TECHNICAL SPECIFICATION 94.03.62.100

BOILER FEEDWATER PUMPS

1. SCOPE: This specification is for the design, fabrication, supply and delivery of a Boiler Feedwater Pump (BFP) package as detailed in the Datasheet (DS). Four (4) 100% motor-driven boiler feed pumps with Voith Turbo fluid couplings shall be provided. These shall be ring section pumps in accordance with Hydraulic Institute Standards, where applicable. Each pump shall be sized to provide 100% of a single HRSG's feedwater flow. Each pump shall provide feedwater at two (2) different pressure levels to a multi-pressure Heat Recovery Steam Generator (HRSG).

1.1 The Equipment offered shall be consistent with the best principles and practices of BFP design. This specification provides the required details of performance and design. The pumps shall be identical in all respects, and parts shall be interchangeable.

1.2 Quality: Quality and NDE requirement shall be per Seller's standard procedures as well as Section M4 – Quality and Examination Requirements to the greatest extent practical.

1.3 Mechanical: Welding shall be per Seller's standard procedure as well as Section M3 – Welding Requirements to the greatest extent practical.

1.4 Structural: Skid and structural support design and fabrication shall be per Sections S1 – Structural Loading and Design, and S2 – Structural Steel Fabrication and Supply.

1.5 Documentation: A Comprehensive Equipment Manual (CEM) shall be provided. All submittals and manuals shall be per Section GR-B – Engineering Data and Submittal Schedule. The documentation submittal schedule shall be per the Seller's Deliverable Schedule (SDS).

1.6 Code Requirements: BFPs shall be designed and manufactured per Section GR-A – General Requirements and Scope of Work, all Technical Sections, as noted within, and per the following standards:

a. American National Standards Institute / Hydraulic Institute (ANSI/HI) 1.1 – 1.2 "Rotodynamic Centrifugal Pumps for Nomenclature and Definitions"
b. ANSI/HI 1.3 "Rotodynamic Centrifugal Pumps for Design and Applications"
c. ANSI/HI 9.6.1 (M118) Centrifugal and Vertical Pumps –NPSH Margin
d. ANSI/HI 9.6.2 (M119) American National Standard for Centrifugal and Vertical Pumps for Allowable Nozzle Loads
e. ANSI/HI 9.6.3 Rotodynamic for Centrifugal and Vertical Pumps for Allowable Operating Region"
f. ANSI/HI 9.6.4 (M121) Centrifugal and Vertical Pumps – Vibration Measurements and Allowable Values

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g. ANSI/HI 9.8 (M123) American National Standard for Centrifugal and Vertical Pump Intake Design
h. ANSI/HI 14.6 “Rotodynamic Pumps for Hydraulic Performance Acceptance Tests”
i. American Petroleum Institute (API) 682 “Pumps-Shaft Sealing Systems for Centrifugal and Rotary Pumps”

2. DESIGN CONSIDERATIONS: Pumps and drivers shall be designed to operate free of harmful vibration or excessive noise, as defined in this specification, under all recommended operating conditions and all cases specified in the DS. Each pump and driver shall operate in dynamic balance as a unit without excessive vibration, as defined by the Hydraulic Institute.

2.1 Stresses: The pumps shall safely withstand momentary stresses due to the following without the need for prewarming; an operating pressure of the pump casing at least 10% higher than the pressure generated by the pump at zero flow while operating at the maximum rotational speed with the maximum suction pressure listed in the DS while using water at 60 °F. The pumps shall be designed to pump water without undue temperature strains being set up within the unit that may cause warping, buckling, misalignment, rubbing, or any other objectionable effect.

2.2 Sudden Water Temperature Changes: The pumps shall be designed to handle sudden changes in water temperature under all conditions of load and operate for extended periods on cold (ambient) water during start-up and cold starts without damage. The pumps shall be capable of operating in daily cycling mode, including load following and daily startups and shutdowns per Section GR-A.

2.3 Starting Condition: The pumps shall be allowed to start at cold (minimum ambient) condition, hot (water design temperature) condition, or at any temperature in between without time constraints, other than that required by the motor. No cool down period shall be required between starts. Seller’s design shall not preclude the pumps from starting in a condition wherein a temperature gradient may exist across the pump and/or rotor in any direction.

2.4 Piping: Seller’s design shall not require external piping connections to be routed by Others.

2.5 Working Range: The pumps shall be capable of continuous satisfactory operation during unit startup and at total heads and capacities ranging from minimum continuous stable flow (MCSF) to runout flow over the speed range from design speed to minimum speed (as defined by Seller, but no less than 2.5:1 turndown from design speed).

