

NIOEC-SP-46-10(1)							
DOCUMENT CODE						NO. OF PAGES: 12	
PLAN/PRJ/SUB	UNIT	PHASE	DISCIPLINE	DOCUMENT TYPE	SERIAL NO.	REV. NO.	DATE
NIOEC	000	EG	PM	SP	4610	A1	JUNE 2016



NATIONAL IRANIAN OIL REFINING & DISTRIBUTION COMPANY
NATIONAL IRANIAN OIL ENGINEERING
& CONSTRUCTION COMPANY

NIOEC SP

NIOEC SPECIFICATION

FOR

INTEGRALLY GEARED CENTRIFUGAL PLANT AND INSTRUMENT AIR COMPRESSOR PACKAGES

FIRST EDITION

JULY, 2005

THIS SPECIFICATION IS THE PROPERTY OF NATIONAL IRANIAN OIL ENGINEERING & CONSTRUCTION COMPANY. IT IS CONFIDENTIAL AND ALL RIGHTS RESERVED TO THE OWNER. NEITHER WHOLE NOR ANY PART OF THIS DOCUMENT MAY BE DISCLOSED TO ANY THIRD PARTY, REPRODUCED, STORED IN ANY RETRIEVAL SYSTEM OR TRANSMITTED IN ANY FORM OR BY ANY MEANS WITHOUT THE PRIOR WRITTEN CONSENT OF THE NATIONAL IRANIAN OIL ENGINEERING & CONSTRUCTION COMPANY.

IN THE NAME OF GOD

FOREWORD

By their very nature, technical Specifications are continuously subject to modifications and revisions. To strengthen their merit and usefulness, continuous improvements, addendum, deletion of disparate information and consequently provision of updated revisions are to be made in order to ascertain that such Specifications meet the current requirements, inclusive of Iranian Petroleum Standards (IPS) and the recognized and acceptable national and international Standards, as well as the optimal codes and practices based on the accumulated in-house know-how and plant knowledge and experiences.

However, in reality, due to several reasons, not to mention the complexity of the matter, the ultimate goal of continuous direct embedment of the required changes on the relevant Specifications may be far reaching. Therefore, in the interim periods between the officially issued revisions, the required changes will appear in other documents related to the engineering and design work of the ongoing projects.

In response to the initiative of the Design and Engineering Directorate, and considering that the task of the execution of several important and mega projects for the realization of the new oil refineries, pipelines and oil terminals as well as improvements of the existing facilities, has been assigned to NIOEC, it was decided to update the NIOEC Specifications and to issue new official revisions.

The Design and Engineering Directorate was itself entrusted to carry out this important task, and as such by forming several special technical committees, working in close co-operation and cohesion and sharing their expertise and knowledge, the updated and revised NIOEC Specifications were successfully prepared and complied.

These Specifications are intended to be used for Oil Refineries, Distribution Depots, Oil Terminals, Pipelines and Pump Stations within NIOEC's projects, and have been proven to be of high value for such purposes. It must however be appreciated that these Specifications represent the minimum requirements and should in no way be interpreted as a restriction on the use of better procedures, engineering and design practices or materials.

We encourage and highly appreciate the users and other clear sighted and experts to send their comments on the Specifications to the Design and Engineering Director of NIOEC for evaluation and approval.

REVISION INDEX

REV. PAGE	1	2	3	4	5	REV. PAGE	1	2	3	4	5	REV. PAGE	1	2	3	4	5	REV. PAGE	1	2	3	4	5
1	X					26						51						76					
2	X					27						52						77					
3	X					28						53						78					
4	X					29						54						79					
5	X					30						55						80					
6	X					31						56						81					
7	X					32						57						82					
8	X					33						58						83					
9	X					34						59						84					
10	X					35						60						85					
11	X					36						61						86					
12	X					37						62						87					
13	X					38						63						88					
14	X					39						64						89					
15						40						65						90					
16						41						66						91					
17						42						67						92					
18						43						68						93					
19						44						69						94					
20						45						70						95					
21						46						71						96					
22						47						72						97					
23						48						73						98					
24						49						74						99					
25						50						75						100					

NOTES:

- 1) THIS SHEET IS A RECORD OF ALL REVISIONS TO THIS SPECIFICATION.
- 2) WHEN APPROVED EACH REVISION SHALL BE CONSIDERED AS A PART OF THE ORIGINAL DOCUMENT.
- 3) NUMBER OF PAGES EXCLUDES THIS SHEET AND THE COVER SHEET.

5					
4					
3					
2					
1	JUNE 2016	M.EJTEMAJOU	GH. ANVARI	M.R.FARZAM	A.R.ARMAN MOGHADAM
0	JULY 2005	FROUTAN / B.A	A.SADEGHILAR	M.R.FARZAM	M.A.A.SAJEDI
REV.	DATE	PREPARED	CHECKED	APPROVED	AUTHORIZED

CONTENTS:	PAGE NO.
INTRODUCTION.....	2
1. SCOPE	2
2. REFERENCES.....	2
3. UNITS	3
4. MODIFICATION TO API 672.....	4

INTRODUCTION

To satisfy the requirements of this NIOEC Standard Specification, API 672 4th edition 2004 (Revised 2007) with the modifications as specified herein after shall be strictly followed.

The following annotations, as specified hereunder, have been used at the bottom right hand side of each clause or paragraph to indicate the type of change made to the equivalent clause or paragraph of API.

Substitution: The clause in API shall be deleted and replaced by the new clause in this Standard.

Addition: The new clause with the new number shall be added to the relevant section of API.

Modification: Part of the clause or paragraph in API shall be modified and/or the new description

1. SCOPE

- 1.1. This specification covers the general requirements of centrifugal plant and instrument air compressor which shall confirm to the American Petroleum Institute Standard 672 4th edition 2004 (Revised 2007) as supplemented and modified herein.
- 1.2. This specification supplements the specification sheets for each individual air compressor package unit on which the operating conditions and special requirements are listed in detail. Whenever the data included on the individual specification sheet conflicts with the provision of this general specification, the former shall govern.
- 1.3. Compliance with the provisions of this specification does not relieve the Contractor and /or Supplier of the responsibility of furnishing compressor and accessories of proper design, mechanically suited to meet operating guaranteed at the specified service conditions.
- 1.4. Unless specific exception accompanied by a description of the proposed substitute is recorded under the heading "Exception" in the manufacturer's proposal, it shall be mutually understood that the proposal is based on equipment which complies strictly with the requirements of these specification.
- 1.5. Resolution on cases not explicitly stipulated in this specification, or on cases where conflicts may arise among the requirements of the referenced / relevant IPS and international standards shall be made through written consent and approval of NIOEC.
- 1.6. Deviations from this specification will only be permitted in obtaining written approval from NIOEC.

2. REFERENCES

The following standards, codes and specifications, to the extent specified herein after, shall constitute a part of this NIOEC specification. Latest edition of the undated referenced documents and the cited edition of the dated references shall apply. The applicability of changes made to the dated references, after the cited date shall be mutually agreed upon between NIOEC and the vendor/contractor.

API (AMERICAN PETROLEUM INSTITUTE)

API STD 670	"Machinery Protection Systems"
API STD 672	"Packaged, Integrally geared Centrifugal Air compressors for Petroleum, Chemical, and Gas Industry Services" – 4 rd edition 2004 (Revised 2007)

TEMA (TUBULAR EXCHANGER MANUFACTURERS ASSOCIATION)**ASME (AMERICAN SOCIETY OF MECHANICAL ENGINEERS)**

ASME	"Section VIII Division 1"
ASME	"Section IX"

ASTM (AMERICAN SOCIETY OF TESTING MATERIALS)

ASTM E-94	"Standard Guide for Radiographic Examination"
ASTM E-186	"Standard Reference Radiographs for Heavy-Walled Steel Castings (50-114mm)"
ASTM E-280	"Standard Reference Radiographs for Heavy-Walled Steel Castings (114-305mm)"
ASTM E-446	"Standard Reference Radiographs for Steel Castings Up to 50mm in Thickness"

NIOEC-SP (NIOEC SPECIFICATION)

NIOEC-SP-00-01	"NIOEC Specification for Site Condition"
NIOEC-SP-00-10	"NIOEC Specification for Units"
NIOEC-SP-40-03	"NIOEC Specification for Spare Parts Requirements"
NIOEC-SP-40-04	"NIOEC Specification for Lubricating, Sealing and Controlling Oil"
NIOEC-SP-46-06	"NIOEC Specification for Special Purpose for Steam Turbines"
NIOEC-SP-46-07	"NIOEC Specification for Lubrication, Shaft Sealing and Control Oil System for Special Purpose Application"
NIOEC-SP-47-10	"NIOEC Specification for Noise Control and Vibration"
NIOEC-SP-60-02	"NIOEC Specification for Low Voltage Induction Motors"
NIOEC-SP-70-01	"NIOEC Specification for Instrumentation"

NIOEC-SIP (NIOEC SHOP INSPECTION PROCEDURE)

NIOEC-SIP-46-04	"NIOEC Shop Inspection Procedure for rotary machines"
NIOEC-SIP-44-01	"NIOEC Shop Inspection Procedure for shell and tube heat exchanger"

3. UNITS

International system of units (SI) shall be used in accordance with NIOEC-SP-00-10, unless otherwise specified.

4. MODIFICATION TO API 672

The paragraph numbering follows API Standard 672 forth Edition March 2004 and each paragraph denotes an addition, substitution, or alteration. Those optional section not covered in the text are included in the compressor data sheets.

6.1.3 Sound Pressure Level (Substitution)

Control of sound level of all equipment furnished shall confirm to the requirements of NIOEC-SP-47-10.

6.1.9 Performance Criteria (Substitution)

The vendor shall be responsible for coordination and guarantee of the overall performance of the compressor, driver and all auxiliaries, within the specified acceptance criteria.

6.1.14 Preliminary Review(Addition)

Many factors (such as piping loads, alignments and operating conditions, supporting structure, handing during shipment, and handling and assembly at site) may adversely affect site performance. To minimize the influence of these factors, the vendor shall review and comment on the purchaser's piping and foundation drawings. The vendor's representative shall do the following:

- a. Observe a check of the piping performed by parting the flanges.
- b. Be present during the initial alignment check.
- c. Check the alignments at the operating temperature.

6.1.15 Winterizing(Addition)

Winterization when required will be specified on the individual data sheets.

6.7.1.3 (Modification)

Add the following sentences at the end of this clause:

First critical speed shall have at least 20% margin from any operating point.

6.7.2 Lateral Analysis (Substitution)

The vendor shall perform a lateral vibration analysis of the complete coupled train and submit the report.

6.7.3.1 (Substitution)

The vendor shall perform a torsional vibration analysis of the complete coupled train and submit the report.

6.7.3.2 (Modification)

Add the following sentences at the end of this clause:

No actual torsional resonant speeds shall be within 10% of the first or second harmonic of the rotational frequency in the operating speed range including up to trip speed.

6.9.1 (Substitute)

Unless otherwise specified, bearings and bearing housings shall be arranged for oil lubrication using a mineral oil in accordance with NIOEC-SP-40-04.

6.9.2 (Substitute)

A pressurized oil system shall be supplied in accordance with NIOEC-SP-46-07 except as noted in 6.9.3 – 6.9.6. (See Annex E, Figure E-1 and Table E-1 for a schematic of the minimum system and the various options applicable.)

6.9.5. (Addition)

Strainers are not permitted in the interior of the reservoir.

6.9.6 (Addition)

Reservoir drain shall be 1½ inches NPS minimum plugged.

6.10.3.1.1 (Modification)

Add the following sentences at the end of this clause:

Approval by the purchaser shall be obtained before any major weld repair is carried out. All repairs shall meet the inspection and acceptance requirements of Section VIII Division 1 and Section IX of the ASME Code and standards for the original material. The definition of a major weld repair is to be taken as either a removal of more than 50% of the wall thickness, or a length of more than 150 mm in one or more directions, or a total surface area of all repairs exceeding 20% of the total casting surface area.

The total quantity of weld metal deposited shall be less than 10% of the mass of the casting. Detail of all major weld repairs, and of the heat treatment where applicable, shall be recorded and reported to the purchaser.

6.10.3.1.2 (Modification)

Add the following sentences at the end of this clause:

Detail of all repairs shall be recorded and reported to the purchaser, who shall be informed the need for plugging before any repair is carried out.

6.11.4 (Modification)

Add the following sentences at the end of this clause:

- g) Year of manufacture
- h) Rated Input Speed.

