



RP 34-1

ROTATING MACHINERY

September 1992

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SCOPE AND PURPOSE This document covers general requirements for rotating machinery for refineries, chemical works, offshore installations, on-shore terminals, pipe lines, pumping stations, oil and gas gathering stations and LNG plants. It calls up all the standards necessary for machinery installations. No additional Standards need be applied.											
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CUSTODIAN (See Quarterly Status List for Contact) Rotating Machinery											
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FOREWORD

Introduction to BP Group Recommended Practices and Specifications for Engineering

The Introductory volume contains a series of documents that provide an introduction to the BP Group Recommended Practices and Specifications for Engineering (RPSEs). In particular, the 'General Foreword' sets out the philosophy of the RPSEs. Other documents in the Introductory volume provide general guidance on using the RPSEs and background information to Engineering Standards in BP. There are also recommendations for specific definitions and requirements.

Value of this Recommended Practice

This document sets out recommendations for machinery selection appropriate to the system requirements, using BP's knowledge and experience worldwide.

Application

Text in *italics* is Commentary. Commentary provides background information which supports the requirements of the Recommended Practice, and may discuss alternative options.

This document may refer to certain local, national or international regulations but the responsibility to ensure compliance with legislation and any other statutory requirements lies with the user. The user should adapt or supplement this document to ensure compliance for the specific application.

Feedback and Further Information

Users are invited to feed back any comments and to detail experiences in the application of BP RPSE's, to assist in the process of their continuous improvement.

For feedback and further information, please contact Standards Group, BP Engineering or the Custodian. See Quarterly Status List for contacts.



1. INTRODUCTION

1.1 Scope

This Recommended Practice covers general requirements for rotating machinery such as pumps, compressors, fans, steam turbines, gas turbines, diesel engines, gears, mixers, centrifuges and their ancillary systems. It includes guidance on machine type, sparing, sizing and integration into a system. It does not in general cover detailed functional, constructional or testing requirements but identifies appropriate BP and industry specifications.

It applies to equipment used in:-

- Refineries and chemical works including offsites and utilities.
- Offshore installations and on-shore terminals.
- Pipelines and pumping stations.
- Crude oil and gas gathering and separation plants.
- LNG plants.

It may be applied to other applications similar to the above but is not intended for specialised drilling operations.

1.2 Conflicting Requirements

In the case of conflict between this Recommended Practice and other documents, the order of precedence shall be:-

- (a) National and local regulations in the country of installation.
- (b) This Recommended Practice.
- (c) Other industry codes and standards.

1.3 Responsibilities

Rotating machinery is usually a package comprising prime mover and driven equipment.

Generally the driven equipment manufacturer should take overall responsibility for the complete package design and installation. However, for large, complex installations, where the cost of the driver represents a significant percentage of the total cost (e.g. a gas turbine) the driver manufacturer may take overall responsibility.

The nominated manufacturer should be fully responsible for all equipment supplied by other vendors. He should also ensure that all such equipment, and also any free-issue equipment, is properly integrated into the whole installation in order to meet the applied specifications. His responsibilities should include dimensional compatibility, shaft system critical speeds, vibration, noise levels, acceptability of pipe loads, arrangement of auxiliary systems and provision of all data needed for the design of support structures or foundations.

2. GENERAL

2.1 Stand-By Equipment

- 2.1.1 The necessity for stand-by machinery should be considered in the context of the reliability/availability of individual items of equipment and the required overall plant availability.

For continuous service it is normal practice to install spares for centrifugal pumps as the life of seals can be unpredictable, and for reciprocating machinery including compressors, pumps and diesel engines as regular maintenance of wearing parts is required.

It is not normal practice to install spares for centrifugal, axial or rotary positive displacement compressors, except for critical utility systems.

- 2.1.2 The maximum use should be made of common installed stand-by pumps performing two or more duties.

2.2 Operating Conditions

- 2.2.1 Process conditions specified for fluid machinery shall cover the full range of flow, pressure, temperature, molecular weight, viscosity, erosive and corrosive properties etc.

- 2.2.2 The design of process control systems associated with fluid machinery shall take into account the need to operate at less than rated conditions. Machine output should be controlled by one of the following methods:-

Centrifugal compressors - Preferably speed regulation or variable angle guide vanes or suction throttling, although discharge throttling can be used.

Centrifugal pumps - Speed regulation or discharge throttling.

Reciprocating compressors - Preferably inlet valve unloading and/or clearance pockets, although external bypassing and intake throttling can be used.

Oil injected rotary positive displacement compressors - Internal slide valve or bypass regulation.

Non lubricated rotary positive displacement compressors - bypass regulation.

Positive displacement pumps - Variable stroke or bypass regulation.

2.2.3 Margins on head and flow should be specified in the process design. Normally, further margins should not be added except for special circumstances e.g. where significant deterioration in machine performance is expected.

2.2.4 Machinery should be suitable for all specified extremes of process, utilities and ambient conditions including those at start up and shutdown. Additionally where commissioning may take place with an alternative fluid which results in higher pressure and/or temperatures, this shall be taken into account.

For service, operation on nitrogen or air will result in higher example centrifugal pumps specified for hydrocarbon service (specific gravity <1) will generate higher differential pressures and will absorb more horsepower when pumping water. For centrifugal compressors specified for hydrocarbon than normal discharge temperatures due to the increased value of Cp/Cv.

2.2.5 Utilities conditions specified should cover:-

- The full range of pressure, temperature, calorific value, etc., for steam, water, air, gas, etc., together with quality limits on impurities.
- Power supplies to be used for auxiliaries and instruments.
- Any pressurisation in vents or drains.
- Any requirement for units to continue in operation on temporary failure of a utility supply.

2.2.6 Weather/environmental conditions specified should cover the full range of ambient and climatic conditions in which the machinery must operate (including maximum and minimum temperatures, wind conditions, salinity, unusual humidity or dust problems) and shall identify the area classification. The nature of the installation should be specified, in particular whether enclosed (naturally or force ventilated, heated or unheated) or unenclosed (with or without a roof).

- 2.2.7 If machinery is subject to sour conditions as defined in BP Group [GS 136-1](#), the materials used should also be in accordance with BP Group [GS 136-1](#). This should apply even when sour conditions only exist for short periods.

