SECTION 11175 - PUMPS, GENERAL

PART 1 -- GENERAL

1.1 WORK OF THIS SECTION

A. The WORK of this Section includes providing general requirements for pumps and pumping appurtenances and providing special tools and spare parts.

B. The WORK also includes coordination of design, assembly, testing and installation.

C. The WORK of this Section applies to the WORK of the following Sections:

1. Section 11176 Submersible Non-Clog Pumps
2. Section 11177 Vertical Sump Pumps
3. Section 11178 Vertical Fiberglass Pumps
4. Section 11191 Chemical Pumps, Metal Body
5. Section 11192 Chemical Pumps, Plastic Body
6. Section 11194 Diaphragm Pumps
7. Section 11195 Drum Pumps
8. Section 11197 Horizontal End-Suction Pumps
9. Section 11198 Horizontal Non-Clog Pumps
10. Section 11199 Horizontal Recessed Impeller Pumps
11. Section 11200 Horizontal Split Case Pumps
12. Section 11201 Hot Water Circulating Pumps
13. Section 11204 Progressive Cavity Pumps
14. Section 11206 Regenerative Turbine Pumps
15. Section 11209 Submersible Sump Pumps (Less Than 10 HP)
16. Section 11212 Vertical Non-Clog Pumps
17. Section 11214 Vertical Turbine Pumps
18. Section 11215 Rotary Lobe Pumps
19. Section 11216 Axial Flow Pumps
20. Section 11217 High Pressure Piston Membrane Pumps
21. Section 11218 Non-Clog Vertical Column Solids Handling Pumps
22. Section 11219 Custom Engineered Vertical Variable-Speed Non-Clog Pumps
23. Section 11221 Custom Engineered Horizontal Variable-Speed Non-Clog Pumps
24. Section 11223 Horizontal Chopper Pumps
25. Section 11224 Recirculating Chopper Pumps

1.2 RELATED SECTIONS

A. The WORK of the following Sections applies to the WORK of this Section. Other Sections of the Specifications, not referenced below, shall also apply to the extent required for proper performance of this WORK.

1. Section 11000 Equipment, General Provisions
2. Section 11002 Equipment Supports, Grouting and Installation

3. Section 11005 Machine Alignment
4. Section 11020 Vibration and Critical Speed Limitations

1.3 SPECIFICATIONS AND STANDARDS

A. Specifications and standards shall comply with Section 11000 and shall include the following:

1.	AISC Manual of Steel Construction	American Institute of Steel Construction, Manual of Steel Construction, Allowable Stress Design - 9th Edition
2.	AISI 1045 Steel	
3.	ANSI/ASME B73.1	Specifications for Horizontal End Suction Centrifugal Pumps for Chemical Process
4.	ANSI/ASME B73.2	Specifications for Vertical In-Line Centrifugal Pumps for Chemical Process
5.	ANSI/AWWA E101	Deep Well Vertical Turbine Pumps - Line Shaft and Submersible Types
6.	ANSI/HI 1.1-1.6	Centrifugal Pumps
7.	ANSI/HI 2.1-2.6	Vertical Pumps
8.	ANSI/HI 3.1-3.6	Rotary Pumps
9.	ANSI/HI 6.1-6.6	Reciprocating Pumps
10.	ANSI/HI 7.1-7.5	Controlled Volume Pumps
11.	ANSI/HI 9.1-9.5	Pumps - General Guidelines
12.	ANSI/HI 9.3.3	Pumps - Polymer Material Selection
13.	ANSI/HI 9.6.1	Centrifugal and Vertical Pumps for NPSH Margin
14.	ANSI/HI 9.6.3	Centrifugal/Vertical Pumps Allowable Operating Region
15.	ANSI/HI 9.6.4	Centrifugal and Vertical Pumps. Vibration Measurements and Allowable Values.
16.	ANSI/HI 9.8	Pump Intake Design Standard
17.	ANSI/IEEE 112	Test Procedure for Polyphase Induction Motors and Generators
18.	ANSI/IEEE 115	Test Procedure for Synchronous Machines
19.	API 610, 1995	Centrifugal Pumps for Petroleum, Heavy Duty Chemical and Gas Industry Services
20.	ASME Code	ASME Boiler and Pressure Vessel Code

21.	ASTM A 53	Pipe, Steel, Black and Hot-Dipped Zinc Coated, Welded and Seamless
22.	ASTM A128	Steel Castings, Austenitic Manganese
23.	ASTM A 216	Specification for Steel Castings, Carbon Suitable for Fusion Welding for High-Temperature Service
24.	ASTM A217	Steel Castings, Austenitic and Martensitic Stainless and Alloy
25.	ASTM A 276	Stainless and Heat-Resisting Steel Bars and Shapes
26.	ASTM A 278	Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650° F (345°C)
27.	ASTM A 283	Low and Intermediate Tensile Strength Carbon Steel Plates
28.	ASTM A 322	Specification for Steel Bars, Alloy, Standard Grades
29.	ASTM A 395	Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures
30.	ASTM A 470	Specification for Vacuum-Treated Carbon and Alloy Forgings for Turbine Rotors and Shafts
31.	ASTM A 536	Specification for Ductile Iron Castings
32.	ASTM A 571	Austenitic Ductile Iron Castings for Pressure-Containing Parts Suitable for Low Temperature Service
33.	ASTM A 576	Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
34.	ASTM A 743	Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, and Nickel-Base Corrosion-Resistant for General Application
35.	ASTM A 744	Castings, Iron Chromium-Nickel, Corrosion Resistant, for Severe Service
36.	ASTM B 62	Specification for Composition Bronze or Ounce Metal Castings
37.	ASTM B 148	Aluminum Bronze Sand Castings
38.	ASTM B 505	Copper-Base Alloy Continuous Castings
39.	ASTM B 584	Copper Alloy Sand Castings for General Applications
40.	ASTM E 448	Recommended Practices for Scleroscope Hardness Testing of Metallic Materials
41.	AWS-B3.0	Welding Procedures and Performance Qualifications
42.	AWS-Dl.1	Structural Welding Code--Steel

43.	Hydraulic Institute Standards	(See applicable ANSI/HI Standard)
44.	ISO 9001	Quality Systems
45.	ISO 10816	Mechanical Vibration--Evaluation of Machine Vibration by Measurement on Non-rotating Parts--Part 1: General Guidelines, Annex B, Table B.1. Zone A, Class I, II or III, as applicable. For the purposes of this specification, Annex B of ISO 10816, Part 1 shall form a part of this specification and ISO 10816, Part 1.
46.	NEMA MG1	Motors and Generators
47.	UL 674	Motors and Generators, Electric, for Use in Hazardous Locations, Class 1, Groups C and D, Class II, Groups E, F and G

1.4 SHOP DRAWINGS AND SAMPLES

A. In addition to the requirements of Section 11000 and the material listed in the detailed specification, the following shall be submitted in compliance with Section 01300:

1. At least one successfully operating installation of comparable size and complexity (including no cavitation, damaging vibration or shaft damage within the first three years of operation) designed and installed in the recent past by the proposed pump manufacturer, with address and telephone numbers.

