

DEP SPECIFICATION

CENTRIFUGAL SUBMERGED MOTOR PUMPS AND ELECTRO SUBMERSIBLE HYDRAULIC TURBINES

DEP 31.29.06.30-Gen.

February 2011
(DEP Circular 52/11 has been incorporated)

ECCN EAR99

DESIGN AND ENGINEERING PRACTICE



© 2011 Shell Group of companies

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, published or transmitted, in any form or by any means, without the prior written permission of the copyright owner or Shell Global Solutions International BV.

This document contains information that is classified as EAR99 and, as a consequence, can neither be exported nor re-exported to any country which is under an embargo of the U.S. government pursuant to Part 746 of the Export Administration Regulations (15 C.F.R. Parts 746) nor can be made available to any national of such country. In addition, the information in this document cannot be exported nor re-exported to an end-user or for an end-use that is prohibited by Part 744 of the Export Administration Regulations (15 C.F.R. Parts 744).

PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of Shell Global Solutions International B.V. (Shell GSI) and, in some cases, of other Shell Companies.

These views are based on the experience acquired during involvement with the design, construction, operation and maintenance of processing units and facilities. Where deemed appropriate DEPs are based on, or reference international, regional, national and industry standards.

The objective is to set the recommended standard for good design and engineering practice to be applied by Shell companies in oil and gas production, oil refining, gas handling, gasification, chemical processing, or any other such facility, and thereby to help achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to Shell companies 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 Units to adapt the information set forth in DEPs to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use DEPs, they shall be solely responsible for such use, including the quality of their work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will typically expect them to follow those design and engineering practices that will achieve at least the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal.

The right to obtain and to use DEPs is restricted, and is granted by Shell GSI (and in some cases by other Shell Companies) under a Service Agreement or a License Agreement. This right is granted primarily to Shell companies and other companies receiving technical advice and services from Shell GSI or another Shell Company. Consequently, three categories of users of DEPs can be distinguished:

- 1) Operating Units having a Service Agreement with Shell GSI or another Shell Company. The use of DEPs by these Operating Units is subject in all respects to the terms and conditions of the relevant Service Agreement.
- 2) Other parties who are authorised to use DEPs subject to appropriate contractual arrangements (whether as part of a Service Agreement or otherwise).
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, Shell GSI disclaims any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any DEP, combination of DEPs or any part thereof, even if it is wholly or partly caused by negligence on the part of Shell GSI or other Shell Company. The benefit of this disclaimer shall inure in all respects to Shell GSI and/or any Shell Company, or companies affiliated to these companies, that may issue DEPs or advise or require the use of DEPs.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, DEPs shall not, without the prior written consent of Shell GSI, be disclosed by users to any company or person whomsoever and the DEPs shall be used exclusively for the purpose for which they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of Shell GSI. The copyright of DEPs vests in Shell Group of companies. Users shall arrange for DEPs to be held in safe custody and Shell GSI may at any time require information satisfactory to them in order to ascertain how users implement this requirement.

All administrative queries should be directed to the DEP Administrator in Shell GSI.

