The trouble level of a battery operated carbon monoxide alarm shall be determined (using the test circuit in Figure 39.1 and the voltage-resistance curves of Figure 39.2) 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 39.1

Test Circuit

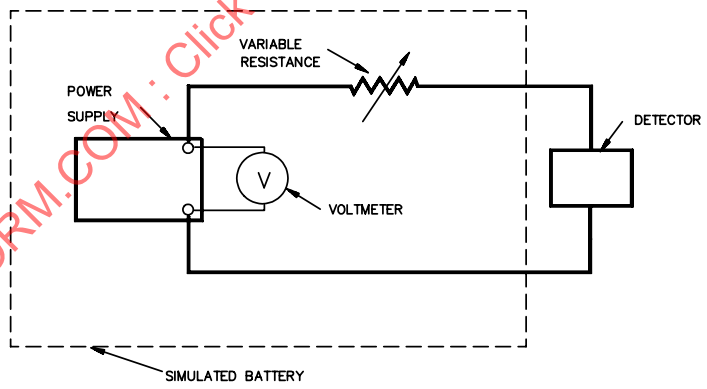

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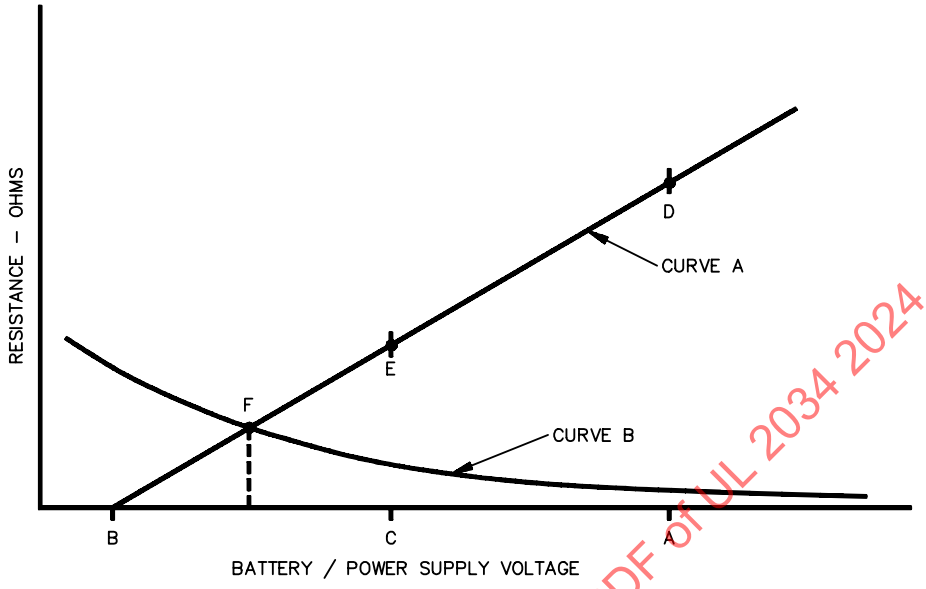
Figure 39.2

Trouble Level Determination Graph



A – Rated battery voltage.

B – Trouble level voltage (assuming minimal resistance).

C – Voltage value between rated and trouble level.

D – Trouble level resistance at rated battery voltage.

E – Trouble level resistance at voltage value C.

F – Maximum permissible battery resistance and minimum voltage after 6 months in long-term battery test.

Curve A – Sample plot of voltage vs. resistance (alarm trouble level curve) at which a trouble signal in an alarm is obtained. Audibility measurement is to be made at points between D and F.

Curve B – Sample plot of battery internal resistance vs. battery open circuit voltage derived from long term (minimum 6 months) battery test. Shape and slope of curve, as well as point of intersection with Curve A, will vary depending on battery used.

39.2.3 To determine compliance with 39.2.1 each of three alarms is to be connected in series with a variable regulated direct current power supply and a variable resistor as illustrated in Figure 39.1. 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 ohms. The resistance 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 alarm is to be tested for alarm operation at each resistance level and at the trouble signal level.

b) Trouble Level Voltage – With the variable resistor set at 0 ohms, the voltage of the power supply connected to the alarm is to be reduced in increments of 1/10 volt per minute to the level where the trouble signal is obtained. The 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 preselected voltages between the rated battery voltage and the trouble level voltage. The series resistance 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 alarm is to be tested for alarm operation at each resistance and voltage level and at the trouble voltage level. A sufficient number of voltage values shall be selected to determine the shape of the trouble level curve.

39.2.4 To determine that a battery is capable of supplying alarm and trouble signal power to the alarm for at least 12 months under the room ambient condition described in the Battery Tests, Section 66, Curve A of Figure 39.2 is to be plotted from the data obtained in the measurements described in 39.2.3 and compared to Curve B of Figure 39.2, which is plotted from data generated in the 6 months battery test. The intersection of Curves A and B shall not occur before 12 months and all points of Curve B to the right of point F (extended to the base line), shall be below Curve A.

39.3 Battery trouble silence

39.3.1 The battery trouble signal from each of three alarms may be temporarily silenced until the battery capacity reaches the trouble level voltage-resistance points described in 39.2.2. The battery trouble signal must restore and no longer be capable of being silenced when the trouble level voltage-resistance points described in 39.2.2 have been reached.

40 Electrical Supervision Test

40.1 General

40.1.1 A carbon monoxide alarm shall be electrically supervised so that any of the following conditions which prevents operation for an alarm signal from the alarm device shall result in an audible trouble signal within 200 seconds of the occurrence of the fault:

a) An instantaneous failure or removal of a limited life component or a sensor,

Exception: The power source of a battery operated alarm.

b) An "open" in an externally connected alarm circuit, or

c) A ground fault in any externally connected wiring.

40.1.2 The wiring extending between alarms wired in a multiple station configuration shall be electrically supervised so that a short or multiple ground fault, which prevents operation for an alarm signal, shall result in an audible trouble signal or result in an alarm signal. An "open" in any of the wiring between alarms is not required to be indicated by a trouble signal if the operation as a single station alarm is not

prevented. This requirement does not apply to the interconnected wiring of alarms intended to be connected by a Class 1 wiring method.

40.1.3 If an audible trouble signal is required to indicate a fault condition, it shall be produced every 30 – 60 seconds ±10 percent for a minimum of seven consecutive days. The trouble signal shall be distinctive from the alarm signal and, if provided, pre-alarm signal.

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

40.1.5 A fault condition (open, ground, or short), of other than the carbon monoxide alarm circuit of a carbon monoxide alarm with a noncarbon monoxide-alarm feature shall not prevent alarm signal operation as a carbon monoxide alarm. For this test the 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 alarm is then to be subjected to a carbon monoxide level of approximately 600 ppm which shall result in an audible alarm.

40.1.6 Units powered by electrical (AC) mains, or primary and/or secondary battery power source shall indicate end-of-life, based on the manufacturer's specified lifetime, with an end-of-life signal (see 5.13). 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).

a) For a unit that employs a signal generated by an internal timer, once maximum specified lifetime is reached the end-of-life signal shall be initiated. The timer can be reset repeatedly, for a period not exceeding 72 hours for each period of reset, if self-diagnostic test(s) indicate that the unit still meets the requirements of this standard. The timer shall not be able to be reset after 30 days following the initial end-of-life signal. The manufacturer shall provide detailed documentation of the timer operation that includes, a description of how the timer data is affected by either short or long term removal of power to the alarm.

b) For a unit that employs a signal generated by a self-diagnostic test, once this test has determined the device no longer meets the requirements of this standard, the end-of-life signal shall be initiated.

c) If the sensor is automatically and periodically tested for response to CO (or an equivalent gas), then the unit's specified lifetime calculations can exclude the sensor component.

40.1.7 In addition to the requirements outlined in 40.1.6 (a), (b) and (c), two alarms employing a replaceable battery or batteries shall be subject to the following requirements in the following order:

a) The alarm shall be configured to signal its end of life. The alarm shall then be reset once (if the alarm is capable of resetting the end-of-life signal).

b) If powered by AC mains or DC mains (Recreational Vehicle and/or Marine Use) the primary power shall first be disconnected prior to removing and installing the replacement battery.

c) The installed battery (original) shall be replaced with a new battery.

d) The new battery shall not be replaced within 15 minutes from removing the original battery. Manufacturer must provide detailed information that outlines the minimum amount of time needed to ensure that the residual power on the alarm has been depleted.

e) After replacing the battery, the timer for the end-of-life signal shall not reset, and the timer shall continue from the cumulated end-of-life time which the battery was removed.

f) 40.1.7 (a), (b) and (c) shall be re-conducted but with the battery replaced one day prior to the maximum end-of-life time period. A second alarm may be used for this requirement.

40.1.8 In addition to the requirements outlined in 40.1.6(a), for an alarm that employs a replaceable battery but does not employ an end-of-life timer reset, the tests specified in clauses 40.1.7 (b), (c), (d), (e) and (f) shall be conducted with the battery being replaced on the first day that the end-of-life signal is generated and the last day following the time period that the unit is not reset as defined in 40.1.6(a).

40.2 AC powered units

40.2.1 Failure of an AC power source to an alarm shall be indicated by de-energization of a "power-on" lamp.

40.2.2 Neither loss nor restoration of power shall cause 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 not considered an alarm signal. 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 (or pre-alarm) signal for more than 1 second.

40.2.3 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 (or pre-alarm) and shall not prevent the operation of the remaining units for alarm.

40.3 Battery powered primary or secondary units

40.3.1 An alarm that uses a battery as the main source of supply shall be capable of producing an alarm signal for at least 12 hours at the battery voltage and/or current at which an audible trouble signal is obtained. Following the alarm signal the source of supply shall then be capable of providing 7 days of audible trouble signal indication. The trouble signal is to be produced every 30 – 60 ±10% seconds for seven consecutive days.

40.3.2 To determine compliance with 40.3.1, three samples shall be equipped with batteries which have been depleted to the trouble signal level. The samples are to be placed in alarm for 12 hours. After the 12 hours of alarm, the trouble signal shall persist for at least 7 consecutive days. A fresh battery is depleted 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 would be depleted by applying a 10 milliamperes (1 percent load) or less drain continuously until the battery voltage reaches the predetermined test level.

40.3.3 If a battery operated alarm locks-in on alarm, it shall automatically transfer from alarm to audible trouble when the battery voltage reaches the trouble signal level. If an alarm does not lock-in on alarm, automatic transfer from alarm to trouble is not required.

40.3.4 To determine compliance with 40.3.3, two samples of an alarm that locks-in on alarm shall be equipped with batteries which have been depleted and stabilized at just above the trouble signal level. The samples are then to be placed in alarm and the battery voltage monitored. The samples shall automatically transfer to audible trouble when the battery trouble voltage is reached. The trouble signal shall persist for seven consecutive days. If the battery voltage recovers to a point where the trouble signal is not longer emitted, the unit shall be placed into alarm again until the trouble signal is reinstituted.

40.3.5 An alarm which uses a battery (or other applicable rechargeable energy storage media) as the secondary source of supply shall be capable of supplying the carbon monoxide alarm with a minimum of 24 hours of power in the normal standby condition. The carbon monoxide alarm shall be capable of producing an alarm signal for at least 12 hours at the battery voltage at which an audible trouble signal is obtained followed by 7 days of audible trouble signal indication.

40.3.6 To determine compliance with 40.3.5 for 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 37.2, Secondary power supply) and allowed to remain in the normal standby condition for a minimum of 24 hours. The samples shall not emit audible low battery trouble signals before the end of the 24 hour 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 12 hours. Following the 12 hours 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.

40.3.7 Primary power for commercial vehicles shall be provided by a permanently sealed, non-replaceable battery installed within the CO alarm and not from an external AC or DC source.

40.4 Component failure

40.4.1 If failure of a critical, limited life electronic component, such as opening or shorting of an electrolytic capacitor, is not indicated by an audible trouble or alarm signal, then a reliable component shall be used. The reliable component shall fall within the reliability prediction described in 5.9 and 5.10.

40.5 External wiring

40.5.1 An open or ground fault in the loop wiring connected from a single station carbon monoxide alarm to additional remote alarms that prevent operation for alarm signals from any of the interconnected alarms, shall not cause an alarm signal but shall result in an audible trouble signal. A short or double ground fault in the leads resulting in an audible trouble signal or an alarm signal is not prohibited.

40.5.2 An open, ground fault, or short in extra-low voltage circuit wiring among multiple station interconnected alarms or any wiring extending to a remote signaling device is not required to be indicated by a trouble signal if the fault does not prevent operation of any of the interconnected units as a single station alarm. A ground fault shall prevent operation for alarm only if the interconnected wiring is to be made in accordance with Class 1 requirements of the National Electrical Code, NFPA 70, or the Canadian Electrical Code, Part I (CSA C22.1). The installation wiring diagram shall indicate the type of connections to be employed.

40.5.3 An open, ground fault, or short in the extra-low voltage circuit conductors extending between the output of a separate power supply and an alarm, which prevents operation of the alarm, shall result in de-energization of the alarm "power-on" light.

41 Sensitivity Test

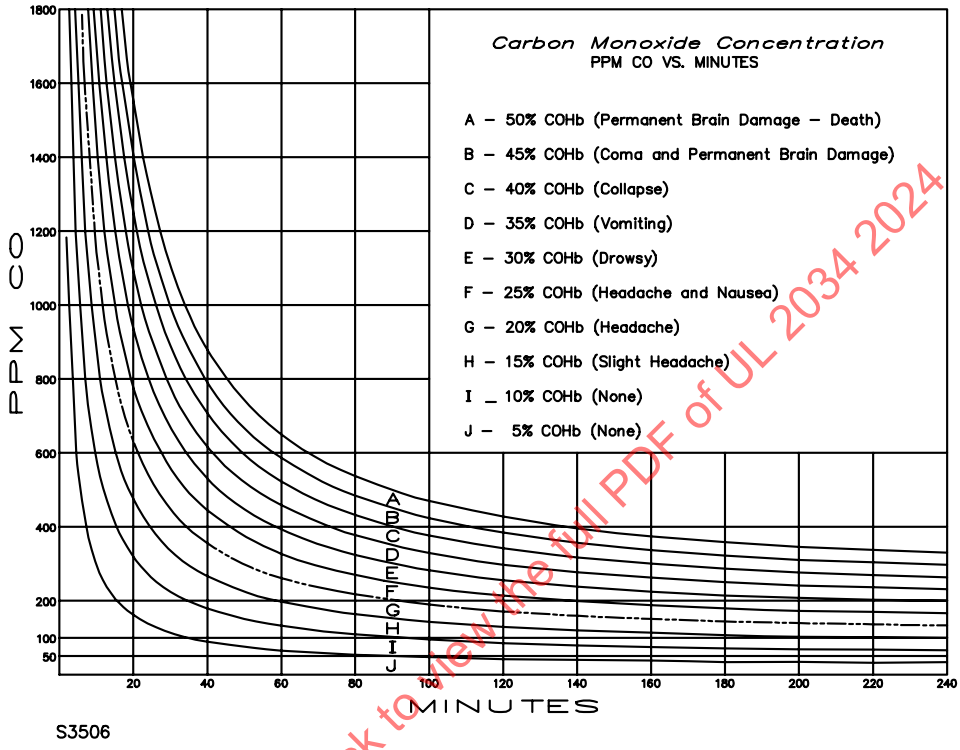
41.1 General

41.1.1 A carbon monoxide alarm shall operate (alarm signal) at or below the test points specified in Part A of Table 41.1 when using the test equipment described in 41.2.1. These test points are based on plotted limits for the 10 percent COHb curve Figure 41.1. If the alarm employs a variable sensitivity setting, test

measurements are to be made at maximum and minimum settings. For this test, three carbon monoxide concentrations (70, 150, and 400 ppm) are to be used as specified in Part A of Table 41.1.

Figure 41.1

Carbon Monoxide Concentration (ppm CO) Versus Time (minutes)



Equation For determining estimated percent COHb in blood[a]

$$\%COHb_t = \%COHb_0 [e^{-(t/2398B)}] + 218[1 - e^{-(t/2398B)}] [0.0003 + (ppm\ CO/1316)]$$

in which:

%COHb$_t$ is the percentage of *COHb* at time *t*,

%COHb$_0$ is the percentage of *COHb* in the blood at time 0,

t is the time in minutes, and

B is 0.0404 (heavy work effort).

[a] A proposal for evaluating human exposure to carbon monoxide contamination in military vehicles, Steinberg, Nielson, March 1977, AMCMS Code 672716.H700011; Coburn, R.F., Forster, R.E., & Kane, P.G. Considerations for the physiological variables that determine the blood carboxyhemoglobin concentration in man. Journal of Clinical Investigation, 1965, 44 1899-1910.

Table 41.1
Carbon Monoxide Concentration Versus Time for Alarm Test Points Based on 10 % Carboxyhemoglobin (COHb)

A. Carbon monoxide concentration and response time	
Concentration, ppm	**Response time, minutes**
70 ±5	60 – 240
150 ±5	10 – 50
400 ±10	4 – 15
B. False alarm – carbon monoxide concentration resistance specifications	
Concentration, ppm	**Exposure time, (no alarm)**
30 ±3	30 days
70 ±5	60 minutes

41.1.2 A carbon monoxide alarm shall not operate (alarm signal) below the test points specified in Part B of Table 41.1, when using the test equipment described in 41.2.1. If the alarm employs a variable sensitivity setting, test measurements are to be made at maximum and minimum settings. For this test, at least two carbon monoxide concentrations (70 and 30 ppm) are to be used as specified in Part B of Table 41.1. It is not prohibited for a pre-alarm signal to occur prior to the exposure time specified for the test points outlined in Table 41.1 provided the gas concentration is in excess of 30 ppm carbon monoxide.

41.1.3 A single station carbon monoxide alarm employing a secondary power supply shall operate within the limits specified in 41.1.1 when operating from the secondary power supply.

41.2 Test equipment

41.2.1 The carbon monoxide alarm shall be installed in a chamber, having a volume of at least 1 cubic foot (0.0283 m^3), constructed so as to permit accurate monitoring and control of chamber air temperature and humidity and oxygen and carbon monoxide concentrations. The following conditions shall be established within the test chamber 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) Air movement within the test chamber shall be within 16.0 ±7 fpm (0.08 m/s), and

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

41.3 Test method

41.3.1 Twelve alarms shall be conditioned for 48 hours under the ambient conditions specified in 41.2.1.

41.3.2 The alarms shall then be placed in a test chamber, either individually or in a group, and operated for 15 ±5 minutes. The test chamber shall then be sealed. Carbon monoxide shall be introduced into the test chamber and slowly circulated in the chamber to produce a uniform concentration of 70 ±5 ppm. This level of carbon monoxide shall be established within 3 minutes after sealing the chamber and shall be maintained throughout the remainder of the test. Once the specified carbon monoxide level has been established, the alarms shall actuate within the time range specified in Table 41.1 (see 41.1.1), but not to exceed 240 minutes.

