TECHNICAL SPECIFICATION

CENTRIFUGAL SUBMERGED MOTOR PUMPS (IN REFRIGERATED PRODUCT OR PRESSURISED STORAGE SERVICE)

DEP 31.29.06.30-Gen.

December 1996
(DEP Circular 25/97 has been incorporated)

DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

PREFACE

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The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for centrifugal submerged motor pumps in refrigerated product or pressurised storage service, whether column-mounted or pot-mounted. This DEP shall be used in conjunction with data/requisition sheet DEP 31.29.02.93-Gen. for centrifugal pumps.

This DEP is a revision of an earlier publication with the same number, dated September 1982.

In the event of conflict between documents relating to the enquiry or order, the following hierarchy shall apply:

upper level: the purchase order and variations thereto
second level: data/requisition sheets and drawings
third level: this DEP

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP and SIEP, the distribution of this DEP is confined to companies forming part of or managed by the Royal Dutch/Shell Group. It may be distributed to Manufacturers nominated by them (i.e. the distribution code is "F", as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants and, where applicable, in exploration and production facilities and supply/ marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this document as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

- ***Best efficiency point*** is the flow at which a pump achieves its highest efficiency.
- ***Continuous service*** for this pump type is an uninterrupted operation period of at least 16 000 hours under the specified conditions for the guarantee point, unless otherwise specified.
- ***Guarantee point*** is the normal operating point as specified on the data/requisition sheet and the point at which the Manufacturer certifies that performance of the pump is within the tolerances specified (ref. API 610, section 4.3.1.1.). At least the following data shall be shown on the data/requisition sheets for this point: flow, total differential head, rated suction pressure, density and viscosity of the pumped liquid, NPSHA and speed.
- ***Intermittent service*** is operation, including intentional stops and starts, under the conditions specified for the guarantee point.
- ***Maximum allowable casing working pressure*** is the greatest pressure at the specified pumping temperature for which the pump casing is designed. This pressure shall be equal to or greater than the maximum differential pressure across the pump.
- ***Maximum discharge pressure*** is the maximum suction pressure plus the maximum differential head which the pump would be able to develop when operating at the specified conditions of speed, maximum density and lowest pumping temperature with the maximum impeller size installed.
- ***Maximum rated discharge pressure*** is the maximum suction pressure plus the maximum differential head which the pump would be able to develop when operating at the specified conditions of speed, maximum density and lowest pumping temperature with the furnished impeller size installed.
- ***Maximum suction pressure*** is the highest suction pressure to which the pump may be subjected during operation.
- ***Minimum flow*** is the higher of the two minimum flows defined below. Minimum flow does **not** refer to the minimum required process flow.
  - ***Minimum continuous thermal flow*** is the lowest flow at which the pump can operate without its operation being impaired by the temperature rise of the pumped liquid.
  - ***Minimum continuous stable flow*** is the lowest flow at which the pump can operate without exceeding the vibration limits imposed by this DEP.
- ***Net positive suction head (NPSH)*** is the total suction head determined at the suction flange (bell mouth) of the pump minus the vapour pressure of the liquid at the highest temperature specified. Both suction head and vapour pressure are expressed in metres liquid absolute.
- ***Net positive suction head available (NPSHA)*** shall be determined by the Principal for the pumping system. NPSHA is the total suction head determined at a reference location (see below) minus the vapour pressure of the liquid at the highest temperature specified and at rated flow. Both suction head and vapour pressure are expressed in metres liquid absolute.

  For *pot-mounted* pumps, the NPSHA is referenced to the suction flange of the pot.

  For *column-mounted* pumps, the NPSHA is referenced to the suction flange (bell mouth) of the pump.
- ***Net positive suction head required (NPSHR)*** is the minimum NPSH required at rated flow and at highest specified liquid temperature to prevent a head drop of more than 3 percent due to cavitation within the pump. This requirement is also applicable to multi-stage pumps when the NPSHR is established by a head drop measurement across the first impeller only; otherwise a head drop limitation of 1% over the total differential head shall be applied. The NPSHR is determined by the Manufacturer and shall be based on the pump handling the actual product specified on the data/requisition sheet. It shall be referenced to the suction flange (bell mouth) of the pump and expressed in metres of

actual liquid (water).

- ***Pressure casing*** comprises all stationary pressure-containing parts of the complete pump unit, including all nozzles or other parts attached thereto subject to a differential pressure greater than 1 bar (ga).