TABLE OF CONTENTS

1.	INTRODUCTION	4
1.1	SCOPE.....	4
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	4
1.3	DEFINITIONS	4
1.4	CROSS-REFERENCES	6
1.5	SUMMARY OF MAIN CHANGES.....	6
1.6	COMMENTS ON THIS DEP	7
1.7	HIERARCHY OF DOCUMENTS	7
2.	DESIGN	8
2.1	GENERAL	8
2.2	NOISE level	8
2.3	ELECTRIC MOTORS / GENERATORS / VARIABLE SPEED DRIVES.....	9
2.4	CRITICAL SPEEDS	10
2.5	VIBRATION AND BALANCE	10
2.6	PRESSURE CASING DESIGN.....	10
2.7	NOZZLES AND MISCELLANEOUS CONNECTIONS	11
2.8	SUCTION AND DISCHARGE FLANGES OF POTS (FOR POT-MOUNTED PUMPS)	11
2.9	BOLTING	11
2.10	IMPELLERS.....	11
2.11	WEAR RINGS.....	12
2.12	RUNNING CLEARANCES.....	12
2.13	BEARINGS.....	12
2.14	VIBRATION AND SPEED MEASUREMENT SYSTEM.....	12
2.15	VENT LINES FROM POT-MOUNTED PUMPS OR EXPANDERS.....	13
2.16	MISCELLANEOUS	13
3.	MATERIALS	15
3.1	GENERAL	15
3.2	MATERIAL INSPECTION	15
3.3	SUCTION POTS	15
4.	SHOP INSPECTION AND TESTS	16
4.1	GENERAL	16
4.2	DIMENSIONAL CHECKS.....	16
4.3	INTERNAL inspection	16
4.4	ELECTRIC MOTOR OR GENERATOR TEST	17
4.5	HYDROSTATIC TESTS.....	17
4.6	PERFORMANCE TESTs	17
4.7	NET POSITIVE SUCTION HEAD TEST	18
4.8	PUMP DOWN TEST	19
4.9	POST TEST DISASSEMBLY.....	19
4.10	FOOT VALVE TEST	20
4.11	LIFTING CABLE TENSILE TEST	20
5.	REFERENCES	21

APPENDICES

APPENDIX 1	RECOMMENDED CLEARANCES FOR CENTRIFUGAL SUBMERGED MOTOR PUMPS IN REFRIGERATED OR PRESSURISED STORAGE SERVICE	23
------------	---	----

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for centrifugal submerged motor pumps (column-mounted or pot-mounted) in refrigerated product or pressurised storage service.

This DEP also specifies requirements and gives recommendations for electro submersible hydraulic turbines, also referred to as liquid expanders.

Note: If a term in this DEP is not applicable to the design, manufacturing, testing, or operation of submerged generator liquid expanders, then any related clause is not applicable.

This DEP is intended to be used in conjunction with API 610/ISO 13709 data/requisition sheets for centrifugal pumps.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorization to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process should be implemented. This is of particular importance when existing facilities are to be modified.

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 that 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 that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that 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/expander type is an uninterrupted operation period of at least 16,000 h under the conditions specified for the guarantee point, unless otherwise specified. Manufacturer/Supplier shall state if longer continuous service is available with different bearing options, i.e., ceramic or hydrostatic sleeve type.

Column-mounted is the installation of a complete pump assembly in a storage tank column.

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 Std 610, section 7.3.1.1). 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.

Design pressure is the greatest pressure at the specified pumping temperature for which the pump casing and the vessel (for pot-mounted pumps) are designed.

NOTE: This includes all intended operating conditions and possible upset conditions.

Maximum discharge pressure is the maximum suction pressure plus the maximum differential head that 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 that 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 (2) 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) or at the centreline of the first impeller or inducer 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 centre line of the inducer or the impeller 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% to the overall head value measured due to cavitation within the pump. This is due to the properties of cold boiling liquids which result in instantaneous loss of performance. The NPSHR is determined by the Manufacturer and shall be based on the pump handling the actual product specified on the data/requisition sheet and expressed in metres of actual liquid.

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 or expander 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 that are in the liquid phase under atmospheric pressure.

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

Note: With respect to submerged generator liquid expanders, the following are not applicable terms: column-mounted, maximum discharge pressure, maximum rated discharge pressure, maximum suction pressure, minimum continuous thermal flow, net positive suction head (NPSH/NPSHR/NPSHA), rated discharge pressure, rated suction pressure.