41.3.3 The test chamber shall be purged with fresh air to remove all carbon monoxide. The carbon monoxide alarms shall be reset according to the manufacturer's instructions, and the test described in 41.3.2 shall be repeated with the carbon monoxide concentration maintained at 150 ±5 ppm. The alarms shall actuate within the time range specified in Table 41.1 (see 41.1), but not to exceed 50 minutes.

41.3.4 The test chamber shall be purged with fresh air to remove all carbon monoxide. The carbon monoxide alarms shall be reset according to the manufacturer's instructions, and the test described in 41.3.2 shall be repeated with the carbon monoxide concentration maintained at 400 ±10 ppm. The alarms shall actuate within the time range specified in Table 41.1 (see 41.1), but not to exceed 15 minutes.

41.3.5 The test chamber shall be purged with fresh air to remove all carbon monoxide. The carbon monoxide alarms shall be reset according to the manufacturer's instructions. The test chamber shall be sealed. Conditions within the chamber shall be 23 ±3C, 50 ±20 percent RH. The atmosphere within the chamber shall be mixed in a manner that ensures uniformity of gas concentration, temperature and humidity. Carbon monoxide shall be injected into the chamber at a constant rate for 30 ±0.3 min. The rate of CO injection shall be determined by the operator through calculation or from previous test experience to attain a concentration increase of 16 ppm CO per minute. The CO injection rate shall not vary from the initial injection rate by more than 10 percent for the 30 ±0.3 min injection period. After injecting CO into the chamber for 30 ±0.3 min., CO gas introduction shall stop and carbon monoxide concentration in the chamber shall be monitored for a period of 3 ±0.3 min. to assure a stable CO concentration of 480 ±15 ppm. Alarms during this test shall activate after 19.0 min and before 30.0 min.

41.3.6 After each exposure to 70, 150, and 400 ppm CO as outlined in 41.3.2 – 41.3.4, the signal produced by the sensing portion of the alarm shall reset or refresh to a value corresponding to the initial clean air value (less than 2 ppm CO) within 16 hours, or less as specified by the manufacturer, before proceeding with the next test. In no case shall recovery time exceed 16 hours.

41.4 Uniformity of operation

41.4.1 The alarm shall be uniform in operation so that the readings of the response time/concentration for one alarm shall be within 50 percent of the overall average of all 12 alarms tested in 41.3.2, 41.3.3, and 41.3.4. If an alarm has a variable sensitivity setting, the requirement applies to each setting tested. All alarms must respond within the limits as specified in 41.1.1.

42 Selectivity Test

42.1 The alarm (or pre-alarm) shall not sound when an alarm is exposed sequentially, as described in 42.3 – 42.6, to the concentrations of gases and vapors shown in Table 42.1. These substances are intended to represent air contaminants found in the vicinity of an installed alarm.

Table 42.1
Gas and Vapor Concentrations

Substance	Concentration, ppm
Methane	500
n-Butane	300
n-Heptane	500
Ethyl acetate	200
Isopropyl alcohol	200
Carbon dioxide	5000

Table 42.1 Continued on Next Page

Table 42.1 Continued

Substance	Concentration, ppm
Ammonia	100
Ethanol	200
Toulene	200
Trichloroethane	200
Acetone	200

42.2 Calculate the interior volume of the test chamber used in 41.2.1. From this volume, calculate the amount of each test substance necessary to supply the concentrations given in Table 42.1.

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

42.4 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 and does not cause localized high concentrations.

42.5 Allow the alarm (or pre-alarm) to remain in the chamber for 2 hours. During this time the alarm shall not sound.

42.6 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 42.1 until the alarm has been exposed to all substances. It is not required that exposure to the substances be in any particular order.

42.7 Following this test, the Sensitivity Test, Section 41, using carbon monoxide is to be performed on the alarms. The sensitivity values used are to comply with those outlined in Table 41.1, Part A – Alarm, and Table 41.1, Part B – False alarm, except the 30 day test is to be conducted for 8 hours. All alarm samples used for and tested to the requirements of the Selectivity Test, Section 42, shall comply with these requirements.

43 Sensitivity Test Feature

43.1 A sensitivity test feature shall be provided on a carbon monoxide alarm, to simulate either mechanically or electrically a specified level of carbon monoxide in the sensing chamber. The test feature shall be manually operated and accessible from outside the alarm, with the alarm installed as intended. The maximum permissible measured level shall not exceed 400 ppm. The test feature when operated shall result in an audible alarm signal of at least two full cycles to allow the user of the alarm device to become familiar with the sound of the alarm.

43.2 As an optional feature, the manufacturer is permitted to include an additional wireless communication remote test feature. If included and tested for compliance with the requirements outlined in 43.3, the remote test feature may be activated through a remote device.

43.3 Carbon monoxide alarms with a wireless communication remote device and employing a remote test feature shall be tested in accordance with one of the following requirements:

a) The remote transmission radio of the carbon monoxide 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 carbon monoxide 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 carbon monoxide alarm does not exceed 984 ft (300 m).

43.4 Four samples, two at maximum and two at minimum sensitivity, are to 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.

44 Stability Tests

44.1 There shall not be false alarms (or pre-alarms) of an alarm set at the maximum sensitivity setting when two representative samples are placed in the test chamber as specified in 41.2.1. Two additional samples are to be tested as described in 44.2. Momentary energization of the alarm (maximum of 1 second) does not constitute a false alarm (or pre-alarm) during this test. Alarms are to be conditioned for not less than 48 hours under the ambient conditions specified in 41.2.1.

a) Place two representative carbon monoxide alarm samples in a test chamber and provide power to the alarms for 15 ±5 minutes. The test chamber is then to be sealed. Carbon monoxide is then to be introduced into the test chamber and slowly circulated in the chamber to produce a uniform concentration of 70 ±5 ppm. This level of carbon monoxide is to be established within 3 minutes after sealing the chamber and is to be maintained throughout the remainder of the test. Once the specified carbon monoxide level has been established, the alarms shall not operate for alarm before 60 minutes has expired.

b) False alarm tests are to be conducted using the procedure specified in (a) except at a carbon monoxide concentration of 30 ±3 ppm for 30 days. Under this test condition, no actuation of the alarm shall occur.

c) Ten cycles of temperature variation between 0 and 49 °C (32 and 120 °F) are to be conducted. 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.

d) Fifty cycles of momentary (approximately 1/2 second) interruption of the alarm power supply at a rate of not more than 6 cycles per minute are to be conducted, followed by 10 cycles of very rapid OFF – ON switching (each consisting of 3 OFF – ON sequences in 1-1/2 seconds) to simulate a loose wire connection in the home or an automatic reclosing circuit in the distribution line, at not more than 1 cycle per minute. It is not prohibited that battery operated alarms be tested in conjunction with the Battery Replacement Test, Section 70.

44.2 Four sets (five sets for testing to the requirements in Section 76) of two representative alarm samples shall be subjected to a series of tests as outlined in 41, 42, 44.1, 50, and 51.

a) Two alarm samples are to be tested sequentially, to the tests referenced above, in the following order: 41, 44.1(a), 44.1(c), 42, and 50.1. The sensitivity reading shall not, in any case, exceed the limits specified in Table 41.1, Part A-Alarm, and Table 41.1, Part B-False Alarm, except the 30 days test is to be conducted for 8 hours.

b) Two alarm samples are to be tested according to 44.1(a), Stability Testing, in 30 ppm CO for 30 days.

c) Two alarm samples are to be tested according to 50.2, Effect of shipping and storage.

d) Two alarm samples are to be tested according to 51.1, High Humidity (52 °C/95 percent RH) and 51.2 Low Humidity 23 °C/15 percent RH).

44.3 For recreational approval (see Section 76), the following substitutions are to be made:

a) 77.1(a), 66 °C, replaces 50.1, 49 °C;

b) 77.1(b), minus 40 °C, replaces 50.1, 0 °C; and

c) 77.1(c), 61 °C/93 percent RH, replaces 51.1, 52 °C/95 percent RH.

Two additional alarm samples can be used for testing to the requirements of 77.1(a).

44.4 For either a residential or a recreational evaluation, a CO alarm manufacturer may choose to have its samples run through any of the tests in 44.2 or 44.3 sequentially, due to shortage of test chambers and equipment.

44.5 A total of four alarms employing a maximum sensitivity setting are to be mounted in a position of normal use, energized from a source of supply in accordance with 37.3.1, and subjected to the tests in 44.1 and 44.2.

45 One Year (minimum) Sensor Stability Test for CO Sensors

45.1 General

45.1.1 A minimum fifteen samples of the carbon monoxide (CO) sensor shall be placed within a closed chamber (test fixture) that shall allow for the following:

a) Logging of the manufacturer's defined sensor output parameters;

b) Control of the rate of CO gas injection to reach the target gas concentration within 3 minutes;

c) Recommended/supporting electronic detection circuitry, which shall be supplied by the sensor manufacturer for each gas sensor under test;

d) Application of the target CO gas concentration for a minimum of one year as follows:

1) For sensors intended to detect CO, all sensors shall be exposed to a minimum of 15 ±3 ppm of CO for a minimum of one year.

2) For a CO gas sensor that is intended to detect more than one gas, the manufacturer shall identify each specific gas type that the sensor is intended to detect;

3) Sensor data from the manufacturer shall be provided demonstrating the sensor's performance when subject to each gas specified in (2).

45.2 Test gas

45.2.1 The test CO gas concentration that envelopes the CO sensor shall be maintained as follows:

a) If the target CO gas concentration flows directly from a gas cylinder onto the sensor, i.e., using a calibration cup provided by the manufacturer, the gas cylinder shall be accurate within ±2 % of the target concentration. The calibration record for the gas cylinder shall be based on the country specific traceability standard, or

b) If the sensors are placed within a test chamber with the test CO gas diluted within the chamber to reach the target gas concentration, the CO gas concentration within the test chamber shall be maintained to within +20, -5 % of the target gas concentration.

c) For (a) and (b), the manufacturer shall demonstrate that the gas flow across the sensor or air movement within the chamber shows the:

1) Airflow is sufficient to uniformly mix the gas,

2) Airflow does not exceed 16 ±7 ft/min (4.88 m ± 2.1 m/min) or,

3) Airflow, if in excess of (c)(2), may be increased or decreased but only if the change in airflow is verified to not affect the intended operation or manufacturer's performance specifications for the sensor. The increase in air flow shall only be used to provide a more homogeneous mixture of the test and/or target CO gas which may be heavier or lighter than air, thus requiring a change in airflow. The airflow shall be set to the minimum level necessary to maintain a homogeneous mixture of the target CO gas.

d) The relative humidity for the test CO gas that envelopes the sensor or environment that the sensor is within shall be maintained at 50 ±20 % for the duration of the test.

e) The temperature for the test CO gas that envelopes the sensor or environment that the sensor is within shall be maintained at 23 ±3 °C (73.4 ±5.4 °F) for the duration of the test.

f) For manufacturer temperature and humidity specifications in excess of (d) and (e), ambient test conditions may also be conducted based on the manufacturer's specifications.

g) If the manufacturer's sensor specification document identifies recommended temperature and/or humidity compensation in excess of (d) and (e), then the tests noted within Section 45 shall also be conducted:

1) For a minimum of one year at the temperature and relative humidity as specified by the manufacturer;

2) With the manufacturer's provided compensation circuitry for each sensor.

h) If required by the CO gas supplier, gas cylinder maintenance procedures for CO gases that have a life expectancy or scheduled maintenance shall be provided.

45.2.2 For target CO gas concentrations exceeding 0.04 % of the total gas concentration, Oxygen (O_2) measurements shall be recorded to demonstrate that the O_2 concentration remains at 20.9 %.

45.2.3 The balance gas, either in the gas cylinder or within the test chamber, shall be as follows:

a) The sensor manufacturer shall identify the gas type, gas concentration and the balance gas concentration(s) that the sensor is intended to be subject to during normal operation;

b) For balance gas identified as "clean air," it shall be verified to consist of a composition not exceeding – 20.9 % O_2 (Oxygen) – Balance N_2 (Nitrogen). With a target gas concentration as specified in 45.2.2, the gas cylinder calibration certificates may be used to verify that the balance gas used in the gas tests defined in 45.2.1 (a) and (b) are representative of clean air or the manufacturer's defined balance gas.

45.2.4 If the test gas concentrations and performance of the CO sensor is not altered or impaired, the sensor manufacturer may provide alternative gas injection, gas maintenance, target gas and balance gas concentrations, methods, and ambient test conditions in addition to the requirements outlined within section 45.4.

45.3 Sensor data collection

45.3.1 Each CO sensor shall be energized with the manufacturer's recommended electronic circuit design. This electronic circuit shall be included as supporting hardware for each sensor. The analog and/or digital output measurements/data from the sensor/circuit and gas analyzer (when used) shall be recorded at least once every 15 minutes for the test duration with the minimum data:

a) Recorded and maintained in a format that is agreed between the test organization and manufacturer, and

b) The test method and data collection shall be reviewed by the test organization at least once every thirty days (monthly) for the duration of the test program.

45.3.2 The sensor data shall include but may not be limited to:

a) All gas cylinder(s) calibration details that include gas supplier, cylinder identification, gas tolerance, CO gas concentration and balance gas concentration and,

b) All ambient environmental test conditions as specified in 45.4 and,

c) Unedited (raw), analog and/or digital output measurements/data from the sensor/circuit and,

d) Where applicable, converted data that correlates the sensor/circuit data to the intended gas concentration and,

e) Calibrated reference analyzer data (if applicable).

45.3.3 The manufacturer shall provide the necessary information to convert the analog and/or digital output measurements/data from the sensor to a correlated test gas concentrations. This information shall also be provided in the manufacturer's specification documentation included with the sensor.

45.3.4 If the test CO gas concentrations and performance of the sensor are not affected, the sensor manufacturer may provide alternative data collection methods and equipment to those defined in 45.3.1 through 45.3.3.

45.4 CO sensor sensitivity test

45.4.1 At the start and end of the one-year test, and at least once monthly, the sensitivity of each sensor shall be checked and recorded as follows:

a) 0 ppm (clean air, 20.9 % O_2 – Balance N_2) or within the tolerance accuracy of the gas monitoring device(s), and

b) CO sensors shall be exposed to the test gas concentrations as defined in the Sensitivity Test, Section 41;

c) Maximum test CO gas concentration defined by the manufacturer.

45.4.2 The sensor shall be subjected to the test CO gas requirements specified in 45.1 through 45.4 and 45.4.1 for a minimum duration of one year.

45.4.3 The CO sensor drift for all sensors shall not exceed the CO sensors' specified tolerance ranges:

a) In clean air and/or,

b) When exposed to CO gas over the course of one year and/or,

c) When subjected to each ambient environmental condition.

45.4.4 The manufacturer's sensor documentation shall be provided with each sensor or with each batch of sensors and include the following:

a) The CO sensor's specified tolerance and/or

b) If applicable, a custom calculation method required to verify the CO sensor's sensitivity performance. This calculation method shall be used to verify that the test data collected during performance testing remains within the manufacturer's defined limits which are based on its custom sensitivity calculation method.

46 Velocity-Sensitivity Test

46.1 Test procedure

46.1.1 When tested in accordance with the sensitivity tests outlined in Section 41, the air velocities are to be separately maintained at 16 ±7 fpm (0.08 m/s) (as conducted in the test chamber specified in the Section 41) and 300 ±25 fpm (91 ±7.5 m/min), as specified in 46.1 – 46.3.

46.1.2 The carbon monoxide alarm shall not produce a false alarm signal or exceed the alarm limits specified Table 41.1 when subjected to the tests specified in this section. The "false alarm" requirement for 30 ppm, as specified in Table 41.1, shall be conducted for 60 minutes.

46.1.3 In addition to 46.1.1 and 46.1.2, carbon monoxide alarms intended for use in commercial vehicles shall also be subjected to an effect of air velocity as specified in 46.3.

46.1.4 Two carbon monoxide alarms shall operate within the sensitivity limits defined in Section 41 and as modified in the requirements of this section. Each carbon monoxide alarm shall be subjected to the sensitivity test:

a) At a velocity of 16.0 ±7 fpm (0.08 m/s),

b) Followed by a velocity of 300.0 fpm (1.5 m/s) ±10 percent, and

c) Commercial vehicle CO alarms shall then be subjected to the effect of air velocity test as specified in 46.3.

46.1.5 The CO alarm may be manually or electronically reset prior to subjecting the samples to each CO concentration during each air velocity specified in 46.1.4.

46.2 Duct test equipment

46.2.1 The following items refer to Figure 46.1. Alternate configurations may be used provided that they produce a homogeneous mixture of carbon monoxide across the detector head or gas sampling tubes and are adjustable from 300 to 4000 fpm (1.52 to 20.3 m/s). At the carbon monoxide alarm test location the cross section is to be 1 square feet (0.093 m^2) and the alarm is to be located at least eight duct widths downstream [8 feet (2.44 m)] from the nearest bend.

a) Test Duct – An oval-shaped duct assembly 30 feet, 7 inches (9.3 m) long and 6 feet, 7 inches (2.0 m) high, with a total effective duct length of 69 feet (21.0 m), constructed of galvanized sheet metal.

b) Velocity Damper – Manually controlled, secondary velocity adjustment damper provided in lower portion of test duct for adjustment of air velocity at the low end of the range. A locking feature is provided.

c) Motor and Belt Drive[a] – Single-phase, capacitor type motor rated 240 volts AC, 3 horsepower, 1750 rpm used in conjunction with an adjustable belt, drive-speed selector.

d) Air Stream Straightener – Aluminum honeycomb, 1/4 inch (6.4 mm) cell size. Overall dimensions are to be 12 by 12 by 3 inches (304 by 304 by 76 mm). An equivalent honeycomb shall be employed only when the cell size length-to-diameter ratio greater than 10.

e) Test Samples – Removable mounting plates are provided on the top and side of the duct for installation of test samples. Five velocity probe inlets, spaced 2 inches (50.8 mm) apart, are located 2 feet (0.6 m) upstream from the samples under test.

