Approval Standard for Heat Responsive Links for Fire Protection

Class Number 2031

July 2001

Foreword

The FM Approvals certification mark is intended to verify that the products and services described will meet FM Approvals' stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of Approval Standards is to present the criteria for FM Approval of various types of products and services, as guidance for FM Approvals personnel, manufacturers, users and authorities having jurisdiction.

Products submitted for certification by FM Approvals shall demonstrate that they meet the intent of the Approval Standard, and that quality control in manufacturing shall ensure a consistently uniform and reliable product. Approval Standards strive to be performance-oriented. They are intended to facilitate technological development.

For examining equipment, materials and services, Approval Standards:

a) must be useful to the ends of property conservation by preventing, limiting or not causing damage under the conditions stated by the Approval listing; and

b) must be readily identifiable.

Continuance of Approval and listing depends on compliance with the Approval Agreement, satisfactory performance in the field, on successful re-examinations of equipment, materials, and services as appropriate, and on periodic follow-up audits of the manufacturing facility.

FM Approvals LLC reserves the right in its sole judgment to change or revise its standards, criteria, methods, or procedures.

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1. INTRODUCTION

1.1 Purpose

1.1.1 This standard states FM Approval criteria for heat responsive links for fire protection service.

1.1.2 FM Approval criteria may include, but are not limited to, performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a follow-up program.

1.2 Scope

1.2.1 This standard sets performance requirements for heat responsive links for use in a variety of applications, including automatic operation of fire doors, heat and explosion vents, wet chemical extinguishing systems and dry chemical extinguishing systems.

1.2.2 Other types of heat responsive links may be Approved if they meet the requirements and intent of this standard. Heat responsive links of unusual design may be subjected to special tests to determine their suitability.

1.2.3 FM Approval standards are intended to verify that the product described will meet stated conditions of performance, safety and quality useful to the ends of property conservation.

1.3 Basis for Requirements

1.3.1 The requirements of this standard are based on experience, research and testing, and/or the standards of other organizations. The advice of manufacturers, users, trade associations, jurisdictions and/or loss control specialists was also considered.

1.3.2 The requirements of this standard reflect tests and practices used to examine characteristics of heat responsive links for the purpose of obtaining FM Approval. Heat responsive links having characteristics not anticipated by this standard may be Approved if performance equal, or superior, to that required by this standard is demonstrated, or if the intent of the standard is met. Alternatively, heat responsive links which meet all of the requirements identified in this standard may not be Approved if other conditions which adversely affect performance exist or if the intent of this standard is not met.

1.4 Basis for FM Approval

FM Approval is based upon satisfactory evaluation of the product and the manufacturer in the following major areas:

1.4.1 Examination and tests on production samples shall be performed to evaluate:

- the suitability of the product;
- the performance of the product as specified by the manufacturer and required by FM Approvals; and, as far as practical,
- the durability and reliability of the product.

1.4.2 An examination of the manufacturing facility(ies) and audit of quality control procedures shall be made to evaluate the manufacturer's ability to consistently produce the product which was examined and tested, and the marking procedures used to identify the product. These examinations are repeated as part of FM Approvals' product follow-up program.

1.5 Basis for Continued Approval

Continued Approval is based upon:

- production or availability of the product as currently Approved;
- the continued use of acceptable quality assurance procedures;
- satisfactory field experience;
- compliance with the terms stipulated in the Approval Agreement;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory Facilities and Procedures Audits (F&PAs) conducted as part of FM Approvals' product follow-up program.

Also, as a condition of retaining Approval, manufacturers may not change a product or service without prior authorization by FM Approvals.

1.6 Effective Date

The effective date of an Approval standard mandates that all products tested for Approval after the effective date shall satisfy the requirements of that standard. Products Approved under a previous edition shall comply with the new version by the effective date or forfeit Approval.

The effective date of this standard is **December 31, 2002** for compliance with all requirements.

1.7 System of Units

Units of measurement used in this standard are United States (U.S.) customary units. These are followed by their arithmetic equivalents in International System (SI) units, enclosed in parentheses. The first value stated shall be regarded as the requirement. The converted equivalent value may be approximate. Appendix A lists the selected units and conversions to SI units for measures appearing in this standard. Conversion of U.S. customary units is in accordance with the American National Standards Institute (ANSI)/Institute of Electrical and Electronics Engineers (IEEE)/American Society for Testing Materials (ASTM) SI 10-97, *"Standard for Use of the International System of Units (SI): The Modern Metric System."*

1.8 Applicable Documents

The following standards, test methods, and practices are referenced in this standard:

ANSI/IEEE/ASTM SI 10 — 1997, *Standard for Use of the International System of Units (SI): The Modern Metric System*

ASTM B-117 — 1990, *Method of Salt Spray (Fog) Testing*

ASTM E-1 — 1991, *Standard Specification for ASTM Thermometers*

FM Global Property Loss Prevention Data Sheets

1.9 Definitions

For purposes of this standard, the following terms apply:

Accepted

This term refers to installations acceptable to the authority enforcing the applicable installation rules. When the authority is FM Global, such locations are termed "FM Global Accepted." Acceptance is based upon an overall evaluation of the installation. Factors other than the use of Approved equipment impact upon the decision to accept, or not to accept. Acceptance is not a characteristic of a product. It is installation specific. A product accepted for one installation may not be acceptable elsewhere. (Contrast with Approved.)