7.1.1.1 (Substitution)

The type of driver shall be specified on the data sheets. The driver shall be sized to meet the maximum specified operating conditions including external gear or coupling losses, or both and shall be in accordance with applicable specifications as stated in the inquiry and order. All driver units shall be suitable for satisfactory operation with the specified electrical power characteristics, site conditions, inlet and exhaust steam pressure and temperatures, or fuel.

7.1.3.1 (Substitution)

Steam turbine driver shall be in accordance with NIOEC-SP-46-06 and shall be capable of developing 110% of the rated compressor brake horsepower including gear, shaft driven pump, and coupling losses required for any of the specified operating conditions while operating at rated speed and specified steam condition.

7.1.2.3 (Addition)

Vibration of electric-motor compressor driver during operation at maximum continuous speed measured on the shaft shall not exceed 25µm double amplitude (peak-to-peak).

7.1.3.4 (Addition)

Vibration of steam turbine compressor driver, during operation at maximum continuous speed, measured on the shaft adjacent to the bearing housing shall not exceed (including shaft run out) 38µm double amplitude (peak-to-peak).

7.3.12 (Modification)

Add the following sentences at the end of this clause:

The baseplate shall be suitable for column mounting, if specified on the data sheets.

7.4.3.1 (Modification)

Add the following sentences at the end of this clause:

Following additional instrumentation shall be provided:

- r) Inter stage air pressure and temperature gages after inter coolers and before intercoolers respectively.
- s) Tachometer for turbine driver units.
- t) Ammeter for compressor motor driver.

7.4.3.2 (Modification)

Add the following sentences at the end of this clause:

A fully enclosed free standing control panel shall be provided and it is required to be local mounted adjacent to the compressor platform floor. This panel will include the automatic control components required for control of the unit furnished and assembled by vendor. Access to easy maintenance to this panel to facilitate easy control of the equipment shall be provided. Special consideration shall be given to the panel location in case of turbine driven machine.

7.4.4.5.1 (Modification)

Add the following sentences at the end of this clause:

Vendor shall provide equipment for monitoring and measurement of shaft radial vibration within each high speed pinion bearing housing and one end of the bull gear, in the case where compressor design involves pinion and bull gear.

A vibration monitoring system consisting of a single radial non contacting shaft vibration sensing probe, oscillator-demodulator, and read-out instrument shall be provided for each high-speed rotor and for driver bearings. For single impeller rotors the probe shall be located at the bearing adjacent to an impeller and turbine driver bearing.

The vendor shall include with his quotation a statement listing whether additional radial probes can be mounted adjacent to each impeller. The monitoring instrument shall be mounted in the compressor instrument and control panel.

7.4.4.5.3 (Addition)

When specified, vibration and axial position transducers shall be supplied, installed and calibrated in accordance with API standard 670.

7.4.4.5.4 (Addition)

When specified, vibration and axial position monitors shall be supplied, installed and calibrated in accordance with API standard 670.

7.4.4.5.5 (Addition)

when specified, a bearing-temperature monitor shall be supplied and calibrated in accordance with API standard 670.

7.4.5.1 (Modification)

The following items shall be added to “Table 3—Equipment Monitoring”.

- Emergency oil pump (if provided) inoperable (Alarm).
- High vibration of turbine driver (if applicable) (Alarm and Shutdown)

7.4.5.1 (Addition)

The steam turbine driven unit shall not shut-down as a result of power failure. Adequate insulation of turbine is mandatory to prevent overheating of instrument panel.

7.4.6.1 (Substitution)

For electrical power supply characteristics of motors, heaters, and instrumentation refer to NIOEC-SP-60-02 , NIOEC-SP-70-01 and NIOEC-SP-46-07.

7.4.6.7 (Addition)

All electrical materials including insulation shall be corrosion resistant and nonhygroscopic insofar as possible.

7.5.2.1 (Substitution)

All lube oil piping and tubing including fitting shall be stainless steel.

Provisions shall be included for flushing all piping in field prior to start-up.

7.6.7 (Addition)

Intercoolers and aftercoolers shall be designed to TEMA Class R.

7.6.8 (Addition)

For maximum interchangeability, all intercooler tube bundles shall be identical.

7.10.22(Substitution)

Intercoolers and aftercoolers shall be designed to TEMA Class R. and shall be constructed with a removable channel cover.

8.1.1(Substitution)

All tests and inspections shall be performed in accordance with the relevant NIOEC inspection and test procedures including Shop Inspection Procedure (NIOEC-SIP-46-04) and (NIOEC-SIP-44-01).

8.1.3 (Addition)

Purchaser's representative shall have the right to reject any part of the equipment which does not conform to the order.

8.1.4 (Addition)

All certificates shall contain the following information:

- Name of manufacturer
- Purchase order number and date
- Identification number of certificate and its date of issue
- Material specification
- Dimensions in SI units
- Material charge number or batch number
- Mechanical properties recorded from test results
- Chemical composition recorded from results of chemical analysis
- NDT methods and results, where applicable

- Heat treatment procedures, furnace charge number and heat treatment records, where applicable
- Name of the independent inspector who has witnessed the tests.

8.2.1.2 (Addition)

The parts which shall be subjected to inspection and the type required, shall be specified in purchase order.

8.3.1.3 (Addition)

Radiography of welded impellers shall also be made by vendor.

8.3.1.4 (Addition)

Radiography shall be in accordance with ASTM E 94.

The interpretation of radiographs shall be in accordance with ASTM E186, ASTM E 280 or ASTM E 446, whichever is applicable.

4.3.1.5 (Addition)

At least 6 weeks before the first scheduled running test, vendor shall submit to the purchaser, for review and comment, detailed procedures for the mechanical running test and all specified running optional tests, including acceptance criteria for all monitored parameters. The oil parameters shall be included in these test procedures.

8.3.1.6 (Addition)

The vendor shall notify the purchaser not less than 6 weeks before the date the equipment will be ready for testing. If the testing is rescheduled, the vendor shall notify the purchaser not less than 6 weeks before the new test date.

8.3.3 Impeller over speed test (Modification)

Add the following sentences at the end of this clause:

After final machining, each impeller shall be subject to an over speed test of at least 115% of maximum continuous speed for a minimum period of 3 minutes.

In principle, no dimensional change is permitted.

If any dimensional changes occur, it shall be reported and acceptance shall be subject to the purchaser's approval.

After the over speed test, impellers shall be checked for cracks and defects, then rebalanced.

8.3.4.1 (Modification)

Add the following sentences at the end of this clause:

A vibration amplitude/frequency sweep shall also be conducted at each test point. Also the vibration shall be measured at the shaft adjacent to each bearing. Performance test shall be

performed unless otherwise specified. Performance curves for capacity, discharge pressure, and brake horse power (kw rating) shall be developed from surge to maximum capacity at 100% speed. Tests shall be conducted in accordance with ASME power test code 10, Class I where conditions permit. Otherwise class II is required.

8.3.4.8 (Addition)

During mechanical running test, contract coupling shall be used.

8.3.4.9 (Addition)

Mechanical running tests are required and shall be witnessed.

8.3.4.10 (Addition)

The air compressor package rated performance shall be verified by a witnessed Performance test at the Vendor's shop prior to shipment.

8.3.4.11 (Addition)

Requirements of witnessed of any other test except above will be specified in data sheets.

8.4.1 (Modification)

Add the following sentences at the end of this clause:

Adequate protection shall be provided against mechanical damage. All equipment shall be packed, securely anchored (skid mounted when required) and weather-protected for the shipment method called for in the Purchaser Order.

8.4.4 (Modification)

Add the following sentences at the end of this clause:

Each compressor shall be identified as required by the purchase order. No material shall be shipped separately. Miscellaneous parts shall be properly tagged or marked with the item number for which they are intended. All such parts shall be suitably boxed, firmly attached to the base plate and shipped with the unit.

8.4.8 (Addition)

Exterior machined surfaces except for corrosion resistant material shall be coated with a suitable rust preventive.

Unless otherwise specified the rust preventive applied to unpainted exterior machined surfaces shall be of a type:

- 1) To provide protection during outdoor storage for a period of twelve months exposed to a normal industrial environment.
- 2) To be removable with mineral spirits or any standard solvent.

8.4.9 (Addition)

Bearings and seal assemblies shall be fully protected from rusting and entry of moisture and dirt.

Each item shall be tagged with its item number. Tags shall be impression stamped "Item No.". Tags shall be attached to each component with wire.

8.4.10 (Addition)

The control panel face shall be finish painted.

8.4.11 (Addition)

After inspection and test, equipment shall be completely free of water and prepared for shipment.

8.4.12 (Addition)

Bracing, supports, and rigging connections shall be provided to prevent damage during shipment, lifting or unloading.

8.4.13 (Addition)

One complete set of the installation, operation and maintenance instructions shall be packed in the boxes or crates with the equipment.

9.2.1 (Modification)

Add the following sentences at the end of this clause:

List of spare parts recommended for normal maintenance purpose (including the price list) should be given at the time of submitting the bids and shall be accordance with NIOEC SP-40-03. The following additional data shall be included in the vendor's proposal:

The make and model of vendor's standard instruments to be furnished.

Proposed material of construction, including alternatives to base proposal, for air side of intercoolers.

Standard type bearings applicable to the machine.

9.2.2 c) (Modification)

Add the following sentences at the end of this clause:

Attached to each final schematic drawing of each auxiliary system shall be a bill of materials describing in detail each item of accessory equipment and including:

- 1- Manufacturer.
- 2- Type of equipment.
- 3- Catalog number.
- 4- Electrical information.

- 5- Set point and ranges for instruments and control valves.
- 6- Capacities.
- 7- Pressures and horsepower for oil pump.

9.3.2 Drawings and Technical Data (Modification)

The information shall include the documents for controls and instrumentation.

The vendor shall give the listed data to the purchaser's representative at the time of or before final inspection. Additionally, the following data shall be included:

Material data for impellers.

Certified copies of test data.

Measured critical speed and shaft vibration at point of measurement.

10. GUARANTEE AND WARRANTY (Add.)

10.1 Mechanical

Unless exception is recorded by the vendor in his proposal, it shall be understood that the vendor agrees to the following guarantees and warranties:

During a period of 12 months after the date of commissioning, the vendor shall, with all possible speed and without cost to the purchaser, replace or repair the goods or any part thereof found to be defective due to faulty material, workmanship or to any act or omission of the vendor. In particular the vendor shall reimburse any transportation and other charges incurred by the purchaser in effecting such replacement or repair at the point of use.

10.2 Performance

The compressor shall be guaranteed for satisfactory performance at all specified operating conditions, including rated operating point. At this point, no negative tolerance is permitted on capacity and discharge pressure and the brake horse power may not exceed 104 percent of the quoted horsepower.

Packaged, Integrally Geared Centrifugal Air Compressors for Petroleum, Chemical, and Gas Industry Services

API STANDARD 672
FOURTH EDITION, MARCH 2004

ERRATA, OCTOBER 2007



.....

Packaged, Integrally Geared Centrifugal Air Compressors for Petroleum, Chemical, and Gas Industry Services

Downstream Segment

API STANDARD 672
FOURTH EDITION, MARCH 2004



SPECIAL NOTES

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations under local, state, or federal laws.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the material safety data sheet.

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. Sometimes a one-time extension of up to two years will be added to this review cycle. This publication will no longer be in effect five years after its publication date as an operative API standard or, where an extension has been granted, upon republication. Status of the publication can be ascertained from the API Standards department telephone (202) 682-8000. A catalog of API publications, programs and services is published annually and updated biannually by API, and available through Global Engineering Documents, 15 Inverness Way East, M/S C303B, Englewood, CO 80112-5776.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this standard or comments and questions concerning the procedures under which this standard was developed should be directed in writing to the Director of the Standards department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005. Requests for permission to reproduce or translate all or any part of the material published herein should be addressed to the Director, Business Services.

API standards are published to facilitate the broad availability of proven, sound engineering and operating practices. These standards are not intended to obviate the need for applying sound engineering judgment regarding when and where these standards should be utilized. The formulation and publication of API standards is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

All rights reserved. No part of this work may be reproduced, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 1220 L Street, N.W., Washington, D.C. 20005.

Copyright © 2004, 2007 American Petroleum Institute

FOREWORD

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any federal, state, or municipal regulation with which this publication may conflict.

Suggested revisions are invited and should be submitted to API, Standards department, 1220 L Street, NW, Washington, DC 20005.

