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Guidance on Practice for Machinery

GP 34-00

BP GROUP
ENGINEERING TECHNICAL PRACTICES

Foreword

This is the first issue of Engineering Technical Practice (ETP) BP GP 34-00. This Guidance on Practice (GP) is based on parts of heritage documents from the merged BP companies as follows:

BP (Pre-1999)

RP 34-1 Rotating machinery.

Amoco

A RE-COMP-00-E	Rotating Equipment—Compressors—Engineering Specification.
A RE-COMP-00-G	Rotating Equipment—Compressors—Guide.
A RE-COMP-HS-G	Rotating Equipment—Compressors—High Speed Reciprocating—Guide.
A RE-ENG-HS-E	Rotating Equipment—Engines—High Speed Gas and Diesel—Engineering Specification.
A RE-ENG-HS-G	Rotating Equipment—Engines—High Speed Gas and Diesel—Guide.
A RE-LUBE-614-E	Rotating Equipment—Lubrication—API 614 Lube Oil and Seal Oil Systems—Engineering Specification.
A RE-LUBE-MST-E	Rotating Equipment—Lubrication—Oil Mist Systems—Engineering Specification.
A RE-LUBE-MST-G	Rotating Equipment—Lubrication—Oil Mist Systems—Guide.
A RE-PUMP-00-A	Rotating Equipment—Pumps—Acceptable Supplier Specification.
A RE-PUMP-00-E	Rotating Equipment—Pumps—Engineering Specification.
A RE-PUMP-00-G	Rotating Equipment—Pumps—Guide.
A RE-TURB-616-E	Rotating Equipment—Turbines—API 616 Gas—Engineering Specification.
A RE-TURB-616-G	Rotating Equipment—Turbines—API 616 Gas—Guide.
A RE-TURB-STM-E	Rotating Equipment—Turbines—Steam—Engineering Specification.
A RE-TURB-STM-G	Rotating Equipment—Turbines—Steam—Guide.
A RE-FUGE-00-E	Rotating Equipment—Centrifuges—Engineering Specification.
A RE-CONV-00-G	Rotating Equipment—Screw Conveyors—Guide.
A RE-CPLG-00-E	Rotating Equipment—Couplings—API 671 Special-Purpose—Engineering Specification.
A RE-MNTR-670-E	Rotating Equipment—Monitoring Systems—API 670—Engineering Specification.
A RE-MNTR-670-G	Rotating Equipment—Monitoring Systems—API 670—Guide.



Table of Contents

	Page
Foreword	2
1. Scope	5
2. Normative references.....	5
3. Terms and definitions.....	7
4. Symbols and abbreviations	7
5. General.....	8
5.1. Conflicting requirements	8
5.2. Developing a purchase specification for machinery.....	8
5.3. Operating conditions	10
5.4. Installation.....	12
5.5. Machinery protection systems.....	13
5.6. Performance monitoring at site	15
6. Equipment & component types	16
6.1. Seals.....	16
6.2. Pumps	17
6.3. Compressors	20
6.4. Fans.....	25
6.5. Expander-compressors.....	25
6.6. Mixers and agitators.....	25
6.7. Centrifuges	26
6.8. Electrical power generators.....	26
6.9. Drivers	26
6.10. Transmissions.....	31
6.11. Extruders	33
7. Auxiliary systems and components.....	33
7.1. Lube oil, shaft sealing and control oil systems	33
7.2. Oil mist systems.....	33
7.3. Steam condensers.....	34
7.4. Vacuum systems.....	34
7.5. Condensate extraction pumps.....	34
7.6. Non-return valves.....	34
7.7. DCS instrument tag descriptions.....	34
7.8. Alarms	34
7.9. Sequence of events recording.....	35
8. Noise	35
9. Procurement	35



List of Figures

Figure 3 Guide to head, flow and speed for centrifugal pumps.....	17
Figure 1 Compressor application flow vs pressure ratio	21
Figure 2 Compressor application operability range	22



1. Scope

- a. This Guidance on Practice covers general requirements for 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.
- b. It applies to equipment used in:
 1. Refineries and chemical works including offsites and utilities.
 2. Offshore installations and on-shore terminals.
 3. Pipelines and pumping stations.
 4. Crude oil and gas gathering and separation plants.
 5. LNG plants.
- c. It may be applied to other applications similar to the above but is not intended for specialised drilling operations.

