GENERAL SPECIFICATION

GIBB 003 – GENERAL PUMPING EQUIPMENT

REV 1.1

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Table of Revisions

Revision	Date	Change Detail	Editor
1.0	December 2020	Initial Release	C. Maine / M. Holmes
1.1	March 2021	Changed Pump Witness Testing to SANS 9906 Grade 1E (with efficiency included as a guarantee requirement). and SANS 9906 Grade 2B	M. Holmes

1 SCOPE

This Specification deals with the manufacture, supply, performance guarantees, installation, testing and commissioning of pumps (sizes DN 100 to DN 600 and pressures PN 10 to PN 25) for handling potable and raw water.

The installation shall be as shown on any applicable drawings provided with the tender documents.

The numbers and sizing of equipment to be provided are specified on any applicable drawings provided with the tender documents.

This Specification is to be read in conjunction with the applicable Project Specification.

2 INTERPRETATIONS

2.1 Normative References

The following Particular Specifications are referred to in this Specification:

a) GIBB-002: General Mechanical Specification
b) GIBB-007: Painting and Corrosion Protection

The following Standards and Codes of Practice are referred to in this Specification:

American National Standards Institute

ANSI B4.1	Preferred limits and fits for cylindrical parts

American Society of Mechanical Engineers

ASME Section VIII	Boiler and Pressure Vessel Code, Division 1 for Unfired Pressure Vessels

British Standards Institution

BS 916	Black bolts, screws and nuts
BS 970	Wrought steels in the form of blooms, billets, bars and forgings
BS 1452	Specification for grey iron castings
BS 2789	Specification for spheroidal graphite or nodular graphite cast iron
BS 3100	Specification for steel castings for general engineering purposes
BS 3468	Austenitic cast iron
BS 4080	Methods for non-destructive testing of steel castings
BS 4504	Flanges and bolting for pipes, valves and fittings
BS 5316	Specification for acceptance tests for centrifugal, mixed flow and axial pumps
BS EN 1092	Flanges and their joints. Circular flanges for pipes, valves, fittings and accessories, PN designated. Steel flanges

South African Bureau of Standards

SANS 1109	ISO pipe threads for pipes and fittings where pressure-tight joints are made on the threads
SANS 0140	Identification colour marking (Part II)
SANS 10108	The classification of hazardous locations and the selection of equipment for use in such locations

SANS 1123 Pipe flanges

SANS 9906 Rotodynamic pumps - Hydraulic performance acceptance tests – Grade 1, 2 and 3

International Standards Organisation

ISO 9001 Quality assurance

ISO 9002 Quality systems. Model for quality assurance in production, installation and service

ISO 9906 Rotodynamic pumps - Hydraulic performance acceptance tests - Grades 1, 2 and 3

When reference is made to a code, specification or standard, the reference shall be taken to mean the latest edition of the code, specification or standard; including addenda, supplements and modifications and revisions thereto, unless otherwise specified.

2.2 Definitions

For the purpose of this document:

a) "Flow rate" means the volume of liquid passing through the pump per unit of time;

b) "Materials" includes both the basic materials used in the manufacture and fabrication of the pump-sets themselves as finished products that are to be installed and commissioned;

c) "Nominal diameter (DN)" means a numerical designation of size that is common to all components in the piping system other than components designated by outside diameters. It is a convenient round number for reference purposes and is only loosely related to the manufacturing dimensions in millimetres.

d) Nominal size is designated by DN followed by the size in millimetres.

e) All equipment of the same size (DN) designated by the same PN number shall have compatible mating dimensions.

f) "Nominal pressure (PN)" means a numerical designation which is a convenient round number for reference purposes.

g) The maximum allowable working pressure depends upon the materials design and working temperature and shall be selected from the pressure/temperature rating table in the appropriate standards. It is the internal pressure corresponding to the maximum allowable working pressure.

h) "Static head" means the difference between the free water surface levels (or equivalent pressure heads) on the suction and delivery sides of the pump when the pump is not in operation.

i) "External friction head" means the head required to overcome the friction external to the works provided under this contract.

j) "Plant losses" means the friction losses in all pipe-work, specials and valves within the limits of this contract.

k) "Velocity head" means the head given by $(v^2/2g)$ at the point of pressure measurement.

l) "Total manometric head" (TMH) is the sum of h), i), j), and k).

m) "NPSH Available (NPSHA)" defines the total pressure at the suction nozzle for a given liquid at a certain flow rate and is independent of the pump itself.

n) "NPSH Required (NPSHR)" is a pressure characteristic of the particular pump and is given by the manufacturer. The head in metres of water required above the reference plane, according to BS 5316 (impeller centre line for horizontally mounted centrifugal pumps) to ensure that cavitation does not occur.

o) "Duty point(s)" means that point (or series of points) on the pump Q-H characteristic curve(s) for the required performance of the pump as stated in terms of total manometric head(s) in metres and minimum required flow rate(s) in m^3/s or l/s or m^3/hr.

p) "Motor power input" means the power absorbed by the motor that is driving the pump.

q) "Coupling" means any process of jointing (except welding) the pump shaft to the motor shaft.

r) "Special" means any pipe other than a straight pipe. Under this definition are included all sizes of specials of shapes such as bends, tees, crosses, angle branches, reducers, and tapers.

s) "Pumpset" means one pump unit together with associated motor, coupling, baseplate and auxiliaries to deliver the specified quantity at the specified head, and all ancillary equipment.

t) "BEP" means best efficiency point which is the point on the pump curve at which the efficiency of the pump is the highest.

2.3 Abbreviations and Material Symbols

For the purpose of this Document, the following abbreviations shall have the meanings given:

AC	:	Alternating current
BEP	:	Best Efficiency Point
CI	:	Cast Iron
DI	:	Ductile Iron
DC	:	Direct current
DFT	:	Dry film thickness
DN	:	Nominal diameter
D/S	:	Downstream
H	:	Total manometric head
IP	:	A symbol which, followed by two characteristic numerals, signifies the degree of mechanical protection to ingress of foreign bodies and water as defined in SANS 1222.
LCD	:	Liquid crystal display
LV	:	Low Voltage (typically V < 1000)
MV	:	Medium Voltage (typically, in this context, 1000 < V ≤ 11000)
MFD	:	Mechanical Flow Diagram
P&ID	:	Process and Instrumentation Diagram
PN	:	Nominal pressure
Q	:	Flow rate
SG	:	Spheroidal Graphite
TP	:	Test pressure
U/S	:	Upstream
VSD	:	Variable Speed Drive
NPSHA:	:	Net Positive Suction Head Available
NPSHR:	:	Net Positive Suction Head Required
Q-H	:	Flow- Head relationship
rms	:	root mean square

3 DESIGN & GENERAL REQUIREMENTS

3.1 General

Pumps and ancillaries shall comply with all of the following requirements and shall be capable of withstanding the applicable test pressure specified in this document.

The materials used, the design and the protection provided shall comply with the relevant requirements set out in this document. The Contractor shall justify the type of pump selected by taking into consideration specific speed calculations, efficiency and reliability.

The manufacturer shall operate a quality assurance system approved to ISO 9001 (and ISO 9002) (latest edition) for the manufacture of pumps and pumping systems in addition to the manufacturer's project management activities.

Hydraulic performance criteria are as outlined in the applicable Project Specification.

3.2 Tender Submission

The Tenderer shall submit with this Tender for each pump offered the following characteristic curves:

With respect to flow:

- total head;
- power demand;
- efficiency;
- net positive suction head (NPSH) requirements, critical and 3% "head loss"

With respect to speed:

- torque requirements rated in absolute units.

Where variable speed pumps are required, the pump characteristic curves submitted for approval shall include a range of curves (at least 6) for different speeds and which indicate the maximum and minimum speeds possible.

Alternatively, NPSH requirements related to 3% drop in head may be given, if preferred, as long as the method of presentation is clearly stated.

These characteristic curves are to be submitted with water flows covering the full possible pump operating range, including transitions between set points where the pump speed is adjusted.

The Contractor may be called upon to provide further curves at the request of the Engineer, especially for starting and stopping analysis, in connection with surge analysis in the rising mains.

3.3 Type & Arrangement of Pumps

In general the Pump type is specified in the Project Specification if not, equipment and designs which have not previously been in common use in South Africa, shall not be acceptable unless the Engineer agrees in writing.

Arrangements incorporating multiple pump units coupled in series to achieve the duties specified in the particular specifications will not considered unless otherwise specified.

Variable speed functionality, if required, shall be specified in the Project Specific Pump Specification GIBB-004.

The arrangement of impellers shall be such as to reduce the residual axial thrust to a minimum.

Designs incorporating a double suction to balance thrust will be preferred.

Pumps incorporating balance discs and/or balance drums are not preferred for raw water.

The orientation and arrangement of the suction and delivery pipes and pumpsets shall be generally in accordance with the Tender drawings. The layout shall be designed to facilitate maintenance whilst being designed for minimum losses and no air traps.

Particular attention in the selection of all pumps, and the respective systems they are working in, under the range of working conditions required, taking all vane pass induced pulsations and the fundamental frequency of various parts of the system into account, and ensure that the system(s) have adequate natural damping.

3.4 Pump Characteristics & Performance

3.4.1 Duty Point(s)

The required pump duty point(s) are as set out in the Project Specific Pump Specification (GIBB-004).

Unless specified to the contrary, the proposed pumps shall be able to operate without perceptible signs of cavitation in the full range of heads specified, pumpsets running singly or in parallel.

The specified operating points (whether there will be one operating point or multiple operating points or a range of operating points) shall be within the pump manufacturer's recommended operating range for the pump as tendered and adequate information shall be provided in the tender to confirm this.

3.4.2 Best Efficiency Point & Impeller Characteristics

The pump operating point shall be generally to the right of the pump's best efficiency point for the chosen impeller size and speed unless there is another overriding factor which affects the choice of pump.

Pump impellers shall have the characteristic of generally decreasing head with increasing capacity from shut-off to maximum capacity.

3.4.3 Efficiency

The efficiency curve shall be flat over a wide range in order to provide efficient working with various pump operating conditions. Where specified, it shall conform to the requirements of the Project Specification.

3.4.4 NPSHR

NPSHR curves for both 0% and 3% cavitation shall be included with the pump characteristic curves.

Should the pump manufacturer not have made such tests, the Engineer will make the following assumptions to obtain an approximate 0% head drop curve to ensure that cavitation does not occur because of insufficient suction pressure when the NPSHA calculations are made:

a) On the left hand side of the 3% curve, 150% will be added to the value shown;
b) At the BEP of the 3% curve, 40% will be added to the value shown;
c) On the right hand side of the 3% curve, 50% will be added to the value shown; and
d) Atmospheric pressures shall be measured at sea level less 1 m, to allow for low atmospheric pressure conditions.