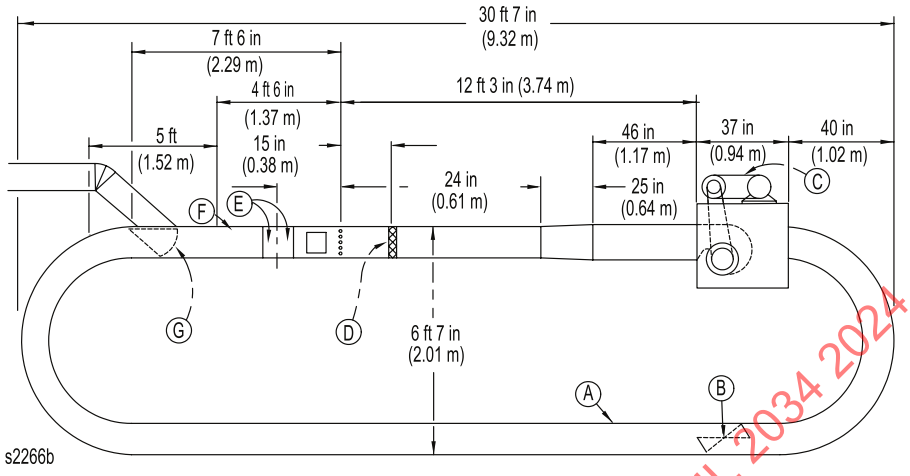
f) CO Analyzer Sample point – Test point for CO Analyzer shall be located 12 ±0.5 inches away from the center of the sample.

g) Exhaust – Metal damper provided for control of smoke exhaust. Provided with a locking feature in both open and closed positions.

[a] A blower intended for this purpose is No. 412-12A manufactured by Lau Inc.

Figure 46.1

Air Duct Test Equipment



46.3 Effect of air velocity – Commercial vehicles

46.3.1 There shall be no false alarms of a CO alarm when subjected to each of the test conditions specified in (a) and (b):

a) Twenty-five cycles of change in a duct air velocity from 0 fpm to 4000 ±300 fpm (20.3 ±1.0 m/s), and

b) Operation for 2 hours in a duct air stream having a velocity of 4000 ±300 fpm (20.3 ±1.0 m/s).

46.3.2 Two carbon monoxide alarms shall be mounted in a position of intended use (see Figure 46.1), one in the horizontal plane and in turn one in the vertical plane, energized from one of the manufacturers' recommended battery models, in accordance with 37.3, and subjected to the test conditions specified in 46.3.1(a) and 46.3.1(b).

46.3.3 For the test in 46.3.1(a), the change in air velocity is to require no more than 10 seconds. Each cycle of change shall be conducted as follows:

a) Start at zero velocity,

b) Reach 4000 fpm in not more than 10 seconds,

c) Maintain the velocity in (b) for at least 30 seconds, and

d) Return to zero velocity in not more than 10 seconds.

47 Temperature Test

47.1 The materials or components employed in an alarm shall not be subjected to a temperature rise greater than that indicated in Table 47.1, under any condition of operation.

Exception: If failure of a component results in an audible trouble signal, the temperature rise of the component in the standby condition is not bound by the limits in Table 47.1, but in no case shall it be greater than the temperature permitted under an alarm condition.

Table 47.1
Maximum Temperature Rises

Device or material	Normal standby, °C	Normal standby, (°F)	Alarm condition, °C	Alarm condition, (°F)
A. COMPONENTS				
1. Capacitors	25	(45)	40	(72)
2. Fuses	25	(45)	65	(117)
3. Rectifiers – At any point				
a) Germanium	25	(45)	50	(90)
b) Selenium	25	(45)	50	(90)
c) Silicon				
Maximum 60 percent or rated volts	50	(90)	75	(135)
60 percent rated volts	25	(45)	75	(135)
4. Relays and other coils with:				
a) Class 105 insulated windings				
Thermocouple method	25	(45)	65	(117)
Resistance method	35	(63)	75	(135)
b) Class 130 insulated windings				
Thermocouple method	45	(81)	85	(153)
Resistance method	55	(99)	95	(171)
5. Resistors[a]				
a) Carbon	25	(45)	50	(90)
b) Wire wound	50	(90)	125	(225)
c) Other	25	(45)	50	(90)
6. Sealing compounds	15 °C (27 °F) less than its melting point			
7. Solid-state devices	See note b			
B. INSULATED CONDUCTORS[c]				
1. Appliance wiring material	25 °C (45 °F) less than the temperature limit of the wire			
2. Flexible cord	35	(63)	35	(63)
C. ELECTRICAL INSULATION – GENERAL				
1. Fiber used as electrical insulation or cord bushings	25	(45)	65	(117)
2. Phenolic composition used as electric insulation or as parts where deterioration will result in a risk of fire or electric shock	25	(45)	125	(225)
3. Varnished cloth	25	(45)	60	(108)
D. GENERAL				
1. Mounting surfaces	25	(45)	65	(117)
2. Wood for other combustible material	25	(45)	65	(117)

[a] The temperature rise of a resistor other than a line voltage dropping resistor may exceed the value shown if the power dissipation is 50 percent or less of the resistor manufacturer's rating.

[b] 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) is to be considered 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.

Table 47.1 Continued on Next Page

Table 47.1 Continued

Device or material	Normal standby, °C	Normal standby, (°F)	Alarm condition, °C	Alarm condition, (°F)
Both solid-state devices and integrated circuits may be operated up to the maximum ratings under any one of the following conditions: 1) The component complies with the requirements of Military Standard 883C. 2) A quality control program is established by the manufacturer consisting of inspection and test of 100 percent of all components, either on an individual basis, as part of a subassembly, or equivalent. 3) 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 recalibration of the sensitivity and retested.				
[c] For standard insulated conductors other than those mentioned, reference should be made to the National Electrical Code, NFPA 70, or the Canadian Electrical Code, Part 1, (CSA C22.1); the maximum allowable temperature rise in any case is 25 °C (45 °F) less than the temperature limit of the wire in question.				

47.2 Except as noted in 47.3, all values for temperature rises apply to equipment intended for use in prevailing ambient temperatures, usually not higher than 23 ±3 °C (73.4 ±5 °F).

47.3 If equipment is intended specifically for use with a prevailing ambient temperature constantly more than 23 ±3 °C (73.4 ±5 °F), the test of the equipment is to be made at the higher ambient temperature, and allowable temperature rises specified in Table 47.1 are to be reduced by the amount of the difference between that higher ambient temperature and 23 ±3 °C (73.4 ±5 °F).

47.4 Temperature measurements on equipment intended for recessed mounting are to be made with the unit installed in an enclosure of nominal 3/4 inch (19.1 mm) wood having clearance of 2 inches (50.8 mm) on the top, sides and rear, and the front extended to be flush with the alarm cover.

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

47.6 Temperatures are to be measured by means of thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2). The preferred method of measuring the temperature of a coil is the thermocouple method, but a temperature measurement by either the thermocouple or change-in-resistance method is acceptable, except that the thermocouple method is not to be employed for a temperature measurement at any point where supplementary thermal insulation is employed.

47.7 Thermocouples consisting of 30 AWG (0.06 mm^2) iron and constantan wires and a potentiometer-type indicating instrument are to be used whenever reference temperature measurements by thermocouples are necessary.

47.8 The thermocouple wire is to conform with the requirements the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ASTM E230/E230M.

47.9 The temperature of a copper coil winding is determined by the change-in-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 °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 °C.

47.10 As it is generally necessary to de-energize the winding before measuring *R*, the value of *R* at shutdown may be 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.

47.11 To determine compliance with this test, an alarm is to be connected to a source of supply in accordance with 37.3.1 and operated under the following conditions:

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

b) Alarm – (1 hour), and

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

47.12 For test condition 47.11(c), the temperature limits shall be exceeded only when there is no manifestation of a fire or approaching failure, and the alarm operates as intended following the test.

47.13 The alarm is to be subjected to the Dielectric Voltage-Withstand Test, Section 56, following tests specified in 47.11(b) and 47.11(c).

48 Overload Test

48.1 Alarm

48.1.1 An 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 alarm at 115 percent of the rated test voltage. Each cycle shall consist of starting with the alarm energized in the standby condition, initiation of an alarm by carbon monoxide or equivalent means, and restoration of the alarm to standby.

48.1.2 Rated test loads are to be connected to those output circuits of the alarm which are energized from the alarm power supply, such as remote indicators, relays, and the like. The test loads shall be those devices, or a device determined to be equivalent, normally intended for connection. If an equivalent load is employed for a device consisting of an inductive load, a power factor of 60 percent is to be employed. The rated loads are established initially with the alarm connected to a source of supply in accordance with 37.3.1 followed by increasing the voltage to 115 percent of rating.

48.1.3 For DC 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 hertz AC voltage equal to the rated DC test voltage. When the inductive load has both the required DC resistance and the required inductance, the current will be 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.

48.2 Separately energized circuits

48.2.1 Separately energized circuits of an alarm such as dry contacts, shall be capable of operating as intended after being subjected for 50 cycles of signal operation at a rate of not more than 6 cycles per

minute while connected to a source of supply in accordance with 37.3.1, with 150 percent rated loads at 60 percent power factor applied to output circuits which do not receive energy from the alarm. There shall not be electrical or mechanical failure of the switching circuit.

48.2.2 The test loads shall be set at 150 percent of rated current while connected to a separate power source of supply in accordance with 37.3.1.

49 Endurance Test

49.1 Alarm

49.1.1 An alarm shall operate as intended after being subjected to 6000 cycles of 5 second signal operation, at a rate of not more than 10 cycles per minute, with the alarm connected to a source of supply in accordance with 37.3.1 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 alarm components. It is not prohibited that battery operated units be connected to an equivalent filtered DC power supply source for this test.

49.1.2 Sensitivity measurements, using carbon monoxide, shall be recorded before and after the Endurance Test using the CO values listed in Table 41.1, Part A – Alarm, and Table 41.1, Part B – False alarm, except the 30 day test is to be conducted for 8 hours. All alarm samples tested as part of the Endurance Test, Section 49, shall comply with these requirements.

49.2 Separately energized circuits

49.2.1 Separately energized circuits of an 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 caused to make and break the normal current at the voltage specified by 37.3.1. The load is to represent that which the device is intended control. The Endurance Tests of the separately energized circuits may be conducted in conjunction with the Endurance Test of the alarm. There shall not be electrical or mechanical malfunction of the alarm nor malfunction or welding of any relay contacts.

Exception: If the contact rating is at least twice that of the load controlled, this test is not required.

49.3 Audible signaling appliance

49.3.1 The audible signaling appliance of each of two alarms shall operate as intended when the alarm is operated for 8 hours of alternate 5-minute periods of energization and de-energization in the standby and alarm conditions, followed by 72 hours of continuous energization in an alarm condition. For this test, the alarms are to be connected to a source of rated voltage and frequency. For a battery operated alarm, a filtered DC supply is to be employed that has an output voltage equivalent to the fresh battery voltage.

49.4 Test means

49.4.1 A sensitivity adjustment switch, test means, or reset switch provided on an 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 sufficient to obtain at least 1 second of alarm. For this test one alarm is to be connected to a rated source of supply voltage and frequency. This test is to be conducted either alone or in conjunction with the endurance test of the alarm (See 49.1.1 and 49.1.2).

50 Variable Ambient Temperature Test

50.1 Operation in high and low ambient

50.1.1 An alarm shall operate for its intended signaling performance and there shall be no false alarms (or pre-alarms) during the exposures when tested at ambient temperatures of 0 °C and 49 °C (32 °F and 120 °F) at a relative humidity as indicated below. Two alarms, one at maximum and one at minimum sensitivity, are to be maintained at both ambient temperatures for at least 3 hours so that thermal equilibrium is reached. The units then are to be tested for sensitivity while connected to a source of supply that is in accordance with 37.3.1.

50.1.2 Sensitivity measurements are to be recorded before and during the Variable Ambient Temperature Test, Section 50, using the CO values listed in Table 41.1, Part A – Alarm, and Table 41.1, Part B – False alarm, except the 30 day test is to be conducted for 8 hours. Sensitivity tests are to be performed at each of the two ambient conditions as follows:

49 °C, Relative humidity = 40 ±10 percent

0 °C, Relative humidity = 15 ±5 percent

Oxygen Concentration = 20.9 ±1 percent

All alarm samples tested as part of the tests in this section shall comply with these requirements.

50.1.3 Both units shall operate as intended in both ambient conditions. The sensitivity readings shall not, in any case, exceed the limits specified in Table 41.1, Part A – Alarm, and Table 41.1, Part B – False alarm, except the 30 day test is to be conducted for 8 hours.

50.2 Effect of shipping and storage

50.2.1 The sensitivity of an 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.

50.2.2 Two end product alarms, as produced in the same factory and manufactured using the manufacturing process that will provide alarms to the consumer, and in point of purchase packaging, 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, exposed to a temperature of minus 40 °C (minus 40 °F) for at least 3 hours, and then warmed up to room 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 at 55 °C for 30 days, or at 60 °C for 20 days as selected by the manufacturer. The alarms then are to be tested for sensitivity while connected to a source of supply in accordance with 37.3.1.

50.2.3 Sealed point-of-sale packaging shall only be opened after the conditioning exposure is complete. Sensitivity measurements shall be recorded, after the Effect of Shipping and Storage Test in 50.2 using the CO values listed in Table 41.1, Part A – Alarm, and Table 41.1, Part B – False alarm, except the 30 day test is to be conducted for 8 hours. All alarm samples tested as part of the Effect of Shipping and Storage Test in 50.2 shall comply with these requirements.

51 Humidity Test

51.1 High humidity (non-condensing)

51.1.1 Two alarms, one at maximum and one at minimum sensitivity, shall operate for their intended signaling performance, and there shall be no false alarms (or pre-alarms) during the exposure when

exposed for 168 hours to air having a relative humidity of 95 ±4 percent at a temperature of 52 ±3 °C (125 ±5 °F) while energized from a source of supply in accordance with 37.3.1.

51.2 Low humidity

51.2.1 Two alarms, one at maximum and one at minimum sensitivity, shall operate for their intended signaling performance, and there shall be no false alarms (or pre-alarms) during the exposure 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.

51.3 Sensitivity measurements

51.3.1 Sensitivity measurements are to be recorded before and during exposure to the humidity condition in accordance with the Sensitivity Test, Section 41.

51.3.2 The sensitivity values using carbon monoxide shall not exceed the limits listed in Table 41.1, Part A – Alarm, and Table 41.1, Part B – False alarm, except the 30 day test is to be conducted for 8 hours. All alarm samples tested as part of the Humidity Test, Section 51, shall comply with these requirements.

52 Leakage Current Test

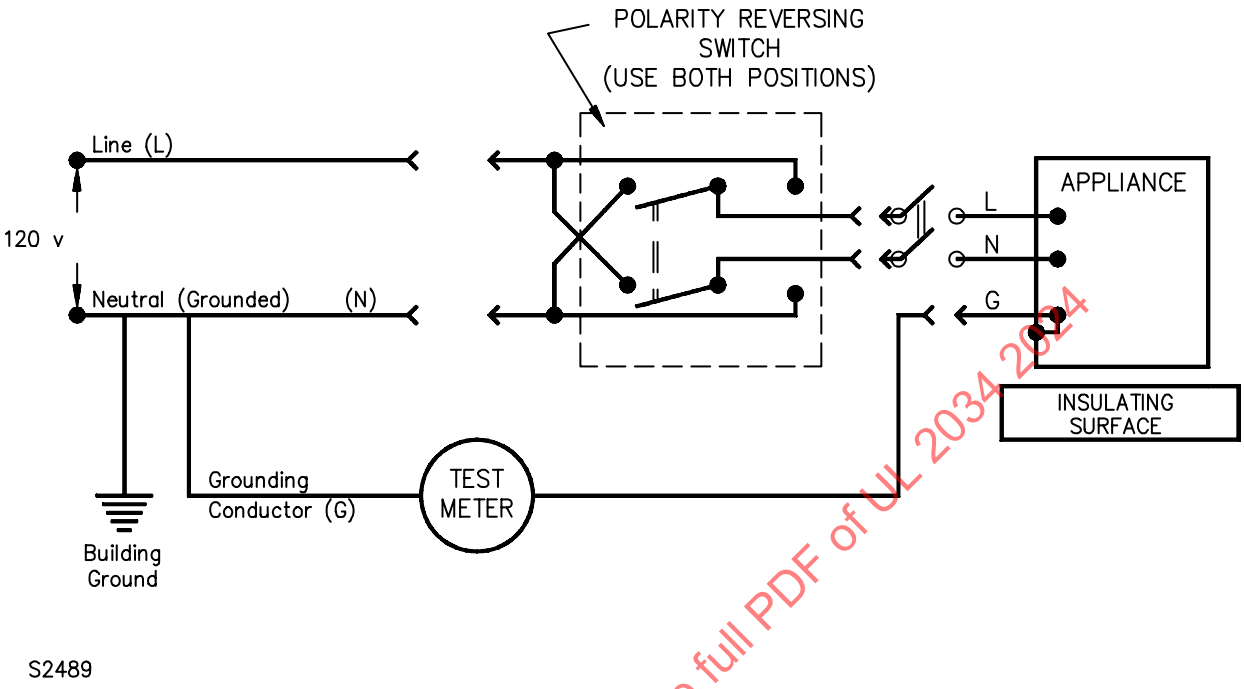
52.1 Following the Humidity Test in Section 51, an alarm other than that operating from a primary battery, shall be subjected to this test, and shall not have leakage current in excess of 0.5 milliampere, AC or DC. All grounding connections to the unit being tested shall be disconnected prior to making the measurement. The leakage current measurement of a permanently installed alarm is to be made with the supply connection polarity as indicated on the installation wiring diagram supplied with the alarm. If a connection polarity is not indicated, the measurement is to be made with both polarities. See Figure 52.1. Measurement shall be made:

a) Between any exposed surface of an alarm that may be contacted by a person, and earth ground and

b) Between any interior parts of an alarm exposed to contact by a person during servicing, and earth ground.

Figure 52.1

Leakage Current Measurement Circuit



52.2 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 essentially 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.

52.3 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 AC measurements, a DC milliammeter, with a maximum impedance of 1000 ohms in the test circuit, is to be employed.

52.4 If 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 10 by 20 centimeters (4 by 8 inches) placed in contact with the surface. Where the surface is less than 10 by 20 centimeters (4 by 8 inches), the metal foil is to be the same size as the surface. The metal foil is not to be pressed into openings and is not to remain in place long enough to affect the temperature of the sample.

52.5 If 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.

53 Transient Tests

53.1 General

53.1.1 An alarm shall operate for its intended signaling performance and its sensitivity shall not be affected adversely when two representative samples (one preset to the maximum and one preset to the minimum production sensitivity) are subjected to 500 supply line (hazardous-voltage) transients, 500 internally induced transients, extraneous transients (radiated), and 60 supply line (low-voltage) circuit transients, while energized from a source of supply in accordance with 37.3.1 and connected to the device(s) intended to be used with the alarm.

53.1.2 Different alarms are to be used for each of the four tests in 53.1.1. The alarms shall not false alarm (or pre-alarm) for more than 1 second. Alarms using a primary battery as a power supply are to be subjected to the extraneous transients test only. When a CO alarm is intended for multiple-station connection, the transient tests are to be first conducted with an individual CO alarm, and secondly with two interconnected CO alarms. The interconnecting wiring shall not exceed 12 in (300 mm).

