



*Member of the FM Global Group*

**Approval Standard  
for  
Flexible Fire Pump Couplings  
and Flexible Connecting Shafts  
for Fire Protection Service**

**Class Number 1336**

**September 2011**

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# 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 surveillance 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 Approval criteria for flexible fire pump couplings and flexible connecting (drive) shafts which provide power transmission from diesel engines or electric motors to fire pumps that supply water to fire protection systems. These flexible fire pump couplings and flexible connecting shafts must have an extended service life, throughout which they must be capable of operating reliably at rated power and speeds during emergency fire incidents, despite being idle for extended periods. The purpose of the flexible coupling and flexible connecting shafts is to compensate for temperature changes and to permit end movement of the shafts without interference with each other while transmitting power from the driver to the pump.
- 1.1.2 Approval criteria include, but are not limited to, performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a surveillance program.
- 1.1.3 Approval standards are intended to verify that the product described shall meet stated conditions of performance, safety, and quality useful to the ends of property conservation.

### 1.2 Scope

- 1.2.1 This standard encompasses the design and performance requirements for flexible fire pump couplings and flexible connecting shafts used in fire pump service that are designed and installed in accordance with FM Global Property Loss Prevention Data Sheets.
- 1.2.2 This standard encompasses flexible fire pump couplings and flexible connecting shafts for use with operating speeds at or below 3600 rpm.
- 1.2.3 This standard encompasses the design and performance requirements for flexible fire pump couplings of 30 hp through 1000 hp load rating, and for flexible connecting shaft diameters of up to 4 inch nominal size used in fire pump service.
- 1.2.4 Flexible couplings and flexible connecting shafts designed for other rated capacities shall be evaluated on a case-by-case basis.

### 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 flexible fire pump couplings and flexible connecting shafts for the purpose of obtaining Approval. Flexible fire pump couplings and flexible connecting shafts having characteristics not anticipated by this standard may be FM Approved if performance equal, or superior, to that required by this standard is demonstrated, or if the intent of the standard is met. Alternatively, flexible fire pump couplings and flexible connecting shafts which meet all of the requirements identified in this standard may not be FM Approved if other conditions which adversely affect performance exist or if the intent of this standard is not met.

#### 1.4 Basis for Approval

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 first audit shall be conducted to evaluate the manufacturer's ability to consistently produce the product that was examined and tested as part of the Approval project. The audit shall review the facility and in-place quality control procedures used in the manufacturing of the product. Typically, areas of review are incoming inspection, work in progress, production testing, final quality control, marking, calibration of equipment, shipping procedures, and document and drawing control. These examinations are repeated periodically as part of the FM Approvals' Surveillance Audit Program. (Refer to Section 5.2, Surveillance Audit Program.)

#### 1.5 Basis for Continued Approval

Continued Approval is based upon:

- Production or availability of the product as currently FM Approved;
- The continued use of acceptable quality assurance procedures;
- Satisfactory field experience;
- Compliance with the terms stipulated in the Master Agreement;
- Satisfactory re-examination of production samples for continued conformity to requirements; and
- Satisfactory Surveillance Audits conducted as part of the FM Approvals' product follow-up program.

Also, as a condition of retaining Approval, manufacturers may not change a product or service without prior written authorization by FM Approvals. (Refer to Section 5.1.3 for further details regarding changes to FM Approved products.)

#### 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 FM 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 **September 30, 2011** 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 Institute of Electrical and Electronics Engineers (IEEE)/ASTM International (ASTM) SI 10-2002, *American National 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 or are beneficial in understanding this standard:

- American Gear Manufacturers Association (AGMA) 922 (Edition A96), *Load classification and Service Factors for Flexible Couplings*
- ANSI/AGMA 9000 (Edition C90), *Flexible Couplings - Potential Unbalance Classification*
- ANSI/AGMA 9001 (Edition B97), *Flexible Couplings - Lubrication*
- ANSI/AGMA 9002 (Edition B04), *Bores and Keyways for Flexible Couplings (Inch Series)*
- ANSI/AGMA 9003, (Edition B08), *Flexible Couplings - Keyless Fits*
- ANSI/AGMA 9004, (Edition B08), *Flexible Couplings - Mass Elastic Properties and Other Characteristics*
- ANSI/AGMA 9008, (Edition B00), *Flexible Couplings - Gear Type, Flange Dimensions, Inch Series*
- ANSI/AGMA 9009-D02 (2002), *Flexible Coupling – Nomenclature for Flexible Couplings*
- ANSI/AGMA 9103-B08 *Flexible Couplings - Keyless Fits (Metric Edition)*
- ANSI/AGMA 9104-A06 *Flexible Couplings - Mass Elastic Properties and Other Characteristics (Metric Edition)*
- ANSI/AGMA 9112-A04 *Bores and Keyways for Flexible Couplings (Metric Series)*
- FM Approvals, Approval Standard 1321/1323-2007, *Fire Pump Controllers for Electric Motor and Diesel Engine Drivers*
- FM Approvals, Approval Standard 1333-2008, *Diesel Engine Fire Pump Drivers*
- FM Global Property Loss Prevention Data Sheet 3-7, April 2008, *Fire Protection Pumps*
- FM Global Property Loss Prevention Data Sheets
- IEEE/ASTM SI 10-2002, *American National Standard for Use of the International System of Units (SI): The Modern Metric System*
- International Organization for Standardization (ISO) 17025 (2005), *General Requirements for the Competence of Testing and Calibration Laboratories*
- ISO 1940-1, 2003, *Mechanical vibration -- Balance quality requirements for rotors in a constant (rigid) state -- Part 1: Specification and verification of balance tolerances*
- National Fire Protection Association (NFPA) 20-2007, *Standard for the Installation of Stationary Pumps for Fire Protection*