3.4.5 Pumped Liquid

The pumps shall be able to handle the designated pumping medium without corrosion, erosion or abrasion throughout its designated life cycle.

3.4.6 Specific Intake Velocity

Specific intake velocity, also referred to as *suction specific speed*, S, (defined hereunder) shall under no circumstances exceed the value of 185 per impeller inlet, unless detailed and acceptable justification is given.

$S = nQ^{0.5} / (Nsh)^{0.75}$

Q = capacity in m3/s (if double entry impeller, equals half pump capacity)

Nsh = absolute suction head in metres (Nsh = Ha - Hs - Po)

Ha = atmospheric pressure at the elevation of the pump in metres of water

n = rotational speed in revolutions per minute

Hs = difference in level of the highest point of the impeller entry above the water level on suction side, increased by the head losses in the suction line in metres of water.

Po = vapour pressure in metres of water.

3.4.7 Impeller

The pumps shall have stable, non-overloading characteristics.

No pump, with a constant speed driver, which requires a maximum or minimum diameter impeller to meet the rated pumping conditions will be acceptable.

The impeller diameter shall be such that at least a 5% increase in head at the rated capacity can be obtained by installing a larger diameter impeller of the same pattern. Minimum allowable diameter shall be at least 105% of the pump supplier's minimum catalogue diameter.

3.4.8 Operating Speed

Pump shaft rotational speed shall not exceed 1 500 r.p.m unless explicitly stated in the Project Specifications.

3.4.9 Operating Temperature

Each pump and electric motor shall be capable of operating satisfactorily at an assumed maximum shade temperature of 45ºC. The temperature of the pumped liquid will not exceed 25ºC.

3.4.10 Vibration Standards

A machine will not be acceptable if vibration is not within the prescribed limits below. Maximum vibration amplitudes are specified on bearing housings measured in the horizontal, vertical and axial planes. Machined surfaces (50 mm x 50 mm) shall be provided for these measurements on the housings.

Pumpsets shall be accurately balanced statically, dynamically and hydraulically in accordance with ISO 1940 Grade G6.3 or approved internationally recognised Standard.

4 MATERIALS

4.1 Pump

Generally:

- Pump bodies shall be cast and shall be coated internally.
- Materials highly resistant (such as high chrome iron) to corrosion/erosion/abrasion shall be used to make the impellers, wear plates, wear rings and liners (as applicable).

Pump materials shall comply with the following or at least be equivalent and as amended in the Project Specifications.

For large pumps (Larger than 50kW):

Table 1: Minimum material requirements for large pumps

PUMP COMPONENT	MINIMUM MATERIAL	MINIMUM GRADE
Impeller	Bronze	
Casing wear rings & impeller wear rings	Stainless steel or non-ferrous material	
Volute casing	Ductile iron	EN-GJS-400-18
Shaft	Chrome steel or stainless steel	431
Shaft sleeves	Phosphor-bronze (PB1)	

PUMP COMPONENT	MINIMUM MATERIAL	MINIMUM GRADE
All fasteners, mechanical seals and all auxiliary steel components	Stainless steel	316

For small pumps (smaller than 50 kW):

Table 2: Minimum material requirements for small pumps

PUMP COMPONENT	MINIMUM MATERIAL	MINIMUM GRADE
Impeller	Gray cast iron	DIN GG-25
Casing wear rings & impeller wear rings	Stainless steel or non-ferrous material	
Volute casing	Cast iron	BS 1452 Gr 260
Shaft	Medium carbon steel	DIN C45 N
Shaft sleeves	Phosphor-bronze (PB1)	
All fasteners, mechanical seals and all auxiliary steel components	Stainless Steel	316

Other approved international standards may be considered. Alternative materials may be considered by the Engineer.

4.2 Care in Handling

The Contractor shall provide temporary end covers that adequately, in the opinion of the Engineer, protect flanges and threads, and prevent damage to internal lining during transportation and during handling on Site.

The pumps shall be so transported, stored, and handled that they are not overstressed at any time and are not damaged in any way. Pumps damaged or cracked in any way shall be removed from the Site.

4.3 Dimensions and Assembly

All parts shall be of ample dimensions and strength and of the best and most suitable material, corrosion-resistant, free from flaws, accurately machined, properly assembled and fitted so as to avoid initial stresses and to ensure free running. All fittings such as packing glands, shaft assemblies, thrust bearings and plummer blocks shall be of adequate size and sound design.

Each pump shall be provided with a cast-in or permanently attached metal plate with direction-of-rotation arrow.

4.4 Flanges & Accessories

All pumps and ancillaries shall be supplied complete with couplings and jointing material. Each flange and fitting shall be supplied complete with one insertion piece of the appropriate diameter and made of a material that is suitable for the maximum working pressure, such as rubber for small diameter low pressure pipelines or compressed fibre cement or other approved material for medium to large diameter and medium to high (2.5 MPa and over) pressure pipelines, and one set of bolts and nuts. The drilling of steel and CI flanges shall conform to the requirements of SANS 1123 or BS EN 1092 or BS 4504 : Part 1, as applicable, appropriate to the class of pipe specified, except that in the case of flanges, where M27 and M33 bolts are specified in BS 4504 : Part 1, M24 and M30 bolts, respectively, shall be used as specified in SANS 1123. The minimum pressure rating of flanges shall be 1.0 MPa.

4.5 Compatibility of Materials

The responsibility for selecting materials, which are compatible with the liquids or surroundings with which the equipment comes into contact, to prevent corrosion and/or abrasion rests with the Contractor. The materials used shall be at least equal and approved to those specified in this Specification and the Project Specification. Materials selected for manufacturing of the pumps shall

conform to the applicable material specifications which are described in above and Appendix B hereof.

4.6 Corrosion Protection

All components shall be suitably designed for corrosion resistance.

Corrosion Protection shall comply generally with the following unless mentioned specifically in the Particular Specification GIBB-007 *Painting and Corrosion Protection*.

Grey cast iron and ductile cast iron wetted parts shall be provided with corrosion resistant coatings over their full wetted surfaces. The coating shall be applied directly to the correctly prepared metal surface. The system's dry film thickness shall be about 500 microns and shall not be less than 450 microns. The system used shall be specifically suitable for pump internals such as a solids bearing vinyl ester acrylic copolymer such as Corrocoat Polyglass VEF or a ceramic coating such as Belzona 1321 or equivalent.

Where abrasion resistance is required, a suitable coating shall be provided over the pump's full wetted surface. The coating shall be specifically suitable for pump internals. The system's DFT shall be about 1 500 microns and shall not be less than 1 200 microns. The coating shall be specifically suitable for pump internals such as a solids bearing vinyl ester copolymer of about 1 500 microns such as Corrocoat Armagel, or a ceramic carbide such as Belzona 1811/1812 or equivalent.

The coatings shall be applied in accordance with the coating supplier's method statement.

Decorative colours shall be in accordance with the Code numbers shown in BS 381C and SABS 1091, SANS 1200 HC as applicable, or otherwise specified in the Project Specifications or as directed by the Engineer.

5 DESIGN & CONSTRUCTION

5.1 Horizontally Split Casing Centrifugal Pumps

The casing shall be of the volute type, split on the rotating element centre line. Both branches shall be cast in the lower portion making it possible to inspect the pump interior and remove the rotating parts without breaking pipe joints or interfering with the alignment.

Volute casings shall be fitted with renewable phosphor bronze or other approved material casing eye rings at the points of running clearance.

The multi-channel, shrouded impellers shall be of the double entry type with, with optimum vane geometry to provide high efficiency, low NPSHR and minimised pulsations in the discharge. Impellers shall be hydraulically, statically and dynamically balanced for two stage pumps, and of the single entry type for single-stage pumps. For multi-stage pumps the impellers shall be mounted back to back to ensure balanced thrust.

All horizontal pumps with two or more stages and all horizontal double suction pumps shall have the impellers mounted between bearings.

Design requirements for split casing pumps:

a) All parts shall be of ample dimensions and strength and made of the best and most suitable materials, corrosion resistant, free of flaws, accurately machined, properly assembled and fitted so as to avoid initial stresses and ensure free running. Where end thrust is unavoidable, adequate long wearing thrust bearings shall be fitted.
b) The horizontal axially split casing shall have the suction and delivery branches in the lower half of the volute casing.
c) The shaft shall be designed for arduous service conditions.
d) Shaft sleeves, which are replaceable, shall be fitted throughout the waterways. The sleeves shall be screwed or either locked to the shaft by means of lock nuts.

e) Bearing housings shall be axially split to allow easy removal of the complete rotating element. The housing shall contain an oil bath and labyrinth seals to secure oil retention and a bearing oil feeder.

f) Replaceable-wearing rings shall be fitted to the impeller and volute casing.

g) The pump shall run quietly over a wide operating range.

h) Requirements for bearings are detailed below:

i) Split Casing pumps shall be able to operate in the vertical or horizontal position, as specified or shown on Drawings.

j) Vertically installed pumps and motor shall include approved support pedestals and a Hardy Spacer, flexible drive shaft or equal approved by the Engineer.

k) Horizontally installed, pumpsets shall be direct coupled by means of an approved flexible coupling and mounted on a substantial base-plate.

l) The shaft bearing support shall also be unaffected by removal of the upper casing; i.e. the bearing housings shall be supported separately from the upper casing.

m) Base plates shall be of rigid design. Fabricated steel base plates shall be stress relieved before any machining is done, and accurately aligned on site.

n) Safety guards shall protect shafts and couplings. The guards shall be removable and of an approved design.

5.2 Other Pumps

Requirements for other pump types required for this contract are detailed in the Project Specific Pump Specification GIBB-004.

5.3 Pump Casing

5.3.1 General

All the pressure casings shall be of such thickness as will be suitable for the maximum discharge pressure (plus surge pressure) at pumping temperature and hydrostatic test pressure at ambient temperature, with a 3 mm minimum corrosion allowance. Casings shall have stiffening ribs at all points of high stress. Particular care shall be exercised in designing a pump casing, which will resist the tendency to crack through the cutwater or guide passage walls during the pressure tests, and the Tenderer is to indicate clearly in his tender the design features incorporated in his pump to ensure that this requirement is satisfied.