53.1.3 Sensitivity measurements shall not exceed the limits specified in 41.1.1.

53.2 Supply line (ring wave surge voltage) transients

53.2.1 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.

53.2.2 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 IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits, IEEE C62.41.

53.2.3 Each unit is to be subjected to 500 oscillatory transient pulses induced at an average rate of three pulses every minute. Each transient pulse is to be induced 90° into the positive half of the 60 hertz 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.

53.3 Internally induced transients

53.3.1 The alarm is to be energized in the standby condition while connected to a source of supply in accordance with 37.3.1. The supply is to be interrupted for approximately 1 second at a rate of not more than 6 cycles per minute for a total of 500 cycles. Following the test the alarm is operated for its intended signaling performance.

53.4 Extraneous transients

53.4.1 Single or multiple station carbon monoxide alarms shall not false alarm (or pre-alarm) and their intended operation shall not be impaired when subjected to extraneous transients generated by the devices and appliances described in 53.4.2. In addition, the alarm shall respond to carbon monoxide during application of the transient condition.

53.4.2 Two single and two sets of multiple station carbon monoxide alarms are to be energized from a source of rated voltage and frequency and subjected to transients generated from the following devices located 1 foot (305 mm) from the alarm, interconnecting wires, or both. The time of application for the condition specified in 53.4.2(a) is to be at least 2 minutes. The conditions specified in 53.4.2(c), 53.4.2(d), and 53.4.2(e) are to be applied for 10 cycles, each application of 2 seconds duration, except the last application shall be of a 10-minute duration. Near the end of the last cycle, an abnormal amount of carbon monoxide is to be introduced into the alarm chamber to determine whether the unit is operational for

carbon monoxide with the transient applied. For the condition specified in 53.4.2(b), the 1-foot distance is to be measured from the transmitter-receiver (walkie-talkie or cellular phone) antenna to the surface of the carbon monoxide alarm.

a) Sequential arc (Jacob's ladder) generated between two 15 inch (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 hertz primary, 10,000 volts, 60 hertz, 23 milliamperes secondary. The two wires are to be formed in a taper starting with an 1/8 inch (3.2 mm) separation at the bottom (adjacent to terminals) and extending to 1-1/4 inches (31.8 mm) at the top.

b) Energization and transmission of random voice message of five separate transmitter-receiver units (walkie-talkies or cellular phones) 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 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 walkie-talkies or cellular phones are to be in the same room and on the same plane as the alarm under test.

c) Energization of an electric drill rated 120 volts, 60 hertz, 2.5 amperes.

d) Energization of a soldering gun rated 120 volts, 60 hertz, 2.5 amperes.

e) Energization of a 6-inch (152-mm) diameter solenoid-type vibrating bell[a] with no arc suppression and rated 24 volts.

[a] Edwards Model 439D-6AW vibrating bell rated 0.075 amperes, 20/24 volt DC or equivalent.

53.5 Supply line (extra-low-voltage) circuit transients

53.5.1 Each of two extra-low-voltage carbon monoxide alarms is to be subjected to 60 transient voltage pulses. The pulses are to be induced into the alarm circuit intended to be connected to the extra-low-voltage initiating device circuit of a system control unit and the extra-low-voltage power supply circuit of the alarm.

53.5.2 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 approximately 80 microseconds, and an energy level of approximately 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.

53.5.3 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 53.5.1) 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 53.5.1) between any two circuit leads or terminals consisting of ten pulses of one polarity and ten of the opposite polarity.

53.5.4 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 41.

54 Surge Immunity Test (Combination Wave)

54.1 The 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 accessibility of energized parts.

54.2 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.

54.3 The surge impulse test levels in Table 54.1 are to be used (combination 1.2/50 µs, 8/20 µs Voltage/Current surge waveform). A separate alarm shall be used for each surge level.

Table 54.1
Surge Impulse Levels

Peak Voltage (kV)	Peak Current (kA)
2	1
4	2
6	3

54.4 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 41.

55 Surge Current Test

55.1 Each of three previously untested representative alarms 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 accessibility of energized parts.

55.2 The alarm is to be mounted on a ceiling surface, or other surface as recommended in the installation instruction, covered with a double layer of white tissue paper. Each 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.

55.3 A permanently-connected alarm is to 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° (+0, -15) and one negative applied at a phase angle of 90° (+0, -15).

56 Dielectric Voltage-Withstand Test

56.1 An alarm shall withstand for 1 minute, without breakdown, the application of an essentially sinusoidal AC voltage of a frequency within the range of 40 – 70 hertz, or a DC voltage, between live parts of hazardous-voltage circuits and exposed dead (grounded) metal parts and live parts of hazardous-voltage circuits and extra-low-voltage circuits. The test voltage is to be:

a) For an alarm rated 30 volts AC rms (42.4 volts DC or AC peak) or less – 500 volts (707 volts, if a DC voltage is used).

b) For an alarm rated between 31 and 250 volts AC rms – 1000 volts (1414 volts, if a DC voltage is used).

c) For an alarm rated more than 250 volts AC rms – 1000 volts plus twice the rated voltage (1414 volts plus 2.828 times the rated AC rms voltage, if a DC voltage is used).

56.2 Any reference grounds are to be disconnected prior to the test applications.

56.3 If the charging current through a capacitor or capacitor-type filter connected across the line, or from line to earth ground, is sufficient to prevent maintenance of the specified AC test voltage. It is not prohibited that the capacitors and capacitor-type filters be tested using a DC voltage in accordance with 56.1.

56.4 The test voltage 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 voltage is to be increased at a rate of approximately 200 volts per minute until the required test value is reached and is to be held at that value for 1 minute.

56.5 A printed-wiring assembly or other electronic-circuit component that short circuits or is damaged by application of the test voltage, is to be removed, disconnected, or otherwise rendered inoperative before the test. It is not prohibited that a representative subassembly be tested instead of an entire unit.

57 Abnormal Operation Test

57.1 An alarm shall operate continuously under abnormal (fault) conditions without resulting in a risk of fire or electric shock.

57.2 To determine if an alarm complies with the requirement of 57.1, it is to be operated under the most severe circuit fault conditions encountered in service while connected to a source of supply in accordance with 37.3.1. There shall not be emission of flame or molten metal, or any other manifestation of a fire, or dielectric breakdown when tested in accordance with the Dielectric Voltage-Withstand Test (Section 56) after the abnormal test.

57.3 In determining if an alarm complies with the requirement with respect to circuit-fault conditions, the fault condition is to be maintained continuously until constant temperatures are attained, or until burnout occurs, if the fault does not result in the operation of an overload protective device. Shorting of the secondary of the power supply transformer and shorting of a limited-life electrolytic capacitor represent typical fault conditions. See 74.3.2.

58 Overvoltage Test

58.1 An alarm other than one operating from a main battery power supply shall operate as intended in the standby condition at both maximum and minimum sensitivity settings and while performing its intended function and connected to a supply source of 110 percent of rated value. If a nominal rated voltage value is specified, the overvoltage shall be 110 percent of the test voltage specified in 37.3.1. If an operating voltage range is specified, the overvoltage shall be either 110 percent of the high value of the voltage range or 110 percent of the test voltage specified in 37.3.1, whichever is higher. Sensitivity measurements at the increased voltage shall not exceed the limits specified in 41.1.1.

58.2 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.

58.3 For operation at the higher voltage, three alarms are to be subjected to the specified increased voltage in the standby condition for at least 16 hours, or as specified by the manufacturer, and then tested for their intended signaling operation and sensitivity.

59 Undervoltage Test

59.1 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 not exceed the limits specified in 41.1.1.

59.2 For 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.

59.3 If the alarm is provided with a standby battery the test is to be conducted at 85 percent of the charged battery voltage. If 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.

59.4 For operation at the reduced voltage, three 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 alarms, or the battery trouble level voltage for battery operated alarms, and then tested for signaling operation and sensitivity.

60 Dust Test

60.1 The sensitivity of an alarm shall not be affected by an accumulation of dust, without an alarm (or pre-alarm) or audible trouble signal being produced.

60.2 To determine compliance with 60.1, a sample in its intended mounting position is to be placed, de-energized, in an air tight chamber having an internal volume of at least 3 cubic feet (0.09 m^3).

60.3 Approximately 2 ounces (0.06 kg) of cement dust, maintained in an ambient room temperature of 23 ±3 °C (73.4 ±5 °F) at 20 – 50 percent relative humidity and capable of passing through a 200 mesh screen, is 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 airflow is to be maintained at an air velocity of approximately 50 fpm (0.25 m/s).

60.4 Following the exposure to dust, the alarm is to be removed carefully, mounted in its intended position, energized from a source of supply in accordance with 37.3.1, and tested for sensitivity. Sensitivity measurements following this test shall not exceed the limits specified in 41.1.1.

61 Static Discharge Test

61.1 The components of an alarm shall be shielded so that its operation is not adversely affected when subjected to static electric discharges. Operation of the trouble circuit during this test is not considered a failure if the subsequent operation of the alarm is not impaired. Operation of the alarm (or pre-alarm) shall terminate in less than 5 seconds. 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 (93 kPa).

61.2 Each of two alarms is to be mounted in its intended mounting position and connected to a source of supply in accordance with 37.3.1. If an alarm is intended to be installed on a metal junction box, the alarm is to be connected to earth ground. A 250-picofarad, low-leakage capacitor, rated 10,000 volts DC, is to be connected to two insulated leads rated for more than 30 volts, 3 feet (0.9 m) long. 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 inch (12.7 mm) diameter metal test probe with a spherical end mounted on an insulating rod. The capacitors are 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 touched to the alarm and the other probe is then to be touched to earth ground.

61.3 Ten discharges are to be applied to different points on the exposed surface of the alarm, recharging the capacitors for each discharge. Five discharges of positive polarity are to be made with one lead connected to earth ground and the other lead probed on the alarm surface followed by five discharges with the polarity reversed. For an alarm intended to be serviced by the consumer, ten additional discharges shall be applied as described above except each lead shall be probed, in turn, on all internal parts that are contacted by the user.

61.4 Following the discharges, the alarm is to be tested for sensitivity. Sensitivity measurements shall not exceed the limits specified in 41.1.1.

62 Vibration Test

62.1 An alarm shall withstand vibration without breakage or damage of parts. Following the vibration, the alarm shall operate as intended.

62.2 To determine compliance with 62.1, sensitivity measurements following the vibration shall comply with 41.1.1.

62.3 Two samples, one at the maximum and one at the minimum sensitivity setting, are to be secured in their intended mounting position on a mounting board and the board, in turn, securely fastened to a variable speed vibration machine having an amplitude of 0.01 inch (0.25 mm). The frequency of vibration is to be varied from 10 to 35 cycles per second in increments of 5 cycles per second until a resonant frequency is obtained. The samples are then to be vibrated at the maximum resonant frequency for a period of 1/4 hour. If no resonant frequency is obtained, the samples are to be vibrated at 35 cycles per second for a period of 4 hours.

62.4 For this test, amplitude is defined as the maximum displacement of sinusoidal motion from a position of rest or one-half of the total table displacement. Resonance is defined as the maximum magnification of the applied vibration.

63 Replacement Test, Head and Cover

63.1 An alarm employing a cover that is intended to be attached or closed by a snap type action or a removable head shall withstand 50 cycles of removal and replacement, or opening and closing, as applicable, of the cover.

63.2 An alarm is to be installed as intended in service and the cover or head removed and replaced, or opened and closed, as recommended by the manufacturer. The unit then is to be subjected to the Jarring Test, Section 64.

64 Jarring Test

64.1 While powered by its rated source of supply, and if applicable secondary supply as specified in 37.3.1, an alarm shall withstand jarring resulting from impact and vibration such as that experienced in service, without causing an alarm or trouble (or pre-alarm) signal, without dislodgement of any parts, and without impairing its subsequent operation.

Exception: A momentary audible trouble signal resulting from the jarring is acceptable if the alarm operation is not affected. Dislodgement 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.

64.2 The alarm and associated equipment, if any, are to be mounted in a position of intended use to the center of a 6 by 4 foot ±1/4 inch (1.8 by 1.2 m ±6.25 mm), nominal 3/4-inch (19.1-mm) thick plywood board which is secured in place at four corners. AC hardwired or AC attachment plug smoke alarms shall be secured to a manufacturer recommend “electrical” box that is secured to the plywood surface.

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

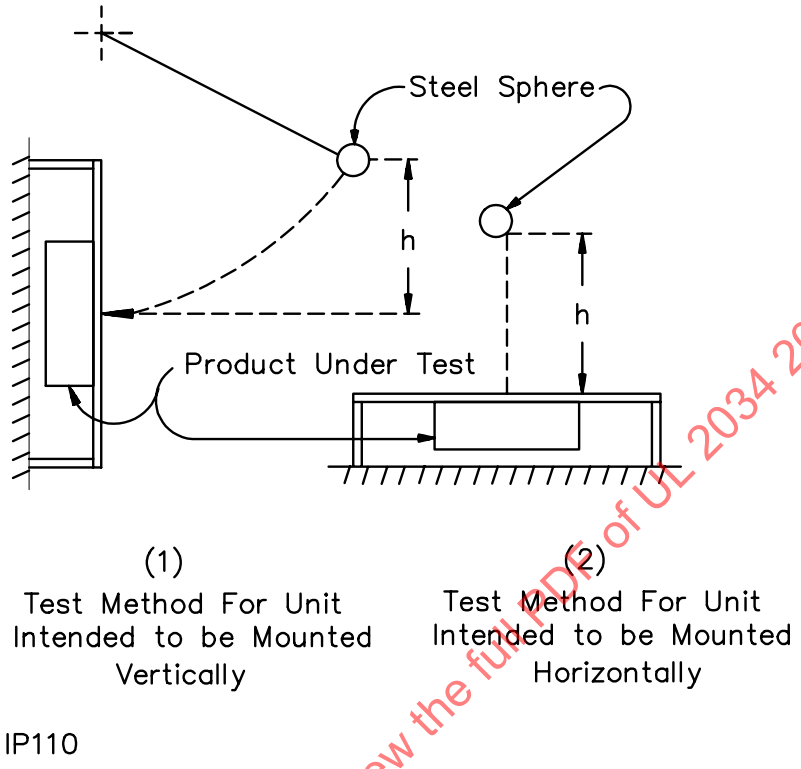
64.4 An impact of 3 foot-pounds (4.08 J) shall be applied once to the center of the reverse side of this board by means of a 1.18 pound (540 g), 2 inch (50 mm) diameter steel sphere either:

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

b) Dropped from a height of 2.54 feet (775 mm) to apply 3 foot-pounds (4.08 J) of energy, depending upon the mounting of the equipment (see Figure 64.1).

Figure 64.1

Jarring Test



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

64.6 Following the jarring test, the alarm shall be tested for sensitivity in accordance with 41.1.1.

65 Corrosion Test

65.1 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 inches (50.8 mm) above the bottom of the chamber. The temperature in the chamber is to 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.

65.2 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.

65.3 Following this test, the alarms shall comply with the sensitivity requirements of 41.1.1.

66 Battery Tests

66.1 If a battery is employed as the main source of power of a single station carbon monoxide alarm, it shall provide power to the unit under intended ambient conditions for at least 12 months in the standby condition, including random and weekly alarm testing, and then operate the alarm for a minimum of 12 hours of alarm, followed by 7 days of trouble signal. See 40.3.1.

66.2 Six samples of the battery or sets of batteries, if more than one is used for primary power, are to be tested under each of the following ambient conditions for a minimum of 12 months while connected to the alarm or a simulated load to which the battery is to supply power.

a) Room Ambient – 23 ±3 °C (73.4 ±5 °F), 30 – 50 percent relative humidity, 760 mm Hg.

b) High Temperature – 45 °C (113 °F).

c) Low Temperature – 0 °C (32 °F).

d) Humidity – 30 ±2 °C (86 ±3 °F), 85 ±5 percent relative humidity.

66.3 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 alarm or an appropriate load simulating maximum alarm conditions. The batteries are to be tested in the mounting clips employed in the alarm.

66.4 Terminals or jacks are to be provided on each test fixture 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 feet (0.9 m) long.

66.5 Prior to placing the battery test setups in the various ambient conditions, each battery is to be subjected to 25 cycles of alarm representing random testing. Each cycle is to consist of 5 seconds of alarm and at least 5 minutes between each application.

66.6 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 alarm is to be placed into an alarm condition weekly. The duration of the weekly alarm test signal is to be 3 seconds.

66.7 At the end of the 12 months, all batteries shall have sufficient capacity to operate the alarm signal for a minimum of 12 hours followed by 7 days of trouble signal. To obtain the trouble signal level, continue the test with the standby current drain for longer than 12 months if necessary. The length of time that the batteries subjected to conditions in 66.2(b), 66.2(c), and 66.2(d) are to operate the alarm signal shall be less than 12 months only if the alarm is marked to indicate the battery limitations for the ambient condition involved. In no case shall the length of time that the batteries are subjected to the condition in 66.2(b), 66.2(c) and 66.2(d) be less than 6 months.

67 Audibility Test

67.1 General

67.1.1 Except as permitted in 67.4.1, the alarm sounding appliance, either integral with the 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 feet (3.05 m) with two reflecting planes assumed. To determine compliance with this requirement, the method described in 67.2.1 – 67.3.2 is to be employed.

67.2 Sound output measurement

67.2.1 The sound power output of the alarm shall be measured in a reverberation room using procedures outlined in ANSI S12.31 (Precision Methods for the Determination of Sound Power Levels of Broad-Band Noise Sources in Reverberation Rooms) or ANSI S12.32 (Precision Methods for the determination of Discrete-Frequency and Narrow-Band Noise Sources in Reverberation Rooms). The sound power in each 1/3 octave band shall be determined using the comparison method. The A-weighting 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 of 10 feet (3.05 m). An additional 6 db is to be added to allow for two reflecting planes.

67.2.2 Each alarm is to be mounted to a 3/4 inch (19.1 mm) plywood board measuring 2 by 2 feet (610 by 610 mm), supported in a vertical plane, and positioned at an angle of 45° to the walls of the reverberation room.

67.2.3 For this test an 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 39.2, or equivalent:

a) Nondischarged battery (a battery with some unknown shelf life, as is purchased at a retail outlet) with sufficient added resistance to obtain a trouble signal (Point D of Figure 39.2), 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.

c) Battery depleted to a voltage value between conditions in 67.2.3(a) and 67.2.3(b) which is evaluated to be the least favorable for sound output. For a straight-line curve it is the midpoint voltage. For a nonlinear curve it is to be selected.

67.2.4 The equivalent of a battery shall be considered to be a voltage source with a series resistance adjusted to a level at which a trouble signal is obtained during the normal standby condition. The resistances and voltages used are to be those that were determined during the Circuit Measurement Test, Section 39.