Approval Mark

The FM Approval Mark is detailed in Appendix B. Its use is mandatory on all units of Approved heat responsive links. These registered marks cannot be used except as authorized by FM Approvals via the granting of Approval to a specific product.

Approved

This term refers to products Approved by FM Approvals. Such products are listed in the FM Approval Guide, issued annually, or one of the supplements. All products so listed have been successfully examined by FM Approvals, and their manufacturers have signed and returned an Approval Agreement to FM Approvals. This form obligates the manufacturer to allow re-examination of the product and audit of facilities and procedures at FM Approvals discretion. It further requires the manufacturer not to deviate from the as-Approved configuration of the product without review by and agreement of FM Approvals. Approval is product specific.

Assembly Load

The force which is applied to the heat responsive link frame due to assembly of the operating parts plus the maximum design load acting on the operating element.

Bulb Element

An operating element that opens under the influence of heat by bursting of a glass bulb through pressure resulting from expansion of the enclosed fluid.

Element Design Load

The load actually applied on the operating element (heat responsive link).

Fusible Element

An operating element that opens under the influence of heat by the melting of a component.

Heat Responsive Link

A thermo-sensitive device designed to react at a predetermined temperature.

Operating Temperature

The temperature in degrees Fahrenheit (°F) or Celsius (°C) at which the heat responsive element operates when subjected to a controlled rate-of-temperature-rise liquid bath.

2. GENERAL INFORMATION

2.1 Product Information

2.1.1 A heat responsive link is a thermo-sensitive device designed to react at a predetermined temperature. The heat responsive element joining two components, or link halves, operates causing the components to separate. Such devices are typically used to automatically operate fire doors, heat and explosion vents or wet chemical extinguishment systems or dry chemical extinguishment systems.

2.1.2 In order to meet the intent of this standard, heat responsive links must be examined on a model-by-model, type-by-type, manufacturer-by-manufacturer, and plant-by-plant basis. This is predicated on the basis that the manufacturing of heat responsive links requires sufficient skill in its execution that identical designs, fabricated in identical materials by different manufacturers or, even by different plants of the same manufacturer, have been seen to perform differently in testing. Sample heat responsive links, selected in conformance to this criterion, shall satisfy all of the requirements of this standard.

2.2 Approval Application Requirements

To apply for an Approval examination the manufacturer, or its authorized representative, shall submit a request to:

Hydraulics Group Manager
Hydraulics Laboratory
An FM Global Affiliate
743A Reynolds Road
West Glocester, RI 02814
U.S.A.

The manufacturer shall provide the following preliminary information with any request for Approval consideration:

- A complete list of all models, types, sizes, and options for the heat responsive links being submitted for Approval consideration;
- A complete set of manufacturing drawings, general assembly drawings, materials list(s) and material specifications (such as ASTM designation or alloy identification), anticipated marking format, brochures, sales literature, specification sheets, installation, operation and maintenance procedures, and;
- the number and location of facilities manufacturing the specified product.

All documents shall identify the manufacturer's name, document number or other form of reference, title, date of last revision, and revision level. All foreign language documents shall be provided with English translation.

2.3 Requirements for Samples for Examination

Following generation and authorization of an Approval examination, the manufacturer shall submit samples for examination and testing. Sample requirements are to be determined by FM Approvals following review of the preliminary information. Sample requirements may vary depending on design features, results of prior or similar testing, and results of the foregoing tests. It is the manufacturer's responsibility to submit samples representative of production. Any decision to use data generated utilizing prototypes is at the discretion of FM Approvals. The manufacturer shall provide any special test fixtures, such as those which may be required to evaluate the strength of heat responsive elements, requested by FM Approvals to evaluate the heat responsive links.

3. GENERAL REQUIREMENTS

3.1 Review of Documentation

During the initial investigation and prior to physical testing, the manufacturer's specifications, technical data sheets, and design details shall be reviewed to assess the ease and practicality of installation and use. The product shall be capable of being used within the limits of the Approval investigation.

3.2 Physical or Structural Features

3.2.1 Stampings shall show no cracking or splitting and be free of burrs.

3.2.2 All operating parts shall have ample clearance with near zero possibility of binding or wedging. An analysis of the design drawings may be conducted to evaluate the worst combination of tolerances in parts so as to assess the possibility of such malfunction.

3.3 Materials

All materials used in these heat responsive links shall be suitable for the intended application. When unusual materials are used, special tests may be necessary to verify their suitability.