The design stress used for any given materials shall not be in excess of the values given in ASME Section VIII, Division 1 for "Unfired Pressure Vessels" for the same material. For cast materials, the factor specified in the ASME Boiler and Pressure Vessel Code shall be applied. Pressure casings furnished of forged steel, rolled and welded plate, or seamless pipe with welded cover shall comply with the applicable standards of ASME Section VIII, Division Cl.

Pumps shall be furnished with suction and discharge flanges integrally cast with the casing and complying with Cl 4.4 above. Where the pump supplier's standard pattern offers a flange thickness and diameter greater than that specified, the heavier flange may be furnished, but it shall be drilled as specified. All cast iron casings with flanges or other bolted mating surfaces shall have a full width gasket surface.

Pumps shall be provided with a vent connection unless the pump is made self-venting. All horizontal drive pumps shall be provided with a drain connection.

The backs of all flanges shall be machined full-face or spot-face and bolt holes shall straddle the horizontal and vertical centrelines. All vent, lantern ring, case drain, or seal recirculation connections on pumps shall be threaded according to SANS 1109.

Preference will be given to a design and arrangement of the pump casing which ensures that it is unnecessary to disconnect the delivery pipework in order to remove or replace the complete rotating element.

Where the pump type allows, provision shall be made on each pump for removing the pump casing cover and the shaft assembly without disturbing the motor drive.

All slings, shackles, spread bars, cradles and other equipment necessary for the lifting of components of the pumpset for installation or maintenance shall be provided by the Contractor and handed over to the Employer's Agent on completion of the Contract.

5.3.2 Castings

Castings shall be sound, free from shrink or blow holes, scale blisters and other similar defects. The surfaces shall be cleaned by the supplier's standard methods. All casting burrs shall be filed or ground flush with the surface of the casting.

No welding, burning, filling or plugging of defective castings shall be permitted without the Engineer's permission in writing, following an inspection of the defects. The repair of leaks and defects in pressure castings shall be allowed only after the approval of the Employer's Agent has been obtained. It shall then be done strictly in accordance with rules of Section VIII of the ASME Code.

5.3.3 Casing eye rings

Renewable phosphor-bronze (PB1) eye rings or similar approved shall be provided on all pumps.

5.4 Impellers

Pinning of the impeller is not acceptable. All impellers shall be statically as well as dynamically balanced, the latter at not less than half the rated speed.

All water passages shall be polished to a smooth finish; water passages which cannot be machined shall be hand ground and filed to a template. The castings shall be free of blow-holes and other defects. No welding, burning, filling or plugging of defective castings shall be permitted without prior approval being obtained from the Employer's Agent in writing, following an inspection of the defects.

Entrance to the vanes at the eye of the impeller shall be smooth and leading edges of the vanes shall be ground to the optimum profile consistent with best efficiency and cavitation-free operation.

Lines showing the designed width of the water passage at the outlet shall be scribed on the impeller periphery when the impeller is being machined. The internal surfaces of the impeller shall be finished off to these machined lines smoothly and symmetrically; bevelling the metal to conform to the scribed lines will not be accepted.

Impeller shrouds shall be of adequate thickness after they have been machined, the thickness depending on the impeller diameter. Impellers for similar pumps shall have the same outside diameter and shall be interchangeable.

Where impeller eye-rings are not fitted, the design of the impeller eye shall be such that sufficient thickness is left so that material can be machined away at a later stage and either impeller eyerings, or undersize casing eyerings fitted. Replaceable wearing rings shall be made of the same material as the impeller. These rings, which shall be "L" cross-section, shall be secured to the impeller with non-corroding screws and mechanically locked.

The rotating assembly shall be designed to have its first critical speed at least 25% above the maximum operating speed.

5.5 Diffusers

Where fitted, diffusers shall be cast in an approved zinc-free bronze or stainless steel and shall be finished smooth all over.

5.6 Pump Shaft and Sleeves

5.6.1 Shafts

The Contractor shall ensure that both the critical speed and torsional oscillation characteristics of the combined pump and motor rotating elements are satisfactory for all possible conditions of operation.

Shafts shall be of sufficient dimensions to transmit the power to which they will be subjected, without undue torsional or bending stresses and deflection. They shall be designed to be resistant to pitting corrosion and fatigue failure.

The shafts shall be stress relieved after initial machining, and ground to final size. The manufacturer shall take special care to avoid sharp radii. Shaft failures due to corrosion are common and the manufacturer shall indicate which steps he has taken to prevent the occurrence of pitting corrosion in pump shafts.

The shafts shall be suitably designed for the reception of the impeller which shall be adequately secured to the shaft in such a manner as to be readily removable without damage to either the shaft or the impeller. They shall be held axially and radially by roller or deep grooved ball bearing. The impeller shall be driven by a sunken shaft key.

Provision shall be made on each pump shaft or coupling for checking speed by means of a hand tachometer of the reflective digital read-out type.

5.6.2 Shaft Sleeves

The shafts shall be adequately protected with replaceable sleeves of an approved bronze or other similar approved non-corrodible material at all areas where wear and/or corrosion could possibly be expected. These sleeves shall be readily removable without causing damage to either the shaft or the sleeves.

Replaceable shaft sleeves shall be made of phosphor-bronze or other approved material. Sleeves shall be ground with a polished finish on the wearing surface. They shall be fitted to all pumps where the shaft passes through the stuffing box. The sleeve shall extend a minimum of 3 mm beyond the gland plate.

Where the pumped fluid is incompatible with the shaft material, suitable sleeves which afford full protection to the shaft shall be fitted.

5.7 Shaft Seals

Unless otherwise stated in the Project Specifications, mechanical seals are the preferred means of shaft sealing.

5.7.1 Glands and Stuffing Boxes

Soft-packed stuffing boxes of ample depth shall be provided where gland packing is specified. Easily removable lantern rings shall be used in all pumps with a liquid or grease seal, and these lantern rings shall be provided with inlet and outlet connections.

Stuffing boxes shall have not less than four rings of packing plus the lantern ring and renewable-type non-ferrous throat bushings. The make and type of packing shall be to the Engineer's approval.

Stuffing box glands shall be easily removable and must permit replacement of packing without removal or dis-assembly of any other part of the pump.

Glands shall be made with completely enclosed bolt holes. Slotted holes open at one side are acceptable only if studs are provided for securing glands. Gland bolts and nuts shall be of grade 304 stainless steel or other material as approved. Gland leakage from the pumps shall be led through suitable tubing to a point immediately outside the pump house or the nearest point inside the pump house provided for this purpose.

If the quality of the water necessitates filtration, the Contractor shall provide the appropriate equipment. Filters shall (as a minimum), be of the "twin-barrel" (quick change-over) type and must default automatically to "bypass" in the event of blockage. The flow of water to or from the glands shall be clearly visible.

In the case of multi stage pumps, the gland pressure shall not exceed the maximum suction supply pressure without the written approval of the Engineer.

5.7.2 Mechanical Seals

The Contractor shall be responsible for obtaining a full guarantee from the seal manufacturer for the seals provided. Seals shall comply with a) or b) below.

The design of the seal gland plate shall have a throttle bushing to restrict the flow to atmosphere in the event of a seal failure.

The mechanical seals shall be capable of resisting without leakage both the suction and discharge pressure as specified.

If cooling water is required for the mechanical seal, full details shall be submitted by the Contractor at tender stage.

The design of the seal shall be such that the static head on the pump discharge induces a closing action on the seal to ensure that no leakage occurs during pump shut-down.

a) Potable water

A single self-aligning balanced mechanical seal manufactured in specified material (Cl 4) and fitted with at least matched solid tungsten carbide (or other approved) rotating and stationary faces shall be supplied.

An external flush shall be provided to ensure heat dissipation through circulation. Unless otherwise specified, seals requiring an independent source (i.e. not the pumped medium) of cooling water are not favoured. See Cl 5.7.3 below for further requirements of water to the seals.

b) Abrasive liquids

A double self-aligning mechanical seal manufactured in specified material (Cl 4) and fitted with at least either carbon on ceramic (for water lubrication) or carbon on solid tungsten carbide (for oil lubrication) shall be fitted on the end of the seal not in contact with the liquid being pumped. At least solid tungsten carbide on solid tungsten carbide shall be fitted on the end in contact with the pumped liquid. If specified, or should the Contractor consider it to be necessary, seals of greater technical sophistication (than tungsten carbide) shall be fitted.

If required, an independent (i.e. not the pumped medium) fresh water (or oil) flush shall be provided. Care shall be taken to ensure that the pressure of the flushing fluid is at least 100 kPa greater than the pressure of the liquid on the inboard side of the seal. See below for further requirements of water to the seals.

Built-in or integral type seals are unacceptable.

5.7.3 Water to the Seals

Where filtration is required, flow and pressure sensors shall be provided in the pipework between the filter (or cyclone) and each shaft seal and these shall be incorporated into a protection loop to prevent dry running. Stainless steel ball isolation valves shall be provided in suitable positions to enable the filter (or cyclone) and the flow indicator to be serviced without having to shut the pump's isolation valves. Valves shall be lockable in the open position. If a cyclone is used, its discharge shall be piped to return to the suction pipework. Pipework shall be of stainless steel, rigidly supported.

Stainless steel piping or tubing shall be used for the flushing fluids to mechanical seals. Tubing fittings and ferrules shall be stainless steel. Copper tubing and brass fittings are unacceptable.

Auxiliary piping connections shall be plugged with solid plugs. Carbon steel plugs shall be used with cast iron casings; otherwise the plugs shall be of the same metals as the casing material. Plugs shall have a shank to permit the use of a pipe wrench.

5.8 Pump Bearings and Lubrication

5.8.1 Bearings

Bearings shall generally comply with the requirements of the relevant Particular Specification.

If the type of bearing required for the pump is not specified, then the bearings shall be of the type recommended by the pump manufacturer. The particular type and system offered by the Tenderer shall be fully specified. The bearings in the pump casing together with the lubricating system shall be suitable for the particular circumstances described in the Specification.

A minimum bearing life of 100 000 hours is required.

All bearings shall be suitable for shaft rotation in both directions.

The pump rotating element shall be positively located in the axial direction. Where necessary a thrust bearing shall be provided to accommodate the end thrust of the impeller(s), and the mass of the rotating element. Thrust bearings for vertical pumps may be located in the drivers.

Slide/journal bearings shall preferably be configured for air cooling and oil-ring lubrication but more complex methods of cooling and lubrication are acceptable if recommended by the pump manufacturer.

The journal bearings of large, slow revving and multi-stage horizontal pumps shall generally be white-metal lined bronze sleeves, split on the horizontal centre line, and/or "Glacier" bearings as specified by the pump manufacturer.

To facilitate replacement, the bearing numbers for all bearings shall be given together with other data to be provided by the Contractor.