  "Pot" mounted is the installation of a complete pump assembly, process auxiliaries and power connections in a pressure vessel.

  Pressurised storage service is the handling of liquefied butane or lighter hydrocarbons stored in pressurised vessels at specified temperature.

- ***Rated discharge pressure*** is the discharge pressure developed by the pump at the guarantee point with the furnished impeller size and at rated flow, speed, suction pressure and density.

- ***Rated flow*** is the flow at the guarantee point.

- ***Rated power*** is the power required by the pump at the guarantee point.

- ***Refrigerated product service*** is the handling of butane or lighter hydrocarbons which are in the liquid phase under atmospheric pressure.

- ***Rated suction pressure*** is the specified suction pressure of the pump at the guarantee point.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (5.).

2. DESIGN

2.1 GENERAL

(a) Pump ratings shall not exceed the limits of the Manufacturer's design and shall be within the Manufacturer's actual experience, i.e. there shall be no extrapolation from existing models/ types. Equipment shall have been proven in similar service.

At least 3 units of the similar type and size shall have had at least 8000 hours of continuous operation each.

(b) Pumps with constant-speed drivers shall be capable of at least a 5% head increase at rated conditions with the impeller(s) replaced by impeller(s) of larger diameter or different proven hydraulic design.

(c) Pumps may be of single or multi-stage design.

(d) All pumps shall have a stable head versus flow curve with a continuous rise in head from rated to zero flow of at least 10%. During performance testing the test points shall always show increasing differential head with decreasing flow. The differential head measured from the minimum flow to zero flow may have to be corrected to cover a change in density resulting from a rise in suction temperature caused by the lower pump efficiency in the low flow ranges.

(e) The pumps shall be selected with the guarantee point between 80% and 100% of best efficiency point, applicable to the impeller diameter fitted.

(f) The end of curve flow rate shall be either 125% of the flow at best efficiency point or as otherwise agreed to limit the motor size. The Manufacturer's proposal shall include both the NPSHR curve from minimum continuous flow rate to end of curve flow rate as well as the power consumption curve.

(g) The pump shall be capable of continuous service at any flow rate between the minimum flow stated in the proposal and the end of curve flow rate, either solo or in parallel with other pumps of similar rating.

(h) The Manufacturer shall include and define in his proposal any special protection and equipment required during shipment, site storage, installation and operation. His proposal shall be based on the environmental conditions at site.

2.2 NOISE CONTROL

The Contractor shall comply with DEP 31.10.00.31-Gen., and thereby communicate to the Manufacturer the specified equipment noise limitations by using data sheet DEP 31.10.00.94-Gen., which forms part of the requisition. The Manufacturer is responsible for assuring that these equipment noise limitations are submitted. This requirement is not applicable to tank mounted pumps.

2.2.1 Information to be submitted with the tender

The Manufacturer shall submit the guaranteed sound power levels and/or sound pressure levels of the equipment, together with any other relevant information as requested in the equipment noise limitation sheet DEP 31.10.00.94-Gen. The Manufacturer shall indicate what special silencing measures, if any, are proposed to meet specified levels.

Tank mounted and pot mounted pumps are exempted from this requirement.

2.3 ELECTRIC MOTORS

Electric motors shall, as far as practically possible, comply with the requirements specified in DEP 33.66.05.31-Gen.

- The motor shall have a power rating which is at least 10% above the maximum value of the power absorbed by the pump between zero and the end of curve flow rate.
- The motor shall be designed for full voltage starting: the torque provided by the motor at 80% of rated voltage shall be capable of accelerating the pump to full speed with an

open discharge valve (no valve restriction).