3.4 Markings

3.4.1 The following shall be displayed on a visible area of a link component that will remain attached to the device that was utilizing the link:

- manufacturer's name or identifying symbol (logo);
- model designation (see Section 3.4.2 below);
- nominal temperature rating;
- year of manufacture (see Section 3.4.3);
- the FM Approval Mark (see Appendix B).

3.4.2 The model and/or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the heat responsive link as Approved. The manufacturer shall not place this identification mark on any other product.

3.4.3 Heat responsive links manufactured in the first 6 months or last 3 months of a calendar year may be marked with the previous or following year respectively, as the year of manufacture.

3.4.4 If a manufacturer produces heat responsive links with the same model designation at more than one facility, each device shall bear a distinctive marking to identify it as the product of a particular location.

3.4.5 For fusible heat responsive links, the operating temperature shall also appear on a visible area of the fusible element or an associated operating component.

3.4.6 For bulb-type heat responsive links, the manufacturer shall place a distinctive mark on a non-operating part of the link to denote the bulb manufacturer if more than one source is used on a given design.

3.4.7 The FM Approval Mark (see Appendix B) shall be displayed visibly and permanently on the product. The manufacturer shall not use this Mark on any other product unless such product is covered by separate agreement with FM Approvals.

3.4.8 All markings shall be legible and durable.

3.5 Manufacturer's Installation and Operation Instructions

The manufacturer shall provide the user with adequate instructions for proper installation with each shipment. Heat responsive links shall be installed and maintained in accordance with applicable installation rules. Field modification of the heat responsive link, such as replacing a component, field plating, or painting, is prohibited.

3.6 Calibration

All examinations and tests performed in evaluation to this standard shall use calibrated measuring instruments traceable and certified to national or international standards.

4. PERFORMANCE REQUIREMENTS

4.1 Examination

4.1.1 Requirements

The heat responsive links shall conform to the manufacturer's drawings and specifications and to FM Approvals requirements.

4.1.2 Test/Verification

A sample shall be examined and compared to drawings and specifications. It shall be verified that the sample conforms to the physical and structural requirements described in Section 3, General Requirements.

4.2 Assembly Load/Frame Strength

4.2.1 Requirements

For heat responsive links incorporating a frame design, the assembly load shall be measured for use in determining compliance with the requirements of the Strength of Heat Responsive Element Test (Section 4.3).

4.2.2 Test/Verification

Fifteen previously untested heat responsive links shall be individually tested to determine the assembly load. With the anchor points of the heat responsive link restrained from movement, the heat responsive element of the test sample shall be removed and the negative axial deflection of the frame, due to the release of the assembly, recorded. A force necessary to return the deflection of the frame to the original zero position shall be reapplied and the value of the force recorded. This force shall be added to the maximum design load acting upon the heat responsive element and shall be used in determining compliance with the requirements of Section 4.3.1.B. Other methods of measuring the assembly load of the heat responsive element may be used, at the discretion of FM Approvals, if the assembly load can not be determined using the above method.

4.3 Strength of Heat Responsive Element

4.3.1 Requirements

A. A heat responsive element of the fusible type shall (1) be capable of sustaining a load 5 times its maximum design load for a period of 150 hours or (2) demonstrate the ability to sustain the maximum element design load when tested in accordance with Section 4.3.2.

B. The lower tolerance limit for bulb strength shall be greater than two times the upper tolerance limit for heat responsive link assembly load based on calculations with a degree of confidence of 0.99. Calculations shall 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. The method for calculating the upper and lower tolerance limits is shown in Appendix D.

4.3.2 Tests/Verification

A. Heat Responsive Element of the Fusible Type

1. Fifteen samples shall be loaded with a weight representing the equivalent of 5 times the maximum design load at an ambient temperature of 70 ± 5°F (21 ± 2.8°C). If all samples remain undamaged after 150 hours, the results shall be deemed acceptable.

2. Fusible type heat responsive elements which cannot pass the test described in 4.3.2.A.1. shall be subjected to the following tests. Sample fusible type heat responsive elements shall be subjected to loads in excess of the design load which will produce failure within and after 1000 hours. The test samples shall be maintained at an environmental temperature of 70 ±5°F (21 ±2.6°C). At least 15 samples are to be loaded at different values to establish a basis of time as a function of load. Failures which are not related to the solder bond shall be disregarded. A least square, full logarithmic regression curve shall be plotted from which the load for failure at 1 hour (L_o) and the load for failure at 1000 hours (L_m) shall be determined. The design load (L_d) shall be less than or equal to the value determined in the expression:

$$L_d \leq 1.02 \frac{L_m^2}{L_o}$$

where:

L_d = Maximum design load for the responsible element

L_m = Load resulting in failure at 1000 hours

L_o = Load resulting at failure in 1 hour

3. Where physical limitations of the fusible element prevent the application of the loads described in Section 4.3.2.A.1. and 4.3.2.A.2., alternate methods of determining the adequacy of the design shall be developed to ensure that such elements should not fail during the anticipated life span.