2. Normative references

The following normative documents contain requirements that, through reference in this text, constitute requirements of this technical practice. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this technical practice are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

BP

GIS 12-201	Guidance on Industry Standard for IEC Low-Voltage Induction Motors.
GIS 12-202	Guidance on Industry Standard for Low-Voltage Induction Motors (IEEE 841).
GIS 12-203	Guidance on Industry Standard for IEC High-Voltage Induction Motors.
GIS 12-204	Guidance on Industry Standard for High-Voltage Induction Motors (API 541).
GIS 12-801	Guidance on Industry Standard for IEC Power Generators.
GIS 12-802	Guidance on Industry Standard for NEMA Power Generators.
*GS 124-1	Firewater pumps for onshore use.
*GS 124-2	Direct diesel engine driven firewater pumps for offshore use.
*GS 124-3	Electric motor driven firewater pumps for offshore use.
*GS 124-4	Hydraulic motor driven firewater pumps for offshore use.
GIS 26-106	Guidance on Industry Standard for Steam Surface Condensers.
GIS 34-101	Guidance on Industry Standard for ISO 10439-2 Axial & Centrifugal Compressors & Expander-Compressors (API Std 617).
GIS 34-102	Guidance on Industry Standard for API Std 672 Packaged, Integrally Geared Centrifugal Air Compressors.
GIS 34-103	Guidance on Industry Standard for ISO 13681 Packaged Reciprocating Gas Compressors (API Specification 11P).



GIS 34-104	Guidance on Industry Standard for ISO 13707 Reciprocating Compressors (API Std 618).
GIS 34-105	Guidance on Industry Standard for Liquid Ring Vacuum Pumps and Compressors (API 681).
GIS 34-106	Guidance on Industry Standard for ISO 10440 Rotary Type Positive Displacement Compressors (API Std 619).
GIS 34-107	Guidance on Industry Standard for API 673 Special Purpose Fans.
GIS 34-201	Guidance on Industry Standard for Centrifugal pumps to API 610.
GIS 34-202	Guidance on Industry Standard for ASME B73.1 Centrifugal Pumps.
GIS 34-203	Guidance on Industry Standard for ASME B73.2M Centrifugal Pumps.
GIS 34-204	Guidance on Industry Standard for ISO 5199 Centrifugal Pumps.
GIS 34-205	Guidance on Industry Standard for ISO 15783 Centrifugal Pumps.
GIS 34-211	Guidance on Industry Standard for Reciprocating Pumps to API 674.
GIS 34-212	Guidance on Industry Standard for Controlled Volume Pumps to API 675.
GIS 34-213	Guidance on Industry Standard for Rotary Pumps to API 676.
GIS 34-301	Guidance on Industry Standard for ISO 10436 General Purpose Steam Turbines (API Std 611).
GIS 34-302	Guidance on Industry Standard for ISO 10437 Special Purpose Steam Turbines (API Std 612).
GIS 34-303	Guidance on Industry Standard for API 616 Gas Turbines.
GIS 34-304	Guidance on Industry Standard for API RP 11PGT Packaged Gas Turbines.
GIS 34-305	Guidance on Industry Standard for the Protection of Diesel Engines Operating in Zone 2 (Division 2) Hazardous Areas.
GIS 34-401	Guidance on Industry Standard for Extruders.
GIS 34-403	Guidance on Industry Standard for Mixers.
GIS 34-501	Guidance on Industry Standard for API Std 613 Special Purpose Gear Units.
GIS 34-502	Guidance on Industry Standard for API Std 677 General Purpose Gear Units.
GIS 34-503	Guidance on Industry Standard for API 671 Special Purpose Couplings.
*GS 134-13	Packaging of rotating machinery for offshore use.
GIS 34-701	Guidance on Industry Standard for API Std 614 Lubrication, Shaft-sealing, and Control-oil Systems and Auxiliaries.
GIS 34-702	Guidance on Industry Standard for Oil Mist Lubrication Systems.
GIS 34-704	Guidance on Industry Standard for Pump Shaft Seal Systems (API 682).
GIS 34-801	Guidance on Industry Standard for API 686 Installation of Mechanical Equipment.
*GS 136-1	Materials for sour service to NACE Std MR0175.
GP 12-20	Guidance on Practice for Electric Motors.
GP 12-80	Guidance on Practice for Power Generators.
*RP 44-6	Area classification to IP 15.
GP 50-XX	Guidance on Practice for Quality and Conformity.