When the pumps are controlled by VSD the bearings shall be insulated from the frame to prevent damage by any shaft stray currents which may be produced.

Grease-lubricated bearings shall be sealed or re-greasable. Ball or roller bearings shall be loaded conservatively in order that the grease may be renewed at intervals of not less than one year and they shall not be equipped with grease nipples or cups. If these are supplied, they shall be replaced with threaded plugs. For purposes of maintenance, end-shield bearings are preferred.

Preferably the same type of bearing will be chosen for motor and pump; if not, the necessary allowance shall be made when aligning pump and motor.

5.8.2 Bearing Housing

Bearing housing closures of the labyrinth type ‘slinger’ are required on horizontal pumps at each point where the shaft projects through the bearing housing, except that mechanical oil seals shall be accessible at the coupling end of the bearing housing.

A non-labyrinth type slinger is acceptable on the stuffing box end seal. Bearing housings of vertical pumps shall have equally adequate protection.

5.8.3 Safety Instrumentation

Bearing temperature and vibration sensors shall be provided as stipulated in Cl 11 herein and as modified by the Project Specification.

5.8.4 Cooling of Lubricating Oil (if applicable)

All bearings shall be designed to run continuously in ambient temperatures of the order of 40^{o}C.

The cooling of the oil may be natural or by forced air circulation or by water circulation through coolers. Natural or forced air circulation is preferred.

If water cooling is necessary, stainless steel oil/water coolers shall be incorporated in the bearing oil reservoirs. Where water cooling is employed, the system shall make use of water of the same quality as the water being pumped. All cooling water pipework, valves and fittings shall be of compatible material. The water side of the cooler tube assembly shall be hydraulically tested after installation has been completed, to 3 times the maximum working pressure. Test pressures shall be maintained for 30 minutes and witnessed by the Engineer. The oil cooler shall be easy to clean out.

5.8.5 Lubrication

All internal surfaces in continuous contact with the lubricating oil such as oil reservoirs, piping, etc, shall be thoroughly cleaned either chemically or by shot blasting and protected by a method to be approved by the Engineer until such time as the system is charged with oil. No site welding of oil circulating pipes will be permitted.

Circulation oil lubrication systems incorporating pumps, when required, shall include:

- Two 100% duty motor driven oil pumps;
- Two 100% rated full-flow oil filters;
- Duplicate pressure relief valves;
- Oil pressure relays;
- Enclosed oil reservoir with level indicator and oil filter and drier breather;
- All necessary piping, valves, gauges, relay switches, alarms etc.

The entire lubricating system shall be fail safe with alarms set to indicate automatic change-over to the stand-by unit.

Selection of duty pump shall be made by a manual selection switch.

5.9 Couplings

The pumps and motors shall be direct coupled with an approved type of flexible coupling which will take up minor misalignment or off-setting of the motor and pump shaft satisfactorily. Flexible tyre-type couplings are acceptable for pumps coupled to motors up to 100 kW. Where motors are rated above 100 kW, all metal (curved tooth or similar) couplings shall be used in all horizontal drive units. Where applicable, provision for adequate lubrication shall be made.

The coupling shall be designed in such a manner that no axial or radial loads will be imposed on the motor and pump bearings in excess of the loads approved by the motor and pump manufacturers respectively for the installation offered. Spacer couplings shall be provided with pumps of the back pull out type, where mechanical seals are fitted or where frequent maintenance is likely to be required.

The couplings shall be robust, shall be readily dismantled and reassembled, and shall have a service factor of at least 2

Couplings shall be balanced as specified in 3.4.10.

For coupling alignment, see Section 8.

5.10 Electric Motors

Refer to Standard Specifications for LV and MV Motors, and to the applicable Project Specifications.

Unless otherwise specified, pump motors shall be selected so that the motor power rating is at least 15 % above the shaft power required by the pump for the application. In variable speed applications, this requirement applies to the pump operating point, which has the highest shaft power demand or the maximum shaft power at full rotational speed whichever is the greatest.

6 SUNDRIES

6.1 Plinth and Baseplate

The Tender drawings show indicative plinth sizes; the Contractor shall finalise the concrete dimensions (to suit the selected pumpset dimensions, configuration and weight), the steel reinforcing and the anchor details for the pumpset plinth and shall submit the design to the Engineer for approval prior to construction. The calculations shall confirm that the pumpset's enforcing vibration will cause no damaging resonant condition and that it is suitable for the ground conditions.

Pumps and motors shall be mounted on baseplates of rigid design, manufactured in either cast iron or fabricated steel, equipped with anchor bolt holes, anchor bolts, drain connections and unobstructed grout holes.

Cast iron base plates shall be fully machined to receive the pump or motor. Fabricated steel baseplates shall be substantially ribbed and stress relieved before any machining is done. Baseplates shall be machined at the points of contact with the pump and motor supports so that the set may be mounted on the baseplate in correct alignment without the use of shims. In addition, at least four levelling pads (all machined to the same height relative to the other machined surfaces) shall be provided so that the baseplate can be accurately levelled up on Site. Machining is not required for units of 15 kW and under. Permanent dowelling pins shall be fitted after each item of plant has been in normal operation for at least 72 h and after the final alignment has been approved by the Engineer in writing.

Baseplates and pump supports shall be so constructed and the pump so mounted as to minimise misalignment caused by deflections arising from normal piping strains, internal differential thermal expansion, hydraulic piping thrust and similar causes.

At least two 100 mm diameter openings for grouting up without the removal of the pump or motor shall be cut into the baseplate. Levelling bolts with set screws and nuts shall be fitted to the base plates of all units 100 kW and above. (Refer Appendix A or similar approved by the Engineer).

Baseplates for pumpsets up to 1 000 kW shall have both pump and motor mounted on a single baseplate. Separate baseplates or sole plates may be used for pumpsets above 1 000 kW.

Baseplates shall be given corrosion protection at least equivalent to that specified elsewhere.

6.2 Fabrication

Fabricated items, including the baseplate, shall comply with the requirements of the relevant Particular Specification.

6.3 Anchor Bolts

Anchor bolts shall not be less than M20 and shall be made of stainless steel, to a minimum Grade of 316. Anchor bolts of an approved design shall be used as anchors.

Unless otherwise specified, one of the following methods to fix the anchor bolts shall be used:

a) The Contractor shall drill holes of an appropriate diameter and depth into the concrete base, and grout the anchor bolts in, using an approved prepacked two-part epoxy mortar.
b) Pockets at least 100 mm square and at least 12 bolt diameters in depth, shall be left in the foundation blocks.

The Contractor shall be responsible for providing an accurately constructed rigid template to fit on top of the foundation formwork and to which the anchor bolts can be bolted. The details of the template shall be such that it does not obstruct the concreting of the foundation block.

6.4 Fasteners

Fasteners shall comply with the requirements of the relevant Particular Specification.

Anchor fasteners shall have a minimum diameter of M16.

6.5 Pump Vent & Drain Cocks

Pump vents and drain cocks shall be manufactured from 316 stainless steel.

Adequate size air valves to enable the entrapped air to be released freely shall be provided on the high point of each pump casing and at any high points on the suction and delivery mains within the limits of this Contract.

Drain cocks shall be provided on the pumps, and also on drains from the pump seals. Drain pipework shall be fitted with T sections at every bend to enable rodding in the event of a blockage occurring.

All water and drain cocks shall discharge visibly into funnel shaped receivers discharging to waste.

6.6 Auxiliary Pipe Systems

Recirculating piping systems for gland oil, lubrication oil and accessories such as gauges and valves, shall be furnished by the Contractor, fully assembled to facilitate easy maintenance. Material used for all auxiliary piping and valves shall be suitable for the designed duty of the pumps and all items shall be properly cleaned before assembly. Auxiliary piping shall be installed in a manner which prevents damage to the instruments and gauges due to the vibration of the pump.

6.7 Pressure Gauges

An approved pressure gauge together with all piping shall be fitted on the suction and delivery sides of all pumps. The pressure gauges shall be calibrated to a common datum corresponding to the pump centre line level. The datum level and the difference in level between the datum level and the mounting height of the pressure gauges shall be indelibly marked on the dials of the respective pressure gauges.

One suction pressure transducer, and one delivery pressure transducer, per pumpset shall be supplied suitable for an input range corresponding to that of the respective pressure gauges. The transducers shall have an output of 4 - 20 mA over the scale range specified for the associated gauge and shall operate over a two wire system. A suitable DC power supply for each pumpset shall be supplied to power the transducer.

After erection, and before completion, each pressure gauge, each pressure transducer and each pressure switch shall be calibrated on Site. Calibration certificates shall be submitted to the Engineer for each gauge, transducer and pressure switch after the Site calibration.

Suitable approved brackets shall be supplied and installed to support the pressure gauges, transducers and switches. Each gauge and transducer shall be provided with an isolating cock and an additional high quality test cock shall be provided at each pressure measuring point, for the connection of test instruments. It shall be possible to check and isolate the pressure instruments without disturbing piping or connections.

The Contractor shall supply and connect all piping and fittings to the instruments.

The DC power supplies shall be supplied as loose items and shall be installed and wired by the Contractor.

6.8 Designation & Information Plates

Each pump set shall be provided with an approved number designation plate (baked enamel coated steel plate, stainless steel, or similar) indicating No. 1, No. 2, etc. The letters shall be at least 100 mm in height and the plate shall be mounted close to the pump set in a position which is readily visible from the control area. The pump number order shall be confirmed by the Engineer.

A corrosion-resistant nameplate shall be permanently attached to each pump and contain the following information:

- Manufacturer's name;
- Year of manufacture;

- Serial number of pump;
- Size and type of pump;
- Size of impeller;
- Rated capacity in cubic metres per hour (m3/h), litres per second (ℓ/s) or cubic metres per second (m3/s);
- Pump head at rated duty in metres (m);
- Pump speed (rpm);
- Maximum allowable casing working pressure in kilopascals (kPa);
- Mass of upper casing in kg, (for horizontal split casing pumps,)
- Mass of lower casing in kg, (for horizontal split casing pumps,)
- Mass of complete rotating element in kg; and
- Mass of completely assembled pumps in kg.

Letters and figures shall be engraved, or embossed, NOT STAMPED.