67.2.5 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 59.2. For AC powered units employing a nonrechargeable standby battery, the measurement shall be made with the 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.

67.3 Alarm duration test

67.3.1 An alarm sounding appliance of an alarm powered by a primary battery that has been discharged to the trouble level condition shall provide the equivalent of 85 db at 10 feet (3.05 m) after 1 minute of continuous alarm operation and shall provide at least 82 db after 4 minutes.

67.3.2 To determine compliance with 67.3.1, 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 foot (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[a] 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.

[a] A suitable meter for the purpose is a General Radio, Type 1551, sound level meter (Type II).

67.4 Supplementary remote sounding appliances

67.4.1 The sound output of a supplementary remote sounding appliance, shall not be less than 85 dbA.

68 Tests of Thermoplastic Materials

68.1 General

68.1.1 Thermoplastic materials intended for the sole support of current-carrying parts or as an enclosure of an alarm shall be subjected to the following tests. If possible, a complete alarm shall be used.

68.2 Accelerated air-oven aging test

68.2.1 There shall not be excessive warping or exposure of uninsulated hazardous-voltage circuit parts so as to impair operation or provide access to uninsulated hazardous-voltage circuit parts when representative samples of a plastic material are aged for 7 days in a circulating-air oven maintained at 90 °C (194 °F), or for 28 days at a temperature of 70 °C (158 °F), and in both cases at a relative humidity of 0 – 10 percent.

68.2.2 At least three representative samples are to be mounted on supports as intended in service and placed in the oven. At the end of the aging period indicated in 68.2.1, the samples are to be removed, permitted to cool, and then examined for adverse distortion. It is not prohibited that the alarm cover fall off during the test if no hazardous-voltage circuit parts are exposed and the cover is replaceable as intended.

68.3 Flame test (3/4 inch)

68.3.1 When equipment is tested as described in 68.3.2 – 68.3.6, 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 by the vertical burning test described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, are not required to be subjected to the flammability test described in 68.3.2 – 68.3.6.

68.3.2 Three samples of the equipment are to 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 are to be tested as described in 68.3.3 – 68.3.6.

Exception: Testing is required 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.

68.3.3 Three samples of the part are to be subjected to the flame test described in 68.3.5. 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 as capable of becoming ignited because of its proximity to a source of ignition. Each sample is to be tested with the flame applied to a different location.

Exception: Only three unconditioned test samples are required for testing 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.

68.3.4 With reference to 68.3.3, the sections judged capable of becoming ignited are to be those adjacent to coil windings, splices, open-type switches, or arcing parts.

68.3.5 The flame of a Bunsen or Tirrill burner having a tube with a length of 100 ±10 mm (3.94 ±0.39 inches) and an inside diameter of 9.5 ±0.3 mm (0.374 ±0.12 inch) is to be adjusted to have a 3/4 inch (19 mm) height of yellow flame with no blue cone. Two 30-second applications of the tip of the flame are to be made to each section of the equipment specified as indicated above, 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) has been found to provide similar results and is appropriate for use.

68.3.6 When one sample from a set of three does not comply with 68.3.1, an additional set of three samples shall be tested. All samples from the second set shall comply with 68.3.1.

68.4 Flame test (5 inch)

68.4.1 When equipment is tested as described in 68.4.1 – 68.4.5, 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 inches (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.

Exception: Parts that are molded from materials that are classed as 5VA by the five inch burning test described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, are not required to be subjected to the flammability tests described in 68.4.1 – 68.4.6.

68.4.2 Three samples of the complete equipment or three test specimens of the molded part 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 are to 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 are to 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 as capable of becoming ignited because of its proximity to a source of ignition. When

more than one part is near a source of ignition, each sample is to be tested with the flame applied to a different location.

Exception: Only three unconditioned test samples are required for testing 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.

68.4.3 The three samples shall perform as described in 68.4.1. 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 68.4.1.

68.4.4 The Bunsen or Tirrill burner with a tube inside diameter of 9.5 ±0.3 mm (0.374 ±0.12 inch), and an length of 100 ±10 mm (3.94 ±0.39 inches), is to be placed remote from the specimen, ignited, and adjusted so that when the burner flame is 5 inches (127 mm), the height of the inner blue cone is 1-1/2 inches (38 mm). The tube is not to be equipped with end attachments, such as stabilizers.

68.4.5 When a complete enclosure is used to conduct the flame test, the sample is to be mounted as intended in service, as long as 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 inches (305 mm) below the point of application of the test flame. The 5-inch (127-mm) flame is to be applied to any portion of the interior of the part judged as capable of being ignited (by its proximity to live or arcing parts, coils, wiring, or other possible sources of ignition) at an angle of 20° 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: The flame is to be applied to the outside of an enclosure when the equipment is of the encapsulated type, or of a size that prohibits the flame being applied inside.

Exception No. 2: Natural gas having a heat content of 1000 Btu/ft^3 (37 MJ/m^3 at 23 °C) has been found to provide similar results and is appropriate for use.

68.4.6 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.

68.5 Impact test

68.5.1 An alarm employing a nonmetallic enclosure shall be subjected to the requirements outlined in 68.5.3, 68.5.4, and 68.5.5 if it:

a) Does not comply with 68.5.2; or

b) Is for use in recreational vehicles, commercial vehicles, unconditioned areas, on recreational boats; or

c) Includes instructions to use an instrument other than remote electronic communication, or a finger or thumb of a person to actuate the test and/or alarm reset/silence feature.

68.5.2 The Impact Test shall not be required if the alarm is only intended for installation on the ceiling, or on the wall no more than 12 inches from the ceiling. For alarms complying with this installation

requirement, it shall be marked with the correct mounting position as noted in 89.4(b) and the installation instructions shall include information as outlined in 91.1(t).

68.5.3 An alarm shall withstand one 5 foot-pound (6.8 N·m) impact without exposure of live parts, impairment of operation, or creation of a risk of electric shock.

68.5.4 The alarm is to be mounted securely in a position of intended use on a surface representative of a typical installation. A 1.18-pound (535-g), 2-inch (50.8-mm) diameter steel sphere is to be dropped from a height of 51 inches (1300 mm) or swung through a pendulum arc from a sufficient height to apply 5 foot-pounds (6.8 N·m) of energy to the weakest section of the enclosure.

68.5.5 Following the impact, the alarm is to be examined and energized from a source of rated voltage and frequency and checked for normal operation. Cracking of the enclosure is acceptable if it does not impair the operation of the alarm. Sensitivity measurements recorded after the impact test shall comply with the Sensitivity Test, Section 41.

69 Paint Loading Test

69.1 Unless marked in accordance with 89.2(j), an alarm shall operate as intended and shall comply with the requirements of the Sensitivity Test, Section 41, after painting of the alarm assembly, screens, openings, or similar items are capable of becoming clogged or covered by painting.

69.2 The exterior surface of two samples, including screened openings, or the like are to be coated with a latex based paint which is spread at approximately two times the paint manufacturer's recommended spreading rate. The paint is to be allowed to dry for 5 days at room temperature. Following this, the samples are to be given a second identical application of paint and again permitted to dry for 5 days. The alarms are to be tested for sensitivity before and after the specified paint loading. Sensitivity measurements following this test shall not exceed the limits specified in 41.1.1.

70 Battery Replacement Test

70.1 The battery clips and holders of a battery operated single station carbon monoxide alarm shall withstand 50 cycles of battery removal and replacement at a rate not to exceed 6 cycles per minute without any reduction in contact or mounting integrity. During battery replacement, the alarm device shall not sound for more than 1 second. The test shall not have an adverse effect on the operation of the alarm.

70.2 For this test an alarm is to be installed as intended in service and the battery(s) removed and replaced as specified by the manufacturer. The unit shall then be tested for its intended operation.

71 Polarity Reversal Test

71.1 A carbon monoxide 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 72. This includes 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 (or pre-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 (or pre-alarm) signal is to be not prohibited under any incorrect polarity applied. A maximum 1-second alarm is not prohibited when the correct polarity is connected.

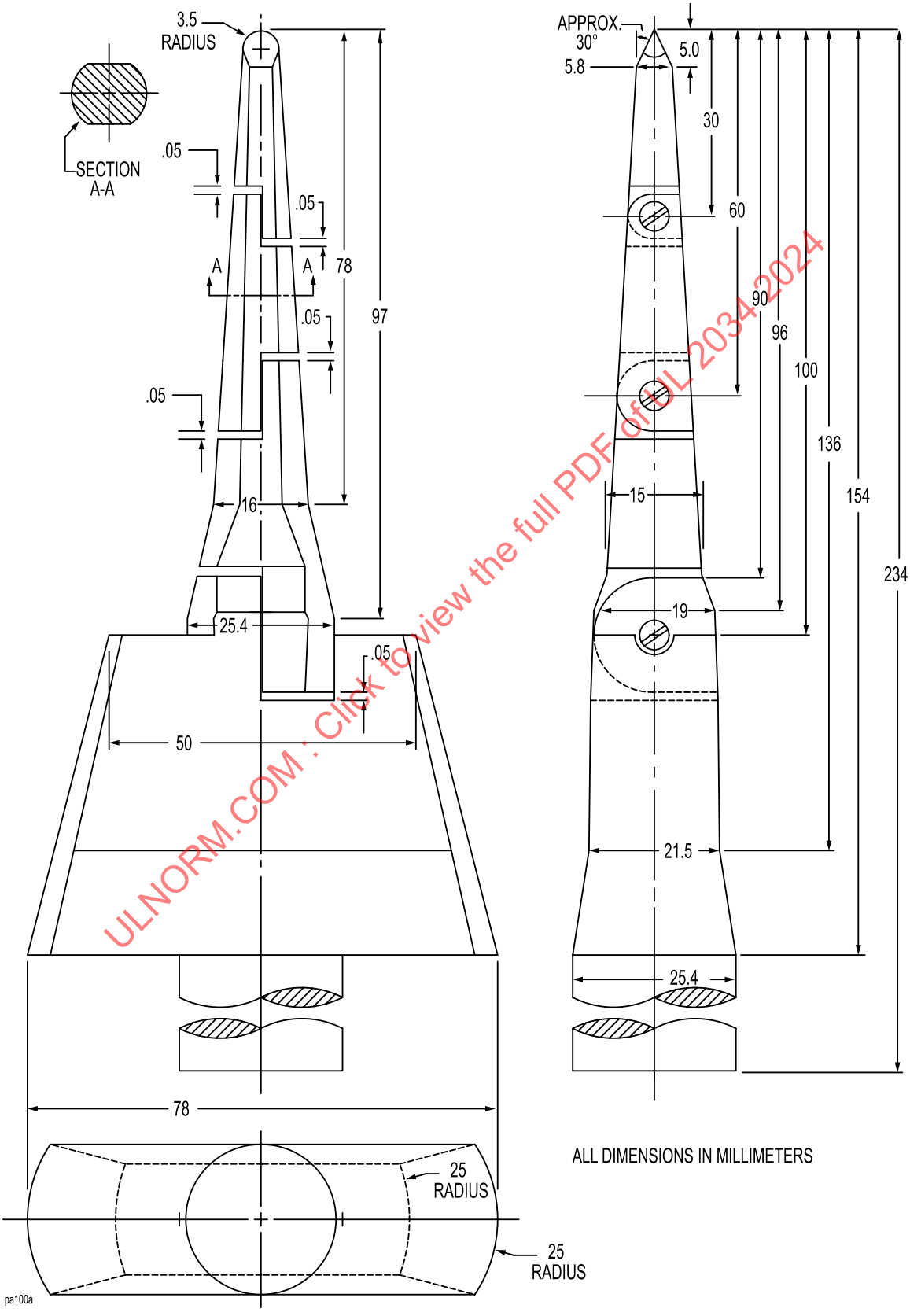
71.2 Two samples are to be subjected to this test. Sensitivity measurements shall comply with 41.1.1.

72 Electric Shock Current Test

72.1 If the open circuit potential between any part that may be contacted by the probe shown in Figure 72.1 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, the part shall comply with the requirements of 72.2 and 72.4.

Figure 72.1

Articulated Probe



72.2 The continuous current flow through a 500-ohm resistor shall not exceed the values specified in Table 72.1 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 72.1
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.

72.3 The duration of a transient current flowing through a 500-ohm resistor connected as described in 72.2 shall not exceed 809 milliamperes, regardless of duration of the value determined by the following equation:

$$T \leq \left(\frac{20\sqrt{2}}{I} \right)^{1.43}$$

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, and

I is the peak current in milliamperes.

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 72.2.

Table 72.2
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

Table 72.2 Continued on Next Page

Table 72.2 Continued

Maximum peak current (I) through 500-ohm resistor, milliamperes	Maximum duration (T) of waveform containing excursions greater than 7.1 milliamperes peak, seconds
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
800.0	0.0083

72.4 The maximum capacitance between the terminals of a capacitor that is accessible during operator servicing shall comply with the following equations:

$$C = \frac{88{,}400}{E^{1.43}(In\ E - 1.26)} \quad for\ 42.4 \leq E \leq 400$$

or

$$C = 35{,}288E^{-1.5364} \quad for\ 400 \leq E \leq 1000$$

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 similar method.

Typical calculated values of maximum capacitance are shown in Table 72.3.

Table 72.3
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
90	43.8
80	53.8
70	68.0
60	89.4
50	124.00
45	150.00
42.4	169.00

72.5 With reference to the requirements in 72.2 and 72.3, 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.

72.6 With reference to the requirements in 72.5, 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-inch (102- by 203-mm) rectangle. Two hands of a person are considered to be able to contact parts simultaneously if the parts are not more than 6 feet (1.83 m) apart.

72.7 Electric shock current refers to all current, including capacitively coupled currents.

72.8 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.

72.9 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.

73 Strain Relief Test

73.1 General

73.1.1 A cord or lead that depends upon a thermoplastic part for strain relief is to be subjected to the applicable tests specified in 73.2.1 – 73.4.1 following exposure to either temperature conditioning test described in 50.1.2.

73.2 Power-supply cord

73.2.1 When tested in accordance with 73.1.1, 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.

73.2.2 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 is stressed from any angle that the construction of the alarm permits. The strain relief shall not, at the point of disconnection of the conductors, show such movement of the cord as to indicate that stress resulted on the connections.

73.3 Field-wiring leads

73.3.1 Each lead employed for field connections, including a battery clip lead assembly, shall withstand for 1 minute a pull of 10 pounds-force (44.5 N) without any evidence of damage or of transmittal of stress to internal connections.

73.4 Special connector

73.4.1 A connector used in the lead assembly of a Class 2 or Class 3 circuit shall withstand a pull of 5 pounds force (22.2 N) without any evidence of damage, transmittal of stress to internal connections, or separation.

74 Power Supply Tests

74.1 General

74.1.1 If a separate power supply, other than a battery, is used to provide energy to one or more alarms, it is to be subjected to the test in 74.2.2 – 74.3.2.

74.2 Volt-amperes capacity

74.2.1 The volt-amperes capacity of the output circuit of a power supply that is separate from the alarms shall not be more than 100 volt-amperes and not more than 30 volts, 60 hertz, 42.4 volts peak or DC.

74.2.2 To determine compliance with the requirements of 74.2.1, a variable resistive load is to be connected to the output circuit of the power supply. With the power supply connected to a rated source of supply, the load is to be varied from open circuit to short circuit in an elapsed time of not less than 1-1/2 nor more than 2-1/2 minutes. Voltage and current measurements are to be recorded for each value and the maximum volt-amperes is to be calculated. If an overcurrent protective device is provided, it shall be shunted out during the test, if necessary.

74.3 Burnout test

74.3.1 There shall not be damage to the enclosure, charring or burning of the cheesecloth, nor emission of flame or molten metal when a power supply is operated under the conditions described in 74.3.2. While still in a heated condition following this test, the power supply shall comply with the requirements of the Leakage Current Test, Section 52, and the Dielectric Voltage-Withstand Test, Section 56.

74.3.2 With the output shorted the supply circuit of the power supply is to be connected to a rated source of voltage and frequency, with the enclosure grounded, and operated for at 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 fuses are provided on the power supply, they are to be shunted out, but inaccessible fuses are to remain in the circuit.

75 Drop Test

75.1 This test is to be conducted only on commercial vehicle alarms and/or portable alarms intended for transient use, such as a travel alarm, and is not to be conducted on alarms intended for stationary installation.

75.2 An alarm shall withstand five drops from a height of 7 feet (2.1 m) onto a tiled concrete floor without exposure of internal hazardous-voltage parts or 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. Parts shall not become dislodged unless the dislodged part does not affect operation or sensitivity of the unit, the dislodged part is replaceable (such as a cover), there are no hazardous-voltage parts exposed, and the condition is visually obvious.

75.3 Each of two alarms is to be raised to a height of 7 feet (2.1 m) and permitted to drop five times onto a concrete floor covered with a 1/8 inch (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 comply with 41.1.1.

CARBON MONOXIDE ALARMS FOR USE IN RECREATIONAL VEHICLES, COMMERCIAL VEHICLES, AND UNCONDITIONED AREAS

76 General

76.1 A carbon monoxide alarm intended for use in recreational vehicles, commercial vehicles, and unconditioned areas such as garages, attics, and the like shall comply with the requirements specified in Sections 77 – 80, in addition to the requirements specified in Sections 1 – 75 and 82 – 91, inclusive.

76.2 Marking

76.2.1 In addition to the applicable requirements in Section 89, a carbon monoxide alarm for use in a Recreational Vehicle, Commercial Vehicle, or Unconditioned Area 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 inch (1.2 mm) high. Item (b) shall be readily visible after installation:

a) Electrical rating in volts and amperes;

b) The type of product, such as "Recreational Vehicle Carbon Monoxide Alarm", “Commercial Vehicle Carbon Monoxide Alarm”, or “Unconditioned Area CO Alarm” or equivalent.

c) The markings specified in (a) – (b) shall be applied in accordance with 76.2.1 and 76.2.2. 89.5 is not applicable for the marking requirements specified in 76.2.1.

76.2.2 For Commercial Vehicle alarms, the model number and date of manufacture shall be readily visible on the front of the enclosure cover of the CO alarm after installation.

Exception: In lieu of the markings specified above, a set of pullout instructions that are accessible after installation may be permanently attached to the enclosure.

77 Variable Ambient Temperature and Humidity Test

77.1 There shall not be false alarms (or pre-alarms) or adverse change in performance when two units, one at maximum and one at minimum sensitivity, are subjected 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); and

c) Ten days in 93 ±2 percent humidity at 61 ±2 °C (142 ±4 °F).

77.2 Sensitivity measurements immediately after conditioning as described in 77.1 shall comply with 41.1.1. During the sensitivity measurement, the environmental chamber is to be within the limits specified in 77.1.