2.3 Non-Return Valves

- 2.3.1 Non-return valves used to prevent reverse rotation of pumps and compressors should be located as close as practicable to the discharge of the machine, but downstream of any recycle connection. For gas service valves should be in line, non-slam type.

2.4 Installation

- 2.4.1 All machinery should be capable of operating unattended.
- 2.4.2 For onshore equipment, shelters should be provided for large machines which have to be maintained in situ. Roofs shall be ventilated. The sides of the shelter shall be sheeted down to the operating platform level, or to a level 2.5 m above grade, whichever is the higher. Where side sheeting is carried down to a level less than 2.5 m above the operating level, the floor shall be of the open grid type to ensure free ventilation.
- 2.4.3 Adequate access and appropriate lifting facilities should be provided for equipment removal or for in-situ maintenance.

2.5 Packaging for Offshore Use

- 2.5.1 For offshore applications, medium and large size complex critical machinery should be packaged in accordance with the requirements of BP Group [GS 134-13](#). This includes all gas turbines, centrifugal compressors, multi-stage centrifugal pumps on water injection, main oil line and high pressure condensate pumping duties, and gas turbine driven alternator sets.

The recommendations of this section result from a study into methods of minimising space, weight, cost and offshore commissioning time.

- 2.5.2 For centrifugal compressors, preference should be given to equipment layouts with down-facing nozzles.

This arrangement eliminates the known possibility of debris or water entering the nozzles during the construction phase, and the consequent need for dismantling and cleaning. It also reduces the risk of liquid entering the machine during operation.

When up-facing connections are used particular attention should be paid to the control of construction work and to the design of suction knock-out facilities.

- 2.5.3 An investigation should be made, at the layout stage, of the casing and support structure deformation that will result from the predicted pipe loads on 3-point mounted machines. Compliance with the supplier's casing and coupling alignment limits should be demonstrated.

For initial design purposes, forces and moments of up to 1.5 times those given in API standards, combined in such a way as to cause maximum distortion, should be used.

The final design of the pipe and machinery support system should include for the effects of:-

- Inaccuracies in construction of piping system

Typically + or - 3 mm in any plane, and 0.75 mm across any diameter of the flange face.

- Distortion of the module structure caused by emplacement offshore, and by platform live loads.

- 2.5.4 The position of 3-point supports should be determined jointly by the contractor and vendor, sufficiently early to ensure optimum utilisation of equipment support steelwork within the module structure.

- 2.5.5 Weather protection should be provided on weather deck mounted units in accordance with the requirements of BP Group [GS 134-13](#).

- 2.5.6 Depending on the overall layout, shelters for weather protection may be designed to enclose a number of units or individual units of machinery. For individual units the shelter may be supplied by the vendor and directly mounted on the machinery skid.

3. PUMPS

3.1 General

- 3.1.1 Centrifugal pumps should be selected wherever possible. Positive displacement pumps may be used where the duty cannot be efficiently performed by a centrifugal pump.

- 3.1.2 On motor driven pumps where the duty requirements demand variable output, the use of variable speed motors or variable speed fluid

couplings may be justified on the grounds of economy or operational convenience.

- 3.1.3 Where a duty is normally met using two or more pumps operating in parallel, specific attention shall be paid to NPSH and power requirements when one pump is operating alone at the maximum capacity that it can deliver through the system.
- 3.1.4 Where pumps handle a corrosive fluid, arrangements should be made to collect and pipe away any possible leakage, so that fluid contact with the baseplate is avoided. Where such pumps are mounted on a concrete plinth the plinth shall be corrosion resistant, and the baseplate shall be supported clear of it on corrosion-resistant spacers.
- 3.1.5 Gauges should be fitted to indicate the discharge pressure of all pumps and should be mounted in the adjacent piping. Unless suction pressure is easily obtainable from elsewhere, pressure gauges should also be fitted at the pump suction. As a minimum, a nipple, valve and plug should be provided in the suction pipework to allow for the temporary or later fitting of a pressure gauge.

3.2 Shaft Seals (Centrifugal and Rotary Pumps)

- 3.2.1 Mechanical seals should be used for all pumps except as indicated in Tables 1 and 2. Packed glands should be used on firewater pumps.
- 3.2.2 Guidance on seal selection for specific duties is given in Table 1. If the specific duty cannot be found in Table 1, Table 2 gives guidance for a more general range of duties. Table 3 gives the principles underlying Tables 1 and 2 and should be used as an aid to their interpretation.
- 3.2.3 The selection of seal flushing plans should follow the guidelines given below. Plan numbers are in accordance with Figures D-2, D-3, D-4 and D-5 of [API 610](#) Seventh Edition, February 1989.
 - 3.2.3.1 Seals should be run dead-ended (Plan 2) wherever possible, if necessary by the use of:-
 - (a) Seal designs and materials suitable for high temperatures (e.g. metal bellows, high temperature elastomers).
 - (b) Seal designs requiring low temperature margins (e.g. low balance ratio, face material of high thermal conductivity, narrow seal face).

'Temperature margin' is the difference between seal chamber temperature and the bubble point at seal chamber pressure.

However, plugged flush connections for possible future use shall be provided.

3.2.3.2 If the use of flush cannot be avoided, Plan 11 should be used.

If the flush has to be cooled, Plan 21 should be used. Specific attention should be given to avoid the risk of product blocking the flush line when cold.

If the pumped liquid contains solids the corresponding Plans 31 and 41 should be used. Use of filters as Plans 12 and 22 should be avoided if possible.

3.2.3.3 For:-

- (a) very dirty liquids,
- (b) liquids so corrosive that suitable seal materials are not available,
- (c) highly toxic materials,

a suitable liquid from an external source should be injected as Plan 32. The source should be reliable, and should be available continuously, including start-up and shutdown.

3.2.3.4 If the presence of abrasive particles at the seals cannot be avoided, both seal faces should be of hard material.

3.2.3.5 Auxiliary or back up seals require auxiliary connections. Plan 61 should be used.

3.2.3.6 Auxiliary connections are also required if provision is to be made for draining or detecting seal leakage. Plan 61 should be used.