1.4 CROSS-REFERENCES

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

1.5 SUMMARY OF MAIN CHANGES

This DEP is a revision of the DEP of the same number, dated April 2003. The following are the main, non-editorial changes:

Old clause	New clause	Change
1.1	1.1	Changed requirement to use this DEP for expanders from may to shall. Changed from DEP pump data sheet to API 610 pump data sheet. Added the addition of applicability to submerged generator liquid expanders (electro submersible hydraulic turbines) results in additional exceptions/deviations.
2.1	2.1	Added note with respect to submerged generator liquid expanders. Added comment that expanders shall be of upward flow design. Refined the requirements for head rise, operating range and guarantee point to be per API 610/ISO 13709. Changed preferred operating range to in accordance with API 610. Added requirement that pump and expander suppliers shall state their minimum continuous flow rate and the basis for this value, i.e. CFD, etc.
2.2	2.2	Deleted reference to DEP 31.10.00.31 Gen, Noise Control as it is not considered suitable for reference in requisitions of individual equipment.
2.3	2.3	For liquid expanders, added Generator DEP and Variable Speed Drive DEP. Deleted reference to DEP 80.00.10.10 and API RP 500 on area classification selection since supplier is not responsible for determining the appropriate area classification, buyer should specify.
2.5	2.5	Modified preferred operating range to be in agreement with API 610.

Old clause	New clause	Change
2.13	2.13	Added requirement for Manufacturer to comment on inlet strainers and mesh sizes. Added comment for Manufacturer to comment on need of ceramic bearings to prevent bearing arcing in for VFD motors or generator applications.
2.14	2.14	Added reference to speed measurement system and that supplier shall comment on new developments to improve reliability.
3.3	3.3	Deleted reference to DEP 30.10.02.31-Gen. Metallic Materials-prevention of brittle fracture since this is not appropriate reference for purchase specification.
4.4	4.4	Added requirements for generator testing.
4.6	4.6	Changed max flow point from 125% to 120% in accordance with API 610. Modified instrument range based on supplier experience. Added requirements for expander runaway test. Added requirement to measure axial position of shaft to ensure thrust equalizing system working properly.
4.7	4.7	Changed basis for NPSHR for multi-stage pumps to 3% drop in total differential head due to properties of cold boiling liquids which result in instantaneous loss of performance.
5.0	5.0	Deleted DEP 31.38.01.11 Gen on piping-general requirements since it was not called out in the DEP. Also deleted DEPs for pump data sheet, noise control, area classification and metallic materials-prevention of brittle fracture.

1.6 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://swwww.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.7 HIERARCHY OF DOCUMENTS

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

- 1st priority: the purchase order and variations thereto;
- 2nd priority: data/requisition sheet and variations thereto;
- 3rd priority: this DEP.

2. DESIGN

2.1 GENERAL

- a) Pump and expander 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.
- b) At least three (3) units of similar type and size shall have had at least 8,000 hours of continuous operation each.
- c) 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. Incorporating a variable speed motor or using blank stage(s) is another means of pump being capable of a 5% head increase.
- d) Pumps may be of single or multi-stage design.
- e) Pumps shall have a stable head versus flowrate curve which continuously rise by at least 5% from rated capacity to shut-off. If parallel operation is specified, the head rise from rated point to shutoff shall be a minimum of 10%, to ensure continuous stable parallel operation. During performance testing, the test points shall always show increasing differential head with decreasing flow.
- f) Pumps shall be selected with the guarantee point between 80% and 110% of best efficiency point, applicable to the impeller diameter fitted.
- g) Pumps shall have a preferred operating region of 70% to 120% of best efficiency flow rate of the pump furnished. 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.
- h) Pumps shall be capable of continuous service at any flow rate between the minimum continuous flow stated in the data/requisition sheet and the end of curve flow rate, either solo or in parallel with other pumps of similar rating.
- i) There shall be at least 1 m margin between NPSHA and NPSHR at rated point. NPSHR at the end of the curve shall be less than NPSHA, but it is not mandatory to have the 1 m margin, though some margin is preferred.
- j) For parallel running pumps, the Manufacturer shall specify the minimum flowrate to be at least 60% of rated flow. A minimum flowrate below 60% of rated flow for parallel running pumps requires specific approval from the Principal. Pump and expander Supplier shall state its standard minimum continuous flow rate and state the basis for this value, i.e. CFD analysis, etc.
- k) The Manufacturer shall include and define in his proposal any special protection and equipment required during shipment, site storage, installation, and operation. Manufacturer proposal shall be based on the environmental conditions at site.
- l) A thrust balancing system shall be furnished. Manufacturer to furnish complete details of the design and operation of the thrust equalizing mechanism (TEM).
- m) With respect to submerged generator liquid expanders, 5% head increase, head rise to shut-off, and end of curve flow are not applicable.
- n) Liquid expanders shall be of the upward flow design to minimize problems due to possible vapour formation at off design conditions.

