INTERNATIONAL MARITIME ORGANIZATION
4 ALBERT EMBANKMENT
LONDON SE1 7SR

Telephone: 020 7587 3152
Fax: 020 7587 3210

IMO

E

Ref. T4/4.01

MSC/Circ.1165
10 June 2005

REVISED GUIDELINES FOR THE APPROVAL OF EQUIVALENT WATER-BASED FIRE-EXTINGUISHING SYSTEMS FOR MACHINERY SPACES AND CARGO PUMP-ROOMS

1 The Maritime Safety Committee, at its sixty-fourth session (5 to 9 December 1994), recognizing the urgent necessity of providing guidelines for alternative arrangements for halon fire-extinguishing systems, approved Guidelines for the approval of equivalent water-based fire-extinguishing systems as referred to in SOLAS 74 for machinery spaces and cargo pump-rooms (MSC/Circ.668).

2 The Committee, at its sixty-sixth session (28 May to 6 June 1996), having considered a proposal by the fortieth session of the Sub-Committee on Fire Protection to revise the interim test method for equivalent water-based fire-extinguishing systems, contained in MSC/Circ.668, approved a revised test method for equivalent water-based fire-extinguishing systems for category A machinery spaces and cargo pump-rooms contained in MSC/Circ.668 (MSC/Circ.728).

3 The Sub-Committee on Fire Protection, at its forty-ninth session (24 to 28 January 2005), reviewed the Guidelines for the approval of equivalent water-based fire-extinguishing systems as referred to in SOLAS 74 for machinery spaces and cargo pump-rooms (annex to MSC/Circ.668, as amended by MSC/Circ.728) and made amendments to the test method for equivalent water-based fire-extinguishing systems for machinery spaces of category A and cargo pump-rooms, taking into account the latest technological progress made in this area.

4 The Committee, at its eightieth session (11 to 20 May 2005), after having considered the above proposal by the forty-ninth session of the Sub-Committee on Fire Protection, approved Revised Guidelines for the approval of equivalent water-based fire-extinguishing systems for machinery spaces and cargo pump-rooms, as set out in the annex.

5 Member Governments are invited to apply the annexed Guidelines when approving equivalent water-based fire-extinguishing systems for machinery spaces and pump-rooms and bring them to the attention of ship designers, ship owners, equipment manufacturers, test laboratories and other parties concerned.

6 Test approvals already conducted in accordance with guidelines contained in MSC/Circ.668, as amended by MSC/Circ.728, should remain valid until 5 years after the date of this circular.

***

ANNEX

REVISED GUIDELINES FOR THE APPROVAL OF EQUIVALENT WATER-BASED FIRE-EXTINGUISHING SYSTEMS FOR MACHINERY SPACES AND CARGO PUMP-ROOMS

General

1 Water-based fire-extinguishing systems for use in machinery spaces of category A and cargo pump-rooms equivalent to fire-extinguishing systems required by SOLAS regulation II-2/10 and chapter 5 of the FSS Code should prove that they have the same reliability which has been identified as significant for the performance of fixed pressure water-spraying systems approved under the requirements of SOLAS regulation II-2/10 and chapter 5 of the FSS Code. In addition, the system should be shown by test to have the capability of extinguishing a variety of fires that can occur in a ship's engine-room.

Definitions

2 *Antifreeze system* is a wet pipe system containing an antifreeze solution and connected to a water supply. The antifreeze solution is discharged, followed by water, immediately upon operation of nozzles.

3 *Bilge area* is the space between the solid engine-room floor plates and the bottom of the engine-room.

4 *Deluge system* is a system employing open nozzles attached to a piping system connected to a water supply through a valve that is opened by the operation of a detection system installed in the same areas as the nozzles or opened manually. When this valve opens, water flows into the piping system and discharges from all nozzles attached thereto.

5 *Dry Pipe system* is a system employing nozzles attached to a piping system containing air or nitrogen under pressure, the release of which (as from the opening of a nozzle) permits the water pressure to open a valve known as a dry pipe valve. The water then flows into the piping system and out of the opened nozzle.

6 *Fire extinction* is a reduction of the heat release from the fire and a total elimination of all flames and glowing parts by means of direct and sufficient application of extinguishing media.

7 *Preaction system* is a system employing automatic nozzles attached to a piping system containing air that mayor may not be under pressure, with a supplemental detection system installed in the same area as the nozzles. Actuation of the detection system opens a valve that permits water to flow into the piping system and to be discharged from any nozzles that may be open.

8 *Water-based extinguishing medium* is fresh water or seawater with or without additives mixed to enhance fire-extinguishing capability.

9 *Wet pipe system* is a system employing nozzles attached to a piping system containing water and connected to a water supply so that water discharges immediately from the nozzles upon system activation.

Principal requirements for the system

10 The system should be capable of manual release.

11 The system should be capable of fire extinction, and tested to the satisfaction of the Administration in accordance with appendix B to these Guidelines.

12 The system should be available for immediate use and capable of continuously supplying water for at least 30 min in order to prevent re-ignition or fire spread within that period of time. Systems which operate at a reduced discharge rate after the initial extinguishing period should have a second full fire-extinguishing capability available within a 5-minute period of initial activation.

13 The system and its components should be suitably designed to withstand ambient temperature changes, vibration, humidity, shock, impact, clogging and corrosion normally encountered in machinery spaces or cargo pump-rooms in ships. Components within the protected spaces should be designed to withstand the elevated temperatures which could occur during a fire.

14 The system and its components should be designed and installed in accordance with international standards acceptable to the Organization[1] and manufactured and tested to the satisfaction of the Administration in accordance with appropriate elements of appendices A and B to these guidelines.

15 The nozzle location, type of nozzle and nozzle characteristics should be within the limits tested to provide fire extinction as referred to in paragraph 10.

16 The electrical components of the pressure source for the system should have a minimum rating of IP 54. The system should be supplied by both main and emergency sources of power and should be provided with an automatic change-over switch. The emergency power supply should be provided from outside the protected machinery space.

17 The system should be provided with a redundant means of pumping. The capacity of the redundant means should be sufficient to compensate for the loss of any single supply pump. The system should be fitted with a permanent sea inlet and be capable of continuous operation using seawater.

18 The piping system should be sized in accordance with an hydraulic calculation technique.[2]

19 Systems capable of supplying water at the full discharge rate for 30 min may be grouped into separate sections within a protected space. The sectioning of the system within such spaces should be approved by the Administration in each case.

---

1 Pending the development of international standards acceptable to the Organization, national standards as prescribed by the Administration should be applied.

2 Where the Hazen-Williams Method is used, the following values of the friction factor "C" for different pipe types which may be considered should apply:

Pipe type	**C**
Black or galvanized mild steel	100
Copper and copper alloys	150
Stainless steel	150

20 In all cases the capacity and design of the system should be based on the complete protection of the space demanding the greatest volume of water.

21 The system operation controls should be available at easily accessible positions outside the spaces to be protected and should not be liable to be cut off by a fire in the protected spaces.

22 Pressure source components of the system should be located outside the protected spaces.

23 A means for testing the operation of the system for assuring the required pressure and flow should be provided.

24 Activation of any water distribution valve should give a visual and audible alarm in the protected space and at a continuously manned central control station. An alarm in the central control station should indicate the specific valve activated.

25 Operating instructions for the system should be displayed at each operating position. The operating instructions should be in the official language of the flag State. If the language is neither English nor French, a translation into one of these languages should be included.

26 Spare parts and operating and maintenance instructions for the system should be provided, as recommended by the manufacturer.

27 Additives should not be used for the protection of normally occupied spaces unless they have been approved for fire protection service by an independent authority. The approval should consider possible adverse health effects to exposed personnel, including inhalation toxicity.

APPENDIX A

COMPONENT MANUFACTURING STANDARDS OF EQUIVALENT WATER-BASED FIRE-EXTINGUISHING SYSTEMS

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

Figures given in square brackets refer to ISO Standard 6182/1.

INTRODUCTION

This document is intended to address minimum fire protection performance, construction, and marking requirements, excluding fire performance, for water-mist nozzles.

Numbers in brackets following a section or sub-section heading refer to the appropriate section or paragraph in the Standard for Automatic sprinkler systems - Part 1: Requirements and methods of test for sprinklers, ISO 6182-1.

The requirements for automatically operating nozzles which involve release mechanism need not be met by nozzles of manually operating systems.

1 DEFINITIONS

1.1 *Conductivity factor* is a measure of the conductance between the nozzle's heat responsive element and the fitting expressed in units of $(m/s)^{0.5}$.

1.2 *Rated working pressure* is the maximum service pressure at which a hydraulic device is intended to operate.

1.3 *Response time index (RTI)* is a measure of nozzle sensitivity expressed as $RTI = tu^{0.5}$, where **t** is the time constant of the heat responsive element in units of seconds, and **u** is the gas velocity expressed in metres per second. RTI can be used in combination with the conductivity factor (C) to predict the response of a nozzle in fire environments, defined in terms of gas temperature and velocity versus time. RTI has units of $(m.s)^{0.5}$.

1.4 *Standard orientation.* In the case of nozzles with symmetrical heat responsive elements supported by frame arms, standard orientation is with the air flow perpendicular to both the axis of the nozzle's inlet and the plane of the frame arms. In the case of non-symmetrical heat responsive elements, standard orientation is with the air flow perpendicular to both the inlet axis and the plane of the frame arms which produces the shortest response time.

1.5 *Worst case orientation* is the orientation which produces the longest response time with the axis of the nozzle inlet perpendicular to the air flow.

2 PRODUCT CONSISTENCY

2.1 It should be the responsibility of the manufacturer to implement a quality control programme to ensure that production continuously meets the requirements in the same manner as the originally tested samples.

2.2 The load on the heat responsive element in automatic nozzles should be set and secured by the manufacturer in such a manner so as to prevent field adjustment or replacement.

3 WATER-MIST NOZZLE REQUIREMENTS

3.1 Dimensions

Nozzles should be provided with a nominal 6 mm (1/4 in.) or larger nominal inlet thread or equivalent. The dimensions of all threaded connections should conform to International Standards where applied. National Standards may be used if International Standards are not applicable.

3.2 Nominal release temperatures (6.2)

3.2.1 The nominal release temperatures of automatic glass bulb nozzles should be as indicated in table 1.

3.2.2 The nominal release temperatures of fusible automatic element nozzles should be specified in advance by the manufacturer and verified in accordance with 3.3. Nominal release temperatures should be within the ranges specified in table 1.

Table 1 – Nominal release temperature

Values in degrees Celsius

GLASS BULB NOZZLES		FUSIBLE ELEMENT NOZZLES	
Nominal release temp.	Liquid colour code	Nominal release temp.	Frame colour code *
57	orange	57 to 77	uncoloured
68	red	80 to 107	white
79	yellow	121 to 149	blue
93-100	green	163 to 191	red
121-141	blue	204 to 246	green
163-182	mauve	260 to 343	orange
204-343	black		

* Not required for decorative nozzles

3.3 Operating temperatures (see 4.6.1) [6.3]

Automatic nozzles should open within a temperature range of

$$X \pm 0.035X + 0.62^{o}C$$

where X is the nominal release temperature.

3.4 Water flow and distribution

3.4.1 Flow constant (see 4.10) [6.4.1]

3.4.1.1 The flow constant K for nozzles is given in the following formula:

$$K = Q/P^{0.5}$$

where:

P is the pressure in bars; and
Q is the flow rate in litres per min.