- The combined pump/motor rotor, which can be subject to reverse rotation for short periods of time, shall be suitable for reverse rotation at up to 125% of rated speed.
- Parts, including the electric cables, motor windings, cable entry seals etc. which are in contact with the product pumped, as specified on the data/requisition sheet, shall be chemically and thermally resistant to this product for the lifetime of the motor.
- The windings of the electric motors shall be provided with at least three thermistor type temperature detectors (positive temperature coefficient). The initiating temperature of these thermistors shall be in accordance with the highest permissible hot-spot temperature for the class of insulation used for the windings.
- The electric cables between the motor and a junction box mounted on the head plate shall be provided by the pump/motor manufacturer and shall be suitable for the refrigerated product service at the voltage level specified on the data/requisition sheet.
- The motor cables shall be provided with suitable supports from the suspension cable to prevent vibration, abrasion of their outer sheath and fatigue cracking of their conductors and sheath.
- The cables shall be compatible with the pump/motor retraction system (i.e. vibration, bending around a bending radius of 1 metre) under all temperatures ranging from the specified minimum operating temperature to maximum ambient temperature. Test reports from an independent testing authority (e.g. Underwriters Laboratories) shall be available to confirm that the above requirements are met.
- An earth conductor shall be provided for the motor. The support cable may be used for the earthing of the motor.
- The motor junction box shall be suitable for a Zone 1 area (as defined by IEC 50) and sized to accommodate the incoming cables as specified on the data requisition sheet.
- A double seal, with a nitrogen purge connection between the seals, shall be provided between the junction box and the head plate to prevent hazardous gases penetrating into the junction box. Other sealing arrangements making use of double junction boxes may be used subject to the approval of the Principal. Means shall be provided to seal the cable ends before the seals to prevent vapour travelling up the cable into the junction box.

2.4 CRITICAL SPEEDS

The rotor of the pump/motor shall be a stiff shaft construction. The first lateral critical speed shall be at least 10% above the maximum operating speed.

If, due to specific design considerations, compliance with the above requirement cannot be obtained for multi-stage pumps the Manufacturer shall submit the wet and dry calculated critical speeds, including the points of maximum amplitudes along the rotor axes and an undampened unbalance response analysis for approval by the Principal. The calculated unbalanced peak-to-peak rotor amplitudes at any speed from zero to maximum speed shall not exceed 75% of the minimum design diametrical running clearances throughout the machine. In these cases the separation margins of the wet critical speed shall comply with the requirements outlined in API 610.

Housing resonances shall not occur between zero and maximum operating speed.

2.5 VIBRATION AND BALANCE

All major parts of the rotating elements shall be individually dynamically balanced in two planes. Single plane component balancing may be applied if the ratio D/B (reference API 610, section 2.8.4.2) is 6.0 or greater.

Rotor assemblies shall be dynamically checked for their balance condition in addition to the balancing of the individual components of the rotor assembly. Maximum permissible out-of-balance shall be in accordance with ISO 1940-1, Quality Class Q 2.5.

During the shop test of the pump, vibration pick-ups, e.g. accelerometers, should be attached to the pump to monitor the vibration at each flow rate during all tests, including NPSH and pump down test. The installation of accelerometers at the outer wall of the column or the pump barrel, if vibration measurements on the pump casing for pump monitoring purposes during testing are not possible, is subject to the approval of the Principal. The Manufacturer shall prove the correlation between pump casing and column wall measurements in the latter case.

The unfiltered root mean square vibration velocity, measured at the upper and lower bearing locations with an instrument conforming to ISO 2954, shall not exceed the following values:

Flow range in % of best efficiency point	RMS vibration velocity, mm/s
25-49	4.5
50-115	3.0
116-125	4.5

2.6 PRESSURE CASING DESIGN

Pressure casings shall be of the required thickness to suit the maximum allowable casing working pressure and test pressure at the specified minimum pumping temperatures.

The allowable design stress to be used shall not exceed the values given for the specific material in ASME VIII, Division 1. For cast materials the factor specified in ASME VIII, Division 1 shall be applied. The maximum allowable casing working pressure shall apply to all parts referred to in the definition of pressure casing. Pressure casings not made out of aluminium or stainless steel shall have a corrosion allowance of at least 1mm.

Pressure pots of forged steel, rolled and welded plate, or of seamless pipe with welded covers, etc., shall comply with the applicable rules of ASME VIII, Division 1.

Manufacturer's data report forms and inspection requirements shall be subject to the approval of the Principal.

Pump casings (cast aluminium) shall comply with (3.1 and 3.2).

2.7 NOZZLES AND MISCELLANEOUS CONNECTIONS

If bored and tapped nozzles are the Manufacturer's standard, they may be used for sizes 1½" and smaller. Flanged and butt welded nozzles shall be used for pipe sizes 2" and larger.

2.8 SUCTION AND DISCHARGE FLANGES OF POTS (FOR POT-MOUNTED PUMPS)

Amended per Circular 25/97

Suction flanges shall have the same ANSI pressure/temperature ratings as the discharge flanges to allow the complete pressure casing to be subjected to the full test pressure.

Integral barrel constructions for high differential head multi-stage "pot" mounted pumps with a suction side at a lower pressure rating than the discharge side may be employed subject to the approval of the Principal for the application under consideration.

