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

Class Number 1370

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Foreword

This standard is intended to verify that the products and services described will meet the stated conditions of performance, safety and quality useful to the ends of property conservation. The purpose of standards is to present the criteria for certification of various types of products and services,

Examination in accordance with this standard shall demonstrate compliance and verify that quality control in manufacturing shall ensure a consistent and reliable product.

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1. INTRODUCTION

1.1 Purpose

1.1.1 This standard states testing and certification criteria for vertical shaft, turbine type, barrel centrifugal fire pumps which are intended supply water to fire protection systems. They are a critical component in a facility's fire protection system. They are expected to automatically start upon loss of fire protection system pressure or by other automatic fire detection means. They are required to supply the necessary water flow and pressure without interruption to a facility's fire protection system under fire conditions despite being idle for extended periods. They are required to provide a high degree of reliability.

1.1.2 Testing and certification criteria may include, but are not limited to, performance requirements, marking requirements, examination of manufacturing facility(ies), audit of quality assurance procedures, and a surveillance audit program.

1.2 Scope

1.2.1 This standard encompasses the design and performance requirements for vertical shaft, turbine type, barrel centrifugal fire pumps for use in fire protection systems. Certification is limited to vertical shaft, turbine type, barrel centrifugal fire pumps that have a minimum rated discharge pressure of at least 40 psi (275 kPa). In cases where metric sized vertical shaft, turbine type, barrel centrifugal fire pumps are to be examined for certification, test criteria equal to or greater than the United States size or value shall be used.

1.2.2 Requirements for other types of centrifugal fire pumps are detailed in the following examination standards:

Standard Class Number	***Centrifugal Fire Pump Type***
1310	Multi Stage, Multi Outlet
1311	Split-Case Type, (Axial or Radial)
1312	Vertical Shaft Turbine Type
1319	Horizontal, End-Suction Type
1371	In-Line Type

1.2.3 Requirements for other major components in the pump package are detailed in the following examination standards:

Standard Class Number	***Equipment***
1046	Fire Pump Flowmeter Systems
1321/1323	Controllers for Electric Motor Driven and Diesel Engine Driven Fire Pumps
1333	Diesel Engine Fire Pump Drivers
1336	Fire Pump Couplings and Flexible Connecting Shafts for Fire Protection Service
2311	Pressure Gauges for Fire Protection Systems

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, barrel centrifugal fire pumps for the purpose of obtaining certification.

1.4 Basis for Certification

Certification 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 for certification; 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. Subsequent surveillance may be required by the certification agency in accordance with the certification scheme to ensure ongoing compliance.

1.5 Basis for Continued Certification

1.5.1 Continued certification is based upon:

- production or availability of the product as currently certified;
- the continued use of acceptable quality assurance procedures;
- compliance with the terms stipulated in the certification;
- satisfactory re-examination of production samples for continued conformity to requirements; and
- satisfactory surveillance audits conducted as part of the certification agency's product surveillance program.

1.6 Effective Date

The effective date of this examination standard mandates that all products tested for certification after the effective date shall satisfy the requirements of this standard.

The effective date of this standard is eighteen (18) months after the publication date of the standard 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. Conversion of U.S. customary units is in accordance with ANSI/IEEE/ASTM SI 10.

Two units of measurement (liter and bar), outside of but recognized by SI, are commonly used in international fire protection and are used in this standard.

1.8 Normative References

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the cited edition applies.

ANSI/WWA E103, *Horizontal and Vertical Line-Shaft Pumps*
ANSI/IEEE/ASTM SI 10, *American National Standard for Metric Practice*
IEC 60034-1, *Rotating electrical machines - Part 1: Rating and performance*
National Electrical Manufacturers Association (NEMA) Standard MG 1, *Motors and Generators*

1.9 Terms and Definitions

For purposes of this standard, the following terms apply:

Accepted
Installations acceptable to the authority having jurisdiction and enforcing the applicable installation rules. Acceptance is not a characteristic of a product. It is installation specific. A product accepted for one installation may not be acceptable elsewhere.

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.

Cavitation
A reduction of pressure within a pump that causes water vaporization. Cavitation reduces a pump's performance and can damage the pump impeller.

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 available, and at maximum speed plus the maximum suction pressure for the pump.

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 examination standard shall be of this type.

Fire Pump Alternate Manufacturing Location
A location that manufactures a complete pump to the design requirements of the Fire Pump Manufacturer (OEM) or modifies (i.e. trimming of a pump impeller) an OEM supplied (bare-shafted) fire pump.

