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

or

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

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 70.3.

Table 70.3
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

Table 70.3 Continued on Next Page

Table 70.3 Continued

Potential across capacitance prior to discharge, volts	Maximum capacitance, microfarads
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

70.5 With reference to the requirements in 70.2 and 70.3, 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.

70.6 With reference to the requirements in 70.5, 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.

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

70.8 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.

70.9 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.

71 Strain Relief Test

71.1 General

71.1.1 A cord or lead that depends upon a thermoplastic part for strain relief is to be subjected to the applicable tests specified in 71.2.1 – 71.4.1 following exposure to either temperature conditioning test described in 48.1.2.

71.2 Power-supply cord

71.2.1 When tested in accordance with 71.1.1, 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.

71.2.2 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.

71.3 Field-wiring leads

71.3.1 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.

71.4 Special connector

71.4.1 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.

72 Power Supply Tests

72.1 General

72.1.1 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 72.2.2 – 72.3.2.

72.2 Volt-amperes capacity

72.2.1 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.

72.2.2 To determine compliance with the requirements of 72.2.1, 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.

72.3 Burnout test

72.3.1 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 72.3.2. While still in a heated condition following this test, the power supply shall comply with the requirements of the Leakage Current Test, Section 50, and the Dielectric Voltage-Withstand Test, Section 54.

72.3.2 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.

73 Drop Test

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

73.2 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.

73.3 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 AND UNCONDITIONED AREAS

74 General

74.1 A carbon monoxide alarm intended for use in recreational vehicles and unconditioned areas such as garages, attics, and the like shall comply with the requirements specified in Sections 75 – 78, in addition to the requirements specified in Sections 1 – 73 and 80 – 88, inclusive.

74.2 Marking

74.2.1 In addition to the applicable requirements in Section 87, a carbon monoxide alarm for use in a Recreational 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. 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 ″Recreational Vehicle Carbon Monoxide Alarm″, or "Unconditioned Area CO Alarm" or equivalent. It is not prohibited that this marking be incorporated in (g); and

g) Identification of switches and light indicators.

75 Variable Ambient Temperature and Humidity Test

75.1 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).

75.2 Sensitivity measurements immediately after conditioning as described in 75.1 shall comply with 41.1.1. During the sensitivity measurement, the environmental chamber is to be within the limits specified in 75.1.

75.3 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 75.4 during each test condition. The tests in 75.1 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.

75.4 All batteries included with Carbon Monoxide alarms intended for use in recreational vehicles or Unconditioned Areas 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.

76 Corrosion (Salt Spray) Test

76.1 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.

76.2 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.

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

77 Vibration Test

77.1 After vibration in accordance with 77.2, an alarm shall not false alarm (or pre-alarm) or be adversely damaged. Sensitivity measurements shall comply with the Sensitivity Test, Section 41.

77.2 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 60. Sensitivity measurements are to be recorded before and after the test.

78 Contamination Test (Cooking By-Products)

78.1 After exposure in accordance with 78.2 – 78.5, 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.

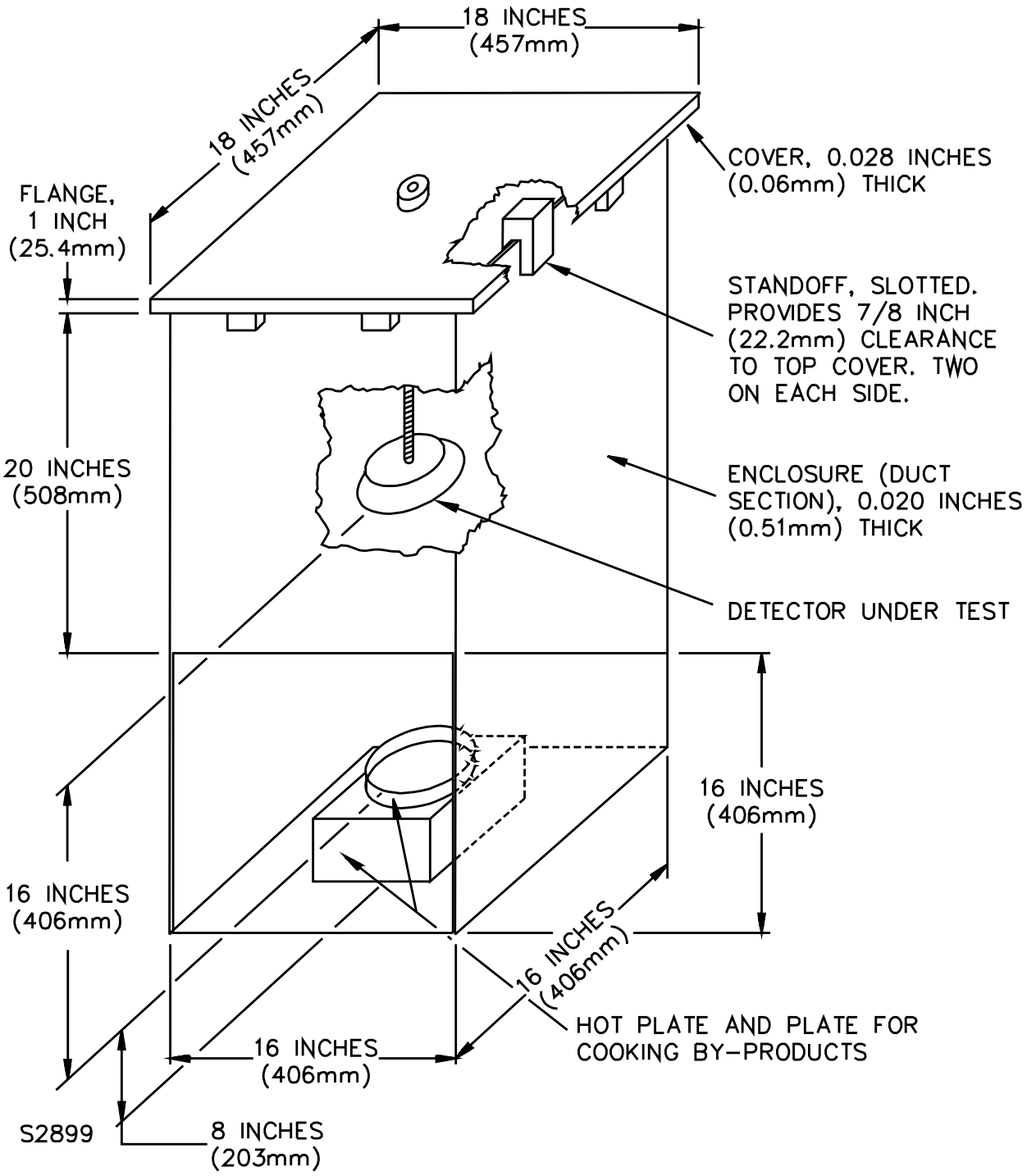
78.2 Two samples are to be subjected to the vaporization of a mixture of 50 grams of animal fat (lard), 50 grams of vegetable fat[a], and 100 grams of beef gravy[b]. The mixture is to be placed in an 8-inch (203-mm) diameter aluminum plate that is heated on an 8-1/2-inch (216-mm) diameter hotplate located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