2.5.1 Runout Flow: The pumps shall be hydraulically capable of runout flows of either 125% of the curve-defining operating point, or 110% of the maximum flow case as defined in the DS. For variable speed pumps, the runout flow capability shall be tested at the pump speed that delivers the flow and head specified for the speed-defining case of those listed in the DS.

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Seller shall represent this additional runout hydraulic capability as a dashed continuation of the pump performance curve.

2.5.2 Recirculation Flow: At light loads and during boiler startup, a portion of the discharge feedwater shall be recirculated and returned to the Low Pressure Steam Drum through a controlled recirculation system (by Buyer).

2.5.2.1 Speed: Maximum pump operating speed (full speed) shall not exceed 5500 rpm. The suction specific speed shall be limited to nominally 10,000 (USGPM, ft) but no greater than 12,000 (USGPM, ft).

2.5.2.2 The minimum continuous thermal flow is defined as the lowest flow at which the pump can continuously operate without being impaired by the temperature rise of the pumped liquid. The minimum continuous stable flow shall be defined as the lowest flow at which the pump can continuously operate without exceeding the Seller's vibration limits or vibration limits imposed by the API standard, whichever are more restrictive.

2.6 Shutoff Head: Centrifugal pumps shall have a rising head/capacity characteristic from design point toward shutoff and the pump/motor combination shall be designed to be non-overloading. Rise to shutoff shall be a minimum of 120%. Based upon the class/rating of the discharge piping, the rise-to-shutoff should be nominally 125%, +/-5% of the curve-defining, rated condition.

2.7 Efficiency: The maximum efficiency point (BEP) for each pump shall occur near the guaranteed pump capacity point. For variable speed pumps, the Seller shall provide performance curves for each operating Case in the DS, both with the proposal and as a formal submittal.

2.8 Flashing: The pumps shall be designed to be capable of withstanding flashing at the suction for short durations. This condition may occur immediately after a full load trip of the HRSG. Pumps shall not be designed for repeated or sustained flashing.

2.9 Net Positive Suction Head: NPSH margin will be such that $NPSH_A$ multiplied by 0.68 will be greater than or equal to $NPSH_R$ at the pump design point. $NPSH_A$ multiplied by 0.77 will be greater than or equal to $NPSH_R$ at runout. The pumps shall be designed to have an $NPSH_R$ to result in a $NPSH_A/NPSH_R$ ratio no less than 1.46 at all other operating points.

2.10 Prime Mover: The pumps shall be driven by an induction electric motor and a variable speed fluid coupling. Motors shall meet the design and test criteria per Section E1 – Motors, Induction, Squirrel Cage Type. The primary drive motors shall be rated for 13.2 kV. Seller shall submit completed Motor Data Sheets from Section E1 with the proposal. Each fluid coupling shall undergo a manufacturer's standard no-load, factory performance test. Seller shall submit the fluid coupling test report. All motors shall be air cooled.

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2.10.1 Motors shall be sized for the runout flow conditions defined herein for the supplied impellers. The motor shall be designed to drive the pump and hydraulic coupling (if applicable) at the following conditions:

2.10.1.1 The pump skid will deliver the performance specified at each case in the DS and not exceed the motor rating with a 1.15 service factor. The motor shall be rated for the greatest of the following conditions: the maximum power required by the pump at the specified cases, 115% of the power required by each case condition other than maximum power case, or 5% larger than the runout horsepower. The motor rating sizing is to include:

a. The acceptance tolerances that may increase the pump power consumption.
b. At least 10% allowance shall be added to the maximum power case to account for pump wear.

2.11 Warm up: The pumps shall be designed to withstand (i.e. not result in high vibration due to differential heating of impellers, diffusers, shaft, and casing) a start at which the pump is initially at 40 °F and is immediately subjected to the feedwater temperatures listed in the DS without pre-warming the pump casing.

2.12 Design Similarity: All parts, including but not limited to the pumps, couplings, drivers, baseplate, etc. shall be duplicated in all respects and like parts utilized for interchangeability. Any skidded equipment shall conform to Sections M1 – General Mechanical Requirements and I2 – Instrumentation.

2.13 Drains: Seller shall provide suitable drain connection points to drain the pump when isolated at the suction, IP, and HP discharge nozzles.

2.14 Flushing: Feedwater piping will be chemically cleaned and flushed prior to initial boiler start-up, during which the pumps will be bypassed.

2.15 Suction Strainers: Buyer will provide in-line suction strainers with the recommended mesh installed for each pump. A 60 mesh screen and perforated plate shall be used for startup operation, whereas a 40 mesh screen and perforated plate shall be used for normal operation. Seller shall provide the recommended strainer mesh size for startup and normal operations if different from those listed above.