3.4.1.2 The value of the flow constant K published in the Manufacturer's Design and Installation Instructions should be verified using the test method of 4.10. The average flow constant K should be verified within ± 5% of the manufacturer's value.

3.5 Function (see 4.5) [6.5]

3.5.1 When tested in accordance with 4.5, the nozzle should open and, within 5 s after the release of the heat responsive element, should operate satisfactorily by complying with the requirements of 4.10. Any lodgement of released parts should be cleared within 60 s of release for standard response heat responsive elements and within 10 s of release for fast and special response heat responsive elements or the nozzle should then comply with the requirement of 4.11.

3.5.2 The nozzle discharge components should not sustain significant damage as a result of the functional test specified in 4.5.6 and should have the same flow constant range and water droplet size and velocity within 5 per cent of values as previously determined per 3.4.1 and 3.4.3.

3.6 Strength of body (see 4.3) [6.6]

The nozzle body should not show permanent elongation of more than 0.2% between the load-bearing points, after being subjected to twice the average service load, as determined using the method of 4.3.1.

3.7 Strength of release element [6.7]

3.7.1 Glass bulbs (see 4.9.1)

The lower tolerance limit for bulb strength should be greater than two times the upper tolerance limit for the bulb design load based on calculations with a degree of confidence of 0.99 for 99 per cent of the samples as determined in 4.9.1. Calculations will be based on the Normal or Gaussian Distribution except where another distribution can be shown to be more applicable due to manufacturing or design factors.

3.7.2 Fusible elements (see 4.9.2)

Fusible heat-responsive elements in the ordinary temperature range should be designed to:

.1 sustain a load of 15 times its design load corresponding to the maximum service load measured in 4.3.1 for a period of 100 hours in accordance with 4.9.2.1; or

.2 demonstrate the ability to sustain the design load when tested in accordance with 4.9.2.2.

3.8 Leak resistance and hydrostatic strength (see 4.4) [6.8]

3.8.1 A nozzle should not show any sign of leakage when tested by the method specified in 4.4.1.

3.8.2 A nozzle should not rupture, operate or release any parts when tested by the method specified in 4.4.2.

3.9 Heat exposure [6.9]

3.9.1 Glass bulb nozzles (see 4.7.1)

There should be no damage to the glass bulb element when the nozzle is tested by the method specified in 4.7.1.

3.9.2 All uncoated nozzles (see 4.7.2)

Nozzles should withstand exposure to increased ambient temperature without evidence of weakness or failure, when tested by the method specified in 4.7.2.

3.9.3 Coated nozzles (see 4.7.3)

In addition to meeting the requirement of 4.7.2 in an uncoated version, coated nozzles should withstand exposure to ambient temperatures without evidence of weakness or failure of the coating, when tested by the method specified in 4.7.3.

3.10 Thermal shock (see 4.8) [6.10]

Glass bulb nozzles should not be damaged when tested by the method specified in 4.8. Proper operation is not considered as damage.

3.11 Corrosion [6.11]

3.11.1 Stress corrosion (see 4.12.1 and 4.12.2)

When tested in accordance with 4.12.1, all brass nozzles should show no fractures which could affect their ability to function as intended and satisfy other requirements.

When tested in accordance with 4.12.2, stainless steel parts of water-mist nozzles should show no fractures or breakage which could affect their ability to function as intended and satisfy other requirements.

3.11.2 Sulphur dioxide corrosion (see 4.12.3)

Nozzles should be sufficiently resistant to sulphur dioxide saturated with water vapour when conditioned in accordance with 4.12.2. Following exposure, five nozzles should operate, when functionally tested at their minimum flowing pressure (see 3.5.1 and 3.5.2). The remaining five samples should meet the dynamic heating requirements of 3.14.2.

3.11.3 Salt spray corrosion (see 4.12.4)

Coated and uncoated nozzles should be resistant to salt spray when conditioned in accordance with 4.12.4. Following exposure, the samples should meet the dynamic heating requirements of 3.14.2.

3.11.4 Moist air exposure (see 4.12.5)

Nozzles should be sufficiently resistant to moist air exposure and should satisfy the requirements of 3.14.2 after being tested in accordance with 4.12.5.

3.12 Integrity of nozzle coatings [6.12]

3.12.1 Evaporation of wax and bitumen used for atmospheric protection of nozzles (see 4.13.1)

Waxes and bitumens used for coating nozzles should not contain volatile matter in sufficient quantities to cause shrinkage, hardening, cracking or flaking of the applied coating. The loss in mass should not exceed 5% of that of the original sample when tested by the method in 4.13.1.

3.12.2 Resistance to low temperatures (see 4.13.2)

All coatings used for nozzles should not crack or flake when subjected to low temperatures by the method in 4.13.2.

3.12.3 Resistance to high temperature (see 3.9.3)

Coated nozzles should meet the requirements of 3.9.3.

3.13 Water hammer (see 4.15) [6.13]

Nozzles should not leak when subjected to pressure surges from 4 bar to four times the rated pressure for operating pressures up to 100 bars and two times the rated pressure for pressures greater than 100 bar. They should show no signs of mechanical damage when tested in accordance with 4.15 and should operate within the parameters of 3.5.1 at the minimum design pressure.

3.14 Dynamic heating (see 4.6.2) [6.14]

3.14.1 Automatic nozzles intended for installation in other than accommodation spaces and residential areas should comply with the requirements for RTI and C limits shown in figure 1. Automatic nozzles intended for installation in accommodation spaces or residential areas should comply with fast response requirements for RTI and C limits shown in figure 1. Maximum and minimum RTI values for all data points calculated using C for the fast and standard response nozzles should fall within the appropriate category shown in figure 1. Special response nozzles should have an average RTI value, calculated using C, between 50 and 80 with no value less than 40 or more than 100. When tested at an angular offset to the worst case orientation as described in section 4.6.2, the RTI should not exceed 600 $(m.s)^{0.5}$ or 250% of the value of RTI in the standard orientation, whichever is less. The angular offset should be 15º for standard response, 20º for special response and 25º for fast response.

3.14.2 After exposure to the corrosion test described in sections 3.11.2, 3.11.3 and 3.11.4, nozzles should be tested in the standard orientation as described in section 4.6.2.1 to determine the post exposure RTI. All post exposure RTI values should not exceed the limits shown in figure 1 for the appropriate category. In addition, the average RTI value should not exceed 130% of the pre-exposure average value. All post exposure RTI values should be calculated as in section 4.6.2.3 using the pre-exposure conductivity factor (C).

3.15 Resistance to heat (see 4.14) [6.15]

Open nozzles should be sufficiently resistant to high temperatures when tested in accordance with 4.14. After exposure, the nozzle should not show:

.1 visual breakage or deformation;

.2 a change in flow constant K of more than 5 per cent; and

.3 no changes in the discharge characteristics of the Water Distribution Test (see 3.4.2) exceeding 5 per cent.

3.16 Resistance to vibration (see 4.16) [6.16]

Nozzles should be able to withstand the effects of vibration without deterioration of their performance characteristics, when tested in accordance with 4.16. After the vibration test of 4.16, nozzles should show no visible deterioration and should meet the requirements of 3.5 and 3.8.

3.17 Impact test (see 4.17) [6.17]

Nozzles should have adequate strength to withstand impacts associated with handling, transport and installation without deterioration of their performance or reliability. Resistance to impact should be determined in accordance with 4.1.

3.18 Lateral discharge (see 4.18) [6.19]

Nozzles should not prevent the operation of adjacent automatic nozzles when tested in accordance with 4.21.

3.19 30 day leakage resistance (see 4.19) [6.20]

Nozzles should not leak, sustain distortion or other mechanical damage when subjected to twice the rated pressure for 30 days. Following exposure, the nozzles should satisfy the test requirements of 4.22.

3.20 Vacuum resistance (see 4.23) [6.21]

Nozzles should not exhibit distortion, mechanical damage or leakage after being subjected to the test in 4.23.

3.21 Water shield [6.22 and 6.23]

3.21.1 General

An automatic nozzle intended for use at intermediate levels or beneath open grating should be provided with a water shield which complies with 3.21.2 and 3.21.3.

3.21.2 Angle of protection (see 4.21.1)

Water shields should provide an "angle of protection" of 45º or less for the heat responsive element against direct impingement of run-off water from the shield caused by discharge from nozzles at higher elevations. Compliance with this requirement should be determined in accordance with 4.21.1.

3.21.3 Rotation (see 4.21.2)

Rotation of the water shield should not alter the nozzle service load when evaluated in accordance with 4.21.2.

3.22 Clogging (see 4.21) [6.28.3]

A water-mist nozzle should show no evidence of clogging during 30 minutes of continuous flow at rated working pressure using water, which has been contaminated in accordance with 4.21.3. Following the 30 minutes of flow, the water flow at rated pressure of the nozzle and strainer or filter should be within ± 10 per cent of the value obtained prior to conducting the clogging test.

4 METHODS OF TEST [7]

4.1 General

The following tests should be conducted for each type of nozzle. Before testing, precise drawings of parts and the assembly should be submitted together with the appropriate specifications (using SI units). Tests should be carried out at an ambient temperature of (20,±5)ºC, unless other temperatures are indicated.

4.2 Visual examination [7.2]

Before testing, nozzles should be examined visually with respect to the following points:

.1 marking;
.2 conformity of the nozzles with the manufacturer's drawings and specification; and
.3 obvious defects.

4.3 Body strength test [7.3]

4.3.1 The design load should be measured on ten automatic nozzles by securely installing each nozzle, at room temperature, in a tensile/compression test machine and applying a force equivalent to the application of the rated working pressure.

4.3.2 An indicator capable of reading deflection to an accuracy of 0.01 mm should be used to measure any change in length of the nozzle between its load bearing points. Movement of the nozzle shank thread in the threaded bushing of the test machine should be avoided or taken into account.

4.3.3 The hydraulic pressure and load is then released and the heat responsive element is then removed by a suitable method. When the nozzle is at room temperature, a second measurement is to be made using the indicator.

4.3.4 An increasing mechanical load to the nozzle is then applied at a rate not exceeding 500 N/minute, until the indicator reading at the load bearing point initially measured returns to the initial value achieved under hydrostatic load. The mechanical load necessary to achieve this should be recorded as the service load. Calculate the average service load.

4.3.5 The applied load is then progressively increased at a rate not exceeding 500 N/minute on each of the five specimens until twice the average service load has been applied. Maintain this load for 15 ± 5 s.

4.3.6 The load is then removed and any permanent elongation as defined in 3.6 is recorded.

4.4 Leak resistance and hydrostatic strength tests (see 3.8) [7.4]

4.4.1 Twenty nozzles should be subjected to a water pressure of twice their rated working pressure, but not less than 34.5 bar. The pressure is increased from 0 bar to the test pressure, maintained at twice rated working pressure for a period of 3 min and then decreased to 0 bar. After the pressure has returned to 0 bar, it is increased to the minimum operating pressure specified by the manufacturer in not more than 5 s. This pressure is to be maintained for 15 s and then increased to rated working pressure and maintained for 15 s.

4.4.2 Following the test of 4.4.1, the twenty nozzles should be subjected to an internal hydrostatic pressure of four times the rated working pressure. The pressure is increased from 0 bar to four times the rated working pressure and held there for a period of 1 minute. The nozzle under test should not rupture, operate or release any of its operating parts during the pressure increase nor while being maintained at four times the rated working pressure for 1 minute.