77.3 During each test condition, the alarm is to be connected to a source of rated voltage. Battery operated alarms and Self Contained Units shall be powered by a battery installed in the alarm that meets or exceeds 77.4 during each test condition. The tests in 77.1 shall be conducted 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.

77.4 All batteries included with Carbon Monoxide alarms intended for use in recreational vehicles, unconditioned areas, or commercial vehicle applications shall at a minimum have a published operational specification range of no greater than minus 20 °C (minus 4 °F) and no less than 60 °C (140 °F). Recommended replacement batteries must also meet the temperature range.

77.5 Primary and recommended replacement batteries must identify the maximum and minimum temperature range as specified in 77.4.

77.6 Batteries shall be tested in accordance with all applicable battery tests outlined within this standard and the battery operating range specified in 77.4 using the methods specified in Battery Tests, Section 66.

78 Corrosion (Salt Spray) Test

78.1 An alarm shall operate as intended and shall not false alarm (or pre-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 B117-85.

78.2 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 41.

78.3 Sensitivity measurements following the exposure shall comply with the Sensitivity Test, Section 41, using carbon monoxide.

79 Vibration Test

79.1 After vibration in accordance with 79.2, an alarm shall not false alarm (or pre-alarm) or be adversely damaged. Sensitivity measurements shall comply with the Sensitivity Test, Section 41.

79.2 Two 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 62. Sensitivity measurements are to be recorded before and after the test.

80 Contamination Test (Cooking By-Products)

80.1 After exposure in accordance with 80.2 – 80.5, an alarm shall not false alarm (or pre-alarm) or otherwise be adversely affected. Sensitivity measurements following the exposure shall comply with the Sensitivity Test, Section 41.

80.2 Two samples are to be subjected to the vaporization of a mixture of 50 grams of animal fat (lard), 50 grams of vegetable fat[a], and 100 grams of beef gravy[b]. The mixture is to be placed in an 8-inch (203-mm) diameter aluminum plate that is heated on an 8-1/2-inch (216-mm) diameter hotplate located on the bottom center of a galvanized sheet metal enclosure.

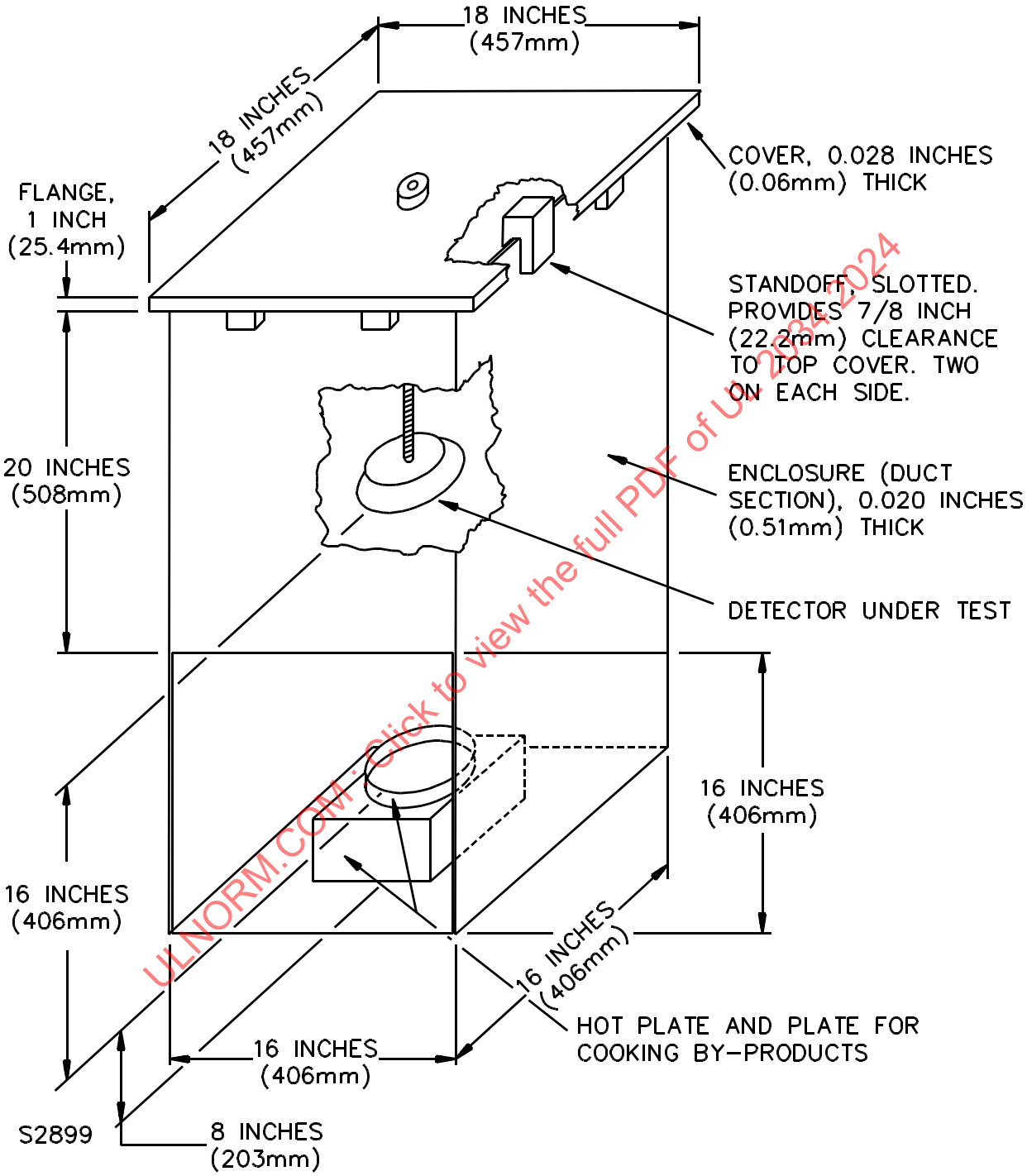
[a] Crisco or the equivalent is acceptable.

[b] Franco-American or the equivalent is acceptable.

80.3 The enclosure is to measure approximately 3 feet (914 mm) high, 16 inches (406 mm) square and have an open top and a 16 inch square opening at the bottom of one side. A sheet metal cover, approximately 18 inches (457 mm) square, with 1 inch (25 mm) flanges, is to be supported at the enclosure top by 7/8 inch (20 mm) high standoffs. See Figure 80.1.

Figure 80.1

Contamination Test (Cooking By-Products)



80.4 The alarm under test is to be supported on the end of a threaded 1/4 inch (6.4 mm) steel rod positioned so that the exposed face of the alarm is approximately 12 inches (304 mm) below the enclosure cover and 16 inches (406 mm) above the aluminum plate. The alarm is not to be energized during the test.

80.5 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 41.

81 Carbon Monoxide Alarms for Use on Recreational Boats

81.1 General

81.1.1 These requirements apply to the construction and performance characteristics of battery-operated (nominal 12, 24, and 32 volts DC) single and multistation carbon monoxide gas alarm systems, fully integrated systems, and self contained units (internal batteries).

81.1.2 These carbon monoxide gas alarms are intended to be installed inside or immediately outside enclosed accommodation spaces in a boat or in areas people inhabit and where carbon monoxide tends to accumulate. These devices shall be wired in accordance with the Standard for the National Fire Protection Association for Motor-Craft (Pleasure and Commercial), NFPA 302, and the applicable regulations of the United States Coast Guard, 33 CFR Part 183, and shall comply with the appropriate installation standards of the American Boat and Yacht Council, Inc., including Carbon Monoxide Gas Detection Systems on Boats, A-24.

81.1.3 These alarms shall be constructed to be watertight or drip-proof. See 81.3 and 81.4.

81.1.4 A metallic part, including mounting brackets, shall be resistant to corrosion. Metal shall be used in combinations that are galvanically compatible. See Corrosion (Salt-Spray) Test, Section 78.

81.1.5 These alarms shall comply with the requirements specified in Section 1 – 75 and 82 – 91 inclusive. The same three sample alarms are to be used for the tests indicated in Table 81.1. The tests are to be conducted in the order specified.

Table 81.1
Samples for Performance Tests

Number of samples[a]	Test
3	Sensitivity Test, Section 41
3	Operation tests following conditioning, 81.2
1	Watertightness test, 81.3
1	Drip test, 81.4
3	Abnormal operation tests, 81.5
1	Salt-spray corrosion test, 81.6
3	Overvoltage and Undervoltage Tests, Sections 58 and 59
3	Endurance Test, Section 49
3	Audibility Test, Section 67

[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.

81.1.6 An alarm that requires a warm-up period to attain intended operation shall not indicate a satisfactory operating condition during the required warm-up period.

81.1.7 During each test condition, the alarm is to be connected to a source of rated voltage. Battery operated alarms and Self Contained Units shall be powered by a battery installed in the alarm that meets or exceeds 81.1.8 during each test condition. The same battery samples shall be used for all of the test conditions. The tests shall be conducted using each battery model specified in the markings or the installation instructions.

81.1.8 All batteries included with Carbon Monoxide alarms intended for use in recreational boats shall at a minimum have a published operational specification range of minus 20 – 60 °C (minus 4 – 140 °F). Recommended replacement batteries must also meet the temperature range.

81.2 Operation tests following conditioning

81.2.1 Immediately following each of the conditions specified in 81.2.3 – 81.2.17, and while in the environmental condition specified in 81.2.3 and 81.2.4, the alarms shall be subject to the Sensitivity Tests specified in Section 41. The sensitivity readings shall not, in any case, exceed the limits specified in Table 41.1, Part A – Alarm, and Table 41.1, Part B – False alarm, except the 30-day test is to be conducted for 8 hours.

81.2.2 The tests specified in 81.2.3 and 81.2.4 shall be conducted in sequential order as outlined in this standard. The same samples used for 81.2.3 and 81.2.4, including remote sensors, are to be used for all tests defined in 81.2.3 – 81.2.17. These samples are to be energized during each environmental exposure.

81.2.3 Three sample alarms are to be placed in an air-circulating oven maintained at 70 ±2 °C (158 ±4 °F) with a relative humidity of 20 ±2.5 percent for 24 hours.

81.2.4 Immediately following the conditioning specified in 81.2.3 and the sensitivity test specified in 81.2.1, the following is to be conducted:

a) It is not prohibited that the same alarms remain powered, and are allowed to pre-condition at the ambient condition specified in 41.2 or gradually transition to the ambient condition specified in 41.2 by turning off the variable ambient chamber and opening the environmental chamber door. The samples are allowed to remain in the ambient condition specified in 41.2 for a maximum of 16 hours prior to initiating the next ambient temperature of minus 40. This 16 hour time period of pre-conditioning is to include the time required to transition to the ambient condition specified in 41.2. The time period to transition to the ambient condition specified in 41.2 shall not exceed 4 hours; or

b) The samples are to remain in the chamber, without powering down the samples, and without removing the samples from the chamber. The environmental chamber is to be set to transition to the next environmental condition as quickly as possible. The transition temperature and humidity from 81.2.3 to the next environmental condition shall not exceed 60 minutes.

The environmental chamber is to be set to minus 40 ±2 °C (minus 40±4 °F) with a relative humidity of 45 +10 percent/ -5 percent for 24 hours. The environmental chamber temperature and relative humidity are to be controlled to ensure that the transition between temperatures does not result in a condensing environment.

81.2.5 Following each environmental condition specified in 81.2.3 and 81.2.4, the sensitivity tests are to be conducted at the conclusion of the 24-hour conditioning environment.

81.2.6 Sensitivity testing shall not be conducted during the pre-conditioning of the samples as specified in 81.2.4 (a) and (b).

81.2.7 The same three alarms used for the temperature conditioning are to be used for the vibration conditioning specified in 81.2.8 and 81.2.9.

81.2.8 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 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 the vibration frequencies and amplitude specified in 81.2.9.

81.2.9 The alarms are to be subjected to a variable frequency vibration along each of three rectilinear orientation axes (horizontal, lateral, and vertical) for 4 hours in each plane (12 hours total) at a peak-to-peak amplitude of 0.015 ±0.001 inches (0.40 ±0.05 mm). The frequency of vibration is to be continuously varied, at a uniform rate, from 10 to 60 to 10 hertz every 4 minutes.

81.2.10 For this test, peak-to-peak amplitude is defined as the maximum displacement of sinusoidal motion (total machine displacement).

81.2.11 The same three alarms used for the vibration conditioning are to be used for the conditioning specified in 81.2.12 – 81.2.15.

81.2.12 The alarms are to be mounted on a shock machine in the same manner as described in the vibration conditioning specified in 81.2.8 and 81.2.9. The shock machine is to produce repeated shock pulses as specified in 81.2.13.

81.2.13 The samples are to be subjected to 5000 shock impacts of 10 g acceleration (98 m/s2) and having a shock duration of 20 – 25 milliseconds as measured at the base of the half-sine shock envelope.

81.2.14 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.

81.2.15 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.

81.2.16 The same three alarms used for the shock conditioning are to be used for this 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 conditioning.

81.2.17 Immediately following the conditioning specified in 81.2.16, 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.

81.3 Watertightness test

81.3.1 A alarm marked "Watertight" is to be tested as specified in 81.3.2. There shall be no evidence of water leakage so as to reach energized parts. No false alarms (or pre-alarms) shall be generated and the alarm shall operate as intended.

81.3.2 One sample detector 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-inch (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 feet (3.1 m) for 5 minutes.

81.3.3 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.

81.3.4 An alarm that complies with this test shall be marked in accordance with 81.7.4. See also 81.7.5.

81.4 Drip test

81.4.1 An alarm not marked "Watertight" is to be tested as specified in 81.4.2 and 81.4.3. No false alarms (or pre-alarms) shall be generated and the alarm shall operate as intended.

Exception: An alarm determined to be watertight complies with this test and does not require testing. See 81.3.

81.4.2 One sample alarm from the humidity conditioning, 81.2.16 and 81.2.17, is to be used for this test. The alarm is to be energized and mounted in accordance with the manufacturer's installation instructions beneath a drip pan that produces both splashing and dripping and that extends beyond all exposed sides of the enclosure. The bottom of the drip pan is to be equipped with uniformly distributed spouts; one spout for each 20 square inches (129 cm^2) of pan area. Each spout is to drip water at a rate of 20 drops per minute. The enclosure is to be subjected to continuously dripping water for 30 minutes.

81.4.3 The alarm is to be oriented from 0 – 15° from the vertical during the test.

81.4.4 An alarm that complies with this test shall be marked in accordance with 81.7.5.

81.5 Abnormal operation tests

81.5.1 After each of the conditions described in 81.5.3, 81.5.5, and 81.5.6, three sample alarms shall activate the alarm in the time specified in 81.5.4, 81.5.5, and 81.5.7, respectively.

81.5.2 The same three alarms used in the Operation tests following conditioning, 81.2 are to be used for the tests in 81.5.3 – 81.5.8.

81.5.3 The alarms are to be energized and placed in a controlled chamber maintained at 23 ±3 °C (73 ±5 °F). The chamber is to be filled with a carbon monoxide concentration of 5,000 ±125 ppm.

81.5.4 As soon as or before the carbon monoxide concentration in the chamber reaches 5,000 ± 125 ppm, each detector shall activate the alarm (for presence of carbon monoxide) in 3 minutes or less.

81.5.5 Immediately following the test in 81.5.4 and while still in the chamber, each detector is to be turned off for 4 hours and subjected to 5,000 ±125 ppm. Following this exposure, each detector is to be energized and shall activate either the presence of carbon monoxide alarm or the malfunction alarm in 3 minutes or less.

81.5.6 While the alarms are still energized and in the chamber following the test in 81.5.5, the chamber is to be completely purged with fresh air and maintained at 23 ±3 °C (73 ±5 °F). The alarms shall return to their normal operating mode within 4 hours. As soon as the alarms have returned to their normal operating mode the chamber is to be filled with 150 ppm of carbon monoxide as specified in Table 41.1 part A.

81.5.7 The sensitivity reading of the alarm samples shall not, in any case, exceed the 50 minutes as specified in Table 41.1 part A.

81.5.8 Immediately following the test in 81.5.7 and while still in the chamber, each alarm is to be turned off for 4 hours and subjected to 185 ppm. Following this exposure, each alarm is to be energized and shall activate either the presence of carbon monoxide alarm or the malfunction alarm in 100 minutes or less.

81.6 Salt-spray corrosion test

81.6.1 One sample alarm from the Abnormal operation tests, 81.5, shall operate as intended and its 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 41.

81.6.2 An 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.

81.7 Marking

81.7.1 In addition to the applicable requirements in Section 89, a carbon monoxide 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 inch (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 Carbon Monoxide Alarm," or the equivalent. It is not prohibited that this marking be incorporated in (g); and

g) Identification of switches and light indicators.

81.7.2 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.

81.7.3 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.

81.7.4 An alarm that complies with the requirements in the Watertightness test, 81.3, shall be marked "Watertight."

81.7.5 An alarm not marked in accordance with 81.7.4 shall be marked "For enclosed spaces only," or the equivalent.

81.8 Operating and installation instructions

81.8.1 Each alarm shall be provided with installation and operating instructions that include the following information:

a) Typical installation drawing layouts for the detector(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) Replacements 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 (or pre-alarm) 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 feet (1.5 m) of any cooking appliance.

81.8.2 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.

81.8.3 The material shipped with the alarm, including the package, instructions, or user's manual, shall not include information contrary to that specified in 81.7.1, 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 TESTS

82 General

82.1 To verify compliance with these requirements in production, the manufacturer shall provide the necessary production control, inspection, and tests. The program shall include at least the tests specified in Sections 83 – 87 conducted on 100 percent of the production. See the Manufacturing and Production Tests, Annex B.

83 Sensitivity Calibration Tests

83.1 The sensitivity of each alarm shall be checked, following the warm-up period specified by the manufacturer, using appropriate instruments to determine that the sensitivity levels are within the marked rating including tolerance, which is within the alarm's specified limits. The test equipment shall verify the value or range of sensitivities marked on the alarm. The value of indication shall be in the form of ppm carbon monoxide and time.

83.2 For the warm-up period, the alarms are to be energized from a source of supply in accordance with 37.3.1. If the alarm sensitivity is not within the manufacturer's specifications, the unit is to be corrected and retested. If a retested sample is still outside the specification, it is to be rejected.

83.3 A warm-up period is required for those alarms employing components whose characteristics are likely to vary during initial warm-up, such as solid-state devices operating at greater than 25 percent of rating, lamp filaments, resistors, and other components that affect sensitivity.

83.4 A warm-up period is not required if the alarm components are operated at not more than 25 percent of rating in the standby condition or if the individual components are burned-in prior to assembly.