Copyright American Petroleum Institute
Provided by IHS under license with API
No reproduction or networking permitted without license from IHS

CONTENTS

	Page
0 INTRODUCTION.....	1
1 SCOPE.....	1
2 NORMATIVE REFERENCES.....	1
3 DEFINITION OF TERMS	2
4 GENERAL.....	4
4.1 Unit Responsibility	4
4.2 Nomenclature	4
5 REQUIREMENTS	4
5.1 Units of Measurement	4
5.2 Statutory Requirements	4
5.3 Alternative Designs	4
5.4 Conflicting Requirements.....	4
6 BASIC DESIGN	4
6.1 General.....	4
6.2 Pressure Casings	6
6.3 Casing Connections	7
6.4 External Forces and Moments	7
6.5 Rotating Elements.....	7
6.6 Seals and Sealing Systems	8
6.7 Dynamics	8
6.8 Bearings and Bearing Housings.....	9
6.9 Lubrication	10
6.10 Materials.....	11
6.11 Nameplates and Rotation Arrows	12
6.12 Additional Requirements for Special Duty Packages.....	13
7 ACCESSORIES.....	14
7.1 Drivers	14
7.2 Couplings and Guards	15
7.3 Baseplate/Support Structure.....	15
7.4 Controls and Instrumentation.....	16
7.5 Piping	20
7.6 Intercoolers and Aftercoolers.....	21
7.7 Inlet Air Filter/Silencer.....	21
7.8 Discharge Blowoff Silence.....	22
7.9 Special Tools.....	22
7.10 Additional Requirements for “Special Duty” packages.....	22
8 INSPECTION, TESTING AND PREPARATION FOR SHIPMENT	23
8.1 General	23
8.2 Inspection	23
8.3 Testing.....	24
8.4 Preparation for Shipment	26
8.5 Additional Inspection, Testing & Preparation for Shipment Requirements for “Special Duty” Packages	26

CONTENTS

	Page
9 VENDOR DATA.....	27
9.1 General.....	27
9.2 Proposals.....	28
9.3 Contract Data	29
9.4 Additional Vendor Data Requirements for “Special Duty” Packages.....	30
ANNEX A DATA SHEETS	31
ANNEX B REFERENCED DOCUMENTS	89
ANNEX C (INFORMATION ON ROTORDYNAMIC ANALYSIS).....	91
ANNEX D VENDOR DRAWINGS AND DATA REQUIREMENTS	101
ANNEX E LUBRICATION SYSTEM SCHEMATIC	107
ANNEX F REQUIREMENT FOR DETERMINING RESIDUAL UNBALANCE	111
ANNEX G INSPECTOR’S CHECKLIST	117
ANNEX H GUIDE TO NOMENCLATURE.....	119
Figures	
C-1 Undamped Unbalanced Response Analysis.....	92
C-2	97
C-3	98
E-1	109
F-1 Residual Unbalance Worksheet	113
F-2 Sample Calculations for Residual Unbalance	115
H-1	119
Tables	
3 Equipment Monitoring	19
E-1 Lube-oil System Requirements.....	114
G-1 Inspector’s Checklist.....	117

Packaged, Integrally Geared Centrifugal Air Compressors for Petroleum, Chemical, and Gas Industry Services

0 Introduction

Users of this International Standard should be aware that further or differing requirements may be needed for individual applications. This International Standard is not intended to inhibit a vendor from offering, or the purchaser from accepting alternative equipment or engineering solutions for the individual application. This may be particularly appropriate where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this International Standard and provide details.

Annex A contains data sheets which purchasers are encouraged to use.

Annex B provides information on normative references.

Annex C specifies requirements for lateral analysis.

Annex D contains forms which may be used to indicate vendor drawing and data requirements.

Annex E contains schematic drawings of lubrication systems.

Annex F specifies requirements for determining residual unbalance.

Annex G contains an inspector's checklist.

Annex H contains an illustration of nomenclature for integrally geared centrifugal air compressors.

This International Standard requires the purchaser to specify certain details and features.

A bullet (●) at the beginning of a paragraph indicates that either a decision or further information is required. Further information should be shown on the data sheets (see example in Annex A) or stated in the quotation request and purchase order.

In this International Standard, where practical, US Customary units are included in brackets for information

1 Scope

1.1 This standard covers the minimum requirements for constant-speed, packaged, general purpose integrally geared centrifugal air compressors, including their accessories. This standard is not applicable to machines that develop a pressure rise of less than 0.35 bar (5.0 psi) above atmospheric pressure, which are classed as fans or blowers.

Note: Special Purpose and Process applications, including Process Air Services, are covered by API Std 617.

- **1.2** Equipment covered by this standard is considered non-critical, usually spared and may be either of two classifications, Basic or Special Duty. The purchaser shall specify which of the two classifications applies.

Basic packages are vendors' standard packages of proven design and include minimal additional requirements.

Special duty packages are typically specified for installations that require higher availability and include additional features and requirements.

1.3 Additional or overriding requirements applicable only to packages that have been specified as "Special Duty" are noted at the end of each section (see 6.12; 7.10; 8.5; and 9.4).

1.4 Conflicting Requirements

In case of conflict between this standard and the inquiry, the inquiry shall govern. At the time of the order, the order shall govern.

2 Normative References

2.1 Reference publications are listed in Annex B.

2.2 All referenced standards, to the extent specified in the text, are normative.

2.3 The editions of the Annex B standards, codes, and specifications that are in effect at the time of publication of this standard shall, to the extent specified herein, form a part of this standard.

The applicability of changes in standards, codes, and specifications that occur after publication of this document shall be mutually agreed upon by the purchaser and the vendor.

2.4 Notes following a paragraph are informative.

- **2.5** Where dual referencing of standards occurs, the system of standards to be used shall be specified.

2.6 Statutory Requirements: The purchaser and the vendor shall mutually determine the measures that must be taken to comply with any governmental codes, regulations, ordinances, or rules that are applicable to the equipment.

3 Definition of Terms

Terms used in this standard are defined in 3.1 – 3.36.

3.1 alarm point : A preset value of a parameter at which an alarm is actuated to warn of a condition that requires corrective action.

3.2 axially split: A joint that is parallel to the shaft centerline.

3.3 bearing housing: All bearing enclosures, including the gear casing.

3.4 critical speed: A shaft rotational speed at which the rotor-bearing-support system is in a state of resonance.

3.5 delivered flow: The flow rate determined at the compressor discharge or after the discharge of the aftercooler when included in the vendor scope.

Note: When the flow is measured before the compressor inlet, it must be adjusted for the effects of aftercooler pressure drop, compressor seal losses, and interstage condensate removal.

3.6 design: A term that may be used by the equipment manufacturer to describe various parameters such as design power, design pressure, design temperature, or design speed.

Note: This terminology should be used only by the equipment manufacturer and not in the purchaser's specifications.

3.7 gear wheel (bull gear): The low-speed rotor of a gear set.

3.8 informative element: Describes part of the standard which is provided for information and is intended to assist in the understanding or use of the standard. Compliance with an informative part of the standard is not mandatory.

Note: An Annex may be informative or normative as indicated.

3.9 inlet volume flow: The flow rate expressed in volume flow units at the conditions of pressure, temperature, compressibility and air moisture content, at the compressor inlet connection.

3.10 local: The location of a device mounted on or near the equipment or console.

3.11 material certificate of compliance: A document by which the vendor certifies that the material represented has been produced and tested in accordance with the requirements of the basic material specification shown on the certificate.

3.12 maximum allowable temperature: The maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified maximum operating pressure.

3.13 maximum allowable working pressure: The maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified maximum operating temperature.

3.14 maximum discharge pressure: The maximum suction pressure plus the maximum differential the compressor is able to develop to surge at the minimum specified inlet temperature.

3.15 maximum sealing pressure: The highest pressure the seals are required to seal during any specified static or operating condition.

3.16 normally open and normally closed: Refers both to on-the-shelf state and to installed deenergized state of devices such as automatically controlled electrical switches and valves.

Note: The normal operating state of such devices is not necessarily the same as the on-the-shelf state.

3.17 normative: A requirement of the standard.

3.18 observed: An inspection or test where the purchaser is notified of the timing of the inspection or test and the inspection or test is performed as scheduled whether or not the purchaser or his representative is present.

3.19 panel: An enclosure used to mount, display, and protect gauges, switches, and other instruments.

3.20 pinion: A high-speed rotor or rotors in a gear set.

3.21 pressure casing: The composite of all stationary pressure-containing parts of the unit, including all nozzles and other attached parts.

3.22 pressure rise to surge: The difference between the discharge pressure at the rated operating point and that at the surge point when the unit is operating at rated inlet conditions and with a constant inlet guide vane position.

3.23 radially split: A joint that is perpendicular to the shaft centerline.

3.24 rated point: The maximum specified flow rate at the specified discharge pressure when operating at the specified inlet conditions and coolant temperature. This is the point at which the vendor certifies that the performance is within the tolerances stated in this standard.

3.25 rated speed (also known as 100% speed): The highest rotational speed required to meet any of the specified operating conditions.

3.26 relief valve set pressure: The pressure at which a relief valve starts to lift.

3.27 remote: The location of a device when located away from the equipment or console, typically in a control room.

3.28 shutdown set point: A preset value of a measured parameter at which automatic or manual shutdown of the system or equipment is required.

3.29 standard volume flow: The flow rate expressed in volume flow units at the following standard conditions:

ISO Standard Conditions

Flow:	Cubic meters per hour (m ³ /h)
Pressure:	1.013 bar
Temperature:	15°C
Relative Humidity:	0% (Dry)

US Standard Conditions

Flow:	Standard cubic feet per minute (scfm) Million standard cubic feet per day (mmscfd)
Pressure:	14.7 PSI
Temperature:	60°F
Relative Humidity:	0% (Dry)

3.30 standby service: A normally idle, or idling, piece of equipment that is capable of immediate automatic or manual start-up and continuous operation.

3.31 total indicated reading (TIR), also known as total indicator runout: The difference between the maximum and minimum readings of a dial indicator or similar device, monitoring a face or cylindrical surface during one complete revolution of the monitored surface.

3.32 trip speed (revolutions per minute): The speed at which the independent emergency overspeed device operates to shut down a variable-speed prime mover. For the purpose of this standard, the trip speed of alternating current electric motors, except, variable frequency devices, is the speed (revolutions per minute) corresponding to the synchronous speed of the motor at maximum supply frequency.

3.33 unit responsibility: The responsibility for coordinating the delivery and technical aspects of the equipment and all auxiliary systems included in the scope of the order. The technical aspects to be considered include but are not limited to such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation, piping, conformation to specifications and testing of components.

3.34 vendor (also known as supplier): The agency that supplies the equipment.

Note: The vendor may be the manufacturer of the equipment or the manufacturer's agent and normally is responsible for service support.

3.35 verified: The purchaser's review and acceptance of vendor's certification or documentation of successful completion of the inspection or test.

3.36 witnessed: An inspection or test where the purchaser is notified of the timing of the inspection or test and a hold is placed on the inspection or test until the purchaser or his representative is in attendance.

Note: The purchaser may want to specify notification of a successful preliminary test prior to travel.

4 General

4.1 UNIT RESPONSIBILITY

The vendor who has unit responsibility shall assure that all subvendors comply with the requirements of this standard and all reference documents.

4.2 NOMENCLATURE

A guide to integrally-gear air compressor nomenclature can be found in Annex H.

5 Requirements

5.1 UNITS OF MEASUREMENT

The purchaser will specify whether data, drawings, hardware (including fasteners), and equipment supplied to this standard shall use the SI or US Customary system of measurements.

5.2 STATUTORY REQUIREMENTS

The purchaser and the vendor shall mutually determine the measures that must be taken to comply with any government codes, regulatory, ordinances, or rules that are applicable to the equipment.

5.3 ALTERNATIVE DESIGNS

The vendor may offer alternative designs for purchaser's consideration.

5.4 CONFLICTING REQUIREMENTS

In case of conflict between this standard and the inquiry, the inquiry shall govern. At the time of the order, the order shall govern.

6 Basic Design

6.1 GENERAL

6.1.1 Service Life

The equipment (including auxiliaries) covered by this standard shall be designed and constructed for a minimum service life of 20 years and at least 3 years of uninterrupted operation.

Note: It is recognized that these are design criteria.

6.1.2 The vendor shall assume unit responsibility for all equipment and auxiliary systems included in the scope of the order.

