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## 2 SUBMERSIBLE PUMPS

### 2.1 GENERAL

#### 2.1.1 Scope

1 This Part specifies the requirements for the design, manufacture, construction, installation, testing and commissioning of submersible pumps, designed to handle raw unscreened sewage with a non-clog type impeller, complete and ready for operation as shown on the Drawings and as specified herein.

Pumps may be used for applications other than sewage, in which case they shall be modified accordingly.

2 Related Parts and Sections are as follows:

This Section

Part 1, ..... General

Section 1, General

Section 8, Drainage Works

Section 10, Instrumentation, Control and Automation

Section 21, Electrical Works

#### 2.1.2 References

1 The following standards or revised/updated versions are referred to in this Part:

BS 970..... Specification for wrought steels for mechanical and allied engineering purposes; (ISO 683-1 Heat-treatable steels, alloy steels and free-cutting steels — Part 1: Non-alloy steels for quenching and tempering; ISO 683-2 Heat-treatable steels, alloy steels and free-cutting steels — Part 2: Alloy steels for quenching and tempering; ISO 683-3 Heat-treatable steels, alloy steels and free-cutting steels — Part 3: Case-hardening steels; ISO 683-4 Heat-treatable steels, alloy steels and free-cutting steels — Part 4: Free-cutting steels; ISO 683-5 Heat treatable steels, alloy steels and free-cutting steels — Part 5: Nitriding steels; EN 10250-4: Open die steel forgings for general engineering purposes - Stainless steels; EN 10095 Heat resisting steels and nickel alloys; BS PD 970 Wrought steels for mechanical and allied engineering purposes. Requirements for carbon, carbon manganese and alloy hot worked or cold finished steels; EN 10089 Hot rolled steels for quenched and tempered springs. Technical delivery conditions; EN 10277 Bright steel products. Technical delivery conditions; EN 10278 Dimensions and tolerances of bright steel products; EN 10088-1 Stainless steels - List of stainless steels; EN 10088-3 Stainless steels - Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes)

BS 1400,..... Specification for copper alloy ingots and copper alloy and high conductivity copper castings; (EN 1982 - Copper and copper alloys. Ingots and castings)

BS 2902..... Specification. Higher tensile steel chain slings and rings, links alternative to rings, egg links and intermediate links

BS 3032..... Specification for higher tensile steel shackles; (ISO 2415 - Forged shackles for general lifting purposes — Dee shackles and bow shackles)

- BS 3468, (ISO 2892).Specification for austenitic cast iron; (EN 13835- Founding. Austenitic cast irons); (ISO 2892- Austenitic cast irons — Classification)
- BS 3551 ..... Specification for alloy steel shackles
- BS 4942-1 ..... Short link chain for lifting purposes - Specification for general conditions of acceptance; (ISO 1834)
- BS 4942-6 ..... Short link chain for lifting purposes - Specification for grade T (8) calibrated chain; (ISO 3077)
- BS 4999.....General requirements for rotating electrical machines; (IEC 60034 Rotating electrical machines- ; IEC 60072 Rotating electrical machines - Dimensions and output series -)
- BS 5512, (ISO 281) Method of calculating dynamic load ratings and rating life of rolling bearings; (ISO 281- Rolling bearings — Dynamic load ratings and rating life)
- BS 5345,.....Code of practice for selection, installation and maintenance of electrical apparatus for use in potentially explosive atmospheres (other than mining applications or explosive processing and manufacture); (IEC 60079- Explosive atmospheres)
- BS 6007, (IEC 60245) Electric cables. Single core unsheathed heat resisting cables for voltages up to and including 450/750 V, for internal wiring (EN 50525- Electric cables. Low voltage energy cables of rated voltages up to and including 450/750 V); (IEC 60245- Rubber insulated cables - Rated voltages up to and including 450/750 V)
- BS 6105, (ISO 3506).Specification for corrosion-resistant stainless steel fasteners; (ISO 3506- Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners)
- BS 6861, (ISO 21940-11; ISO 21940-14) Mechanical vibration. Balance quality requirements of rigid rotors; (ISO 21940-11 Mechanical vibration — Rotor balancing - Part 11: Procedures and tolerances for rotors with rigid behaviour; ISO 21940-14 Mechanical vibration - Rotor balancing - Part 14: Procedures for assessing balance errors)
- BS 6994.....Specification for steel shackles for lifting and general engineering purposes: grade M(4); (ISO 2415 - Forged shackles for general lifting purposes — Dee shackles and bow shackles)
- BS 7671,.....Requirements for Electrical Installations. IET Wiring Regulations
- EN 1092.....Flanges and their joints - Circular flanges for pipes, valves, fittings and accessories, PN designated
- EN 1561, .....Founding - Grey cast irons; (ISO 185 - Grey cast irons — Classification)
- ISO 2903 .....ISO metric trapezoidal screw threads — Tolerances
- ISO 7595 .....Socketing procedures for wire ropes — Molten metal socketing; (ISO 17558 - Steel wire ropes — Socketing procedures — Molten metal and resin socketing)
- ISO 9906 .....Rotodynamic pumps — Hydraulic performance acceptance tests — Grades 1, 2 and 3