2. A Certificate of Unit Responsibility Assignment signed by officers of both the CONTRACTOR and the pump manufacturer corporations, attesting to the assignment of responsibility in accordance with these Contract Documents. ***No other submittal material will be reviewed until the certificate has been received and found to be in conformance with these requirements.***

3. A copy of this specification section and the referencing section and all other applicable specification sections governing the pump, drive and motor, supports and specified appurtenances. The specification copies shall be complete with addendum updates included, with each paragraph check-marked to indicate specification compliance or marked to indicate requested deviations from specification requirements. Check marks (✔) shall denote full compliance with a paragraph as a whole. If deviations from the specifications are indicated and, therefore requested by the CONTRACTOR, each deviation shall be underlined and denoted by a number in the margin to the right of the identified paragraph. The remaining portions of the paragraph not underlined will signify compliance on the part of the CONTRACTOR with the specifications. The submittal shall be accompanied by a detailed, written justification for each deviation. ***Failure to include a copy of the marked-up specification sections, along with justification(s) for any requested deviations to the specification requirements, with the submittal shall be sufficient cause for rejection of the entire submittal with no further consideration.***

4. A copy of the contract document control diagrams and process and instrumentation diagrams relating to the submitted equipment, with addendum updates that apply to the equipment in this section, marked to show specific changes necessary for the equipment proposed in the submittal**.** If no changes are required, the drawing or drawings shall be marked *"**no changes required**"*. ***Failure to include copies of the relevant drawings with the submittal shall be cause for rejection of the entire submittal with no further review***

5. Documentation of certification in accordance with ISO 9001 as specified under paragraph 11175-2.1A.

6. Predicted pump performance curves for each condition point specified showing head, power, efficiency, and NPSH required on the ordinate plotted against capacity (in mgd) on the abscissa. Pump inlet, bowl, column and discharge head losses for column pumps shall be shown as separate curves. Curves for variable speed pumps shall be provided at 100-rpm intervals between the minimum and maximum speeds required to achieve the specified operating conditions. Manufacturer's recommended operating range for stable operation and prevention of surge, cavitation and vibration. Under no circumstances shall the manufacturer's recommended operating range be less than that required to meet the pump operating conditions specified.

7. NPSHR margin calculations performed in accordance with paragraph 11175-1.9G.2 or 3 as applicable and including the information required under paragraph 11175-1.9G.1.

8. Motor submittal information as specified in paragraph 16040-1.5. In addition, this information shall include certified calculations for motor rotor and frame reed frequencies, as specified under paragraph 11175-1.9H.

9. Complete description and sketch of proposed test setup for factory test if a factory test is required by the terms of these specifications, at least 10 weeks in advance of the proposed test date. Submittal material shall include sample calculations and proposed test log format. Submittal shall be in accordance with paragraph 11175-1.7C.6.

10. Information required under Section 11020.

11. Drawings showing general dimensions and confirming the size of pumps, motors, drives, flywheels (if required), and specified appurtenances; piping connections; construction details of equipment; wiring diagrams; and weight of equipment.

12. Variable-speed drive information as required under Sections 11030 and [11033] if the equipment specified includes variable speed capability.

13. Drive unit support calculations and data if the drive is separately supported and if the analysis under the requirements of paragraph 11175-1.10 is required by the terms of these specifications.

14. Qualifications of the design professional performing the mass elastic design analyses specified under paragraph 11175-1.10 if the subject analysis is required by the terms of these specifications.

15. Critical speed calculations and mass elastic systems analyses for pumps as specified in paragraphs 11175-1.9C or 11175-1.10, if the subject analyses are required by the terms of these specifications.

16. Manufacturer's design and calculations for intermediate shafting, if intermediate shafting is required. Show shaft lengths, location of bearing supports, and shaft critical speed.

17. Shaft deflection calculations to demonstrate compliance with paragraph 11175-1.10 if shaft deflection calculations are required by the terms of these specifications.

18. Calculations justifying the dimensions of flywheels, if flywheels are required.

19. Details of the pump and drive unit foundation, including type, size, number, and arrangement of anchor bolts, dimensional drawings of the sole and base-plates, and all other information required under Section 11002.

20. If factory tests are required by the terms of these specifications, certification of satisfactory testing of each unit as specified. The certified material shall include copies of test logs and resulting performance curves at least four weeks prior to shipping the units from the factory. Manufacturer's reports on hydrostatic tests, including calibration test results on all instruments used to conduct the factory hydrostatic and performance tests.

21. Results of motor rotor, frame and assembly bump tests, certified as specified under paragraph 11175-1.9H, along with the design professional's supplementary report as specified under paragraph 11175-1.10B.

22. Vibration measurement results as specified in paragraph 11175-3.5.

1.5 OWNER'S MANUAL

A. In addition to the requirements of Section 11000, the following shall be included in the OWNER'S MANUAL submittal in compliance with Section 01300:

1. Manufacturer's written guarantee that pumping equipment operates with efficiencies, heads and flow ranges indicated and meets vibration and critical speed limitations indicated.

2. Drive unit support calculations and data if the drive is separately supported and if the analysis under the requirements of paragraph 11175-1.10 is required by the terms of these specifications.

3. Critical speed calculations and mass elastic systems analyses for pumps as specified in paragraphs 11175-1.9C or 11175-1.10, if the subject analyses are required by the terms of these specifications.

4. Shaft deflection calculations to demonstrate compliance with paragraph 11175-1.10 if shaft deflection calculations are required by the terms of these specifications.

5. Calculations justifying the dimensions of flywheels, if flywheels are required.

6. Performance guarantee as specified in paragraph 11175-1.7C if a Performance Guarantee has been specified.

7. Balance logs for pumps with nozzles sizes 6 inches in diameter and greater, certified, signed and notarized in accordance with paragraph 11175-2.7.

8. If factory tests are required by the terms of these specifications, certified copies of test logs and resulting performance curves. Manufacturer's reports on hydrostatic tests, including calibration test results on all instruments used to conduct the factory hydrostatic and performance tests.

9. Vibration measurement results as specified in paragraph 11175-3.5.

NTS: The paragraph, "Services of Manufacturer," has been included in the detailed pump specifications only where the size, complexity, and number of pumps would most likely warrant such a requirement. However, the DESIGN CONSULTANT should review each specific case and decide about the inclusion or exclusion of this requirement.

1.6 SERVICES OF MANUFACTURER

A. Services of manufacturer shall be provided in accordance with Section 11000, this Section, and the detailed pump specifications.

1.7 FACTORY TESTING

A. The CONTRACTOR shall be responsible for all costs associated with inspection and testing of materials, products, or equipment at the place of manufacture. This shall include costs for travel, meals, lodging, and car rental for [two] OWNER-designated inspectors for the number of days indicated to complete such inspections or observations, if the place of manufacture, fabrication and factory testing is more than fifty (50) miles outside the geographical limit of the City. The CONTRACTOR shall not be responsible for salary or salary-related costs of the inspectors. The CONTRACTOR shall comply with the requirements of Section 01400.

B. **Performance Curves:** Centrifugal pumps shall have a continuously rising curve toward the shut-off head and in no case shall the required horsepower at any point on the performance curve exceed the rated horsepower of the motor or engine. The allowable operating region for all centrifugal and axial flow pumps shall comply with the requirements of paragraph 11175-1.9.

C. **Performance Confirmation:** Pumps, drives, and motors shall be factory-tested to confirm specified requirements in accordance with the applicable ANSI/HI Pump Standards Test Code for Centrifugal, Vertical, Rotary, and Reciprocating Pumps, and test data shall be recorded. Tests shall be performed on all pumps and motors of sizes 25 horsepower and larger. Prototype model tests will not be acceptable.