B. Heat Responsive Element of the Bulb Type

The results of Section 4.3.2.A shall form the basis for the upper tolerance limit for the heat responsive link assembly load calculations. The lower tolerance limit for bulb strength shall be determined using the results obtained from subjecting a minimum of 20 sample bulbs to an increasing load until the bulbs fail. Each test shall be conducted with the bulb mounted in hardened steel inserts with seating surfaces or dimensions that conform to the actual mating components of the heat responsive link. The inserts shall have a hardness within the range Rockwell C 38-50 (see Figure E-1). They shall be provided by the manufacturer each time the test is specified. The load shall be applied at a rate of compression not exceeding 0.05 in./min (1.27 mm/min). The results obtained from the two sets of data shall be utilized for the tolerance limit calculations as described in Appendix D, Tolerance Limit Calculations.

4.4 Operating Temperature (Liquid Bath)

4.4.1 Requirements

The operating temperature of at least 10 heat responsive links shall fall within the specified range of the nominal operating temperature. The operating temperature for all samples shall be within ±3.5 percent of the marked nominal temperature rating.

4.4.2 Tests/Verification

Ten previously untested heat responsive links shall be immersed in a vessel containing water or, for nominal temperature ratings in excess of 200°F (93°C), vegetable oil.

The heat responsive links shall be placed in a fixture which applies a load equal to the manufacturer's specified minimum design load. The fixture shall be placed on a grate suspended above the bottom of the vessel. The liquid level shall not exceed 1 in. (25.4 mm) above the top of the heat responsive links. The vessel shall be provided with a source for heating the liquid, a means to agitate the liquid, and a device to measure the temperature of the liquid bath. The device used to measure the temperature of the liquid bath shall be calibrated in accordance with the ASTM Standard E-1, *Standard Specification for ASTM Thermometers*, or the equivalent.

The temperature of the bath shall be raised until the liquid is 20°F (11.1°C) below the nominal temperature rating of the heat responsive links. The temperature rise shall then be controlled at a rate not exceeding 1°F (0.56°C) per minute until operation or until a bath temperature ten percent above the nominal temperature of the heat responsive links is reached. The temperature of the liquid bath at the time of operation of each heat responsive link shall be recorded.

4.5 High Ambient Temperature Exposure (90 Day Test)

4.5.1 Requirements

Heat responsive links shall be capable of withstanding an exposure to a high ambient temperature in accordance with Table 4.5.1 and Section 4.5.2 for a period of 90 days without evidence of weakness or failure. Following exposure, half of the samples shall be tested for conformance with the requirements for sensitivity as described in Section 4.10 (Sensitivity [Air Oven]). The remaining samples shall be tested for operating temperature as described in Section 4.4 (Operating Temperature [Liquid Bath]).

Table 4.5.1 High Ambient Temperature Exposure Test Conditions

Heat Responsive Link Nominal Temperature Rating		*Nominal[1] Test Temperatures*	
°F	*(°C)*	*°F*	*(°C)*
135 to 170	(57 to 77)	100	(38)
175 to 225	(79 to 107)	150	(66)
250 to 300	(121 to 149)	225	(107)
325 to 375	(163 to 191)	300	(149)
400 to 475	(204 to 246)	365	(185)
500 to 575	(260 to 302)	465	(241)
650	(343)	Evaluated on a case-by-case basis	

Note: [1]Tolerance on Nominal Test Temperature at stabilized condition: ± 3°F (1.7°C)

4.5.2 Test/Verification

Ten previously untested heat responsive links shall be placed in a vertical position in a fixture which applies a load equal to the manufacturer's specified maximum design load and shall be subjected to the high ambient temperature selected in accordance with Table 4.5.1 for a period of 90 days. An automatically controlled, constant-temperature convection oven shall be used for this test.

Following this test, the samples shall be subjected to the post-tests detailed in Section 4.5.1. Manufacturers may submit additional samples for evaluation prior to completion of the required test period. Such samples are for reference only.

4.6 Corrosion — Salt Spray

4.6.1 Requirements

In order to evaluate the resistance to corrosion of the assembly, heat responsive links shall withstand a timed exposure to a salt spray atmosphere. When tested as detailed in Section 4.6.2, visual evidence of severe deterioration or impending failure of the components shall constitute failure. Following exposure, half of the samples shall be tested for conformance with the requirements for sensitivity as described in Section 4.10 (Sensitivity [Air Oven]). The remaining samples shall be tested for operating temperature as described in Section 4.4 (Operating Temperature [Liquid Bath]).

4.6.2 Test/Verification

Eight previously untested heat responsive links shall be supported in a vertical position in a fixture which, at the discretion of FM Approvals, applies a load equal to the manufacturer's specified maximum design load and the samples shall be exposed to salt spray (fog) as specified by ASTM B117 — 1990, *Standard for Salt Spray (Fog) Testing*. The salt solution shall consist of 20 percent by weight of common salt (sodium chloride) dissolved in deionized water.