2.16 Arrangement: All pumps shall be installed on skids in positions convenient for operation and servicing per Section GR-C – Component Access. Each pump and its associated equipment shall be arranged in such a manner as to permit easy access for operation, maintenance, and pump removal. Load rated lifting eyebolts, with means for attachment or pad eyes, shall be provided to aid in handling heavy parts.

2.17 Pressure pulsations shall be designed to be below 3% of total pump head.

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3. CONSTRUCTION:

3.1 Case: Boiler feedwater pumps shall be of the type as described in the DS. Pump shall be furnished with casing wear rings. Pump shall be centerline supported to ensure alignment is maintained at elevated operating temperatures. The components shall be designed for high working pressures, defined as cold suction conditions at pump shutoff with maximum suction pressure. The centerline supports shall be integral to the suction/discharge heads and pump casing to transfer all nozzle loads directly to the baseplate.

3.1.1 Buyer connections shall be raised face flanges sized per ANSI. Ring-type joint (RTJ) flanges are not acceptable. All high-energy case connections, including but not limited to drains, vents, gages, and seal flushes, shall be seal welded or flanged. Threaded connections without seal welds are not allowed. All pumps shall be furnished with all necessary vents, drains, leak-offs and gauges. Ancillary pressure gauges on the Seller's skid that are not connected to high energy piping may be threaded per Seller's standard.

3.2 Seals: Seller's seal design may or may not be housed in a water-cooled jacket. Minimum and maximum cooling water temperatures for the seals and jacket, if applicable, are stated in Section GR-A. Seal piping shall be factory installed. If required, the seal piping arrangement shall be in accordance with API Standard 682, Plan 23 and the cooling water piping shall be in accordance with API Standard 610, Plans K or M**.** The plan shall include cooler seal flush and vent piping, a magnetic separator (if required in the DS), and temperature indicator at the cooler outlet, in addition to Seller's standard fittings for temperature and pressure. Mechanical seal materials shall be in accordance with the requirements in the DS.

3.2.1 Mechanical cartridge type seals shall be of the pressure balanced design and furnished complete with gland plate and shaft sleeve designed and machined to fit on the shaft. The seal shall be assembled on the shaft sleeve, and spring compression shall be adjustable before the seal cartridge is installed in the pump.

3.3 Mechanical Seal Flush Systems: If needed to supplement the seal cooling system specified herein, mechanical seal flush systems shall be required to provide cool, clean fluid for flushing the seal faces and pressurizing the stuffing boxes to provide the seal with the proper environment for a long seal life. The required seal piping configuration is specified elsewhere in this document.

3.4 Shaft: Pump shaft shall be of sufficient diameter to operate with low stress levels and shall have bearing spacing such that deflection is minimized over the entire operating range from MCSF to runout capacity. The shaft design shall incorporate a staggered keyway to transmit torque. The axial thrust shall be applied over a conservatively designed shoulder and split ring groove. All shoulders shall have generous fillet radii to reduce stress concentrations Pressure reducing sleeves or bushings shall be fastened to the shaft in a similar manner where appropriate. Shaft slingers shall be provided to prevent gland leakage water from entering the bearing housing. If necessary, labyrinth seals shall be provided to prevent contamination of the bearing housings.

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3.5 Stuffing Box: The stuffing boxes shall be designed to withstand maximum suction pressure and to accept mechanical seals. The seals shall be serviced without disturbing suction and discharge piping, tie rods, or main pump bundle. The stuffing box shall be sealed to the heads by means of a centering fit and ethylene propylene O-rings.

3.6 Impellers: The impellers shall be of the enclosed type with each impeller optimized for hydraulic performance. If required by Seller's design, each impeller shall be furnished with a wear ring. The impeller surface shall be inspected per Seller's quality standards before and after machining. The running clearance at both surfaces shall be per API or Seller's standard and shall have no less than a 58 BHN differential in intermediate surface hardness. All horizontal centrifugal pumps shall be dynamically and statically balanced to meet vibration limits of ANSI/HI 9.6.4. Hydraulic passages within the impellers shall have an as-cast finish. Impellers shall be stainless steel.

3.6.1 The impellers shall be sized on the shaft and held in place via stacked impeller arrangement. Impellers shall be assembled such that hydraulic and centrifugal forces tend to assure positive seating of the impeller. The impeller to shaft fit will be a clearance fit. The entire rotor assembly shall be dynamically balanced.