3.2.3.7 If the duty conditions are such that coking or the deposition of crystals is likely, a quench should be provided as Plan 62.

3.2.3.8 Pumps on hot duties where the fluid is likely to solidify at ambient temperatures will require provision for heating the seal chamber and possibly the seal seat. Arrangements similar to Plan 62, and Plans C and D of Figures D-4 and D-5 may be considered.

3.2.3.9 Tandem seals require Plan 52, while double seals require Plans 53 or 54.

3.2.3.10 In general, seals require to form a liquid seal between the faces for satisfactory operation. Particular attention should be paid to balanced seals when the seal chamber pressure is low or sub atmospheric, and to unbalanced seals when the seal pressure is high, especially if either of these are combined with large seal diameter and high shaft speed.

The ability to form a liquid film between seal faces is governed by a number of factors. Film formation can be expected to be satisfactory if the following inequality is satisfied.

$$\Delta p(1-B) - p_s \pm \rho \omega^2 (R_o^2 - R_i^2)/8 + C > 0$$

Where

B = Balance ratio

C = a pressure determined from experience, typically $C = 90,000 \text{ N/m}^2$

p_s = Face pressure due to springs

R_i = Face inner radius

R_o = Face outer radius

Δp = Differential pressure across seal

ρ = Liquid density

ω = Seal angular velocity

+ is used with externally mounted seals

- is used with internally mounted seals

C is thought to be due to surface tension effects and the ability of the liquid to wet the seal faces. The suggested value is for seal faces which are easily wetted.

If the above inequality is not satisfied, the seal is likely to run under conditions of boundary lubrication. Verify that the 'PV' value for the face material combination is such that a satisfactory life can be expected.

Note:-

(i) PV is often quoted for a one year life. To a first approximation life is inversely proportional to PV provided individual values of P and V are not extreme.

(ii) The definition of PV varies from vendor to vendor.

For further information and basis of these statements see 'Mechanical Seal Practice for Improved Performance' I.Mech.E. (First published 1988.)

3.3 Centrifugal Pumps (Including Mixed and Axial Flow Types)

3.3.1 Centrifugal pumps should comply with BP Specifications as follows:-

- BP Group [GS 134-11](#) for all glandless pumps.
- BP Group [GS 134-14](#) for non-critical duties within the following limits:-

Maximum discharge pressure	19 bar (ga)
Maximum pumping temperature	150°C
Maximum rated speed	3600 rpm
Maximum driver rating for horizontal end suction or vertical in line pumps	75 kW
Maximum rated total head	120 metres
Maximum suction pressure	5 bar (ga)
Maximum impeller diameter for horizontal end suction or vertical in line pumps	333 mm

- BP Group [GS 124-1](#) for firewater pumps
- BP Group [GS 134-4](#) for other duties except for large cooling water pumps and other duties of a particularly specialised nature.

3.3.2 The NPSHA should be greater than the NPSHR by 15% or 1m, whichever is the larger. NPSHR should be based on the 3% head loss criteria and NPSHA should be the minimum pertaining to any CONTINUOUS operating case.

For pumps which develop heads per stage in excess of 200 m and whose availability is crucial to plant operations (e.g. main oil line, water injection, reactor charge) the NPSHA at normal operating conditions should equal or be greater than the NPSHR required to meet the 40,000 hour impeller life criteria.

3.3.3 Safety valves shall be fitted downstream of centrifugal pumps when the maximum pressure that can be generated exceeds the rating of downstream equipment that is not otherwise protected. When determining the maximum pressure that can be generated, the effects of high suction pressures, high specific gravity, high speeds and low flows shall all be considered.

3.3.4 All pumps that could be required to operate continuously below their minimum continuous stable flow ([API 610](#), 7th Edition paragraph 1.11.11) should be provided with a recycle system.

3.3.5 If operation is possible with suction, discharge, or both valves closed protection against zero flow should be provided, unless it can be shown that no damage to the pump or piping system would result.

3.3.6 For sump duties, horizontal self-priming pumps shall be used wherever possible. Where suction lift or vapour pressure considerations or duty



requirements preclude their use, the choice of vertical pump type should be based on the following:-

- Vertical turbine type pumps should be used for clean liquid duties only.
- Vertical wet sump pumps with external discharge pipe should be used only when adequate lubrication for the intermediate column bearings can be provided by the pumped fluid.
- Vertical cantilever shaft pumps should be used for abrasive or corrosive applications or applications where adequate lubrication for intermediate column bearings cannot be provided by the pumped fluid.

3.4 Positive Displacement Pumps

- 3.4.1 Full flow pressure relief shall be provided at the pump discharge upstream of any isolating valve. Where the nature of the fluid would make relief valves unreliable, bursting discs should be used either alone or in conjunction with relief valves.
- 3.4.2 Reciprocating pumps (excluding metering pumps) should comply with [API 674](#).
- 3.4.3 Metering (or controlled volume) pumps should comply with [API 675](#).
- 3.4.4 Rotary positive displacement pumps should comply with [API 676](#).

4. COMPRESSORS

4.1 General

- 4.1.1 Centrifugal compressors are the generally preferred type.

It is recognised that they will not be practical and cost-effective for all applications.

Reciprocating machines may be better suited to an application involving large variations in flowrate and/or molecular weight.

Rotary positive displacement machines may be well suited to dirty duties but are inherently very noisy and require installation in a noise attenuating housing.

- 4.1.2 Condensate knock-out facilities should be provided in the compressor suction line and between stages for multi-stage machines. The suction facilities should include, as a minimum, drum, demister pads, level glass, and means of drainage. The suction line between the drum and the compressor should be self draining.

- 4.1.3 Air compressor intakes should be provided with filters. Intakes should be sited to minimise the risk of ingestion of contaminants, in particular flammable gases.

If the climate is such that inlet icing can occur, an anti-icing facility should be provided.

4.2 Reciprocating Compressors

- 4.2.1 Reciprocating compressors should conform to BP Group [GS 134-6](#) for all services except:-

- (a) portable air compressors, and
- (b) standard utility air compressors of 450 kW or less with not more than 9 bar (ga) discharge pressure which should comply with [API 680](#).