78.3 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 78.1.

Figure 78.1
Contamination test (cooking by-products)



78.4 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.

78.5 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.

79 Carbon Monoxide Alarms for Use on Recreational Boats

79.1 General

79.1.1 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).

79.1.2 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.

79.1.3 These alarms shall be constructed to be watertight or drip-proof. See 79.3 and 79.4.

79.1.4 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 76.

79.1.5 These alarms shall comply with the requirements specified in Section 1 – 73 and 80 – 88 inclusive. The same three sample alarms are to be used for the tests indicated in Table 79.1. The tests are to be conducted in the order specified.

Table 79.1
Samples for performance tests

Number of samples[a]	Test
3	Sensitivity Test, Section 41
3	Operation tests following conditioning, Section 79.2
1	Watertightness test, Section 79.3
1	Drip test, Section 79.4
3	Abnormal operation tests, Section 79.5
1	Salt-spray corrosion test, Section 79.6
3	Overvoltage and Undervoltage Tests, Sections 56 and 57
3	Endurance Test, Section 47
3	Audibility Test, Section 65

[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.

79.1.6 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.

79.1.7 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 79.1.8 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.

79.1.8 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.

79.2 Operation tests following conditioning

79.2.1 Immediately following each of the conditions specified in 79.2.3 – 79.2.17, and while in the environmental condition specified in 79.2.3 and 79.2.4, 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.

79.2.2 The tests specified in 79.2.3 and 79.2.4 shall be conducted in sequential order as outlined in this standard. The same samples used for 79.2.3 and 79.2.4, including remote sensors, are to be used for all tests defined in 79.2.3 – 79.2.17. These samples are to be energized during each environmental exposure.

79.2.3 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.

79.2.4 Immediately following the conditioning specified in 79.2.3 and the sensitivity test specified in 79.2.1, 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 79.2.3 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.

79.2.5 Following each environmental condition specified in 79.2.3 and 79.2.4, the sensitivity tests are to be conducted at the conclusion of the 24-hour conditioning environment.

79.2.6 Sensitivity testing shall not be conducted during the pre-conditioning of the samples as specified in 79.2.4 (a) and (b).

79.2.7 The same three alarms used for the temperature conditioning are to be used for the vibration conditioning specified in 79.2.8 and 79.2.9.

79.2.8 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 79.2.9.

79.2.9 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.

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

79.2.11 The same three alarms used for the vibration conditioning are to be used for the conditioning specified in 79.2.12 – 79.2.15.

79.2.12 The alarms are to be mounted on a shock machine in the same manner as described in the vibration conditioning specified in 79.2.8 and 79.2.9. The shock machine is to produce repeated shock pulses as specified in 79.2.13.

79.2.13 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.

79.2.14 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.

79.2.15 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.

79.2.16 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.

79.2.17 Immediately following the conditioning specified in 79.2.16, 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.

79.3 Watertightness test

79.3.1 A alarm marked "Watertight" is to be tested as specified in 79.3.2. 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.

79.3.2 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.

79.3.3 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.

79.3.4 An alarm that complies with this test shall be marked in accordance with 79.7.4. See also 79.7.5.

79.4 Drip test

79.4.1 An alarm not marked "Watertight" is to be tested as specified in 79.4.2 and 79.4.3. 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 Section 79.3.

79.4.2 One sample alarm from the humidity conditioning, 79.2.16 and 79.2.17, 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.

79.4.3 The alarm is to be oriented from 0 – 15 degrees from the vertical during the test.

79.4.4 An alarm that complies with this test shall be marked in accordance with 79.7.5.