1. Test data shall include the following:
   Hydrostatic test results

   Hydraulic test results with, unless otherwise specified, a minimum of 10 readings between shutoff head and 25 percent above design capacity.
   Certified pump curves showing head/flow, horsepower, efficiency and NPSHR curves.
   Certification that the pump horsepower demand will not exceed the rated motor horsepower beyond a 1.0 service rating at any point on the curve.

   Motor test results

   NPSH margin test results, if NPSH margin tests are required

2. Factory Tests of Motors: All pump motors of sizes 25 horsepower and larger, shall be assembled, tested, and certified at the factory and the working clearances checked to insure that all parts are properly fitted. The tests shall comply with ANSI/IEEE 112 and ANSI/IEEE 115 standards, including heat, running and efficiency tests.

3. Hydrostatic Tests: All pressure sustaining parts shall be subjected to factory hydrostatic tests. Hydrostatic tests for centrifugal and axial flow pumps shall conform to the requirements of API 610.

4. Performance Guarantee: Unless specified otherwise, pump performance, including NPSHR for centrifugal and axial flow pumps, shall be guaranteed by the pump manufacturer to the most restrictive tolerances set forth in the applicable ANSI/HI Standard. The guarantee shall be in writing, shall be signed by an officer of the manufacturing corporation and shall be notarized. Under no circumstances shall deviations from specified operating conditions, though allowed by the referenced standards, result in overload of the driver furnished with the equipment, nor shall such deviations result in power requirements greater than the driver's nameplate rating.

NTS: The DESIGN CONSULTANT shall verify with MWWD the minimum size pump for which the factory tests will be witnessed.

5. Factory Witnessed Tests: Unless otherwise specified, pumps, variable speed drives (if any), and motors, for pumping units [150] horsepower and larger, shall be factory tested as complete, assembled units and witnessed by a representative of the CONSTRUCTION MANAGER and of the OWNER.

6. The CONTRACTOR shall submit a sketch of the proposed witnessed test setup, along with a description of the proposed testing procedure to the CONSTRUCTION MANAGER for acceptance at least 10 weeks in advance of the proposed test date. No tests shall be performed until the test procedure meets with the CONSTRUCTION MANAGER'S approval. In addition, the CONTRACTOR shall furnish the CONSTRUCTION MANAGER with at least 4 weeks advance written notice of the date and location of the witnessed performance tests.
7. Witnessed Tests: Witnessed pump performance tests shall be in accordance with the applicable ANSI/HI test standard. NPSHR tests shall also be performed for centrifugal and axial flow pumps to confirm the data used to establish NPSHA margin as specified in paragraph 11175-1.9G. NPSHR tests for column type (axial flow and vertical turbine) pumps shall be performed using the method described for Figure 2.6.3 or Figure 2.6.4 in ANSI/HI 2.6. All NPSHR tests shall extend from 10 percent to 120 percent of Best Efficiency Flow at full speed, or to not less than 10 percent (in terms of flow) past the flow at Operating Condition B, whichever is greater. Not less than ten data points shall be developed during the test. Failure to achieve guaranteed performance (capacity and head, efficiency or NPSHR) shall be cause for rejection. Tolerances shall be the most restrictive set forth in the applicable standard. All test procedures shall be in strict conformance with the referenced standards, except prediction of performance of a trimmed impeller from test data of the larger impeller will not be permitted. If trimming is required, the pump shall be retested. Under no circumstances shall deviations from specified operating conditions, though allowed by the referenced standards, result in overload of the driver furnished with the equipment, nor shall such deviations result in power requirements greater than the driver's nameplate rating.

8. Non-Witnessed Tests: Where non-witnessed tests are permitted, centrifugal and axial flow pumps shall be tested in accordance with ANSI/HI 1.6 or 2.6, as applicable. Not less than ten data points shall be developed during the test. NPSHR tests shall also be performed to confirm the data used to establish NPSHA margin as specified in paragraph 11175-1.9G. NPSHR tests for column type (axial flow and vertical turbine) pumps shall be performed using the method

described for Figure 2.6.3 or Figure 2.6.4 in ANSI/HI 2.6. All NPSHR tests shall extend from 10 percent to 120 percent of Best Efficiency Flow at full speed, or to not less than 10 percent (in terms of flow) past the flow at Operating Condition B, whichever is greater. Failure to achieve guaranteed performance (capacity and head, efficiency or NPSHR) shall be cause for rejection. Tolerances and restrictions shall be as set forth above for witnessed tests. The CONTRACTOR shall furnish the CONSTRUCTION MANAGER with not less than two weeks' advance written notice of the date and place of the non-witnessed tests.

9. In the event of failure of any pump to meet any of the specified requirements or efficiencies, the CONTRACTOR shall make all necessary modifications, repairs, or replacements to conform to the requirements of the Contract Documents and such pump shall be retested at no additional cost to the OWNER, until found satisfactory.

10. All test results (data sheets, test logs and generated performance curves) shall be signed and certified correct by an officer of the manufacturing corporation and shall be notarized.

11. Upon completion of testing, curves shall be produced showing pump performance (head, efficiency, NPSHR (if applicable), and power required versus capacity) at full speed and predicted performance at speeds required to meet all other indicated operating conditions. The test results shall be certified and notarized as noted above and submitted to the CONSTRUCTION MANAGER. The pumps shall not be shipped until authorized, in writing, by the CONSTRUCTION MANAGER. Final acceptance of the equipment will depend on satisfactory operation after installation.

1.8 FIELD TESTS

A. All pumping units shall be field tested after installation to demonstrate proper operation, without excessive noise, vibration, cavitation, and overheating of bearings. The field testing shall be performed in the presence of an experienced field representative of the manufacturer of the equipment, who shall certify in writing that the equipment and controls have been properly installed, aligned, lubricated, adjusted, and readied for operation and shall witness the following:

1. Startup, checking, and operation of the equipment over the entire speed range. For pumps smaller than [50] horsepower without variable speed drives, the vibration shall be within the limits specified in Section 11020 and the vibration shall be recorded at a minimum of 4 pumping conditions which have been reviewed by the CONSTRUCTION MANAGER. Vibration requirements for pumps [50] horsepower and larger and all pumps with variable speed drives are specified in paragraph 11175-3.5.

2. Pump performance shall be documented by obtaining concurrent readings, showing motor voltage, amperage, pump suction head, and pump discharge head, for at least 4 pumping conditions at the respective pump rpm. Each power lead to the motor shall be checked for proper current balance.

3. Determination of bearing temperatures by a contact-type thermometer. A running time of at least 20 minutes shall be maintained for this test, unless liquid volume available is insufficient for a complete test.

4. Ensure that electrical and instrumentation testing complies with Sections 13300 and Division 16 Sections.

Additional field testing requirements are specified in Section 11000, Part 1, and may be specified in

the individual equipment specifications.

1.9 DESIGN REQUIREMENTS FOR CENTRIFUGAL AND AXIAL FLOW PUMPING EQUIPMENT

A. **General:** Provisions and requirements contained in this paragraph (1.9) apply specifically to centrifugal and axial flow pumps, both vertical and horizontal, commonly falling into the generic types covered by ANSI/HI 1.1 through 1.6 and 2.1 through 2.6. More restrictive requirements, where found in individual pump specifications, shall supercede requirements of this paragraph. This paragraph does not apply, except by specific reference, to positive displacement pumps of any type.