6.1.3 Sound Pressure Level

Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the purchaser and the vendor having unit responsibility. The equipment furnished by the vendor shall conform to the maximum allowable SPL specified. In order to determine compliance, the vendor shall provide expected maximum sound pressure level data per octave band for the equipment.

6.1.4 Packaged Equipment

Compressor package shall include:

- a. Integrally geared centrifugal air compressor
- b. Coupling and coupling guard
- c. Baseplate (or structural framework)
- d. Intercoolers and aftercooler, moisture separator and drain system
- e. Lubrication oil system
- f. Controls and instrumentation
- g. Driver
- h. Interstage air piping
- i. Inlet and discharge expansion joints
- j. Accessories as noted in this standard.

Note: Inlet piping from air inlet filter to compressor inlet control device, discharge piping between compressor package flange and discharge check valve, piping to blow-off valve, and mounting of accessory components is typically supplied by the purchaser. Piping should be designed with adequate supports to prevent undue loads on compressor flanges, including transient loads such as blow-off. The aftercooler is often shipped loose. The inlet throttle device, blow-off valve, and discharge check valve, are typically shipped loose for field installation by the purchaser

● 6.1.5 Environmental Conditions

The equipment, including all auxiliaries, shall be suitable for operation under the environmental conditions specified by the purchaser. These conditions shall include whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), maximum and minimum temperatures, unusual humidity, and dusty or corrosive conditions.

6.1.6 Cooling Water Systems

Unless otherwise specified, cooling water systems shall be designed for the following conditions:

Water Velocity over heat exchange surfaces (Note 1)	1.2 – 2.5 m/s	4 – 8 ft/s
Maximum allowable working pressure (MAWP)	≥ 7 bar (Note 2)	≥ 100 psig
Maximum pressure drop	1 bar	15 psi
Maximum inlet temperature	30°C	90°F
Maximum outlet temperature	50°C	120°F
Maximum temperature rise	20K	30°F
Minimum temperature rise	5K	10°F
Fouling factor on water side (Note 3)	0.18 m ² K /kW	0.001 hrft ² °F/Btu
Shell corrosion allowance	1.5 mm	0.0625 in.

Note: The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchanger surfaces result in conflict. The criterion for velocity over heat exchange surfaces is intended to minimize water-side fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water.

Note 2: Gauge pressure.

Note 3: Based on site coolant conditions and user experience, the purchaser may specify a different coolant-side fouling factor. For example, for a closed loop glycol system, 0.0005 hrft² °F/Btu may be adequate; conversely, for poorer quality coolant, 0.002 hrft² °F/Btu (or higher) may be required.

6.1.7 Package Arrangement

6.1.7.1 The arrangement of the package (including piping coolers, pumps, and controls) shall provide adequate clearance areas and safe access for operation and maintenance.

6.1.7.2 All equipment shall be designed to permit rapid and economical maintenance. Major parts such as casing components and bearing housings shall be designed and manufactured to ensure accurate alignment on reassembly. This may be accomplished by the use of shoulders, cylindrical dowels or keys.

6.1.7.3 Provisions shall be made for complete venting and draining of liquid-filled systems

● 6.1.8 Motors and Electrical Components

Motors, electrical components, and electrical installations shall be suitable for the area classification (class, group, and division or zone) specified by the purchaser and shall meet the requirements of the applicable sections of IEC79 or NFPA 70, Articles 500, 501, 502, and 504, as well as local codes. Local codes shall be furnished by the purchaser on request of the Vendor.

6.1.9 Performance Criteria

The equipment (compressor, driver and auxiliary equipment) shall perform on the test stand and on their permanent foundation within the specified acceptance criteria. After installation, the performance of the package shall be the joint responsibility of the purchaser and the vendor who has unit responsibility.

6.1.10 Purchaser Connections

All openings or nozzles for purchaser connections shall be DN 12 ($1/2$ NPS) or larger and shall be in accordance with ISO 6708. Sizes DN 32, DN 65, DN 90, DN 125, DN 175 and DN 225 ($1/4$, $2 1/2$, $3 1/2$, 5, 7, and 9 NPS) shall not be used.

6.1.11 Bolting

Bolting shall be furnished as specified in 6.1.11.1 – 6.1.11.4.

6.1.11.1 The details of threading shall conform to ISO 261, ISO 262, ISO 724, and ISO 966 or ASME B1.1.

6.1.11.2 Adequate clearance shall be provided at all bolting locations to permit the use of socket or box wrenches

6.1.11.3 Slotted-nut, or spanner-type bolting shall not be used unless specifically approved by the purchaser.

6.1.11.4 Manufacturer's marking shall be located on all fasteners 6 mm ($1/4$ in.) and larger (excluding washers and headless set screws). For studs, the marking shall be on the nut end of the exposed stud end.

6.1.12 Compressor Performance

6.1.12.1 The compressor total head curve shall be developed from the differential pressure measurement between the compressor inlet flange and the final-stage discharge flange.

The purchaser and vendor shall mutually agree on the pressure drop considerations for the inlet filter, aftercooler, check valves, and associated piping.

6.1.12.2 When the compressor is operating at rated operating conditions, the overall performance shall provide a minimum of 10% continuous pressure rise from rated capacity to surge.

● 6.1.13 Mounting Surfaces

When specified, mounting surfaces shall meet the following criteria:

1. They shall be machined to a finish of 6 μ m (250 μ in.) arithmetic average roughness (Ra) or better.
2. To prevent a soft foot, they shall be in the same horizontal plane within 25 μ m (0.001 in.).
3. Each mounting surface shall be machined within a flatness of 80 μ m per linear meters (0.001 in. per linear foot) of mounting surface.
4. Different mounting planes shall be parallel to each other within 50 μ m (0.002 in.).
5. The upper machined or spot faced surface shall be parallel to the mounting surface.
6. Hold-down bolt holes shall be drilled perpendicular to the mounting surface or surfaces, spot faced where necessary to accommodate fasteners and tools.

Note: Spot face is typically not necessary if surface is perpendicular to bolting within 1 degree.

6.2 PRESSURE CASINGS

6.2.1 The stress values used in the design of the casing for any material shall not exceed twenty-five percent (25%) of the ultimate stress at the maximum specified operating temperature. The vendor shall state the internationally recognized standard from which the ultimate stress value is obtained. For cast materials a factor of 0.8 for steel or 0.9 for cast and ductile iron shall be applied unless additional casting NDE is applied. The thickness of the casing shall be suitable for the maximum working and test pressure and shall include a corrosion allowance of at least 3 mm (0.125 in.).

Manufacturing data report forms, third party inspections, and stamping as specified in pressure vessel codes are not required.

6.2.2 The maximum allowable working pressure of each casing shall be at least 1.10 times the maximum discharge pressure of the stage.

6.2.3 For casing joint bolting, an allowable stress of 0.25 times the minimum ultimate tensile strength shall be used to determine the total bolting area based on hydrostatic load and gasket preload as applicable. The preload stress shall not exceed 0.75 times the bolting material minimum yield.

6.3 CASING CONNECTIONS

6.3.1 The first-stage inlet and final-stage outlet connections shall be flanged.

6.3.2 Connections welded to the casing shall meet the material requirements of the casing, including impact values, rather than the requirements of the connected piping. All welding of connections shall be completed before the casing is hydrostatically tested (see 8.3.2).

6.3.3 For connections other than main process connections, if flanged or machined and studded openings are impractical, threaded connections for pipe sizes not exceeding DN 40 (1½ NPS) may be used with purchaser's approval as follows:

- a. On non-weldable materials, such as cast iron
- b. Where essential for maintenance (disassembly and assembly).

6.3.4 Threaded openings and bosses for tapered pipe threads shall conform to ISO 7—Parts 1 and 2 or ANSI/ASME B16.5.

6.3.5 Threaded openings not required to be connected to piping shall be plugged with steel plugs in accordance with ANSI/ASME B16.11. Thread tape shall not be used.

6.3.6 Flanges shall conform to ISO 7005-1 or 7005-2 (ASME B16.1, B16.5, B16.42, or B16.47 Series B) as applicable except as specified in 6.3.6.1 and 6.3.6.2. Class 200 and 400 flanges shall not be used.

6.3.6.1 Cast iron flanges shall be flat faced and conform to the dimensional requirements of ISO 7005-2 or ANSI/ASME B16.1 or B16.42. Class 125 flanges shall have a minimum thickness equal to Class 250 for sizes DN 200 (NPS 8) and smaller.

6.3.6.2 Flat-faced flanges with full raised-face thickness are acceptable on casings of all materials. Flanges in all materials that are thicker or have a larger outside diameter than required by ISO (ANSI) are acceptable. Non-standard (oversized) flanges shall be completely dimensioned on the arrangement drawing.

6.3.7 Machined and studded connections shall conform to the facing and drilling requirements of ISO 7005-1 or 7005-2 or ASME B16.1, B16.5, B16.42, or B16.47. Studs and nuts shall be furnished installed, the first 1.5 threads at both ends of each stud shall be removed.

6.3.8 To minimize nozzle loading and facilitate installation of piping, machine flanges shall be parallel to the plane shown on the general arrangement drawing to within 0.5 degrees. Studs or bolt holes shall straddle centerlines parallel to the main axes of the equipment.

6.3.9 All of the purchaser's connections shall be accessible for disassembly without requiring the machine, or any major part of the machine, to be moved.

6.4 EXTERNAL FORCES AND MOMENTS

6.4.1 The maximum allowable forces and moments that may be imposed on the package by the purchaser's piping shall be stated in the proposal.

6.4.2 The maximum allowable forces and moments shall be shown on the outline drawing.

6.5 ROTATING ELEMENTS

6.5.1 Shafts

6.5.1.1 Shafts shall be forged or hot-rolled alloy steel and machined throughout their entire length.

6.5.1.2 The rotor shaft sensing areas to be observed by radial vibration probes shall be concentric with the bearing journals. All shaft sensing areas shall be free from stencil and scribe marks or any other surface discontinuity, such as an oil hole or keyway, for a minimum of one probe tip diameter on each side of the probe. These areas shall not be metallized, sleeved, or plated. The sensing

face finish shall be a maximum of 0.8 μm (32 $\mu\text{in.}$) Ra, preferably obtained by honing or burnishing. These areas shall be demagnetized as necessary to minimize electrical runout. The combined electrical and mechanical runout shall be measured and recorded.

6.5.1.3 Chrome plating of the shaft at the journal area is unacceptable.

6.5.1.4 All shaft keyways shall have fillet radii conforming to ISO 773 ANSI/ASME B17.1.

6.5.2 Impellers

6.5.2.1 The impeller material shall be stainless steel, of cast or milled construction.

6.5.2.2 The vendor's proposal shall describe in detail the type of impeller construction and the method of attachment to the shaft.

6.5.3 Gears

6.5.3.1 As a minimum, gearing shall be designed and manufactured to the tolerances specified in ISO 1328, Grade 5.

Note: For equivalent loading conditions gearing produced to higher quality levels will always result in longer service life and reduced bearing loads. The ISO tolerancing system has replaced the AGMA system of Quality Numbers. A practical comparison is to subtract the ISO number from 17 to arrive at the closest AGMA Quality Number.

6.5.3.2 The gear unit shall be rated in accordance with AGMA 6011 using minimum service factors of 1.4 for induction motor driven units and 1.6 for steam-turbine- and synchronous motor driven units. The rating shall be based on the driver nameplate rating.

6.5.3.3 Gear wheels and pinion hardness combinations shall be in accordance with the values recommended in AGMA 6011.

6.5.3.4 The tooth portion of pinions shall be integrally forged with their shaft.

6.5.3.5 Gear wheels shall be of forged construction and shall be assembled on the shaft with an interference fit.

6.6 SEALS AND SEALING SYSTEMS

6.6.1 Air and oil shaft seals shall be provided to achieve the following:

- a. Contain compressed air inside the compressor casings
- b. Prevent oil from entering the compressor casings and contaminating the compressed air
- c. Prevent oil from leaking out of the bearing housing into the atmosphere
- d. Prevent contamination of the oil system or compressed air by atmospheric dirt or moisture.

6.6.2 There shall be an atmospheric space between the air and oil seals.

6.6.3 The sealing system shall be furnished complete with piping, filters, instrumentation, and necessary start-up interlocks as applicable. This system, including air consumption, shall be fully described in the proposal.

6.6.4 Seal operation shall be suitable for all specified operating conditions, including suction throttling, startup, shutdown, standby, and momentary surge. The type of standby operation shall be agreed upon by the purchaser and the vendor.