Flanges shall be in accordance with ASME/ANSI B16.5 or BS 1560. Pipe sizes 1¼", 2½", 3½", 7" and 9" are considered non-standard and shall not be used.

Flange facing finish shall be in accordance with ASME/ANSI B16.5.

2.9 BOLTING

All bolting/locking material shall be of stainless steel.

All wet bolting shall be double-locked. The Manufacturer shall state the selected double

locking method in the proposal for approval by the Principal.

The bolting used for fasteners, cable constructions, etc., shall also be locked by one of the following methods:

- Washer and locking wire
- Washer and self locking nut

2.10 IMPELLERS

Impellers shall be made in one piece and shall be secured to the pump shaft by keys, except for pumps with overhung shafts whose impellers shall be secured to the shaft by a self locking nut or cap screw, which tightens in the direction of normal rotation. A positive mechanical locking method, e.g. set screw, tongue-type washers, belleville springs etc., shall be provided. Cap screws shall be ASTM A 320-L7 or ASTM A 320-B8M or equivalent, with fillets and a reduced diameter shank to decrease stress concentrations. The use of collets is subject to the approval of the Principal.

To reduce the NPSHR at rated capacity in pressurised storage service, the use of inducers (either vane-type or spiral type) may be considered. Final implementation is subject to the approval of the Principal.

To reduce the "dead stock" level in the refrigerated storage tank, inducers (either vane-type or spiral type) may be used. The NPSHR level at rated capacity shall be considered as "dead stock" level.

2.11 WEAR RINGS

The material and hardness of wear rings shall be as specified on the data/requisition sheet.

Renewable wear rings shall be assembled with a shrink fit and be secured by three set screws or by tack welding at three points. The latter method shall be used only if the materials concerned are suitable for welding and the coefficients of thermal expansion are equal.

All pump bodies and/or impeller covers shall be sized for installation of wear rings for repair purposes at a later date if not already installed in the original design.

2.12 RUNNING CLEARANCES

When establishing running clearances between wear rings and other moving parts, consideration shall be given to pumping temperatures, suction conditions, character of fluid handled, and the thermal expansion and galling characteristics of the ring material.

Clearances between impeller and casing wear rings and intermediate bushings shall not be less than the minimum clearances shown in Appendix 1.

If the Manufacturer's standard clearances have to be enlarged to meet these requirements, he shall quote and guarantee efficiencies and power consumption on the basis of the enlarged clearances.

The Manufacturer's clearances as applied in the thrust balancing equalizing system are not subject to the above requirement.

2.13 BEARINGS

The thrust and radial bearings shall be suitable for lubrication and cooling by the pumped fluid under stable as well as transient conditions. The Manufacturer shall define in the proposal any precautions considered necessary to restrict the ingress of dirt to the bearings and to prevent vapour locking.

The Manufacturer shall demonstrate with test curves of identical impellers and the thrust balancing device that the expected thrust load for the full pump operating range will be within the load carrying capacity of the bearings to be used, so that the required operating period will be achieved. If test curves of identical impellers are not available, axial thrust test

measurements or alternatively water tests shall be carried out to verify the calculated thrust.

2.14 MISCELLANEOUS

The Manufacturer shall define in his proposal all the precautions necessary to guarantee satisfactory operation. The Manufacturer shall clearly define in the proposal any limitations and special precautions required to lower the liquid level in the storage vessel or tank to the absolute minimum should it be necessary to empty the storage vessel or tank.

Cables supplied for the pump-lifting/supporting system shall be of the non-twisting type and shall be made of AISI type 304 stainless steel or equivalent.

The Manufacturer shall indicate in his proposal whether special tools are required or recommended for dismantling and assembling the unit (e.g. hydraulic bolt-tensioning tools).

Foot valves of the "spring-loaded to close" design or an agreed other proven equivalent shall be provided for column-mounted pumps. The Manufacturer's intended sealing arrangement shall be subject to approval by the Principal.

All pump units shall have nameplates of corrosion-resistant metallic material mounted outside on the head plate assembly.

At least the following information shall be stamped on this nameplate:
- Manufacturer's name;
- pump type;
- model;
- r/min;
- minimum to maximum flow range (m^3/h) and corresponding differential heads (m);
- maximum allowable working pressure and corresponding temperature (kPa -°C);
- year of manufacture;
- purchase order number;
- identity code numbers of the anti-friction bearing manufacturer;
- asset number (plant registration number).