ISO 10816-1 .....Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 1: General guidelines; (ISO 20816-1 - Mechanical vibration — Measurement and evaluation of machine vibration — Part 1: General guidelines)

ISO 10816-7 .....Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 7: Rotodynamic pumps for industrial applications, including measurements on rotating shafts

### 2.1.3 Submittals

- 1 In addition to the requirements of Part 1 of this Section the Contractor shall provide data and information described in the following paragraphs
- 2 Design Data
  - (a) the Contractor shall provide manufacturer's published pump curves, system curves and parallel operation curves (all pumps) and the necessary hydraulic calculations to justify the sizes of any pumps selected.
- 3 Shop Drawings
  - (a) the Contractor shall provide the following:
    - (i) impeller diameter
    - (ii) maximum impeller diameter
    - (iii) minimum impeller diameter
    - (iv) velocity of liquid in pump suction at duty point
    - (v) velocity of liquid in pump delivery at duty point
    - (vi) velocity of liquid in the pump casing or impeller eye at duty point
    - (vii) net positive suction head (dry well submersibles only)
    - (viii) the materials of construction shall be specified in detail and itemised against a sectional drawing of the pump proposed.
    - (ix) characteristic curves for the full range of impeller diameters.
  - (b) after approval of the pump types the Contractor shall submit the test data as required under factory inspection and testing
- 4 Operation and Maintenance Manuals and Instructions. The Contractor shall include all the documentation provided as above and as required in Part 1.

## 2.2 PRODUCTS

### 2.2.1 General

- 1 Pumps and drives shall be rated for continuous duty and shall be capable of pumping the flow range specified in the Project Specification without surging, cavitation, or excessive vibration to the limits specified. All pumps and drives shall be from approved manufacturers.
- 2 The pumps shall meet maximum allowable shut-off head, and if dry-mounted submersibles, the maximum allowable required net positive suction head (NPSH) designated in the Project Specification.
- 3 The Contractor shall verify the NSPA value prior to ordering of pumps

- 4 The pumps shall not overload the motors for any point on the maximum pump speed performance characteristic curve and the pump operating range, within the limits of stable pump operation, as recommended by the manufacturer, to prevent surging, cavitation, and vibration.
- 5 To ensure vibration-free operation, all rotative components of each pumping unit shall be statically and dynamically balanced to ISO 21940-11 and the following requirements shall be met:
  - (a) the mass of the unit and its distribution shall be such that resonance at normal operating speeds is within acceptable limits
  - (b) in any case, the amplitude of vibration as measured at any point on the pumping unit shall not exceed the below limits
  - (c) at any operating speed, the ratio of rotative speed to the critical speed of a unit, or components thereof, shall be less than 0.8 or more than 1.3.
- 6 Vibration outside the limits specified in 2.2.2.8 shall be sufficient cause for rejection of the equipment.
- 7 The completed units, when assembled and operating, shall be free of cavitation, vibration, noise, and oil or water leaks over the range of operation.
- 8 All units shall be so constructed that dismantling and repairing can be accomplished without difficulty.
- 9 The Contractor shall be responsible for proper operation of the complete pumping system, which includes the pump, motor, variable speed drive unit (if designated), and associated controls furnished with the pump.
- 10 The Contractor shall ensure that the controls and starting equipment are suitable for use with the pump motor, taking into account all requirements including starting currents and number of starts per hour.
- 11 For the performance curve of the selected pump impeller, the head shall continuously rise as flow decreases throughout the entire curve from run out to shutoff head.
- 12 The Contractor shall ensure that drive motors, variable speed drive systems (if designated) and pumps shall be supplied and tested together by the pump manufacturer, who shall supply full certification for the proper function of the entire pumping system.
- 13 If variable speed drive systems are specified, motor and drive system shall be fully compatible, and shall be of sufficient power and torque, and be capable of sufficient heat transfer for starting, accelerating and continuously operating over the entire range of head/capacity conditions, from minimum to maximum pump operating speed, as designated. The motor shall be derated to take into consideration the reduced cooling effect when running at the lowest speed with the variable speed drive.