## 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 FM 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 this definition with FM Approved.)

### **Angular Misalignment**

Misalignment where the pump shaft and the driver shaft axes are not parallel.

### **Axial Misalignment**

Misalignment caused when one shaft moves along its axis relative to the other shaft (end float).

### **Close-Coupling**

Direct connection or “close-coupling” of the pump and driver is acceptable for electrically driven, in-line, vertically mounted, horizontal split case, and end-suction pumps.

***Critical Speed***

Any operating speed that corresponds to the natural period of vibration (natural frequency) of the rotating shafts.

***Diesel Engine***

An internal combustion engine in which the fuel is ignited entirely by the heat resulting from the compression of the air supplied for combustion.

***Elastomeric Components***

Any flexible non-metallic element that is a part of the coupling assembly. Usually, these components are used between two rigid end connections in the coupling assembly, to provide dampening and flexibility during operation. FM Approvals does not allow the only source of torque transmission to be an elastomeric or polymeric component.

***Fire Pump Package***

An assembled unit consisting of a fire pump, driver, controller, and accessories.

***Flexible Connecting Shaft***

A flexible mechanical device used to connect the shafts or other torque-transmitting components from a driver to the pump, used for transmitting torque and rotation.

***Flexible Drive Coupling***

A device used to connect the shafts or other torque-transmitting components from a driver to the pump. The device shall not rely on an elastomeric or polymeric element as a sole means of torque transmission. All FM Approved flexible drive couplings must have metal-to-metal contact of components to drive the pump in case of elastomeric or polymeric element failure. The coupling assembly shall permit minor angular and parallel misalignment as restricted by both the pump, driver and coupling manufacturers. Examples of recommended couplings are: pin and bushing, jaw, disc, drive shaft, or steel-grid-type couplings where the drive components are metallic.

***FM Approvals Certification Marks***

The FM Approvals Certification Marks are detailed in Appendix B. Their use is mandatory on all units of FM Approved flexible fire pump couplings and flexible connecting shafts. These registered marks cannot be used except as authorized by FM Approvals via the granting of Approval to a specific product.

***FM Approved***

This term refers to products FM Approved by FM Approvals. Such products are listed in the Approval Guide, an online resource of FM Approvals. All products so listed have been successfully examined by FM Approvals, and their manufacturers have signed and returned a Master Agreement to FM Approvals. The Master Agreement obligates the manufacturer to allow re-examination of the product and surveillance audits at FM Approval's discretion. It further requires the manufacturer not to deviate from the as-FM Approved configuration of the product without review by and agreement of FM Approvals. Approval is product specific.

***Hollow Shaft***

This pertains to the hollow vertical drive shaft of electric motors or right angle gear drives used to drive vertical turbine pumps. The hollow drive shaft is designed to accept the solid line shaft of the pump. The design facilitates impeller adjustment within the bowl assembly and the installation of a non-reverse ratchet into the motor or gear drive.

***Line Shaft***

A shaft which transmits the power from the driver to the pump shaft.

***Misalignment***

A situation created by two shafts whose axes are not in the same straight line.

***Non-Reverse Ratchet***

A mechanism installed as an integral part of the hollow shaft electric motor or hollow shaft right angle gear drive to prevent reverse rotation of the pump-driver assembly.

***Parallel Misalignment***

Misalignment where the pump shaft and the driver shaft axes are parallel but not on the same center line.

***Polymeric Components***

Any flexible non-metallic element that is a part of the coupling assembly. Usually, these components are used between two rigid end connections in the coupling assembly, to provide dampening and flexibility during operation. FM Approvals does not allow the only source of torque transmission to be a polymeric or elastomeric component.

***Radial Misalignment***

See Parallel Misalignment.

***Rated Horsepower***

The manufacturer's maximum sustained load rating at or below which the coupling or drive shaft shall operate trouble free. This number does not include the service factors for determining application torque. This also sets the basis for the testing described in Section 4, Performance Requirements. The minimum load rating considered for FM Approval is 30 hp (20 kW).