Lettering shall be 4 mm high. The text on the nameplate shall be in English, unless otherwise specified by the Principal.

The pump serial number, code numbers of the bearings installed, asset number and the direction of rotation shall be legibly stamped/engraved on the pump casing.

3. MATERIALS

3.1 GENERAL

The aluminium casting material of the pump casing and impellers shall be in accordance with ASTM B 26, alloy 356.0, temper T6. The selection and use of materials in accordance with other recognised International codes is subject to the approval of the Principal.

3.2 MATERIAL INSPECTION

Inspection of the aluminium casting should be done at the foundry.

Material inspection for acceptance or certification purposes shall be carried out after final heat treatment.

Leaks and defects in pressure castings shall not be repaired by peening, plugging or impregnation.

The following Inspection requirements shall apply:

- 100% liquid penetrant examination in accordance with ASME VIII, Division 1 Appendix 8.
- Areas for radiography shall be agreed between the Principal and the Manufacturer. Any radiographic examination shall be in accordance with ASTM E 94. The acceptance criteria are based on reference radiographs ASTM E 155 with the acceptance level as specified in ASTM B 26, table 3, grade C.

The Principal shall be informed about the need to repair before any repair welding is carried out. All repairs shall be recorded on a drawing and shall meet the inspection requirements and acceptance standards of the original material. The repairs shall be carried out in accordance with welding procedures and by welders qualified to ASME IX.

3.2.1 Shafts

Pump/motor shafts in refrigerated product service for propane and lighter, below -40 °C, with a length/diameter ratio of >30, shall be thermo-cycled at least 5 times between ambient and the lowest operating temperature specified to demonstrate that no material phase transformation occurs resulting in transformation stresses causing shaft deflections outside the Manufacturer's tolerances.

The Manufacturer shall furnish a thermo-cycling inspection report including shaft run-out measurements before and after the thermo-cycles.

3.2.2 Certification

Material certification in accordance with ISO 10474, type 3.1B, shall be provided for pressure-containing parts.

3.3 SUCTION POTS

DEP 30.10.02.31-Gen. shall apply. Welding procedure qualification tests shall also include impact testing, which shall also include the heat affected zone.

Bolting for all flanges shall be ASTM A 320-B8M, class 2, and shall be provided with material certificates in accordance with ISO 10474, type 3.1B.

The use of bolting of a different standard is subject to the approval of the Principal.

Suction pots shall be designed and tested to ASME VIII, Division 1.

All accessible pressure containing welds on suction pots and head plates shall be 100% radiographed, and all other welds shall be liquid penetrant examined. Acceptance criteria shall be in accordance with ASME VIII, Division 1.

4. SHOP INSPECTION AND TESTS

4.1 GENERAL

All pumps shall be individually inspected and tested in accordance with this DEP.

Unless otherwise specified on the data/requisition sheet, the inspection and test procedure summarised below and detailed thereafter shall be carried out:

- dimensional check against certified outline drawings;
- internal check;
- electric motor test;
- hydrostatic test;
- performance test;
- NPSH test;
- pump down test;
- post test disassembly;
- foot valve test;
- power cable bend and potential test;
- lifting cable tensile test;
- chemical and/or physical analysis of materials to be carried out as indicated in the inspection plan and to be covered by certificates as specified in this DEP. Certificates for components not specified in this DEP shall be as specified by the Principal.

4.2 DIMENSIONAL CHECK

Dimensional checks shall be carried out for all pumps and auxiliaries prior to the performance test.

This check shall include:
- wear ring clearances;
- main dimensions of pump unit to comply with the approved drawings;
- size, position and rating of flanges (for pot-mounted pumps only);
- size and type of threaded connections;
- support bracket dimensions of electric cables and locking devices;
- dimensions of head plate, position of junction box, dimension, position, orientation and rating of discharge nozzle;
- dimensions of foot valve assembly relative to pump inlet dimensions with pump in lowered and lifted position.

4.3 INTERNAL CHECK

Checking and inspection of all parts shall comprise:

- Check of wall thicknesses of castings and any repairs made.
- Check of running clearances; wear ring clearances shall be measured and recorded.
- Inspection in respect of workmanship, finish and surface defects.
- Check for rubbing marks at the thrust balancing device, impellers, inducers.
- Cleanliness of filters and vents.