## 2.2.2 Design Conditions

- 1 Pumps shall be designed and constructed to satisfactorily operate and perform within the designated design conditions and the requirements specified herein. They shall be designed for a life of 20 years with service intervals at 20,000 hours..
- 2 Castings, fabrications, machined parts and drives shall conform to the industry standards for strength and durability and shall be rated for continuous duty over the entire operating range.
- 3 Bearings shall be of the anti-friction type designed for an L10 life of at least 100,000 hours in accordance with ISO 281 .

- 4 Pump maximum operating speed shall not exceed 1500 rpm.
- 5 Pumps shall be designed to pass all suspended solids up to 100mm diameter, including stringy matter, rags, paper, plastics, etc. without choking except in the case of pumps delivering into a 100mm diameter rising main where the capability shall be 80mm diameter.
- 6 Pumps shall be suitable for use in the conditions specified in Section 1.
- 7 Renewable impeller wear rings shall be fitted, to the impeller and case, except where not available on a standard production unit.
- 8 Vibration levels of the pump shall not exceed the levels given in ISO 10816-1 (ISO 20816-1), and ISO 10816-7, quality bands A and B.
- 9 Submersible pumps shall have the duckfoot bends flanged to EN 1092 PN16. In the case of dry mounted submersible pump the outlet and inlet shall be flanged to EN 1092 PN16.
- 10 The pump, motor and associated electrical equipment shall be rated for a minimum 10 starts per hour, unless otherwise designated.
- 11 The Contractor shall ensure that the pump manufacturer provides certification which guarantees the following:
  - (a) flow rate
  - (b) total head
  - (c) power input
  - (d) efficiency
  - (e) NPSH required

### 2.2.3 Materials

- 1 Pumps shall be manufactured of the following materials as a minimum:
  - (a) volute casings shall be cast iron, EN 1561 Grade 250
  - (b) impellers shall be duplex stainless steel
  - (c) casing wear rings (where fitted) shall be Bronze BS 1400 or
  - (d) to the approved manufacturer's standard according to the applications.
  - (e) impeller wear rings shall be stainless steel BS 970 316 S31
  - (f) bends shall be cast iron, EN 1561 Grade 250
  - (g) motor casings shall be cast iron, EN 1561 grade 250 and cooling jacket (inner and outer) shall be SS316 S31
  - (h) shafts shall be stainless steel, Grade 316 S31 to BS 970-1
  - (i) fasteners shall be stainless steel Grade 316S31 to BS 970-1.
- 2 The lifting system shall be manufactured of the following materials:
  - (a) the guide rail system shall be stainless steel, BS 970 Type 316 S31
  - (b) lifting chains, rings, hooks and shackles shall be stainless steel BS 970 Grade 316 S31.