2.2 NOISE level

The Supplier shall advise the guaranteed noise levels by completing data sheet DEP 31.10.00.94-Gen., which forms part of the requisition. This requirement is not applicable to column-mounted pumps.

2.3 ELECTRIC MOTORS / GENERATORS / VARIABLE SPEED DRIVES

Electric motors shall, as far as practically possible, comply with DEP's outlined under Reference section (5) and with the following requirements:

- a) Motor shall have power rating as per API 610 para 6.1.3, table-11. The motor shall also be able to meet the power requirement to cover end of curve operation, but the margin is not mandatory to avoid un-necessary motor over sizing. For all column mounted pumps the motor power rating shall be minimum 135% BEP, the capacity corresponding to worst case column filling situation at start up.
- b) Motors shall be designed for full voltage starting. The torque provided by a motor at 80% of rated voltage shall be capable of accelerating the pump to full speed with an open discharge valve (no valve restriction).
- c) The combined pump/motor rotor that can be subject to reverse rotation for short periods of time, shall be suitable for reverse rotation at up to 120 % of rated speed.
- d) All components, 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. Liquid composition and possible impurity quantities, such as H₂O, NH₃, CO₂, and H₂S, shall be stated to assess the suitability of cables, feed throughs, motor windings, materials of construction, and insulation materials.
- e) Windings of the electric motors shall be provided with at least three (3) 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. Manufacturer shall comment on other methods of temperature detection if thermistors are ineffective for submerged motors that are pump product cooled. This requirement is not applicable to wet stator design of motors.
- f) Electric cables between the motor or generator and a junction box mounted on the head plate shall be provided by the pump/motor or expander/generator Manufacturer and shall be suitable for the refrigerated product service at the voltage level specified on the data/requisition sheet.
- g) Motor/generator 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.
- h) Motor/generator cables shall be compatible with the pump/motor or expander/generator retraction system, i.e., vibration, bending around a bending radius of 1 m, 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.
- i) An earth conductor shall be provided for the motor/generator. The support cable may be used for the earthing of the motor or generator.
- j) The motor/generator junction box shall be suitable for the hazardous area and sized to accommodate the incoming cables as specified on the data requisition sheet.
- k) 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.

**Amended per
Circular 52/11**

Generators shall, as far as practically possible, comply with the requirements specified in DEP 33.66.05.31- Gen:

- i. With respect to submerged generator liquid expanders, the sizing criteria for generators (expanders) is different than motors (pumps) and dependent upon the expander design (e.g. variable speed versus fixed speed).
- ii. Generator sizing and margin information shall be provided with proposal.

Variable speed drives (VSDs) shall, as far as practically possible, comply with the requirements specified in DEP 33.66.05.33-Gen.

2.4 CRITICAL SPEEDS

The rotor of the pump/motor or expander/generator shall be a stiff shaft construction.

The first damped (wet) lateral critical speed shall be at least 10% above the maximum operating speed.

If a lateral analysis is required per API 610 paragraph 8.2.4.1.2 (Table 16), a damped unbalance response analysis shall be performed in accordance with API 610 section I.1.4 and Figure I.1, "Damping factor versus frequency ratio".

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 (2) planes. Single plane component balancing may be applied if the ratio D/b (reference API Std 610, section 5.9.4.2) 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 or expander, 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.

- Installation of accelerometers at the outer wall of the column or the pump barrel, if vibration measurements on the casing are not possible, is subject to the approval of the Principal.
- Manufacturer shall prove the correlation between casing and column wall measurements for accelerometers installed on the barrel.

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
35 - 69	4.5
70 - 120	3.0

2.6 PRESSURE CASING DESIGN

Pressure casings shall be designed to suit the design pressure at the specified minimum and maximum temperatures. Maximum temperature shall be based on maximum fluid temperature during operation.

