Approval Standard for Centrifugal Fire Pumps (Vertical Shaft, Turbine Type)

Class Number 1312

December 1999

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 vertical shaft, turbine type, centrifugal fire pumps which supply water to fire protection systems. These pumps must have an extended service life, throughout which they must be capable of operating reliably at rated capacities and pressures during emergency fire incidents, despite being idle for extended periods.

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 encompasses the design and performance requirements for vertical shaft, turbine type, centrifugal fire pumps for use in fire protection systems. Approval is limited to vertical shaft, turbine type, centrifugal fire pumps which have a minimum rated pressure of 40 psi (275 kPa). In cases where metric sized vertical shaft, turbine type, centrifugal fire pumps are to be examined for Approval, test criteria comparable to the United States equivalent size shall be used.

1.2.2 Requirements for other types of centrifugal fire pumps are detailed in the following FM Approval Standards:

Class 1311 Horizontal, Split-Case Type

Class 1319 Horizontal, End-Suction Type

Class 1370 Vertical Turbine Barrel Type

Class 1371 In-Line Type

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 vertical shaft, turbine type, centrifugal fire pumps for the purpose of obtaining FM Approval. Vertical shaft, turbine type, centrifugal fire pumps 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, vertical shaft, turbine type, centrifugal fire pumps 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 facilities 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, 2001*** 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 and Materials (ASTM) SI 10-97, *"Standard for Use of the International System of Units (SI): The Modern Metric System."*

1.8 Applicable Documents

The latest versions of the following standards, test methods, and practices are referenced in this Standard:

ANSI/IEEE/ASTM SI 10-97, *Standard for Use of the International System of Units (SI): The Modern Metric System.*

ANSI/American Water Works Association (AWWA) E101, *AWWA Standard for Vertical Turbine Pumps – Line Shaft and Submersible Types.*

FM Global Property Loss Prevention Data Sheets

Hydraulic Institute Standards, *Standard for Centrifugal, Rotary and Reciprocating Pumps.*

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 pumps. 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 agreement 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.

Bowl Assembly

The actual pumping component which develops the necessary pressure and flow rate. The pump assembly may consist of one or more stages, or bowl assemblies.

Characteristic Curve

Graphic representation of the variation of the pump's total head, efficiency and brake horsepower versus the pump's capacity at a constant speed.

Column Pipe

The pipe which suspends the pump bowl assembly from the head assembly and serves as a conductor for the water from the pump bowl assembly to the discharge head.

Corrosion Resistant

Having resistance to corrosion equal to or exceeding that of bronze alloy having a minimum copper content of 80 percent, or being of Series 300 Stainless Steel construction.

Datum

The elevation of the surface from which the pump head or baseplate is supported.

Design Working Pressure

The maximum pressure for which a pump component is designed. This pressure is equal to or greater than the maximum pressure developed by the pump at shut off or churn conditions with the largest impeller, the most stages available, and at maximum speed.

Discharge Head

A part of the pump assembly which supports the driver, pump, and column; aligns the driver and pump; seals the pumped water from atmosphere; and changes the vertical flow to a horizontal direction.

Efficiency

The ratio of the energy delivered by the pump to the energy supplied to the pump shaft (liquid power divided by applied power).

Enclosed Impeller

An impeller in which the pumped liquid is confined by the sidewalls (shrouds) and vanes of the impeller. All impellers supplied in accordance with this Approval Standard shall be of this type.

Hollow Shaft

Pertains to the hollow drive shaft of electric motors or right angle gear drives. The hollow drive shaft is designed to accept the solid line shaft. This design facilitates impeller adjustment within the bowl assembly and the installation of a nonreverse ratchet into the motor or gear drive.

Line Shaft

A shaft which transmits the power from the driver to the pump shaft. Line shafts can be either of the open, water lubricated, or enclosed, oil lubricated, type.

Maximum Power

The greatest speed-corrected power required to drive the pump at rated speed and at any point along its characteristic curve, and through the pump's total run out condition.

Minimum Submergence

The minimum depth of water required for proper pump operation, as specified by the manufacturer.

Multiple Stage Pumps

Vertical shaft, turbine type, centrifugal fire pumps with more than one impeller and bowl on the same shaft. The number of stages is determined by the number of impellers.