4.4 ELECTRIC MOTOR TEST

In addition to the specified tests in DEP 33.66.05.31-Gen., the windings shall be tested to NEMA submerged stator test - MG 1-20.49.

4.5 HYDROSTATIC TEST

All pump suction pots, pump castings, column head plates and terminal header assemblies shall be hydrostatically tested at 1.5 x the maximum allowable working pressure, without consideration of cryogenic strength factors.

If the terminal header assembly contains the electrical penetration seals it shall be tested separately.

Testing shall be carried out with fresh water and the test pressure shall be maintained for at least 30 minutes. The water purity shall be compatible with the material to be tested.

There shall be no leakage or weeping from the material of suction pots, pump castings, terminal header assemblies or internal transfer tubes at the swaged ends.

Casing wear rings shall not be fitted during the hydrostatic test of the pump casing.

After having passed the hydrostatic test, the suction pot shall be die-stamped with the pressure applied in kPa.

Repairs made on any pressure part of the cast pump casing shall be inspected and accepted before commencing a second hydrostatic test.

The electrical terminal header double seal shall be subjected to a helium leak test in addition to a hydrostatic test. The measured leakage rate shall be less than 10^{-6} cm^3/s with a test pressure of 8 bar (abs).

4.6 PERFORMANCE TEST

The performance test shall be carried out at maximum operating speed with a tolerance of ±5% and with the voltage and frequency as specified on the data/requisition sheet.

Each pump shall run continuously for a period of at least two hours at rated flow at the actual temperature of the liquid to be pumped or in a representative condition approved by the Principal, unless otherwise specified on the data/requisition sheet. Pumps should be tested with the liquid and at the operating conditions as specified. If this is not possible, the Manufactuer shall propose for the Principal's approval a suitable test liquid and temperature to simulate future site conditions.

An accumulated two-hour run is acceptable only if the quantity of the cooling medium is insufficient for a continuous run in which case there shall be no more than 2 interruptions during this two-hour run. The performance test shall include eight data points, including shut-off. The minimum thermal flow point shall be used instead if the shut-off can not be established in a practical way. One point shall be 125% of the flow at best efficiency point. All conditions shall be stable for each test point. The performance test shall be carried out at a constant temperature level between the actual temperature as given on the data/requisition sheet as a maximum and a subcooling of 5 °C as a minimum. This latter requirement is not applicable to pumps in pressure storage service. The curve shall comply with (2.1.d).

Unless otherwise specified, the effectiveness of the axial thrust compensation device shall be demonstrated and measured during testing.

Only measuring instruments which can be demonstrated to have been previously calibrated satisfactorily and are still within their documented calibration period (interval) shall be used for inspection and testing. The range of these instruments shall be such that the maximum pressure to be indicated is between 40 and 60% of the total range.

A certificate showing the density and vapour pressure characteristics of the test fluid used shall be available. The Principal may specify a laboratory analysis of the test fluid in addition to this certificate.

The actual density of the test fluid shall be verified prior to and immediately after the performance test.

Power consumption shall be determined for all performance data points.

Test data shall be corrected for specified operating conditions such as speed, viscosity and density. The corrected data shall be within the tolerances allowed for guaranteed figures as stated under Performance Tolerances in API 610. If the impeller needs to be modified to meet these tolerances, apart from an impeller diameter reduction as per API 610, section 4.3.3.4.1, the pump shall be retested.

The corrected data shall be submitted in a graph showing test data, corrected data and guaranteed figures.

During the performance test, vibration measurement data from the measurement points as agreed under 2.5 shall be recorded for all eight performance data points. Acceptance criteria shall be as specified in this DEP. Vibration measuring instruments shall have a valid calibration certificate.

A starting current test shall be performed on each motor.

4.7 NET POSITIVE SUCTION HEAD TEST

For pumps in refrigerated service the NPSH test shall be carried out at a slightly subcooled temperature (at least 5 °C) using the actual fluid to be pumped or an alternative liquid as agreed with the Principal. For pumps specified in pressurised storage service, the NPSH test shall be carried out at ambient temperature using the liquid specified in the data/requisition sheets. If this is not possible, an alternative liquid or test shall be agreed with the Principal.

The NPSH test shall be carried out at the minimum flow and at 80%, 100% and 125% of the rated flow.

If several identical pumps are specified in the order, at least two pumps out of the series shall have an NPSHR test carried out as stated above, while the remaining pumps shall have an NPSHR test at the rated flow only.