6.7 DYNAMICS

6.7.1 Critical Speeds

6.7.1.1 For information on critical speeds, refer to Annex C.

6.7.1.2 Resonances of structural support systems that are within the vendor's scope of supply and that affect the rotor vibration amplitude shall not occur within the specified separation margins (see C.2.4, Annex C) unless the resonances are critically damped. The effective stiffness of the structural support shall be considered in the analysis of the dynamics of the rotor-bearing-support system.

Note: Resonances of structural support systems may adversely affect the rotor vibration amplitude.

6.7.1.3 The vendor shall determine that the drive-train (turbine, gear, motor, and the like) critical speeds (rotor lateral, system torsional, blading modes, and the like) will not excite any critical speed of the machinery being supplied and that the entire train is suitable for the rated speed and any starting-speed detent (hold-point) requirements of the train. A list of all undesirable speeds from zero to trip shall be submitted to the purchaser for his review and included in the instruction manual for his guidance (see Annex D, item 26d).

6.7.1.4 For the purposes of this standard, critical speeds and other resonant conditions of concern are those with an amplification factor (AF) equal to or greater than 6.5.

6.7.2 Lateral Analysis

The vendor's standard critical speed values that have been analytically derived and proven by testing of previously manufactured compressors of the same frame size are acceptable. A report is not required.

6.7.3 Torsional Analysis

6.7.3.1 The vendor's torsional critical speed values that have been analytically derived and proven by successful operation of previously manufactured compressor drive trains are acceptable. A report is not required.

6.7.3.2 The undamped torsional natural frequencies of the complete train shall be at least 10% above or 10% below any possible excitation frequency.

6.7.3.3 Torsional criticals at two or more times running speeds shall preferably be avoided or, in systems in which corresponding excitation frequencies occur, shall have no adverse effect. In addition to multiples of running speeds, torsional excitations that are not a function of running speeds or that are nonsynchronous in nature shall be considered in the torsional analysis when applicable and shall have no adverse effect.

6.7.3.4 When torsional resonances are calculated to fall within the margin specified in 6.7.3.2 a stress analysis shall demonstrate that the resonances have no adverse effect on the complete train. The assumptions made in this analysis regarding the magnitude of excitation and the degree of damping shall be clearly stated.

6.7.3.5 The vendor shall perform a transient torsional vibration analysis for synchronous-motor-driven units. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and the vendor.

6.7.4 Vibration and Balancing

6.7.4.1 Manufacturer's standard balancing procedure shall be used

6.7.4.2 When spare rotating elements are supplied, they shall be dynamically balanced to the same tolerances as the main rotating elements.

6.7.4.3 During the shop test of the machine, assembled with the balanced rotors, operating at its rated speed, the peak-to-peak amplitude of unfiltered vibration in any plane, measured on the shaft adjacent and relative to each radial bearing, including runout, shall not exceed the following value or 40 μm (1.5 mils), whichever is less:

In SI units:

$$A = 25.4 \times (12\,000 / N)^{1/2}$$

In customary units,

$$A = (12\,000 / N)^{1/2}$$

Where:

A = amplitude of unfiltered vibration, in μms (mil) true peak to peak.

N = rated speed, in revolutions per minute.

Note: These limits are not to be confused with the limits specified in Section C.3 of Annex C for shop verification of unbalanced response.

6.8 BEARINGS AND BEARING HOUSINGS

6.8.1 Bearings—General

6.8.1.1 Unless otherwise specified, hydrodynamic radial and thrust bearings shall be provided.

6.8.1.2 Bearings shall be designed to prevent incorrect positioning.

6.8.2 Radial Bearings

6.8.2.1 Radial bearings shall be designed for ease of assembly, precision bored and of the sleeve or pad type with babbitted replaceable liners, pads, or shells. These bearings shall be equipped with antirotation pins and shall be positively secured in the axial direction.

6.8.2.2 The bearing design shall suppress hydrodynamic instabilities and provide sufficient damping over the entire range of allowable bearing clearances to limit rotor vibration to the maximum specified amplitudes (see 6.7.4.3) while the equipment is operating loaded or unloaded at the rated operating speed.

6.8.3 Thrust Bearings

6.8.3.1 Thrust loads from impellers and gears and couplings shall be absorbed by individual thrust bearings on pinions, or transmitted to the gear wheel thrust bearing by means of thrust rider rings fixed to the pinions and gear wheel. All specified operating conditions and start up conditions shall be evaluated for resulting thrust loads.

6.8.3.2 Thrust bearings shall be selected using manufacturer's standard criteria.

Note: In sizing thrust bearings, consideration should be given to the following for each specific application:

- a. The shaft speed
- b. The temperature of the bearing babbitt
- c. The deflection of the bearing pad
- d. The minimum oil-film thickness
- e. The feed rate, viscosity, and supply temperature of the oil
- f. The design configuration of the bearing
- g. The babbitt alloy
- h. The turbulence of the oil-film.

6.8.3.3 Thrust forces from flexible-element couplings shall be calculated on the basis of the maximum allowable deflection permitted by the coupling manufacturer.

6.8.3.4 If two or more rotor thrust forces are to be carried by one thrust bearing, the resultant of the forces shall be used provided the directions of the forces make them numerically additive; otherwise, the largest of the forces shall be used.

6.8.3.5 Thrust bearings shall be babbitted, and arranged for continuous pressurized lubrication. Integral thrust collars are preferred. When replaceable collars are furnished (for assembly and maintenance purposes), they shall be positively locked to the shaft to prevent fretting.

6.8.3.6 The faces of the thrust collar or rider rings shall have a surface finish of not more than 0.4 μm (16 $\mu\text{in.}$) Ra, and the axial total indicator runout of either face shall not exceed 12 μm (500 $\mu\text{in.}$).

6.8.4 Bearing Housings

6.8.4.1 Bearing Housings shall be arranged so that bearings can be replaced without disturbing equipment driver or mounting.

Note: May require removal of gear housing cover.

6.8.4.2 Bearing housings shall be arranged to minimize foaming. The drain system shall be adequate to maintain the oil and foam level below shaft end seals. The bearings shall be designed not to exceed 30°C (50°F) oil temperature rise and an outlet temperature of 80°C (180°F).

Note: This is a design criteria. Bearing exit temperature is not measured in actual machines.

6.8.4.3 Bearing housings shall be equipped with replaceable labyrinth-type end seals and deflectors where the shaft passes through the housing; lip-type seals shall not be used. The seals and deflectors shall be made of nonsparking materials. The design of the seals and deflectors shall effectively retain oil in the housing and prevent entry of foreign material into the housing.

6.9 LUBRICATION

6.9.1 Unless otherwise specified, bearings and bearing housings shall be arranged for oil lubrication using a mineral oil in accordance with ISO 3448.

6.9.2 A pressurized oil system shall be supplied in accordance with ISO 10438 Part 3 or API Std 614 Chapter 3 except as noted in 6.9.3 – 6.9.4. (See Annex E, Figure E-1 and Table E-1 for a schematic of the minimum system and the various options applicable.)

6.9.3 Lube oil shall be supplied at the required pressure or pressures, as applicable, to the following:

- a. The bearings of the integrally geared compressor
- b. The spray nozzles for the gear teeth
- c. The bearings of the driver when specified or required.

6.9.4 The oil reservoir shall be fabricated carbon steel construction with an oil-compatible corrosion resistant internal coating.

6.10 MATERIALS

6.10.1 General

6.10.1.1 Materials of construction shall be the manufacturer's standard for the specified operating conditions, except as required or prohibited by this standard.

6.10.1.2 The materials of construction of all major components shall be clearly stated in the vendor's proposal. Materials shall be identified by reference to applicable international standards, including the material grade. When no such designation is available, the vendor's material specification giving physical properties, chemical composition, and test requirements shall be included in the proposal.

6.10.1.3 External parts that are subject to rotary or sliding motions (such as control linkage joints and adjusting mechanisms) shall be of corrosion-resistant materials suitable for the site environment and of sufficient hardness to resist wear.

6.10.1.4 Minor parts such as nuts, springs, washers, gaskets, and keys shall have corrosion resistance at least equal to that of specified parts in the same environment.

6.10.1.5 If austenitic stainless steel parts exposed to conditions that promote intergranular corrosion are to be fabricated, hard faced, overlaid, or repaired by welding, they shall be made of low-carbon or stabilized grades.

Note: Overlays or hard surfaces that contain more than 0.10% carbon can sensitize both low-carbon and stabilized grades of austenitic stainless steel unless a buffer layer that is not sensitive to intergranular corrosion is applied.

6.10.1.6 The vendor shall select materials to avoid conditions that may result in electrolytic corrosion. Where such conditions cannot be avoided, the purchaser and the vendor shall agree on the material selection and any other precautions necessary.

Note: When dissimilar materials with significantly different electrical potentials are placed in contact in the presence of an electrolytic solution, galvanic couples that can result in serious corrosion of the less noble material may be created. The NACE Corrosion Engineer's Reference Book is one resource for selection of suitable materials in these situations.

6.10.2 Low-carbon steels can be notch sensitive and susceptible to brittle fracture at ambient or lower temperatures. Therefore, only fully killed, normalized steels made to fine-grain practice are acceptable. The use of steel made to a coarse austenitic grain size practice (such as ASTM A515) is prohibited.

6.10.3 Castings

6.10.3.1 Pressure containing ferrous castings shall not be repaired except as specified in 6.10.2.1.1 – 6.10.2.1.3.

6.10.3.1.1 Weldable grades of steel castings, may be repaired by welding, using a qualified welding procedure based on the requirements of an internationally recognized pressure vessel welding standard. After major weld repairs, and before hydrotest, the complete repaired casting shall be given a postweld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal and dimensional stability during subsequent machining operations.

6.10.3.1.2 Cast gray iron or nodular iron may be repaired by plugging within the limits specified in ASTM A 278, A 395, or A 536. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed.

6.10.3.1.3 All repairs not covered by the applicable international material specification shall be subject to the purchaser's approval.

6.10.3.1.4 Fully enclosed cored voids, which become fully closed by methods such as plugging, welding, or assembly, are prohibited.

6.10.3.1.5 Nodular iron castings shall be produced in accordance with an internationally recognized standard such as ASTM A 395, or A 536.

6.10.4 Welding

6.10.4.1 Welding of piping and pressure-containing parts, as well as any dissimilar-metal welds and weld repairs, shall be performed and inspected by operators and procedures qualified in accordance with internationally recognized welding standards such as Section VIII, Division 1, and Section IX of the ASME Code or purchaser-approved standard, such as EN 287 or EN 288. No weld repairs are permitted after final machining.

6.10.4.2 The vendor shall be responsible for the review of all repairs and repair welds to ensure that they are properly heat treated and nondestructively examined for soundness and compliance with the applicable qualified procedures. Repair welds shall be nondestructively tested by the same method used to detect the original flaw.

- **6.10.4.3** When specified, documentation of major defects shall be submitted to the purchaser prior to any repairs being conducted at the manufacturer's shop and shall include the following

- a. Extent of the repair
- b. Location
- c. Size
- d. Welding procedure specification
- e. Detailed photographs of the defect prior to any preparatory work and after preparation but prior to the actual repair. If the location of the defect cannot be clearly defined by photographic means, the location shall be indicated on a sketch or drawing of the affected component.

6.10.4.4 Repairs performed at the manufacturer's shop shall be considered major if any of the following conditions apply:

- a. Castings leak during hydrostatic testing
- b. The depth of the repair cavity prepared for welding exceeds 50% of the wall thickness or 25 mm (1 in.), whichever is smaller
- c. The surface area of all repairs to the part exceeds 10% of the surface area of the part
- d. The repair cavity is longer than 150 mm (6 in.) in any direction
- e. Repairs are to any rotating components.

6.10.4.5 Unless otherwise specified, other welding, such as welding on baseplates, non-pressure ducting, lagging, and control panels, shall be performed by welders qualified in accordance with an appropriate internationally recognized structural welding standard such as AWS D1.1.

6.10.4.6 Connections welded to pressure casings shall be installed as specified in 6.10.3.6.1 and 6.10.3.6.2.

6.10.4.6.1 Post-weld heat treatment, when required, shall be carried out after all welds, including piping welds have been completed.

6.10.4.6.2 Unless exempted by the applicable pressure vessel code, all welds shall be heat treated in accordance with internationally recognized standards such as Section VIII, Division 1, Sections UW-10 and UW-40, of the ASME Code.