4.5 Functional test (see 3.5) [7.5]

4.5.1 Nozzles having nominal release temperatures less than 78°C, should be heated to activation in an oven. While being heated, they should be subjected to each of the water pressures specified in 4.5.3 applied to their inlet. The temperature of the oven should be increased to 400 ± 20°C in 3 min measured in close proximity to the nozzle. Nozzles having nominal release temperatures exceeding 78°C should be heated using a suitable heat source. Heating should continue until the nozzle has activated.

4.5.2 Eight nozzles should be tested in each normal mounting position and at pressures equivalent to the minimum operating pressure, the rated working pressure and at the average operating pressure. The flowing pressure should be at least 75% of the initial operating pressure.

4.5.3 If lodgement occurs in the release mechanism at any operating pressure and mounting position, 24 more nozzles should be tested in that mounting position and at that pressure. The total number of nozzles for which lodgement occurs should not exceed 1 in the 32 tested at that pressure and mounting position.

4.5.4 Lodgement is considered to have occurred when one or more of the released parts lodge in the discharge assembly in such a way as to cause the water distribution to be altered after the period of time specified in 3.5.1.

4.5.5 In order to check the strength of the deflector/orifice assembly, three nozzles should be submitted to the functional test in each normal mounting position at 125 per cent of the rated working pressure. The water should be allowed to flow at 125 per cent of the rated working pressure for a period of 15 min.

4.6 Heat responsive element operating characteristics

4.6.1 Operating temperature test (see 3.3) [7.6]

4.6.1.1 Ten nozzles should be heated from room temperature to 20 to 22°C below their nominal release temperature. The rate of increase of temperature should not exceed 20°C/min and the temperature should be maintained for 10 min. The temperature should then be increased at a rate between 0.4°C/min to 0.7°C/min until the nozzle operates.

4.6.1.2 The nominal operating temperature should be ascertained with equipment having an accuracy of ±0.35% of the nominal temperature rating or ±0.25°C, whichever is greater.

4.6.1.3 The test should be conducted in a water bath for nozzles or separate glass bulbs having nominal release temperatures less than or equal to 80°C. A suitable oil should be used for higher-rated release elements. The liquid bath should be constructed in such a way that the temperature deviation within the test zone does not exceed 0.5%, or 0.5°C, whichever is greater.

4.6.2 Dynamic heating test (see 3.4)

4.6.2.1 Plunge test

4.6.2.1.1 Tests should be conducted to determine the standard and worst case orientations as defined in 1.4 and 1.5. Ten additional plunge tests should be performed at both of the identified orientations. The worst case orientation should be as defined in 3.14.1. The RTI is calculated as described in 4.6.2.3 and 4.6.2.4 for each orientation, respectively. The plunge tests are to be conducted using a brass nozzle mount designed such that the mount or water temperature rise does not exceed 2°C for the duration of an individual plunge test up to a response time of 55 s. (The temperature should be measured by a thermocouple heatsinked and embedded in the mount not more than 8 mm radially outward from the root diameter of the internal thread or by a thermocouple located in the water at the centre of the nozzle inlet.) If the response time is greater than 55 s, then the mount or water temperature in degrees Celsius should not increase more than 0.036 times the response time in seconds for the duration of an individual plunge test.

4.6.2.1.2 The nozzle under test should have 1 to 1.5 wraps of PTFE sealant tape applied to the nozzle threads. It should be screwed into a mount to a torque of 15 ±3 Nm. Each nozzle is to be mounted on a tunnel test section cover and maintained in a conditioning chamber to allow the nozzle and cover to reach ambient temperature for a period of not less than 30 min.

4.6.2.1.3 At least 25 ml of water, conditioned to ambient temperature, should be introduced into the nozzle inlet prior to testing. A timer accurate to ±0.01 s with suitable measuring devices to sense the time between when the nozzle is plunged into the tunnel and the time it operates should be utilized to obtain the response time.

4.6.2.1.4 A tunnel should be utilized with air flow and temperature conditions[1] at the test section (nozzle location) selected from the appropriate range of conditions shown in table 2. To minimize radiation exchange between the sensing element and the boundaries confining the flow, the test section of the apparatus should be designed to limit radiation effects to within ± 3% of calculated RTI values[2].

4.6.2.1.5 The range of permissible tunnel operating conditions is shown in table 2. The selected operating condition should be maintained for the duration of the test with the tolerances as specified by footnotes 4 and 5 in table 2.

4.6.2.2 Determination of conductivity factor (C) [7.6.2.2]

The conductivity factor (C) should be determined using the prolonged plunge test (see 4.6.2.2.1) or the prolonged exposure ramp test (see 4.6.2.2.2).

4.6.2.2.1 Prolonged plunge test [7.6.2.2.1]

.1 the prolonged plunge test is an iterative process to determine C and may require up to twenty nozzle samples. A new nozzle sample must be used for each test in this section even if the sample does not operate during the prolonged plunge test;

.2 the nozzle under test should have 1 to 1.5 wraps of PTFE sealant tape applied to the nozzle threads. It should be screwed into a mount to a torque of 15 + 3 Nm. Each nozzle is to be mounted on a tunnel test section cover and maintained in a conditioning chamber to allow the nozzle and cover to reach ambient temperature for a period of not less than 30 min. At least 25 ml of water, conditioned to ambient temperature, should be introduced into the nozzle inlet prior to testing;

.3 a timer accurate to ± 0.01 s with suitable measuring devices to sense the time between when the nozzle is plunged into the tunnel and the time it operates should be utilized to obtain the response time;

.4 the mount temperature should be maintained at 20 ± 0.5°C for the duration of each test. The air velocity in the tunnel test section at the nozzle location should be maintained with ± 2% of the selected velocity. Air temperature should be selected and maintained during the test as specified in table 3;

---

[1] Tunnel conditions should be selected to limit maximum anticipated equipment error to 3%.

[2] A suggested method for determining radiation effects is by conducting comparative plunge tests on a blackened (high emissivity) metallic test specimen and a polished (low emissivity) metallic test specimen.

.5 the range of permissible tunnel operating conditions is shown in table 3. The selected operating condition should be maintained for the duration of the test with the tolerances as specified in table 3; and

.6 to determine C, the nozzle is immersed in the test stream at various air velocities for a maximum of 15 min.[1] Velocities are chosen such that actuation is bracketed between two successive test velocities. That is, two velocities must be established such that at the lower velocity (u_j) actuation does not occur in the 15 min test interval. At the next higher velocity (u_h), actuation must occur within the 15 min time limit. If the nozzle does not operate at the highest velocity, select an air temperature from table 3 for the next higher temperature rating.

Table 2 – Plunge oven test conditions

	Air temperature ranges*			**Velocity ranges****		
Normal Temperature, ºC	**Standard Response, ºC**	**Special Response, ºC**	**Fast Response, m/s**	**Standard Response, m/s**	**Special Response, m/s**	**Fast Response Nozzle, m/s**
57 to 77	191 to 203	129 to 141	129 to 141	2.4 to 2.6	2.4 to 2.6	1.65 to 1.85
79 to 107	282 to 300	191 to 203	191 to 203	2.4 to 2.6	2.4 to 2.6	1.65 to 1.85
121 to 149	382 to 432	282 to 300	282 to 300	2.4 to 2.6	2.4 to 2.6	1.65 to 1.85
163 to 191	382 to 432	382 to 432	382 to 432	3.4 to 3.6	2.4 to 2.6	1.65 to 1.85

* The selected air temperature should be known and maintained constant within the test section throughout the test to an accuracy of ±1ºC for the air temperature range of 129 to 141ºC within the test section and within ±2ºC for all other air temperatures.

** The selected air velocity should be known and maintained constant throughout the test to an accuracy of ±0.03 m/s for velocities of 1.65 to 1.85 and 2.4 to 2.6 m/s and ±0.04 m/s for velocities of 3.4 to 3.6 m/s.

Table 3 – Plunge oven test conditions for conductivity determination

Nominal nozzle temperature, ºC	**Oven temperature, ºC**	**Maximum variation of air temperature during test, ºC**
57	85 to 91	± 1.0
58 to 77	124 to 130	± 1.5
78 to 107	193 to 201	± 3.0
121 to 149	287 to 295	± 4.5
163 to 191	402 to 412	± 6.0

[1] If the value of C is determined to be less than 0.5 $(m.s)^{0.5}$ a C of 0.25 $(m.s)^{0.5}$ should be assumed for calculating RTI value.

Test velocity selection should ensure that:

$(U_H/U_L)^{0.5} \leq 1.1$

The test value of C is the average of the values calculated at the two velocities using the following equation:

$$C = (\Delta T_g / \Delta T_{ea} - 1)u^{0.5}$$

where:

ΔT_g Actual gas (air) temperature minus the mount temperature (Tm) in ºC.

ΔT_{ea} Mean liquid bath operating temperature minus the mount temperature (Tm) in ºC.

u Actual air velocity in the test section in m/s.

The nozzle C value is determined by repeating the bracketing procedure three times and calculating the numerical average of the three C values. This nozzle C value is used to calculate all standard orientation RTI values for determining compliance with 3.14.1.

4.6.2.2.2 Prolonged exposure ramp test [7.6.2.2.2]

.1 the prolonged exposure ramp test for the determination of the parameter C should be carried out in the test section of a wind tunnel and with the requirements for the temperature in the nozzle mount as described for the dynamic heating test. A preconditioning of the nozzle is not necessary;

.2 ten samples should be tested of each nozzle type, all nozzles positioned in standard orientation. The nozzle should be plunged into an air stream of a constant velocity of 1 m/s ± 10% and an air temperature at the nominal temperature of the nozzle at the beginning of the test; and

.3 the air temperature should then be increased at a rate of 1 ± 0.25ºC/min until the nozzle operates. The air temperature, velocity and mount temperature should be controlled from the initiation of the rate of rise and should be measured and recorded at nozzle operation. The C value is determined using the same equation as in 4.6.2.2.1 as the average of the ten test values.

4.6.2.3 RTI value calculation [7.6.2.3]

The equation used to determine the RTI value is as follows:

$$RTI = \frac{-t_r\,(u)^{0.5}(1+C/u^{0.5})}{In[1 - \Delta T_{ea}\quad(1+C/(u)^{0.5})/\Delta T_g]}$$

where:

t_r Response time of nozzles in seconds

u Actual air velocity in the test section of the tunnel in m/s from table 2

ΔT_{ea} Mean liquid bath operating temperature of the nozzle minus the ambient temperature in ºC

ΔT_g Actual air temperature in the test section minus the ambient temperature in ºC

C Conductivity factor as determined in 4.6.2.2

4.6.2.4 Determination of worst case orientation RTI

The equation used to determine the RTI for the worst case orientation is as follows:

$$RTI_{wc} = \frac{-t_{r-wc}\,(u)^{0.5}[(1+C(RTI_{wc}/RTI)/(u)^{0.5})]}{In\{1 - \Delta T_{ea}\quad[1+C(RTI_{wc}/RTI)/(u)^{\ 0.5})]/\Delta T_g\}}$$

where:

$T_{t\text{-}wc}$ Response time of the nozzles in seconds for the worst case orientation

All variables are known at this time per the equation in paragraph 4.6.2.3 except RTI_{wc} (Response Time Index for the worst case orientation) which can be solved iteratively per the above equation.

In the case of fast response nozzles, if a solution for the worse case orientation RTI is unattainable, plunge testing in the worst case orientation should be repeated using the plunge test conditions under Special Response shown in table 2.