Non-reverse Rachet

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.

Oil Lubricated Pump

A design in which the shaft is enclosed in a tube and the shaft bearings are lubricated by oil.

Overall Length

The length from the datum to the bottom of the strainer.

Rated Capacity

Rate at which water is delivered, in gal/min (L/min), at rated pressure and rated speed.

Rated Pressure

Pressure in pounds per square inch – psi (kilopascals -kPa) developed by the pump when operating at rated capacity.

Setting

The nominal vertical distance in feet (meters) from the datum to the column pipe connection at the bowl assembly.

Shutoff or Churn Pressure

The net pressure in psi (kPa) developed by the pump at rated speed with zero flow.

Single Stage Pump

A pump in which the total head is developed by one impeller/bowl assembly.

Total Discharge Head

The gauge reading in psi (kPa) at the discharge of the pump, measured at the pump centerline, plus the velocity head at the point of gauge attachment, plus the elevation difference between the discharge gauge centerline and the sump water level.

Total Suction Head

The vertical distance in feet (meter) from the water surface to the datum.

Water Lubricated Pump

A design in which the shaft is open and the shaft bearings are lubricated by the pumped water.

2. GENERAL INFORMATION

2.1 Product Information

2.1.1 Pumps covered by this Standard include those designed for one of the following capacities: 25, 50, 100, 150, 200, 250, 300, 400, 450, 500, 750, 1000, 1250, 1500, 2000, 2500, 3000, 3500, 4000, 4500, 5000 gal/min (95, 190, 380, 570, 755, 945, 1135, 1515, 1705, 1895, 2840, 3785, 4730, 5680, 7570, 9465, 11 355, 13 250, 15 140, 17 035, 18 925 L/min) or larger. Pumps designed for other rated capacities shall be evaluated on a case-by-case basis.

2.1.2 Pumps shall have a minimum rated pressure of 40 psi (275 kPa).

2.1.3 In order to meet the intent of this Standard, vertical shaft, turbine type, centrifugal fire pumps 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 fire pumps, 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, should submit a request to:

Hydraulics Group Manager
FM Approvals Hydraulics Laboratory
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 products or services being submitted for Approval consideration;
- Anticipated pump performance, including total head, power requirements, and efficiency versus flow characteristics. If different bowl assemblies or impellers are used to obtain the rated head range for the pump being examined, complete details shall be provided concerning the range of performance specifications to be evaluated. The range of impeller diameters as well as the maximum and minimum number of bowl assemblies available shall be included;
- Calculations to determine size of the shafts, shaft couplings, assembly bolts, thrust bearings, and anti-friction bearing life;
- General assembly drawings (showing the pump and attachments), one complete set of manufacturing drawings, materials list(s) and physical property specifications, anticipated marking format, brochures, sales literature, specification sheets, installation, operation and maintenance procedures; and
- The number and location of manufacturing facilities.

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 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 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 vertical shaft, turbine type, centrifugal fire pumps.

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 Pump

Pumps shall be designed for flow rates equal to or greater than 25 gal/min (95 L/min). Rated pump pressures shall be at least 40 psi (275 kPa). Castings shall be free of defects which could make them unfit for their intended use. Flange dimensions, bolt layouts, and threaded openings used in pipe connections shall conform to a recognized national or international standard. Two or more pump ratings may be assigned to a single characteristic curve; however, the maximum power requirements used in selecting a driver shall be based on the highest power requirement, regardless of where it occurs on the entire characteristic curve.

3.2.2 Pump Components

The manufacturer shall be able to supply the necessary pump accessories (controller, driver and accessories, gauges, etc.) to provide a complete pump installation, as detailed in FM Global Property Loss Prevention Data Sheets. The pump manufacturer shall be held accountable for the complete pump package and installation for any pump bearing the FM Approval Mark.

If fabricated (welded) steel or cast fittings which are not currently FM Approved are provided by the pump manufacturer as a part of the pump assembly (i.e., suction and discharge adaptors), they shall be evaluated as part of the pump Approval program for use in the pump package only. This shall normally include a review of detail drawings and hydrostatic pressure tests to at least 700 psi (4825 kPa) or four times the rated working pressure, whichever is greater, for 5 minutes.