Centrifugal and axial flow pumping equipment shall conform to the requirements of paragraph 2.1.1, API 610. All components in the rotating elements in the drive train, including equipment supports and supports for rotating elements, shall be selected and designed to function without damage or disassembly at reverse rotational speeds up to 150 percent of maximum operational speed during flow reversals through the pump. The complete pumping unit shall operate without overload on any component at any point along the pump's entire full-speed operating curve. Pumps required by virtue of the specified operating conditions to operate against a closed or throttled valve for any period of time exceeding five seconds, shall be furnished with drivers sized to operate continuously at the power requirement for that condition even though the power requirements at the rated condition may be less.

B. **Pump Selection:** Pumps shall be selected to place all specified continuous duty operating conditions within the manufacturer's Allowable Operating Range as defined in ANSI/HI 9.6.3. Unless otherwise specified in individual pump specifications, rated conditions and all other continuous duty full speed operating conditions specified in the detailed pump specifications shall fall within the manufacturer's Preferred Operating Range as defined in ANSI/HI 9.6.3. The Preferred Operating Range shall be not less than that specified in paragraph 2.1.12, API 610. Proposed pump selections shall be selected to allow not less than a five percent increase in head, as specified in paragraph 2.1.4 of API 610. Variable speed operation to achieve this objective will not be considered. Pump selections proposing maximum diameter impellers for the proposed pump model and casing size will not be accepted. Pumping equipment shall be suitable for the operating modes described in the detailed pump specifications and other relevant portions of the Contract Documents.

All pumps shall be designed in accordance with applicable portions of ANSI/HI 1.1 – 1.6, 2.1 – 2.6 and ANSI/HI 9.1 – 9.6 and the requirements of this Section. The pumps shall be specifically designed to pump the fluids described in the detailed pump specifications and shall operate without clogging or fouling caused by material in the pumped fluid at any operating condition within the range of service specified.

The pumps shall operate without cavitation or damaging vibration over the entire specified range of flow and head conditions and shall be specifically selected for NPSHR characteristics conforming to the requirements of paragraph 11175-1.9G.

Unless otherwise indicated, the pump head capacity curves shall slope in one continuous curve within the specified operating conditions. No points of reverse slope inflection capable of causing unstable operation will be permitted within the specified zone of continuous duty operation. Pumps with head/capacity curves as described in paragraph 9.6.3.3.12 of ANSI/HI 9.6.3 are specifically prohibited if these characteristics will cause unstable operation within the specified range of operating conditions and where startup/shutdown conditions entail operation against a slow opening/closing valve.

C. **Critical Speeds and Natural Frequencies:** Unless otherwise specified for variable speed pumping equipment or for custom engineered pumping equipment, the complete pumping unit, including all

related frames, supports, enclosures, and casings, shall be free from dangerous critical speeds from 20 percent below to 30 percent above the operating speeds required to achieve the performance characteristics specified.

The logarithmic decrement for each damped natural frequency within this range shall be greater than +0.3.

Unless otherwise specified, the CONTRACTOR shall furnish documentation under paragraph 11175-1.4 demonstrating compliance with this requirement for all pumping equipment with discharge nozzle sizes 6 inches in diameter and greater.

D. **Impeller Clearances and Keyways:** The radial clearance between the tip of the impeller vane and diffuser or volute vanes shall be not less than 3 percent and 6 percent, respectively, of impeller diameter. The ratio of liquid channel widths (diffuser or volute/impeller) shall be not less than 1.15 nor more than 1.3 for diffuser pumps and 1.4 – 1.5 for volute-type pumps.

Impeller keyways for multistage diffuser-type pumps shall be cut at differing positions on the impeller shaft to avoid multiple simultaneous vane passing pulses.

E. **Component Design Criteria:**

1. **General:** Unless otherwise indicated, combined stresses in steel frames and supports shall not exceed those permitted by the AISC Manual of Steel Construction. Combined stresses in cast, forged, rolled or fabricated pressure retaining components, frames and supports shall not exceed that allowed for the given material in Section VIII, Division 1 of the ASME Code. Design pressures for pressure-retaining parts shall be not less than twice the pump's shutoff head at the manufacturer's listed maximum operating speed.
   The term "combined stresses" in this paragraph (1.9) shall mean the sum of all operating stresses, including stresses induced by dynamic and static forces as developed via the analysis procedures stipulated in this section. Dynamic forces shall include both steady state and transient stresses induced by operating conditions.

2. **Anchorage:** Unless otherwise indicated, anchor bolts for vertical volute-type and vertical axial flow pumps shall be designed to restrain twice the forces developed by operation of the pump at maximum speed against a closed valve with no restraint at the pump inlet and discharge flanges.

   Bases for horizontal pumps shall be designed in accordance with paragraph 11175-2.5, and shall provide common support for the pump and motor (and flywheel, if one is specified).

   All vertical (column type) pumps with unit weights (including drive, if supported by the pump) weighing more than 1,000 pounds and all volute type pumps with nozzle sizes 16 inches in diameter and greater and all separately supported motors shall be supported on a sole plate provided by the pump manufacturer. Sole plates shall be designed in accordance with paragraph 11175-2.6.

NTS: Anchor bolts for large pumps and pumps with high discharge heads can rarely be designed to withstand the nozzle reaction thrust developed. If the required restraint cannot be provided at the anchor bolts, restrained double pipe couplings, specifically designed to maintain adjustment for misalignment, must be provided. The DESIGN CONSULTANT should contact the pump manufacturer for guidance.

Anchor bolts and connecting bolts for all assemblies supported by other assemblies furnished under this Section or sections referencing this Section, shall be designed in accordance with the requirements of this Section, Section 11000, and the individual pump specifications. Anchor bolts, nuts and washers shall comply with paragraph 11175-2.2.

3. **Torsional and Combined Shaft Stresses:** The pump rotor shall be free from torsional criticals and shall comply with all stress requirements indicated in paragraph 11000-1.12A. Additional requirements are indicated in paragraph 11000-1.12.

4. **Shaft Deflection:** Pump shafts on volute type pumps shall be designed to provide sufficient stiffness to operate without distortion or damaging vibration throughout the range of service specified. Shaft deflection at the face (impeller side) of the shaft seal shall be limited to no more than 1.5 mils at any continuous operating condition within the zone described by the specified continuous duty operating conditions. Deflection at the shaft seal shall be calculated using the relationship set forth in paragraph 11175-1.10D.3.
5. **Bearings:** Unless otherwise specified, anti-friction bearings shall be selected for an L−10 life expectancy in accordance with the requirements specified in paragraph 11000-2.8. Radial loads shall be calculated in accordance with the provisions set forth in paragraph 11175-1.10.

F. **Rotor and Critical Speed Analysis and System Design:** Requirements for the rotor and critical speed analysis and system design are specified in paragraph 11175-1.10.

NTS: Net Positive Suction Head limitations have taken on a much greater importance with the publication of ANSI/HI 9.6.1. The following paragraph deals with the implications of that standard by establishing rules for use of the standard on MWWD projects, and placing the responsibility for selection in accordance with those rules on the pump manufacturer. It is important that all specified operating conditions for centrifugal and axial flow pumps include the Net Positive Suction Head Available at each condition.