## **2. GENERAL INFORMATION**

### **2.1 Product Information**

- 2.1.1 Flexible couplings for fire protection service addressed in this standard have a 30 hp through 1000 hp load rating, and flexible connecting shaft diameters of up to 4 inch nominal size used in fire pump service. Other sizes shall be evaluated on a case-by-case basis.
- 2.1.2 In order to meet the intent of this standard, flexible fire pump couplings and flexible connecting shafts 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 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 flexible fire pump couplings and flexible connecting shafts, selected in conformance to this criterion, shall satisfy all of the requirements of this standard.

### **2.2 Approval Application Requirements**

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

Group Manager - Hydraulics  
FM Approvals  
Member of the FM Global Group  
743A Reynolds Road  
West Glocester, RI 02814 USA

- 2.2.2 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 products or services being submitted for Approval consideration;

- General assembly drawings, one complete set of manufacturing drawings, materials list(s) and physical property specifications (such as ASTM A48 CL 40 - Cast Iron), anticipated marking format, brochures, sales literature, specification sheets, installation, operation and maintenance procedures;
- The number and location of manufacturing facilities.

2.2.3 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 set-up and authorization of an Approval examination, the manufacturer shall prepare 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 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 the test facilities, which are required to evaluate the flexible fire pump couplings and flexible connecting shafts.

## 3. GENERAL REQUIREMENTS

### 3.1 Review of Documentation

- 3.1.1 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. These documents shall be controlled as outlined in the Manufacturer's Quality Assurance Plan.
- 3.1.2 The manufacturer's dimensional specifications and/or dimensional drawings shall fully describe the product. All critical dimensions shall be indicated with the allowed upper and lower tolerance limits clearly shown.
- 3.1.3 All documents pertaining to the product materials, dimensions, processing and marking shall be controlled by the manufacturer's quality assurance procedures, and 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.

### 3.2 Physical or Structural Feature

- 3.2.1 Flexible fire pump couplings and flexible connecting shafts shall be designed for adverse environmental locations.
- 3.2.2 Flexible fire pump drive shafts shall have a minimum B-10 life rating of 5000 hours.

$$B-10 = \frac{1.5 \times 10^6}{N \times A} * \left( \frac{BLF}{T_a} \right)^{10/3}$$

Where:

- B-10* - Bearing Life rating, hours  
*N* - Maximum Operating Speed, rpm  
*A* - Operating Angle, degrees  
*BLF* - Manufacturer's recommended Bearing Life Factor, ft-lbs  
*T<sub>a</sub>* - Adjusted Torque, ft-lbs = Manufacturer's recommended torque times a service factor of 3.25 (worst case for fire protection pumps or per Table 3.2.6)

- 3.2.3 Flexible fire pump couplings with polymeric or elastomeric materials shall be a “Fail-safe” design. That is, the wear or failure of the polymeric or elastomeric components shall not interrupt the transmission of full torque from the diesel engine or electric motor to the fire pump. Typical examples of these couplings are: pin and bushing, steel flex grid, jaw-type, and drive shafts.
- 3.2.4 The connections to the engine or motor and pump drive shafts shall be keyed and double setscrews 90 degrees apart. In addition there shall be a mechanical method, (*i.e.* shaft bushings, metal cover/shroud, double backed fasteners, etc.) to prevent the two coupling hubs from becoming disengaged in the event of setscrew failure. Other connection designs shall be evaluated on a case-by-case basis, provided such connections are compatible with the requirements of FM Global Loss Prevention Data Sheets.
- 3.2.5 Sizing of the flexible connecting driveshaft shall be based on rating of the driver and not the pump.
- 3.2.6 Service factors for determining the application torque for the flexible fire pump couplings and flexible connecting shafts shall be equal to or greater than the service factors listed in Table 3.2.6.

Table 3.2.6 Service Factors for Determining Application Torque

<i>Pump Type</i>	<i>Electric Motor</i>	<i>Diesel Engine (5 or less cylinders)</i>	<i>Diesel Engine (6 or more cylinders)</i>
Centrifugal	1.00	2.00	1.50
Reciprocating – Double Action	2.00	3.00	2.50
Reciprocating – 1 or 2 Cylinders	2.25	3.25	2.75
Reciprocating – 3 or more Cylinders	1.75	2.75	2.25
Rotary – Gear, Lobe or Vane	1.50	2.50	2.00

- 3.2.7 Manufacturer’s literature for the flexible fire pump couplings and flexible connecting shafts shall state the maximum torque, maximum speed and information on the use of service factors.

### 3.3 Materials

Flexible fire pump couplings and flexible connecting shafts shall be fabricated from materials capable of handling the torque loads and environmental conditions associated with being mounted adjacent to and coupled with large diesel engines or electric motors, and shall be capable of sustaining the parallel and angular misalignments as stated by the manufacturer in their catalogs, without spalling, flaking, or fatigue failure of the components. When unusual materials are used, special tests may be necessary to verify their suitability. All components shall withstand the normal abuse of shipping, handling, and installation.