3.2.3 Discharge Head

The discharge head shall be designed to support and align the driver, bowl assembly, shaft, column pipe, and suction strainer. The discharge head shall redirect the vertical flow to a horizontal direction and, as a minimum, shall contain a stuffing box and packing to seal around the drive shaft and to prevent pumped water from entering the driver assembly. Either surface or underground discharge heads are acceptable. If underground head is provided, access to the shaft seal stuffing box must be available for maintenance.

3.2.4 Water Passages

All water passages shall be designed to minimize the possibility of foreign materials becoming lodged in them. The minimum width of these passages at the periphery or at any point within the impeller shall be at least ½ in. (13 mm) for pumps rated 500 gal/min (1895 L/min) and larger. Passages in pumps having rated capacities of 100 to less than 500 gal/min (380 to 1895 L/min) shall be at least ⅜ in. (10 mm). Passages in pumps having rated capacities less than 100 gal/min (380 L/min) shall be at least ¼ in. (6 mm).

3.2.5 Bowls

For oil-lubricated pumps and shafts, the discharge bowl shall have a seal to minimize the leakage of water into the shaft enclosing tube and shall have bypass ports of sufficient area to permit the escape of water which may leak through the seal or bushing. Bowl wear rings shall be provided.

3.2.6 Impeller

Impellers shall be securely attached in an axial direction to the pump shaft. No impeller shall contact the bowl under operating conditions. Impellers shall be the closed type. A suitable adjustable mechanism to achieve the proper axial position of the impeller with respect to the bowl shall be provided. Impellers shall be dynamically or statically balanced and securely fastened to the impeller shaft.

3.2.7 Column Pipe

Column pipe shall be of adequate size and strength to withstand the forces and stresses imposed during all pump operating conditions. To facilitate maintenance and repair, column piping is to be supplied in interchangeable lengths not exceeding 10 ft (3.1 m) and coordinated with the line shaft bearing spacings discussed in Section 3.2.11. Column pipe connections shall provide accurate alignment and adequate water tightness. This can be accomplished by using threaded sleeve type, flange type, or equivalent couplings.

3.2.8 Shaft

Shafts shall be of adequate size and strength to successfully transmit the torques encountered in starting and during operation while supporting the impellers and other rotating parts. Calculations shall be submitted to FM Approvals as part of the drawing review process.

In order to safeguard against shaft failure, the maximum combined shear stress, as calculated by the following formula, which occurs in the pump line or top shaft, shall not exceed 30 percent of the tensile yield strength and 18 percent of the ultimate tensile strength of the shaft material. For shafts with keyways, a further 25 percent reduction in the allowable stresses is required. Shaft sizing in accordance with ANSI/AWWA E101, ''AWWA Standard for Vertical Turbine Pumps – Line Shaft and Submersible Types'' is satisfactory.

The following formula for calculating the combined shear stress is taken from ANSI/AWWA E101, ''AWWA Standard for Vertical Turbine Pumps – Line Shaft and Submersible Types''.

English

$$S = \sqrt{\left[\frac{2f}{\pi D^2}\right]^2 + \left[\frac{321{,}000P}{ND^3}\right]^2}$$

Metric

$$S = 1 \times 10^6 \sqrt{\left[\frac{2f}{\pi D^2}\right]^2 + \left[\frac{46{,}835P}{ND^3}\right]^2}$$

Where: S – combined shear stress, psi (kPa)
f – total axial thrust, including the weight of the shaft and all rotating parts supported by it, pounds (newtons)
N – rated speed, r/min
D – shaft diameter at the root of the threads or the minimum diameter of any undercut, in. (mm), if smaller
P – power, horsepower (watts)

Renewable shaft sleeves shall be provided at bearing surfaces of the line shaft to adequately safeguard the line shaft against wear, erosion, and corrosion. Shaft sleeves shall be of a hard bronze or other corrosion resistant material.

Line shafts shall be furnished in interchangeable and uniform sections not exceeding 10 ft (3.1 m) in length.

3.2.9 Line Shaft Couplings

In order to reduce the effect of galvanic action between two unlike materials, line shaft sections shall be connected by left-hand threaded couplings or keyway couplings, composed of a material similar or superior to those of the line shafts. Coupling threads shall be nontapered and tend to tighten during pump operation. Calculations shall be submitted to FM Approvals as part of the drawing review process.