4.7 Heat exposure test [7.7]

4.7.1 Glass bulb nozzles (see 3.9.1):

.1 glass bulb nozzles having nominal release temperatures less than or equal to 80°C should be heated in a water bath from a temperature of (20 ± 5)ºC to (20 ± 2) ºC below their nominal release temperature. The rate of increase of temperature should not exceed 20°C/min. High temperature oil, such as silicone oil should be used for higher temperature rated release elements; and

.2 this temperature should then be increased at a rate of 1°C/min to the temperature at which the gas bubble dissolves, or to a temperature 5°C lower than the nominal operating temperature, whichever is lower. Remove the nozzle from the liquid bath and allow it to cool in air until the gas bubble has formed again. During the cooling period, the pointed end of the glass bulb (seal end) should be pointing downwards. This test should be performed four times on each of four nozzles.

4.7.2 All uncoated nozzles (see 3.9.2) [7.7.2]

Twelve uncoated nozzles should be exposed for a period of 90 days to a high ambient temperature that is 11°C below the nominal rating or at the temperature shown in table 4, whichever is lower, but not less than 49°C. If the service load is dependent on the service pressure, nozzles should be tested under the rated working pressure. After exposure, four of the nozzles should be subjected to the tests specified in 4.4.1, four nozzles to the test of 4.5.1, two at the minimum operating pressure and two at the rated working pressure, and four nozzles to the requirements of 3.3. If a nozzle fails the applicable requirements of a test, eight additional nozzles should be tested as described above and subjected to the test in which the failure was recorded. All eight nozzles should comply with the test requirements.

4.7.3 Coated nozzles (see 3.9.3) [7.7.3]:

.1 in addition to the exposure test of 4.7.2 in an uncoated version, twelve coated nozzles should be exposed to the test of 4.7.2 using the temperatures shown in table 4 for coated nozzles; and

.2 the test should be conducted for 90 days. During this period, the sample should be removed from the oven at intervals of approximately 7 days and allowed to cool for 2 h to 4 h. During this cooling period, the sample should be examined. After exposure, four of the nozzles should be subjected to the tests specified in 4.4.1, four nozzles to the test of 4.5.1; two at the minimum operating pressure and two at the rated working pressure, and four nozzles to the requirements of 3.3.

Table 4 – Test temperatures for coated and uncoated nozzles

Values in degrees Celsius		
Nominal release Temperature	**Uncoated nozzle test temperature**	**Coated nozzle test temperature**
57-60	49	49
61-77	52	49
78-107	79	66
108-149	121	107
150-191	149	149
192-246	191	191
247-302	246	246
303-343	302	302

4.8 Thermal shock test for glass bulb nozzles (see 3.10) [7.8]

4.8.1 Before starting the test, condition at least 24 nozzles at room temperature of 20 to 25ºC for at least 30 min.

4.8.2 The nozzle should be immersed in a bath of liquid, the temperature of which should be 10 ± 2ºC below the nominal release temperature of the nozzles. After 5 min., the nozzles are to be removed from the bath and immersed immediately in another bath of liquid, with the bulb seal downwards, at a temperature of 10 ± 2ºC. Then test the nozzles in accordance with 4.5.1.

4.9 Strength test for release elements [7.9]

4.9.1 Glass bulbs (see 3.7.1) [7.9.1]

4.9.1.1 At least 15 sample bulbs in the lowest temperature rating of each bulb type should be positioned individually in a text fixture using the sprinkler seating parts. Each bulb should then be subjected to a uniformly increasing force at a rate not exceeding 250 N/s in the test machine until the bulb fails.

4.9.1.2 Each test should be conducted with the bulb mounted in new seating parts. The mounting device may be reinforced externally to prevent its collapse, but in a manner which does not interfere with bulb failure.

4.9.1.3 Record the failure load for each bulb. Calculate the lower tolerance limit (TLI) for bulb strength. Using the values of service load recorded in 4.3.1, calculate the upper tolerance limit (TL2) for the bulb design load. Verify compliance with 3.7.1.

4.9.2 Fusible elements (see 3.7.2)

4.10 Water flow test (see 3.4.1) [7.10]

The nozzle and a pressure gauge should be mounted on a supply pipe. The water flow should be measured at pressures ranging from the minimum operating pressure to the rated working pressure at intervals of approximately 10% of the service pressure range on two sample nozzles. In one series of tests, the pressure should be increased from zero to each value and, in the next series, the pressure shall be decreased from the rated pressure to each value. The flow constant, K, should be averaged from each series of readings, i.e., increasing pressure and decreasing pressure. During the test, pressures should be corrected for differences in height between the gauge and the outlet orifice of the nozzle.

4.11 Corrosion tests [7.12]

4.11.1 Stress corrosion test for brass nozzle parts (see 3.11.1)

4.11.1.1 Five nozzles should be subjected to the following aqueous ammonia test. The inlet of each nozzle should be sealed with a nonreactive cap, e.g., plastic.

4.11.1.2 The samples are degreased and exposed for 10 days to a moist ammonia-air mixture in a glass container of volume 0.02 ± 0.01 m^3.

4.11.1.3 An aqueous ammonia solution, having a density of 0.94 g/cm^3, should be maintained in the bottom of the container, approximately 40 mm below the bottom of the samples. A volume of aqueous ammonia solution corresponding to 0.01 ml per cubic centimetre of the volume of the container will give approximately the following atmospheric concentrations: 35% ammonia, 5% water vapour, and 60% air. The inlet of each sample should be sealed with a nonreactive cap, e.g., plastic.

4.11.1.4 The moist ammonia-air mixture should be maintained as closely as possible at atmospheric pressure, with the temperature maintained at 34 ± 2°C. Provision should be made for venting the chamber via a capillary tube to avoid the build-up of pressure. Specimens should be shielded from condensate drippage.

4.11.1.5 After exposure, rinse and dry the nozzles, and conduct a detailed examination. If a crack, delamination or failure of any operating part is observed, the nozzle(s) should be subjected to a leak resistance test at the rated pressure for 1 min and to the functional test at the minimum flowing pressure (see 3.1.5).

4.11.1.6 Nozzles showing cracking, delamination or failure of any non-operating part should not show evidence of separation of permanently attached parts when subjected to flowing water at the rated working pressure for 30 min.

4.11.2 Stress-Corrosion Cracking of Stainless Steel Nozzle Parts (see 3.11.1)

4.11.2.1 Five samples are to be degreased prior to being exposed to the magnesium chloride solution.

4.11.2.2 Parts used in nozzles are to be placed in a 500-millilitre flask that is fitted with a thermometer and a wet condenser approximately 760 mm long. The flask is to be filled approximately one-half full with a 42% by weight magnesium chloride solution, placed on a thermostatically-controlled electrically heated mantel, and maintained at a boiling temperature of 150 ± 1°C. The parts are to be unassembled, that is, not contained in a nozzle assembly. The exposure is to last for 500 hours.

4.11.2.3 After the exposure period, the test samples are to be removed from the boiling magnesium chloride solution and rinsed in deionised water.

4.11.2.4 The test samples are then to be examined using a microscope having a magnification of 25X for any cracking, delamination, or other degradation as a result of the test exposure. Test samples exhibiting degradation are to be tested as described in 4.12.5.5 or 4.12.5.6, as applicable. Test samples not exhibiting degradation are considered acceptable without further test.

4.11.2.5 Operating parts exhibiting degradation are to be further tested as follows. Five new sets of parts are to be assembled in nozzle frames made of materials that do not alter the corrosive effects of the magnesium chloride solution on the stainless steel parts. These test samples are to be degreased and subjected to the magnesium chloride solution exposure specified in paragraph 4.12.5.2. Following the exposure, the test samples should withstand, without leakage, a hydrostatic test pressure equal to the rated working pressure for 1 minute and then be subjected to the functional test at the minimum operating pressure in accordance with 4.5.1.

4.11.2.6 Non-operating parts exhibiting degradation are to be further tested as follows. Five new sets of parts are to be assembled in nozzle frames made of materials that do not alter the corrosive effects of the magnesium chloride solution on the stainless steel parts. These test samples are to be degreased and subjected to the magnesium chloride solution exposure specified in paragraph 4.12.5.1. Following the exposure, the test samples should withstand a flowing pressure equal to the rated working pressure for 30 minutes without separation of permanently attached parts.

4.11.3 Sulphur dioxide corrosion test (see 3.11.2 and 3.14.2)

4.11.3.1 Ten nozzles should be subjected to the following sulphur dioxide corrosion test. The inlet of each sample should be sealed with a nonreactive cap, e.g., plastic.

4.11.3.2 The test equipment should consist of a 5 litre vessel (instead of a 5 litre vessel, other volumes up to 15 litre may be used in which case the quantities of chemicals given below shall be increased in proportion) made of heat-resistant glass, with a corrosion-resistant lid of such a shape as to prevent condensate dripping on the nozzles. The vessel should be electrically heated through the base, and provided with a cooling coil around the side walls. A temperature sensor placed centrally 160 mm ± 20 mm above the bottom of the vessel should regulate the heating so that the temperature inside the glass vessel is 45°C ± 3ºC. During the test, water should flow through the cooling coil at a sufficient rate to keep the temperature of the discharge water below 30°C. This combination of heating and cooling should encourage condensation on the surfaces of the nozzles. The sample nozzles should be shielded from condensate drippage.

4.11.3.3 The nozzles to be tested should be suspended in their normal mounting position under the lid inside the vessel and subjected to a corrosive sulphur dioxide atmosphere for 8 days. The corrosive atmosphere should be obtained by introducing a solution made up by dissolving 20 g of sodium thiosulphate ($Na_2S_20_3H_2O$) crystals in 500 ml of water.

4.11.3.4 For at least six days of the 8-day exposure period, 20 ml of dilute sulphuric acid consisting of 156 ml of normal H_2SO_4 (0.5 mol/litre) diluted with 844 ml of water should be added at a constant rate. After 8 days, the nozzles should be removed from the container and allowed to dry for 4 to 7 days at a temperature not exceeding 35°C with a relative humidity not greater than 70%.

4.11.3.5 After the drying period, five nozzles should be subjected to a functional test at the minimum operating pressure in accordance with 4.5.1 and five nozzles should be subjected to the dynamic heating test in accordance with 3.14.2.

4.11.4 Salt spray corrosion test (see 3.11.3 and 3.14.2) [7.12.3]

4.11.4.1 Nozzles intended for normal atmospheres

4.11.4.1.1 Ten nozzles should be exposed to a salt spray within a fog chamber. The inlet of each sample should be sealed with a nonreactive cap, e.g., plastic.

4.11.4.1.2 During the corrosive exposure, the inlet thread orifice is to be sealed by a plastic cap after the nozzles have been filled with deionised water. The salt solution should be a 20% by mass sodium chloride solution in distilled water. The pH should be between 6.5 and 7.2 and the density between 1.126 g/ml and 1.157 g/ml when atomized at 35ºC. Suitable means of controlling the atmosphere in the chamber should be provided. The specimens should be supported in their normal operating position and exposed to the salt spray (fog) in a chamber having a volume of at least 0.43 m^3 in which the exposure zone shall be maintained at a temperature of 35 ± 2ºC. The temperature should be recorded at least once per day, at least 7 hours apart (except weekends and holidays when the chamber normally would not be opened). Salt solution should be supplied from a recirculating reservoir through air-aspirating nozzles, at a pressure between 0.7 bar (0.07 MPa) and 1.7 bar (0.17 MPa). Salt solution runoff from exposed samples should be collected and should not return to the reservoir for recirculation. The sample nozzles should be shielded from condensate drippage.