### 3.4 Markings

- 3.4.1 Each flexible fire pump coupling and/or flexible connecting shaft, discussed in this standard, shall be permanently marked with the following information:
- Manufacturer’s name or trademark;
  - Model designation or catalog number;
  - Nominal size and bore dimensions;
  - Class or power rating [maximum speed, rpm and power; hp (kW)];
  - Manufacturing date and/or source code as applicable;
  - FM Approvals Certification Mark, (see Appendix B); and
- 3.4.2 Each required marking listed in Section 3.4.1 shall be legible and durable and applied in any of, or any combination of die-stamping, forging, roller embossing or electro-etching. A suitable alternative is a permanently-marked, legible, corrosion-resistant nameplate. The nameplate shall be permanently attached to the flexible fire pump coupling where it shall be easily visible and in a manner that allows the nameplate to remain in place during normal operation.

- 3.4.3 Markings that are die-stamped, forged, roller embossed or electro-etched shall be made in low stress areas that will not affect coupling life.
- 3.4.3 Any other pertinent marking information required by the national or international standard to which the flexible fire pump coupling is manufactured shall be permanently marked on the outside surface of each assembly.
- 3.4.4 It is not necessary to mark each component of the assembly. However, all required markings shall be contained on a complete assembly, and shall be able to be read without disassembly of the coupling. The additional markings shall not interfere with the legibility, or otherwise obscure, the required markings.
- 3.4.5 The model or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the product as FM Approved. The manufacturer shall not place this model or type identification on any other product unless covered by a separate agreement.
- 3.4.6 The FM Approvals Certification 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.
- 3.4.7 All markings shall be legible and durable.

### 3.5 Manufacturer's Installation, Operation, and Maintenance Instructions

Installation, operation, and maintenance instructions, including any special dimensional requirements, shall be furnished by the manufacturer of the flexible fire pump coupling or flexible connecting shaft, and subsequent parties involved with the packaging of the flexible coupling or flexible connecting shaft for fire pump service. For each manual provided, the warranty and service contact information shall be clearly identified. Instructions shall be provided with each flexible fire pump coupling or flexible connecting shaft and shall include the following information at minimum:

#### Installation:

- Assembly of the components;
- Maximum allowable displacements (angular, radial and axial);
- Maximum allowable speed and torque;
- Torsional Vibration Analysis (TVA) The torsional vibration analysis must indicate that all torsional natural frequencies possess greater than 10% separation with frequencies of potential torsional excitation. A Campbell Diagram with all potential torsional excitation frequencies displayed shall be included in the torsional vibration analysis. The torsional vibration analysis must include the softening effects of keyways or shaft penetration into coupling hubs (shrunk-on coupling hubs).
- Service factors for determining the application torque
- Details on proper alignment of the coupling;
- Pump coupling balance requirement shall be per ISO 1940, Balance Quality Grade 2.5, or equivalent
- Color codes of polymeric or elastomeric materials, (if utilized); and,
- Tightening torque for setscrews, (when utilized)

#### Operation:

- Proper steps for initial start-up; and,
- Operating temperature limits
- A complete Bill of Materials must be included with the coupling and include manufacturer's controlled part numbers (excluding hardware/fasteners)

**Maintenance:**

- Failure modes and typical causes and solutions;
- Recommended service check and required intervals; and,
- Information on obtaining spare parts

**Warnings:**

- Safety guards shall be used with flexible fire pump coupling or flexible connecting shafts
- For diesel-driven vertical turbine pumps, a mass elastic torsional analysis of the system (engine, coupling, gear drive, and pump) must be conducted to ensure there are no damaging stresses or critical speeds in the range of 25 percent above and below the operating speed of the system components.
- Selection of flexible driveshaft shall be based on rating of the driver and not the pump.

**3.6 Calibration**

All equipment used to verify the test parameters shall be calibrated within an interval determined on the basis of stability, purpose, and usage of the equipment. A copy of the calibration certificate for each piece of test equipment is required for FM Approvals records, indicating that the calibration was performed against working standards whose calibration is certified as traceable to the National Institute of Standards and Technology (NIST) or to other acceptable reference standards and certified by a ISO 17025 calibration laboratory. The test equipment must be clearly identified by label or sticker showing the last date of the calibration and the next due date. A copy of the service accreditation certificate as an ISO 17025, "General Requirements for the Competence of Testing and Calibration Laboratories", calibration laboratory is required for FM Approvals records.

The calibration of recently purchased new equipment is also required. Documentation indicating either the date of purchase or date of shipment, equipment description, model and serial number is required for identification. The period from the time the equipment was put into service to the date of testing must be within an interval that does not require the equipment to be calibrated as determined on the basis of the parameters mentioned above.

**3.7 Test Facilities**

If review of all required information indicates suitability for Approval, testing of sample flexible fire pump couplings and/or flexible connecting shafts shall be scheduled. The range of tests to be conducted shall be specified by FM Approvals. The manufacturer shall provide facilities and all properly calibrated instrumentation necessary to perform the tests described below, and any other tests deemed necessary by FM Approvals. The manufacturer shall also provide personnel to install and operate the flexible fire pump couplings and/or flexible connecting shafts, and make the required measurements. Test facilities shall be able to measure precisely the operating alignment of shaft ends to ensure that set-up alignments have not changed as a result of temperature or structural flexibility. FM Approvals shall witness the tests and shall receive copies of the data and calibration certificates. All the tests shall be conducted at normal room temperature, except as noted.