The maximum combined shear stress in the coupling shall not exceed 20 percent of the tensile yield strength or be more than 12 percent of the ultimate tensile strength of the coupling material. The following formula for calculating the combined shear stress is taken from ANSI/AWWA E101, ''AWWA Standard for Vertical Turbine Pumps – Line Shaft and Submersible Types''.

English

$$S = \sqrt{\left[\frac{2f}{\pi(D^2-d^2)}\right]^2 + \left[\frac{321{,}000P}{N(D^3-d^3)}\right]^2}$$

Metric

$$S = 1\times10^6 \sqrt{\left[\frac{2f}{\pi(D^2-d^2)}\right]^2 + \left[\frac{46{,}835P}{N(D^3-d^3)}\right]^2}$$

Where: S – combined shear stress, psi (kPa)
f – total axial thrust, including the weight of the shaft and all rotating parts supported by it, pounds (newtons)
N – rated speed, r/min
D – outside diameter of the coupling, in. (mm)
d – inside diameter of the coupling at the root of the threads, in. (mm)
P – power, horsepower (watts)

3.2.10 Shaft Seals

The shaft seal shall adequately safeguard against excessive water leakage out of the pump when suction pressure is above atmospheric.

Note: Mechanical seals, in their present state of design, are not acceptable due to potential for damage due to sticking of the sliding surfaces after prolonged periods of non-operation, and other unfavorable wear characteristics.

3.2.11 Line Shaft Bearings

A. Water Lubricated Pumps

In order to insure adequate centering of the line shaft within the column, bearings shall be spaced no more than 10 ft (3.1 m) apart. These bearings shall be lubricated by the pumped water.

B. Oil Lubricated Pumps

The line shaft bearings which are an integral part of the couplings for the shaft-enclosing tube shall be spaced no more than 5 ft (1.5 m) apart. These bearings shall be lubricated by the oil within the shaft-enclosing tube. Calculations shall be submitted to FM Approvals as part of the drawing review process.

To provide adequate durability, anti-friction bearings shall have the following features:

- A minimum calculated life rating of not less than 5000 hours at maximum load;
- Arrangement to float axially on one or both ends; and,
- Lubrication by the pumped water in open line shafts, or lubrication by the oil within the enclosed line shafts.

3.2.12 Shaft-Enclosing Tube

Pumps of the enclosed line shaft, oil lubricated type shall be furnished with a shaft-enclosing tube of Schedule 80 or heavier steel pipe in interchangeable sections of not more than 5 ft (1.5 m) in length. The enclosing tube shall be adequately supported within the column pipe.

3.2.13 Driver Connection

Vertical turbine pumps shall be designed to be driven by a vertical hollow shaft electric motor or with an Approved vertical hollow shaft right angle gear drive, with diesel engine or steam turbine driver.

3.2.14 Non-Reverse Ratchets

Although non-reverse ratchets are not a part of the pump itself, Approved pumps must be suitable for use with hollow shaft electric motors or right angle gear drives which have integral non-reverse ratchets, in accordance with Section 3.2.13 (Driver Connection).

3.2.15 Rated Speed

The rated speed of the pump shall not exceed 1800 r/min under any condition. Increased speeds could accentuate imbalances within rotating parts and could result in a decrease of system reliability.

3.2.16 Strainers

There are two types of strainers normally used with vertical turbine fire pumps, a basket strainer that is connected to the suction bell, or a conical strainer that is connected to a suction tail pipe. Either the basket or the conical strainer shall have a free area of at least 400 percent of the internal cross section area of the suction tail pipe. For pumps 500 gal/min (1895 L/min) and larger the openings shall be small enough to restrict the passage of a sphere ½ in. (13 mm) in diameter. Other sizes shall be evaluated on a case by case basis. The strainer shall be fabricated from non-ferrous material.

3.3 Materials

All materials used in these fire pumps shall be suitable for the intended application. At a minimum, the impellers, impeller collet nut, bowl wear rings, water-seal rings, stuffing box gland, gland nut, shaft sleeve, suction strainer, and interior bolts or screws shall be constructed of corrosion resistant materials. When unusual materials are used, special tests may be necessary to verify their suitability.