The samples shall be exposed for a period of 10 days.

Following the exposure to the salt spray (fog), the samples shall be removed from the test chamber and permitted to air dry for a two- to four-day drying period. Following this drying period, the samples shall be subjected to the post-exposure tests as required in Section 4.6.1.

4.7 Corrosion — Stress Cracking

4.7.1 Requirements

Heat responsive links shall be resistant to stress corrosion cracking, as determined through the process described in Section 4.7.2. Following exposure, the samples shall show no evidence of cracking, delamination, or degradation.

Following exposure, half of the samples shall be tested for conformance with the requirements for sensitivity as described in Section 4.10 (Sensitivity [Air Oven]). The remaining samples shall be tested for operating temperature as described in Section 4.4 (Operating Temperature [Liquid Bath]).

4.7.2 Test/Verification

In order to determine the susceptibility of heat responsive link parts to stress corrosion cracking, four previously untested heat responsive links shall be free from a protective coating and, if necessary, degreased. If the coating is an inherent part of the design, such coating shall be subjected to tests as deemed necessary by FM Approvals to evaluate its protective integrity. The samples shall be tested in their intended orientation with no load applied.

There shall be provisions in the test chamber to prevent droplets of condensation from falling from the top of the enclosure directly onto the heat responsive links. Such shield or other means shall be constructed of glass or other non-reactive materials.

The samples shall be exposed to the moist ammonia-air mixture maintained in a glass chamber with a volume of 0.73 ±0.34 ft^3 (0.02 ±0.01 m^3) for a period of 10 days.

Aqueous ammonia having a density of 5.86×10^{-5} lb/ft^3 (0.94 g/cm^3) shall be maintained in the bottom of the chamber, approximately 1.5 in. (40 mm) below the bottom of the samples. A volume of aqueous ammonia equal to 0.075 gal/ft^3 (10 L/m^3) of the test chamber volume shall result in approximately the following atmospheric concentrations: 35 percent ammonia, 5 percent water vapor, and 60 percent air. The moist ammonia-air mixture shall be maintained at essentially atmospheric pressure with the temperature held at 93 ±4°F (34 ±2°C). Provision shall be made for venting the chamber, such as by the use of a capillary tube, to avoid buildup of pressure.

Upon removal, heat responsive links shall be rinsed in potable water and dried. Following a two- to four-day drying period, visual examination of the samples shall be made. The samples shall then be subjected to the post-exposure tests as required in Section 4.7.1.

Heat responsive links composed of unusual materials shall withstand comparable tests based upon the type of material employed at the discretion of FM Approvals.

4.8 Corrosion — Carbon Dioxide-Sulfur Dioxide

4.8.1 Requirements

Heat responsive links shall be resistant to corrosion resulting from exposures to a moist carbon dioxide-sulfur dioxide-air mixture. Following the exposure period, the samples shall be examined for deterioration or impending failure of any component. Such condition is unacceptable and constitutes failure. Subsequently, the samples shall be tested for compliance with Section 4.4 (Operating Temperature).

4.8.2 Test/Verification

Four previously untested heat responsive links shall be exposed to a moist carbon dioxide-sulfur dioxide-air mixture for a period of 10 days.

The heat responsive links shall be tested in their intended installation position.

There shall be provisions in the test chamber to prevent droplets of condensation from falling from the top of the enclosure directly onto the heat responsive links. Such shield or other means shall be constructed of glass or other non-reactive materials.

The samples shall be tested in a chamber having provisions for gas inlet and outlet. Sulfur dioxide and carbon dioxide are to be supplied to the test chamber from commercial cylinders. An amount of sulfur dioxide equivalent to one percent of the volume of the test chamber, and an equal volume of carbon dioxide shall be introduced into the chamber each working day after the chamber has been purged. Deionized water shall be maintained at a depth approximately 2 in. (51 mm) in the bottom of the chamber.

Following the exposure, the samples shall be removed from the test chamber and permitted to air dry for a two- to four-day drying period. Following this drying period, the samples shall be subjected to the post-exposure tests as required in Section 4.8.1.

4.9 Corrosion — Hydrogen Sulfide

4.9.1 Requirements

Heat responsive links shall be resistant to corrosion resulting from exposures to a moist hydrogen sulfide-air mixture. Following the exposure period, the samples shall be examined for deterioration or impending failure of any component. Such condition is unacceptable and constitutes failure. Subsequently, the samples shall be tested for compliance with Section 4.4, (Operating Temperature).

4.9.2 Test/Verification

Four previously untested heat responsive links shall be exposed to a moist hydrogen sulfide-air mixture for a period of 10 days.

The heat responsive links shall be tested in their intended installation position.

There shall be provisions in the test chamber to prevent droplets of condensation from falling from the top of the enclosure directly onto the heat responsive links. Such shield or other means shall be constructed of glass or other non-reactive materials.