**3.8 Tolerances**

Tolerances on units of measure shall be as described in Appendix E, unless otherwise specified.

## 4. PERFORMANCE REQUIREMENTS

The manufacturer shall provide facilities and all properly calibrated instrumentation necessary to perform the tests described below, and any other tests deemed necessary by FM Approvals. The manufacturer shall also provide personnel to install and operate the necessary test equipment, and record the required measurements. A representative of FM Approvals shall witness the tests.

### 4.1 Examination

#### 4.1.1 Requirements

The flexible fire pump coupling(s) and/or flexible connecting shaft(s) shall conform to the manufacturer's drawings and specifications and to Approval requirements.

#### 4.1.2 Test/Verification

A sample of each model and size submitted for Approval 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. The manufacturer shall supply, at a minimum, the following information for each flexible fire pump coupling or flexible connecting shaft model submitted for Approval:

- A. Model designation(s), size(s) and speed(s) for which Approval is sought;
- B. Maximum allowable displacements including a method of determining the maximum permissible displacement when two or more displacements arise (angular, radial and/or axial);
- C. General assembly drawings, one complete set of overall package drawings, materials list(s) and physical property specifications;
- D. Marking drawings;
- E. Desired normal operating temperature range;
- F. Documentation on safety guards which cover moving parts required and/or supplied by the manufacturer; and,
- G. Brochures, sales literature, specification sheets, installation, operation and maintenance procedures or manuals

### 4.2 High Temperature Test (Elastomeric Components Only)

#### 4.2.1 Requirement

Couplings containing polymeric or elastomeric components shall have those components subjected to a long term high temperature exposure prior to the performance testing being conducted.

#### 4.2.2 Test/Verification

Each different style of coupling shall have their polymeric or elastomeric components subjected to a high temperature exposure in a circulating air oven. Depending on the degradation temperature of the elastomer, the time exposure and the temperature exposure may be taken from Table 4.2.2. The samples shall not touch each other or the inner walls of the oven during the temperature exposure. When removed from the high temperature exposure, the polymeric or elastomeric element(s) shall retain their flexibility; and shall not have a tendency to crumble, flake, or crack.

Table 4.2.2 Typical Time vs. Temperature Combinations

<i>Temperature</i>		<i>Time</i>
<i>°F</i>	<i>(°C)</i>	<i>Days</i>
266	(130)	30
244	(120)	60
230	(110)	90
224	(105)	120
212	(100)	180
188	(85)	430

The aged polymeric or elastomeric samples shall then be used in all further performance testing of the flexible couplings submitted.

### 4.3 Full Load Test with Maximum Misalignment

#### 4.3.1 Requirement

The flexible coupling and/or flexible connecting shaft shall be able to operate at two times the manufacturer's stated limits of misalignment and the maximum gap between hubs for 20 starting cycles and for 24 hours continuous operation, followed by a second set of 20 starting cycles, without failure, at the maximum rating of the flexible coupling and/or flexible connecting shaft. A flexible coupling and/or flexible connecting shaft shall be tested with its intended driver. The efficiency of the flexible coupling and/or flexible connecting shaft, (power in compared to power out) shall be determined.

#### 4.3.2 Test/Verification

A flexible coupling and/or flexible connecting shaft intended for electric motor service shall be tested with an electric motor driver. A flexible coupling and/or flexible connecting shaft intended for diesel engine service shall be tested with a diesel engine driver. A flexible coupling and/or flexible connecting shaft intended for both electric motor and diesel engine service shall be tested with an electric motor driver for the 20 starting cycles, then tested with a diesel engine for the 24 hour continuous operation and then followed by 20 starting cycles with an electric motor. A soft start device shall not be used with the electric motor for the starting cycle tests.

A sample of each type of flexible coupling, with aged elastomeric components, or flexible connecting shaft shall be run at two times the manufacturer's maximum allowable misalignments (angular and parallel/radial misalignment) and gap between hubs (axial misalignment). Prior to a 24 hour endurance test, the diesel engine or electric motor shall be started, and accelerated to full power and rpm rating for the flexible coupling or flexible connecting shaft, for a cycling test. Other torque-transmitting devices (i.e. dynamometer, hydraulic motor, etc.) can be used if the system can simulate an equivalent or more challenging starting condition. Lubrication of the coupling is permitted, only if called for in the manufacturer's installation instructions. The driver shall be operated for a minimum of 30 seconds at full rated load of the coupling. The driver shall then be shut off, and permitted to come to a full stop. Repeat the starting cycle 20 times. The maximum length flexible connecting shaft shall be used for this test.

A sample of each type of flexible coupling or flexible connecting shaft shall be operated for 24 hours, continuously at its maximum power and rpm. No additional lubrication is permitted. No failure of any components is permitted. FM Approvals personnel shall have unrestricted access to the test facility at any time of day or night during each 24 hour test. There shall be some means of recording the power transmitted to insure continuous testing.