G. **Net Positive Suction Head Required Limitations:**

1. **General:** Pumps furnished under this section and sections referencing this section shall be selected for NPSHR (Net Positive Suction Head Required) characteristics using the suction energy methodology set forth in ANSI/HI 9.6.1. NPSHR characteristics for the candidate pump shall be based upon documented test data not more than five years old, performed on a pump not more than two nominal pump diameters larger or smaller than the proposed pump with an impeller of the same geometry as that proposed for the pump to be used for the subject application, and operating at the same speed as the pump for the proposed application. The CONTRACTOR shall document the basis for NPSH characteristics as set forth in this paragraph.

Individual restrictions shall apply to NPSH margin as set forth below, depending upon the type of pumping equipment and the fluid to be pumped. The detailed specification sections provide NPSHA (Net Positive Suction Head Available or wet well elevation) information for anticipated operating conditions for each application. This information is generally referenced to a specific elevation, stated in terms of project datum. It shall be the CONTRACTOR's responsibility to adjust the NPSHA information to the elevation of the pump impeller eye for the specific pump model and size proposed for the application. NPSHR, as used in the following paragraphs, shall mean the NPSHR at the impeller eye, determined in accordance with ANSI/HI 1.6 or 2.6, as applicable for the proposed pump. The CONTRACTOR shall document the method used to determine NPSHR for the proposed pump and justifying compliance with the NPSH margin limitations established under this paragraph in material submitted under paragraph 11175-1.4. The documentation shall include justification of the NPSHR tests used to develop NPSHR characteristics, including the following:

a. Date, test procedure, and test logs of original NPSHR information used to project requirements for pump selected for the application.

b. Test pump size, impeller diameter, impeller model, eye diameter, and speed.

c. Calculations projecting NPSHR test information to NPSHR curve information for pump proposed for the application.

d. Calculations demonstrating compliance with the NPSH margin requirements established in this paragraph.

The CONTRACTOR, using suction energy rules in selecting pumps proposed for each application, shall apply criteria set forth in the individual paragraphs below. Percentages stated below shall apply to pump capacity on the selected pump's head/capacity curve at the speed required to achieve the specified operating condition.

The CONTRACTOR shall submit the manufacturer's suction energy calculations justifying the proposed pumps selections with the material required under paragraph 11175-1.4.

2. **Pumps Used for Solids Bearing Liquids:** The following restrictions shall apply to pumps specified for wastewater, stormwater, primary effluent, return mixed liquor, RAS, and trickling filter service:

a. A minimum NPSHA/NPSHR margin ratio of 1.3 shall apply at any operating condition within 85 percent and 115 percent of the best efficiency capacity. The minimum acceptable NPSHA/NPSHR margin ratio at any other locations on the pump's head/capacity curve shall be 1.8.

b. Notwithstanding item a above, the manufacturer shall use the methodology in ANSI/HI 9.6.1 to determine the proposed pump's suction energy. In determining the proposed pump's suction energy, the inlet nozzle size shall be increased by two nozzle sizes to account for impeller design considerations. In employing the suction energy method, the minimum NPSHA/NPSHR ratio shall be not less than that recommended in ANSI/HI 9.6.1 or item a., above, whichever is greater. For submersible and wet pit pumps, suction nozzle size shall be the impeller eye diameter of the proposed pump.

c. If the proposed pump's suction energy, as determined in item b, falls into the "high" or "very high" region, as determined from Figure 3 in ANSI/HI 9.6.1, the minimum

acceptable NPSHA/NPSHR margin ratios shall be 1.5 and 2.0, respectively.

3. **Pumps Used for Clear Liquids:** The methodology set forth in ANSI/HI 9.6.1 shall be employed for determining NPSHA margin for pumps to be used on liquids which do not normally contain solids, such as potable and process water, heating water, and secondary and tertiary effluent pumping service. The acceptable minimum NPSHA less NPSHR margin shall be 5 feet at any specified operating condition falling within 85 percent and 115 percent of best efficiency capacity at the speed required to achieve the specified operating condition, and not less than 8 feet for any specified operating condition falling outside that zone. Suction nozzle size for wet pit and column-type pumps shall be the impeller eye diameter of the proposed pump.

H. **Motor Selection:** Unless otherwise specified, pumps shall be electric motor driven. Electric motors shall conform to the requirements set forth for heavy duty motors in Section 16040 or shall be as specified in the detailed pump specification. All motors shall be selected to be non-overloading at any operating point along the pump's full speed operating curve, including all points located beyond specified operating conditions. Motors furnished with pumps specified for operation at variable speed shall be inverter duty types conforming to the requirements of Section 16040 and shall be compatible with the variable speed equipment furnished with the pump.

In addition to the information submitted under the requirements of Section 16040, the CONTRACTOR shall provide certified reed frequency calculations for both the motor rotor and frame for motors driving "Custom Engineered" pumps, with the data to be submitted under paragraph 11175-1.4. Upon completion of construction of the motors driving "Custom Engineered" pumps for this project, each rotor and frame and the completed assembly shall be given a bump test to confirm the reed frequency calculations. The results of the bump test, certified by an officer of the manufacturing corporation and notarized, shall be furnished to the design professional responsible for the rotor and critical speed analysis (paragraph 11175-1.10) and submitted under paragraph 11175-1.4 and included in the Owner's Manual.

1.10 ROTOR AND CRITICAL SPEED ANALYSIS AND SYSTEM DESIGN

A. **General:** The requirements of this paragraph shall apply to all variable speed pumping systems with pump nozzle sizes 12 inches in diameter and greater, all pumping unit specifications where the words "Custom Engineered" appear in the title or in paragraph 1.1A of the specification section, and elsewhere when a detailed pump specification makes reference to this paragraph. In addition, overhung shaft pumps operating in single volute casings shall be subject to analysis for shaft deflection in accordance with the terms of this paragraph.

B. **Requirements:** The complete pumping unit, including rotating elements, frames, supports, and all related structural elements, including pump, motor and bearing supports, shall be subjected to a lateral rotordynamic analysis, including a rotordynamic critical speed analysis, to identify and eliminate harmful resonant conditions.

The complete pumping unit rotating element, including pump, motor, intermediate shaft and flywheel rotors (if specified), and all other elements in the power train or powered via the power train, shall be designed to limit torsional stresses.
The torsional and rotordynamic analyses shall together be termed the pumping equipment's mass elastic design. The mass elastic design shall be the product of a registered design professional who has been responsible for the design of at least one successfully operating mass elastic design of comparable size and complexity in the recent past. The CONTRACTOR shall submit the

qualifications of the proposed design professional as a part of the initial submittal information required under paragraph 11175-1.4.

Upon completion and receipt of certified results of the bump tests required for the motor rotor, frame and assembly specified under paragraph 11175-1.9H, the design professional shall review the data and submit a supplemental report either accepting the test results or recommending alterations to assembly structures to adjust for differences between calculated values used for the original analyses and actual values determined subsequent to motor fabrication.

Reports, calculations and recommendations resulting from the required analyses shall bear the design professional's original signature and professional registration seal. All reports, recommendations and calculations produced under this paragraph shall be submitted as specified in paragraph 11175-1.4. The format and documentation for the reports shall follow the requirements of ANSI/HI 9.6.4.

If the CONTRACTOR proposes the use of alternative methods for the required analyses, documentation shall be submitted justifying the substitution. The documentation shall include justification that product results will be equivalent to that specified and with an equivalent level of accuracy. The location and description of projects of an equivalent size where the procedure has been employed and the length of time these projects have been in actual service shall also be included.