3.6.2 If the pump impellers and the impeller shaft are of different material, any portion of the impeller shaft that could be in contact with the fluid must be covered by a sleeve of the same material as used in the impeller construction. All materials shall be in accordance with the specified code where such exists, or with other recognized industry standards. Alternatively, shaft chrome-plating may be used in lieu of shaft sleeves.

3.6.3 The pumps shall be equipped with impellers sized smaller than the maximum allowable for the pump casing such that an additional 5 percent head can be achieved with replacement of a larger impeller.

3.7 Diffusers: The diffusers shall be precision cast or forged to optimize the surface finish and to provide sound, void-free castings. Diffusers on high-energy applications shall be shrouded to eliminate the possibility of vane breakage due to metal fatigue. Each diffuser shall be inspected per Seller's quality standards before and after machining and a visual inspection report shall be available upon request. All critical dimensions shall be checked, and non-destructive testing shall be performed as required per Seller's standard quality plan.

3.8 Rotor: The pumps shall be designed such that rotor dynamic stability is guaranteed during the operation of the conditions described in the DS. Each running fit on the rotor shall be checked to ensure proper clearance, concentricity, and minimum runout. Final rotating assembly shall be balanced to ISO 21940-11, G2.5.

3.8.1 The rotating assembly shall not have a critical speed within 25% of the pump operating speed. The rotating part of the pump shall be balanced statically and then dynamically at a speed below the first critical speed after its rated speed.

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3.9 Wear Rings and Sleeves: To ensure maximum reliability at the running fit, casing wear rings shall be employed to ensure the maintainability of the unit and allow renewable running clearances. The casing wear rings shall be assembled into the stage casings using a shrink fit. All circular parts such as rings and sleeves must meet stringent tolerances for concentricity and parallelism of surfaces.

3.10 Bearings: Bearings shall be oil lubricated. Double bearing design shall be used with bearings on either side of the impellers. Bearings shall be arranged to facilitate alignment and maintenance and to permit easy replacement. Provisions shall be made to prevent throwing of oil and to prevent contamination of the oil from moisture or dirt. Radial journal bearings shall be sleeve pressure or hydrodynamic type. Bearing housings shall be dust-resistant and shall prevent the entrance of water into the housing and leaking of lubricant along the shaft. Axial thrust shall be accommodated by a tilting-pad thrust bearing. Thrust bearings shall positively prevent contact of rotating and stationary pump parts in the axial direction.

3.10.1 Bearings with oil splash lubrication shall have their own reservoir and the means to deliver the oil to surfaces that require lubrication. An oil sight gauge shall be provided to indicate proper oil level in the reservoir.

3.11 Pump and skid mounted items are to be constructed so that bearings, seals and balance drum may be accessed without removing the pump.

3.12 Balance Device: Hydraulic balancing of the axial thrust generated by the impellers shall be accomplished using one of the following arrangements, as specified in the DS. The balancing device shall be treated stainless steel or alloy steel suitable for the service. The balancing device, in conjunction with the tilting pad thrust bearing, shall be designed to completely balance the thrust during the operating conditions described in the DS. The balancing device shall be sized conservatively to reduce stress levels in highly loaded areas. The clearance shall be self-compensating or be such that it can be easily renewed. The balancing device shall be such that it may be replaced or re-machined in the field without removing the suction or discharge piping, tie rods, or casing components.

3.12.1 Balance Disc: This device shall be provided with a titling pad thrust bearing that will separate the rotating balance disc from its stationary seat during pump startup and shutdown.

3.13 Balance Leak-Off Line: If a balancing line is required by design, Seller shall provide pressure reduction suitable for the required pressure and temperature. No Buyer connections shall be required for the balancing line.

3.14 Lubrication System: Seller shall provide a forced feed lubricating oil system to provide lubricating oil to the pump and motor bearings. The pressure oil lubrication system (used with sleeve radial and disk and plate thrust bearings) shall be furnished by the Seller. Interconnecting pipe shall be furnished as part of the lubrication system. Lubricating oil supply and return piping shall be stainless steel and shall not be less than 1/2 inch size. There shall be

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sufficient valves, instrumentation, controlling devices, and accessories to function under all operating loads, over the entire range of ambient temperatures, and with sufficient flanges to facilitate system maintenance and flushing. A low level switch shall be provided. Bearing lubricants shall contain a corrosion inhibitor. The type and grade of lubricant shall be indicated on a nameplate attachment to the motor frame or end shield adjacent to the lubricant-filling device. Refer to Specification E1 for information regarding a forced lubrication system. The lube oil system shall include the following components or functions:

3.14.1 Full-capacity electric type heater for the lube oil reservoir with all required controls including contactor to allow the pump and hydraulic coupling start permissives to be met, without Operator intervention of the cooling water system, at the lowest specified ambient temperature and lowest specified cooling water temperature.