The Fire Pump Alternate Manufacturing Location may be an alternate facility owned and operated by the OEM or a facility owned by others that performs the complete, or partial, manufacturing of the complete fire pump and/or package under direct control of the OEM.

Fire Pump Manufacturer

The manufacturer of the certified fire pump is also referred to as the Original Equipment Manufacturer (OEM) of the fire pump.

Fire Pump Package

An assembled fire pump, driver, controller and components, see Appendix D, necessary to provide a complete pump installation.

Fire Pump Packager

The Fire Pump Manufacturer can delegate, through a legal agreement, the function of assembling the fire pump package to a third party known as the fire pump packager. Alternatively, or in addition to, a Fire Pump Packager may package or just distribute complete private labeled fire pump packages.

The Fire Pump Packager may be a facility owned and operated by the Fire Pump Manufacturer or a facility owned by others that performs the assembly of the complete fire pump package under direct control of the OEM.

Fire Pump Private Labeler

A company, other than the Fire Pump Manufacturer (OEM), that has a legal agreement with the OEM whereby the pump is manufactured and labeled by the OEM in the name of the Private Labeler.

In order to enter into a Fire Pump Private Label agreement, a Fire Pump Private Labeler must be one of the following entities:

- Fire Pump Manufacturer
- Fire Pump Alternate Manufacturer
- Fire Pump Packager

Flexible coupling

A device used to connect a driver to a pump; it can compensate for small misalignments and dampen vibration.

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 non-reverse 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.

Mass Elastic Torsional Analysis

An engineering analysis conducted for the purpose of identifying and eliminating damaging torsional forces and linear resonant frequencies from the operating speed range of rotating equipment.

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 pumps total run out condition. This is determined under conditions of increasing positive suction head.

Minimum Submergence

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

Multiple Stage Pumps

Vertical shaft, turbine type, barrel 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 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.

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 the manufacturer's requested speed and capacity.

Off-Site Test Facilities
The location where testing will be performed that is not operated by the certification agency and which provides all of the following:
a.) All required test and data collection equipment.
b.) A formal calibration system with traceability to nationally recognized standards by an ISO 17025 accredited calibration service.
c.) Test personnel who possess a thorough understanding of, and the ability to conduct, the required tests.

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

Service factor
A multiplier that, when applied to the rated horsepower of an ac motor, indicates a permissible horsepower loading that can be carried at the rated voltage, frequency, and temperature. The service factor multiplier (e.g., 1.15) indicates that the motor is permitted to be overloaded 1.15 times the rated horsepower without insulation breakdown or otherwise significantly reducing service life.

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.

Total Discharge Head
The gauge reading in psi (kPa) at the discharge of the pump, referred to 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.

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

2.1.3 In order to meet the intent of this standard, vertical shaft, turbine type, barrel 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 Certification Application Requirements

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

- a complete list of all models, types, sizes, and options for the products or services being submitted for certification consideration;
- anticipated pump performance, including total head, power requirements, and efficiency versus flow characteristics. If different impellers or a range of 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, including maximum and minimum characteristic curves for each rated speed;
- the pump manufacturer shall, for each model pump, conduct performance tests prior to the certification program on minimum and maximum impeller diameters. Suction pressure shall be sufficient to determine maximum power requirements. The maximum horsepower measured shall be used to size the electric motor(s) for certification tests and, ultimately, for site installation. Performance curves of the total head and power versus flow shall be drawn from the data from these tests and submitted to the certification agency prior to scheduling the witnessed certification tests.
- motor specifications for each motor used, including power rating, speed, frame size, radial thrust capacity, shaft deflection versus radial thrust, minimum shaft fatigue lift, maximum shaft runout, and minimum “L-10" bearing life;
- calculations to determine shaft size, shaft runout, stuffing box runout, shaft deflection, and casing bolt size;
- general assembly drawings (showing the pump and attachments), 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; 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

2.3.1 Following set-up and authorization of a certification examination, the manufacturer shall submit samples for examination and testing based on the following:

Sample requirements are to be determined by the certification agency.

2.3.2 Requirements for samples may vary depending on design features, results of prior testing, and results of the foregoing tests.

2.3.3 The manufacturer shall submit samples representative of production.

2.3.4 It is the manufacturers responsibility to provide the test facilities, which are required to evaluate the vertical shaft,

turbine type, barrel centrifugal fire pumps.