3.4 Markings

3.4.1 A permanently-marked, legible, corrosion-resistant nameplate shall be securely attached to the pump or bedplate where it shall be easily visible. The nameplate shall include the following information:

- manufacturer’s name and address;
- model or type designation;
- rated capacity;
- rated total head;
- rated speed;
- maximum power required;
- impeller diameter(s);
- number of stages;
- pump serial number; and
- FM Approval Mark, (see Appendix B).

3.4.2 Pumps that are produced at more than one location shall be identified as the product of a particular location.

3.4.3 An arrow indicating the direction of pump rotation shall be cast into the pump discharge head. A corrosion resistant metal nameplate bearing the arrow shall be considered acceptable if permanently fastened to the fire pump discharge head.

3.4.4 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.

3.4.5 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.

3.4.6 All markings shall be legible and durable.

3.5 Manufacturer's Installation and Operation Instructions

Maintenance, operation and installation instructions, including any special dimensional requirements, shall be furnished by the manufacturer. Instructions shall be provided with each fire pump.

3.6 Calibration

All examinations and tests performed in evaluation to this Standard shall use calibrated measuring instruments traceable and certified to acceptable national standards.

4. PERFORMANCE REQUIREMENTS

4.1 Performance

4.1.1 Requirements

The pump shall develop its rated pressure when delivering its rated capacity.

The pump shall develop at least 65 percent of its rated pressure while delivering 150 percent of the rated capacity.

The pump shall not exceed 140 percent of its rated pressure at any point along its characteristic curve (pressure vs. flow), including the shutoff point. The shutoff head shall not be less than 99 percent of the maximum head.

The maximum power required shall be determined.

4.1.2 Test/Verification

At least one sample of each rated capacity shall be tested. If one or more impellers, having a range of impeller diameters, or stages are used to obtain the desired head range for the pump, the minimum and maximum stages and impeller diameters of each type shall be tested. Intermediate stages or impeller diameters may be tested at the discretion of FM Approvals.

The pump shall be operated at various flow rates to generate total head, power, and efficiency curves. Performance test shall be conducted at the minimum submergence recommended by the manufacturer. At each flow the total head, power required, and speed shall be measured. A minimum of nine flow readings shall be taken to generate the curve. Three of the flow readings shall be in close proximity to 150 percent of rated flow, with the 150 percent point within the span of these points. All measured test speeds must be ±4 percent of the requested rated speed. In order to develop characteristic curves, test data shall be corrected to rated speed by means of the affinity relationships.

A total suction head adequate to produce the maximum power requirement for the pump shall be provided. Maximum power is the greatest power required to drive the pump at any point along its characteristic curve, noted by a gradual decline or leveling off in power.

4.2 Flange And Gasket Tightness

4.2.1 Requirement

No leakage, except at the shaft packing, shall be observed in a 5 minute test when hydrostatically tested at the design working pressure.

4.2.2 Test/Verification

A sample pump assembly, (bowls, column pipe and discharge head) of each model and material shall be hydrostatically tested to a pressure equal to, or greater than, twice the design working pressure or 250 psi (1725 kPa), whichever is greater. The design working pressure is the highest shutoff pressure obtained in testing the range of impeller diameters, stages and speeds submitted for Approval. The test pressure shall be held for five minutes. Bowl bolts normally provided shall be used for this test. In no case shall the test be run at a pressure less than 250 psi (1725 kPa).

4.3 Hydrostatic Strength

4.3.1 Requirement

No rupture, cracking or permanent distortion of any part of the pump, hose headers or fabricated (welded) steel or cast fittings shall be observed in a 5 minute test when hydrostatically tested at the required pressure.

4.3.2 Tests/Verification

A sample pump assembly, (bowls, column pipe and discharge head) of each model and material shall be hydrostatically tested to a pressure equal to, or greater than, three times the design working pressure or 400 psi (2760 kPa), whichever is greater. The design working pressure is the highest shutoff pressure obtained in testing the range of impeller diameters, stages and speeds submitted for Approval. The test pressure shall be held for five minutes. In no case shall the test be run at a pressure less than 400 psi (2760 kPa).