The samples shall be tested in a chamber having provisions for gas inlet and outlet. Hydrogen sulfide is to be supplied to the test chamber from commercial cylinders. An amount of hydrogen sulfide equivalent to one percent of the volume of the test chamber shall be introduced into the chamber each working day after the chamber has been purged. Deionized water shall be maintained at a depth of approximately 2 in. (51 mm) in the bottom of the chamber.

Following the exposure, the samples shall be removed from the test chamber and permitted to air dry for a two- to four-day drying period. Following this drying period, the samples shall be subjected to the post-exposure tests as required in Section 4.9.1.

4.10 Sensitivity (Air Oven)

4.10.1 Requirements

The operating time for each heat responsive link shall not exceed the appropriate value shown in Table 4.10.1(a).

Heat responsive links which have been subjected to environmental testing shall operate within the limits stated in Table 4.10.1(b).

Table 4.10.1(a). Air Oven Sensitivity for New Heat Responsive Links Utilizing the Time Vs. Temperature Data per Table 4.10.2

Heat Responsive Link Nominal Temperature Rating		*Maximum Operating Temperature*		*Maximum Operating Time*
°F	*(°C)*	*°F*	*(°C)*	*min:sec*
135-170	(57-77)	525	(274)	1:15
175-225	(79-107)	550	(288)	1:45
250-300	(121-149)	575	(302)	3:00
325-375	(163-191)	605	(318)	5:00
400-475	(204-246)	640	(338)	7:30
500-575	(260-302)	735	(391)	15:00

Table 4.10.1(b). Air Oven Sensitivity for Aged or Elevated Temperature Exposed Heat Responsive Links Utilizing the Time Vs. Temperature Data per Table 4.10.2

Heat Responsive Link Nominal Temperature Rating		*Maximum Operating Temperature*		*Maximum Operating Time*
°F	*(°C)*	*°F*	*(°C)*	*min:sec*
135-170	(57-77)	555	(291)	2:00
175-225	(79-107)	575	(302)	3:00
250-300	(121-149)	605	(318)	5:00
325-375	(163-191)	645	(341)	8:00
400-475	(204-246)	670	(354)	10:00
500 and Over (260 and Over)		to be evaluated on a case-by-case basis		

4.10.2 Test/Verification

Ten previously untested heat responsive links of each temperature rating shall be supported in a vertical position in a fixture which applies a load equal to the manufacturer's specified minimum design load and shall be operated in an air oven. The controlled rate-of-temperature-rise within the oven shall be in accordance with Table 4.10.2.

Table 4.10.2. Time Vs. Temperature Points for Air Oven Sensitivity Test

Time (min:sec)	*Temp °F (°C)*		*Time (min:sec)*	*Temp °F (°C)*		*Time (min:sec)*	*Temp °F (°C)*	
0:15	275	(135)	6:00	620	(327)	16:00	750	(399)
0:30	410	(210)	7:00	630	(332)	17:00	765	(407)
0:45	475	(246)	8:00	645	(341)	18:00	778	(414)
1:00	505	(263)	9:00	660	(349)	19:00	790	(421)
1:15	525	(274)	10:00	670	(354)	20:00	805	(429)
1:30	540	(282)	11:00	685	(363)	22:00	830	(443)
2:00	555	(291)	12:00	695	(368)	24:00	855	(457)
3:00	575	(302)	13:00	710	(377)	26:00	880	(471)
4:00	590	(310)	14:00	725	(385)	28:00	905	(485)
5:00	605	(318)	15:00	735	(391)	30:00	930	(499)

4.11 Thermal Shock (Glass Bulb Heat Responsive Links Only)

4.11.1 Requirements

Heat responsive links having frangible bulbs shall operate within their nominal operating temperature range after having been exposed to a series of thermal shocks. Full operation in the cold bath shall not constitute failure of this test. Operation in the hot bath during the cycling portion of this test is not acceptable. Following the sequence detailed in Section 4.11.2, each sample shall meet the operating temperature requirements specified in Section 4.4 (Operating Temperature).

4.11.2 Test/Verification

Five previously untested samples shall be conditioned for five minutes in a liquid bath maintained at a temperature of seven percent below their nominal rating.

The heat responsive links shall then be removed and immediately submerged for a period of 15 to 30 seconds into a cold water bath maintained at 50 ±2°F (10 ±1.1°C). This sequence of heating and plunging into the cold water bath shall be repeated three times on each sample.

Following this test, the samples shall be subjected to the post-tests detailed above.

4.12 Additional Tests

Additional tests may be required, depending on design features, results of any tests, material application, or to verify the integrity and reliability of the heat responsive link, at the discretion of FM Approvals.

Unexplainable failures shall not be permitted. A re-test shall only be acceptable at the discretion of FM Approvals and with adequate technical justification of the conditions and reasons for failure; otherwise, a design change will be required.