6.9 Instrumentation

Notwithstanding the requirements for instrumentation set out in the Project Specification, at least the following shall be fitted to the pumpset:

a) All motors shall have embedded in their stator windings, two RTD per phase which shall automatically shut off the motor in the event of overheating of the stator windings.

b) All pump-motor-sets rated 55 kW and over shall be fitted with RTD, thermal sensors in the drive-end and non-drive-end bearings to give a warning and automatically shut off the motor in the event the bearing temperature exceeds 80°C, or as recommended by the manufacturer.

c) All pump-motor-sets rated 110 kW and over, shall be fitted with vibration detectors on the bearings and automatically shut off the motor in the event the amplitude exceeds the manufacturer recommended limit. Vibration sensors in horizontal multistage pumps shall be provided in the ‘x’ and ‘y’ directions. Axial vibration sensors shall not be provided on horizontal multistage pumps.

6.10 Lifting

Suitable lifting points shall be incorporated in the design of all equipment.

6.11 Safety

Each pumpset shall be provided with an emergency stop station in an appropriate position.

Removable or hinged galvanized wire, expanded steel mesh or sheet metal cages shall protect all shafting and couplings. Guards shall be sufficiently heavy and rigid in design to avoid contact with the coupling or shaft as a result of accidental body contact. In the single shaft system, the bottom couplings only shall be guarded and in the two shaft system the complete shaft shall be protected with a cage from top to bottom, with hinged inspection openings for inspection and lubrication of the joints. All motor stool openings shall similarly be protected with removable guards.

Equipment or a combination of equipment shall not exceed the maximum noise limit of 85 dBA. (Refer to the latest version of BS EN 60034-9). The noise level shall be measured during workshop testing as well as on site.

7 PLANT

7.1 General

The Contractor shall provide all plant that is necessary to install, test and commission all items covered in this specification.

7.2 Handling and Rigging

The plant and rigging equipment used by the Contractor for the handling and placing of pumps, motors, valves and pipes shall be such that no installed equipment is over-stressed during any operation.

7.3 Setting Out

The Contractor may use any acceptable device to control the installation and alignment of the pumpsets, etc.

7.4 Testing

7.4.1 Hydraulic pressure test for leakage

The equipment provided by the Contractor for testing shall include the pump, pressure gauges, meters and the necessary tools and fittings required for the performance of the tests given in Cl 10.

7.4.2 Performance test

a) Works test

The equipment provided by the Contractor to verify the guaranteed pump performance, shall consist of the complete pump test rig including instrumentation to test the pumps in accordance with SANS 9906 Grade 1E (with Efficiency as a Guarantee requirement) including an NPSH test.

b) Site test

The equipment provided by the Contractor on Site to test the performance of the equipment shall include all the instrumentation not included in the permanent installation, (e.g. Watt meter, suitable pressure gauges, water meter of sufficient accuracy to ensure testing to SANS 9906 Grade 1E), and all tools and suitably trained staff necessary.

8 DELIVERY/INSTALLATION/SITE WORKS

Installation work shall generally comply with the requirements of the relevant Particular Specification.

8.1 Transport

When assembled pumps are transported, care shall be taken to prevent damage to bearing elements. Either the shaft shall be secured against relative movement or the pump base shall be mounted on suitable anti-vibration mounts during transport.

8.2 Placing on Foundation Blocks

After the casting foundation blocks is complete, with holding down bolt pockets, for pumps, motors, valves and pipework, the installation of pumps, motors, valves and pipework on those foundations shall take place.

Before positioning the pumps on their foundations the Contractor shall roughen the concrete surface, and ensure that all surfaces are free of all foreign materials, grease, oil, etc. The pumps shall be aligned as specified below before grouting commences.

The pumps shall be placed such that grouting clearances are maintained between the machine base, foundations and formwork.

NOTE: The concrete foundation blocks shall be to suit the dimensions and positions of the equipment supplied by the contractor.

8.3 Alignment

The Contractor shall align and level accurately the pump unit, using metal blocks and shims under the base at the anchor studs and, in the case of heavy equipment, midway between studs. The anchor nuts shall then be drawn tight against the base. The pump and motor shall then be checked for alignment.

If alignment needs improvement, metal shims or wedges shall be added at the appropriate places under the base. The Contractor shall align the units using laser beam alignment, and shall ensure that the measured deviations nowhere exceed the smallest values recommended by the manufacturers of the motors, pumps and flexible couplings respectively. The readings shall be recorded and made available to the Engineer upon request.

The Contractor shall be responsible for filling the voids inside and under the baseplate with an approved non-shrink grout.

The Contractor shall satisfy himself that the baseplate is fully supported over its whole length and that no voids have been left on the underside of any parts of the baseplate.

After the pumps have been in operation about one week, the foundation bolts shall be finally tested for tightness, the alignment checked (using clock gauges) and dowel pins fitted in the pump and motor feet in the approved manner.

When the grout has thoroughly dried (about 14 days after grouting), the exposed edges shall be painted by the Contractor using an approved oil paint of the same colour as the pump baseplate.

8.4 Defects

Each pump set and each piece of ancillary equipment shall be thoroughly cleaned and carefully examined for damage and defects immediately before installation. Should any damaged or defective pump set or ancillary piece of equipment be installed, it shall be removed and replaced at the Contractor's expense and to the satisfaction of the Engineer.

8.5 Keeping Pump Sets Clean

Every reasonable precaution shall be taken during installation to prevent the entry of foreign matter and water into the pump(s).

8.6 Mounting

In addition to supplying and installing the pump sets, the Contractor shall supply and install all appurtenant pipework and valves and he shall connect the pump sets to the pipework using, inter alia, acceptable forms of restrained flexible connections.

8.7 Electrical Inspection

The Contractor shall check all items of electrical plant for direction of rotation, correct phasing, motor and terminal voltage, and insulation resistance.

Before energising any of the motors for the purpose of commissioning, the Contractor shall measure the insulation resistance of each motor between phases and to the casing.

8.8 Stuffing Boxes and Mechanical Seals

Gland bolts shall be left completely loose and the final gland packing and tightening of gland bolts shall only be done after the motors have been tested for direction of rotation and once the plant is ready for commissioning.

Where mechanical seals are fitted and the pump design allows it, the motor couplings shall be disconnected during the initial dry run tests of the motors to ensure that the seals are not damaged.

8.9 Priming of Pumps

Where a positive head is available on the suction side of the pumps, no special priming equipment is required.

8.10 Finishing and Painting

Finishing and painting and cleaning up the Site are regarded as inherent parts of the installation. On completion of erection, all pipework, control gear and indicating gear within the pump house shall be thoroughly cleaned. Steelwork not treated in accordance with Cl 4.6 shall be primed with an alkyd

resin based primer and painted two coats gloss alkyd enamel. Other pipework, control gear and indicating gear shall receive two coats of enamel or other approved paint to the colour(s) selected by the Engineer, in accordance with SABS 0140 Part II, or as specified elsewhere. The whole of the work shall be left in a clean and properly finished condition. All paints, and materials used in their preparation, shall be of the best quality of their respective kinds. The paints and their colour shall be approved. All paint work shall be executed by tradesmen skilled in this class of work, and in strict accordance with the paint manufacturer's recommendations as approved.

9 TOLERANCES

9.1 General

The standards laid down in this Specification shall be adhered to in all cases unless the standards used by the Contractor are more stringent. In all cases where the Contractor deviates from the above standards, the Engineer shall be informed in writing and only after acceptance by the Engineer can the alternative standards be used.

9.2 Shafts

The surface of the shaft (or sleeve) through the stuffing box shall not exceed a roughness of 32 rms (root mean square) and the pump shaft (or sleeve) shall be straight and any runout, as measured by a dial indicator, shall not exceed 0.050 mm total indicator reading.

Dynamic shaft deflection measured under the worst conditions of load shall not exceed 0.050 mm maximum at the face of the stuffing box.

The balancing of all rotating equipment shall comply with the requirements of ISO 1940/1 (Balance Quality Requirements of Rigid Bodies) using balance grade G1 or Balance Tolerance grade API. Complete test certificates shall be submitted for evaluation before assembly of the units.

The alignment of shafts shall comply with the requirements of BS 3170. The shafts should be aligned in such a manner that both parallel and angular misalignment is eliminated. The acceptable alignment tolerance for parallel misalignment is 0.07 mm and for angular misalignment 0.07 mm / 100 mm.

9.3 Performance

Permissible variations from the required performance are as for SANS 9906 Grade 1E (with Efficiency as a Guarantee requirement) including an NPSH test, or SANS 9906 SANS 9906 Grade 1E (Site Works).

9.4 Vibration

Should vibration testing be specified (see Cl 10), the following shall apply.

9.4.1 Pumps

Vibration shall be measured and tolerances shall be in accordance with ISO 10816-7, Category I pumps.

9.4.2 Electrical motors

Test data taken on electrical motors running solo:

- Motor to have a ½ key installed.
- Motor to be placed on rubber mat at least 6mm thick or free-hanging.
- Where possible motor to be tested at full service speed.
- Measurement must be taken in the horizontal, vertical and axial direction on each bearing (HVA).
- Maximum amplitude of any peak in each frequency range to be recorded.
- Maximum line amplitude is the amplitude value of the highest discrete frequency component within the stated frequency range in any direction (HVA).
- Factory test certificates from the motor manufacturer must be included with delivery.

TABLE 3

VIBRATION ACCEPTANCE CRITERIA FOR MOTORS > 370 kW:

FREQUENCY RANGE		AMPLITUDE In Any Direction (mm/sec, peak)
Frequency	**Related to RPM**	
Overall vibration	Overall	2.5
Sub-harmonic	< 1 x RPM	0.6
Harmonic	1 x RPM	2.4
Lower multiples	(2 to 9) x RPM	0.9
Higher frequencies	(10 to 50) x RPM	0.3
OVERALL ACCELERATION	0 to 20 kHz	0.5 g at peak

10 TESTING/COMMISSIONING

10.1 General

All pump casings shall be hydraulically tested at the factory to at least 1.5 times the maximum possible working pressure of the pumps before any corrosion protection is applied. Through bolting, for the purpose of blanking the casing at the gland housing for pressure test purposes, will not be permitted.

Pumps and pipework shall be hydraulically pressure tested in situ by the Contractor to 1.5 times the working pressure for the pumps at their "duty point", or 1.3 times the pump shut-off pressure, whichever is the greater, by means of test equipment supplied by the Contractor.

Each test shall be carried out and certified by the manufacturer in the presence of the Engineer or his representative. The Contractor shall be responsible for all expenses incurred in carrying out all tests. When carrying out the hydraulic test (see 10.2), the Contractor shall ensure that all valves, tees and bends are properly secured and shored to prevent movement of pipes and fittings. Should any movement occur, the Contractor shall, at his own expense, reposition and, if necessary, repair the pipes and fittings and the securing means.