C. **Critical Speeds:** Process sensitivities are such that operation of variable speed pumps at infinitely variable speed within the specified operational conditions is an absolute requirement. The CONTRACTOR is advised and warned that any remedy imposing a locked-out speed interval or intervals will not be considered an acceptable remedy for identified critical speeds. The CONTRACTOR shall adjust component sizes, and/or provide appropriate energy absorbing devices or other approved remedies to eliminate critical speeds within the operating range required to meet specified performance requirements.

D. **Methodology:**

1. **Rotordynamic Analysis:** The rotor dynamic analysis shall follow the procedure prescribed in Corbo and Malanoski, 1998, and shall include the following features:

    a. The procedure shall consider all speeds required to operate the equipment within the envelope of continuous operating conditions specified.

    b. The procedure shall produce Campbell diagrams for both wet and dry conditions.

    c. The procedure shall consider variations in assumed coefficients for seal and wearing ring clearances (Lomakin effect), bearing damping and stiffness, rotor imbalance (up to 10 percent of rotor disc weight at each disc position), impeller destabilizing forces, rotor shaft bending, hydraulic imbalance at not less than five operating conditions within the envelope of continuous operating conditions specified in addition to the specified operating conditions, and impeller vane/diffuser (cutwater) vane clearance. Unless specifically accepted by the OWNER, the range in variation of component characteristics shall comply with the ranges recommended in Corbo and Malanoski, 1998.

    d. The final report shall include a three-dimensional graphic presentation of shaft distortion and rotor element performance at identified critical speeds within the pump's operating range.

2. **Torsional Vibration:** The methodology used for evaluation of the mass elastic system and shaft combined stresses shall follow the approach prescribed in Corbo and Malanoski, 1996, using either the Matrix-Eigenvalue or Holzer methods for determining natural frequencies. The computer analysis results shall be verified by hand calculations for the fundamental frequency and for mode shapes. Exciting frequencies to be considered during the analysis shall be 0.5, 1, and 2 times running speed, vane passing frequencies for the pump impeller/cutwater-diffuser vane combinations, line and twice line frequency, motor pole frequency and motor starting transients. Forcing function magnitudes used for the analysis shall be not less that 10 percent of the maximum transmitted torque. The analysis shall also include evaluation of control pulse frequencies induced by the variable frequency drive. The analysis report shall include a statement produced by the variable frequency drive manufacturer detailing all control pulse frequencies generated by the equipment between 1/4 and 18 times motor running speed.

   The stress analysis procedure shall be based upon a finite element analysis technique using a digital computer program that has been successfully field calibrated with at least one installation of comparable size and complexity in the recent past. Unless otherwise justified by documentation supported by independent studies, the analysis procedure shall use the range of factors recommended in Corbo and Malanoski, 1996. The CONTRACTOR shall produce a Campbell-type interference diagram showing the relationship between operating range, natural frequencies and exciting frequencies.

   The analysis shall include a time-integration study showing transient peak stresses resulting from startup, shutdown and motor control transients if synchronous drives are specified. The diagrams shall include calculated stresses throughout the range of frequencies considered in the analysis. Tomographic diagrams, displaying colorimetrically peak stresses at all positions in the pump shaft and all frames, including roots at changes in section and keyways or other stress concentrating locations, shall be provided with the analysis report. The diagram shall indicate operating speeds identified that produce the peak stresses and shall be specific for speeds inducing identified peak stresses at keyways, changes in section and at connections to other components.

3. **Shaft Radial Load and Deflection:**

   a. **Overhung Shaft Pumps:** Shaft radial loads and deflection for overhung shaft pumps operating in single volute casings shall be calculated using the following relationship:

$$\Delta_{MAX} = \frac{R}{3E}\left[\frac{a^2c - abc}{I_c} + \frac{1}{I_a}\left(\frac{b^3 - 3a^2b}{2} + a^2\right)\right]$$

   Where:

   Δmax = deflection, inches, at the outboard (impeller side) face of the shaft seal

   E = modulus of elasticity, psi
   30×10^6 for carbon steel
   28×10^6 for 316 stainless steel
   Alternate materials: as accepted by OWNER

   a = shaft length, inches, from the centroid of the impeller profile (from inlet to

discharge nozzle) to the centerline of the radial bearing

b = shaft length, inches, from the centroid of the impeller profile (from inlet to discharge nozzle) to outboard (impeller side) face of shaft seal

c = shaft length between centerline of bearings, inches

I_a = moment of inertia of the shaft at section a, in^4

I_c = moment of inertia of the shaft at section c, in^4

R = radial force, pounds, at any specified operating condition or any operating condition within the envelope of specified operating conditions resulting in peak loads imposed on the shaft:

$$R=(K)(H)(D)(Y)+W$$

where:

K = Radial thrust factor. K shall vary with flow and specific speed in accordance with the following:

Q/Q_{BEP}	K, N_S = 2000	K, N_S = 3500
0.0	0.31	0.38
0.1	0.30	0.375
0.2	0.28	0.36
0.3	0.26	0.345
0.4	0.24	0.325
0.5	0.22	0.3
0.6	0.18	0.27
0.7	0.15	0.23
0.8	0.12	0.185
0.9	0.08	0.14
1.0	0.05	0.09
1.1	0.06	0.12
1.2	0.11	0.17
1.3	0.20	0.25

NOTES:

1. *Q/Q_{BEP} in the table is the ratio of flow at the operating condition to flow developed by the pump at best efficiency*

2. *N_S in the table is specific speed, as defined in ANSI/HI 1.1 - 1.6*

3. *K for pumps with specific speeds between 2000 and 3500 shall be established by a*

straight line interpolation from the above values.

4. *K for pumps with specific speeds greater than 3500 shall be established by a straight line extrapolation from the above values. The manufacturer is at liberty to use differing values of K from that above so long as they are greater than those listed in the table. Under no circumstances will lesser values of K be acceptable.*

H = Head (psi) developed by the pump at any specified duty point, including operating conditions within the envelope of conditions specified

D = Mean impeller diameter, inches

Y = Impeller width, inches, at discharge, including shrouds

W = Impeller weight with wearing ring, pounds (W = 0 if vertical pump)

Radial loads calculated in accordance with the above procedure shall be used for bearing life calculations as required under paragraph 11175-1.9E.5.

Flexural stress calculations shall be based upon the loading criteria specified above and shall be incorporated into the combined stress calculations specified under paragraph 11175-1.9E.3.

b. **Impeller between Bearings Pumps:** Shaft deflection for single volute pumps with the impeller mounted between bearings such as for split case centrifugal pumps shall be calculated in accordance with the following formula:

$$\Delta_{max} = \frac{(R_x)(3L^2 - 4x^2)}{48EI}$$

Where:

Δmax = deflection, inches, at the face (impeller side) of the shaft seal

R = radial force, as defined above

L = distance between bearings, inches

E = modulus of elasticity for the shaft material, as defined above

I = shaft moment of inertia at the bearings, inches^4

x = distance between bearing and seal face (impeller side), inches

4. **Reference Documents:** The Corbo and Malanoski documents referenced in paragraphs 11175-1.10D.1 and 11175-1.10D.2. are available from the City of San Diego, Metropolitan Wastewater Department, on an as-needed basis, to those with the need to know as determined by the CITY:

a. Corbo and Malanoski, 1996 Practical Design Against Torsional Vibration. From *Proceedings of the 25th Turbomachinery Symposium*, Turbomachinery Laboratory, Texas A & M University,

College Station, TX, pp.189-222, 1996.

b. Corbo and Malanoski, 1998 — Pump Rotordynamics Made Simple. From *Proceedings of the 15th International Pump Users Symposium*, Turbomachinery Laboratory, Texas A & M University, College Station, TX, pp.167-204, 1998.