5. OPERATIONS REQUIREMENTS

A quality control program is required to assure that subsequent heat responsive links produced by the manufacturer at an authorized location, shall present the same quality and reliability as the specific heat responsive links examined. Design quality, conformance to design, and performance are the areas of primary concern. Design quality is determined during the Approval examination and tests, and is covered in the Approval Report. Conformance to design is verified by control of quality and is covered in the Facilities and Procedures Audit (F&PA). Quality of performance is determined by field performances and by periodic re-examination and testing.

5.1 Demonstrated Quality Control Program

5.1.1 The manufacturer shall demonstrate a quality assurance program which specifies controls for at least the following areas:

- existence of corporate quality control guidelines;
- incoming quality assurance, including testing;
- in-process quality assurance, including testing;
- final inspection and tests;
- equipment calibration;
- drawing and change control;

- packaging and shipping;
- handling and disposition of non-conformance materials.
- in order to assure adequate traceability of materials and products, the manufacturer shall maintain records of all quality control tests performed, for a minimum period of two years from the date of manufacture.

5.1.2 Documentation/Manual

There shall exist an authoritative collection of procedures and policies. Such documentation shall provide an accurate description of the quality management system while serving as a permanent reference for implementation and maintenance of that system. The system shall require that sufficient records are maintained to demonstrate the required quality and verify operation of the quality system.

5.1.3 Drawing and Change Control

The manufacturer shall establish a system of product configuration control that shall allow no unauthorized changes to the product. Changes to critical documents, identified in the Approval Report, must be reported to, and authorized by, FM Approvals prior to implementation for production. The manufacturer shall assign an appropriate person or group to be responsible for reporting proposed changes to Approved or Listed products to FM Approvals before implementation. The manufacturer shall notify FM Approvals of changes in the product or of persons responsible for keeping FM Approvals advised by means of FM Approvals Form 797, Approved Product Revision Report or Address/ Contact Change Notice. Records of all revisions to all Approved products shall be maintained.

5.2 Facilities and Procedures Audit (F&PA)

5.2.1 An audit of the manufacturing facility is part of the Approval investigation to verify implementation of the quality control program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to insure a consistently uniform and reliable product. Initial inspections of facilities already producing similar products may be waived at the discretion of FM Approvals.

5.2.2 Unannounced follow-up inspections shall be conducted at least annually by FM Approvals, or its designate, to determine continued compliance. More frequent audits may be required by FM Approvals.

5.2.3 The client shall manufacture the product or service only at the location(s) audited by FM Approvals and as specified in the Approval Report. Manufacture of products bearing the FM Approval mark is not permitted at any other locations without prior written authorization by FM Approvals.

5.3 Manufacturer's Responsibilities

The manufacturer shall notify FM Approvals of changes in product construction, design, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation of such changes.

5.4 Manufacturing and Production Tests

5.4.1 *Test Requirement No. 1 — Operating Temperature*

The manufacturer shall perform periodic tests for operating temperature of heat responsive elements.

5.4.2 *Test Requirement No. 2 — Element Strength*

The manufacturer shall perform periodic tests for operating element strength.

APPENDIX A

UNITS OF MEASUREMENT

LENGTH:	in. – ''inches'' (mm – ''millimeters'') mm = in. × 25.4 ft – ''feet'' (m – ''meters'') m = ft × 0.3048
AREA	in^2 – ''square inches'' (mm^2 – ''square millimeters'') $mm^2 = in^2 \times 6.4516 \times 10^2$ ft^2 – ''square feet'' (m^2 – ''square meters'') $m^2 = ft^2 \times 0.0929^2$
MASS:	lb – ''pounds'' (kg – ''kilograms'') kg = lb × 0.454
PRESSURE:	psi – ''pounds per square inch'' (kPa – ''kilopascals'') kPa = psi × 6.8948 psf – ''pounds per square foot'' (kPa – ''kilopascals'') kPa = psf × 0.0479
ENERGY:	Btu – ''British thermal units'' (J – ''joules'') $J = Btu \times 1.0551 \times 10^3$
TEMPERATURE:	°F – ''degrees Fahrenheit'' (°C – ''degrees Celsius'') °C = (°F – 32) × 0.556
LIQUID:	gal – ''gallons'' (L – ''liters'') L = gal × 3.7854
FLOW:	gal/min – ''gallon per minute'' (L/min – ''liters per minute'') L/min = gal/min × 3.7854
FORCE:	lb – ''pounds'' (N – ''newtons'') N = lb × 4.4482
TORQUE/MOMENT:	lb·ft – ''pound-feet'' (N·m – ''newton-meters'') N·m = lb·ft × 1.356

APPENDIX B

APPROVAL MARKS

REPRODUCTION ART: FM Approval Marks

For use on nameplates, in literature, advertisements, packaging and other graphics.

1) The FM diamond mark is acceptable to FM Approvals as an Approval mark when used with the word ‘‘Approved.’’

2) The FM Approval logomark has no minimum size requirement, but should always be large enough to be readily identifiable.

3) Color should be black on a light background or a reverse may be used on a dark background.