3.14.2 Reservoir shall be sized per manufacturer's standard retention time. Fittings for side stream filtering / conditioning shall be provided on the reservoir. The reservoir shall be stainless steel, unless it is an integral part of a fluid coupling, in which case it shall be coated carbon steel. The reservoir shall be complete with all necessary appurtenances, including fill and drain connections and suitable vent. The reservoir shall have an oil level gauge.

3.14.3 Duplex filters with local differential pressure indication and high differential pressure alarm switches shall be provided.

3.14.4 A shaft-driven oil supply pump shall be provided. An A/C backup pump shall be provided in addition to supply all bearings from the common oil system.

3.14.5 Sight glasses shall be provided in each bearing drain line.

3.14.6 Flow at each bearing supply shall be controlled through fixed orifices or valves that can be locked in position after adjustment.

3.14.7 Oil cooler

3.14.8 Pressure relief valve

3.14.9 Pressure and temperature gauges at all locations that will permit monitoring performance of the system.

3.15 Connections: Connections shall be adequately sized and of the proper pressure class for the design conditions stated in the DS. Should Seller's design require multiple interstage tappings for the intermediate pressure takeoff, Seller shall manifold the connections to allow for a single piping connection point. All manifold branch connections shall be made with pipe fittings or include an adequately sized reinforcement pad per ASME B31.1. A connection for a pressure transmitter shall be provide at the first stage discharge and shall be used during the $NPSH_R$ test.

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3.16 Allowable Nozzle Loadings: The Suction IP and HP discharge connections shall be provided such that the simultaneous allowable nozzle loading due to external piping vectors shall be at minimum two (2) times the allowable reactions recommended by the latest edition of API 610 (Table 5). See Section M1 for additional minimum nozzle loading design considerations.

3.17 Baseplate: Seller shall furnish the Seller's standard baseplate to accommodate the pump, driver, coolers, bearing lubrication system and extend beyond the perimeter of all the equipment. The baseplate shall be of heavy rigid construction, allow for external forces to two (2) times API 610 latest revision requirements, and shall be made of suitable structural steel members to provide a stable platform for the pump, driver, and accessories.

3.17.1 The baseplate shall be suitably reinforced and braced to minimize deflection or bending during shipment and to allow setting of the baseplate without removal of the pump or hydraulic coupling (if applicable) from the baseplate. Open baseplate or sufficient grout holes (minimum 6-inch diameter) and grouting area vent holes in each section of the baseplate or each grout space shall be provided Seller shall advise anchor bolt sizes to be supplied by Buyer. Anchor bolt sizes shall be Standard English units.

3.17.2 The pump and fluid coupling shall be mounted on the baseplate and aligned in the factory prior to shipment. The pump and fluid coupling shall be mounted on the baseplate in the factory and shipped as a unit with temporary wood blocking to prevent any deformation of the baseplate during shipment and erection. The driver shall be shipped separately. The baseplate shall be provided with lifting lugs, horizontal alignment screws, and leveling screws to facilitate proper installation. Baseplate shall be rigid enough so that pumps and fluid couplings are delivered completely assembled and the baseplate will not deflect when lifted. The baseplate shall include provisions to contain 115% of the lubricant contained in the skid. The baseplate shall collect drainage and include a single point drain connection with a ball valve. The drip lip shall extend along the sides to a tapped drain connection located in the middle of the pump end of the base.

3.17.3 For Drivers with main terminal boxes that are unable to be supported by the driver frame, these terminal boxes will be mounted off the baseplate by Buyer, all required hardware to complete connections between driver and terminal box shall be provided by the Seller. Motors shall be installed after baseplate has been set. The feedwater pump and motor shall each be individually mounted such that they can be easily removed for a quick change out with the warehoused spare pump. Piping will be routed so that it does not interfere with this operation.

3.17.4 All large rotating equipment shall have accelerometers mounted to them for verification that equipment was not dropped, hit or otherwise damaged during shipping.

3.18 Coupling: Seller shall provide an all metal, flexible disk or diaphragm, non-lubricated spacer type coupling to suit operating speed, horsepower, and service requirements with a service factor of no less than 1.5 times the maximum torque. The flexible coupling, mounted on a cylindrical pump shaft extension, shall facilitate removal of the inboard bearing-

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housing assembly and cartridge mounted seal assembly for easy maintenance. Exposed coupling shall be covered with solid metal non-sparking guard rigidly supported from the baseplate. Coupling guards will have closed ends in accordance with OSHA requirements.