PART 2 -- PRODUCTS

2.1 GENERAL

A. **General:** Pumping equipment shall comply with this Section, the detailed pump specification, and Section 11000. In addition, the pump manufacturer and the pump manufacturing site shall be certified under ISO 9001. Evidence of the required certifications shall be included with the initial submittal under paragraph 11175-1.4.

B. **Combinations of Equipment:** Pumping equipment shall be new and shall incorporate all necessary mechanisms, couplings, electric motor and drives, shafts, appurtenances, and mounting.

C. **Tools:** Tools shall comply with Section 11000 and shall include one pressure grease gun for each type of grease required for pumps and motors.

D. **Spare Parts:** Spare parts shall include for each pump [ ] complete sets of seals, packing, gaskets, nuts, bolts, washers, wear rings, lantern ring removal tools, and a set of spare bearings as well as all parts indicated in the detailed pump specifications.

E. **Nameplates:** Nameplates shall comply with Section 11000 and shall indicate rated head and flow, impeller size and pump speed. Flywheel nameplates shall include manufacturer, serial number, model, weight, and moment of inertia.

2.2 MATERIALS

A. **General:** Materials used in the pumping equipment shall be suitable for the intended application and shall be free from defects. **Materials of construction specified under the individual pump sections take precedence. Materials of construction not specified in the individual pump sections shall conform to the requirements listed below. However, where the individual pump sections and this Section are silent with respect to materials of construction of any component, material selection shall follow the requirements of Table H-1, API 610, Materials Class I-1.**

1. Cast Iron: Close-grained gray cast iron conforming to ASTM A 48, with 2 to 3 percent nickel added to the cast iron for raw sewage, wastewater and sludge applications. Pressure class shall be suitable for the application but shall be not less than Class 30 for pumps [4] [6]-inch and larger.

2. Ductile Iron (where indicated): ASTM A 395.
3. Pressure Casings, Inner Casing Parts such as Bowls, Diffusers and Diaphragms, and Impellers: Cast iron conforming to the requirements of API 610, Materials Class I-1 and paragraph 2.2A.1 above.

4. Stainless Steel Pump Impellers (where indicated): Cast Type 316 stainless steel conforming to

API 610, Materials Class S-8.

5. Bronze Pump Impellers (where indicated): ASTM B 62 or ASTM B 584.

6. Pump Shafts: Stainless steel, Type 316 unless higher strength is required.

7. All shaft sleeves for packed boxes, fretting seals and inter-stage seals shall be Type 316 stainless steel conforming to API 610, Materials Class S-8 requirements.

8. Miscellaneous Stainless Steel Parts: Type 316 except Type 304 in septic environments.

9. Internal Fastener Parts of All Types in Wetted Areas: Type 316 stainless steel conforming to API 610, Materials Class S-5.

10. Discharge Heads and Suction Cans: Carbon steel conforming to the requirements of API 610, Materials Class I-1.

11. Anchor Bolts, Nuts and Washers: Materials shall be as specified in paragraph 11000-2.20.

B. **General Quality: Details of manufacture and assembly of equipment furnished under the individual pump sections and this Section shall follow the requirements of API 610 with respect to the following features (paragraph references, API 610):**

1. Alignment aids (paragraph 2.1.24).

2. Removal of rotating element (paragraph 2.1.25).

3. Jackscrews for assistance in alignment on all base-plates and equipment supports (paragraph 5.3.7.3.4).

4. Castings (paragraph 2.11.2).
5. Welding (paragraph 2.11.3).

C. **Wearing Rings:** Unless otherwise specified, centrifugal and axial flow pumps shall be fitted with both stationary and rotating wearing rings. Wearing rings shall be of hard faced Type 316 stainless steel and shall conform to the requirements of API 610, paragraph 2.6.2, Material class S-8. Maximum wearing ring clearances shall not exceed 150 percent of the values stated in Table 2-2, API 610. Provisions shall be made for adjustment of wearing ring clearance via adjusting screws and shims in the back head design. L-form wearing rings are not acceptable for wastewater, sewage, stormwater, thickener overflow, mixed sludge, digester circulation, digested sludge, waste activated sludge, return activated sludge or primary effluent pumping service. Wearing rings shall be the axial type with a wear allowance of 0.25 inches minimum. Minimum wearing ring hardness on the rotating ring shall be 350 (BHN), with the stationary ring not less than 100 hardness points greater.

D. **Spacer Coupling:** Horizontal pump and electric motor shall be connected with a flexible coupling which will not transmit backlash. The coupling shall be selected to provide sufficient gap between the pump and motor [or flywheel] shafts to allow complete withdrawal and removal of the pump backhead, frame and rotor without disturbing the motor [or flywheel] when the coupling is removed. Couplings shall comply with paragraph 11000-2.6.

E. **Protective Coatings:** Pumps shall be protected with coatings as specified in Section 09800, unless

otherwise specified in the individual equipment specifications.

2.3 ACCESSORIES

A. **Solenoid Valves:** Pumps shall include solenoid valves at the inlet of water, oil lubrication, and cooling water connections. Solenoid valves shall be continuous time rated for the voltage and service conditions indicated.

B. **Pressure Gauges:** Pressure gauges shall be installed at pump suction and discharge lines except sump pumps and hot water circulating pumps. Pressure gauges shall comply with Section 13300 and shall be mounted at a location selected to minimize the effect of vibrations.

C. **Pump Suctions:** Compound gauges shall be installed at pump suctions and where subject to shock or vibrations, the pressure gauges shall be wall-mounted or attached to [galvanized] [Type 316 stainless steel] channel floor stands located where they will not impede pump maintenance access and connected to the pump by means of flexible connectors.

D. **Variable Speed Drives:** Where indicated, variable speed drives, drive motors, speed control equipment, and accessories shall comply with Sections 11030 and [11033].

E. **Local Control Panels:** The NEMA rating of local control panels shall comply with the area designations of Section 16050, unless indicated otherwise.

F. **Lifting Eyes:** Pumps and nozzles shall be provided with lifting eyes to permit removal and/or disassembly.

2.4 PUMP REQUIREMENTS

A. Pumps shall comply with the following:

1. Lubrication: Except as otherwise indicated, line shaft bearings of vertical turbine mixed flow, and propeller pumps shall be utility water-lubricated and deep-well pumps and pumps with enclosed line shafts shall have fresh water- or oil-lubricated bearings and seals.

2. Handholes: Handholes on pump casings shall be designed to follow the contours of the casing to avoid any obstructions in the water passage.

3. Umbrellas: For column pumps, the inlet wet well design is based upon the geometric relationships described in ANSI/HI 9.8, and a bell intake velocity of 5.5 fps shall be assumed. If the bell intake velocity for a proposed pump will exceed 5.5 fps, the CONTRACTOR shall require the pump manufacturer to furnish an umbrella fitted to the pump inlet bell that will effectively reduce the intake velocity to 5.5 fps, at no additional cost to the OWNER.

4. Drains: Gland seals, air valves, and cooling water drains, and drains from variable speed drive equipment shall be piped to the nearest floor drain, with galvanized steel pipe or copper tube; an air separation complying with the Uniform Plumbing Code shall be provided.

5. Grease Lubrication: Unless otherwise specified, all vertical propeller, mixed-flow, and turbine pumps, (other than deep well pumps), shall be equipped with a stainless steel tube designed for lubrication of bottom bearing.