- 4.2.2 When cylinders on a single frame are used for different duties, independent flow control should be provided for each duty.

- 4.2.3 Lubricated cylinder and gland packings should be used on all machines except where safety or process considerations dictate otherwise, e.g. explosion risk, catalyst damage or product contamination.

- 4.2.4 Full flow pressure relief should be provided at each stage.

4.3 Rotodynamic Compressors

- 4.3.1 Centrifugal compressors should comply with BP Group [GS 134-5](#), except for plant air compressors and duties with delivery pressure less than 0.35 bar (ga). Packaged, integrally geared compressors should comply with [API 672](#).

- 4.3.2 Axial compressors should comply with the relevant sections of BP Group [GS 134-5](#), and also those sections of BP Group [GS 134-7](#) relating to blade design.

- 4.3.3 Safety valves shall be fitted downstream of rotodynamic compressors when the maximum pressure that can be generated exceeds the rating of the compressor itself or downstream equipment that is not otherwise protected. When determining the maximum pressure that can be generated, the effects of high suction pressures, high molecular weights, high speeds, low temperatures and low flows shall all be considered.

- 4.3.4 Rotodynamic compressors should be provided with anti-surge equipment unless it can be shown that the machine cannot surge during normal operation. The surge control system should be of modulating type, and designed to ensure that while the bypass valves are in operation, the compressor operates on the anti-surge control line. The recycle system should be designed for not less than the compressor normal flow, with cooling sufficient to return the gas to the rated suction temperature, and with no valves within the recycle circuit other than the recycle control valve.
- 4.3.5 The response time for the control equipment should be such as to prevent surge during any anticipated process condition including start-up and shut down, due consideration being given to the speed at which process changes or upsets can move the compressor operation towards surge.
- 4.3.6 For the more complicated installations with multiple stages and sidestreams, or multiple units (in series or parallel) or variable speed units, an analysis of the stability of the process and anti-surge control systems may also be necessary.
- 4.3.7 The volume of discharge pressure gas trapped on machine shutdown should be minimised by locating the discharge non-return valve and recycle control valve as close to the compressor as possible. In all cases the energy that would be released by the trapped gas expanding back through the compressor should not be more than twice the full speed kinetic energy of the whole train.
- 4.3.8 Overpressure protection on the suction side of the compressor shall be adequate to cater for the combined reverse flow through the compressor and the recycle valve in the event of failure of the discharge non-return valve in the wide open position.
- 4.3.9 The settle-out pressure on tripping should be calculated assuming:-
- (a) Non-return valves function properly.
 - (b) Non-return valves full open, but any motorised valves operate correctly.

The system should be designed to cater for both conditions.

4.4 Rotary Type Positive Displacement Compressors

- 4.4.1 Rotary type positive displacement compressors should conform to BP Group [GS 134-9](#).



- 4.4.2 Full flow pressure relief should be provided at each stage for positive displacement compressors, either directly on the machine or between the machine and the discharge isolating valve.

4.5 Compressors for Instrument Air

- 4.5.1 The oil content of instrument air at the normal temperature/pressure operating conditions shall not exceed 1 ppm by mass/mass at the exit of the instrument air package.

If the final oil separating equipment is not supplied by the compressor vendor, this limit shall apply to the outlet of the separating equipment.

- 4.5.2 Rotary positive displacement or centrifugal compressors are preferred and the following Standards should apply:-

[API 619](#) - Rotary Type Positive Displacement Compressors for General Refinery Services.

[API 672](#) - Packaged Integrally Geared Centrifugal Air Compressors for General Refinery Service.

Where reciprocating compressors are used, they should comply with [API 680](#), Packaged Reciprocating Plant and Instrument Air Compressors for General Refinery Services.

- 4.5.3 Air compressor drive should normally be by induction motor.
- 4.5.4 Standby compressors with an alternative type of drive or independent electrical supply should be supplied for emergency use and should be arranged to come into operation automatically on detecting failure of the air supply.
- 4.5.5 For reciprocating compressors on standby service where there is a possibility of condensation in the cylinders due to relatively low jacket temperature, auto start-up and shut-off of cooling water should be provided.
- 4.5.6 Compressors should be fitted with coolers which will cool the air at the final discharge to within 15°C of the inlet temperature of the specified cooling medium.
- 4.5.7 Knock-out pots and automatic liquid drain traps should be provided to remove condensate produced in the coolers.

5. FANS

- 5.1 Centrifugal fans of more than 20 kW power used on process units, heaters, and boilers should comply with [API 673](#).

6. TANK MIXERS

- 6.1 Side entry mixers used for blending of products or for the prevention of crude sludge deposition should comply with BP Group [GS 134-2](#).
- 6.2 Mixers used to prevent sludge deposition should preferably be of the swivel type.
- 6.3 Where there is no regular supervision, means shall be provided for indication of, and shutdown from, excessive bearing wear or seal leakage.

7. CENTRIFUGES

7.1 Scope

- 7.1.1 This section covers process plant centrifuges and not machines intended for lubricating and seal oil conditioning duties.

7.2 General

- 7.2.1 Machines handling hydrocarbons at pressures close to atmospheric should be continuously purged with an inert gas.
- 7.2.2 For machines operating at sub-ambient temperatures, provision should be made for pre-cooling the machine before introduction of the feed.
- 7.2.3 All machines should be mounted on vibration isolators to minimise the transmission of vibration to the supporting structure.
- 7.2.4 As far as is practicable ancillary systems, e.g. lubricating and seal oil, and instrumentation should be installed away from the machine, on the foundation side of the vibration isolators. Adequate flexibility should then be introduced into the pipe and cable connections to the machine.
- 7.2.5 High vibration alarms should be fitted. High vibration trips may also be necessary in particular installations.
- 7.2.6 For machines with high inertia and which require relatively frequent shutdowns for process or maintenance reasons, the provision of braking systems to minimise rundown times should be considered.

8. ELECTRICAL POWER GENERATORS

8.1 Generators over 300 kW should comply with BP Group [GS 112-6](#).

9. DRIVERS

9.1 General

9.1.1 Direct drive should be used unless the use of geared drive gives clear cost, size, weight or efficiency advantages.