For single-stage pumps the NPSHR shall be based on a 3% head drop with an allowable tolerance at the guarantee point of + 0%. Multi-stage pumps shall have the NPSHR based on a 1% drop in total differential head or a 3% drop in differential head across the first impeller.

In situations where the test liquid is not of high purity and the vapour pressure cannot be accurately determined, an alternative test shall be carried out in accordance with the following procedure:

a. Density of the boiling liquid shall be measured prior and after the test.

b. Head correction shall be made with the average liquid density if the change in density is more than 2% between the beginning and the end of the test period.

c. After completion of the calibration/two-hour performance test, allow the fluid in the test loop to heat up to boiling point.

d. At the start of the test, pump submergence should be at least 3 times the NPSHR at the guarantee point.

e. Reference for the 3% head drop is the developed head with the boiling fluid at the guarantee flow.

f. Flow point should be set; with the liquid return valve to storage closed if applicable.

g. The liquid level in the test loop should be gradually lowered by pumping fluid back to storage.

h. Readings for discharge pressure, suction temperature, discharge temperature, tank pressure, liquid level and vibrations should be taken at regular intervals, e.g. at every 200 mm reduction in level. When the NPSHR point is approached, readings should be taken at every 100 mm reduction in level.

   The storage return valve should be closed while the readings are being taken.

i. After the NPSHR point is reached, emptying of the system should continue until the pump loses prime. Readings should be taken at 100 mm intervals with the return valve closed.

j. For those pumps where the additional NPSHR points at minimum flow and 80% and 125% of the rated flow are required, tests shall be carried out in the same way as described above, but with the respective differential heads at the corresponding flows.

4.8 PUMP DOWN TEST

After the NPSHR test has been completed, the pump down test shall be started at the rated flow and at the liquid level equal to the NPSHR required.

The liquid level shall be reduced until the pump loses prime (head drop > 45%); readings for pressure, level, temperature and vibration should be taken at 100 mm suction level intervals with the return valve closed.

All column-mounted pumps shall be subjected to a pump down test at rated flow.

NOTE: The pumps that have had additional NPSHR points measured should also be subjected to a pump down test at the additional flow points for minimum flow, and 80% and 125% of the rated flow.

4.9 POST TEST DISASSEMBLY

All pumps shall be disassembled after testing for inspection of the condition of the internals e.g. bearings, wear rings, impellers, bushings etc.

Wear ring abnormalities shall be recorded and clearances verified.

4.10 FOOT VALVE TEST

All foot valves for column-mounted pumps in refrigerated service shall be tested at the actual temperature of the liquid to be pumped in service unless otherwise agreed with the Principal, using methanol or nitrogen over a pressure range equivalent to the head of a 150% full tank and a tank at minimum level (the minimum level should be taken as the NPSH required level at rated flow). Foot valves for column-mounted pumps operating in pressurised storage service shall be tested over a pressure range from 150% of the maximum storage vessel pressure to the lowest vapour pressure combined with minimum liquid level.

Leakage over a period of two hours at minimum pressure shall be not more than 50 dm^3 liquid per metre of circumference of the valve. If the foot valve is equipped with a purge seal, the seal shall be pressurised during the test to 20 kPa greater than the simulated tank head. Leakage through the seal shall be zero after 30 minutes.

4.11 LIFTING CABLE TENSILE TEST

Each batch of lifting cables, which shall be designed to take at least three times the weight of the total pump unit, shall be proof tested and shall have a material certificate (ISO 10474, type 3.1.B) showing the mechanical and chemical properties.

5. REFERENCES

**Amended per
Circular 25/97**

In this DEP, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Metallic materials - Prevention of brittle fracture	DEP 30.10.02.31-Gen.
Noise control	DEP 31.10.00.31-Gen.
Data/requisition sheet for Equipment Noise Limitation	DEP 31.10.00.94-Gen.
Data/requisition sheet for centrifugal pumps	DEP 31.29.02.93-Gen.
Piping - General requirements	DEP 31.38.01.11-Gen.
Electric motors, cage-induction and synchronous type	DEP 33.66.05.31-Gen.
Data/requisition sheet for electric motors	DEP 33.66.05.93-Gen.
Field commissioning and maintenance of electrical installations and equipment	DEP 63.10.08.11-Gen.

AMERICAN STANDARDS

Pipe flanges and flanged fittings, NPS $^1/_2$ through NPS 24	ASME/ANSI B16.5

Issued by:
American Society of Mechanical Engineers
345 East 47th Street
New York NY 10017
USA.