6. Stuffing Boxes: Where shaft packing is indicated, stuffing boxes shall be tapped to permit

introduction of seal liquid and shall hold a minimum of five rows of packing. Stuffing boxes shall be face attached. Stuffing box and shaft shall be suitable for field installation, without machining or other modifications, of the mechanical seal indicated for the applicable pump and operating conditions.

Unless otherwise indicated, lantern rings shall be bronze, packing shall be die-molded packing rings of non-asbestos material suitable for the intended service and as recommended by the manufacturer, and glands shall be bronze, two piece split construction. Lantern rings shall be of two-piece construction and shall be provided with tapped holes to facilitate removal. Lantern rings shall be drilled and tapped 1/4 NC-20. Threaded lantern ring removal tools shall be provided with spare parts for each pump. Seals shall be flushed with utility water cleaned by means of a solids separator, or with process water. Except as otherwise indicated, the packing material shall be interlaced Teflon braiding, containing 50 percent ultra fine graphite impregnation complying with the following:

Shaft speeds	-	up to 2500 fpm
Temperature	-	up to 500 degrees F
pH range	-	1 to 14

7. **Mechanical Seals: Shafts for pumps specified with mechanical seals shall be furnished with no reduction in size through the seal area. Hard/hard faces shall be used. The seal design must be such that the dynamic o-ring moves towards a clean surface as the face wears and the springs are not in the fluid pumped to avoid fouling. The cartridge/split seal shall be a single balanced design capable of 400 psig service with o-ring secondary seals. For ease of equipment maintenance split seals shall be preferred, such as the Chesterton 442, Burgmann VGH, or approved equal. Should an unsplit cartridge design be used, acceptable designs include AES CURC, Chesterton 155, or approved equal. Materials shall be carbide or carbon faces, 316SS metals, Hastelloy/Elgiloy springs, and Viton elastomers. The mechanical seal shall be drilled and tapped for connection of a clean water purge supply. Pumps shall be fitted with SpiralTrac Version D, installation type I, as recommended by EnviroSeal Engineering Products, Ltd, Nova Scotia, Canada. Material of construction shall be stainless steel. For vertical (not vertical turbine) pumps an automated air vent shall be installed to vent the stuffing box of air.**

B. **Bearing Temperatures**: Where possible, the bearing temperature at the worst loading condition and ambient temperature shall not exceed 150 degrees F. Where this is not possible, all exposed bearings shall be effectively shielded with permanent metal safety guards to prevent accidental contact by operators.

2.5 SOLE PLATES FOR VERTICAL CENTRIFUGAL AND AXIAL FLOW PUMPS

A. Sole plates for vertical column type pumps and separately mounted vertical pumps, shall be designed to be installed on the concrete foundation curbs shown and shall be milled flat to within 0.002-inch per foot in all directions on the face mating with the pump support. Prior to milling, sole plates shall have the words “THIS SIDE DOWN” permanently affixed to the underside using welding rod material. Unless otherwise specified, sole plates shall comply with Section 11002.

2.6 BASEPLATES AND DRIVE UNIT SUPPORTS

A. Base-plates for horizontal pumps shall be fabricated and finished in accordance with paragraph 3.3, API 610. All base-plates shall be designed for grouting on the housekeeping pads specified.

B. Drive unit supports for separately mounted vertical pump drives shall be of fabricated steel, ASTM

A36. Drive unit supports shall be designed to span an opening in the floor sufficient to allow removal for the complete pump. Rolled steel beams shall be provided to stiffen the support and a fabricated steel drive unit support pedestal with a plate milled flat within two light bands shall be provided to mate with the drive enclosure. The support shall be designed to be supported on a sole plate embedded in a housekeeping pad at the edges of the floor opening or as indicated. Other details for the drive unit support shall be as indicated.

C. Unless otherwise specified, base plates and drive unit supports shall comply with Section 11002.

2.7 BALANCE

A. Balancing for centrifugal and axial flow pumps with nozzle sizes 6 inches in diameter and greater shall conform to the requirements set forth in API 610, paragraph 2.8.4.1. All balance logs, certified correct and signed by an officer of the manufacturing corporation and notarized, shall be included in the Owner's Manual.

2.8 MANUFACTURERS

A. Products of the type indicated shall be manufactured by the following (or equal):

1. Solids Separator for Seals Flushed with Utility Water:

John Crane Co.
Lakos (Claude Laval Corp.)

2. Self-Aligning, Self-Centering, Single Rotary Cartridge Type Mechanical Seals:

Chesterton 155
AES

3. Self-Aligning, Self-Centering, Single Split Cartridge Type Mechanical Seals:

Chesterton 442
Beurgmann VGH

PART 3 -- EXECUTION

3.1 GENERAL

A. Installation shall comply with Section 11000, the requirements of this Section, and the requirements of the detailed pump specifications. Equipment with pump nozzle sizes 12 inches in diameter and greater shall be installed under the presence of a factory authorized installation specialist or specialists. Under no circumstances shall any installation procedures take place without the installation specialists present. Equipment and anchor bolt installation procedures shall conform to the requirements of Section 11002.

3.2 SOLE PLATES

A. Sole plates, if provided as required by this Section, where required by the equipment manufacturer's recommendation, or any section referencing this section, shall be leveled in the presence of a factory

authorized installation specialist to a maximum tolerance of 0.002-inches/foot in all directions. Where the equipment manufacturer requires more stringent tolerances, those tolerances shall prevail.

3.3 ALIGNMENT

A. Equipment furnished under this Section and any referencing section shall be aligned as specified in Section 11005.

3.4 TESTING

A. Field testing shall be performed as specified in Part 1 of this Section. Testing also shall conform to the requirements of paragraph 11000-1.7A. For all units with variable speed drives and any unit with pump nozzle size 12 inches in diameter and greater, the testing procedure shall be a plan developed jointly by the CONTRACTOR and the equipment manufacturer to demonstrate performance of each item of equipment at all specified operating conditions.

3.5 VIBRATION

A. Vibration of installed pumps shall be measured in accordance with ISO 10816 for all pumps with variable speed drives and pumps with shaft power requirements [50] horsepower and greater. An independent testing laboratory specializing in this work, retained by the CONTRACTOR but acceptable to the CONSTRUCTION MANAGER, shall perform the measurements and shall submit the results directly to the CONSTRUCTION MANAGER. **RMS vibration velocity on any component when the pump is operating at any specified continuous duty operating condition shall not exceed the limits established for the appropriate machine by Tables 2-5 and 2-6 in API 610.** Vibration limits for pumps used for wastewater, grit, and sludge service shall be 150 percent of that established in the referenced tables. For all other installed pumps, vibration at the specified continuous duty operating conditions shall be measured by the independent testing laboratory noted above, and shall not exceed the limits specified in Section 11020. Vibration measurement results shall be included in the Owner's Manual.

3.6 TRAINING

A. Training shall conform to the requirements of paragraph 11000-1.7B and the individual equipment specifications. Unless otherwise indicated, the training requirement is waived for constant speed pumping equipment with nozzle sizes 4 inches in diameter and smaller and for all centrifugal and axial flow pumps with connected power requirements 10 horsepower and less. The training session for maintenance personnel shall include complete field and shop disassembly and subsequent reassembly of one complete pumping unit selected by the CONSTRUCTION MANAGER.

** END OF SECTION **