3 GENERAL REQUIREMENTS

3.1 Review of Documentation

During the initial investigation and prior to physical testing, the manufacturer's specifications, and details shall be reviewed to assess the ease and practicality of installation and use.

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 discharge 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 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.

3.2.3 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 1/4 in. (6 mm) for pumps having rated capacities less than 100 gal/min (380 L/min). Passages in pumps having rated capacities of 100 to less than 500 gal/min (380 to 1895 L/min) shall be at least 3/8 in. (10 mm). Passages in pumps rated 500 gal/min (1895 L/min) and larger shall be at least.1/2 in. (13 mm).

3.2.4 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.

3.2.5 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 enclosed 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 balanced per ISO 1940-1:2003, balance quality grade G6.3, or equivalent. Impellers shall be securely fastened by left-hand threaded nut or other suitable method to prevent the impeller from loosening from the impeller shaft. Impellers shall be keyed and/or set screwed to prevent rotation in relation to the shaft.

3.2.6 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 3.2.10. 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.

3.2.7 Shaft

The shaft (and shaft extension and coupling, when used) shall be of adequate design to successfully transmit the torques encountered in starting and during operation while supporting the impellers and other rotating parts. Calculations shall be submitted to the certification agency as part of the drawing review process. The electric motor manufacturer's data shall be reviewed to evaluate the motor shaft's size and strength.

In order to safeguard against shaft failure, the maximum combined shear stress, as calculated by the following formula, that occurs in the shaft shall not exceed 30 percent of the minimum allowable tensile yield strength value of the shaft material and 18 percent of the minimum allowable ultimate tensile strength value of the shaft material. For shafts with keyways, a further 25 percent reduction in the allowable stresses is required.

The following formula for calculating the combined shear stress is taken from ANSI/AWWA E103, *Horizontal and Vertical Line-Shaft Pumps*.

English

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

Metric

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

Where:

S - Combined shear stress, psi (kPa)
f - Total axial thrust at shutoff, 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 - Maximum power, horsepower (watts)

Renewable shaft sleeves shall be provided, regardless of the shaft material, at bearing surfaces to adequately safeguard the 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.

3.2.8 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 not be tapered and shall tighten during pump operation. Calculations shall be submitted to the certification agency as part of the drawing review process.

The maximum combined shear stress in the coupling shall not exceed 20 percent of the minimum allowable tensile yield strength value of the coupling material or be more than 12 percent of the minimum allowable ultimate tensile strength value of the coupling material. The following formula for calculating the combined shear stress is taken from ANSI/AWWA E103, *Horizontal and Vertical Line-Shaft Pumps*.

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 at shutoff, 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 - Maximum power, horsepower (watts)

3.2.9 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.

3.2.10 Line Shaft Bearings

3.2.10.1 Water Lubricated Pumps

In order to ensure 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.

3.2.10.2 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.

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 applied load. Axial loads shall be incorporated into the bearing calculations. Calculations shall be submitted to the certification agency as part of the drawing review process;
- 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.

3.2.11 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.

3.2.12 Driver Connection

Vertical turbine pumps shall be designed to be driven by a vertical hollow shaft electric motor or with a certified vertical hollow shaft right angle gear drive, with diesel engine or steam turbine driver. For diesel-driven vertical turbine pumps, a mass elastic torsional analysis of the system (engine, coupling, gear drive, and pump) shall 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.

The certified gear drive shall be sized so both the maximum power required by the pump and the maximum thrust forces generated by the pump are less than or equal to the gear drive nameplate rating.

3.2.13 Non-Reverse Ratchets

Although non-reverse ratchets are not a part of the pump itself, certified 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 3.2.12 (Driver Connection).

3.2.14 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.

3.2.15 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 1⁄2 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 Pump Package

The pump manufacturer shall assemble and supply the complete pump package (as detailed in Appendix D).

Certified fire pumps shall be manufactured or packaged at the location(s) audited by the certification agency and as specified in the report.

3.4 Electric Motor

3.4.1 The electric motor shall be provided as an integral part of the pumping unit. Drivers shall be electric motors designed per NEMA MG 1, the IEC 60034-1.

3.4.2 The motor shall be sized (in horsepower or kilowatts) such that the maximum motor current in any phase under any anticipated condition of pump load and voltage unbalance does not exceed the motor rated full-load current multiplied by the motor service factor.

3.4.3 Electric motors for fire pump service require a winding insulation temperature rating of NEMA/IEC Class B 266°F (130°C) or greater.

3.4.4 To protect against water ingress, electric motors for fire pump service require minimum rating equivalent to a NEMA open drip poof type or have a minimum IEC rating of IP22.