9.1.2 All expected combinations of operating conditions should be considered in determining the maximum power requirement for the driven machine. Maximum power should be determined at the driver coupling, and should include all transmission losses.

9.1.3 Electric motors should have power ratings of at least:-

Maximum Power Motor Rating % of Maximum
Requirement Power Requirement

20 kW and less 125

Above 20 kW and

below 75 kW 115

75 kW and above 110(1)

(1) plus half any positive tolerance allowed by standards on guaranteed power of driven machine.

9.1.4 Gas turbine drivers should be rated for 113% of the maximum power requirement of the driven equipment, plus half of any positive tolerance on guaranteed power of the driven machine.

Gas turbines should be able to provide this output power without exceeding the site base-load rating. The site base-load rating should be obtained in accordance with [ISO 3977](#) using:-

- Average site ambient pressure,
- That ambient temperature that is exceeded for only 5% of the year,
- Total design (clean) inlet and exhaust pressure losses, including waste heat recovery systems if appropriate.

Where the rating is critical to gas turbine selection, or where large variations of the driven load occur, short-term power excursions up to the peak site rating may be acceptable, providing that it can be shown

by analysis that the nominal time between overhauls is not reduced by more than 15% from the base rating time between overhauls.

The 13% margin is based on the following coincident losses:-

- *Deterioration of the driven machine.*
- *Fouling of inlet filters and the gas turbine compressor.*
- *Atmospheric pressure less than average.*
- *Gas turbine deterioration.*

No specific margins are applied for uprating of driven machines or for errors in the prediction of driven machine duties. However, additional margins will often be available since the large steps between ratings usually leads to a larger-than-needed selection. Also, for most of the operating time the losses listed above will be less than 13%.

9.1.5 Steam turbine drivers should be sized as follows:-

Rated power should be 110% of the maximum power requirement of the driven equipment at the specified speed and shall be on the basis of normal steam conditions.

Additionally the turbine should be capable of developing the maximum power requirement of the driven equipment at the specified speed on the basis of coincident minimum inlet and maximum exhaust steam conditions.

9.1.6 Other drivers should have ratings of at least 110% of the normal maximum power demand of the driven machine, plus half any positive tolerance allowed by standards on guaranteed power of the driven machine.

9.1.7 Where a high load demand occurs as an abnormal situation of short duration, the driver should meet the abnormal load, but no further margins should be applied.

Examples are centrifugal pumps and compressors on uncontrolled duties, or in parallel service when the tripping of one machine results in an increased load.

9.2 Electric Motors

9.2.1 High voltage and low voltage induction motors should comply with BP Group [GS 112-4](#) and BP Group [GS 112-3](#) respectively.

9.2.2 Two pole motors should not be used above ratings of 5 MW at 50 Hz or 3.5 MW at 60 Hz.

- 9.2.3 Where a speed increasing gearbox is required, a 4-pole motor should be used in preference to a 2-pole motor provided the gearbox ratio is suited to single stage parallel shaft gearing and cost, space and weight penalties are not significant.

9.3 Steam Turbines

- 9.3.1 Turbines should be specified as general purpose or special purpose according to the definitions given in [API 611](#) and [612](#) respectively.
- 9.3.2 General purpose turbines should meet the requirements of [API 611](#) and special purpose turbines should meet the requirements of BP Group [GS 134-7](#).
- 9.3.3 Condensers for condensing steam turbines should conform to BP Group [GS 156-2](#). Such condensers should be designed for optimum vacuum and cooling water quantity, determined by a study of the cost of steam and cooling water and the initial cost of the turbine and condenser. For the purposes of the study the turbine should be considered to be operating at the specified normal power output, with the cooling water at the annual mean temperature, and the tubes in the fouled condition.
- 9.3.4 Where the turbine casing or condensers are not designed to withstand the full mains steam pressure, they shall be protected by relief valves capable of passing maximum steam flow. Sentinel warning valves alone are not adequate.
- 9.3.5 On process duties, turbines to BP Group [GS 134-7](#) should be provided with a steam separator on the steam supply to the turbine. This separator should be located upstream and as close as possible to the turbine trip valve.

9.4 Combustion Gas Turbines

- 9.4.1 Combustion gas turbines should comply with BP Group [GS 134-12](#).
- 9.4.2 Multi-shaft machines may be used for power generation duties providing it can be shown that speed of response to load shedding and application is fast enough to meet the needs of the particular application.
- 9.4.3 Air intakes shall be located in a non-hazardous area. In addition the plant layout should minimise the risk of ingestion into the inlet of:-
- Flammable gas, from leaks or intermittent vents, either on the gas turbine itself or from adjacent plant.

- Dust from process operations or from the surrounding areas.
- Corrosive gases from process vents and flues.
- Hot exhaust gases from the turbine itself or other adjacent machinery or plant.
- Oil mist from oil system vents.
- Snow/ice.

9.4.4 Where process emissions from normal operation may contaminate combustion intake air, this should be taken into account when selecting materials of construction of gas turbine intake systems.

9.4.5 The fuel specification and composition should be agreed with the turbine vendor before placement of order to ensure that the turbine can be designed for reliable operation without excessive maintenance.

9.4.6 Where automatic gas to liquid fuel changeover is specified, the mass of gas retained in the system after interruption of the supply must be sufficient to maintain the pressure above the minimum required by the turbine throughout the period of changeover.

It should be noted that for high power machines this could necessitate large and expensive gas storage, hence automatic gas to liquid should not be specified unless really necessary.

9.4.7 Fuel gas shall be supplied to the turbine at a temperature at least 20°C above the hydrocarbon condensate dew point. In addition, a knockout pot with drain and high level alarm should be installed adjacent to each machine.

9.4.8 Facilities for cleaning liquid fuel may be required, particularly if fuel is stored in contact with water.

9.4.9 Gas turbines shall not be permitted in hazardous areas classified as Zone 0 and 1.

9.4.10 Gas turbines in Zone 2 shall be enclosed. Ventilation air shall be taken from a safe area, and gas detectors shall be fitted at both combustion air and ventilation air inlets.