American Petroleum Institute (API)

API Std 610	Centrifugal Pumps for Petroleum, Heavy Duty Chemical, and Gas Industry Services.
API Std 611	General Purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services.
API Std 612	Special-Purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services.
API Std 613	Special-Purpose Gear Units for Petroleum, Chemical, and Gas Industry Services.
API Std 619	Rotary-Type Positive Displacement Compressors for Petroleum, Chemical, and Gas Industry Services.
API Std 672	Packaged, Integrally Geared Centrifugal Air Compressors for Petroleum, Chemical, and Gas Industry Services.
API Std 674	Positive Displacement Pumps – Reciprocating.
API Std 675	Positive Displacement Pumps – Controlled Volume.
API Std 676	Positive Displacement Pumps – Rotary.

American Gear Manufacturer's Association (AGMA)

AGMA 421	Standard Practice for High Speed Helical and Herringbone Gear Units.
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Heat Exchanger Institute (HEI)

Standard for Steam Surface Condensers.

International Organization for Standardization (ISO)

ISO 3977	Gas turbines – procurement.
ISO 15663	Petroleum and natural gas industries – Life cycle costing.
ISO 13631	Petroleum and natural gas industries – Packaged reciprocating gas compressors.

3. Terms and definitions

For the purposes of this GP, the following terms and definitions apply:

criticality rating

Rating determined by evaluating the combined effect of the likelihood of failure and its consequence, i.e. financial, safety or environmental. “Criticality one” equipment has the most impact.

4. Symbols and abbreviations

For the purpose of this GP, the following symbols and abbreviations apply:

LCC	Life Cycle Cost
LNG	Liquefied natural gas
NDE	Non-Destructive Examination
NPSH	Net positive suction head
NPSHA	Net positive suction head available



NPSHR Net positive suction head required

5. General

5.1. Conflicting requirements

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

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

5.2. Developing a purchase specification for machinery

5.2.1. Teamwork

- a. The satisfactory performance of any machinery is founded on its purchase specification which is the result of the efforts of a multi-discipline team led by a mechanical/machinery engineer and including process, instrumentation, electrical, control and procurement functions.
- b. Team members can be drawn from the end user, engineering contractor and the machinery vendor.

5.2.2. Life Cycle Costs (LCC)

- a. Machinery shall be selected on the basis of minimum life cycle cost (LCC).
- b. The principles of LCC are described in ISO 15663 and the Hydraulic Institute and European Pump Manufacturers' Association have produced a working guide.

5.2.2.2. Standby equipment

- a. The necessity for stand-by machinery should be considered in the context of the LCC analysis that incorporates 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.

- b. Where possible the amount of equipment installed should be minimised e.g. by use of common, installed stand-by pumps performing two or more duties.

5.2.3. Criticality analysis & quality programme

5.2.3.1. General

- a. A criticality analysis to determine the probability of meeting the required availability shall be performed for each machine and this determines the quality programme applicable to it.
- b. The quality programme shall identify the inspection and testing requirements for the machine covering the design, manufacture, installation and commissioning.

*The topic is further addressed in **GP 50-XX**.*



5.2.3.2. Testing

- a. Factory Testing - For criticality one machinery and its associated systems factory testing should be done. Depending on the equipment the testing should include, but need not be limited to:

1. Hydrotesting.
2. NDE testing.
3. Mechanical run test.
4. Performance test.

Under certain circumstances (e.g. for offshore facilities) this may take the form of a full speed, full pressure, full load test using gas that is the same or closely resembles the field gas properties. This test would be expensive.

5. Balancing test - Balancing should conclude with a residual unbalance check in accordance with API Publication 684 Appendix 3B.

The purpose of this test is to determine the magnitude and direction of the unbalance in the rotor. It also confirms the calibration of the balancing machine.

6. Overspeed testing.
7. Functional testing of systems e.g. oil pump switchovers, governor testing.

- b. Field testing

1. A program of field tests should be developed and executed to assure the readiness of a machine for commissioning.

Such a program might include oil flushing, system cleanliness tests and instrumentation functional checks.