6.10.5 Low Temperature

The Vendor shall define the minimum design metal temperature (MDMT) of the equipment. If the minimum site ambient temperature is below the equipment MDMT, the Vendor and the purchaser shall agree and implement measures to assure that the equipment will not be operated with pressure casing at a metal temperature below the MDMT, to avoid brittle failures.

6.11 NAMEPLATES AND ROTATION ARROWS

6.11.1 A nameplate shall be securely attached at a readily visible location on the equipment and on any major piece of auxiliary equipment.

6.11.2 Rotation arrows shall be cast in or attached to each major item of rotating equipment at a readily visible location.

6.11.3 Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or nickel-copper alloy such as UNS N04400 alloy. Attachment pins shall be of the same material. Welding is not permitted.

6.11.4 As a minimum, the following data shall be clearly stamped or engraved on the compressor nameplate:

- a. Vendor's name
- b. Serial number
- c. Size, model and type
- d. Rated capacity

- e. Rated discharge pressure
- f. purchaser's item number.

Units shall be consistent with those used on the data sheets.

6.12 ADDITIONAL REQUIREMENTS FOR SPECIAL DUTY PACKAGES

6.12.1 Jackscrews, guide rods, cylindrical casing-alignment dowels, and/or other appropriate devices shall be provided to facilitate disassembly and reassembly. Guide rods shall be of sufficient length to prevent damage to the internals or casing studs by the casing during disassembly and reassembly. Lifting lugs or eyebolts shall be provided for lifting only the top half of the gear casing.

When jackscrews are used as a means of parting contacting faces, one of the faces shall be relieved (counterbored or recessed) to prevent a leaking joint or improper fit caused by marring of the face.

6.12.2 Gearing shall be designed and manufactured to the tolerances specified in ISO 1328-2, Grade 4.

- **6.12.3** When specified, the vendor shall provide a damped unbalanced response analysis for each machine to assure acceptable amplitudes of vibration at any speed from zero to trip.
- **6.12.4** When specified, a damped unbalanced response analysis shall be conducted and confirmed by test stand data in accordance with Annex C.
- **6.12.5** When specified, the vendor shall perform a torsional vibration analysis of the complete coupled train and shall be responsible for directing the modifications necessary to meet the requirements of 6.7.3.2 – 6.7.3.5.

Note: Excitations of undamped torsional natural frequencies may come from many sources, which should be considered in the analysis. These sources may include but are not limited to the following:

- a. Gear phenomena such as unbalance and pitch line runout
- b. Startup conditions such as speed detents and other torsional oscillations
- c. Torsional transients such as start-ups of synchronous electric motors and transients due to generator phase-to-phase fault or phase-to-ground fault
- d. Torsional excitation resulting from drivers
- e. One and two times line frequency
- f. Running speeds.

6.12.6 Major parts of the rotating elements, such as the shaft and impellers, shall be dynamically balanced. When a bare shaft with a single keyway is dynamically balanced, the keyway shall be filled with a fully crowned half-key, in accordance with ISO 8821. A shaft with keyways 180 degrees apart but not in the same transverse plane shall also be filled. The initial balance correction to the bare shaft shall be recorded.

6.12.7 The rotating elements shall be multiplane dynamically balanced during assembly. This shall be accomplished after the addition of each major component. Balancing correction shall be applied only to the elements added. Balancing of impellers by welding is prohibited. Minor correction of other components may be required during the final trim balancing of the completely assembled element. In the sequential balancing process, any half-keys used in the balancing of the bare shaft (see 6.12.6) shall continue to be used until they are replaced with the final key and mating element. On rotors with single keyways, the keyway shall be filled with a fully crowned half-key. The weight of all half-keys used during final balancing of the assembled element shall be recorded on the residual unbalance work sheet (see Annex F). The maximum allowable residual unbalance per plane (journal) shall be calculated as follows:

In SI units:

$$U_{\max} = 6350W/N \text{ for } N < 25,000 \text{ rpm} \quad (2a)$$

$$U_{\max} = 6350W/25,000 \text{ for } N > 25,000 \text{ rpm} \quad (2b)$$

In customary units:

$$U_{\max} = 4W/N \text{ for } N < 25,000 \text{ rpm}$$

$$U_{\max} = 4W/25,000 \text{ for } N > 25,000 \text{ rpm}$$

Where:

$U_{\max}$ = residual unbalance, in gram-mm (ounce-in.).

W = journal static weight load, in kg (lbs.).

N = rated speed, in revolutions per minute (rpm).

Note: Balance tolerance above 25,000 rpm is based on an eccentricity of 0.25 μm (10 $\mu\text{in.}$) for each journal static weight load. Unbalance readings are measured at each journal-bearing position with no compensation to actual balance planes.

- **6.12.8** When specified, after the final balancing of each assembled rotating element has been completed, a residual unbalance check shall be performed and recorded in accordance with the residual unbalance work sheet (see Annex F).
- 6.12.9** Thrust bearings shall be selected such that under any operating condition the load does not exceed 50% of the bearing manufacturer's ultimate load rating. The ultimate load rating is the load that will produce the minimum acceptable oil-film thickness without inducing failure during continuous service or the load that will not exceed the creep-initiation or yield strength of the babbitt at the location of maximum temperature on the pad, whichever is less.
- **6.12.10** When specified, thrust bearings and radial bearings shall be fitted with bearing-metal temperature sensors.
- **6.12.11** When specified, installation of bearing-metal temperature sensors shall be in accordance with API Std 670.
- **6.12.12** When specified, oil cooler tubes shall have a 13 mm (0.5 in.) minimum outside diameter and be made of inhibited admiralty with an average wall thickness of 18 BWG.
- **6.12.13** When specified, an austenitic stainless steel oil reservoir shall be supplied.

7 Accessories

7.1 DRIVERS

7.1.1 General

7.1.1.1 The driver shall be of the type specified, shall be sized to meet the maximum specified operating conditions, including gear and coupling losses, and shall be in accordance with applicable specifications as stated in the inquiry and order. The driver shall be suitable for satisfactory operation under the utility and site conditions specified in the inquiry.

7.1.1.2 The driver, in combination with the controls provided, shall be sized to accept any specified process variations such as changes in the pressure, temperature, relative humidity of the air, cooling water temperature, and plant start-up conditions.

7.1.1.3 The driver shall be capable of starting under the conditions specified and the starting method shall be agreed by the purchaser and the vendor.

7.1.1.4 The driver nameplate rating (exclusive of the service factor) shall be at least 110% of the power required at the rated point.

- **7.1.1.5** When specified, the driver nameplate rating (exclusive of the service factor) shall be at least 110% of the maximum power required for all of the specified operating conditions.

7.1.1.6 For drivers that weigh more than 225 kg (500 lbs), the driver feet shall be provided with vertical jackscrews. Alternatively, a hydraulic jack may be proposed as a special tool.

7.1.2 Electric Motors

7.1.2.1 Unless otherwise specified, motor drives shall conform to internationally recognized standards such as API Std 541, 546, or IEEE 841 as applicable.

7.1.2.2 The motor's starting-torque requirements shall be met at a specified reduced voltage, and the motor shall accelerate to full speed within a period of time agreed upon by the purchaser and the vendor.

Note: Industry standards typically specify 90% voltage for starting, but for many plants the starting voltage may be 80% of the normal voltage. The time required to accelerate to full speed is generally less than 15 sec.

7.1.3 Steam Turbines

7.1.3.1 Unless otherwise specified, steam turbine drivers shall conform to ISO 10436. For purposes of this standard, API Std 611 is considered equivalent to ISO 10436.

- **7.1.3.2** The steam turbine shall be equipped with a NEMA Class D constant speed governor as specified in NEMA SM 23. The purchaser will specify whether the governor is to be hydraulic or electronic.

7.2 COUPLINGS AND GUARDS

7.2.1 Couplings

Couplings between drivers and driven equipment shall be supplied by the manufacturer of the driven equipment and shall meet the requirements of 7.2.1.1 – 7.2.1.7.

7.2.1.1 The coupling shall be of the forged-steel, nonlubricated, flexible-element spacer type. The flexible elements shall be stainless steel or suitably coated to prevent corrosion. The purchaser and the vendor shall mutually agree upon the make, model, type, and mounting arrangement of the coupling.

7.2.1.2 The coupling spacer shall be of sufficient length to allow maintenance of the compressor, including shaft alignment, without requiring the compressor or driver to be removed.

7.2.1.3 Coupling hubs shall be keyed to the shaft. Keys and keyways and their tolerances shall conform to ISO R773, normal fit or ANSI/AGMA 9002, Commercial Class.

7.2.1.4 Flexible couplings with cylindrical bores shall be mounted with an interference fit. Cylindrical shafts shall comply with ISO R775 or ANSI/AGMA 9002 and the coupling hubs shall be bored to the following ISO 286-2 tolerances:

- a. For shafts of 50 mm (2 in.) diameter and smaller — Grade N7.
- b. For shafts larger than 50 mm (2 in.) diameter — Grade N8.

7.2.1.5 When the coupling hubs must be removed for maintenance, they shall be furnished with tapped puller holes of at least 10 mm (0.375 in.) diameter.

7.2.1.6 The maximum coupling operating torque load shall be limited to 80% of the manufacturer's published continuous rating. Couplings bored larger than the manufacturer's nominal rating shall be subject to the purchaser's approval.

7.2.1.7 The coupling-to-shaft juncture shall be designed and manufactured to be capable of transmitting power at least equal to the power rating of the coupling.

7.2.2 Coupling Guards

7.2.2.1 Coupling guards shall be provided and shall sufficiently enclose the coupling and the shafts to prevent any personnel from contacting parts during operation of the equipment train.

7.2.2.2 Guards shall be constructed with sufficient rigidity to withstand a 900 N (200 lb.) static point load (or force) in any direction without the guard contacting moving parts.

7.2.2.3 Guards shall preferably be fabricated from solid sheet or plate with no openings. Guards fabricated from expanded metal or perforated sheets are acceptable, provided the size of the openings does not exceed 10 mm (0.375 in.) diameter. Unless otherwise specified, guards may be constructed of either metallic or nonmetallic materials. Guards of woven wire shall not be used.

7.2.2.4 The guard shall be designed to prevent drawing oil out of adjacent bearing housings.

7.3 BASEPLATE/SUPPORT STRUCTURE

7.3.1 Unless otherwise agreed, the compressor and all other machine components shall be supported on a rigid steel frame. The frame may have full-length structural members in contact with the foundation, or it may have support feet. The term baseplate shall refer to either design.

Note: Some units are now designed with the unit's base integrally cast with the gearbox, and with the driver either flange-mounted or foot-mounted or on tubular rails. For this type equipment, the purchaser and manufacturer will need to review the applicability of 7.3.2 – 7.3.6 and 7.3.9 – 7.3.10.

7.3.2 A baseplate shall be a single fabricated steel unit, unless the purchaser and the vendor mutually agree that it may be fabricated in multiple sections. Multiple-section baseplates shall have machined and doweled mating surfaces which shall be bolted together to ensure accurate field reassembly.

7.3.3 The baseplate shall have major load-bearing members under the mounting surfaces of the major components. The structure shall be provided with lifting lugs for at least a four-point lift. Lifting the baseplate complete with all equipment mounted shall not permanently distort or otherwise damage the baseplate or the mounted equipment.

7.3.4 The bottom of the baseplate between structural members shall be open. When the baseplate is installed on a concrete foundation, accessibility shall be provided for grouting under all load-carrying structural members.

7.3.5 Mounting surfaces shall be provided for the integrally geared compressor and all drive train components. The mounting surfaces shall be at least 25 mm (1 in.) larger than the foot of the mounted equipment to allow leveling of the baseplate without removal of the equipment. The surfaces shall:

- a. be machined after the baseplate is fabricated;
- b. have corresponding pads in the same horizontal plane within 25 μm (0.001 in.);
- c. have each mounting surface machined within a flatness of 80 μm per linear meter (0.001 in. per linear ft) of mounting surface;
- d. have different mounting planes parallel to each other within 400 μm per m (0.005 in. per ft). This requirement shall be met by supporting and clamping the baseplate at the foundation bolt holes only.

7.3.6 The baseplate shall be drilled only for drivers that are shop fitted. The baseplates shall be supplied with leveling screws. Baseplates that are to be grouted shall have 50-mm-radius (2-in.-radius) outside corners (in the plan view). Mounting surfaces that are not to be grouted shall be coated with a rust preventive immediately after machining.

Note: UngROUTED installation is common for this equipment and some baseframe designs REQUIRE that one end of the support structure is left free to expand with thermal growth.