3.18.1 Motor Coupling Hub Option: Seller shall offer an option for shop-installation of motor coupling hubs before shipping to Site.

3.19 Cooling Water Piping: Seller shall provide single Buyer interface connections for cooling water supply and return. Seller is responsible for distributing cooling water to and from the seal coolers, lube oil cooler, and jacket cooling (if applicable). Flexible piping may be used for ease of fitting and to avoid imposing additional stresses on pump components. Piping with valves shall be assembled in the factory as completely as possible on the pump baseplate. Equipment interfacing directly with the closed cooling water system shall be rated for a design pressure of at least 150 psig. Aboveground cooling water piping shall be ASTM A106 Grade B or A53 Gr. B.

3.19.1 Piping shall be per Section M1. Where ANSI or ASTM standards are referenced, equivalent DIN and JIS standards shall also be acceptable.

3.20 Seller Experience: All manufacturer's standard devices, accessories, valves, controls and appurtenances shall be manufactured by suppliers experienced in the work. New, untried and/or prototype designs are not acceptable. The Seller may provide their standard valves, instruments, etc. for "on-skid" devices.

4. MATERIALS: Pump components shall be fabricated from materials as specified by API 610 Column C6 except as modified in the DS. Where materials are not specified, Seller's standard that is applicable to the service shall be acceptable with Buyer's approval. Where ANSI or ASTM standards are referenced, equivalent DIN or JIS standards shall also be acceptable.

5. SHOP APPLIED COATINGS: Unless otherwise specified, all pumps, skids, and non-corrosion resistant surfaces shall be provided with a factory installed protective coating per Section P1 – Shop Applied Coatings. The pump, coupling, lubrication system, driver, carbon steel piping and complete baseplate assembly shall be thoroughly cleaned and prepared for the application of paint coatings in strict accordance with the paint manufacturer's recommendations. Those surfaces not receiving paint coatings such as bearing surfaces, internal piping and connection surfaces, shall be adequately protected by removable tape or other means. Seller shall provide finish paint for touch-up painting at the project site. Seller shall provide the information needed for Buyer to procure the touchup paint locally.

6. SPECIAL TOOLS: One (1) set of new, unused special tools and devices, if required for operation and maintenance, shall be furnished and delivered with the Equipment in a separate container. All special tools and devices required for installation shall be furnished to Buyer.

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7. SPARE PARTS: Seller shall furnish with his proposal a complete list of recommended startup and operational spare, including pricing. The base bid shall include the supply of the following for each pump:

7.1 One (1) set of spare gaskets and O-rings.

7.2 One (1) mechanical seal repair kit.

7.3 One (1) spare set of oil filters for each skid.

8. TESTING: Seller shall include as part of his proposal a section that describes the shop tests to be conducted prior to shipment of pumps to the Job Site. Buyer shall have the opportunity to comment to the procedure when it is again submitted as required by the SDS.

8.1 Seller Shop Testing: Seller shall perform a witnessed performance test on one pump prior to shipment and shall perform unwitnessed performance tests on the balance of the pumps. Each pump shall be shop tested with either a shop motor or a job motor by the Contractor in accordance with the Hydraulic Institute 14.6 Acceptance Grade 1U, except total head shall be limited to +3%. Seller shall provide certified copies of all test reports and dynamic balance certificates for couplings in accordance with the SDS. Buyer shall be notified prior to shop tests in accordance with the SDS and shall have the option of witnessing the performance and NPSHr tests.

8.1.1 Vibration and sound levels shall be part of the tests.

8.1.2 Waterborne pressure pulsation tests data shall not exceed three percent of the pump's developed head per stage and shall be reviewed and approved by the Buyer. A pressure pulsation test shall be completed for each pump.

8.1.3 A minimum of ten test points shall be taken for IP and HP head, capacity, brake horsepower, and efficiency, all at full design speed and temperature as specified herein. Flows shall range from pump minimum flow to runout, but shall be not less than 25% beyond the design flow or 10% beyond the maximum flow case. With the tapping closed, one of the test points shall be at the specified head and capacity, another at the design minimum flow. Shop testing shall be performed with water at ambient temperature ("cold"). The plotted curves shall be corrected to the design conditions. Test data shall be approved by Buyer prior to shipment. Buyer shall be notified prior to shop tests in accordance with the SDS.

8.1.3.1 Performance: The following operating points shall be tested with the tapping open to demonstrate the expected tapping flow and head at the following conditions:

8.1.3.1.1 Pump design point (i.e. curve-defining case)

8.1.3.1.2 Pump guarantee point(s)

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8.1.3.1.3 Not Used.