After the 24 hour test, the alignment of shaft ends shall be measured to ensure that set-up alignments have not changed as a result of temperature or structural flexibility. The flexible coupling or flexible connecting shaft shall then be disassembled as necessary and the components examined, to verify that there is sufficient integrity left in the assembly to continue. The flexible coupling or flexible connecting shaft shall then be re-assembled with no additional lubrication permitted. The driver shall then be started, and accelerated to the full power and

rpm rating of the test coupling or connecting shaft. The driver shall operate for a minimum of 30 seconds at full load. The driver shall then be shut off, and permitted to come to a full stop. Repeat the starting cycle 20 times. The flexible coupling or flexible connecting shaft shall then be disassembled and examined for wear and damage. Failure will be defined as deterioration of the flexible coupling or flexible connecting shaft to no longer transmit torque or create a safety hazard.

#### **4.4 Secondary Drive Mechanism**

##### **4.4.1 Requirement**

Couplings that utilize elastomeric components as the primary means of power transmission shall be capable of providing power transmission without the elastomeric components. The two coupling halves shall have metal-to-metal engagement in case of flexible element failure. The diesel engine or electric motor shall continue to drive the fire pump during a catastrophe, including complete disintegration of the flexible element.

##### **4.4.2 Test/Verification**

The flexible element shall be removed entirely from the coupling assembly. The two coupling halves shall be re-assembled on the appropriate engine or motor and pump drive shafts at two times the manufacturer's maximum allowable misalignments (angular and parallel/radial misalignment) and gap between hubs (axial misalignment) and the driver shall be operated at full power and rpm rating of the coupling, as previously tested in Section 4.3.2, for four hours. The engagement between the coupling halves shall be maintained by the axial retaining feature throughout the full four hours and there shall not be excessive stress due to excessive temperature or vibratory forces put in to the driver or driven equipment. No additional cycling test is required following this test.

#### **4.5 Additional Tests**

Additional tests may be required depending on design features, results of other performance tests, material application, or to verify the integrity and reliability of the product, at the discretion of FM Approvals.

Unexplained failures shall not be permitted. A re-test shall only be acceptable at the discretion of FM Approvals with adequate technical justification of the conditions and reasons for failure.

## 5. OPERATIONS REQUIREMENTS

A quality control program is required to assure that subsequent flexible fire pump couplings and/or flexible connecting shafts produced by the manufacturer at an authorized location shall present the same quality and reliability as the specific flexible fire pump couplings and/or flexible connecting shafts 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 Surveillance Audit Program. 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 assurance 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; and,
- 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 should be 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 should require that sufficient records are maintained to demonstrate achievement of 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 FM Approved or Listed products to FM Approvals before implementation. In situations involving significant modifications to an FM Approved product, the notification shall be in the form of a formal request for an Approval examination. For modifications of a more common nature, 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, FM Approved Product Revision Report or Address/Contact Change Notice. Records of all revisions to all FM Approved products shall be maintained.

- 5.1.3.1 The table below has been included as a guide to manufacturers of what is considered to be a significant change to FM Approvals. As mentioned above, modifications that fit this category should be documented by means of a letter stating the change, and requesting a quotation for an Approval examination.

MODIFICATION	DESCRIPTION/EXAMPLE
INCREASE IN SPEED RATING:	THE COUPLING WAS ORIGINALLY FM APPROVED FOR 2400 RPM, AND NOW IS TO BE EVALUATED TO 3000 RPM.
INCREASE IN POWER RATING:	THE COUPLING WAS ORIGINALLY FM APPROVED FOR 185 HP, AND NOW IS TO BE EVALUATED TO 288 HP.
CHANGE IN MANUFACTURING PROCESS:	CHANGE FROM SET SCREW ON SHAFT DESIGN TO KEYWAY CONNECTION
ADDITION OR RELOCATION OF THE MANUFACTURING LOCATION:	THE PRODUCT WAS ORIGINALLY FM APPROVED WHEN MADE IN LOCATION A, AND NOW IT IS DESIRED TO MAKE IN LOCATIONS A AND B, OR IN LOCATION B ONLY.
CHANGES TO CRITICAL DIMENSIONS:	MODIFICATIONS THAT WOULD DEPART FROM THE NATIONAL OR INTERNATIONAL STANDARDS THAT ARE USED IN THE MANUFACTURING OF THE PRODUCT AS ORIGINALLY FM APPROVED.
	MODIFICATIONS THAT WOULD HAVE AN EFFECT ON THE USE OF THE PRODUCT WITH STANDARDIZED CONNECTIONS.
	MODIFICATIONS THAT WOULD HAVE AN EFFECT ON THE ABILITY OF THE PRODUCT TO MAINTAIN THE SAME PERFORMANCE AS THE ORIGINALLY APPROVED PRODUCT. AN EXAMPLE OF THIS WOULD BE A SIGNIFICANT REDUCTION OF WALL THICKNESS IN THE AREA OF SHAFT CONNECTION.