4.11.4.1.3 Fog should be collected from at least two points in the exposure zone to determine the rate of application and salt concentration. The fog should be such that for each 80 cm^2 of collection area, 1 m1 to 2 ml of solution should be collected per hour over a 16 hour period and the salt concentration shall be 20 ± 1% by mass.

4.11.4.1.4 The nozzles should withstand exposure to the salt spray for a period of 10 days. After this period, the nozzles should be removed from the fog chamber and allowed to dry for 4 to 7 days at a temperature of 20°C to 25°C in an atmosphere having a relative humidity not greater than 70%. Following the drying period, five nozzles should be submitted to the functional test at the minimum operating pressure in accordance with 4.5.1 and five nozzles should be subjected to the dynamic heating test in accordance with 3.14.2.

4.11.4.2 Nozzles intended for corrosive atmospheres [7.12.3.2]

Five nozzles should be subjected to the tests specified in 4.12.3.1 except that the duration of the salt spray exposure shall be extended from 10 days to 30 days.

4.11.5 Moist air exposure test (see 3.11.4 and 3.14.2) [7.12.4]

Ten nozzles should be exposed to a high temperature-humidity atmosphere consisting of a relative humidity of 98% ± 2% and a temperature of 95°C ± 4ºC. The nozzles are to be installed on a pipe manifold containing de-ionized water. The entire manifold is to be placed in the high temperature humidity enclosure for 90 days. After this period, the nozzles should be removed from the temperature-humidity enclosure and allowed to dry for 4 to 7 days at a temperature of 25 ± 5°C in an atmosphere having a relative humidity of not greater than 70%. Following the drying period, five nozzles should be functionally tested at the minimum operating pressure in accordance with 4.5.1 and five nozzles should be subjected to the dynamic heating test in accordance with 3.14.2[1].

4.12 Nozzle coating tests [7.13]

4.12.1 Evaporation test (see 3.12.1) [7.13.1]

A 50 cm^3 sample of wax or bitumen should be placed in a metal or glass cylindrical container, having a flat bottom, an internal diameter of 55 mm and an internal height of 35 mm. The container, without lid, should be placed in an automatically controlled electric, constant ambient temperature oven with air circulation. The temperature in the oven should be controlled at 16°C below the nominal release temperature of the nozzle, but at not less than 50°C. The sample should be weighed before and after 90 days exposure to determine any loss of volatile matter; the sample should meet the requirements of 3.12.1.

4.12.2 Low-temperature test (see 3.12.2) [7.13.2]

Five nozzles, coated by normal production methods, whether with wax, bitumen or a metallic coating, should be subjected to a temperature of -10°C for a period of 24 hours. On removal from the low-temperature cabinet, the nozzles should be exposed to normal ambient temperature for at least 30 min before examination of the coating to the requirements of 3.1.12.2.

4.13 Heat-resistance test (see 3.15) [7.14]

One nozzle body should be heated in an oven at 800°C for a period of 15 min, with the nozzle in its normal installed position. The nozzle body should then be removed, holding it by the threaded inlet, and should be promptly immersed in a water bath at a temperature of approximately 15°C. It should meet the requirements of 3.14.

4.14 Water-hammer test (see 3.13) [7.15]

4.14.1 Five nozzles should be connected, in their normal operating position, to the test equipment. After purging the air from the nozzles and the test equipment, 3,000 cycles of pressure varying from 4 ± 2 bar ((0.4 ± 0.2)MPa) to twice the rated working pressure should be generated. The

[1] At the manufacturer's option, additional samples may be furnished for this test to provide early evidence of failure. The additional samples may be removed from the test chamber at 30-day intervals for testing.

pressure should be raised from 4 bar to twice the rated pressure at a rate of 60 ± 10 bar/s. At least 30 cycles of pressure per minute should be generated. The pressure should be measured with an electrical pressure transducer.

4.14.2 Visually examine each nozzle for leakage during the test. After the test, each nozzle should meet the leakage resistance requirement of 3.8.1 and the functional requirement of 3.5.1 at the minimum operating pressure.

4.15 Vibration test (see 3.16) [7.16]

4.15.1 Five nozzles should be fixed vertically to a vibration table. They should be subjected at room temperature to sinusoidal vibrations. The direction of vibration should be along the axis of the connecting thread.

4.15.2 The nozzles should be vibrated continuously from 5 Hz to 40 Hz at a maximum rate of 5 min/octave and an amplitude of 1 mm (1/2 peak-to-peak value). If one or more resonant points are detected, the nozzles after coming to 40 Hz, should be vibrated at each of these resonant frequencies for 120 hours/number of resonances. If no resonances are detected, the vibration from 5 Hz to 40 Hz should be continued for 120 hours.

4.15.3 The nozzle should then be subjected to the leakage test in accordance with 3.8.1 and the functional test in accordance with 3.5.1 at the minimum operating pressure.

4.16 Impact test (see 3.17) [7.17]

4.16.1 Five nozzles should be tested by dropping a mass onto the nozzle along the axial centreline of waterway. The kinetic energy of the dropped mass at the point of impact should be equivalent to a mass equal to that of the test nozzle dropped from a height 1 m (see figure 2). The mass is to be prevented from impacting more than once upon each sample.

4.16.2 Following the test a visual examination of each nozzle shall show no signs of fracture, deformation, or other deficiency. If none is detected, the nozzles should be subjected to the leak resistance test, described in 4.4.1. Following the leakage test, each sample should meet the functional test requirement of 4.5.1 at a pressure equal to the minimum flowing pressure.

4.17 Lateral discharge test (see 3.18) [7.19]

4.17.1 Water is to be discharged from a spray nozzle at the minimum operating and rated working pressure. A second automatic nozzle located at the minimum distance specified by the manufacturer is mounted on a pipe parallel to the pipe discharging water.

4.17.2 The nozzle orifices or distribution plates (if used), are to be placed 550 mm, 356 mm and 152 mm below a flat smooth ceiling for three separate tests, respectively at each test pressure. The top of a square pan measuring 305 mm square and 102 mm deep is to be positioned 152 mm below the heat responsive element for each test. The pan is filled with 0.47 litres of heptane. After ignition, the automatic nozzle is to operate before the heptane is consumed.

4.18 30-day leakage test (see 3.19) [7.20]

4.18.1 Five nozzles are to be installed on a water filled test line maintained under a constant pressure of twice the rated working pressure for 30 days at an ambient temperature of (20 ± 5°C).

4.18.2 The nozzles should be inspected visually at least weekly for leakage. Following completion of this 30-day test, all samples should meet the leak resistance requirements specified in 3.2.4 and should exhibit no evidence of distortion or other mechanical damage.

4.19 Vacuum test (see 3.20) [7.21]

Three nozzles should be subjected to a vacuum of 460 mm of mercury applied to a nozzle inlet for 1 min at an ambient temperature of 20 ± 5°C. Following this test, each sample should be examined to verify that no distortion or mechanical damage has occurred and then should meet the leak resistance requirements specified in 4.4.1.

4.20 Clogging Test (see 3.22) [7.28]

4.20.1 The water flow rate of an open water-mist nozzle with its strainer or filter should be measured at its rated working pressure. The nozzle and strainer or filter should then be installed in test apparatus described in Figure 3 and subjected to 30 minutes of continuous flow at rated working pressure using contaminated water which has been prepared in accordance with 4.20.3.

4.20.2 Immediately following the 30 minutes of continuous flow with the contaminated water, the flow rate of the nozzle and strainer or filter should be measured at rated working pressure. No removal, cleaning or flushing of the nozzle, filter or strainer is permitted during the test.

4.20.3 The water used during the 30 minutes of continuous flow at rated working pressure specified in 4.20.1 should consist of 60 litres of tap water into which has been mixed 1.58 kilograms of contaminants which sieve as described in table 6. The solution should be continuously agitated during the test.

4.20.4 Alternative supply arrangements to the apparatus shown in figure 3 may be used where damage to the pump is possible. Restrictions to piping defined by note 2 of table 5 should apply to such systems.

Table 5 – Contaminant for the contaminated water cycling test

SIEVE DESIGNATION*	NOMINAL SIEVE OPENING, MM	GRAMS OF CONTAMINANT (± 5%)**		
		PIPE SCALE	TOP SOIL	SAND
No. 25	0.706	-	456	200
No. 50	0.297	82	82	327
No. 100	0.150	84	6	89
No. 200	0.074	81	-	21
No. 325	0.043	153	-	3
	TOTAL	400	544	640

* Sieve designations correspond with those specified in the standard for wire-cloth sieves for testing purposes, ASTM E11-87, CENCO-MEINZEN sieve sizes 25 mesh, 50 mesh, 100 mesh, 200 mesh and 325 mesh, corresponding with the number designation in the table, have been found to comply with ASTM E11-87.

** The amount of contaminant may be reduced by 50 per cent for nozzles limited to use with copper or stainless steel piping and by 90 per cent for nozzles having a rated pressure of 50 bar or higher and limited to use with stainless steel piping.

5 WATER-MIST NOZZLE MARKING

5.1 General

Each nozzle complying with the requirements of this Standard should be permanently marked as follows:

(a) trademark or manufacturer's name;

(b) model identification;

(c) manufacturer's factory identification. This is only required if the manufacturer has more than one nozzle manufacturing facility;

(d) nominal year of manufacture[1] (automatic nozzles only);

(e) nominal release temperature[2]; and

(f) K-factor. This is only required if a given model nozzle is available with more than 1 orifice size.

In countries where colour-coding of yoke arms of glass bulb nozzles is required, the colour code for fusible element nozzles should be used.

5.2 Nozzle housings

Recessed housings, if provided, should be marked for use with the corresponding nozzles unless the housing is a non-removable part of the nozzle.

---

1 The year of manufacture may include the last three months of the preceding year and the first six months of the following year. Only the last two digits need be indicated.

2 Except for coated and plated nozzles, the nominal release temperature range should be colour-coded on the nozzle to identify the nominal rating. The colour code should be visible on the yoke arms holding the distribution plate for fusible element nozzles, and should be indicated by the colour of the liquid in glass bulbs. The nominal temperature rating should be stamped or cast on the fusible element of fusible element nozzles. All nozzles should be stamped, cast, engraved or colour-coded in such a way that the nominal rating is recognizable even if the nozzle has operated. This should be in accordance with table 1.