Sample hose headers, fabricated (welded) steel or cast fittings of each size and material shall be hydrostatically tested to a pressure equal to, or greater than, four times the design working pressure or 700 psi (4825 kPa), whichever is greater. The design working pressure is the highest shutoff pressure obtained in testing the range of impeller diameters, stages and speeds submitted for Approval. The test pressure shall be held for five minutes. In no case shall the test be run at a pressure less than 700 psi (4825 kPa).

4.4 Test Procedure

Pump testing is normally performed by the manufacturer at the manufacturing facility. FM Approvals shall witness the testing and obtain copies of the data and calibration certificates. The range of tests to be conducted shall be specified by FM Approvals. Test procedures shall be in accordance with recommendations of the latest edition of the Hydraulic Institute Standards, *Standard for Centrifugal, Rotary and Reciprocating Pumps*. If other test procedures are contemplated, they should be forwarded to FM Approvals for review and acceptance prior to testing.

4.5 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 fire pumps, 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 with adequate technical justification of the conditions and reasons for failure.

5. OPERATIONS REQUIREMENTS

A quality control program is required to assure that subsequent vertical shaft, turbine type centrifugal fire pumps produced by the manufacturer at an authorized location, shall present the same quality and reliability as the specific vertical shaft, turbine type centrifugal fire pumps 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 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, and shall maintain these records 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 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 – Performance Test*

The manufacturer shall performance test 100 percent of production fire pumps, recording flow, total head, speed and power consumed at a minimum of six points spanning from shut off to beyond 1.5 times rated flow. All measured test speeds shall be within ±4 percent of the rated speed. In order to develop the characteristic curve, test data shall be corrected to rated speed by means of the affinity relationship. This corrected curve shall be supplied with the pump.

5.4.2 *Test Requirement No. 2 – Leakage Test*

The manufacturer shall test 100 percent of production fire pumps for body leakage to 2 times the maximum design working pressure, but not less than 250 psi (1725 kPa). The pressure shall be held for a minimum of five minutes with no objectionable leakage (except at the shaft packing), at any joint. Pump casing distortion or leakage is not allowed.

APPENDIX A

UNITS OF MEASUREMENT

LENGTH:	in. – ‘‘inches’’; (mm – ‘‘millimeters’’) mm = in. × 25.4
	ft – ‘‘feet’’; (m – ‘‘meters’’) m = ft × 0.3048
FLOW:	gal/min – ‘‘gallons per minute’’; (L/min – ‘‘liters per minute’’) L/min = gal/min × 3.785
POWER:	hp – ‘‘horsepower’’; (kW – ‘‘kilowatt’’) kW = hp × 0.7457
PRESSURE:	psi – ‘‘pounds per square inch’’; (kPa – ‘‘kilopascals’’) kPa = psi × 6.895 in. of Hg – ‘‘inches of mercury’’ psi = in. of Hg (mercury) × 0.491
	bar – ‘‘bar’’; (kPa – ‘‘kilopascals’’) bar = kPa × 0.01 bar = psi × 0.06895
TEMPERATURE:	°F – ‘‘degrees Fahrenheit’’; (°C – ‘‘degrees Celsius’’) °C = (°F -32) × 0.556
ROTATIONAL SPEED:	rpm – ‘‘revolutions per minute’’; (same in SI Units)
TORQUE:	ft•lb_f – ‘‘foot pound-force’’; (N•m – ‘‘Newton-meters’’) N•m = ft•lb_f × 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 Approvals 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

TEST PROCEDURES

There are several acceptable methods of obtaining the test data needed. In order to establish uniformity in method selection, the following techniques, based on recommendations by the Hydraulic Institute, are listed below. For more specific information such as test set-ups and the equations needed to compute results from raw data, reference should be made to the "Hydraulic Institute Standards", latest edition.

C.1 Capacity Measurements

C.1.1 Weight

Scale measurements with an accuracy of ±0.25 percent of full scale shall be obtainable.

C.1.2 Volume

Reservoir measurements with an accuracy of ±0.5 percent of the reading shall be obtainable.

C.1.3 Venturi

A certified curve showing the calibration of the meter shall be provided. Machined tubes shall be accurate within ±0.75 percent of the rate of flow. The size of the venturi needed shall be determined by the throat velocity. A minimum of 20 ft/sec (6.1 m/sec) shall be effected at the venturi throat at the rated capacity of the pump.