### 2.2.4 Fabrication

- 1 General. Pumps shall be fabricated in accordance with the following requirements:
  - (a) pump shall be capable of handling raw, unscreened sewage
  - (b) in the case of submersible installations no portion of the pump shall bear directly on the floor of the wet well. In the case of dry mounted pumps a substantial purpose built mounting frame shall be provided by the pump manufacturer

- (c) pressure gauge taps and air bleed taps shall be provided as stated under accessories
- (d) all castings shall be produced in accordance with the pump manufacturer's specifications under the manufacturer's direct supervision
- (e) pumps shall be designed with dual mechanical seals, as below

2 Wet well pumps shall incorporate the following features:

- (a) pumps shall utilise a guide system to permit easy removal and reinstallation without dewatering the pump sump
- (b) discharge connections shall be made automatically with a simple downward motion without rotation when the pump is lowered into operating position. The pump shall be capable of being removed without disconnecting any fasteners
- (c) an appropriate length of chain shall be connected to the motor eyebolts to permit raising and lowering of the pump. The lifting chains shall be fitted with suitable additional rings in order that the pumps can be lifted in stages from the sump invert level using the lifting gear. An additional hook and chain permanently fixed to the bottom of the lifting equipment to support the weight of the pump set during lifting operations shall be provided.

3 Impeller. Impellers shall be fabricated according to the rated motor size as follows:

- (a) non-clog type statically and dynamically balanced, keyed to the shaft
- (b) provided with pump-out vanes to prevent material from getting behind the impeller and into mechanical seal area
- (c) provided with wear ring as necessary to assure efficient sealing between volute and impeller
- (d) impellers shall not be trimmed unless approved by the Engineer
- (e) single/multi vane or vortex type, with a cutter impeller in the case of small flows.

4 Discharge Connection and Guide Rails. Sliding guide bracket and discharge connections shall be provided which, when bolted to the floor of the sump and to the discharge line, will receive the pump discharge connecting flange without need of adjustment, fasteners, clamp, or similar devices. The guide rails shall not support any portion of the weight of the pump. The pump discharge connections shall incorporate a sealing face and connection yoke to allow for automatic coupling to fixed discharge connection pipework. The guide rails shall be fabricated in stainless steel BS 970 Grade 316 S31.

5 Pump Shafts:

- (a) pump shafts shall be of such diameter that they will not deflect more than 0.05 mm measured at the mechanical seal, whilst operating at full driver output
- (b) the shaft shall be turned, round and polished
- (c) shaft shall be key-seated for securing the impeller. Details of the fixing arrangements shall be indicated in the proposal. Other kind of fixing arrangement shall provide with similar rigidity of key-seated assembly subject to Engineer pre-approval.

6 Shaft Seals:

- (a) the drive motor and pump/motor bearings shall be sealed along the shaft with tandem mechanical seals operating in an oil filled chamber. The seals shall require neither routine maintenance or adjustment, but shall be capable of being easily inspected and replaced.
- (b) two back to back mechanical seals shall seal the motor off from the pump.

- (c) the upper seal shall be oil lubricated with a carbon rotating component and fixed tungsten / silicon carbide component depending on pumped media.
- (d) the lower seal shall have both parts in tungsten / silicon carbide.
- (e) a detector shall indicate when moisture is leaking past the first seal.
- (f) The lower mechanical seal shall be of covered spring type.

7      Bearings:

- (a) bearings shall be capable of taking the static weight of the rotating parts and any thrust generated by the operation of the pump
- (b) the upper bearing(s) shall be of the grease lubricated sealed for life type, the lower bearing(s) shall be lubricated by the internal oil supply
- (c) the bottom bearing(s) shall be angular contact ball bearing arrangement .
- (d) if required in the project specification, remote indication shall be provided for bearing high temperature, using a thermistor at the lower bearing, to provide a signal at 95 °C.