FIGURE 1

RTI AND C LIMITS FOR STANDARD ORIENTATION

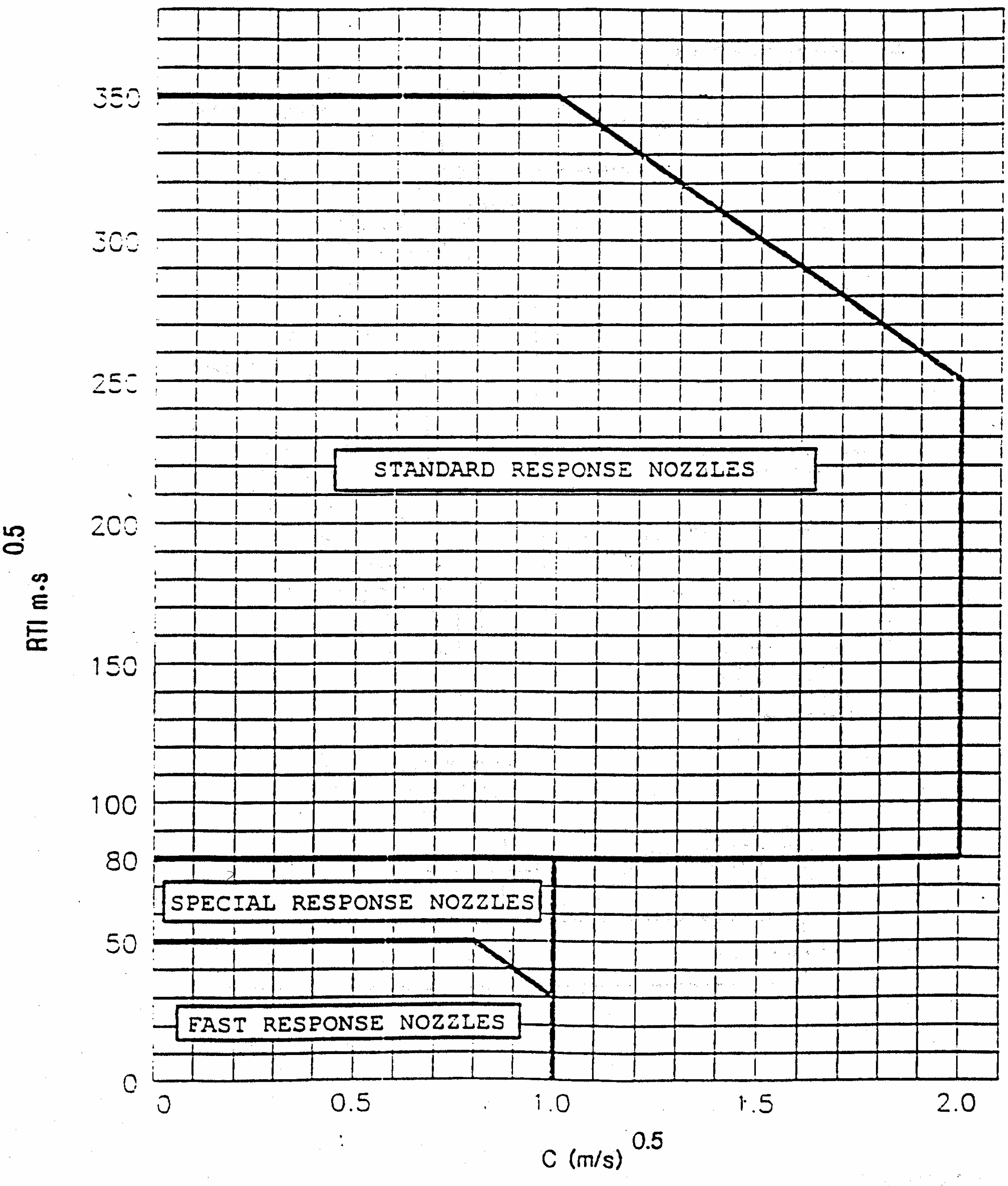


FIGURE 2

IMPACT TEST APPARATUS

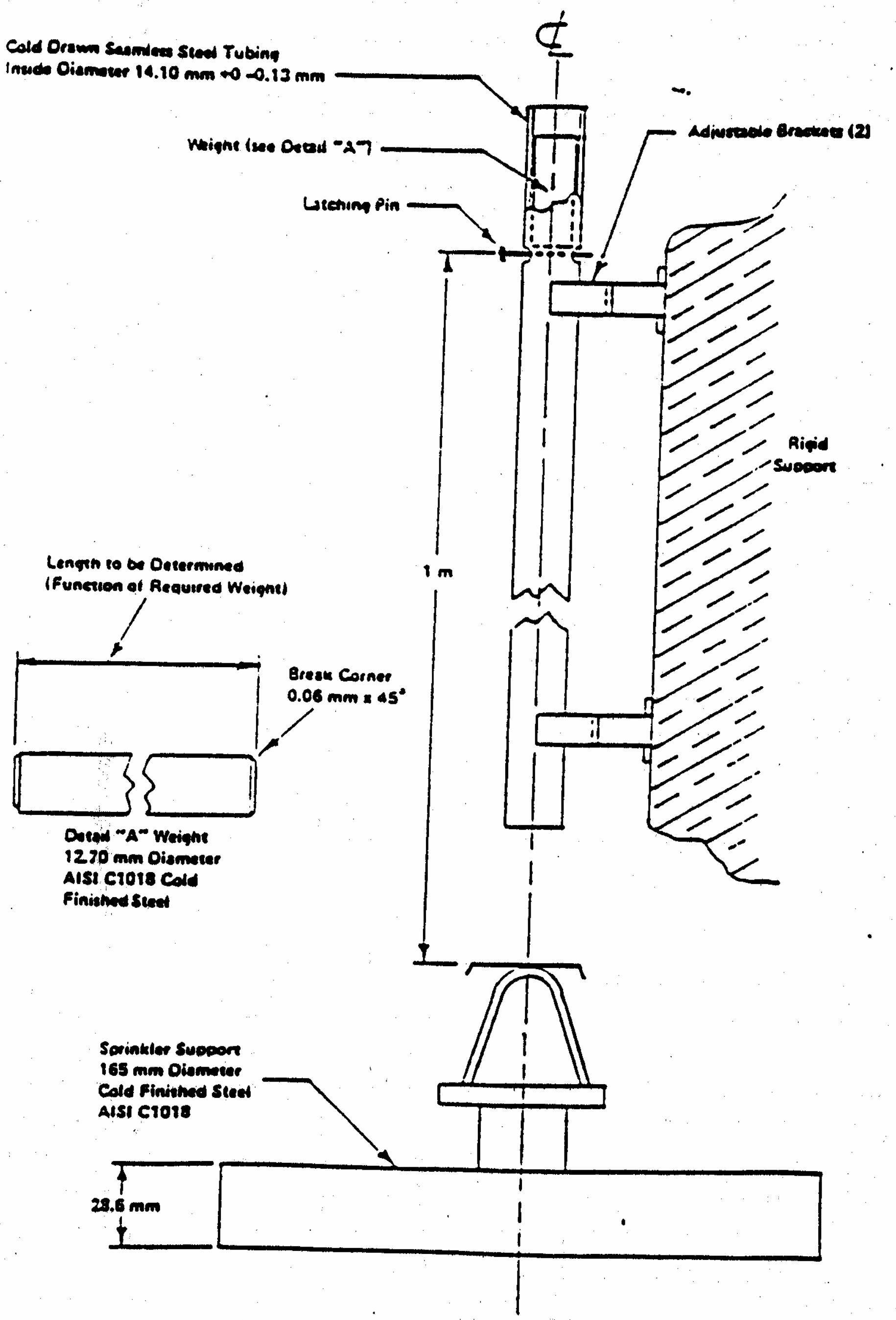
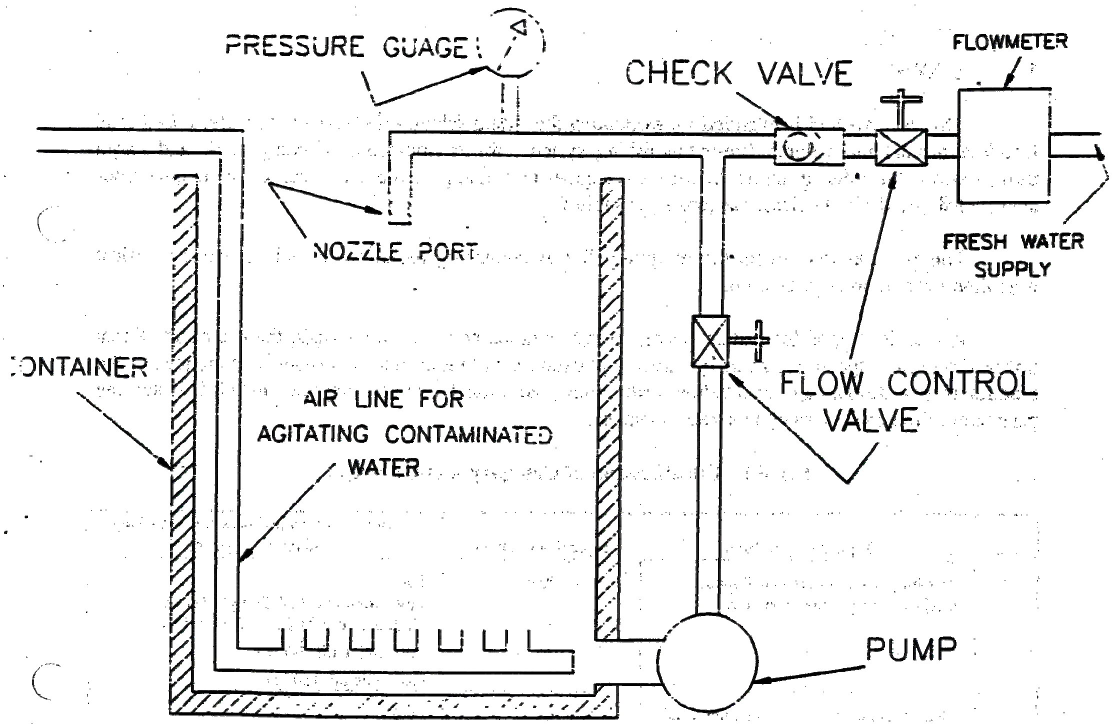


FIGURE 3

CLOGGING TEST APPARATUS



APPENDIX B

TEST METHOD FOR FIRE TESTING EQUIVALENT WATER-BASED FIRE-EXTINGUISHING SYSTEMS FOR MACHINERY SPACES OF CATEGORY A AND CARGO PUMP-ROOMS

1 SCOPE

1.1 This test method is intended for evaluating the extinguishing effectiveness of water-based total flooding fire-extinguishing systems for the protection of engine-rooms of category A and cargo pump-rooms.

1.2 The test method covers the minimum fire-extinguishing requirement and prevention against reignition for fires in engine-rooms.

1.3 It was developed for systems using ceiling mounted nozzles or multiple levels of nozzles. Bilge nozzles are required for all systems. The bilge nozzles may be part of the main system, or they may be a separate bilge area protection system.

1.4 In the tests, the use of additional nozzles to protect specific hazards by direct application is not permitted. However for ship board applications additional nozzles may be added as recommended by the manufacturer.

2 FIELD OF APPLICATION

The test method is applicable for water-based fire-extinguishing systems which will be used as alternative fire-extinguishing systems as required by SOLAS regulation II-2/10.4.1 and II-2/10.9.1. For the installation of the system, nozzles shall be installed to protect the entire hazard volume (total flooding). The installation specification provided by the manufacturer should include maximum horizontal and vertical nozzle spacing, maximum enclosure height, and distance of nozzles below the ceiling and maximum enclosure volume which, as a principle, should not exceed the values used in approval fire test. However, when based on the scientific methods developed by the Organization*, scaling from the maximum tested volume to a larger volume may be permitted. The scaling should not exceed twice the tested volume.

3 SAMPLING

The components to be tested should be supplied by the manufacturer together with design and installation criteria, operational instructions, drawings and technical data sufficient for the identification of the components.

* To be developed by the Organization.

4 METHOD OF TEST

4.1 Principle

This test procedure enables the determination of the effectiveness of different water-based extinguishing systems against spray fires, cascade fires, pool fires, and Class A fires which are obstructed by an engine mock-up.