The accuracy of the venturi meter depends upon its installation within the hydraulic system. The meter shall not be adversely affected by improper flow conditions immediately preceding the venturi tube. Non-uniform velocity distribution or swirling or pulsating flow will affect the value of the coefficient. Table C.1.3 shows the length of straight pipe required ahead of the venturi tube expressed in terms of equivalent diameters.

Table C.1.3
Straight Pipe Required After Any Fitting
Before the Venturi Meter in Diameters of Pipe

Meter Ratio (Throat to Inlet Diameter)	0.4	0.5	0.6	0.7	0.8
One standard short radius elbow	1	2	3	4	6
Two elbows in same plane	2	3	4	6	8
Two elbows in planes at 90° and with straightening vanes	2	3	4	5	7
Standard cast iron flanged reducer	2	5	7.5	10	13
Standard cast iron flanged increaser	1	2	3	4.5	6
Globe valve with straightening vanes	2	4	6	9	12
Gate valve – 0.2 open	2	4	6	9	12
Gate valve – 0.5 open	2	3	4	6	8
Gate valve – full open	0	0.5	1	2	3

Note: A centrifugal pump pumping directly into a venturi meter should have at least 10 pipe diameters of straight pipe between it and the meter. This distance can be reduced if straightening vanes are properly used between the pump and venturi.

C.1.4 Nozzles

A certified curve showing the calibration of the nozzle shall be provided. When ASME long radius flow nozzles are used with an outlet to inlet diameter ratio from 0.2 to 0.7, the tolerance in the rate of flow should not exceed ±0.75 percent for 3 in. pipe and over. When other nozzles are used with the same specifications listed above, the error should not exceed ±1 percent of the rated flow. The nozzle size shall be selected to provide a minimum velocity of 20 ft/s (6.1 m/s) at the nozzle throat.

C.1.5 Orifice Plate

A certified curve showing the calibration of a square edged concentric orifice plate shall be provided. The error should not exceed ±1.5 percent of the reading when using an orifice-to-pipe diameter ratio from 0.10 to 0.80. Ratios outside of these limits should not be used. Preferred orifice to pipe diameter ratios are from 0.20 to 0.60.

To ensure accurate flow measurements, a sufficient length of straight pipe is required preceding and following the orifice plate. The values required expressed in terms of equivalent diameters, are shown in Tables C.1.5 (a) and (b). When ''pipe taps'' are used, the values shown in Tables C.1.5 (a) and (b) should be increased by 2 diameters.

Table C.1.5 (a)
Straight Pipe Required After Any Fitting
Before Meter in Diameters of Pipe

Meter Ratio (Throat to Inlet Diameter)	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Tee or wye within line flow	6	6	6.5	7	8.5	10.5	14
One elbow, branch flow thru tee or wye, or flow from drum or separator	6	6	6.5	7	9	13	20.5
Globe valve – wide open	9	9	9.5	10.5	13	15	21
Gate valve – wide open	6	6	6	6	7.5	9.5	13.5
Two or more short radius elbows or bends in the same plane	7.5	7.5	8.5	10.5	13.5	18	25
Two or more long radius elbows or bends in the same plane	6	6	6.5	8	11	16	23
Two short radius elbows or bends in different planes	14.5	16	17.5	20.5	24.5	30	40
Two long radius elbows or bends in different planes	7	8	10	12	16	22	33

Note: A centrifugal pump pumping directly into a nozzle or orifice should have at least 10 pipe diameters of straight pipe between it and the meter. This distance can be reduced if straightening vanes are properly used between the pump and nozzle or orifice.

Table C.1.5 (b)
Straight Pipe Required After Meter
Before Any Fitting in Diameters of Pipe

Meter Ratio (Throat to Inlet Diameter)	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Gate valve – wide open	0	0	0	0	0	0	0
Wye	0	0	0	0	0	0	4
Tee	0	0	0	0	0	3.5	4
Expansion joint	0	0	0	0	0	3.5	4
45° Elbow	0	0	0	0	3.5	3.5	4
Long radius elbow or bend	2	2.5	2.5	3	3.5	3.5	4
Regulators, control valves, and partly throttled gate valves	6	6	6	6	6	6	6

C.1.6 Weir

A rectangular sharp crested weir with a smooth vertical crest wall, complete crest contraction, free overfall and with the end contraction suppressed, is a suitable capacity measuring device. The weir should be calibrated in place with the water circuit.