3.4.5 Eyebolts or equivalent lifting points shall be provided on the electric motor to lift the motor safely. Strength calculations for lifting mechanism shall be provided.

3.5 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 casings and impellers are cast of alternate materials, performance and/or pressure tests of sample assemblies of each material may be required.

3.6 Markings

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

- manufacturer’s name, and address of manufacture;
- country of manufacture (if different than above)
- model or type designation;
- rated capacity;

- rated total head;
- rated speed;
- maximum power required;
- impeller diameter(s);
- number of stages;
- pump serial number;
- manufacturer and serial number of the driver;
- manufacturer and serial number of the controller; and;
- certification agency's mark of conformity.

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

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

3.6.4 The model or type identification shall correspond with the manufacturer's catalog designation and shall uniquely identify the product as certified. The manufacturer shall not place this mark on any other product unless covered by a separate agreement.

3.6.5 The certification agency's mark of conformity 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 the certification agency.

3.6.6 All markings shall be legible and durable.

3.7 Manufacturer's Installation and Operation Instructions

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

3.8 Calibration

3.8.1 Each piece of 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. The certificate shall indicate that the calibration was performed against working standards whose calibration is certified and traceable to an acceptable reference standard and certified by an ISO 17025 accredited calibration laboratory. The test equipment shall be clearly identified by label or sticker showing the last date of the calibration and the next due date. A copy of the service provider's accreditation certificate as an ISO 17025 accredited calibration laboratory should be available.

3.8.2 When the inspection equipment and/or environment is not suitable for labels or stickers, other methods such as etching of control numbers on the measuring device are allowed, provided documentation is maintained on the calibration status of thus equipment.

3.9 Tolerances

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

4 PERFORMANCE REQUIREMENTS

4.1 Design and Calculation Review

4.1.1 The pump shall conform to the manufacturer's drawings and specifications and to the certification agency's design and calculation requirements stated in Section 3.

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

4.1.3 The following calculations shall be reviewed and compared to the requirements stated in Section 3:

- Maximum torsional shearing stress;
- Casing bolt strength;
- Axial Loads;
- Bearing life calculations;
- Shaft deflection and impeller clearance/interference;
- Radial load calculations.

4.2 Performance

4.2.1 The following pump performance and testing is required:

- 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.

4.2.2 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 as needed to ensure the certification agency's understanding of the intermediate size impeller pump performance.

4.2.3 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.

4.2.4 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.

4.3 Flange and Gasket Tightness

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

4.3.2 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 certification. The test pressure shall be held for five minutes. Bowl bolts, gaskets and sealants 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).

4.4 Hydrostatic Strength

4.4.1 No rupture, cracking or permanent distortion of any part of the pump shall be observed in a 5 minute test when hydrostatically tested at the required pressure.

4.4.2 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 certification. 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).

4.5 Barrel Hydrostatic Strength

4.5.1 No rupture, cracking or permanent distortion of the pump barrel shall be observed in a 5 minute test when hydrostatically tested at twice the maximum suction design pressure.

4.5.2 A sample pump barrel of each model and material shall be hydrostatically tested to a pressure equal to, or greater than, two times the maximum suction design pressure or 400 psi (2760 kPa), whichever is greater. The maximum suction design pressure is the maximum pressure developed by the pump at rated capacity in testing the range of impeller diameters, stages and speeds submitted for certification. 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).

4.6 Test Procedure

Pump testing shall be performed by the manufacturer at its facility. The certification agency shall witness the testing and obtain copies of the data and calibration certificates. The specific tests to be conducted shall be in accordance with the certification agency's test plan. Test procedures shall be in accordance with recommendations of the Hydraulic Institute Standards, *Standard for Centrifugal, Rotary and Reciprocating Pumps* (Appendix C).

5 OPERATIONS REQUIREMENTS

5.1 Demonstrated Quality Control Program

5.1.1 A quality control program is required to assure that subsequent in-line type centrifugal fire pumps produced by the manufacturer shall present the same quality and reliability as the specific in-line type centrifugal fire pumps examined. Design quality, conformance to design, and performance are the areas of primary concern.

- Design quality is determined during the examination and tests and may be documented in the certification report.
- Continued conformance to this standard is verified by the certifier's surveillance program.
- Quality of performance is determined by field performances and by periodic re-examination and testing.

5.1.2 The manufacturer shall demonstrate a quality assurance program which specifies controls for 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; and,
- handling and disposition of non-conformance materials.