8.1.4 NPSH test points shall be taken at the conditions and flow range stated above, except the water temperature shall not exceed 150°F for this test. NPSH required shall be measured at 4 test points, which is sufficient to establish the NPSH curve. The NPSHR test (based on head reduction percentage specified in the DS) shall be performed on one of the pumps at MCSF, design, and runout with cold water. For the $NPSH_R$ test, the 3% head loss shall be measured at the discharge.

8.1.5 Seller shall perform vibration tests to establish base line vibration signatures of each sensor under the conditions and flow range stated above.

8.1.6 Each pump shall be subjected to a hydrostatic test of at least 1-1/2 times the maximum pressure at rated speed or 1-1/4 times the maximum expected shutoff discharge pressure of the largest diameter impeller that the pump casing can accommodate, whichever is greater (per the HI standard), but not less than 50 psig. Zero leakage shall be demonstrated for a period of 30 minutes. Test(s) shall follow Hydraulic Institute requirements.

8.1.6.1 Mechanical seal shall not be used during hydrostatic test. Water to be used for hydrostatic test must have a maximum chlorides content of 50 ppm. Pumps must be cleaned and dried after hydrostatic test.

8.1.6.2 Test will be acceptable if there is not any leak at welding joints and flanged connections.

8.1.6.3 If hydrostatic test is not acceptable, supplier must make suitable repairs. After correction hydrostatic test must be repeated.

8.1.7 As-Tested Head-Capacity Curve:

8.1.7.1 The curve shall be stable, steadily rising from the design point to shutoff.

8.1.8 As-Tested Horsepower Curve:

8.1.8.1 Design point horsepower shall not be exceeded at any point from zero capacity to design capacity.

8.1.8.2 The curve shall have values not exceeding the corresponding design curve values in the runout area. As an alternative, so as to cover overshoot of head, the design curve may indicate a maximum horsepower at design and a maximum horsepower at runout.

8.1.9 As-Tested NPSH Curve: As-tested NPSH curves shall align with the Seller's standard curve format and shall align with the following criteria to the greatest extent practical:

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8.1.9.1 Shall have values less than the design NPSH at all capacities below design capacity.

8.1.9.2 Shall have values not exceeding the corresponding design values in the runout area.

8.1.9.3 Shall state the test conditions of speed and water temperature and basis of the test curve, i.e., 3% head loss across the first stage at the "break-away" points.

8.1.9.4 The as-tested first stage suction specific speed shall not exceed the design value.

8.1.9.5 If the test curves are rejected based upon deviations from the above requirements, it is understood that all corrective measures are to be at Sellers's expense.

8.1.10 Efficiencies and brake horsepower shall be determined preferably by use of a calibrated torque-measuring device. Alternately, a motor furnished for the pumps can be used for the shop tests if the motor performance has been tested and certified by the manufacturer and witnessed by Buyer.

8.1.11 If a certified motor is used to determine pump efficiency and brake horsepower, the tolerances of the electrical instruments used on the pump tests shall be factored into the test readings so that the calculated power input at the pump coupling would be the maximum expected values.

8.1.12 Vibration shall be tested in the radial direction, in two orthogonal positions at each radial bearing and in the axial direction at the thrust bearing. Values shall not exceed the required limits, at the guaranteed rated flow and operating speed. A vibration measurement at all test points from MCSF to runout flow shall be included for each bearing in both the x and y directions. One set of vibration readings (two readings, 90° apart) and an axial position reading shall be taken on each pump bearing housing during shop testing and the results provided to Buyer.

8.1.13 Post-Test Inspection: Buyer may witness a post-test inspection (PTI) to verify all surfaces and fits are within design tolerance. Any damage or deviation will require repair and re-test.

9. PERFORMANCE GUARANTEES: The pumps shall be guaranteed to deliver at least the specified flow at the specified head for all conditions listed in the DS. Seller shall guarantee the pumps will operate over the entire specified range including minimum stable continuous flow without excessive noise, cavitation, vibration, or pitting. The pumps shall be guaranteed to operate satisfactorily either individually or in parallel or when taking one (1) pump out of service or bringing on one (1) stand-by pump while the other pump is in service.

9.1 Values and Tolerances: Seller shall guarantee the pump's HP and IP total dynamic head, efficiency and motor input power consumption (kW) at the HP and IP guarantee flow rates

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in the Guaranteed Case(s). Pump performance shall be per Hydraulic Institute-14.6 tolerances, acceptance grade 1U, except total head shall be limited to +3%. Motor efficiency shall be per IEEE standards. Pumps shall be capable of delivering their rated capacity at efficiency of no less than 50%, or where applicable, NEMA MG1 efficiencies shall apply.