8      Motors:

- (a) motors shall be 415 V / 690V or as indicated in project requirements, phase, 50 Hz, rated at 10 % above the maximum power requirement
- (b) motors shall be squirrel cage, induction, air filled, totally sealed to IP 68, suitable for the maximum immersion depth likely to be encountered, rated for zone 2 use with group 1 gases, to BS 5345
- (c) motor insulation shall be Class F, limited to a Class B temperature rise
- (d) motor temperature shall be monitored using a thermistor, in each phase of the winding, set to stop the motor when the monitored absolute temperature reaches 130 °C
- (e) a watertight cable junction box sealed from the motor shall be provided for the motor power and signalling
- (f) cables shall be EPR insulated, Niplas sheathed, flexible 450/750 volts grade, oil and grease resistant, with tinned annealed copper conductors in accordance with BS 6007. The cable shall be brought directly out of the submersible motor without joints, and shall be of sufficient length, minimum 20 m to be terminated in an IP67 junction box outside adjacent to the wet well. They shall be sized in accordance with QGEWC regulations and BS 7671
- (g) cables shall be supported using a proprietary 'sock' arrangement at the top of the wet well
- (h) Pumps shall be provided with proprietary monitoring and control units for inclusion in the motor controls. Analogue inputs shall include the following:
  - (i) winding temperature
  - (ii) bearing temperature
  - (iii) cooling oil temperature

Digital inputs shall include the following:

- (iv) high winding temperature
- (v) high bearing temperature

(vi) loss of coolant oil/seal failure

(vii) over temperature

(viii) moisture ingress

- (i) Motors shall be capable of start - up and operation in the event of a completely flooded wet well. Motors shall be selected to meet the maximum power required for the selected impeller at all operating conditions
- (j) Motor cooling shall be an efficient system to the manufacturer's design.
- (k) motors shall be derated for dry well and/or variable speed operation

9 Coatings and Protection

- (a) Cathodic protection with replaceable sacrificial zinc anodes shall be provided if required in the Project Specification.
- (b) all other parts shall be to the approved manufacturer's standard protection

**2.2.5 Accessories**

1 The following accessories shall be provided for each pump:

- (a) pressure gauges. The discharge pipework of each pump shall be provided with a 19 mm diameter tapped opening and stainless or brass isolating valves and diaphragm pressure gauges In the case of dry-mounted submersibles a similar tapping valve and gauge shall also be provided on the suction pipework of each pump
- (b) air bleed offs. In the case of submersible pumps automatic brass air bleed ball valves shall be provided on the reflux valves, venting via a 40 mm diameter stainless steel pipe to the wet well. In the case of dry mounted submersible pumps these valves shall be provided on the highest point of the volute casing
- (c) labels. Each pump shall have a stainless steel label permanently fixed to the pump and an identical label fixed to the pump starter compartment.

**2.2.6 Factory Inspection and Testing**

1 The Contractor shall secure from the pump manufacturer certification that the following internal inspections and tests have been conducted on each pump at the factory, and submit to the Engineer prior to FAT witness proposed:

- (a) the pump casing has been tested hydrostatically to 1.5 times the maximum closed valve pressure
- (b) impeller, motor rating and electrical connections checked for compliance with the Project Specifications
- (c) motor and cable insulation tested for moisture content or insulation defects
- (d) prior to submergence, the pump has been run dry to establish correct rotation and mechanical integrity
- (e) the pump has been run for 30 minutes submerged under a minimum of 2 m water
- (f) after the operational test (e) above, the insulation tests (b) above has been performed again, and after the performance test (2) below
- (g) NPSH required (dry well mounted submersible pumps only)

2 The Contractor/Manufacturer shall submit detailed and complete shop testing procedure for the pump at early stage of factory internal performance test.

- 3    Each pump shall be tested at the factory for performance according to ISO 9906 Grades 1, 2 and 3, including:
- (a) flow
  - (b) inlet pressure
  - (c) outlet pressure
  - (d) motor power
  - (e) torque
  - (f) efficiency
  - (g) Net Positive Suction Head (NPSH) required (valid for dry well submersible pumps).

Duly attested factory internal performance test reports for all the pumps shall be submitted for review and approval.

The pump curves shall be plotted at minimum five heads/flow rates together with efficiencies, power and NPSH (applicable for dry well submersible pump) etc.

Tolerance for flow and heads shall be in accordance with ISO 9906 – Grade 1 and 2. However for efficiency, no negative tolerance is acceptable.