9.4.11 The level of SO₂ and NO_x exhaust emissions shall meet any prevailing authority requirements.

9.5 Diesel Engines

- 9.5.1 Permanently installed diesel engines should wherever possible be sited in non-hazardous areas.
- 9.5.2 Diesel engines shall not be used in Zone 0 areas.
- 9.5.3 Permanently installed diesel engines shall not be permitted in Zone 1 areas.
- 9.5.4 Mobile diesel engines should not be used in Zone 1 areas. If unavoidable, they shall comply with BP Group [GS 134-8](#), and their use shall be regulated by a work permit system.
- 9.5.5 Permanently installed diesel engines may be installed in Zone 2 areas if either:-
- (a) Un enclosed and meet requirements of 9.5.6.
 - or (b) Enclosed, taking combustion air and ventilation air locally and meet requirement of 9.5.7.
 - or (c) Enclosed, taking combustion air and ventilation air from a safe area and meet requirement of 9.5.8.
- 9.5.6 Un enclosed engines should be avoided wherever possible, but if they are necessary they should comply with BP Group [GS 134-8](#). Notwithstanding compliance with BP Group [GS 134-8](#), air inlets and exhausts should, wherever possible, be located in a safe area.
- 9.5.7 Enclosed engines taking combustion and ventilation air locally should comply with BP Group [GS 134-8](#). Ventilation equipment shall be suitable for Zone 1. Instrumentation and electrical equipment shall also be suitable for Zone 1 unless it is automatically isolated on loss of ventilation, in which case it need only meet Zone 2 requirements.
- 9.5.8 Enclosed engines taking combustion and ventilation air from a safe area need not comply with BP Group [GS 134-8](#) providing all the following requirements are met:-
- (a) Enclosure pressurised to at least 0.5 mbar.
 - (b) 100% stand-by, automatically started, ventilation system.
 - (c) Engine shutdown on loss of pressurisation.

- (d) Gas detection at ventilation exhaust giving audible or visual alarm.
 - (e) Engine exhaust discharged in a safe area, and exhaust piping cooled where it runs through the Zone 2 area.
- 9.5.9 Unattended mobile engines may be operated in Zone 2 areas if they comply with BS Group [GS 134-8](#).
- 9.5.10 Attended mobile engines shall either comply with BP Group [GS 134-8](#), or comply with as much of BP Group [GS 134-8](#) as possible and operate under a work permit system.
- 9.5.11 Engines permanently installed in safe areas, but required for emergency duty, e.g. fire pumps, emergency generators, shall meet any special safety requirements of the applicable national regulating body.
- 9.5.12 As first choice, the exhausts of diesel engines should be arranged to discharge vertically upwards. Where this is impractical, downward discharging exhausts are acceptable providing the gases can be adequately dispersed without contaminating work areas or ventilation intakes.

10. TRANSMISSIONS

10.1 Gear Drives

- 10.1.1 In general, gear units should be of the parallel shaft type. However, epicyclic units may be considered where they form an integral or standard feature of a machine, e.g. certain designs of gas turbine.
- 10.1.2 Single and double helical, one and two stage speed increasers and reducers of parallel shaft design which operate under any or all of the following conditions should meet the requirements of BP Group [GS 134-10](#).
 - (a) Equivalent synchronous or actual pinion speeds of 3000 rev/min and higher.
 - (b) Pitch line velocities of 20 m/s and higher.
 - (c) Journal velocities of 7.5 m/s and higher.
 - (d) Forming part of an unsparred critical duty machinery train.
- 10.1.3 For gearing which does not fall into the above categories, [AGMA 420](#) should be used.

- 10.1.4 Gear units located next to the driver should be rated for the maximum horsepower capability of the driver.
- 10.1.5 Gear units located between two items of driven equipment should have a rating no less than 110% of the maximum power required by the driven equipment, and not less than the maximum power of the driver proportioned between the two items of driven equipment, based on their normal power demands.
- 10.1.6 If the maximum torque occurs at other than the rated speed, this torque and its corresponding speed should be considered in the gear design.
- 10.1.7 Gear service factors should be not less than those required by [API 613](#), [AGMA 420](#) as applicable.
- 10.1.8 Gear units should be designed to withstand safely any transient torsional loads imposed during start-up, re-acceleration after a power interruption, short circuits and mal-synchronisation of the driven equipment.

Gear teeth and gearbox bearings are relatively highly loaded at rated conditions, and hence any abnormal loads that occur need consideration. High transient loads commonly arise at start-up but are generally allowed for by the service factors. However, special consideration may need to be given to equipment trains incorporating synchronous motors which, during run-up, develop oscillating torques that can be amplified when passing through torsional critical speeds. Additionally, re-acceleration of electric motors following a power interruption or the short circuiting of electric motors and generators can give rise to very high transient torques at the motor (generator) although these torques are not seen in full by a gearbox.

If abnormal torques are likely to exceed the rated torques by a ratio greater than the service factor, they should be specifically considered in the design.

10.2 Belt Drives

- 10.2.1 Belt drives should be limited to 110 kW. They should be either integral multi-V, or multiple V-belts supplied in matched sets. A minimum of two V-belts should be provided. For this minimum configuration, capacity of each belt should be not less than 150% of the transmitted power.

Belt drives can be cost-effective at low powers but at high powers it becomes increasingly difficult to achieve adequate reliability and life, and maintenance requirements increase. Satisfactory experience exists up to approximately 150 kW.

- 10.2.2 Belt material should be oil-resistant, fire-retardant, anti-static to [NCB Specification 244](#).

- 10.2.3 Belts should be adjustable without the need to remove the guard.

10.3 Shaft Couplings

- 10.3.1 Dry couplings (e.g. flexible element) are preferred.

- 10.3.2 Where the driver is an electric motor of the type not fitted with rotor locating bearings, and a gear coupling is used, a limited end float feature is required to restrain the motor rotor within its permissible axial movement limits. A limited end float coupling may also be required when a flexible element coupling is used depending on the inherent axial stiffness of the coupling.

This applies with the majority of 2 pole sleeve bearing motors, and the larger sizes of 4 pole sleeve bearing motors.

- 10.3.3 All flexible couplings incorporating a spacer piece shall be of a design in which the spacer piece is positively constrained from flying out in the event of failure of the flexible elements. In Zone 1 areas all coupling components liable to rub as a result of failure of the flexible elements shall be of non-sparking materials.