7.3.7 Anchor bolt holes shall be drilled perpendicular to the mounting surfaces.

7.3.8 Anchor bolts will be furnished by the purchaser.

7.3.9 Driver support mounting surfaces shall be machined to allow the installation of vendor supplied austenitic stainless steel, precut, full bearing shim packs, 3 mm – 6 mm (0.125 in. – 0.250 in.) thick with no more than 5 shims in the pack between the driver and each mounting surface. Laminated shims are not acceptable. Shims shall be slotted so they can be installed and removed without removing the fasteners.

7.3.10 When the supported driver weighs more than 225 kg (500 lbs), the driver mounting plates shall be furnished with axial and lateral jackscrews the same size as or larger than the vertical jackscrews. The lugs holding these jackscrews shall be attached to the mounting plates so that the lugs do not interfere with the installation or removal of the equipment, jackscrews, or shims. If the equipment is too heavy to use jackscrews, other means shall be provided.

Note: The integral gearbox is the fixed point, and adjustments are made on the driver.

7.3.11 The underside mounting surfaces of the baseplate shall be in one plane to permit use of a single-level foundation.

7.4 CONTROLS AND INSTRUMENTATION

7.4.1 General

7.4.1.1 Unless otherwise specified, controls and instrumentation shall be in accordance with ISO 10438 Part 1 or API Std 614, Ch. 1, Section 6, except as noted below:

7.4.1.2 Unless otherwise specified, controls and instrumentation shall be designed for outdoor installation and shall meet the requirements of IP65 as detailed in IEC 79 (NEMA 4X, as detailed in NEMA Publication 250).

7.4.1.3 Unless otherwise specified, a microprocessor based control and instrumentation system shall be provided.

- **7.4.1.4** When specified, the microprocessor shall be capable of communicating with the purchaser's distributed control system (DCS).

Note: The purchaser should advise the communication protocol to be used.

7.4.1.5 All conduit, armored cable and supports shall be designed and installed so that it can be easily removed without damage and shall be located so that it does not hamper removal of bearings, seals, or equipment internals.

7.4.1.6 Neither piping without breakout points nor rigid conduit shall be routed over the cases of horizontally split rotating machinery and they shall not be routed over or in front of removable heads on vessels and exchangers, or where the piping impairs the functionality of inspection openings or panel doors.

7.4.2 Control Systems

- **7.4.2.1** The purchaser will specify which of the following compressor capacity control modes shall be furnished by the vendor:
 - a. Capacity modulation (inlet throttle device or variable inlet guide vanes) used when constant discharge pressure to surge is required and when the system air demand is relatively constant
 - b. Automatic dual control-capacity modulation plus intermittent (load-unload) mode control for smaller air demand
 - c. An automatic start and automatic stop control.

7.4.2.2 When more than one mode is specified, a means to change to any mode shall be supplied. If multiple compressors are to be operated in parallel, the control system proposed shall include all the necessary controls to permit the operation of all compressors on the same control mode or individual units on separate control modes.

7.4.2.3 A compressor surge recognition and protection system shall be furnished.

Note: Typically an on/off blow-off valve is provided, and is controlled by monitoring motor amps or fluctuation in discharge pressure.

7.4.2.4 An automatic driver-overload control system shall be included to permit continuous operation at minimum ambient air and water temperatures without exceeding the nameplate rating (excluding service factor, if any).

7.4.2.5 Manual override at the control panel shall be provided to allow manual operation of the inlet throttle device and discharge blowoff valve. The system shall provide bumpless transfer from manual to automatic for smooth mode transfer. The surge protection system shall remain in effect even when the manual override is active.

7.4.2.6 To reduce driver load during startup of a motor-driven compressor, automatic unloading of the compressor by closing the inlet throttle device and opening the discharge blowoff valve shall be provided by the vendor. (An auxiliary source of control air or nitrogen may be required for initial startup.)

7.4.2.6.1 The control system shall provide a “soft” shutdown (or unloaded condition) in which the inlet valve is closed and the unloading valve is opened prior to terminating the power source to the driver except for an emergency stop. This feature allows for less severe surging when stopping the unit.

7.4.2.6.2 The control system shall also provide warning to the operator that a hot-start condition exists for the motor driver because the unit was shut down and an adequate cool-down time period has not occurred for restart of the driver.

7.4.3 Instrument and Control Panels

7.4.3.1 A panel from which startup and shutdown can be accomplished shall be provided and shall include the following:

- a. Components for control systems as defined in 7.4.2.1, exclusive of the inlet throttle device or variable inlet guide vanes and discharge blowoff valve
- b. A control mode selector (see 7.4.2.2)
- c. Manual override and adjustment of control valves (see 7.4.2.5)
- d. Digital-readout pressure measurements
- e. Digital-readout temperature measurements
- f. A display for annunciation (see 7.4.5.2)
- g. Control devices for alarms and shutdowns
- h. An alarm indication and reset push button.
- i. The capability for starting and stopping the package from the control panel
- j. Vibration measurement and readout instruments (see 7.4.4.5)
- k. Self-diagnostics to check that the microprocessor and all instruments are functioning properly
- l. Logging of the compressor’s cumulative operating time
- m. Logging of the total number of compressor starts
- n. On/off switch for panel power
- o. On/auto/standby switch for auxiliary oil pump

- p. Auxiliary pump running indicator
- q. Lubrication oil heater status indicator.

7.4.3.2 The panel shall be fully enclosed. The panel enclosure shall have a display visible in darkness or direct sunlight, and shall be mounted on the package baseplate. If required to meet the area classification, purging shall be provided in accordance with NFPA 496. The panel shall include the following:

- a. Shielding of the devices in the panel for protection from 5 watts radio-frequency (RF) interference at 1 m (3 ft) using commercial frequency bandwidths
- b. Cooling for devices within the panel if the temperature inside the panel exceeds the electronic hardware temperature rating

Note: typically of concern for ambient conditions above 38°C (100°F)

- c. An interior panel heater for units when required by the ambient condition
- d. Driver, instrumentation, and control power separated in the same cabinet
- e. Sun screen/shade for control panel display for outdoor installations without a roof.

7.4.4 Instrumentation

7.4.4.1 Unless otherwise specified, signals may be generated from transmitters, transducers or switches.

7.4.4.2 Thermowells

7.4.4.2.1 Temperature sensing elements that are located in pressurized or flooded lines shall have DN 12 (NPS $\frac{1}{2}$) minimum thermowells made of austenitic stainless steel.

- **7.4.4.2.2** When specified, thermowells shall be at least DN 19 (NPS $\frac{3}{4}$).

7.4.4.3 Thermocouples and Resistance Temperature Detectors

Thermocouples and Resistance Temperature Detectors shall meet requirements of ISO 10438 Part 1 or API Std 614, Fourth Edition, Ch. 1, 6.4.4.

7.4.4.4 Pressure Indication

Unless otherwise specified, pressure indications shall be on the local panel display screen. When pressure gauges are specified, they shall be in accordance with API Std 614, Ch. 1, 6.4.5.2.

7.4.4.5 Vibration and Position Detectors

7.4.4.5.1 Each bearing adjacent to an impeller shall be provided with a vibration-monitoring system consisting of the following:

- a. single, radially oriented, noncontacting shaft vibration sensing probe;
- b. an oscillator-demodulator; and
- c. a readout instrument.

7.4.4.5.2 The vendor shall include with his proposal a statement listing whether phase angle probe and both x and y radial probes can be mounted adjacent to each impeller shaft. Where possible, casings shall have tapped and plugged holes for mounting a second vibration probe at 90° from the original probe. Angular orientation of probe mounting holes shall be the same for both ends of each pinion. Unless otherwise specified, these devices are monitored by the compressor control system.

Note: The vibration monitoring system supplied as standard is substantially different from an API Std 670 standard system and may not interface with other user systems.

7.4.4.6 Solenoid Valves

Solenoid valves shall meet requirements of API Std 614, Ch. 1, 6.4.7.

7.4.4.7 Pressure Limiting Valves

Pressure Limiting valves shall meet requirements of API Std 614, Ch. 1, 6.4.8.

7.4.4.8 Flow indicators

Where practical, flow indicators shall be furnished in the atmospheric oil-drain return lines.

Note: Flow indicators are not feasible from individual compressor bearing drains, and sometimes not from the gear casing drain.

7.4.5 Alarms and Shutdowns

● 7.4.5.1 General

Switches, sensors, control devices, and annunciation function shall be furnished as specified by purchaser and mounted by the vendor and shall include those listed in Table 3 as a minimum. The alarm setting shall precede the shutdown setting. Program logic shall distinguish between a shutdown device and alarm device such that failure of a shutdown device will not allow operation of the compressor until the device problem is corrected; whereas, failure of an alarm device will cause an alarm condition but will allow continued operation of the compressor.

Table 3—Equipment Monitoring

Condition	Alarm	Shutdown
High vibration of compressor	X	X
High last-stage air temperature (inlet)	X	X
Low lube-oil pressure	X	X
High oil-supply temperature	X	X
High oil filter differential pressure	X	
Low sealing-system pressure ^a	X	
Operation of the standby oil pump	X	
Low-lube level in reservoir ^b	X	
High inlet-air filter differential pressure	X	
High vibration of driver ^c	X	
Panel purge ^d	X	
Surge recognition	X	
Permissive start contact ^e	X	

Notes:

^a If applicable

^b With oil heater cutout

^c If specified

^d If required

^e Separate pilot-light indication

7.4.5.2 Annunciator

The vendor shall furnish first-out annunciation either as a separate device or as a function contained within the control system, e.g., a section of the PLC or microprocessor used for control of the compressor. If a separate annunciator is utilized, the annunciator shall contain approximately 25% spare points, and connections shall be provided for actuation of a remote signal when any function alarms or trips. The sequence of operation shall be as specified in 7.4.5.2.1 – 7.4.5.2.5.

7.4.5.2.1 The alarm condition shall be acknowledged by operating an alarm-silencing button via the keypad or a switch common to all alarm functions.

- **7.4.5.2.2** When specified, alarm indication shall consist of a flashing or rotating beacon, or equivalent, and the sounding of an audible device.

7.4.5.2.3 When the alarm is acknowledged, the flashing display or alarm shall change to steady display of alarm. The annunciator shall be capable of indicating a new alarm (with a flashing display) if another function reaches an alarm condition, even if the previous alarm condition has been acknowledged but still exists.

7.4.5.2.4 Alarm and shutdown set points shall have default values set by the vendor. These values shall be field configurable with a user-defined password or key.

7.4.5.2.5 Connections shall be provided for a common remote alarm and a common remote shutdown indication.

Note: typically this would be in the form of a relay dry (unpowered) contact.

7.4.5.3 Alarm and Shutdown Devices

7.4.5.3.1 Unless otherwise specified, the alarm and shutdown device shall utilize a single instrument located to facilitate inspection and maintenance. Where switches are specified, refer to API Std 614, Fourth Edition, Ch. 1, 6.3.4, for requirements. Mercury switches shall not be used.

7.4.5.3.2 Unless otherwise specified, contacts shall be configured to open (deenergize) to initiate alarms and shutdowns.

Note: Contacts that open (deenergize) are normally considered to be fail safe.

7.4.5.3.3 Where switches are provided, alarm and shutdown settings shall not be adjustable from outside the housing.

7.4.5.3.4 Unless otherwise specified, shutdown systems shall be provided with switches or another suitable means to permit testing without shutting down the unit.

- **7.4.5.3.5** When specified, alarm and shutdown instruments shall be arranged to permit testing of the control circuit, including when possible the actuating element, without interfering with normal operation of the equipment. The vendor shall provide a clearly visible light on the panel to indicate when shutdown circuits are in a test bypass mode.

7.4.5.3.6 The vendor shall furnish with the proposal a complete description of the alarm and shutdown facilities to be provided.

7.4.6 Electrical Systems

7.4.6.1 Electrical Systems shall meet requirements of ISO 10438, Part 1 or API Std 614, Ch. 1, Section 6.5, except as modified below.

7.4.6.2 Electrical starting and supervisory controls may be either AC or DC.

7.4.6.3 To guard against accidental contact, enclosures shall be provided for all terminal strips, relays, switches and other energized parts. Electrical power wiring shall be segregated from instrument and control signal wiring both externally and, as far as possible, inside enclosures. Inside enclosures which may be required to be opened with the equipment in operation, for example, for alarm testing or adjustment, shall be provided with secondary shields or covers for all terminal strips and other exposed parts carrying electrical potential in excess of 50 volts. Maintenance access space shall be provided around or adjacent to electrical equipment or in accordance with the appropriate code such as the National Electrical Code, Article 110.