9.2 Seller Obligations: The pumps will be tested in the field during Plant performance testing to verify their performance. Failure of the pumps to meet the guaranteed performance on flow rate and TDH shall result in a "make good" obligation on the Seller to correct pump deficiencies that prevent this guarantee from being met. Failure of the pumps to meet the guaranteed performance for kW shall result in liquidated damages as defined in the Agreement.

10. NOISE LIMITATIONS: Noise levels shall be per Section GR-A and the DS. Seller shall provide appropriate acoustical treatment for installation by Buyer.

11. INSTRUMENTATION: Seller shall provide the required instrumentation to monitor operating and alarm conditions of the pump, including bearing temperature and vibration sensors, and vibration detecting equipment. As a minimum, each pump shall be furnished with the following instrumentation as specified elsewhere in these Specifications. Seller shall provide a drawing depicting mounting location of each instrument. See Sections E1, E2 – Seller Furnished Controls and Wiring and Section I2 – General Instrumentation Requirements for more details. Feedwater pumps shall have monitoring equipment per API 670 (instruments provided by Seller; vibration monitoring system provided by the Buyer). Minimum requirements are as follows:

11.1 Two (2) dual element Type K thermocouples, one (1) in each pump radial bearing.

11.2 Two (2) dual element Type K thermocouples, one (1) each on inboard and outboard sides of thrust bearing.

11.3 Two (2) pressure gauges; one (1) to monitor IP discharge pressure, and one (1) to monitor HP discharge pressure. Gauges shall be provided with pulsation dampening as needed. Gauges shall be provided with dual isolation valves. Pressure gauges shall be provided with diaphragm seals for freeze protection at site low ambient temperature listed in Section GR-A.

11.4 Cooling water return-side sight flow indicator on each cooler outlet.

11.5 Seal flush supply-side temperature gauges.

11.6 Motor RTD and Thermocouple requirements as specified in Section E1.

11.7 Lube oil return-side sight flow indicators for each pump and motor bearing.

11.8 Not Used.

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11.9 Lube oil inlet and outlet temperature gauges for lube oil cooler.

11.10 Lube oil filter differential pressure indicating transmitter.

11.11 Lube oil supply-side pressure indicating transmitter located downstream of filter and cooler.

11.12 Lube oil supply side Type K thermocouple located downstream of cooler.

11.13 Oil sump Type K thermocouple

11.14 Oil sump temperature gauge

11.15 Working oil inlet and outlet temperature gauges for working oil cooler.

11.16 Two (2) working oil Type K thermocouples, one each located upstream and downstream of cooler.

11.17 Speed sensors mounted on pump and motor.

12. VIBRATION MONITORING SYSTEM: The vibration probes/sensors shall be per Sections E1 and E2, and any additional requirements below. Seller-provided vibration probes shall be compatible with Bently Nevada's Orbit 60 system.

12.1 Vibration Equipment: The vibration probe/sensor power and control signals shall be wired to a junction box containing separate terminal blocks for the power and control leads. Each pump and motor radial bearing shall be provided with XY proximity probes. The thrust bearing for each pump shall be provided with two axial proximity probes. For hydraulically coupled pumps and motors, two key phasors shall be provided; one for the motor and one for the pump. Hydraulic couplings shall be provided with coupling housing vibration velocity contact probe; one near the input shaft bearing and one near the output shaft bearing. The shafts shall be burnished in the area where proximity probes are used. Each vibration probe measurement shall be transmitted via unconditioned 4-20 mA signal to Buyer's DCS. Speed monitoring modules shall be shipped loose and shall be mounted outside the skid frame.

12.2 Vibration Acceptance: The ISO 10816-7 vibration criteria shall be met with the pump operating within the preferred operating range of 70-120% of the best efficiency point. Seller shall advise vibration alarm and trip set points. Refer to the DS for additional vibration information.

12.3 Vibration Interference: Vibration equipment supplied shall include sufficient radio frequency shielding to eliminate radio frequency interference from a keyed communication radio within two feet of the vibration sensor.

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13. INSULATION AND LAGGING: Seller shall provide Blanket type insulation for the pump ring sections and all other exposed surfaces, including oil piping, for personnel protection. Sufficient insulation shall be installed to maintain a maximum surface temperature as specified in the DS at all plant operating points and ambient conditions. The blankets shall require minimal effort to remove for maintenance access. Pump shall be fitted with a suitable heavy-duty lagging, lined with high quality insulating material. Insulation coverings containing polyvinyl chloride or polyurethane compounds shall not be allowed. In general, for equipment and process piping above 140°F Mineral Wool, or approved equal shall be used.

END OF SECTION

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