Until the pumps, pipework, valves, specials and joints have shown zero leakage when subjected to the pressure test, the plant will not be accepted. The test shall be repeated until the Engineer is satisfied that there is no leakage.

Pumps manufactured in cast steel shall have their casting and test bars inspected and tested at the factory (the Contractor's works) in accordance with latest BS EN 10293 when the power absorbed by the pumps exceeds 250 kW and/or where the working pressure exceeds 1.6 MPa.

10.2 Standard Hydraulic Tests

The specified test pressure for medium pressure pipework, valves, etc., shall be applied by means of a test pump. All pipes, specials, joints and fittings shall be carefully inspected for leaks. All visible leaks shall be made good and any pipe, special or fitting found to be defective shall be removed and replaced at the expense of the Contractor. Such replacement material shall, after installation, be tested at the expense of the Contractor.

The above tests shall be complete and the test results submitted to the Engineer in writing before any running tests are undertaken on Site.

10.3 Pumpset Testing

10.3.1 General

a) Where witnessed works or Site tests are required, the Contractor shall conduct trial test runs, and satisfy himself that the test results are in accordance with the requirements specified, before notifying the Engineer. The Contractor shall be liable for the cost incurred by the Employer in the event of an abortive test requiring a retest.

b) Any pump that requires segmental hydrotest shall have the method of hydrotesting fully described in the proposal.

c) If hydrostatic tests are performed with the shaft in position, the mechanical seals shall be removed and tests conducted with other types of seals or sealing methods.

d) In carrying out the tests, the quantity of water pumped shall be measured volumetrically if facilities are available, but, if not, by a meter made in strict accordance with SANS 9906. The readings of discharge given by the meter shall be taken to be correct and accepted as such by the Contractor.

e) Apparatus shall be provided to calibrate the testing equipment before and after the tests and to measure accurately the electrical power consumed.

The Contractor shall carry out the tests specified below and such additional tests in the Manufacturer's works, on the Site or elsewhere as in the opinion of the Engineer are necessary to determine that the Works comply with this Specification. Where mechanical seals are specified or form an integral part of the pumps installed under this Contract, all performance tests shall be conducted with the seals installed, except as specified in Cl 10.3.1 c) above.

If the Engineer so requires, all instruments forming part of or used in the Works shall be calibrated at the expense of the Contractor by an approved independent authority.

Except as provided for in a) and b) below, all labour, materials, fuel, stores, apparatus and instruments for the tests shall be supplied at no extra cost by the Contractor.

a) The cost of such tests and/or analyses as are required by the Engineer to be effected by independent authorities will be refunded to the Contractor by the Employer if the results of such tests and/or analyses prove satisfactory.

b) The Employer will provide free of charge, as and when available, the electrical load or supply and the necessary water required to run the plant for the Contractor's preliminary runs and for the final acceptance tests.

If relevant to the contract, the Contractor shall carry out the tests on Site so as not to interfere with the operation of the Works or the execution of other contracts.

Three copies of the Contractor's records of all tests shall be furnished to the Engineer, as specified in Cl 10.4 d). The vibration testing shall be done by an approved agency when requested by the Engineer. Payment will be as specified in a) above.

In the event of the pump plus pipework's failure to meet the specified values, the Contractor shall be responsible for the cost of the tests, rectification and subsequent re-testing until the specification is met.

10.3.2 Pump Tests - Manufacturer's Works

All test bed testing shall be carried out under the supervision of competent and experienced staff, fully conversant with the test bed. Test measurements shall generally be carried out in accordance with SANS 9906 Grade 1E (with Efficiency as a Guarantee requirement).

Non-conforming pumps shall be modified or replaced by other pumps in order to achieve the guaranteed efficiency at the duty point.

A test manual, fully describing the test procedure, etc., as well as details of the calibration procedures and calibration interval of all instruments, shall be available at all times while the pumps are under

test. The test manual shall include simplified explanations of all key points necessary on measurements, datum corrections, calculations and all points to be considered in assessing mechanical integrity. The manual shall be sufficiently comprehensive to make it the only document required by test personnel.

If required performance and/or vibration testing shall be carried out by the pump/motor manufacturer at an approved test facility and witnessed by the Engineer or his representative.

Certified test results, whether from the manufacturer's works or elsewhere, shall be provided to the Engineer before delivery.

The pump shall be inspected at the factory. The impeller shall be available for inspection.

If the equipment is manufactured and assembled in South Africa, the Contractor shall make all arrangements and carry all costs for the Engineer to inspect equipment and fabrications in the workshop prior to dispatch to Site. Fabrications shall be inspected prior to corrosion protection.

If the equipment is manufactured and assembled outside South Africa, the Contractor shall make all arrangements and carry all costs for an Engineer approved inspection authority to inspect the equipment in the workshop prior to dispatch. The inspection shall include a full report on compliance of the equipment with this specification and this report shall be submitted to the Engineer prior to dispatch of the unit from the workshop.

The Contractor shall make all arrangements for the Engineer to witness the following for pumps with motor ratings of 100 kW and above:

- the casing being pressure tested to 1,5 times design pressure for a period of 30 minutes.
- the performance testing for flow, head and efficiency at the specified duty point. The test shall be performed in accordance with SANS 9906 Grade 1E (including Efficiency as a Guarantee requirement) including an NPSH test; preferably at the manufacturer's works.

The Contractor shall arrange that a test report for the following shall be submitted to the Engineer for pumps with motor sizes smaller than 100 kW:

- the casing being pressure tested to 1,5 times design pressure for a period of 30 minutes.
- the performance testing for flow, head and efficiency at the specified duty point. The test shall be performed in accordance with SANS 9906 Grade 2B.

10.3.3 Pump Unit Tests - Site of Works

The correct operation of the equipment and achievement of the specified performance requirements shall be demonstrated to the Engineer prior to the commissioning of the Works.

During witness testing in accordance with the specified SANS 9906 grade of test, the pump shall perform within the standard's acceptable tolerances for differential pressure across the pump, volume flow and energy efficiency.

Vibration testing shall be carried out in accordance with BS ISO 10816-7, Category I pumps.

During witness testing of the pump casing, the pump shall exhibit no leakage.

Two separate series of tests called the Preliminary Acceptance Test and Final Acceptance Test shall be carried out by the Contractor on all pumping units after installation. Test measurements shall generally be carried out in accordance with SANS 9906.

10.3.3.1 Final Acceptance Test

The Final Acceptance Test shall be carried out after he has run the plant for a period of 48hours. The Contractor shall provide all necessary instruments, staff and labour for the tests and a representative of the Engineer will be present at all tests and shall be provided with full details and the calculated results, all recorded as shown in Appendix D.

If in the Final Acceptance Test, the characteristics fall short of those specified by the SANS 9906 grade of test, the Contractor shall immediately remedy the defects to ensure that the installation complies with these requirements, at his own expense and within such time as may be laid down by the Engineer. When the Contractor has made good the defects, and is satisfied that the pumping unit is ready to be taken over by the Employer, a second Acceptance Test shall be carried out, by the Contractor.

If, in the second Acceptance Test, the performance of any of the pump units falls short of requirements, using the criteria in the preceding paragraph, the equipment or part thereof may be rejected, in which case the Contractor shall take immediate steps to replace the rejected equipment with equipment complying with the specifications.

Such replaced equipment shall be subjected to a Final Acceptance Test and the provisions of the two preceding paragraphs shall apply thereto.

10.4 Guarantees of Performance

a) The Contractor shall guarantee the output and efficiency of all machines, which guarantees shall be binding under the Contract.

b) The fulfilment of these guarantees shall be demonstrated at the Contractor's factory premises or a suitable off-site test facility approved by the Engineer in accordance with SANS 9906 Class 1 and shall be verified on Site in accordance with SANS 9906 Class 2.

c) All measuring instruments used in the tests shall have previously been certified by an independent testing authority, not more than one month prior to the test and to the Engineer's satisfaction. The pump power output shall be based on the total head as defined in the Project Specification.

d) Where guaranteed performance is specified, certified test curves shall be drawn from the test data obtained from the purchased pumps and shall include; head (m), quantity pumped (m3/h or ℓ/s), efficiency (%), power consumption (kW), speed in rpm and speed/torque (rpm/kNm). The probable performance with maximum and minimum impellers shall also be indicated, as well as tested (or probable) NPSH available.

e) Each pump shall be checked for acceptable vibration limits and noise limits if required during testing.

10.5 Failure to Achieve Guarantees

a) The Contractor shall ensure that the pumps deliver the "Required minimum discharge", by fitting new impellers or taking whatever action is necessary should there be any shortfall in the quantity of water measured when the pumps are delivering at the total head associated with the "duty point" in fulfilment of the Guaranteed Performance criteria.

b) Payment by the Contractor in lieu of under-performance of the pumpsets relative to the Guaranteed Performance will not be acceptable.

11 MONITORING OF PUMPS AND MOTORS

11.1 Monitoring Devices

11.1.1 General

The indicating or monitoring equipment shall not be affected by surges in the supply system or by portable radio transmitting equipment.

All sensors shall be compatible with the associated monitoring equipment.

Monitoring equipment shall be suitable for flush panel mounting at any angle between the vertical and horizontal planes.

Full details of the sensing equipment and of the associated control and monitoring or indicating equipment shall be submitted with the tender offer. Evidence shall also be submitted that adequate spares and services are readily available in this country.

11.1.2 Temperature monitoring devices

It shall be the full responsibility of the Contractor to ensure that all temperature sensing devices for either motor or pump and their respective monitoring equipment are compatible with the local network and other systems installed in the Pumpstation.

Refer to clauses elsewhere for temperature monitoring of pump and motor bearings.

a) Temperature sensors

Either thermocouples or resistance temperature detectors (RTD's) shall be installed, depending on which is more suitable to the duty and application. Unless otherwise specified, pumps with motors smaller than 50 kW shall have thermocouples installed. Pumps with larger motors shall have RTD's installed. At least two RTD's shall be installed per phase (a minimum of 6 RTD's in total for a 3 phase motor)

b) Location of temperature probes

Separate temperature probes shall be installed at the sleeve and/or rolling bearings of each pump and motor and at the gland housings (where applicable) of the pump to monitor the temperatures at these points. If suitable, probes shall also be installed in the slots of the motor stator windings together with the coils, one per phase, to monitor motor winding temperatures as required in the Project Specific Pump Specification.

Each pump casing (for split casing pumps) shall be fitted with a RTD to safeguard the pump in the event of inadvertent sustained operation against a closed discharge valve. The RTD's shall be calibrated to close when the temperature of the water in the pump casing exceeds 40°C. The RTD shall be settable over a range of 20 to 60 degrees and shall provide a digital output to the pumpline PLC.