When rectangular suppressed weirs are used, the error shall not exceed ±2 percent of the flow under the following limitations of flow:

- The head is not smaller than 0.2 ft (61 mm).
- The head is not larger than one-half the height of the weir.
- The head is not larger than one-half the length of the weir.

C.2 Head Measurements

C.2.1 Instruments to measure head shall, when practical, be water columns or manometers and for high pressures shall be mercury manometers, bourdon gauges, electrical pressure transducers or dead weight gauge testers. If water gauges are used, errors due to water temperature difference within the gauge and pump, shall be avoided. Measuring instrumentation shall have records of calibration. Tolerances shall not exceed ±1.0 percent of the full scale.

C.2.2 It is important that steady flow conditions exist at the point of instrument connection. For this reason, it is necessary that pressure or head measurement be taken on a section of pipe where the cross-section is constant and straight. Five to ten diameters of straight pipe of unvarying cross-section following any elbow or curved member, valve, or other obstruction, are usually necessary to ensure steady flow conditions.

C.2.3 Special care shall be taken in the drilling of orifice or tap openings for gauges. The following precautions shall be taken:

- The orifice in the pipe shall be flush with and normal to the wall of the water passage;
- The wall of the water passage shall be smooth and of unvarying cross-section. For a distance of at least 12 in. (305 mm) preceding the orifice, all tubercles and roughness shall be removed with a file or emery cloth, if necessary;
- The orifice shall be of a diameter from ⅛ in. to ¼ in. (3.2 mm to 6.4 mm) and of a length equal to twice the diameter; and,
- The edges of the orifice shall be provided with a suitable radius tangential to the wall of the water passage, and shall be free from burrs or irregularities.

C.2.4 The datum shall be taken as the centerline of the pump.

C.3 Power Measurements

C.3.1 Pump input power shall be determined by either transmission dynamometers, torsion dynamometers, strain gauge type torque measuring devices, or by the use of calibrated drivers.

C.3.2 When pump input power is to be determined by transmission dynamometers, the unloaded and unlocked dynamometer must be properly balanced, prior to the test, at the same speed at which the test is to be run. The scales should be checked against standard weights.

C.3.3 When pump input power is to be determined by torsion dynamometers, the unloaded dynamometer shall be statically calibrated prior to the test by measuring the angular deflection for a given torque; the tare reading on the dynamometer scale is taken at rated speed with the pump disconnected.

C.3.4 When strain gauge type torque measuring devices are used to measure pump input power, they shall be calibrated, with their accompanying instrumentation, at regular intervals.

C.3.5 When pump input power is to be determined by the use of a calibrated motor, measurements of power input shall be made at the terminals of the motor to exclude any line losses that may occur between the switchboard and the driver itself. Certified calibration curves of the motor must be provided. The calibration shall be conducted on the specific motor in question, and not on a similar machine. Such calibrations must indicate the true input-output value of the motor efficiency and not some conventional method of determining an arbitrary efficiency.

C.3.6 After the completion of any of the above tests, recalibration or rebalancing shall be checked to assure that no change has taken place. In the event of appreciable change, the test shall be rerun.

C.3.7 Calibrated laboratory type electric meters and transformers shall be used to measure power input to all electric motors.

C.4 Speed Measurement

C.4.1 Measurement of speed shall be made by means of revolution counters, tachometers, or stroboscopic devices.

C.4.2 For speed measurements taken by means of a revolution counter, the timing period shall be of sufficient length to obtain a true average speed. The stopwatch shall be checked against a standard timer. If electric/electronic speed sensing element with electronic counter is used, it shall be checked against a suitable secondary frequency standard.

C.4.3 When a tachometer is used, it shall be calibrated against a revolution counter before and after the test. Tachometer readings shall be made at frequent intervals during the period each test reading is taken to determine an accurate measurement of average speed over that reading period.

C.4.4 When a stroboscopic device is used, the comparison frequency source shall be either line frequency, where stable, or a stable independent frequency. The speed shall be determined by the observation and deduction of slip from the synchronous speed.

C.5 Time Measurement

Time measurement with an accuracy of ±1/100 of a second shall be obtainable.

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