- 10.3.4 For all types of coupling it should be possible to remove the half couplings or coupling hubs in situ without moving driving or driven equipment including gearboxes. This will necessitate setting of the shaft ends a sufficient distance apart.

- 10.3.5 Oil lubricated couplings should be such as to avoid accumulation of sludge due to centrifuging. This will normally require absence of dams or similar devices intended to prevent complete oil draining.



SELECTION OF SEAL TYPE - SPECIFIC DUTIES

TABLE 1

SEAL TYPE (Numbers in table indicate order of preference)									
FLUID	FLUID CATEGORY (RP 44-6)	NOTES	HIGH INTEGRITY (7)			ENHANCED INTEGRITY (7)		STANDARD (7)	
			GLANDLESS	DOUBLE SEAL	TANDEM SEAL	SINGLE SEAL		SINGLE SEAL	
						+ BU	+ TB	+ LIP	+ TP
			(1)	(2)	(3) (4)	(5) (6)	(5) (6)	(5)	-
LNG	A		1						
LPG (Ambient Temp.)	A		1		2				
LPG (Refrigerated)	A		1		2				
Unstabilised Crude	B			2	1				
Stabilised Crude	C			2	1		1		



TABLE 2

[illegible]

NOTES TO TABLES 1 AND 2

INTRODUCTION

The guidelines given in Tables 1 and 2 assume that pumps are installed in a well ventilated position onshore. For offshore installations or cases where ventilation is poor, seal arrangements giving a reduced possibility of leakage shall be selected.

NOTES ON SEALS

- (1) 'Glandless' pumps include canned motor, wet wound and magnetic transmission designs. The following points shall be considered:-
 - (a) Canned motor and magnetic transmission designs have limited pressure capability unless special features are incorporated.
 - (b) Canned motor and wet wound designs are subject to temperature limitations on the windings.
 - (c) Wet wound designs require careful consideration of chemical compatibility of pumped liquid with the stator insulation.
 - (d) Glandless pumps should only be used where the pumped liquid is a suitable lubricant for the bearings.
 - (e) Power limits may make glandless pumps unsuitable for pumping duties with a high power requirement.
- (2) In this context, 'Double Seal' includes both Back-to-Back and Face-to-Face designs. Special designs of seal are required to accommodate pressure reversal on the inner seal. Suitable seals are said to be 'Double Balanced'.
- (3) Tandem seals should not be used at seal chamber temperatures above 120°C.
- (4) In tandem seals, the outer seal is likely to run at low pressure. Attention is drawn to the need to ensure that operating conditions will allow the formation of an adequate liquid film between the faces.
- (5) Note that 'BU' signifies a dry running back-up seal and 'TB' signifies API throttle bush.

Single seal arrangements are subject to the following limitations:-

- (a) Single seals are not suitable for dry running.
- (b) Where the pumped liquid contains abrasives special attention to face material selection and seal flush are required.

- (c) Back-up (BU) seals are dry running seals which are superficially similar to mechanical seals. They are subject to the following limitations:-
- (i) Liquid shall be clean and free from dissolved solids or a tendency to deposit heavy components or polymerise.
 - (ii) At present back-up seals are subject to limits.

seal chamber pressure	15 bar (ga)	) Flexibox
seal chamber temperature	50°C	) Abeyance Seal
seal chamber pressure	2 bar (ga)	) Borg-Warner
seal chamber temperature	50°C	) GU Seal
 - (iii) Lower temperature limits depend upon secondary seal material. Take seal vendor's advice below 0°C.
- (d) Lip seals are subject to the following limitations:-
- (i) Liquid shall not tend to deposit crystals.
 - (ii) At present lip seals are subject to limits.

seal chamber pressure	5 bar (ga)	) Crane
seal chamber temperature	50°C	) Safe T Seal
 - (iii) Lower temperature limits depend upon lip material. Take seal vendor's advice below 0°C.
- (6) Where back-up or lip seals are used in pumps handling flammable liquids the following features are required in the installation:-
- (a) Since back-up and lip seals have limited lives some form of detection of primary seal failure is required. This may take the form of a level or pressure switch, depending on the expected phase of the leakage.
 - (b) Since all seals leak, provision should be made for venting normal leakage from the primary seal.
- If the leakage is expected to be in the vapour phase it may be taken to an atmospheric vent via an orifice of not less than 3 mm diameter. A pressure switch may then be used to detect primary seal failure.
- The acceptability of venting to atmosphere and the implications for area classification shall be considered.

If leakage is expected to be in the liquid phase it may be taken to a suitable drain. A chamber with a level switch may be used to detect primary seal failure.

On Category B liquids the drain should be connected to a closed unpressurised system. If not, then the implications for area classification shall be considered.

Venting to flare implies that the back-up or lip seal will be exposed to flare back pressure. Since the composition of flare gas is unpredictable this is only acceptable when the back-up seal is of a permanently contacting type. At present this limits back-up seal selection to the Borg Warner GU seal. Lip seals are not acceptable.

- (7) The terms 'High Integrity', 'Enhanced Integrity' and 'Standard' have the meanings assigned in BP Group [RP 44-6](#), and determine the hazard radius for the purpose of area classification.

NOTES ON FLUIDS

- (8) Auto-ignition temperature (AIT) = 210°C unless otherwise specified.
- (9) Narrow boiling range refers to essentially pure materials and also to mixtures in which all of the compounds are of similar volatility, e.g. LPG.
- Medium boiling range refers to mixtures containing compounds with significant differences in boiling point, e.g. a typical petroleum distillate.
- Wide boiling range refers to mixtures containing compounds with appreciable differences in boiling point, e.g. a crude oil.
- (10) 'Dirty' liquids are defined as those which contain solid particles or constituents which are likely to deposit sludges, polymers or decomposition products.
- (11) 'Clean' liquids are those which do not fall into the 'dirty' category.
- (12) 'High pour point' liquids are those which require the pump to be heated to be pumpable.
- (13) 'Highly toxic' substances are those where the liquid or vapour may produce long term effects or death. Carcinogens should be classed as 'highly toxic'.
- (14) 'Mildly toxic' substances are those where the liquid or vapour may produce short term effects which disappear once exposure ceases.