5.2.4. Plant philosophies**5.2.4.1. General**

- a. Machinery and its associated systems shall be specified to integrate with the existing philosophies described in paragraphs 5.2.4.2 through 5.2.4.5 as operated at the manufacturing site.
- b. If these philosophies are not in place (e.g. in green field developments) they shall be developed before the machinery is ordered.

5.2.4.2. Condition monitoring

- a. Continuous on line systems, off line monitoring or both?
- b. Networking of systems.
- c. Internet monitoring capability.
- d. Coverage of mechanical and performance conditions.
- e. Vibration, temperatures, tribology.

5.2.4.3. Maintenance

- a. In house or contracted out labour?
- b. Machinery healthcare contracts.
- c. Site configurations and limitations.



5.2.4.4. Operation

- a. Minimum manning of plants.
- b. Local or remote operation or both?
- c. No local instrumentation?
- d. Tripping policy.

5.2.4.5. Spare parts inventory

- a. Managed in house or outsourced?
- b. System in place for adding to stock – covering availability requirement of machine, part lead time.
- c. Critical machinery spare rotor management system - to give assurance the condition of the spare rotors including but not limited to:
 1. Balance.
 2. Probe track run out.
 3. Corrosion protection.
 4. Documentation.

5.2.5. Use of BP Guidance on Industry Standards (GIS) and industry standards

- a. Machinery specifications shall be developed based on the appropriate BP GIS and associated industry standards.
- b. If the industry standard has data sheets and purchaser decision points these shall be completed.

5.2.6. Responsibilities

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

- a. 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.
- b. The nominated manufacturer should be fully responsible for all equipment supplied by other vendors. He should also ensure that all such equipment, and 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.

“Free issue equipment” is kit supplied to, but not procured by, the nominated manufacturer. The equipment is not “free” for the user and should be included in any LCC analysis.

5.3. Operating conditions**5.3.1. Process, utilities and transients**

- a. Machinery should be capable of operating unattended. The circumstances for attended operation shall be specified e.g. start up, shutdown, abnormal conditions.



- b. Process conditions specified for fluid machinery shall cover the full range of flow, pressure, temperature, molecular weight, viscosity, erosive and corrosive properties, etc.
- c. If new machinery is to be installed as part of an expansion to existing plant then the impact of operational upsets of the existing machinery on the new machinery (and vice versa) shall be specified. Both driving and driven equipment systems should be considered.
- d. Machinery should be suitable for operation at all specified ambient conditions and controlled ranges of process, utilities including those at start up and shutdown. Additionally if commissioning may take place with an alternative fluid that results in higher pressure and/or temperatures, this shall be taken into account.

Machine operation at the suction pressure relief valve setting is not usually a design case as it could lead to excessive driver power. The machine and components should be designed to withstand the static relief valve pressure.

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

- e. If machinery is subject to sour conditions as defined in **GS 136-1**, the materials used should be in accordance with **GS 136-1**. This should apply even when sour conditions only exist for short periods.
- f. Utilities conditions specified should cover:
 - 1. The full range of pressure, temperature, calorific value, for steam, water, air, gas, together with quality limits on impurities.
 - 2. Power supplies to be used for auxiliaries and instruments.
 - 3. Any pressurisation in vents or drains.
 - 4. Any requirement for units to continue in operation on temporary failure of a utility supply.

5.3.2. Machine control methods

- a. The design of process control systems associated with fluid machinery shall take into account the need to operate at less than rated conditions.
- b. Operating efficiency at part load should be considered when determining the method of machine control.
- c. Machine output should be controlled by one of the following methods:
 - 1. Centrifugal compressors - Preferably speed regulation or variable angle guide vanes or suction throttling. Discharge throttling can be used but is a less stable control method and is highly inefficient.
 - 2. Centrifugal pumps - Speed regulation or discharge throttling.

From a LCC viewpoint speed regulation is the more energy efficient method of control particularly if the system curve is predominantly friction losses.
 - 3. Reciprocating compressors - Preferably inlet valve unloading and/or clearance pockets, although external bypassing and intake throttling can be used.
 - 4. Oil injected rotary positive displacement compressors - Internal slide valve or bypass regulation.
 - 5. Non lubricated rotary positive displacement compressors - Bypass regulation.
 - 6. Positive displacement pumps - Variable stroke or bypass regulation.