- 4    The Contractor shall secure from the pump manufacturer the following 3.1 type certification and submit to the Engineer prior to shipment:

- (a) certified copies of the pump characteristic curves and reports generated by the tests described above and as required by ISO 9906 Grades 1 and 2.
- (b) foundry composition certificates for all major castings (pump case, impeller, motor housing) showing exact material composition and tests conducted to ensure compliance with the pump manufacturer's material specifications.
- (c) Material certificate for pump shaft and wear rings.
- (d) the lifting chains, rings and shackles shall be load tested and Proof tested compare with one of the below mentioned applicable codes requirements, and clearly and permanently tagged with the SWL. Test certificates shall be supplied with Authorised TPA approval.

Chain (sling and hooks): BS 4942-1(ISO 1834) and BS 4942-6 (ISO 3077)/ ISO 2903 / ISO 7595 (ISO 17558)

Shackles: BS 3551 / BS 3032 (ISO 2415) / BS 6994 (ISO 2415)

Ring and Links: BS 2902

## 2.2.7 Spare Parts and Tools

- 1    The Contractor shall ensure that the pump manufacturer provides all spares and special tools required during the commissioning and maintenance periods, and as required below.
- 2    In addition to the spare parts required in Part 1 the following spare parts for each pump shall be furnished to the Employer:
- (a) One set of complete upper and lower bearings
  - (b) Two sets of wear rings
  - (c) three sets of gaskets and three sets of 'O' rings complete
  - (d) One set of upper and lower mechanical seals
  - (e) additional spare parts as recommended by pump manufacturer to cover two years of operation following the maintenance period.

## 2.3 INSTALLATION AND COMMISSIONING

### 2.3.1 General

- 1 The equipment delivered to the Site shall be examined by the Contractor to determine that it is in good condition and in conformance with the approved working drawings and certifications. All equipment shall be installed in strict conformance with Part 1 of this Section and the manufacturer's instructions.

### 2.3.2 Site Inspection and Testing

- 1 If required in the Project Specification, or in the case of submersible pumps rated at 50 kW or greater, the Contractor shall provide the services of the pump manufacturer's representative to supervise the installation, commissioning and start-up of the pumping equipment.
- 2 The commissioning tests shall be performance and reliability trials, mainly for the purpose of satisfying the Engineer that the pumpsets have been correctly assembled and installed and that their performance matches that obtained during the manufacturer's works tests. In the event of an unwarranted change in the pump performance characteristics or power consumption, all necessary steps shall be taken as soon as possible to establish the cause and remove the fault. Similar action shall be taken for an undue increase in bearing or gland temperature, increased gland leakage rates, unsatisfactory vibration levels or any other fault or defect in the operation of the pumpset.
- 3 The site reliability trials shall include the following:
  - (a) a record of bearing and coupling clearance and alignments shall be tabulated to show the "as-built" condition of each pump
  - (b) a record of all overload, timing relay and oil pressure relays shall be tabulated to show the "as-built" condition of each motor starter
  - (c) all cables shall be "megger" tested to confirm the integrity of the insulation. A tabulated record of results shall be made
  - (d) the control panel shall be statically tested with motors disconnected to confirm the correct sequence of operation
  - (e) each pump shall be operated individually over the range from closed valve to maximum emergency top water level, on a recirculation basis, using fresh water, and for a minimum of four hours continuously. During this test the following parameters will be recorded:-
    - (i) motor phase currents
    - (ii) pump output
    - (iii) ambient and test water temperatures
    - (iv) motor/pump casing temperature
    - (v) power consumed
    - (vi) power factor
    - (vii) vibration
    - (viii) signs of cavitation noise
  - (f) Parallel operations of the pumps shall be carried out during commissioning tests and reliability trials to ensure that the pump performance matches with the requirements.

- (g) the commissioning trials shall extend until each pump unit has run 'continuously' for at least 3 days under all operating conditions. The term 'continuously' shall include running at various speeds or on a start/stop basis as determined by the control system
- (h) the Contractor's supervisory staff, and the pump manufacturer's representative, if required by the Project Specification or the above, shall be present during the period of the tests and trials. The Contractor shall be responsible for any failure of the whole equipment or any part thereof, whether such failure shall be determined by the methods detailed herein or otherwise. If the pump test or trial is interrupted by the Contractor, or through negligence on the part of the Contractor's staff, it shall be completely repeated for the pumpset concerned.

END OF PART

ARAB ENGINEERING BUREAU