4.2 Apparatus

4.2.1 *Engine mock-up*

The fire test should be performed in a test apparatus consisting of:

.1 an engine mock-up of the size (width × length × height) of 1 m × 3 m × 3 m constructed of sheet steel with a nominal thickness of 5 mm. The mock-up is fitted with two steel tubes of 0.3 m in diameter and 3 m in length that simulate exhaust manifolds and a grating. At the top of the mock-up, a 3 m^2 tray is arranged (see figure 1); and

.2 a floor plate system of the size (width × length × height) of 4 m × 6 m × 0.5 m, surrounding the mock-up. Provision shall be made for placement of the fuel trays, described in table 1, and located as described in figure 1.

4.2.2 *Fire test compartment*

The tests should be performed in a room having a specified area greater than 100 m^2, a specified height of at least 5 m and ventilation through a door opening of 2 m × 2 m in size. Fires and engine mock-up should be according to tables 1, 2, 3 and figure 2. The test hall should have an ambient temperature of between 10°C and 30°C at the start of each test.

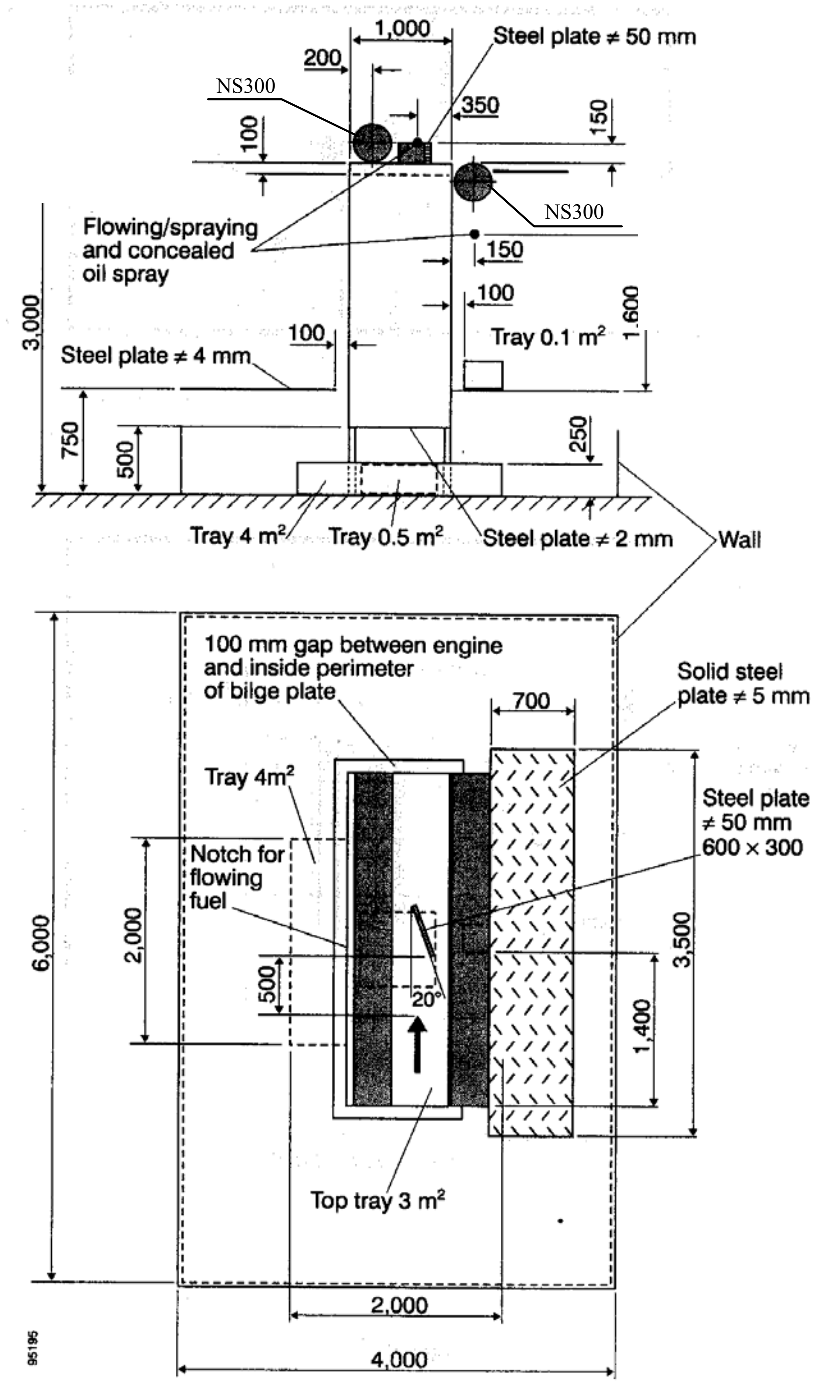

1,000
Steel plate ≠ 50 mm
200
NS300
350
150
100
NS300
Flowing/spraying
and concealed
oil spray
150
100
3,000
100
Tray 0.1 m²
1,600
Steel plate ≠ 4 mm
750
500
250
Tray 4 m²
Tray 0.5 m²
Steel plate ≠ 2 mm
Wall
100 mm gap between engine
and inside perimeter
of bilge plate
Solid steel
plate ≠ 5 mm
700
Tray 4m²
Steel plate
≠ 50 mm
600 × 300
Notch for
flowing
fuel
6,000
2,000
500
20°
1,400
3,500
Top tray 3 m²
2,000
4,000
95195

Figure 1

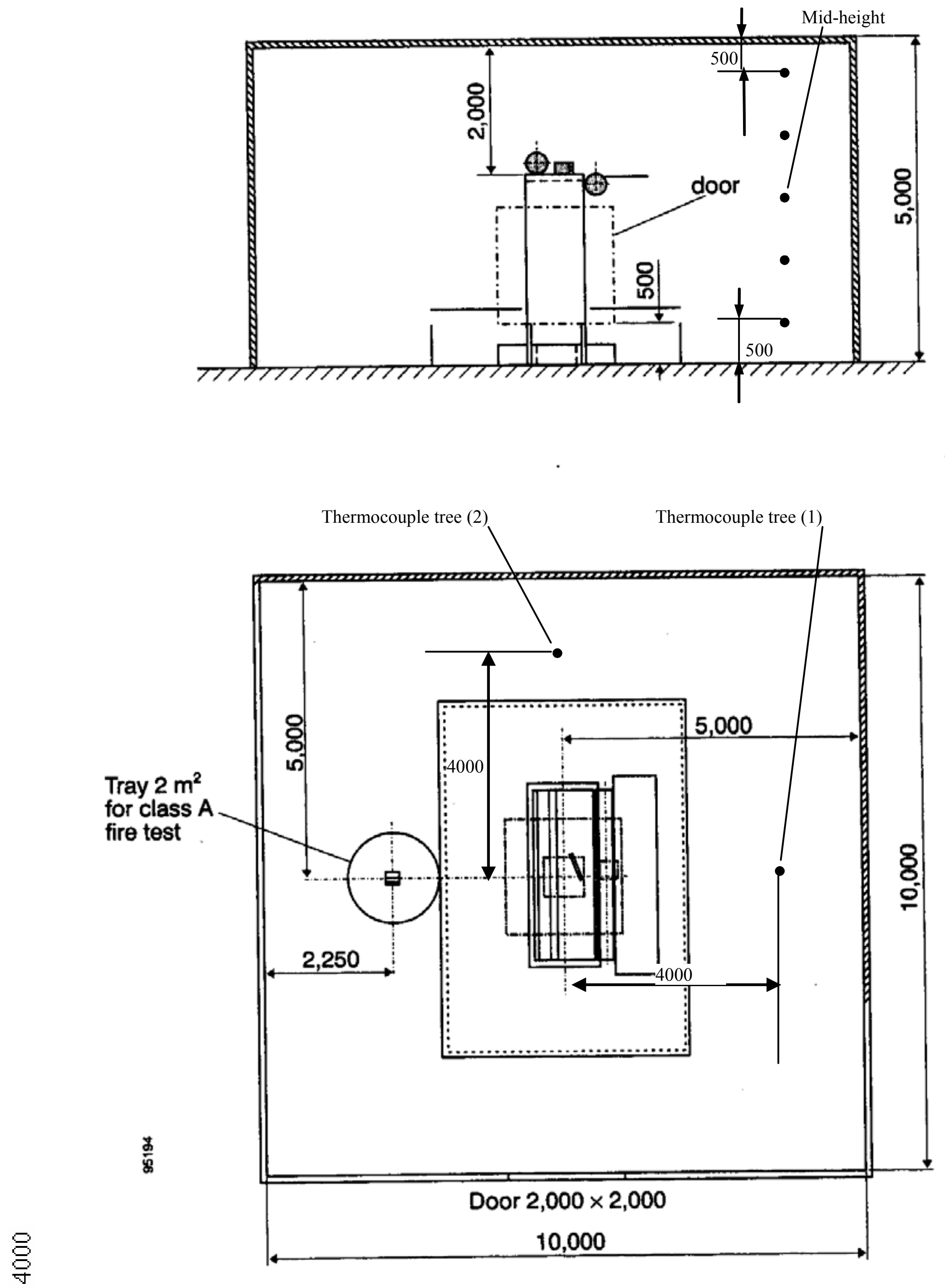

Mid-height
500
2,000
door
500
5,000
500
Thermocouple tree (2)
Thermocouple tree (1)
5,000
4000
5,000
Tray 2 m²
for class A
fire test
2,250
4000
10,000
95194
Door 2,000 × 2,000
10,000
4000

Figure 2

4.3 Test scenario

4.3.1 *Fire-extinguishing tests*

Table 1

Test No.	Fire Scenario	Test Fuel
1	Low pressure horizontal spray on top of simulated engine between agent nozzles.	Commercial fuel oil or light diesel oil
2	Low pressure spray in top of simulated engine centred with nozzle angled upward at a 45° angle to strike a 12-15 mm diameter rod 1 m away.	Commercial fuel oil or light diesel oil
3	High pressure horizontal spray on top of the simulated engine.	Commercial fuel oil or light diesel oil
4	Low pressure concealed horizontal spray fire on the side of simulated engine with oil spray nozzle positioned 0.1 m in from the end of the engine and 0.1 m^2 tray positioned on tope of the bilge plate 1.4 m in from the engine end at the edge of the bilge plate closest to the engine.	Commercial fuel oil or light diesel oil
5	Concealed 0.7 m × 3.0 m fire tray on top of bilge plate centred under exhaust plate.	Heptane
6	Flowing fire 0.25 kg/s from top of mock-up (see figure 3).	Heptane
7	Class A fires wood crib (see Note) in 2 m^2 pool fire with 30 s preburn. The test tray should be positioned 0.75 m above the floor as shown in figure 1.	Heptane
8	A steel plate (30 cm × 60 cm × 5 cm) offset 20° to the spray is heated to 350°C by the top low pressure spray nozzle positioned horizontally 0.5 m from the front edge of the plate. When the plate reaches 350°C, the system is activated. Following system shutoff, no reignition of spray is permitted.	Heptane

Note: 1 The wood crib is to weigh 5.4 to 5.9 kg and is to be dimensioned approximately 305 mm × 305 mm × 305 mm. The crib is to consist of eight alternate layers of four trade size 38.1 mm × 38.1 mm kiln-dried spruce or fir lumber 305 mm long. The alternate layers of the lumber are to be placed at right angles to the adjacent layers. The individual wood members in each layer are to be evenly spaced along the length of the previous layer of wood members and stapled. After the wood crib is assembled, it is to be conditioned at a temperature of 49 ± 5°C for not less than 16 h. Following the conditioning, the moisture content of the crib is to be measured with a probe type moisture meter. The moisture content of the crib should not exceed 5% prior to the fire test.