The probes shall be installed in direct contact with the motor stator windings and/or shall be spring loaded to ensure positive contact with the bearing shells or gland stuffing boxes.

Each probe shall be complete (where required) with an integral and continuous compensating lead of sufficient length to permit a neat installation between the probe and the terminal point. The compensating lead shall be adequately protected against the risk of mechanical damage.

Each probe shall be clearly identified by means of an engraved marking on the sheath and shall be individually calibrated. Test certificates covering the calibration results of all temperature probes shall be submitted to the Engineer.

Temperature probe terminals shall be clearly marked in order to prevent inadvertent reversed readings.

c) Temperature monitoring equipment

Temperature monitoring equipment shall feed analogue (4-20 mA or similar) signals to the pumpline PLC and display of the temperature shall be on the HMI panel as well as remotely.

11.1.3 Pressure Devices

a) Pressure gauges

Each pumpset shall be equipped with two 160 mm diameter dial flush mounting stainless steel pressure gauges. The gauges shall be calibrated in Kilo-Pascals (Kpa) and the range shall suit the particular application. The gauge shall be filled with glycerine, and the bubble shall be out of the range of usual reading. The gauges shall be of a type that can be recalibrated (dead-weight method) and reset on Site. Where there are more than one pump in a pumpline operating in series, the pressure between pumplines shall also be indicated on a pressure gauge.

Pump discharge pressure gauges shall be capable of reading pump closed valve pressures. The gauge indicating the pump suction pressure shall a combination gauge capable of indicating the maximum possible suction pressure as well as full vacuum conditions.

All pressure gauges shall be supplied and installed complete with isolating and drain cocks, piping, etc., and fitted with a pulsation snubber.

Pressure gauges, if located on the control console, shall be mounted in a compartment totally separated from the electrical equipment. The compartment shall be equipped with a drain.

b) Suction Pressure Switch

If required in the Project Specific Pump Specification, a pressure switch shall be fitted to the suction pipe of each pump downstream of the inlet isolating valve, and interlocked with the pump control circuit.

c) Pump suction and delivery pressure transducers

Where required in the Project Specific Pump Specification Project Specification, suction and delivery pressures shall be registered by suitable pressure transducers and the signals of these instruments shall feed into the pump PLC. Analogue signals shall be generated by these devices.

d) Pumpstation suction and delivery pressures

A signal derived from a suitable source on the suction manifold or pumpstation forebay and an appropriate tapping on the venturi flow element (if installed) or other suitable source on the delivery manifold shall be utilised to indicate the station suction and delivery pressures in the position specified.

e) Hydraulic snubbers

Hydraulic pulsation snubbers complete with throttle/isolating/bleed devices shall be fitted in series with all pressure sensing devises.

11.1.4 Pumpset Vibration Sensors

Suitable vibration sensors shall be mounted on each pumpset to stop it on detection of excessive vibration. At least two detectors shall be provided on each pumpset, i.e. one on the motor bearing (drive end) and one on the pump bearing (drive end), situated as close as possible to those bearings where the highest vibration levels are encountered.

Monitoring equipment similar to that described in clauses above for the temperature sensors shall be installed for monitoring the vibration sensors. The indicating instruments shall be suitably calibrated. They shall be of a type such that it is possible to set different tripping levels corresponding to different RMS velocities.

The monitoring of vibration shall be made via a suitable timing device in order to avoid tripping when starting the pumpset or during other transitory conditions.

11.1.5 Flow and Power indicators, Hour meters

a) Flow measurement for the complete Pumpstation

Indication on the appropriate HMI screen and recording of total Pumpstation output measured in the rising main shall be provided if required in the Project Specification. Two sets of figures shall be recorded, one resettable and the other not.

b) Flow Sensing for each pumpset (where required)

If required, indication of flow from each pumpset shall be as specified in the Project Specific Pump Specification. The presence of flow from each pumpset shall be registered on the appropriate HMI screen.

c) Power (where not addressed elsewhere)

Where required in the Project Specification, the power absorbed by each main pumpset motor shall be displayed on a power meter, calibrated to indicate the rated motor power, of the industrial grade complying with BS 89, wired to appropriate sources of current and potential, and mounted on each local control panel.

d) Hour meter (where not addressed elsewhere)

The total number of hours for each machine shall be displayed on the appropriate HMI screen. Two figures shall be recorded, one resettable and the other not.

11.1.6 Additional sundry sensing devices

a) All valves in the main pumpline (except for when a reflux valve is called for) shall be provided with both "fully open" and "fully closed" limit switches. A pump control valve may require additional switches to facilitate its design function.

b) Valve actuators shall be provided with torque limit switches.

c) A flow sensor shall be provided in the motor cooling-water circuit (if applicable).

d) A temperature sensor will be provided in the inlet and outlet of each cooling water circuit (if applicable).

e) A pressure sensor will be provided in the inlet of each cooling water circuit (if applicable)

f) Any additional sensing devices as more fully described in the Project Specific Pump Specification.

11.2 Pump Control Panels

This clause shall generally only apply to smaller pumps.

The requirements for larger pumps are dealt with in the relevant Particular and Project Specifications.

11.2.1 General

Unless otherwise stated in the Project Specification, a small desk-type console, shall be provided for each pumpset and mounted in close vicinity of the pump on the pumpwell floor. The console shall be fully enclosed and fitted with removable front panel to facilitate mounting of monitoring equipment, instruments and associated wiring. All displays, and control equipment as specified, shall be flush mounted on the consoles. Engraved labels indicating the designation of each instrument, indicator lamp or control, shall be fixed below each item.

If two pumps operate in series, each pumpset shall be provided with all the monitoring equipment specified, mounted on one common control console. As far as control is concerned, the pump line shall be treated as a whole with only one start/stop switch.

The layout of the control console and the equipment contained therein shall be as more fully described in the Project Specification and to the approval of the Engineer.

11.2.2 Rated voltage

The voltage available for the Local Control Panel (LCP) will be 48V DC. If any of the equipment inside the panel requires a different voltage, the Contractor shall make provision for this voltage from the 48 V DC.

Equipment located in the console shall be suitable for operation at any voltage within the range plus 10%, minus 20%.

11.2.3 Labelling

Labels shall be in English and shall be of Traffulyte or rear engraved Perspex. Lettering shall be in black on white background. Punched tape is not acceptable.

Each panel shall be fitted with a general information plate at least 150 mm wide made of either chrome-plated steel or stainless steel on which the following information is clearly engraved (as applicable).

- The pumpset number at least 100 mm tall.
- Pump : as per Cl 6.8
- Motor : manufacturer, type or designation, power kW, cooling media
- Inlet valve : manufacturer, design, type or designation, nominal bore
- Control valve (if required): manufacturer, design, type or designation, nominal bore.
- Check valve : manufacturer, design, type or designation, nominal bore.
- Delivery valve : manufacturer, design, type or designation, nominal bore.

11.2.4 Control Panel Cabinet

Refer to GIBB-011 General Electrical Specification, and the Umgeni Water particular specifications.

11.3 Mounting of Equipment

All indicating or monitoring equipment as well as control equipment providing indication and setting facilities, are to be flush-mounted on the consoles and all other components are to be mounted internally. At least 10% of free space shall be provided inside the console.

All components shall be inter-connected and fully wired and all connections shall be clearly identified by means of suitable numbered ferrules. All outgoing circuits shall be wired to terminal blocks comprising suitable screw connectors and situated near the base above the gland plate. All terminals shall be labelled and at least 10% free terminals shall be provided as spare. Cables will enter the consoles from below through slots in the floor.

12 MEASUREMENT & PAYMENT

The tendered rates or sums shall cover the cost of anything not specially mentioned, but which an experienced contractor can reasonably foresee as being required to enable the apparatus and equipment to be installed and/or function safely and correctly as specified. No claims whatsoever for extras will be allowed on the grounds that a necessary piece of equipment or part thereof is not specifically mentioned in the Schedule of Quantities.

Measurement and payment of pumpsets shall comprise payment in two stages:

- Design, supply, and delivery
- Installation, testing, and commissioning.

The term ‘pumpset’ refers to the complete set of pump, motor, shaft, couplings, baseplates, fasteners, holding down bolts and all accessories necessary for a complete functional unit.

12.1 Design, supply, and delivery of pumpset, Instrumentation and accessories

Design, supply and delivery of pumpset, Instrumentation and accessories: [description of pumps. Describe additional requirements where applicable]	……Unit: No. or Sum

This shall include the set of all equipment, instrumentation, couplings, cabling, and ancillary items considered to form a complete pumpset, including the motor and accessories thereof.

Design: The rate tendered shall include full compensation for the design of the complete installation including full design calculations; detail working Drawings for all items; Specifications; schematic diagrams; electrical Drawings and wiring diagrams; layout Drawings, quality control plans, and provision of the above to the Employer's Agent for approval in accordance with the requirements of the Scope of Work.

Supply: The tendered sum shall cover the cost of the supply of the goods, testing as specified, provision of test certificates certifying compliance of the goods with the applicable standards, quality control, corrosion protection, if not scheduled separately, and supply of all special tools and keys required for maintenance and installation. Payment for supply of the relevant equipment will not be effected until the draft copies of the related sections of the Operation and Maintenance Manuals have been submitted.

Delivery: The tendered rate or sum shall cover the cost of preparation and packing for transport; transport from place of manufacture to the Site; insurance, harbour dues etc., during transport; loading and unloading; storage under appropriate conditions from date of delivery until commencement of erection; and any other work as specified. Where a rate or sum has been tendered for delivery of goods, which are then, stored, the Engineer at his sole discretion may certify an amount for partial or full payment of the relevant item, if in the Engineer's opinion such a payment is justified by reason of the transportation of such goods to their place of storage.

12.2 Installation, Testing and Commissioning of complete pumpset, instrumentation and accessories

Installation, testing and commissioning of complete pumpsets, instrumentation and accessories [description of pumpsets. Describe additional requirements where applicable]	……Unit: No. or Sum

The scope shall include the pump, pump ancillary items, motor, motor ancillary items, and instrumentation specific to each pump-line, and all other components, accessories, equipment and civil works necessary for a complete functional installation.

Installation: The tendered rate or sum shall cover the cost of all necessary site oriented activities such as handling at the Site, storing, sorting, erecting, all painting, including all costs of transport of personnel and their erection gear to Site, and the cost of all materials, labour and consumables. Where items of equipment are to be grouted in (such as for anchors and pumpset base plates), the installation sum shall include for such work.