84 Measurement of In-Service Reliability

84.1 Required in-service reliability

84.1.1 Reliability for Supervised Failures: CO detectors shall have a mean time between failure (MTBF) of no less than 100,000 hours when estimated at a 90 percent confidence level for Supervised Failures averaged over the devices' specified lifetime. At this failure rate the cumulative Supervised Failures over the devices' specified lifetime shall not exceed 23 percent at a 90 percent confidence level.

84.1.2 Reliability for Unsupervised Failures: CO detectors shall have a mean time between failure (MTBF) of no less than 166,667 hours when estimated at a 90 percent confidence level for Unsupervised Failures averaged over the devices' specified lifetime. At this failure rate the cumulative Unsupervised Failures over the devices' specified lifetime shall not exceed 14.6 percent at a 90 percent confidence level.

84.2 Sample frequency and sample size

84.2.1 In-service reliability shall be estimated by subjecting a suitable sample of devices to the Sensitivity Test of Section 41 and Table 41.1 for tests at CO concentrations of 70, 150, and 400 ppm. The test at 30 ppm shall be excluded.

84.2.2 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.

84.2.3 Prior to testing, devices shall be installed and operated in an actual or simulated residential 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.

84.2.4 The sample size for tests shall be determined according to widely accepted procedures for statistical quality control, as summarized in Annex E. A statistically significant sample of representative devices shall be randomly chosen to estimate the required in-service reliability at the required confidence level.

84.3 Test results and record keeping

84.3.1 The manufacturer shall maintain data and records of all tests performed to evaluate devices' conformance to the required in-service reliability.

85 Production Line Dielectric Voltage-Withstand Tests

85.1 Each alarm rated at more than 30 volts AC (42.4 volts DC or AC peak) shall withstand, without breakdown, as a routine production-line test, the application of an essentially sinusoidal AC voltage of a frequency within the range of 40 to 70 hertz, or a DC voltage, between hazardous-voltage circuit live parts and the enclosure, high-voltage live parts and exposed dead (grounded) metal parts, and live parts of circuits operating at different voltages or frequencies. The test voltage is to be:

a) For an alarm rated at 250 volts AC or less – either 1000 volts (1414 volts, if a DC voltage is used) applied for 60 seconds or 1200 volts (1697 volts, if a DC voltage is used) applied for 1 second.

b) For an alarm rated at more than 250 volts – either 1000 volts plus twice the rated voltage (1414 volts plus 2.828 times the rated AC voltage, when a DC voltage is used) applied for 60 seconds or 1200 volts plus 2.4 times the rated voltage (1697 volts plus 3.394 times the rated AC voltage, if a DC voltage is used) applied for 1 second.

Exception: A product, the enclosure of which is entirely comprised of polymeric materials, is not required to be subjected to this test if there are no exposed dead metal parts that may become energized under fault conditions.

85.2 If the alarm employs hazardous-voltage and extra-low-voltage circuits, the test is to be conducted with the extra-low-voltage circuit connected to the cabinet, chassis, or other dead (grounded) metal parts so that the voltage that is applied between the hazardous-voltage live parts and dead (grounded) metal parts will be applied simultaneously between hazardous-voltage live parts and extra-low-voltage circuits.

85.3 In cases where the application of the test potential will either damage or short-circuit a printed-wiring assembly or other electronic-circuit component, the assembly or component shall be disconnected or otherwise rendered inoperative prior to the test. It is not prohibited that a representative subassembly be tested instead of an entire unit.

85.4 A 500 volt-amperes or larger transformer, the output voltage of which is variable, is to be used to determine compliance with 85.1. A 500 volt-amperes or larger transformer is not required if the high voltage testing equipment used is such that it maintains the specified high voltage at the equipment for the duration of the tests.

85.5 The test equipment used for this test is to include a visible indication of application of the test voltage 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 shall not be considered unless determined to achieve the results contemplated.

85.6 If 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 voltage, the alarm is to be tested using a DC test voltage in accordance with 85.1.

86 Production Line Grounding Continuity Tests

86.1 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 pin of the attachment-plug.

86.2 For this test, the manufacturer is to employ an acceptable resistance-indicating instrument with leads and terminals by which the grounding circuit continuity is determined.

86.3 If an investigation of the alarm has shown all exposed dead metal parts that will 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 pin and the frame or enclosure is sufficient.

87 Audibility Test

87.1 The manufacturer shall test a minimum of two sample alarms per production lot and shift to verify that the sound output level of the representative production samples can produce a minimum 85 db sound pressure level, as measured in accordance with 67.2 or the equivalent.

88 Alarm Shipment

88.1 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.

88.2 A nonrechargeable standby battery of an AC operated accessory to a single- or multiple-station alarm is not required to be shipped with the unit provided instructions on the unit specify the battery to be used by model number and manufacturer. A rechargeable standby battery shall be shipped with the unit in which it is to be employed.

MARKING

89 General

89.1 Markings shall comply with the following:

a) The marking shall be in a contrasting color, finish, or equivalent.

b) Unless the letter height is specified, all markings shall be at least 3/64 inch (1.2 mm) high.

c) The removal or opening of an enclosure cover or the removal of mounting screws, or an equivalent arrangement to view the marking is acceptable with the exception of the “do not paint” marking and 89.2(c).

89.2 The following markings are required to be on all alarms:

a) Name or identifying symbol and address of the manufacturer or private labeler.

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), and DAY (in 2 digits) located on the outside surface of the CO alarm.

c) Identification of the product (carbon monoxide alarm shall be marked in contrasting color from the background on the face of the unit), lights, switches, and meters, regarding their function unless their function is obvious. The following message shall be located adjacent to the visual indicator for alarm: "Exit to fresh air."

d) Maximum rating of fuse in each fuse holder.

e) Identification of batteries by part number, manufacturer's model number or equivalent, located adjacent to the component.

f) Reference to the manufacturer’s published instructions.

g) Maintenance instructions, such as cleaning and battery replacement.

h) Distinction between alarm, pre-alarm, end-of-life, and trouble signals on units employing these signals.

i) 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.

j) If a manufacturer produces alarms at more than one factory, each such assembly shall have a distinctive marking to identify it as the product of a particular factory.

k) The following warning shall be placed on the carbon monoxide alarm. The hazard symbol and letters used for the word "WARNING" shall be boldfaced type having a minimum letter height of 0.120 inch (3.05 mm). The minimum vertical spacing between lines of type shall be 0.046 inch (1.17 mm).

Carbon monoxide (CO) is a colorless, odorless, poisonous gas. You can't taste, see, or smell CO, but it can kill in just minutes.

This alarm will sound in a 4-beep pattern if life threatening levels of CO are detected.

If the alarm sounds:

1) Immediately evacuate all occupants from the space and go outdoors to fresh air.

2) Call emergency responders (911 or fire department) for help; notify the building or vehicle owner, as necessary.

l) An alarm not intended to be painted in use shall be marked on the outer surface of the enclosure with the following or equivalent notice: "Do Not Paint" or the symbol below (min 1/2” in diameter. The letters shall not be less than 1/8 inch (3.2 mm) high. See the Paint Loading Test, Section 69.

m) For a battery operated alarm, 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 May Have A Detrimental Effect On Alarm Operation." The letter height shall be a minimum of 1/8 inch (3.2 mm) for "WARNING" and 3/64 inch (1.2 mm) for the rest of the notice.

n) For an alarm employing a nonrechargeable standby battery the marking information described in 16.3 shall be in letters not less than 1/8 inch (3.2 mm) high.

89.3 The following or equivalent qualifying statement on a battery-operated alarm where battery operation, under other than normal room temperature conditions during the long term battery tests, is less than 12 months but not less than 6 months or less than 10 years for a sealed 10-year alarm must be marked on the alarm. "Constant exposures to high or low temperatures or high humidity may reduce battery life."

89.4 The following may be marked on the alarm or be included the manufacturer's published instructions:

a) For AC (mains powered) alarms: Electrical rating, in volts, amperes, or watts, and frequency.

b) Correct mounting position if a unit is intended to be mounted in a definite position. Carbon monoxide alarms that comply with 68.5.2 shall include marking information that clearly indicates that the product is only intended for installation on the ceiling, or on the wall no more than 12 inches from the ceiling.

c) Reference to a source for battery replacement.

d) A battery-operated alarm that employs a battery trouble silence feature shall describe its operation.

e) The sensitivity setting. The marked sensitivity shall be indicated by ppm and time.

89.5 If 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 inch (3.2 mm) high is to be provided on the outside or inside of the alarm: "Additional marking on back. Disconnect power."

89.6 Additional marking requirements are specified in 13.6.4, 19.5.1 and 21.2.1.

89.7 With regard to the requirement in 7.3, a warning flag or hinged cover as described in 7.1 or 7.2 (inside or outside), or equivalent, shall be marked with the word "WARNING" and the following or equivalent text: "Battery Has Been Removed." The letter height shall be a minimum of 3/8 inch (9.5 mm).

90 Marking Permanence

90.1 General

90.1.1 Markings affixed to a carbon monoxide alarm shall be sufficiently durable as to resist the deleterious effects of handling, cleaning agents, and the like, expected in the intended use.

90.1.2 Two or more label samples are to be provided with all of the required markings printed as specified in this Standard (e.g. required letter height). Each sample that includes indelibly-printed, pressure-sensitive labels secured by adhesive that, upon investigation, is rated for the type of surface and temperatures of the surface to which it is affixed, shall comply with the requirements specified in UL 969 and CSA C22.2 No. 0.15. All “Exposure Conditions” shall apply to marking and labeling systems as follows:

a) The maximum “Test Temperature” shall be conducted at 87 ±2 °C (189 ±3.6 °F), as specified in UL 969;

b) The minimum “Test Temperature” shall be conducted at minus 40 ±5 °C (minus 40 ±5 °F), as specified in CSA C22.2 No. 0.15;

c) The “Humidity Exposure” test shall be conducted at 40 ±2 °C (104 ±3.6 °F) at relative humidity of 95 ±5 % for a period of 72 ±0.5 hour, with the sample placed vertically in the environmental chamber. Following the conditioning period, the sample shall be placed in an ambient environment that is 23 ±5 °C (73.4 ±9.0 °F) and a relative humidity of 50 ±30 % for a minimum of 24 hour, then subject to visual examination and the Adhesion Test, as specified in CSA C22.2 No. 0.15;

d) For the “Adhesion Test”, the average quantitative adhesion value shall be at least 0.20 N/mm (1.14 lb/in), as specified for Type A labels in CSA C22.2 No. 0.15; and

e) The “Water Immersion” test shall be conducted as specified in 7.1, All marking and labeling systems, of UL 969.

90.1.3 Following each of the test conditions specified in 90.1.2, label samples shall meet the requirements of Section 4, General, in the Performance subdivision of UL 969, except the average quantitative adhesion value shall be at least 0.20 N/mm (1.14 lb/in).

90.1.4 Painted, stenciled, and ink stamped, other than on a pressure-sensitive label, that is evaluated in accordance with the requirements in the Permanence of Marking Test, 90.2.

90.2 Permanence and legibility of marking test

90.2.1 If required under 90.1.4, the manufacturer is to submit two samples of the painted, stenciled, ink stamped, or other means of permanent ink markings applied to the material on which it will be placed. Both samples are to be immersed in de-mineralized water for 48 hours. Upon completion of the conditioning, the markings are to be vigorously rubbed back and forth 10 times, with thumb or forefinger, with a downward force of approximately 18 N (4 lb-f). The results are considered acceptable if the marking remains legible, as specified in UL 969.

INSTRUCTIONS

91 General

91.1 Each single and multiple station carbon monoxide alarm shall be provided with installation instructions which shall include the following information:

a) Typical installation drawing layouts for the unit(s) indicating locations and wiring methods which shall be in accordance with the National Electrical Code or Canadian Electrical Code. Locations where alarms are not to be installed shall also be included.

b) Description of the operation, testing, and proper maintenance procedures for the unit(s).

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 parts are obtainable.

d) The hazard symbol ⚠, the word "WARNING," and at least the following or equivalent information in an obvious and prominent manner, such as by being underlined, encircled, or printed in larger or different color type. The letters used for the word "warning" shall be boldfaced in a color that contrasts with the background and shall be a minimum size of 18 points or a minimum of 1.5 times larger than the safety message letters. The letters used for the safety message words shall be boldfaced Helvetica type with a minimum size of 12 points. Lowercase letters shall be compatible with the uppercase letter specification. The safety message shall be separate and distinct from the other messages and graphics in the owner's manual.

⚠ "WARNING"

Carbon monoxide (CO) is a colorless, odorless, poisonous gas. You can't taste, see, or smell CO, but it can kill in just minutes.

This alarm will sound in a 4-beep pattern if life threatening levels of CO are detected.

If the alarm sounds:

1) Immediately evacuate all occupants from the space and go outdoors to fresh air.

2) Call emergency responders (911 or fire department) for help; notify the building or vehicle owner, as necessary.

e) This carbon monoxide alarm is designed to detect carbon monoxide gas from ANY source of combustion. It is NOT designed to detect smoke, fire or any other gas, unless the product has been investigated and determined to comply with the applicable requirements.

f) More detailed information on the alarm, pre-alarm, end-of-life, and trouble signals and an indication where false alarms or trouble signals would be anticipated; such as to reduce the possibility of nuisance tripping of the alarm's alarm circuit, the instructions shall state that accommodation spaces are to be well ventilated when household cleaning supplies or similar contaminants are used. 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 users 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 acceptable for installation at a higher or lower ambient temperature, in which case those tested extreme operating temperatures shall be listed in the manual.

i) Reference to a source(s) of limited energy cable for multiple station interconnection or connection of supplementary devices.

j) The following symptoms are related to CARBON MONOXIDE POISONING and are to be discussed with ALL members of the household:

1) Mild Exposure: Slight headache, nausea, vomiting, fatigue (often described as "Flu-like" symptoms).

2) Medium Exposure: Severe throbbing headache, drowsiness, confusion, fast heart rate.

3) Extreme Exposure: Unconsciousness, convulsions, cardiorespiratory failure, death.

4) Many cases of reported CARBON MONOXIDE POISONING indicate that while victims are aware they are not well, they become so disoriented they are unable to save themselves by either exiting the building or calling for assistance. Young children and household pets are typically the first affected.

k) The following information:

1) Name and address of manufacturer or private labeler.

2) Model number.

3) Electrical rating in volts, amperes or watts, and frequency. Not required for battery operated alarms.

4) Name and address of firm to whom alarm is to be sent for servicing.

l) For 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 adjacent apartments may have similar systems.

m) For alarms also acceptable for installation in recreational vehicles, the word "WARNING," and the following or equivalent text: "TEST ALARM OPERATION AFTER VEHICLE HAS BEEN IN STORAGE, BEFORE EACH TRIP, AND AT LEAST ONCE PER WEEK DURING USE." A label with identical marking is to be provided by the alarm manufacturer, with instructions that it be permanently and visibly located within 24 inches (610 mm) of the alarm.

n) The word "WARNING" and the following or equivalent text: " This product is intended for use in ordinary indoor locations of family living units. It is not designed to measure compliance with Occupational Safety and Health Administration (OSHA) commercial or industrial standards."

Exception: If a manufacturer chooses a concentration level below 70 ppm for the tests in this standard it is not prohibited that the warning be revised to reflect actual testing.

o) The word "CAUTION" and the following or equivalent: "This alarm will only indicate the presence of carbon monoxide gas at the sensor. Carbon monoxide gas may be present in other areas."

p) The instructions shall also state that individuals with medical problems may consider using warning devices which provide audible and visual signals for carbon monoxide concentrations under 30 ppm.

q) A statement shall be provided to specify that the alarm, including a sensor, is not to be located within 5 feet (1.5 m) of any cooking appliance.

r) More detailed information on conditions which can result in transient CO situations, such as:

1) Excessive spillage or reverse venting of fuel burning appliances caused by:

i) Outdoor ambient conditions such as wind direction and/or velocity, including high gusts of wind; heavy air in the vent pipes (cold/humid air with extended periods between cycles).

ii) Negative pressure differential resulting from the use of exhaust fans.

iii) Simultaneous operation of several fuel burning appliances competing for limited internal air.

iv) Vent pipe connection vibrating loose from clothes dryers, furnaces, or water heaters.

v) Obstructions in or unconventional vent pipe designs which amplify the above situations.

2) Extended operation of unvented fuel burning devices (range, oven, fireplace, etc.).

3) Temperature inversions which can trap exhaust gasses near the ground.

4) Car idling in an open or closed attached garage, or near a home.

s) A minimum of two self-adhesive labels with the information as described in 91.1(d) shall be provided by the alarm manufacturer. Directions shall instruct the user of the alarm to add the telephone numbers of their emergency service provider and a qualified technician to the labels. Instructions shall be given for the user of the alarm to place one label next to the alarm, and the other label near a source of fresh air where they plan to gather after the alarm indicates the presence of carbon monoxide.

t) Products that comply with 68.5.2 and are not subjected to the Impact Test, 68.5, shall include information clearly indicating that the user shall actuate the test and/or alarm reset/silence feature remotely (via an electronic signal or aerosol test gas), or by use of a person's finger or thumb, and that the use of any other instrument(s) is strictly prohibited.

u) 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.

91.2 The instructions may be incorporated on the outside of the unit, on a separate sheet, or as part of a manual. If not included directly on the device, the instructions or manual shall be referenced in the marking information on the unit.

91.3 The material shipped with the alarm, including the package, instructions, or user's manual, shall not include information other than that specified in 91.1, such as manufacturer's claims on the operation of the alarm which have not been substantiated by the performance tests included in this or other standards. The package, instructions, and user's manual shall include the information described in 91.1 (c), (k), (n), and (p). The package shall also include the end-of-life information described in 91.1(f).

91.4 For multiple-station interconnected carbon monoxide alarms with alarm reset/silencing means, other than physically depressing the reset/silence button, the resetting/silencing of the initiating alarm shall describe the following:

a) An example and information detailing the alarm information as communicated to the user. The remote silencing device shall provide instructions to the user as noted in item (b) below after the user attempts to activate the remote reset/silence feature;

b) At a minimum, all instructions and the remote device (if provided) shall include instructions to the user to move to fresh air upon activation of an alarm signal.

92 Installation and Operating Instructions for Evaluation

92.1 A copy of the installation and operating instructions intended to accompany each unit or component, or equivalent information, is to be included in the examination and test of the equipment. For this purpose a draft, rather than a printed edition, is suitable.

92.2 The instructions and drawings shall include such directions and information as deemed by the manufacturer to be necessary for proper and safe installation, testing, maintenance, operation, and use of the alarm. Such instructions and drawings shall comply with the requirements of Instructions, General, Section 91.

ANNEX A (Informative) – RELIABILITY AND FAILURE RATE DETERMINATION INFORMATION

The information contained in this supplement is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. As such, this supplement may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary to fulfill the objectives of the standard.