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 casting factor specified in ASME VIII shall be applied.

Design 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 1 mm.

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.

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)

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 used subject to the approval of the Principal.

Flanges shall be in accordance with ASME/ANSI B16.5 or BS 1560:Sec 3.1. 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 made 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 (1) 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., setscrew, tongue-type washers, belleville springs etc., shall be provided.

Cap screws shall be ASTM A 320/A 320M-L7, -8M or equivalent, with fillets and a reduced diameter shank to decrease stress concentrations.

The use of collets is subject to 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.

- To reduce the "dead stock" level in the refrigerated storage tank, inducers (either vane-type or spiral type) may be used.
- NPSHR level at rated capacity shall be considered as "dead stock" level.
- Final implementation of inducers is subject to approval of the Principal.

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 (3) setscrews or by tack welding at three (3) points. Tack welding 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, efficiencies and power consumption shall be quoted and guaranteed on the basis of the enlarged clearances.

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

2.13 BEARINGS

Thrust and radial bearings shall be suitable for lubrication and cooling by the pumped fluid under both stable and transient conditions.

Manufacturer shall define in the proposal any precautions considered necessary to restrict the ingress of dirt to the bearings and to prevent vapour locking. Manufacturer should state mesh size for temporary startup inlet strainers and any requirements for permanent inlet strainers.

Manufacturer shall demonstrate with test curves of identical impellers and the thrust balancing system that the expected thrust load for the full pump or expander operating range is within the load carrying capacity of the bearings to be used, so that the required operating period is 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.

Pot-mounted pumps and expanders shall be internally self-venting. Venting arrangements shall ensure that the bearings are adequately lubricated during start-up and operation.

Manufacturer shall state if ceramic type bearings are recommended to prevent arcing damage for VFD motors or generators.

2.14 VIBRATION AND SPEED MEASUREMENT SYSTEM

A vibration and speed measurement system shall be supplied.

Manufacturer shall ensure a functional design of the vibration and speed measurement system by taking into account the items below:

- Measurement transducers and wet part of the instrument cabling shall be free of signal disturbances during running at any allowable operational point on the curve.
- Frequency range of the system shall be capable of measuring the spectrum between 2 Hz and 10,000 Hz.
- Threaded connections in aluminium casings, e.g., for accelerometers, shall have replaceable thread inserts to avoid damage to the casing. Vibration transducers shall be positively locked and secured so they cannot loosen and fall off in service.

- Manufacturer shall supply at least three (3) references of similar systems and similar components in operation in comparable conditions.
- Vibration and speed measurement system shall be from a single Supplier. A hybrid system from multiple Suppliers is not allowed.
- The Supplier shall comment on any new developments related to speed monitoring systems that improve reliability.
- Column-mounted pumps shall have two (2) fully redundant accelerometers, including cabling and connections, installed on the pump body.

2.15 VENT LINES FROM POT-MOUNTED PUMPS OR EXPANDERS

Vent lines from the vessel and from the suction of pot-mounted pumps or expanders shall be run individually and shall be continuously sloping, with a minimum rate of 1:12 gradient upwards to the suction drum until the lines are above the maximum liquid level.

Discharge line of pot-mounted pumps or expanders shall have a vent connection at the highest point to allow venting during cool down and initial filling.

2.16 MISCELLANEOUS

Manufacturer shall define in the proposal all the precautions necessary to guarantee satisfactory pump operation.

The Manufacturer shall 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.

Manufacturer shall indicate in the 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. Manufacturer's sealing arrangement for the foot valves shall be subject to approval by the Principal.

All pump and expander units shall have nameplates of corrosion-resistant metallic material mounted outside on the head plate assembly. As a minimum, the following information shall be stamped on the nameplate:

- Manufacturer's name;
- Pump or expander type;
- Model;
- r/min;
- Minimum to maximum flow range (m³/h) and corresponding differential heads (m);
- Design 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).

Text on the nameplate shall be 4 mm high, and shall be in English, unless otherwise specified by the Principal.