5.1.3 Documentation/Manual

There should be an authoritative collection of procedures/policies. It should 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.

5.1.4 Records

To assure adequate traceability of materials and products, the manufacturer shall maintain a record of all quality assurance tests performed, for a minimum period of two years from the date of manufacture.

5.1.5 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 certification report, may be required to be reported to, and authorized by, the certification agency prior to implementation for production.

- Records of all revisions to all certified products shall be maintained.

5.2 Surveillance Audit

5.2.1 An audit of the manufacturing facility may be a part of the certification agency's surveillance requirements to verify implementation of the quality assurance program. Its purpose is to determine that the manufacturer's equipment, procedures, and quality program are maintained to ensure a uniform product consistent with that which was tested and certified.

5.2.2 Certified products or services shall be produced or provided at, or provided from, location(s) disclosed as part of the certification examination. Manufacture of products bearing a certification mark is not permitted at any other location prior to disclosure to the certification agency.

5.2.3 The Fire Pump Manufacturer shall maintain design/documentation control and manufacture certified fire pumps

only at the location(s) audited by the certification agency and as specified in the certification report.

5.2.4 The OEM is responsible to rectify any non-conformances discovered at the Alternate Manufacturing and/or the Fire Pump Packager facility to the satisfaction of the certification agency.

5.3 Manufacturer's Responsibilities

The manufacturer shall notify the certification agency of changes in product construction, components, raw materials, physical characteristics, coatings, component formulation or quality assurance procedures prior to implementation.

The electric motor is an integral part of the pump assembly and changes to the design of the electric motor will possibly affect the performance of the pump. The pump manufacturer shall institute a quality control program sufficient to discover any changes to motor shaft or bearing design that could affect the pump performance. The certification agency shall evaluate said program and judge its adequacy. An acceptable program shall include procedures to prohibit the shipment of any pump assemblies incorporating revised motor designs prior to notification to and their acceptance by the certification agency.

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 1.5 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.

5.4.3 Test Requirement No. 2 - *Torsional Analysis (Diesel-Driven Vertical Turbine Pumps Only)*

For diesel-driven vertical turbine pumps, a mass elastic torsional analysis of the system (engine, coupling, gear drive, and pump) shall 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.

APPENDIX A:

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APPENDIX B:

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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".

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 affected 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.1.7 Electromagnetic Flow Meters

Electromagnetic flowmeters are based on Faraday's Law of Magnetic Induction that states that a voltage will be induced when a conductor, in this case water, moves at right angles through a magnetic field is proportional to the velocity of that conductor - the faster the flow rate, the higher the voltage. This voltage is picked up by sensing electrodes mounted in the meter tube and sent to the transmitter which takes the voltage and calculates the flow rate based on the cross-sectional area of the meter tube. Pressure drop across the meter is the same as it is through an equivalent length of pipe because there are no moving parts or obstructions to the flow.

Electromagnetic flow meters shall have an accuracy of ± 0.5 percent of the flow reading.

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 1/8 in. to 1/4 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.

APPENDIX D: Fire Pump Unit (Packages)

The fire pump package consists of the following components which are furnished by the pump manufacturer, alternate manufacturer, or a fire pump packager. Where marked (*) certified components shall be supplied.

1. Vertical shaft, turbine type fire pump*
2. Driver - diesel engine* or electric motor
3. Pump controller* (electric motor or diesel engine)
4. Flexible coupling (not all elastomeric) or drive shaft
5. Right angle gear drive*, when required
6. Right angle gear drive cooling water lines, when required
7. Torsional coupling, when required
8. Discharge pressure gauge* and connections
9. Pressure-relief valve* and waste cone, when required
10. Automatic air release valve*
11. Substantial bedplate for pump and driver
12. Diesel engine accessories:
    i. starting batteries
    ii. rigid cooling water and fuel lines (may have short flexible elements in close proximity to engine to minimize vibration)
    iii. exhaust piping and muffler
    iv. fuel tank
13. Instruction, Operation and maintenance manual in local language

APPENDIX E: Tolerance

Unless otherwise stated, the following tolerances shall apply:

Flow	+ 1/- 0 percent of value
Frequency (Hz):	± 5 percent of value
Length:	± 2 percent of value
Volume:	+ 1/- 0 percent of value
Power	± 1.5 percent of value
Pressure:	± 0.5 percent of value
Speed	± 0.3 percent of value
Temperature:	± 4°F (2°C)
Time:	+ 5/–0 seconds +0.1/–0 minutes

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