- 5.1.3.2 The table below has been included as a guide to modifications which may be submitted on FM Approvals Form 797.

<i>MODIFICATION</i>	<i>DESCRIPTION/EXAMPLE</i>
CHANGE IN COMPANY CONTACT INFORMATION:	CONTACT NAME, TITLE, PHONE NUMBER, FAX NUMBER, E-MAIL ADDRESS, COMPANY OFFICE ADDRESS, COMPANY NAME
UPDATING OF DRAWINGS:	MINOR DIMENSIONAL CHANGES, OR NOTE CHANGES, RE-CREATION OF OLD DRAWING ON CAD
CHANGE IN MATERIAL OR MARKING:	WHERE NEW MATERIAL IS SUPERIOR, OR TO SHOW PROPOSED NEW MARKING

- 5.1.3.3 For the instances where the change is difficult to categorize, manufacturers are encouraged to contact FM Approvals and to discuss the proposed change, and the best way to transmit the request.

## 5.2 Surveillance Audit Program

- 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 surveillance audits shall be conducted periodically, but at least annually, by FM Approvals, or its representatives or more frequently depending on jurisdictional requirements, and to determine continued compliance. At issue of this standard the Occupational and Safety Health Administration (OSHA) of the United States Department of Labor requires audits of manufacturing sites producing products for use in hazardous locations during each quarter the product is manufactured. 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. FM Approvals does not permit manufacture of products bearing the FM Approvals Certification Mark at any other locations without prior written authorization by FM Approvals. A separate audit and product examination shall be required at each location.

### 5.3 Manufacturer's Responsibilities

- 5.3.1 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.
- 5.3.2 Where all or part of the quality control has been subcontracted, the manufacturer shall, at a minimum, conduct sufficient oversight audits to verify the continued application of the required controls.

### 5.4 Manufacturing and Production Tests

#### 5.4.1 Test Requirement No. 1 – *Dimensional Checks*

The manufacturer shall perform periodic measurements and record critical component dimensions, material thickness, markings, and threaded connections (as applicable) according to their quality control program based on a scientifically significant lot. These measurements shall be recorded. The number of samples to be measured shall be based on the manufacturer's Quality Control Manual, but in no case shall be less than five samples. Measurements shall be compared to the latest revision of the component drawings.

#### 5.4.2 Test Requirement No. 1 - *Material Composition*

Composition of materials shall be verified by vendor certifications. The chemical or physical properties that are critical to the functioning of the item shall be sample tested. Testing shall be performed by the manufacturer or, on their behalf, by an agency independent of the vendor. Testing shall be conducted at a minimum of once a year.

## APPENDIX A: Units of Measurement

**Length:** in. - “inches”; (mm - “millimeters”)  
 $\text{mm} = \text{in.} \times 25.4$

ft - “feet”; (m - “meters”)  
 $\text{m} = \text{ft} \times 0.3048$

**Mass:** lb - “pounds”; (kg - “kilograms”)  
 $\text{kg} = \text{lb} \times 0.454$

**Power:** hp - “horsepower”, (kW - “kilowatt”)  
 $\text{kW} = \text{hp} \times 0.7457$

**Rotational Speed:** r/min - “revolutions per minute”; (same in SI Units)

**Temperature:** °F- “degrees Fahrenheit”;(C- “degrees Celsius”)  
 $^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 0.556$

**Torque or Moment:**  $\text{lb}_f \text{ft}$  - “pound-force foot”;(N·m- “Newton-meters”)  
 $\text{N}\cdot\text{m} = 0.7376 \text{ lb}_f \text{ft}$   
 $\text{kg}_f\cdot\text{m} = 7.233 \text{ lb}_f\text{ft}$

$\text{in}\cdot\text{lb}_f$  - “inch pound-force”  
 $\text{in}\cdot\text{lb}_f = 8.85 \text{ N}\cdot\text{m}$

## APPENDIX B: FM Approvals Certification Marks

FM Approvals certifications marks are to be used only in conjunction with products or services that have been FM Approved by FM Approvals and in adherence with usage guidelines.



### FM APPROVED mark:

Authorized by FM Approvals as a certification mark for any product that has been FM Approved. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.



### FM APPROVED mark with "C" only:

Authorized by FM Approvals as a certification mark for any product that has been evaluated by FM Approvals in accordance with Canadian codes and standards. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.



### FM APPROVED mark with "C" and "US":

Authorized by FM Approvals as a certification mark for any product that has been evaluated by FM Approvals in accordance with US and Canadian codes and standards. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable. The mark should be produced in black on a light background, or in reverse on a dark background.



### Cast-On FM APPROVALS marks:

Where reproduction of the FM APPROVED mark described above is impossible because of production restrictions, use these modified versions of the FM APPROVED mark. There is no minimum size requirement for the mark, but it must be large enough to be readily identifiable.

