General-Purpose Gear Units for Petroleum, Chemical and Gas Industry Services

API STANDARD 677
THIRD EDITION, APRIL 2006

REAFFIRMED, NOVEMBER 2010

AMERICAN PETROLEUM INSTITUTE

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Downstream Segment

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General-purpose Gear Units for Petroleum, Chemical and Gas Industry Services

1 General

1.1 SCOPE

1.1.1 This standard covers the minimum requirements for general-purpose, enclosed single and multistage gear units incorporating parallel shaft helical and right angle spiral bevel gears for the petroleum, chemical, and gas industries. Gears manufactured according to this standard shall be limited to the following pitchline velocities. Helical gears shall not exceed 60 m/s (12,000 ft/min), and spiral bevels shall not exceed 40 m/s (8,000 ft/min). Spiral bevel gearsets shall be considered matched sets.

Note 1: This standard is not intended to apply to gears in special-purpose service, which are covered in API Std 613; to gears integral with other equipment; to epicyclic gear assemblies; or gears with non-involute tooth forms.

Note 2: This standard requires the purchaser to specify certain details and features. A bullet (•) at the beginning of a paragraph indicates that either a decision by, or further information from, the purchaser is required. Further information should be shown on the data sheets or stated in the quotation request and purchase order.

1.1.2 General-purpose gears are applied in equipment trains that are usually spared, or are in noncritical service.

Typical applications for which this standard is intended are cooling tower water pump systems, forced and induced draft fan systems, and other general-purpose equipment trains.

1.2 ALTERNATIVE DESIGNS

The vendor may offer alternative designs. Equivalent metric dimensions, fasteners, and flanges may be substituted as mutually agreed upon by the purchaser and the vendor.

1.3 CONFLICTING REQUIREMENTS

In case of conflict between this standard and the inquiry or order, the information included in the order shall govern.

1.4 DEFINITION OF TERMS

Terms used in this standard are defined in 1.4.1 through 1.4.26.

1.4.1 axially (horizontally) split: A joint that is parallel to the shaft centerline.

1.4.2 bending stress number (*S*): Defined in 2.4.4.2.

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

1.4.4 design: Requirements normally defined by the equipment designer and the manufacturer.

Note: The use of the word design in any term (such as design power, design pressure, design temperature, or design speed) should be avoided in the purchaser's specifications.

1.4.5 DN: An alphanumeric designation of size for components of a pipework system, which is used for reference purposes. It comprises the letters DN followed by a dimensionless whole number which is indirectly related to the physical size, in millimeters (mm), of the bore or outside diameter of the end connection.

Note 1: The number following the letters DN does not represent a measurable value (ISO 6708: 1995).

1.4.6 gear: Refers to either the pinion or gear wheel.

1.4.7 gear-rated power: The maximum power specified by the purchaser on the data sheets and stamped on the nameplate (see 2.4.1).

1.4.8 gear service factor (*SF*): The factor that is applied to the tooth pitting index and bending stress number, depending on the characteristics of the driver and the driven equipment, to account for differences in potential overload, shock load, and/or continuous oscillatory torque characteristics.

1.4.9 hunting tooth combination: Exists for mating gears when a tooth on the pinion does not repeat contact with a tooth on the gear until it has contacted all the other gear teeth.

1.4.10 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 mandated.

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

1.4.11 maximum allowable speed (in revolutions per minute): The highest speed at which the manufacturer's design will permit continuous operation.

1.4.12 maximum continuous speed (in revolutions per minute): The speed at least equal to 105% of the rated pinion speed for variable-speed units and is the rated pinion speed for constant-speed units.

1.4.13 minimum allowable speed (in revolutions per minute): The lowest speed at which the manufacturer's design will permit continuous operation.

1.4.14 nominal pressures (*PN*): A numerical designation relating to pressure that is a convenient round number for reference purposes.

1.4.15 normal transmitted power: The power at which usual operation is expected and optimum efficiency is desired. The normal transmitted power may be equal to or less than the gear-rated power.

1.4.16 normative: A requirement of the standard.

1.4.17 pinion: The higher speed element of a gear set.

1.4.18 rated input speed of the gear unit (in revolutions per minute): The specified (or nominal) rated speed of its driver, as designated by the purchaser on the data sheets.

1.4.19 rated output speed of the gear unit (in revolutions per minute): The specified (or nominal) rated speed of its driven equipment, as designated by the purchaser on the data sheets.

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

1.4.21 thermal capacity: The horsepower a unit will transmit continuously for 3 hours or more without exceeding an operating sump temperature rise of 45°C (80°F) above ambient.

1.4.22 total indicator reading (TIR), also known as total indicated 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.

Note: For a perfectly cylindrical surface, the indicator reading implies an eccentricity equal to half the reading. For a perfectly flat face the indicator reading gives an out-of squareness equal to the reading. If the diameter in question is not perfectly cylindrical or flat, interpretation of the meaning of TIR is more complex and may represent ovality or lobing.