PRINCIPLES UNDERLYING TABLES 1 AND 2

TABLE 3

TYPE OF FLUID	FLUID CHARACTERISTICS	REQUIREMENTS WITH RESPECT TO LEAKAGE		SEAL TYPE	
		NORMAL OPERATION	WITH PRIMARY SEAL FAULT	PREFERRED	ACCEPTABLE
RP 44-6 Category A.	Would vaporise rapidly and substantially on release. Leakage could form extensive vapour cloud	Nil	Very small	Glandless	Double or Tandem
RP 44-6 Category B. Narrow boiling range	High proportion would vaporise on release. Leakage could form extensive vapour cloud	Nil	Very small	Glandless	Double or Tandem
RP44-6 Category B. Wide boiling range	Smaller proportion would vaporise on release. Leakage would form a vapour cloud of smaller extent than for the examples above.	Very small	Severely restrict for a limited period at least	Single + lip + Throttle Bush or Single + Back-up + Throttle Bush	If the preferred types are not practical, upgrade seal type.
RP 44-6 Category C.	Little vaporisation on release. Spray could enlarge the effective area of release.	Very small	Restrict	Single + lip + Throttle Bush or Single + Back-up + Throttle Bush	Single + Throttle Bush
Flammable, below flashpoint	Vaporisation low, unlikely to form flammable atmosphere unless mist is produced or vaporisation occurs on hot surfaces.	Very small	Restrict	Single + lip + Throttle Bush	Single + Throttle Bush
Flammable, well below flashpoint	Vaporisation very low. Ignition unlikely unless vaporisation occurs on hot surfaces.	Small	Restrict if possible	Single + Throttle Bush	Single
High temp., above AIT	Ignition inevitable if leakage is significant.	Nil	Very small	Glandless	Double
Highly toxic	May cause long term effects or death.	Nil	Very small	Glandless	Double
Mildly toxic	May cause short term effects.	Very small	Severely restrict, at least for a limited period	Single + lip + Throttle Bush or Single + Back-up + Throttle Bush	If the preferred seal type is not practical, review seal type.
Non-hazardous		No special requirements		Single	

DEFINITIONS AND ABBREVIATIONS**Definitions**

Standardised definitions may be found in the BP Group RPSEs Introductory Volume.

Abbreviations

AGMA	American Gear Manufacturers Association
AIT	Auto ignition temperature
API	American Petroleum Institute
BU	Back-up (dry running seal)
FP	Flash point
IP	Institute of Petroleum
ISO	International Standards Organisation
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
NACE	National Association of Corrosion Engineers
NCB	National Coal Board
NPSH	Net positive suction head
NPSHA	Net positive suction head available
NPSHR	Net positive suction head required
TB	Throttle bush
VP	Vapour pressure

LIST OF REFERENCED DOCUMENTS

A reference invokes the latest published issue or amendment unless stated otherwise.

Reference standards may be replaced by equivalent standards that are internationally or otherwise recognised provided that it can be shown to the satisfaction of the purchaser's professional engineer that they meet or exceed the requirements of the referenced standards.

National and Industry Documents

NCB Spec 244	Fire-resistant and anti-static endless V-belts
API 610	Centrifugal pumps for general refinery services
API 611	General purpose steam turbines for refinery services
API 612	Special-purpose steam turbines for refinery services
API 613	Special-purpose gear units for refinery services
API 619	Rotary-type positive displacement compressors for general refinery services
API 672	Packaged integrally geared centrifugal air compressors for general refinery service
API 673	Special-purpose centrifugal fans for general refinery service
API 674	Positive displacement pumps - reciprocating
API 675	Positive displacement pumps - controlled volume
API 676	Positive displacement pumps - rotary
API 680	Packaged reciprocating plant and instrument air compressors for general refinery services.
AGMA 420	Practice for enclosed speed reducers or increasers using spur, helical, herringbone and spiral bevel gears
AGMA 421	Standard practice for high speed helical and herringbone gear units
NACE Std MR-0175	Material requirement. Sulfide stress cracking resistant metallic material for oil field equipment
NFPA 20	Standard for the installation of centrifugal fire pumps
ISO 3977	Gas turbines - procurement.

BP Group Documents

BP Group RP 44-6	Area Classification to IP 15 (replaces BP CP 39)
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BP Group GS 112-3	Low-voltage induction motors (replaces BP Std 221)
BP Group GS 112-4	High-voltage induction motors (replaces BP Std 220)
BP Group GS 112-6	Electrical requirements for ac generators. Part 1, AC generators (replaces BP Std 224)
BP Group GS 124-1	Fire Pumps and Drives (replaces BP Std 217)
BP Group GS 134-2	Side entry impeller mixers for vertical storage tanks (replaces BP Std 140)
BP Group GS 134-4	Centrifugal pumps to API 610 (replaces BP Std 195)
BP Group GS 134-5	Centrifugal compressors to API 617 (replaces BP Std 196)
BP Group GS 134-6	Reciprocating compressors to API 618 (replaces BP Std 197)
BP Group GS 134-7	Special purpose steam turbines to API 612 (replaces BP Std 198)
BP Group GS 134-8	Requirements for the protection of diesel engines operating in zone 2 hazardous areas (replaces BP Std 200)
BP Group GS 134-9	Rotary type positive displacement compressors to API 619 (replaces BP Std 201)
BP Group GS 134-10	Special purpose gear units to API 613 (replaces BP Std 202)
BP Group GS 134-11	Glandless pumps (replaces BP Std 203)
BP Group GS 134-12	Packaged gas turbines to API RP11 PGT. (replaces BP Std 204)
BP Group GS 134-13	Packaging of rotating machinery for offshore use (replaces BP Std 205)



BP Group [GS 134-14](#)

General purpose pumps
(replaces BP Std 208)

BP Group [GS136-1](#)

Materials for sour service to NACE Std MR-01-75
(replaces BP Std 153)

BP Group [GS 156-2](#)

Surface condensers for steam turbines
(replaces BP Std 133)

Others

I.Mech.E

Mechanical Seal Practice for Improved Performance