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

For the column in column-mounted pumps, the headspace shall have a length dimension of 1.5 times the column diameter. Manufacturer shall review and comment on the discharge header layout.

3. MATERIALS

3.1 GENERAL

The material of construction for the pump components shall be in accordance with the requirements specified in the data requisition sheets. Aluminium castings for the casing and impellers shall be in accordance with ASTM B 26/B 26M, alloy 356.0, temper T6. Use of material that conforms to other standards is subject to the approval of the Principal.

3.2 MATERIAL INSPECTION

3.2.1 General

Inspection of aluminium castings should be done at the foundry.

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

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 E94. The acceptance criteria shall be based on reference radiographs ASTM E155 with the acceptance level as specified in ASTM B26/B 26M, table 3, grade C.

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

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 ASME IX welding procedures, and by welders qualified to that standard.

3.2.2 Shafts

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

Manufacturer shall furnish a thermocycling inspection report including shaft run-out measurements before and after the thermocycling is carried out.

3.2.2 Certification

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

3.3 SUCTION POTS

Welding procedure qualification tests for suction pots shall include impact testing and shall include the heat-affected zone.

Bolting for all flanges shall be ASTM A 320/A 320M-B8M, Class 2, and shall be provided with material certificates in accordance with ISO 10474, type 3.1B. 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 and expanders shall be individually inspected and tested in accordance with this DEP.

Unless otherwise specified on the data/requisition sheet, the following inspections and tests shall be carried out:

- dimensional check against certified outline drawings;
- internal check;
- electric motor or generator 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.

Note: The following are not applicable to liquid expanders: NPSH test, pump down test, foot valve test, and lifting cable tensile test.

4.2 DIMENSIONAL CHECKS

Dimensional checks shall be carried out for all pumps or expanders and auxiliaries prior to the performance test. This check shall include:

- wear ring clearances;
- main dimensions of pump or expander unit to comply with the approved drawings;
- size, position, and rating of flanges (for pot-mounted units 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 (not applicable to liquid expanders).

4.3 INTERNAL inspection

Internal inspection is comprised of the following:

- Check of wall thicknesses of castings and any repairs made;
- Check running clearances; wear ring clearances shall be measured and recorded;
- Inspect workmanship, finish, and surface defects;

- check for rubbing marks at the thrust balancing system, impellers, inducers;
- Inspect cleanliness of filters and vents.

4.4 ELECTRIC MOTOR OR GENERATOR TEST

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

**Amended per
Circular 52/11**

Generators shall be tested in accordance with DEP 33.66.05.31-Gen.

Pump/expander Manufacturer shall state what testing is to be done by the motor/generator manufacturer and what testing is to be done by the pump/expander manufacturer after assembly.

4.5 HYDROSTATIC TESTS

All pump suction pots, pump/expander castings, column head plates, and terminal header assemblies shall be hydrostatically tested at 1.5 times the design 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. Water purity shall be compatible with the material to be tested.

Test pressure shall be maintained for at least 30 min.

There shall be no leakage or weeping from the suction pots, pump/expander 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 passing 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/expander 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} cm³/s with a test pressure of 8 bar (abs).

4.6 PERFORMANCE TESTS

Performance tests shall be carried out at maximum operating speed with a tolerance of $\pm 5\%$, and with the voltage and frequency as specified on the data/requisition sheet.

Pumps/expanders 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. An cumulative 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 two (2) interruptions during the run.

Pumps/expanders should be tested with the liquid and at the operating conditions as specified. If this is not possible, the Manufacturer shall propose for the Principal's approval a suitable test liquid and temperature to simulate future site conditions.

A performance test shall include eight (8) data points, including shut-off. The minimum thermal flow point shall be used if the shut-off cannot be established in a practical way.

- One (1) data point shall be 120% of the flow at best efficiency point.
- All conditions shall be stable for each data point.

- Power consumption shall be determined for all data points.

Performance tests shall be carried out at a constant temperature level within the following range:

- maximum – temperature on data/requisition sheet;
- minimum – temperature on data/requisition sheet, less 5°C.