Testing and commissioning: The tendered rate or sum shall cover the cost of pre-commissioning tests, as well as commissioning tests, including putting the Works into operation. All costs of transport to and from Site, and Site accommodation of personnel and their gear shall be included in the tendered rates.

12.3 Spare Parts

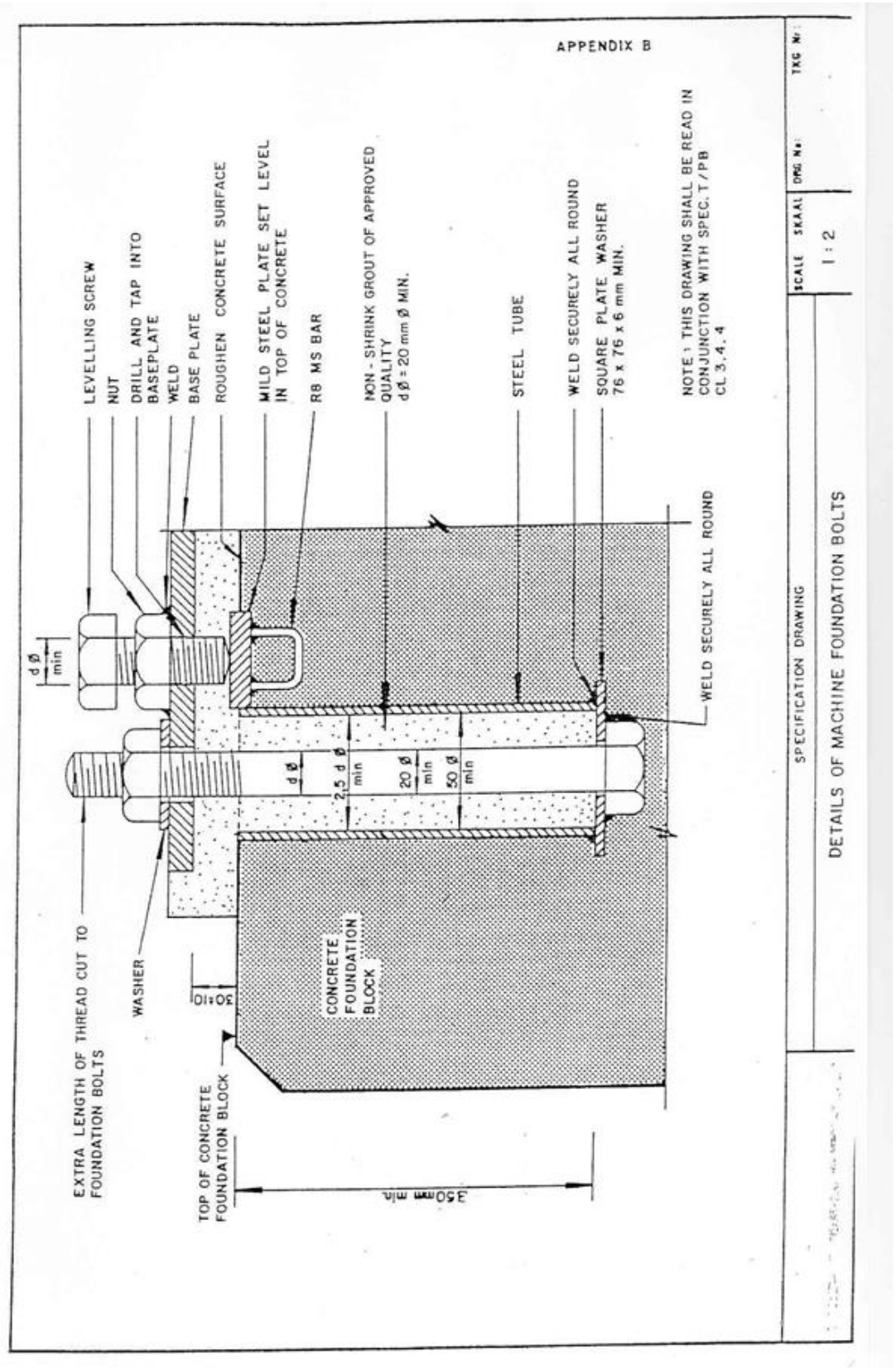
Design, Manufacture Supply and delivery to site of complete set of spare parts as described below:	……Unit: Lump sum (Sum)

*(example list of required spares provided below)

- Spare impeller, spare shaft sleeves, all mounted on a spare shaft with all keys in position. (1 set)
- Casing wear ring. (1 No)
- Impeller wear ring. (1 No)
- Drive end seal. (1no.)
- Non-drive end seal. (1 No)
- Drive end bearing, including all washers, seals, sleeves, etc. (1 Sets)
- Non-drive end bearing, including all washers, seals, sleeves, etc. (1 Sets)
- Complete set of gaskets, O rings, V rings, etc., for a single pump (1 Sets)

Where applicable spares shall be mentioned in the payment item description.

APPENDIX A: DETAILS OF MACHINE FOUNDATION BOLTS



APPENDIX B : RECOMMENDED CAST MATERIALS

Description	Preferred alloys			Specific application alloys		
	British Standard Specification	Near equivalent specifications		British Standard Specification	Near equivalent specification	
		American	German		American	German
Grey cast iron	BS 1452 Grade 190	ASTM A48 Class 25	DIN 1691 GG-20	BS 1452 Grade 270	ASTM A48 Class 40	DIN 1691 GG-25
	BS 1452 Grade 220	ASTM A48 Class 30	DIN 1691 GG-20	BS 1452 Grade 315	ASTM A48 Class 45	DIN 1691 GG-30
Spheroidal or nodular graphite cast iron	BS 2789 Grade 420/12	ASTM A536 Grade 60-40-18	DIN 1693 GGG-40	BS 2789 Grade 600/3	ASTM A536 Grade 80-55-06	DIN 1693 GGG-60
Flake graphite austenitic cast iron	BS 3468 AUS 101 Grade A	ASTM A436 Type 1	DIN 1694 GGL-NiCuCr 1562	BS 3468 AUS 102 Grade B	ASTM A436 Type 2b	DIN 1694 GGL-NiCr 203
Spheroidal graphite austenitic cast iron	BS 3468 AUS 202 Grade A	ASTM A439 Type D2	DIN 1694 GGG-NiCr 202	BS 3468 AUS 202 Grade B	ASTM A439 Type D2B	DIN 1694 GGG-NiCr 203
Carbon steel	BS 1504-161 Grade A or BS 592 Grade A	ASTM A216 Grade WCA or ASTM A352 Grade LCB	DIN 1681 GS-45	BS 1504-161 Grade B or BS 592 Grade B	ASTM A216 Grade WCB	DIN 1681 GS-52
Austenitic corrosion resisting steel	BS 1504-821 Grade Nb or BS 1631 Grade B	ASTM A296 Grade CF-8C	DIN 17006 G-X7 CrNiNb 189	NONE	-	-
	BS 1504-845 Grade B or BS 1632 Grade B	ASTM A296 Grade CF-8M	DIN 17006 G-X5 CrNiMo 1810	BS 1504-845 Grade Nb or BS 1632 Grade C	ASTM A296 Grade CF-8M	DIN 17445 G-X7 CrNiMoNb 1810
Martensitic corrosion resisting steel	NONE	-	-	BS 1504-713 or BS 1630 Grade B	ASTM A296 Grade CA-15	DIN 17445 G-X20 Cr 14
Leaded gunmetal	BS 1400 LG2	ASTM B145-No. 836 SAE No. CA 836	DIN 1705 G-CuSn5ZnPb	NONE	-	-
	BS 1400 LG4	-	DIN 1705 G-CuSn6ZnNi	NONE	-	-
Copper-tin alloy	NONE	-	-	BS 1400 CTI	SAE No. CA 905	DIN 1705 G-CuSn10
Aluminium bronze	NONE	-	-	BS 1400 AB2	ASTM B148 No. 955	DIN 1714 G-CuAl10Ni
Phosphor bronze	BS 1400 PB1	SAE No. CA 907	-	NONE	-	-
Leaded bronze	BS 1400 LB2	ASTM B22 No. 937	DIN 1716 G-CuPb10Sn	NONE	-	-
Leaded phosphor bronze	NONE	-	-	BS 1400 LPB1	-	-
Aluminium alloy	BS 1490 LM6	ASTM B85 Alloy S12A	DIN 1725 Sheet 2 G-AlSi12			
	BS 1490 LM9	ASTM B85 Alloy SG100A	DIN 1725 Sheet 2 G-AlSi10Mg	BS 1490 LM 24	ASTM B85 Alloy SC84A	DIN 1723 Sheet 2 G-AlSi8Cu3
	BS 1490 LM 25	ASTM B26 Aloy SG70A ASTM B108 Alloy No. 356.0	DIN 1725 Sheet 2 G-AlSi7Mg wa			

APPENDIX C : MEASUREMENT ACCURACIES

The accuracy of the measurement of pump performance is dependent on the test loop design and the instrumentation used.

The Contractor shall provide testing in accordance with SANS 9906 as applicable to the pumps. Test loops shall have:

- An axially symmetrical velocity distribution;
- A uniform static pressure distribution; and
- Freedom from swirl induced by the installation.

With test loops designed to conform with these standards, the limits of error shall be within those shown in Table 10 of SANS 9906. The quoted figures are maximum values, but greater accuracies can be obtained if the available instruments operate near to their full scale value.

APPENDIX D : PUMP TEST SHEET

Client: ..... Client's Order No.: ..... Test Date: ..... S.A. Job No: .....

Size of Pump: ..... Nameplate No: ..... Flow: ..... N.G.H. ..... rpm .....

Size of Motor: ..... Nameplate No: ..... Volts: ..... Amperes: ..... Power: ..... rpm .....

Test No Time	R P M	Volts K =	Amps K =	Watts K =	Flow Meter %	Flow	Actual Delivery Gauge Reading	Corrected Delivery Gauge Reading	Actual Suction Gauge Reading	Corrected Suction Gauge Reading	Velocity Head Correction	Total Head inc. diff in level of Gauge of =	Motor Power Input	Motor Effcy %	Pump Power Input	Pump Power Output	Pump Effcy. %	Remarks

Impeller Dia:		Shroud Width:	Tip Width:	Imp. Drg. No:
Voltmeter No:	Barometric Press	Time Started Up:	Orifices Used:	Tested by:
Ammeter No:	Balance Water:	Time Shut Down:	Constant: K =	Witnessed by:
Wattmeter No:	Pressure Gauge No./Range		Suction Gauge No./Range	Passed O.K. Mechanically by:
				Passed O.K. Hydraulically by: