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5 ARCHIMEDIAN SCREW PUMPS

5.1 GENERAL

5.1.1 Scope

- 1 This Part specifies the requirements for the design, manufacture, construction, installation testing and commissioning of open type Archimedes screw pumps.
- 2 Related Sections and Parts are as follows:

Section 1, General
Section 8 Drainage Works
Section 10, Instrumentation, Control and Automation
Section 13, Building Electrical Works
Section 21 Electrical works

5.1.2 References

- 1 The following standards or revised/updated versions and documents of other organisations are referred to in this Part:

AGMA.....American Gear Manufacturers' Association Standards

BS 4,.....Structural steel sections; (EN 10025 Hot rolled products of structural steels; EN 10056 Structural steel equal and unequal leg angles; EN

BS 970 (ISO 683).....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 3496Specification for E glass fibre chopped strand mat for reinforcement of polyester and other liquid laminating systems (EN 14118-1 Reinforcement - Specifications for textile glass mats (chopped strand and continuous filament mats) - Part 1: Designation; EN 14118-2 Reinforcement - Specifications for textile glass mats (chopped strand and continuous filament mats) - Part 2: Methods of test and general requirement; EN 14118-3 Reinforcement - Specifications for textile glass mats (chopped strand and continuous filament mats) - Part 3: Specific requirements)
- BS 3532Method of specifying unsaturated polyester resin systems
- BS 3749Specification for E glass fibre woven roving fabrics for the reinforcement of polyester and epoxy resins systems
- BS 4395Specification for high strength friction grip bolts and associated nuts and washers for structural engineering; (EN 14399 High-strength structural bolting assemblies for preloading-)
- BS 4604 (ISO 225, 272, 885, 887, 888, 4759) Specification for the use of high strength friction grip bolts in structural steelwork.
- BS 4604-1Specification for the use of high strength friction grip bolts in structural steelwork. Metric series - General grade
- BS 4604-2Specification for the use of high strength friction grip bolts in structural steelwork. Metric series - Higher grade (parallel shank)
- BS 4604-3Specification for the use of high strength friction grip bolts in structural steelwork. Metric series - Higher grade (waisted shank)
- BS 4870Specification for approval testing of welding procedures; (ISO 14732 Welding personnel. Qualification testing of welding operators and weld setters for mechanized and automatic welding of metallic materials; ISO 15614-1 Specification and qualification of welding procedures for metallic materials. Welding procedure test - Arc and gas welding of steels and arc welding of nickel and nickel alloys; ISO 15614-2 Specification and qualification of welding procedures for metallic materials. Welding procedure test - Arc welding of aluminium and its alloys; ISO 15614-8 Specification and qualification of welding procedures for metallic materials. Welding procedure test - Welding of tubes to tube-plate joints)
- BS 4871Specification for approval testing of welders working to approved welding procedures; (ISO 9606 Qualification testing of welders. Fusion welding : ISO 9606-1 Qualification testing of welders. Fusion welding - Steels; ISO 9606-2 Qualification test of welders. Fusion welding - Aluminium and aluminium alloys)
- 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 5950,.....Structural use of steel work in building (EN 1993- Eurocode 3: Design of steel structures; EN 1994 Eurocode 4. Design of composite steel and concrete structures - EN 1090-2 Execution of steel structures and aluminium structures - Technical requirements for steel structures)

- BS 6105, (ISO 3506)..Specification for corrosion-resistant stainless steel fasteners; (ISO 3506- Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners)
- BS 6460Accreditation of testing laboratories.
- BS 6460-1Accreditation of testing laboratories. - Specification of the general requirements for the technical competence of testing laboratories
- EN 287Qualification test of welders - Fusion welding; (EN 287-1 test of welders - Fusion welding - Part 1: Steels: ISO 9606-1 Qualification testing of welders - Fusion welding - Part 1: Steels; ISO/AWI 9606.2 Qualification testing of welders — Fusion welding; EN 287-2 Approval testing of welders - Fusion welding - Part 2: Aluminium and aluminium alloys: ISO 9606-2 Qualification test of welders - Fusion welding - Part 2: Aluminium and aluminium alloys)
- EN 288Specification and approval of welding procedures for metallic materials; (ISO 15607 Specification and qualification of welding procedures for metallic materials — General rules; ISO 15609-1 Specification and qualification of welding procedures for metallic materials — Welding procedure specification — Part 1: Arc welding; ISO 15614-1 Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys; ISO 15614-2 Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 2: Arc welding of aluminium and its alloys; ISO 15610 Specification and qualification of welding procedures for metallic materials — Qualification based on tested welding consumables; ISO 15611 Specification and qualification of welding procedures for metallic materials — Qualification based on previous welding experience; ISO 15612 Specification and qualification of welding procedures for metallic materials — Qualification by adoption of a standard welding procedure specification; ISO 15613 Specification and qualification of welding procedures for metallic materials — Qualification based on pre-production welding test)
- ISO 281Rolling bearings — Dynamic load ratings and rating life
- ISO 225Fasteners — Bolts, screws, studs and nuts — Symbols and descriptions of dimensions
- ISO 272Fasteners — Hexagon products — Widths across flats
- ISO 885General purpose bolts and screws — Metric series — Radii under the head
- ISO 887Plain washers for metric bolts, screws and nuts for general purposes — General plan
- ISO 888Fasteners — Bolts, screws and studs — Nominal lengths and thread lengths
- ISO 4759Tolerances for fasteners -
- ISO/IEC 17025General requirements for the competence of testing and calibration laboratories

5.1.3 Submittals

In addition to the requirements of Part 1 of this Section, the Contractor shall provide data and information as described in the following paragraphs.

- 1 Design data providing the following information:
 - (a) the calculations justifying the sizing of the screw, speed, flow rate, efficiency, rating of motor, gearbox and bearings
 - (b) User certificates shall be supplied.
- 2 Shop Drawings
The Contractor shall provide calculations for the following:
 - (a) the maximum deflection of the screw
 - (b) the maximum static and dynamic stresses on the torque tube, torque tube -to -flight welded joints and radial welded joints on the tube segment
 - (c) the calculations shall demonstrate that, including for cyclic stress, the screw has a life in excess of 10 years
 - (d) Mill certificates for the steel used, welding consumables and procedures.
- 3 Operation and maintenance manuals and instructions. These shall include the documentation required above and the results of any factory tests, site inspections and testing.

5.2 PRODUCTS

5.2.1 General

- 1 All equipment shall be provided including screw, bearings, gearbox, motor drive, lubrication system, couplings, guards and appurtenances to provide a fully operational system to perform the duties specified herein and in the Project Specification.
- 2 The Contractor shall be fully responsible for the integrated operation and warranty of all components supplied.
- 3 The screw pumps welding and NDT to meet the AWS D1.1 requirements.

5.2.2 Design Conditions

- 1 The pumps shall be designed to handle raw sewage with stringy wastes, rags, paper and plastics.
- 2 The Contractor shall obtain a chemical analysis of the particular sewage to be pumped, and select the pump materials and coatings accordingly.
- 3 The equipment shall be capable of continuous duty unattended, be fully automatic in operation, and require the minimum of maintenance.
- 4 The design criteria for the system are given in the Project Specification. The peripheral speed of the screw blades shall not exceed 3 m/s and the shaft speed shall not exceed 60 rpm.
- 5 The screw pumps shall be designed taking into account the emergency top water level in the sump. The pumps may operate at this level. The tendency for the rotating assembly of the pump to float shall be taken into consideration when selecting bearings and other components, and also in the design of the screw assembly and fixings.
- 6 The screw pump and bearings shall be sized for the worst case i.e. the weight of the screw and water, neglecting any buoyancy effect.

7 The design of the screw pump must take into account the following:

- (a) start-up inertia forces
- (b) cyclic forces during operation
- (c) deflection induced stresses
- (d) unbalanced stress effects.

5.2.3 Materials

1 Screws shall be manufactured from mild steel, to BS 970 Part 1.

2 Screw covers shall be as sub-clause 9

3 Top and bottom bearing shall use life lubricated ball bearings

4 Fasteners. These shall be stainless steel, BS 970 type 316 S31, except for those securing the bearing stub shafts to the screws. These shall be to BS 4395 and BS 4604

5 Coating system. This shall consist as follows for the screw. Alternative coating systems shall be to the approval of the Engineer.

- (a) two component polyamide cured zinc epoxy primer, dry film thickness (DFT) 40 microns
- (b) two component micaceous iron oxide pigmented polyamide cured epoxy sealer, DFT 50 microns
- (c) two coats of two component high solids polyamine cured epoxy coating, each coat DFT 200 microns
- (d) the steel shall be blast cleaned to ISO SA 2½ with a blasting profile of 40 -70 microns
- (e) the remainder of the components shall be painted as Section 8.

5.2.4 Fabrication

1 Components shall be fabricated as described in the following paragraphs.

2 Screw pumps

- (a) screw pumps shall be of fabricated welded construction and consist of a mild steel screw operating in an inclined steel trough liner which shall be grouted into a concrete channel.
- (b) screws shall be electric motor driven through a heavy duty speed reducing gearbox
- (c) screws shall consist of a robust mild carbon steel tube onto which are welded two or more cold formed helical mild steel blades to make a continuous spiral, with stub shaft housings at the ends
- (d) screw pumps deflection shall be limited to the screw length between bearing supports divided by 360 in accordance with the value given in BS 5950 Part 1 tables, or the screw manufacturer's recommendations
- (e) tubes shall have a minimum wall thickness of 9 mm or greater, if required, to limit the deflection in accordance with the above
- (f) welds shall be continuous fillets on each side of each blade, except when crossing a tube weld, which shall be continuous seam welds parallel to the tube axis
- (g) circumferential welds for joining tubes shall not occur at a greater distance than 20% from the extremities of the finished tube. If possible they shall be at the lower end of the tube
- (h) blades shall have a minimum thickness of 12 mm

- (i) the tips of the blades shall be reinforced by means of a stainless steel strip 60mm wide and of the same thickness as the screw. This shall be welded onto the side of the blade, with full penetration weld
- (j) the stub shaft housing at each end of the centre tube shall effect a gradual reduction in diameter and shall be weldable steel castings, to BS 6460 1979 equal. The stub shafts shall be steel forging to BS 970 Part 1; 1972 or equal and the fastenings to the housings shall not under any circumstances be subject to cyclical stressing. The stub shaft shall be readily removable from the housing prior to transport and readily replaceable at site. The stub shaft housing at each end should be sealed and equipped with an accurately machined face to which the stub shaft forgings are bolted
- (k) the whole assembly, with the stub shafts bolted on, shall be placed in a lathe and machined true after all the welding has been completed, except for the helix edge reinforcement strips
- (l) pumps shall be equipped with a side rail or splash plate which shall extend the full length of the trough and around 230° of the circumference. The splash plate shall be fabricated from G.R.P
- (m) sufficient tolerances should be provided throughout screws, associated bearings and transmissions to permit thermal movement of units due to ambient and operating temperatures.
- (n) all welding shall be by welders coded to BS 4871 and EN 287
- (o) all welding procedures shall confirm to BS 4870 and EN 288.

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Bearings

- (a) screws shall be supported at the top by a self aligning double spherical ball or roller bearing designed to accommodate the required axial and radial loads
- (b) thrust shall be transferred from the shaft to the bearing by means of a thrust ring. Circlips or locknuts are not acceptable
- (c) facilities should be provided for adjustment of bearings to permit realignment of the screw if necessary
- (d) bearing supports shall be of fabricated steel or cast iron and shall be of adequate area to transmit all live and dead loads to the concrete structures supporting them
- (e) a minimum of four holding down bolts shall be provided for each support
- (f) screws shall be supported at the bottom by ball bearings. The bottom bearing housing and mounting shall be designed to withstand radial and axial forces including any upward forces due to buoyancy during emergency sump level conditions. A sensing probe for any water entrainment on the bottom bearing housing shall be provided.
- (g) the two halves of the bearing shell shall be identical, so that they can be interchanged to equalise wear
- (h) seals shall consist of multiple split packing glands and labyrinth arrangement to protect the seals from any debris in the pumped medium. It shall be possible to renew the seals without removing the stubshaft, or supporting the screw.
- (i) alternatively the bottom bearing may comprise of an eco-friendly lubricated for life bearing, fully self aligning in all three axis. No grease lines shall be provided. The lower bearing housing shall be suitable for continuous or intermittent operation when submerged or running in air. The lower bearing housing shall be specifically designed to exclude the pumped liquid and shall contain not less than two lip seals running in a hardened section of the shaft. Confirmation that the lip seals are compatible with the lubricant (pumped liquid) shall be provided.

- (j) an external stationary split cast iron shroud shall be provided to prevent detritus damaging the bearing and seal
- (k) an external stationary split cast iron shroud shall be provided to prevent detritus damaging the bearing and seal
- (l) bearings shall be rated for an L10 life of at least 100,000h in accordance with BS 5512.

4 Gearbox

- (a) the screws shall be coupled to heavy duty totally enclosed, robust and oiltight speed reducing gearbox rated for continuous duty, having the output shaft at right angles to the input shaft
- (b) gearboxes shall be designed to operate continuously at the required angle of inclination, and shall have adequate oil capacity to avoid frequent attention and shall be equipped with a level indicator with maximum and minimum levels clearly marked
- (c) backstops shall be fitted to prevent reverse rotation of the screw when the motor is de-energised. This may be contained within main gearboxes, or be fitted externally in the form of a suitable brake
- (d) gearmotors in lieu of separate motor and gearbox are not acceptable
- (e) gearboxes shall be rated as AGMA standards, quality class 12 or higher, to handle the shock loadings appropriate to the prime mover, and shall be suitably derated to allow for frequency of operation, ambient temperature and running time
 - (i) the minimum calculated life under normal operation shall exceed 100 000 h as AGMA standards
 - (ii) adequate cooling facility for the gear box shall be provided. Cooling system equipments from the gear box manufacturer shall be procured.
 - (iii) cooling fins on the gearbox and/or fans shall not be permitted.
- (f) transmissions shall be capable of the withstanding maximum torque generated by the prime movers and shall be rated either 1.5 times the power needed to drive the gearbox at its specified capacity or 1.1 times the motor Kw rating, which ever is greater
- (g) gearboxes shall be directly driven through flexible couplings or 'V' belt transmissions, as specified
- (h) pump drives fitted with belt transmissions shall have a means for increasing the screw speed to achieve a future increase in capacity of not less than 10 %
- (i) belts shall be rated at 1.5 times the Kw rating of the motor, and shall be oil, heat and static resistant.
- (j) access for inspection purposes shall be allowed for in the design of the gearbox castings.

5 Drive motors

- (a) the drive motor shall be a totally-enclosed fan-cooled unit as Section 1
- (b) the motor and transmission shall be continuously rated and of adequate capacity to meet the power requirement of the pump
- (c) the motors shall be foot mounted near the gear box and supplied with slide rails where necessary for the adjustment of belt tension
- (d) motors shall be designed to operate continuously at the required angle of inclination
- (e) motors shall have power rating 1.15 times greater than the power required to drive the pump at its specified capacity, or be rated to drive the pump in emergency conditions, which ever is greater.

6 Bed Plate

The drive motor and gearbox shall be mounted on a substantial fabricated steel mounting bed plate. The base of the fabrication shall be suitable for mounting on a horizontal concrete mounting plinth. The fabrication shall be stress relieved when all welding is complete and prior to machining. The bed plate shall be provided with Tee slots for bolts to facilitate removal of the motor without lifting clear of studs or other protrusions.

7 Couplings

Two types of coupling shall be fitted on the screw pumps, as follows:

- (a) coupling between gearbox and screw pump. This shall be a flexible multipin and bush, rated as the gearbox. It shall include the following features:
 - (i) not less than six driving pins and bushes. The bushes shall have an inner sleeve to allow rotation in the pin. The pins shall all be shouldered
 - (ii) bosses shall be a tight fit in the shafts and shall be secured with hand fitted keys
 - (iii) couplings shall be machined balanced matching sets.
- (b) the coupling between the motor and gearbox shall be of the fluid coupling type to instantaneously protect the motor and gearbox should the screw become suddenly arrested in rotation. The coupling shall be fully rated to transmit the motor full load power without exceeding normal working temperature. The fluid coupling shall be rated to take account of the specified climate conditions and shall be tested and adjusted for static and dynamic balance. It shall incorporate the following features:
 - (i) the weight of the coupling shall only be taken on the motor shaft providing the motor shaft and bearing are adequate for the load without significant lift reduction. Alternatively, a separate support bracket shall be provided.
 - (ii) a flexible element between the coupling output shaft and the gearbox input shaft shall be provided. Bosses shall be a tight fit on shafts and secured with hand – fitted keys.
 - (iii) the casing shall be fitted with filler plugs and fusible plug for high fluid temperature protection in event of the screw pump becoming suddenly arrested in rotation.
 - (iv) internal bearings shall be adequately lubricated and all seals shall be efficient.
 - (v) the fluid used shall be inhibited against foaming oxidation and rusting and suitable for operating in the ambient temperature range as specified.
 - (vi) the filling of the coupling shall be carefully regulated to suit the torque characteristics of the Screw and Gearbox Unit during both the starting and running conditions.
 - (vii) the slip of the fluid coupling shall be taken into consideration when sizing the Screw Pump.

8 Screw Channel Covers

- (a) Insulated covers in glass reinforced plastic material shall be provided over all screw pumps. The manufacturer shall be a specialist firm approved by the Engineer.
- (b) Covers shall be manufactured using unsaturated polyester resin with a corrosion resistant layer on the underside of an approved resin of the vinyl ester type.
- (c) The top (or main) laminate shall be reinforced in the proportions 35% "E" glass as chopped strand mat to 65% resin.
- (d) The first intermediate (or internal) insulating layer shall be of polyurethane foam or polystyrene 50mm thick.

- (e) The second intermediate (or internal) layer shall be reinforced in the proportion of 10% "E" glass as chopped strand mat to 70% resin (with 20% filler). This layer shall have a minimum thickness of 0.1mm and a maximum thickness of 1.25mm.
- (f) The lower, corrosion resistant, layer shall be reinforced in the proportion 10% "C" glass veil or polyester tissue of 90% resin, this layer shall have a minimum thickness of 0.75mm and a maximum thickness of 1.00mm.
- (g) The total thickness of the internal and the corrosion resistant layers shall be 2.0mm.
- (h) The lower face of the corrosion resistant layer shall have a smooth surface finish as produced by contact with a mould.
- (i) The upper surface of the top layer shall be provided with a non-slip finish as produced by dusting the surface of the laminate with silica sand as soon as the resin has set to a soft gel and removing surplus sand after 24 hours.
- (j) To prevent weathering the covers shall be treated by painting or the addition of approved additives to the resin, to provide ultra-violet protection and to give a final colour to be approved by the Engineer.
- (k) Covers shall consist of individual units not exceeding 30kg in weight. All joints and fixings shall be made using stainless steel fittings and corrosion resistant gaskets all to the approval of the Engineer. Fixings shall be such that individual units can be removed and replaced from above.
- (l) Covers shall be capable of withstanding vertical loads of + 750 kg/m².
- (m) Lifting handles shall be manufactured from stainless steel to BS 970 Part 1, Grade 316 S31 and the fixing shall pass through the cover such that the handle and/or fixings can be readily replaced. Handles shall not be part of, or cast into, the covers.

9 Trough Liner

- (a) Screw pumps shall be mounted in steel troughs supplied and installed by the Contractor. The Contractor shall provide all necessary brackets and fixings for the adequate installation of the trough within the channel.
- (b) The Contractor shall be responsible for the final alignment of the trough to provide the correct clearances, and for the grouting-in of the trough.
- (c) The Screw Pump trough shall be a leak free mild steel fabrication of not less than 5mm thickness formed to give the correct clearances to the Screw Pump.
- (d) The trough shall extend between the pump inlet well and the discharge channel without distortion. The Contractor shall provide all necessary end and intermediate fixing/support brackets.
- (e) The trough shall be so shaped as to avoid 'wedges' between screw and side walls and to provide for return of any excess liquid or solids without interference with pump rotation.
- (f) GRP side profiles pieces shall be provided to contain the pumped liquid on the high water level side of the screw axis. The profiles shall be fixed to the steel trough and the channel side wall using approved stainless steel fixing bolts, to maintain a small clearance around approximately 230° of the screw circumference.

5.2.5 Factory Inspection and Testing

- 1 The Contractor shall secure from the pump manufacturer certification that the following inspections and tests have been conducted before shipment from the factory

- (a) inspection of all welds and 100% radiographic testing for full penetrated welding/butt welding and 100% Magnetic Particle Inspection (MPI) or Dye Penetration Inspection (DPI) for fillet welding as AWS D1.1 requirements
- (b) static deflection test (unloaded)
- (c) measurement of coating system thickness
- (d) testing of motor as required by Section 21.

5.2.6 Spare Parts and Tools

- 1 The Contractor shall provide, from the specialist manufacturers of the screw pump equipment, all the spares and tools required during the commissioning and maintenance periods as specified in Part 1, including those required below.
- 2 Special tools, if required for normal operation and maintenance, shall be furnished with the equipment.
- 3 The following spare parts shall be provided for each pump size:

| | |
|------------------------------|--------|
| Bottom bearing | 1 set |
| Lubricant pump system | 1 set |
| Gearbox bearings and gaskets | 1 set |
| Belt drives | 1 set |
| Top bearing | 1 |
| Coupling rubbers | 1 set |
| Torque release coupling | 1 |
| Bearing seals | 1 set |
| Rupture discs | 2 sets |

5.3 INSTALLATION AND COMMISSIONING

5.3.1 Installation

- 1 The Contractor shall arrange to have the manufacturer or supplier of the equipment furnished under this Part provide the services of competent factory-trained personnel to supervise the installation and initial operation. Installation of all assemblies and components shall be in accordance with the details indicated on the approved shop drawings and the printed instructions of the manufacturer.

5.3.2 Site Inspection and Testing

- 1 The Contractor shall operate each pumping unit over the entire designated operating range. The operation over the entire range shall be free of vibration and noise.
- 2 The screw shall be run dry and the following monitored over a 1 day period:
 - (a) motor power consumption
 - (b) gearbox, top and bottom bearing temperature
 - (c) lubricant temperature
 - (d) Backstop temperature.
- 3 The screw shall be run with water in and the following monitored over a 7 day period
 - (a) water flow rate or depth of water the screw is immersed
 - (b) motor power consumption

- (c) gearbox and top bearing temperature
 - (d) lubricant temperature
 - (e) backstop temperature
- 4 At the end of the 7 day period the Contractor shall change the lubricants and filter in the bottom bearing lubricant system and the gearbox. The oils shall be analysed for any contaminants at an accredited laboratory. After a further 3 months the contractor shall return and sample the oil in the both systems. These shall be analysed as above. If excessive levels of contaminants are present in the oil, then the Engineer will instruct the Contractor to take action accordingly.
- 5 The lubricants shall be changed at the end of the guarantee in all the rotating elements of the screw pumps. These shall be analysed as above for contaminants.

END OF PART