Downloadable art and other FM Approvals resources are available by visiting our Web site at [www.fmapprovals.com](http://www.fmapprovals.com)

## FM Approvals Certification Marks

### Usage Guidelines

- All FM Approvals certification marks are the sole property of FM Approvals LLC (“FM Approvals”) and are registered or the subject of applications for registration in the United States and many other countries. They are for use only according to these guidelines.
- FM Approvals certification marks may be used only on FM Approved products and related product packaging, in advertising material, catalogs and news releases. Use of FM Approvals certification marks on such material is not a substitute for use of the complete FM Approvals certification mark on FM Approved products and/or product packaging.
- No FM Approvals certification mark or aspect thereof may be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. This includes both design aspects (the FM Approvals “diamond,” etc.) and word aspects (“FM,” “Approved,” etc.). The use of any FM Approvals certification mark as a trademark is strictly prohibited.
- The Approval Standard number or class number may not be incorporated as part of a business name, Internet domain name, or brand name/trademark for products/product lines. For example, a company may not say “ABC Company’s 4100 Fire Door is FM Approved”; the proper terminology is, “ABC Company’s Fire Door is FM Approved per Approval Standard 4100.”
- FM Approvals certification marks, except for the FM Approvals Quality System Registration mark, may not be used on business stationery/cards/signage because this could mischaracterize the relationship with FM Approvals. Additionally, these items should not reference any FM Approvals certification mark.
- Products or services may not be marketed under any mark or name similar to “FM Global,” “FM Approvals” or any of the FM Approvals certification marks. Further, products or services may not be marketed to imply a relationship beyond the scope of any Approval made by FM Approvals.
- When an FM Approvals certification mark is used in advertising material or on product packaging, all material must reflect the specific circumstances under which the product was FM Approved. The material must clearly differentiate between products that are FM Approved and those that are not, and may not, in any way, imply a more substantial relationship with FM Approvals.
- A company may not reference the intent to submit a product for Approval or the expectation that a company will have a certain product FM Approved in the future. For example, a company may not state, “Approval by FM Approvals pending” or “Approval by FM Approvals applied for.”
- FM Approvals certification marks should not be preceded or followed by a qualifier that indicates a degree of certification or acceptability. For example, “exceeds,” “first” or “only” may not be used to qualify any FM Approvals certification mark.
- Only original artwork issued by FM Approvals should be used. The FM Approvals certification marks should not be altered in any way other than to resize the artwork proportionately. Unacceptable uses of the marks include, but are not limited to, adding/deleting wording or artwork, reducing the artwork to an illegible size, animation or distortion.
- The text of the FM Approvals certification marks may not be translated into any language other than English.
- FM Approvals certification marks must appear in a size and location that is readily identifiable, but less prominent than the name of the owner of the certification or the manufacturer/seller/distributor of the certified products.

## APPENDIX C: Sample Listing

### Couplings

ABC Company, 123 Merle Street, City, State, Zip Code

<i>Product Designation</i>	<i>Connection Shaft Size inches</i>	<i>Rated Power</i>		<i>Rated Speed r/min</i>
		<i>hp</i>	<i>(kW)</i>	
ABCD	1-1/2 to 3	50 - 150	(35 - 110)	2100
ABCE	1-3/4 to 3	75 - 200	(315)	2100
CDEF	2 to 4	100 - 300	(345)	2800
CDEG	3 to 6	200 - 400	(375)	2800

### Flexible Connecting Shafts

XYZ Company, 123 Merle Street, City, State, Zip Code

<i>Product Designation</i>	<i>Minimum Rated Speed, r/min</i>	<i>Rated Torque at Minimum Speed lb-ft, (N-m)</i>	<i>Maximum Power at Minimum Speed hp (kW)</i>	<i>Maximum Rated Speed, r/min</i>	<i>Rated Torque at Maximum Speed lb-ft, (N-m)</i>	<i>Maximum Power at Maximum Speed hp (kW)</i>
DCBA	1470	380 (515)	105 (80)	1760	360 (490)	120 (90)
	1760	360 (490)	120 (90)	2100	340 (460)	135 (100)
	2100	340 (460)	135 (100)	2350	330 (445)	150 (110)
ECBA	2100	360 (515)	550 (410)	2600	340 (460)	565 (420)
	2600	340 (460)	565 (420)	2800	320 (435)	580 (430)
	2800	320 (435)	580 (430)	3000	300 (405)	595 (445)

## APPENDIX D: Tolerances

Unless otherwise stated, the following tolerances shall apply:

Angle	$\pm 1$ percent of value
Frequency (Hz)	$\pm 5$ percent of value
Length	$\pm 2$ percent of value
Power	$\pm 1$ percent of value
Speed	$\pm 3$ percent of value
Temperature	$\pm 4$ °F ( $\pm 2$ °C)
Time	+ 5/-0 seconds + 0.1/-0 minutes + 0.1/-0 hours + 0.25/-0 days
Torque	$\pm 2$ percent of value

Unless stated otherwise, all tests other than operating tests shall be carried out at a room (ambient) temperature of  $68$  °F  $\pm 9$  °F ( $20$  °C  $\pm 5$  °C).