GENERAL

A1 Instructions for Determining a Reliability Prediction for Carbon Monoxide Alarms

A1.1 Make a list of every component in the alarm.

A1.2 By circuit analysis or experimentation, determine the effect of any failure mode (short or open) of each component on the alarm operation and the rationale for the decision. This will determine if a component is to be considered critical, conditionally critical, or noncritical.

A1.3 A component is considered noncritical if all failure modes of the component will result in a trouble signal, or have no effect on the intended operation of the alarm for alarm and trouble signals, and will not affect the alarm sensitivity.

A1.4 A component is considered critical if two or more failure modes of the component, which will affect the intended operation or the sensitivity of the alarm, do not result in a trouble signal[a].

A1.5 A component is considered conditionally critical if only one failure mode of the component will affect the intended operation or the sensitivity of the alarm, and does not result in a trouble signal[a].

[a] A trouble signal may be indicated by energization of an audible signal, energization of a separate visual indication (amber or orange), or de-energization of a power-on light. If a visual indication is depended on to denote a trouble condition, it shall have a documented predicted failure rate of not greater than 2.5 failures per million hours.

A1.6 Make a list of all critical and conditionally critical components in the alarm.

A1.7 For each critical and conditionally critical component, the expected failure rate, based upon a minimum confidence factor of 60 percent, may be determined from the screening burn-in or published component reliability data method.

A1.8 For each conditionally critical component, the expected failure rate may be determined by calculating only the failure rate for the mode meeting the conditions of A1.5 or by applying a 0.75 multiplying factor to the value determined by the PARTS COUNT or PARTS STRESS ANALYSIS method described in MILITARY HANDBOOK 217b).

A2 Methods of Determining Failure Rate

A2.1 PARTS COUNT METHOD – When using this method the failure rate is to be determined as follows, using Section 3 of Military Handbook 217b):

a) Employ generic failure rate from Table A2.1 – Table A2.6 which most closely approximates the component employed.

b) Determine the quality factor multiplier for each component from Table A2.7 – Table A2.9.

c) Multiply each generic failure rate by its associated quality factor multiplier to obtain the final failure rate for the component. See example calculation, Table A2.10.

d) Add all individual failure rates of critical and conditionally critical components to obtain the overall failure rate for the alarm.

NOTE – Mil-specification numbers in Table A2.4 and Table A2.5 are provided for reference only to determine general component type.

Table A2.1
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.	

Table A2.2
Generic Failure Rate for Standard Bipolar Beam Lead and ECL, Bipolar and MOS Linear, and All Other MOS Devices in Failures 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.	

Table A2.3
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

Table A2.3 Continued on Next Page

Table A2.3 Continued

Part type	Failure rate
Diodes	
Silicon, general-purpose	0.12
Germanium, general-purpose	0.26
Zener and avalanche	0.16
Thyristor	0.16
Silicon microwave detector	2.2
Ge microwave detector	5.6
Silicon microwave mixer	3.0
Ge microwave mixer	10.0
Varactor, step	1.5

[a] A lower failure rate (0.16 failures/106 hours) may be assigned when the construction of the device is comparable to that of a thyrister.

Table A2.4
Generic Failure Rate for Resistors in Failures Per Million Hours

Resistors, fixed			Failure rate
Construction	Style	Mil-R-Spec. (reference only)	
Resistors, fixed			
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	12934	2.7
Wire-wound, semi-precision	RA	19	2.3
Wire-wound, semi-precision	RK	39002	2.3
Wire-wound, power	RP	22	2.3
Nonwire-wound, trimmer	RJ	22097	4.6
Composition (common pot)	RV	94	
Factory preset and sealed			0.46
Field variable			3.7

Table A2.5
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 A2.6
Generic Failure Rate for Miscellaneous Parts in Failures Per Million Hours

Part type	Failure rate
Pulse transformer	0.0027
Audio transformer	0.0066
Power transformer and filters	0.021
RF transformer and coils	0.022
Connectors	0.45
Connections	
Solder, reflow lap to printed-wiring boards	0.00012
Solder, wave to printed-wiring boards	0.00044
Other hand solder connections	
(for example, wire to terminal board)	0.0044
Crimp	0.0073
Weld	0.002
Wirewrap	0.0000037
Coaxial connectors	0.63
Toggle switches	0.57
Push button switches	0.38
Sensitive switches	0.90
Rotary switches	1.4

Table A2.6 Continued on Next Page

Table A2.6 Continued

Part type	Failure rate
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 boards	0.30
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. Selected 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 A2.7
Quality Factors for Table A2.1 and Table A2.2

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 A5.1	8

Table A2.8
Quality Factor for Table A2.3

Part class	Quality factor
JANTXV	0.1
JANTX	0.2
JAN	1.0
Commercial grade	1.0

Table A2.9
Quality Factor for Table A2.4 and Table A2.5

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 is 1.5. The quality factor for all miscellaneous parts is 1.0.	

Table A2.10
Alarm Reliability Prediction – Parts Count Method Sample Calculation

Component	Generic failure rate (A)	Quality factor multiplier (B)	Failure rate 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, dry 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
Total alarm failure			3.371

A2.2 [a]PARTS STRESS ANALYSIS METHOD – The failure rate is calculated using the procedure in Military Handbook 217B, Section 2. Calculations and supporting data on rating of components for the determination will be required for review. See also Table A2.11 and Figure A2.1 for equations and tabulation sheets.

[a] If a Mil-Spec component is required in an alarm but does not employ a specific marking to that effect, it will be necessary for the alarm manufacturer to provide documentation to verify that the component is Mil-Spec graded. The documentation may be in the form of a shipping order, invoice, or equivalent, provided by the component vendor.

Table A2.11
Parts Stress Analysis Method References

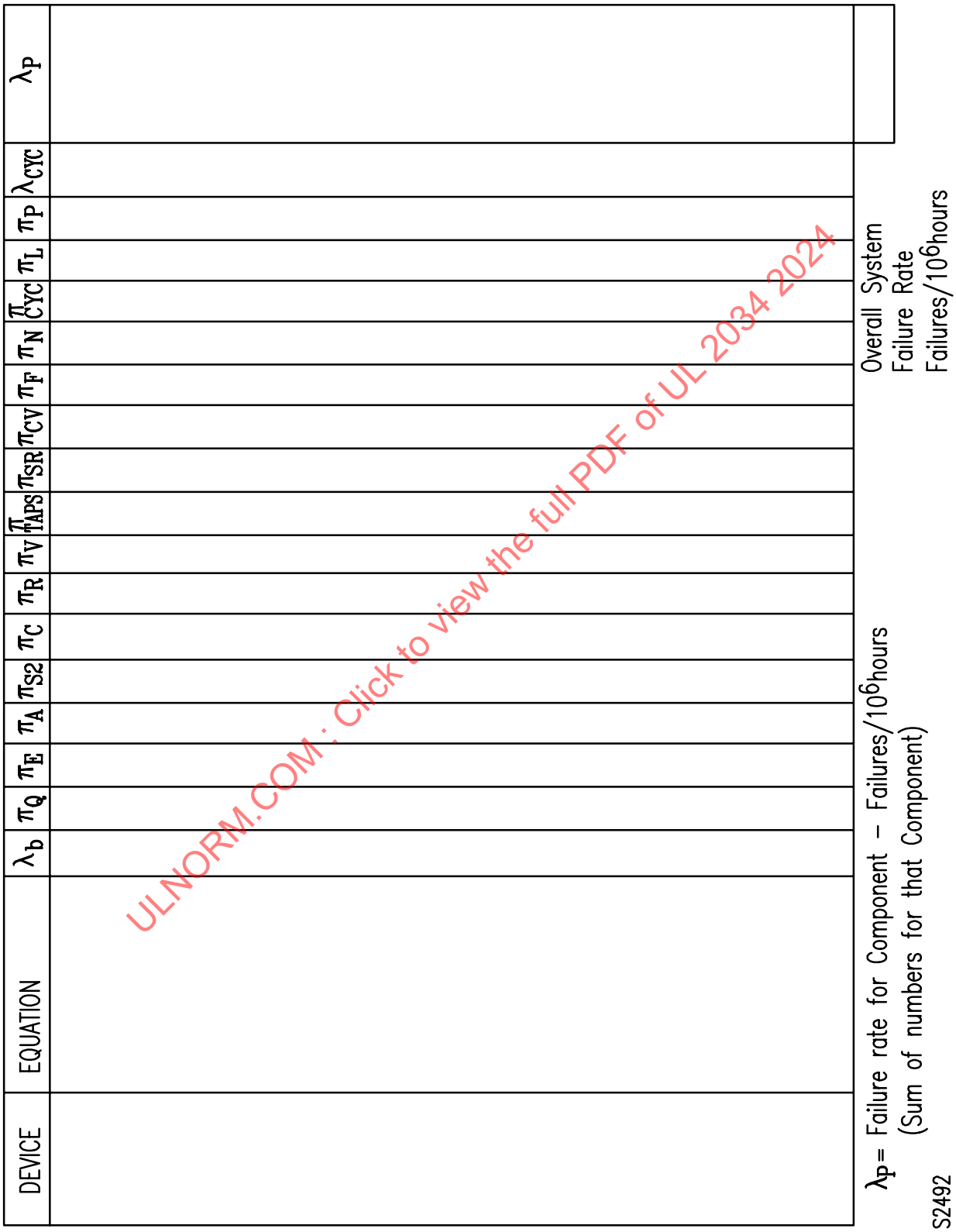
Type device	Applicable equation	MIL-HDBK-217B 9/20/74 page reference
Monolithic bipolar and MOS digital SSI/MSI devices 100 gates or 400 transistors		2.1.1-1
Monolithic bipolar and MOS linear devices		2.1.2-1
Monolithic bipolar and MOS digital LSI devices 100 gates or 400 transistors		2.1.3-1
Monolithic MOS and bipolar memories		2.1.4-1
Hybrid devices		2.1.7-1
Transistors Group I, general purpose		2.2.1-1
Transistors Group II, field effect transistors		2.2.2-1
Transistors Group III, unijunction		2.2.3-1
Diodes, Group IV, general-purpose		2.2.4-1
Diodes, Group V, zeners		2.2.5-1
Diodes, Group VI, thyristers		2.2.6-1
Diodes, Group VII, microwave detectors and mixers		2.2.7-1
Diodes, Group VIII, varactor step recovery tunnel		2.2.8-1
RCR and RC insulated fixed composition		2.5.1-1
RLR, RL, RNR, RN, fixed film-insulated		2.5.2-1
RD/P power film		2.5.2-5
RBR and RB fixed wire wound		2.5.3-1
RWR and RW power-type fixed wire-wound		2.5.3-3
RER and RE power-type, chassis-mounted fixed wire-wound		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		2.5.5-1
RR precision wire-wound potentiometers		2.5.5-3
RA and RK (Not ER) semi-precision wire-wound potentiometers		2.5.5-7
RP high-power wire-wound potentiometers		2.5.5-13
RJ nonwire-wound trimmers		2.5.6-1
RV composition potentiometers		2.5.6-5
CPV paper and plastic film, Est. Rel.		2.6.1-1
CHR metalized paper, Est. Rel.		2.6.1-1
CQ & CQR paper and plastic film, ER & NON-ER		2.6.1-1
CM mica-molded, CMR mica-dipped, Est. Rel.		2.6.2-1
CB button mica		2.6.2-3
CYR glass capacitors, Est. Rel.		2.6.3-1
CK ceramic, general-purpose, CKR ceramic, general-purpose, Est. Rel.		2.6.4-1
CC ceramic, temperature compensating		2.6.4-5
CSR solid tantalum electrolytic, Est. Rel.		2.6.5-1
CLR nonsolid tantalum, Est. Rel., CL nonsolid tantalum, NON Est. Rel.		2.6.5-3

Table A2.11 Continued on Next Page

Table A2.11 Continued

Type device	Applicable equation	MIL-HDBK-217B 9/20/74 page reference
CU aluminum oxide electrolytic		2.6.6-1
CE aluminum, dry electrolyte		2.6.6-3
CV variable ceramic capacitors		2.6.7-1
PC variable, piston-type tubular trimmer		2.6.8-1
Transformers		2.7-1
Motors, high-speed		2.8.1-1
Blowers		2.8.2-1
Relays		2.9-1
Switches, snap-action toggle or pushbutton		2.10-1
Basic sensitive switches		2.10-2
Rotary, ceramic or glass wafer silver alloy contacts		2.10-3
Connectors		2.11-1
NOTE: $_Q$ multiplier same as for JAN Class C if Table A5.1 screening is conducted.		

Figure A2.1
Tabulation Sheet



A2.3 SCREENING BURN-IN METHOD – This method is required for the evaluation of custom integrated circuit "chips" although it may also be applied to any other component of an alarm, including generic "chips." The evaluation shall 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. Refer to Criteria for Acceptance of Microelectronic Devices, Sections A4 – A6.

A2.4 ALTERNATE METHOD (GENERIC DEVICES ONLY) – An alternate for generic components only shall consist of the burn-in test program to determine the numerical failure rate coupled with the component manufacturer's standard screening program which is employed for the device family of the component. The condition of acceptance of the limited screening shall include the following:

a) A test sample lot shall be screened in accordance with the component manufacturer's standard program and then subjected to the Burn-In Test described in Sections A4 – A6.

b) The component manufacturer shall provide failure rate data on the particular device being tested or the device family[b] from a second source, such as field failure rate data or a separate burn-in test.

c) A comparison of the burn-in test data from A2.4(a) and A2.4(b) shall be made and results from A2.4(a) shall not be worse than those in A2.4(b) by one order of magnitude (10:1).

[b] Similar devices manufactured under same process and design rules.

A2.5 PUBLISHED RELIABILITY DATA – This method may be employed for the evaluation of generic integrated circuit "chips" as well as any other component of an alarm, except for a custom "chip." The evaluation is derived by the use of generic failure rate data from industry and military recognized 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," "Digital Generic Data." Devices evaluated by this method shall conform to the identification program in A4.3, and the minimum screening program of Table A5.1.

A2.6 The overall failure rate of the components of an alarm may be evaluated by combination of two or more of the failure rate determination methods described in A2.1, A2.2, A2.3, A2.4, and A2.5.

A3 Maximum Alarm Failure Rates

A3.1 The overall failure rates for the alarm shall not be greater than indicated in Table A3.1.

Table A3.1
Maximum Alarm Failure Rate

Method of failure rate computation	Maximum alarm failure rate (failures per million hours)
Parts count	3.5
Parts stress analysis	4.0
Screening burn-in	4.0
Published reliability data	4.0
Any combination of above	Lower failure rate number

CRITERIA FOR ACCEPTANCE OF MICROELECTRONIC DEVICES

A4 General

A4.1 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 alarm manufacturer, to assure uniformity of production.

b) Part II includes a determination of a failure rate for the device supplemented by a one time burn-in test.

A4.2 Although this program is oriented primarily to custom integrated circuit "chips," it can also be applied for other microelectronic devices.

A4.3 Components that meet the requirements of this program shall be distinctively marked for identification purposes. The alarm manufacturer shall maintain on file, accessible to an inspector, copies of the purchase and shipping orders for all alarms and "chips" so that a tally of alarms shipped can be compared to the quantity of screened devices procured from the component vendor.

A5 Quality Assurance Screening Program

A5.1 The following minimum screening program (see Table A5.1) is to be established by either the component manufacturer (vendor) or the alarm manufacturer. If the screening program is conducted by the component manufacturer, each lot or shipment to the alarm manufacturer is to be accompanied by a certificate of compliance with the Quality Assurance Screening Program.

Table A5.1
Minimum Screening Programs

A. HERMETIC PACKAGES	
1. Internal visual (Method 2010.1, Condition B modified)	100 %[a]
2. Bond strength (Method 2011)	Sample Basis[a]
3. Stabilization bake (Method 1008C, 150 °C, 24 hours)	100 %[b]
4. Temperature cycling (Method 1010C, minus 55 °C to 150 °C, 10 cycles)	100 %[e]
5. Seal (Fine leak, Method 1014B 5×10^{-8} CC/Sec)	100 %[c]
6. Seal (Gross leak, Method 1014B fluorocarbon)	100 %
7. Functional electrical, 25 °C	100 %
8. External visual, Method 2009	100 %
9. Quality conformance	AQL 1.5 % 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	
B. PLASTIC PACKAGES	
1. Internal visual (Method 2010.1, Condition B modified)	100 %[a]
2. Bond strength (Method 2011)	Sample Basis[a]
3. Temperature cycling (Method 1010C, minus 55 °C to 125 °C, 10 cycles)	100 %[e,f]
4. Functional electrical test, 25 °C	100 %
5. External visual, Method 2009	100 %
6. Quality conformance	AQL 1.5 % 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 are to be submitted for review.

Table A5.1 Continued on Next Page

Table A5.1 Continued

[b] Stabilization bake may be waived if production process includes equivalent conditioning.

[c] May be reduced to 1.5 % AQL when vendor's first lot of 25,000 units shows statistical justification.

[d] May be waived if justified by the reject rate in Item A5.

[e] Thermal shock Method 1011.1, Condition B or C, may be substituted.

[f] May be waived if 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. This audit may be in the form of selecting samples from the same package type and subjecting them to the Temperature Cycling or Thermal Shock (Methods 1010C or 1011.1, Conditions B or C, Military Handbook 883D, April 9, 1979). Records shall be maintained for inspection.

A5.2 The test methods and conditions referenced in Table A5.1 are based on MIL-STD-883B dated July 31, 1977 and its most current revisions.

A6 Determination of Failure Rate Number Supplemented by Burn-In Test

A6.1 General

A6.1.1 The objective of this part is to determine a numerical failure rate for the device to be employed in the overall reliability calculation of the alarm. The method employs Arrehenius calculations and activation energy tables to correlate elevated temperature operation to a failure rate of 38 °C (100 °F) (maximum installation ambient temperature of the alarm).

A6.2 Determination sequence

A6.2.1 The following step-by-step procedure is to be employed in determining the failure rate number.

a) Estimate numerical failure rate desired.

b) Select desired test temperature for acceptance test.

c) Using selected test temperature, refer to curves in Figure A6.1 to determine related test time for initial conditional acceptance and final acceptance.

d) Using the equation in A6.5.1 and the initial conditioning test time determined in A6.2.1(c)

e) Sample lot size to be used in temperature test is determined from Table A6.1. 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. If a different temperature is employed, lot sizes can be derived from a table of Summation of Terms of Poisson's Exponential Binomial Limit[d] at a 60 percent confidence level.

f) Using the Arrehenius equation and the final test time determined in A6.2.1(c), calculate the failure rate of the device for final acceptance.

[d] Reliability Handbook by W. Grant Ireson

Figure A6.1

Time-temperature regression and allowable time limits for test condition