Table 2 - *Test Programme for Bilge Nozzles*

Test No.	Fire Scenario	Test Fuel
1	0.5 m^2 central under mock-up	Heptane
2	0.5 m^2 central under mock-up	SAE 10W30 mineral based lubrication oil
3	4 m^2 tray under mock-up	Commercial fuel oil or light diesel oil

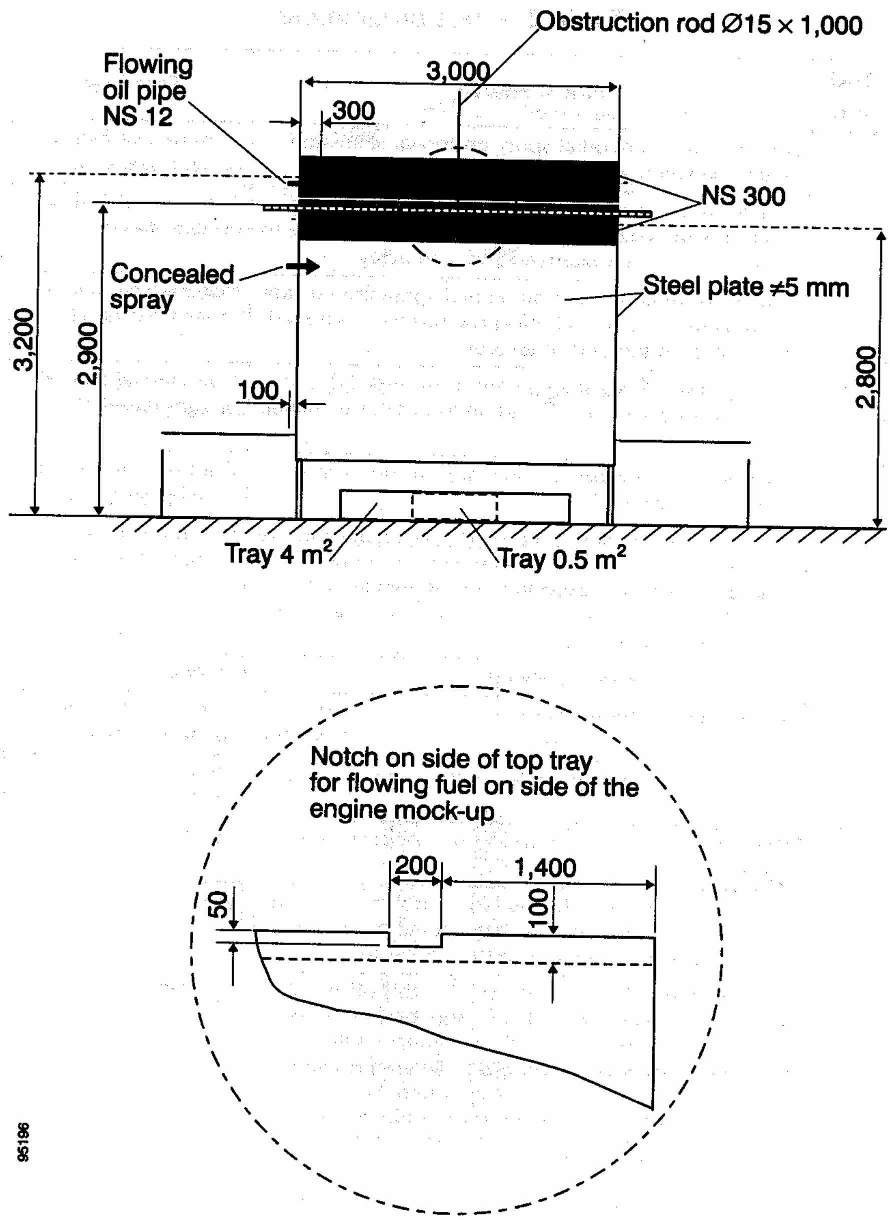


Figure 3

Table 3 - S*pray fire test parameters*

Fire type	**Low pressure**	**High pressure**
Spray nozzle	Wide spray angle (120° to 125°) full cone type	Standard angle (at 6 bar) full cone type
Nominal fuel pressure	8 bar	150 bar
Fuel flow	0.16 ± 0.01 kg/s	0.050 ± 0.002 kg/s
Fuel temperature	20 ± 5°C	20 ± 5°C
Nominal heat release rate	5.8 ± 0.6 MW	1.8 ± 0.2 MW

4.3.2 *Thermal management tests*

4.3.2.1 Instrumentation

4.3.2.1.1 Thermocouples should be installed in two trees. One tree should be located 4 m from the centre of the mock-up, on the opposite side of the 2 m^2 tray for class A fire test as shown in figure 2. The other tree should be located 4 m from the centre of the mock-up, on the opposite side of the door opening.

4.3.2.1.2 Each tree should consist of five thermocouples of diameter not exceeding 0.5 mm, positioned at the following heights: (1) 500 mm below the ceiling; (2) 500 mm above floor level; (3) at mid-height of the test compartment; (4) between the uppermost thermocouple and the thermocouple at mid-height and (5) between the lowest thermocouple and the thermocouple at mid-height.

4.3.2.1.3 Measures should be provided to avoid direct water spray impingement of the thermocouples.

4.3.2.1.4 The temperatures should be measured continuously, at least once every two seconds, throughout the test.

4.3.2.2 Fire size and position

4.3.2.2.1 For the determination of the thermal management, an obstructed n-Heptane pool fire scenario should be used. The nominal fire sizes should be correlated to the test compartment volume according to table 4. The test tray should be positioned in accordance with test No.7 as shown in table 1 and figure 2.

Table 4 - Correlation between nominal pool fire sizes and test compartment volume

Test compartment volume	Pool fire scenario
500 m^3	1 MW
1000 m^3	2 MW
1500 m^3	3 MW
2000 m^3	4 MW
2500 m^3	5 MW
3000 m^3	6 MW

Note: Interpolation of the data in the table is allowed.

4.3.2.2.2 The rim height of the trays should be 150 mm and the tray should be filled with 50 mm of fuel. Additional water should be added to provide a freeboard of 50 mm. Table 5 provides examples of pool tray diameters and the corresponding area, for a selection of nominal heat release rates.

Table 5 - Pool tray diameters and the corresponding area, for a selection of nominal heat release rates

Nominal HRR	Diameter (cm)	Area (m^2)	Size of obstruction steel plate (m x m)
0.5 MW	62	0.30	2.0 x 2.0
1 MW	83	0.54	2.0 x 2.0
2 MW	112	0.99	2.0 x 2.0
3 MW	136	1.45	2.25 x 2.25
4 MW	156	1.90	2.25 x 2.25
5 MW	173	2.36	2.5 x 2.5
6 MW	189	2.81	2.5 x 2.5

Note: Interpolation or extrapolation of the data is allowed according to the following equation:

$$Q = 2.195A - 0.18$$

where:

Q = the desired nominal heat release rate (MW)
A = the area of the fire tray (m^2)

4.3.2.2.3 A square horizontal obstruction steel plate should shield the pool fire tray from direct water spray impingement. The size of the obstruction steel plate is dictated by the size of the fire tray, as indicated in table 5. The vertical distance measured from the floor to the underside of the obstruction steel plate should be 1.0 m.

4.3.2.2.4 The thickness of the steel plate should be a nominal 4 mm. The vertical distance measured from the rim of the trays to the underneath of the horizontal obstruction steel plate should be 0.85 m.

4.4 Extinguishing system

4.4.1 During fire test conditions the extinguishing system should be installed according to the manufacturer's design and installation instructions in a uniformly spaced overhead nozzle grid. The lowest level of nozzles should be located at least 5 m above the floor. For actual installations, if the water-mist system includes bilge area protection, water-mist nozzles must be installed throughout the bilges in accordance with the manufacturer's recommended dimensioning, as developed from bilge system testing using the tests in table 2, conducted with the bilge plate located at the maximum height for which approval is sought. Tests should be performed with nozzles located in the highest and lowest recommended position above the bilge fires. Bilge systems using the nozzle spacing tested may be approved for fire protection of bilge areas of any size.

4.4.2 The system fire tests should be conducted at the minimum system operating pressure, or at the conditions providing the minimum water application rate.

4.4.3 During the laboratory fire tests the bilge system nozzles may not be located beneath the engine mock-up, but should be located beneath the simulated bilge plates at least one-half the nozzle spacing away from the engine mock-up.

4.5 Procedure

4.5.1 *Ignition*

The trays used in the test should be filled with at least 50 mm fuel on a water base. Freeboard is to be 150±10 mm.

4.5.2 *Flow and pressure measurements (Fuel system)*

The fuel flow and pressure in the fuel system should be measured before each test. The fuel pressure should be measured during the test.

4.5.3 *Flow and pressure measurements (Extinguishing system)*

Agent flow and pressure in the extinguishing system should be measured continuously on the high pressure side of a pump or equivalent equipment at intervals not exceeding 5 s during the test, alternatively, the flow can be determined by the pressure and the *K* factor of the nozzles.

4.5.4 *Duration of test*

4.5.4.1 After ignition of all fuel sources, a 2-min preburn time is required before the extinguishing agent is discharged for the fuel tray fires and 5-15 s for the fuel spray and heptane fires and 30 s for the Class A fire test (Test No.7).

4.5.4.2 The fire should be allowed to burn until the fire is extinguished or for a period of 15 minutes, whichever is less, measured from the ignition. The fuel spray, if used, should be shut off 15 s after the end of agent discharge.

4.5.5 *Observations before and during the test*

4.5.5.1 Before the test, the test room, fuel and mock-up temperature is to be measured.

4.5.5.2 During the test the following items should be recorded:

.1 the start of the ignition procedure;

.2 the start of the test (ignition);

.3 the time when the extinguishing system is activated;

.4 the time when the fire is extinguished, if it is;

.5 the time when the extinguishing system is shut off;

.6 the time of re-ignition, if any;

.7 the time when the oil flow for the spray fire is shut off;

.8 the time when the test is finished; and

.9 data from all test instrumentation.

4.5.6 *Observations after the test*

.1 damage to any system components;

.2 the level of fuel in the tray(s) to make sure that the fuel was not totally consumed; and

.3 test room, fuel and mock-up temperature.

5 CLASSIFICATION CRITERIA

5.1 Fire-extinguishing tests

All fires in the fire-extinguishing tests should be extinguished within 15 minutes of system activation and there should be no re-ignition or fire spread.

5.2 Thermal management tests

The 60 s time-weighted average temperature should be kept below 100°C, no later than 300 s after activation of the system for the thermal management test in 4.3.2.

6 TEST REPORT

The test report should include the following information:

.1 name and address of the test laboratory;

.2 date and identification number of the test report;

.3 name and address of client;

.4 purpose of the test;

.5 method of sampling;

.6 name and address of manufacturer or supplier of the product;

.7 name or other identification marks of the product;

.8 description of the tested product:

- drawings,
- descriptions,
- assembly instructions,
- specification of included materials, and
- detailed drawing of test set-up;

.9 date of supply of the product;

.10 date of test;

.11 test method;

.12 drawing of each test configuration;

.13 measured nozzle characteristics;

.14 identification of the test equipment and used instruments;

.15 conclusions;

.16 deviations from the test method, if any;

.17 test results including observations during and after the test; and

.18 date and signature.

___