This latter requirement is not applicable to pumps in pressure storage service. The curve shall comply with paragraph (2.1.e).

The effectiveness of the axial thrust balancing system shall be demonstrated and measured during testing.

Only measuring instruments that can be demonstrated to have been previously calibrated satisfactorily and are still within their documented calibration period (interval) shall be used for performance tests.

- The range of the instruments shall be such that the maximum pressure to be indicated is between 20% and 80% of the total range.
- Vibration measuring instruments shall have a valid calibration certificate.

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 tests.

Test data shall be corrected for specified operating conditions such as speed, viscosity, and density.

- Corrected data shall be within the tolerances allowed for guaranteed figures as stated under Performance Tolerances in API Std 610.
- If the impeller requires modification to meet these tolerances, apart from a reduction of its diameter as described in API Std 610, section 7.3.3.5, the pump shall be retested. Trimming of expander runners is not applicable.
- Data shall be submitted in a graph showing test data and corrected data.

During the performance tests, vibration measurement data from the measurement points as specified in [2.5] shall be recorded for all eight (8) performance data points. Acceptance criteria shall be as specified in this DEP.

For pumps with thrust equalizing mechanism (TEM), axial position of the shaft shall be measured with a proximity probe and recorded during all portions of the performance test, including startup and shutdown. The position shall be compared to the bearing deflection limits to verify that the bearing is operating in a zero thrust load condition. The shaft axial travel shall be measured and recorded prior to the performance test in order to determine this acceptable operating range.

A starting current test shall be performed on each motor.

For liquid expanders, an expander runaway test shall be performed. Expanders shall be adjusted to the zero-torque condition corresponding to the head at the rated case that defines the runaway point. This condition shall be held for a minimum of two minutes. Speed and vibration shall be recorded.

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 in pressurised storage service, the NPSH test shall be carried out at ambient temperature with the liquid specified in the data/requisition sheets. If this is not possible, an alternative liquid or test shall be agreed with the Principal.

NPSH test shall be carried out at the minimum flow and at 80%, 100%, and 120 % of the rated flow.

If multiple identical pumps are specified in the order, at least two (2) 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 3% drop in total differential head.

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 that conforms to the following:

- Density of the boiling liquid shall be measured before and after the test.
- 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.
- After completion of the calibration/two-hour performance test, allow the fluid in the test loop to heat up to boiling point.
- At the start of the test, pump submergence should be at least three (3) times the NPSHR at the guarantee point.
- Reference for the 3 % head drop is the developed head with the boiling fluid at the guarantee flow.
- Flow point should be set; with the liquid return valve to storage closed if applicable.
- Liquid level in the test loop should be gradually lowered by pumping fluid back to storage.
- 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.
- Liquid return valve to storage should be closed while the readings are being taken.
- 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.

For pumps where the additional NPSHR points at minimum flow and 80% and 120% of the rated flow are required, tests shall be carried out in the same way as specified above, but with the respective differential heads at the corresponding flows.

4.8 PUMP DOWN TEST

Pump down test shall be started at the rated flow and at the liquid level equal to the NPSHR required.

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 120% of the rated flow.

4.9 POST TEST DISASSEMBLY

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

New bearings shall be installed prior to shipment.

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. Test shall be conducted with 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.

As an alternative to the above, the Supplier may quote testing one (1) foot valve of each model at, or below, the operating temperature to prove the design, and testing the remainder of the foot valves in water to confirm tightness.

Valve leakage over a period of two hours at minimum pressure shall not be more than 50 dm³ 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 min.

4.11 LIFTING CABLE TENSILE TEST

Each batch of lifting cables, which shall be designed to take at least three (3) 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

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

- NOTES:
1. Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.
 2. The DEPs and most referenced external standards are available to Shell users on the SWW (Shell Wide Web) at <http://sww.shell.com/standards>.