Centrifugal Pumps for General Refinery Services	API 610, 8th edition

Issued by:
American Petroleum Institute
Publications and Distribution Section
2101 L Street Northwest
Washington DC 20037, USA.

ASME Boiler and Pressure Vessel Code	
Non-destructive examination	ASME V
Rules for construction of pressure vessels	ASME VIII, Div. 1
Welder qualification	ASME IX

Issued by:
The American Society of Mechanical Engineers
345 East 47th Street, New York
NY 10017, USA.

Specification for alloy-steel bolting materials for low-temperature service	ASTM A 320
Aluminum alloys	ASTM B 26
Radiographic testing	ASTM E 94
Reference radiographs for aluminum alloys	ASTM E 155

Issued by:

American Society for Testing and Materials
1916 Race Street, Philadelphia
19103, USA.

BRITISH STANDARDS

Steel Pipe Flanges and Flanged Fittings for the Petroleum Industry	BS 1560

Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL
United Kingdom.

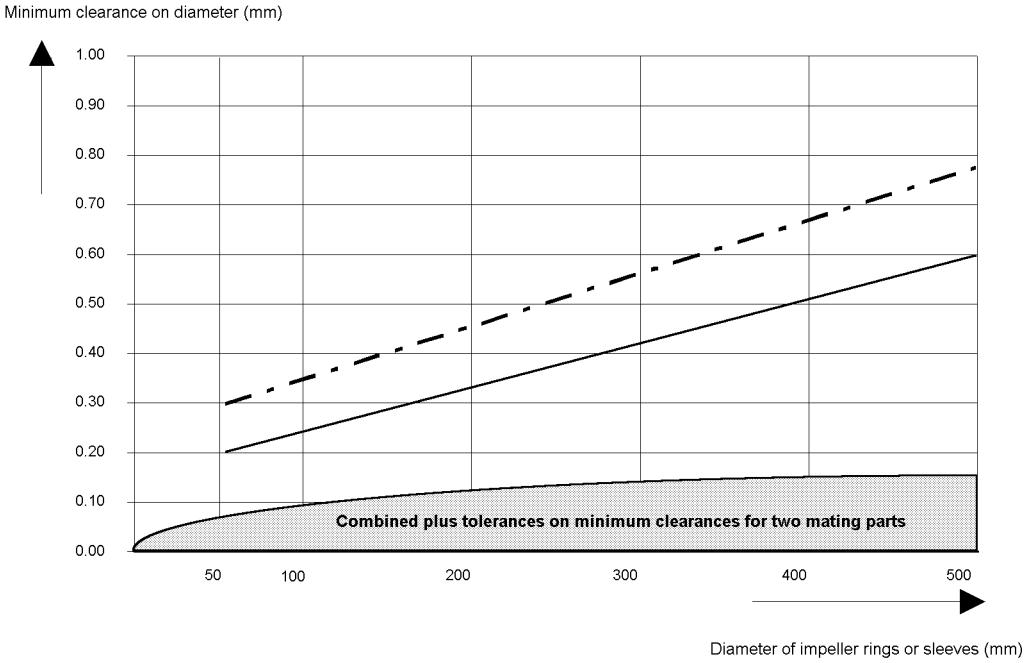
INTERNATIONAL STANDARDS

International electrotechnical vocabulary	IEC 50
Mechanical vibration - Balance quality requirements of rigid rotors; Part 1: Determination of permissible residual unbalance	ISO 1940-1
Mechanical vibration of rotating and reciprocating machinery - Requirements for instruments for measuring vibration severity	ISO 2954
Steel and steel products - Inspection documents	ISO 10474

Issued by:
Central Secretariat of ISO
1, rue de Varembé, 1211 Geneva 20
Switzerland.

Copies can also be obtained from national standards organisations.

APPENDIX 1 RECOMMENDED CLEARANCES FOR CENTRIFUGAL SUBMERGED MOTOR PUMPS IN REFRIGERATED OR PRESSURISED STORAGE SERVICE



A. For casing rings and impeller rings use _____ for single-stage and two-stage

___ ___ for multi-stage

Add combined tolerances for machining given in bottom part of graph at the point indicating the impeller ring diameter.

B. 1. For intermediate bushings and sleeves, use minimum clearances found for casing ring and impeller ring (See A).

2. Subtract 0.1 mm.

3. Add tolerance for the correct sleeve diameter.