Note: The 50 volt components inside a panel are meant to be in a secondary enclosure.

7.4.6.4 No terminal blocks shall be located in wire-ways. The terminals shall be straight-through compression type with shrouded screws (dead front) and center tapping for test purposes. Terminal block connections shall be single level (not tiered). The panel shall contain two bare soft copper grounding connections. One shall be used for a signal ground, the other an equipment ground bus. The instrument case shall not be grounded through the steel of the panel.

7.4.6.5 Control, instrumentation, and power wiring, that is not within a fully enclosed panel or other enclosure, shall be in the form of armored cable or shall be run in metal conduit as specified. Cables shall be supported on cable trays. Conduit shall be properly supported to avoid damage caused by vibration and isolated and shielded to prevent interference between different services. Conduits may terminate (in the case of the leads to temperature elements, shall terminate) with a length of flexible metal conduit, long enough to facilitate maintenance without removal of the conduit.

7.4.6.6 Internal vibration probe or thermocouple leads exposed to lube-oil turbulence shall be sufficiently anchored to prevent fatigue failures due to excessive movement.

7.5 PIPING

7.5.1 General

7.5.1.1 Piping shall meet requirements of ISO 10438, Part 1 or API Std 614, Ch. 1, Section 5 except as specifically modified below:

- **7.5.1.2** When specified, a manifolded cooling water piping system shall terminate with flanged single-supply and single-return connections at the edge of the package. It is not necessary to provide flanged connections for tubing systems.

7.5.1.3 The minimum requirement for piping material shall be as specified by ISO 10438, Part 1 or API Std 614 Ch. 1 Tables 1A, 1B, 1C, and 1D except as allowed below including 7.5.2.

7.5.1.4 Special pipe fittings in air, water or atmospheric oil service may be acceptable with purchaser approval.

Note: Such fittings facilitate maintenance and allow for misalignment of close-coupled systems.

7.5.1.5 Sealwelding of galvanized pipe as noted in ISO 10438, Part 1 or API Std 614 4th Edition, Ch. 1, Table 1-C, is not allowed.

7.5.1.6 Steel flanges mating with iron compressor flanges shall be flat faced.

7.5.1.7 Butterfly valves are acceptable for water balance valves DN 80 (NPS 3) and larger and for inlet air throttling valves. They shall not be used for other services unless approved by the purchaser.

7.5.1.8 Gaskets and packing for flanges, valves, and other components shall not contain asbestos.

7.5.2 Oil Piping

7.5.2.1 Oil piping, tubing, and fittings downstream of filters (excluding slip-on flanges), shall be stainless steel (see ISO 10438, Part 1 or API Std 614 Table 1-D).

7.5.2.2 Oil drains shall be sized to run no more than half full and shall be arranged or sloped to ensure good drainage using manufacturer's proven practices.

7.5.2.3 Pipe joints downstream of the oil filter (filter to supply points) shall be butt-welded. Piping joints in return lines and upstream of the filter (reservoir to filter) may be socket welded. Threaded connections shall be used for instrument connections and where tubing is used.

7.5.3 Instrument Piping

Instrument piping shall meet requirements of ISO 10438, Part 1 or API Std 614, Ch. 1, 5.3, except bleeder valves are required between instruments and their isolating valves. Combinations of isolating and bleeder valves may be used.

7.6 INTERCOOLERS AND AFTERCOOLERS

Intercoolers and aftercoolers shall meet requirements of ISO 10438, Part 1 or API Std 614, Ch. 1, 5.5, except as specifically noted below:

7.6.1 The vendor shall provide an inter-cooler between each compression stage. Unless otherwise specified, an aftercooler shall be provided after the final compression stage.

7.6.2 Unless otherwise specified, the coolers shall have continuous-bleed notched gate valves to permit removal of liquid.

7.6.3 Unless otherwise specified, intercoolers and aftercooler shall be of the water-cooled shell and tube type with water on the tube side. A removable-bundle design is required. Tubes shall not have an outside diameter of less than 15 mm (5/8 in.), and the tube wall shall not have a thickness of less than 18 BWG, 1.25 mm (0.049 in.). Each cooler shall be sized to accommodate the total cooling load of the associated stage.

Note: Due to physical limitations, smaller units are commonly supplied with 10 mm (3/8 in.) tubes and thinner walls which may be acceptable with purchaser approval.

7.6.4 Double-pipe coolers and finned double-pipe designs may be furnished only when specifically approved by the purchaser.

7.6.5 Unless otherwise specified, cooler shells shall be of steel; tube sheet shall be carbon steel, painted on each side with a suitable coating for corrosion protection; and tubes shall be of manufacturer's standard copper alloy. U-bend tubes are not permitted.

Note 1: Typical tube materials are 90-10 copper-nickel, or hard drawn Cl 220 copper.

Note 2: Some plant locations may require consideration of alternative materials to combat atmospheric corrosion.

7.6.6 The vendor shall include in the proposal complete details of any proposed air-cooled cooler.

7.7 INLET AIR FILTER/SILENCER

The vendor shall furnish a dry-type multistage, high-efficiency air intake filter-silencer suitable for mounting outdoors. Unless otherwise specified, the filter-silencer shall be shipped loose for field installation by purchaser. This filter-silencer shall be provided with the following:

- a. Differential pressure alarm instrumentation and indication
- b. Filter portion designed such that the first-stage (prefilter) elements may be changed while the unit is operating
- c. Weather hood or louvers

- d. Clean pressure drop across the filter elements which shall not exceed 5.0 millibar (2 in.) water gauge
- e. Removal of a minimum of 99.5% of particle sized 2 micron or larger over the inlet capacity range
- f. Element(s) designed to withstand pressure reversal from compressor surge
- g. Carbon steel components shall be galvanized to resist internal and external corrosion. The internal fasteners and hardware downstream of the final filter element shall be stainless steel.

Note 1: Many configurations and arrangements are available. Thus, the purchaser will need to specify any required specific features.

Note 2: The filter-silencer may be elevated some distance above the compressor for certain plant locations subject to unusual conditions such as sand storms. Inlet piping between filter-silencer and the compressor is typically supplied by the purchaser. The piping should be of corrosion-resistant material to avoid ingestion of rust into the compressor.

7.8 DISCHARGE BLOWOFF SILENCER

7.8.1 The vendor shall furnish a flanged discharge blowoff silencer. The silencer is typically shipped loose for field installation by the purchaser.

7.8.2 Silencer construction shall be suitable for service in an unprotected location. The silencer preferably should be located immediately downstream of the discharge blowoff valve and oriented as specified.

7.9 SPECIAL TOOLS

7.9.1 When special tools and fixtures are required to disassemble, assemble, or maintain the unit, they shall be included in the quotation and furnished as part of the initial supply of the machine. For multiple-unit installations, the requirements for quantities of special tools and fixtures shall be mutually agreed upon by the purchaser and the vendor. These or similar special tools shall be used during shop assembly and post-test disassembly of the equipment.

7.9.2 When special tools are provided, they shall be packaged in a separate, rugged metal box or boxes and shall be marked "special tools for (tag/item number)." Each tool shall be stamped or tagged to indicate its intended use.

7.10 ADDITIONAL REQUIREMENTS FOR "SPECIAL DUTY" PACKAGES.

- **7.10.1** When specified, the product of driver nameplate rating and any applicable service factor shall be no less than the power required (including losses from shaft-driven oil pump, coupling, and gear) when the compressor is operated unthrottled (inlet throttle device wide open) at the specified low-ambient operating conditions. The purchaser will specify the inlet air temperature and the inlet cooling water temperature to be used by the vendor in calculating the maximum unthrottled power.

Note: The specified inlet temperature is not necessarily the minimum ambient temperature.

- **7.10.2** When specified, drain rim decking shall extend under the drive-train components so that any leakage from these components is contained.
- **7.10.3** When specified, the vendor shall commercially sand blast, in accordance with ISO 8501, Grade Sa2 or SSPC SP6, all grout contact surfaces of the baseplate, and coat those surfaces with a primer compatible with epoxy grouting.

7.10.4 The microprocessor shall be capable of communicating with the purchaser's distributed control system (DCS).

Note: The purchaser should advise the communication protocol to be used.

- **7.10.5** When specified, a surge avoidance system shall be provided.

Note: Typically this requires additional instrumentation for measuring flow, pressure and temperature, a modulating type anti-surge (blow-off) valve and additional control logic.

- **7.10.6** When specified, the system shall have the capability of recording data at multiple intervals just prior to an alarm or trip as an aid for troubleshooting compressor operational problems.
- **7.10.7** When specified, provisions for phase reference (phase angle probes) shall be made on all pinions in accordance with API Std 670.
- **7.10.8** When specified, a tapped and plugged hole shall be provided for mounting a probe to sense axial position of the gear wheel. Manufacturer shall advise if their thrust bearing arrangement makes it more advantageous to utilize axial position probes on the pinions instead of the bullgear.
- **7.10.9** When specified, gear casing shall have a machined surface for mounting the purchaser's accelerometer in accordance with API Std 670.

Note: This requirement is for purchaser's field diagnostics of gear condition.

- **7.10.10** When specified, vibration and axial position transducers shall be supplied, installed, and calibrated in accordance with API Std 670.
- **7.10.11** When specified, vibration and axial position monitors shall be supplied, installed, and calibrated in accordance with API Std 670.
- **7.10.12** When specified, a bearing-temperature monitor shall be supplied and calibrated in accordance with API Std 670.
- 7.10.13** The control system shall maintain a chronological record of the shutdowns. The panel shall have the capability of storing operational parameters related to the chronological shutdowns in a battery-backed nonvolatile memory. The Vendor and the purchaser shall mutually determine the required parameters to be stored.
- **7.10.14** When specified, each alarm device and each shutdown device shall be furnished as separate devices.
- **7.10.15** When specified, a pilot light shall be provided on the incoming side of each supply to indicate that the circuit is energized. The pilot lights shall be installed on the control panel.
- 7.10.16** If temperature element heads are exposed to temperatures above 60°C (140°F), a 19-mm (³/₄ in.) bronze hose with four-wall-interlocking construction and joints with packed-on heatproof couplings shall be used.
- 7.10.17** Piping wall thickness shall conform to the minimum requirement of ISO 10438, Part 1 or API Std 614, Table 2-A. Where space does not permit the use of NPS ¹/₂, ³/₄, or 1 pipe, seamless tubing may be furnished in accordance with ISO 10438, Part 1 or API Std 614 Table 2-B. Stainless steel fittings shall be furnished with stainless steel tubing. The make and model of fittings shall be subject to purchaser's approval.
- **7.10.18** When specified, piping on external return lines and upstream of filters shall be stainless steel (excluding slip-on flanges).
- **7.10.19** Heads of oil-actuated control valves shall be vented back to the reservoir. When specified, instrument sensing lines to safety switches shall have a continuous through flow of oil.
- 7.10.20** All piping components such as flanges, valves, control valve bodies or heads, and relief valves shall be made of steel.
- **7.10.21** When specified, intercooler and aftercooler channels and covers shall be of steel; tube sheet shall be of brass and tubes shall be of inhibited admiralty.
- 7.10.22** Intercoolers and aftercoolers shall be in accordance with TEMA Class C and shall be constructed with a removable channel cover.

8 Inspection, Testing and Preparation for Shipment

8.1 GENERAL

- 8.1.1** Unless otherwise specified, inspection, testing and preparation for shipment shall be in accordance with ISO 10438, Part 1 or API Std 614, Ch. 1, Section 7 except as noted below:
- **8.1.2** When specified, the purchaser's representative, the vendor's representative, or both shall indicate compliance in accordance with the inspector's checklist (see Annex G) by initialing, dating, and submitting the completed checklist to the purchaser prior to shipment.

8.2 INSPECTION

8.2.1 General

The vendor shall keep the following data available for at least 20 years:

- a. Material certificates of compliance for shafts, pinions, gear wheels, and impellers
- b. Documentation to verify that the requirements of this specification have been met, for the required level of service
- c. Results of documented tests and inspections, including fully identified records of all heat treatment and nondestructive examinations.

- 8.2.1.1** Pressure-containing parts shall not be painted until the specified inspection and testing of the parts is complete.

Note: Purchased auxiliaries typically arrive already tested and painted. Some components may be primed at the sub-supplier.