Amended per
Circular 52/11

SHELL STANDARDS

Data/requisition sheet for equipment noise limitation	DEP 31.10.00.94-Gen.
Electrical machines – cage-induction types (amendments/supplements to IEC 60034-1 and IEC 60034-14)	DEP 33.66.05.31-Gen.
A.C. Electrical Variable Speed Drive Systems	DEP 33.66.05.33-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 petroleum, heavy duty chemical, and gas industry services	API Std 610, Tenth Edition, October 2004
---	--

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

ASME Boiler and Pressure Vessel Code	
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

Standard specification for alloy/steel bolting materials for low-temperature service	ASTM A 320/A 320M
Standard specification for aluminium-alloy sand castings	ASTM B 26/B 26M
Standard guide for radiographic examination	ASTM E 94
Standard reference radiographs for inspection of aluminium and magnesium castings	ASTM E 155

Issued by:
American Society for Testing and Materials
1916 Race Street, Philadelphia
19103, USA

Motors and generators	MG 1
-----------------------	------

Issued by:
National Electrical Manufacturers Association
1300 N 17th Street; Suite 1847
Rosslyn, VA 22209, USA

BRITISH STANDARDS

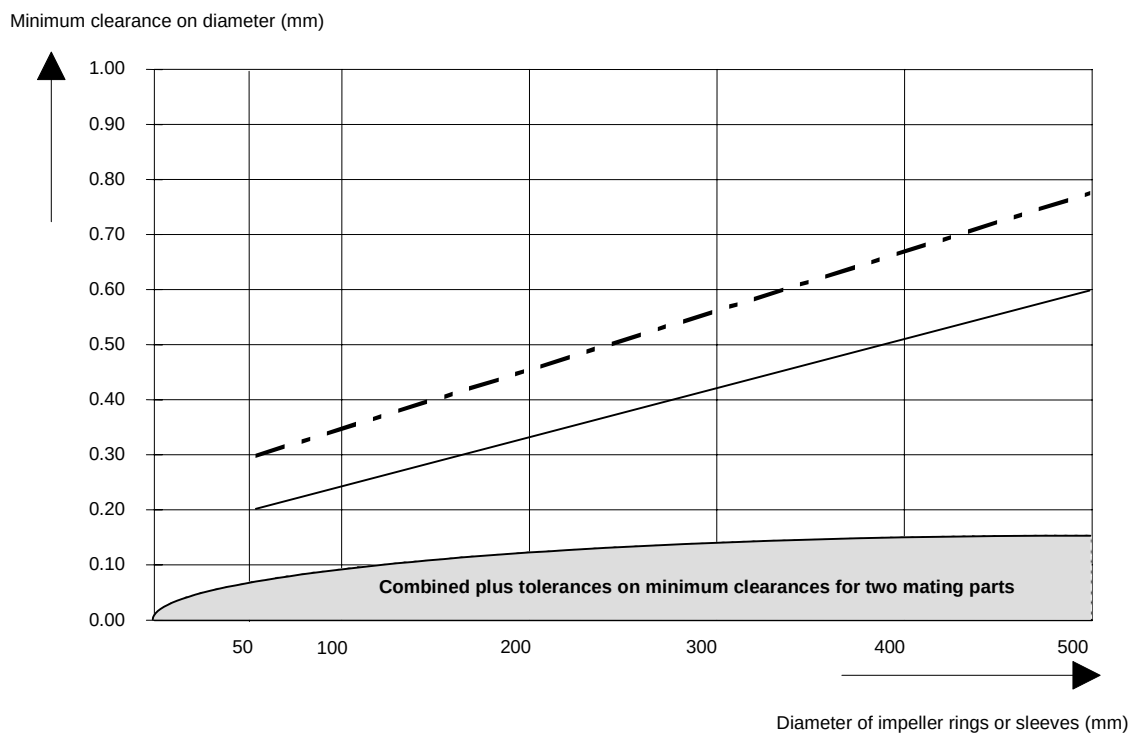
Steel pipe flanges and flanged fittings (nominal sizes ½ inch to 24 inch) for the petroleum industry – Part 3: Steel, cast iron and copper alloy flanges – Section 3.1: Steel flanges BS 1560:Sec 3.1

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

INTERNATIONAL STANDARDS

International electrotechnical vocabulary	IEC 60050
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.