For Cast-On Marks

4) Where reproduction of the mark described above is impossible because of production restrictions, a modified version of the diamond is suggested. Minimum size specifications are the same as for printed marks. Use of the word ‘‘Approved’’ with this mark is optional.

NOTE: These Approval marks are to be used only in conjunction with products or services that have been FM Approved. The FM Approval marks should never be used in any manner (including advertising, sales or promotional purposes) that could suggest or imply FM Approval or endorsement of a specific manufacturer or distributor. Nor should it be implied that Approval extends to a product or service not covered by written agreement with FM Approvals. The Approval marks signify that products or services have met certain requirements as reported by FM Approvals.

Additional reproduction art is available through

FM Approvals
P.O. Box 9102,
Norwood, Massachusetts 02062
U.S.A.

APPENDIX C

TOLERANCES

Unless otherwise stated, the following tolerances shall apply:

Angle	±2°
Frequency (Hz)	±5 of value
Length	±2 of value
Volume	±5 of value
Rotation	±1 RPM
Pressure	±3 of value
Temperature	±5 of value
Time	+ 5/–0 seconds +0.1/–0 minutes +0.1/–0 hours +0.25/–0 days

Unless stated otherwise, all tests shall be carried out at a room (ambient) temperature of 68 ± 9°F (20 ± 5°C).

APPENDIX D

TOLERANCE LIMIT CALCULATIONS

Utilizing the data obtained as described in Sections 4.2.2 and 4.3.2(B), the mean and standard deviation for the assembly load and the bulb strength shall be calculated using the following equation:

$$\sigma_{n-1} = \left(\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1} \right)^{1/2}$$

where:

σ_{n-1} = standard deviation
$\bar{x}$ = sample mean
x_i = individual values of each sample tested
n = number of samples tested

Based upon the number of heat responsive links or bulbs tested (n), a value, γ, shall be selected from Table D.1 where the degree of confidence is 0.99 and the proportion of samples is 0.99.

Table D.1. γ Factors for One-Sided Tolerance Limits for Normal Distributions (99 Percent of Samples)

n	γ	*n*	γ	*n*	γ
10	5.075	17	4.038	24	3.638
11	4.828	18	3.961	25	3.601
12	4.633	19	3.893	30	3.446
13	4.472	20	3.832	35	3.334
14	4.336	21	3.776	40	3.250
15	4.224	22	3.727	45	3.181
16	4.124	23	3.680	50	3.124

Tolerance limits shall then be calculated as follows:

$LTL = \bar{x}_B - \gamma_B \sigma_{(n-1)B}$

$UTL = \bar{x}_S + \gamma_S \sigma_{(n-1)S}$

where:

LTL = lower tolerance limits for bulb strength

UTL = upper tolerance limit for heat responsive link assembly load

$\bar{x}_B$ = mean bulb strength

γ_B = bulb strength factor (γ) from Table D1

$\sigma_{(n-1)B}$ = sample unbiased standard deviation for the bulb

$\bar{x}_S$ = mean assembly load

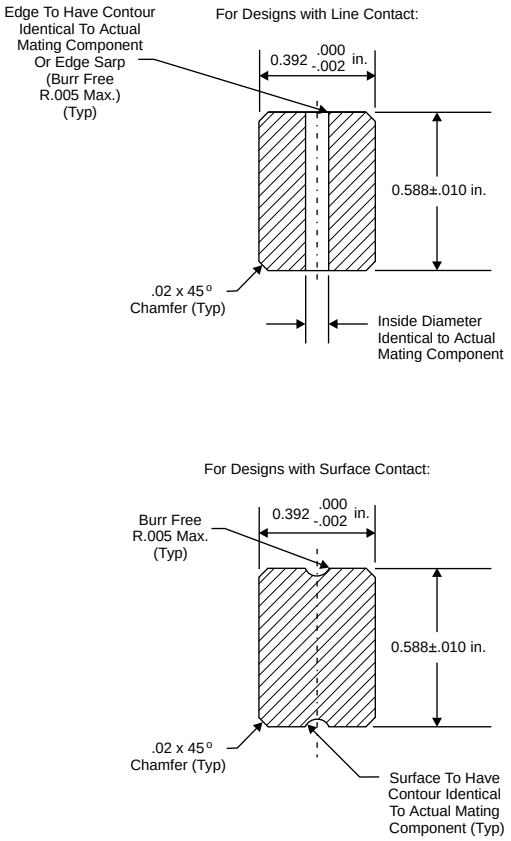
$\sigma_{(n-1)S}$ = sample unbiased standard deviation for the assembly load

γ_S = assembly load factor (γ) from Table D1

Compliance with the requirement shall be confirmed if LTL > UTL.

Outliers may be discarded from the sample base utilizing appropriate statistical techniques at the discretion of FM Approvals.

APPENDIX E



REQUIRED:
* Material - Hardened Steel, Rockwell C38 - 50
*Markings - Manufacturer, Bulb Size, Seat Diameter

Figure E-1. Bulb Crush Inserts For Strength of Element Test.