1.4.23 trip speed (in revolutions per minute): The speed at which the independent emergency overspeed device operates to shut down a prime mover. For steam turbines and reciprocating engines, the trip speed will be at least 110% of the maximum continuous speed. For gas turbines, the trip speed will be at least 105% of the maximum continuous speed.

1.4.24 tooth pitting index (*K*): Defined in 2.4.3.

1.4.25 unit responsibility: The responsibility for coordinating the technical aspects of the equipment and all auxiliary systems included in the scope of the order. It includes responsibility for reviewing such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation, piping, and testing of components.

1.4.26 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.

1.5 REFERENCED PUBLICATIONS

1.5.1 Referenced publications are listed in Appendix F.

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

1.5.3 Notes following a paragraph are informative.

1.5.4 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.

1.5.5 It is the vendor's responsibility to invoke all applicable specifications to each subvendor.

1.5.6 For unit conversion, the factors in API *MPMS* Ch. 15 *Manual of Petroleum Measurement Standards* were used to convert from Customary to SI units. The resulting exact SI units were then rounded off.

1.5.7 The editions of the Appendix F 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 the inquiry shall be mutually agreed upon by the purchaser and the vendor.

• 1.6 DIMENSIONS

Purchaser shall specify whether data, drawings, hardware (including fasteners) and equipment supplied to this standard shall use the SI or U.S. Customary system of measurements.

Note: Dedicated data sheets for SI and for U.S. Customary units are provided in Appendix A.

2 Basic Design

2.1 GENERAL

2.1.1 Gear units purchased according to this standard shall conform to AGMA 6010 or 6011 and to related standards referenced therein, except as modified or supplemented by this standard.

2.1.2 The equipment (including auxiliaries) covered by this standard shall be designed and constructed for a minimum service life of 20 years and at least 5 years of uninterrupted operation.

Note: It is recognized that these are design criteria.

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

• **2.1.4** The purchaser shall specify the equipment's normal transmitted power (see 2.4.1 for gear-rated power). This is the power associated with the normal operating point of the driven equipment.

• **2.1.5** When required, the purchaser shall also indicate on the data sheets the allowable percentage of variation in the designated gear ratio.

Note: In selecting the number of teeth for the pinion and gear, it is often impractical for the vendor to match exactly both the rated input and rated output speeds designated on the data sheets. The purchaser will therefore indicate which of the two is specified (that is, must be exactly adhered to by the vendor) and which is nominal (that is, permits some variation). An *S* will be used to indicate the specified speed, and an *N* will be used to indicate the nominal speed.

• **2.1.6** 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 both maximum sound pressure and sound power level data per octave band for the equipment.

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

Water velocity over heat exchange surfaces	≥ 1.5 m/s – 2.5 m/s	(5 ft/s – 8 ft/s)
Maximum allowable working pressure (MAWP)	≥ 7.0 bar (Note 1)	(≥ 100 psig)
Test pressure (≥ 1.5 MAWP)	≥ 10.5 bar	(≥ 150 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	20 K	(30°F)
Minimum temperature rise	10 K	(20°F)
Water side fouling factor	0.35 m^2K/kW	(0.002 hr-ft^2-°F/Btu)
Corrosion allowance for carbon steel shells	3 mm	($^1/8$ in.)

Note 1: Gauge pressure.

Note 2: To avoid condensation, the minimum inlet water temperature to water cooled bearing housings should preferably be above the ambient air temperature.

The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a 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. If such a conflict exists, the purchaser will approve the final selection.

2.1.8 Equipment shall be designed to run without damage to the trip speed setting indicated in Table 1. Rotors for turbine-driven gear units shall be designed to operate without damage at momentary speeds up to 110% of the trip speed.

2.1.9 The arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the purchaser and the vendor. The arrangement shall provide adequate clearance areas and safe access for operation and maintenance.

• **2.1.10** 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 IEC 60079-0 (NFPA 70, Articles 500, 501, 502, and 504) as well as any local codes specified and furnished on request by the purchaser (see 1.5.4). Refer to Appendix F table of standards for a listing of typical applicable electric codes.

2.1.11 Oil reservoirs and housings that enclose moving lubricated parts, such as bearings, shaft seals, highly polished parts, instruments, and control elements, shall be designed to minimize contamination by moisture, dust, and other foreign matter during periods of operation and idleness.

2.1.12 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 shouldering, cylindrical dowels or keys.

2.1.13 After installation, the combined performance of gear unit (with driver and driven machines) shall be the joint responsibility of the purchaser and the vendor.

Table 1—Driver Trip Speeds

Drive Type	Trip Speed (% of Max Continuous Speed)
Steam Turbine	
NEMA Class A[a]	115
NEMA Class B, C, D[a]	110
Gas Turbine	105
Variable-speed Motor	110
Constant-speed Motor	100
Reciprocating Engine	110

[a]Indicates governor class, as specified in NEMA SM23.

2.1.14 In designing the gear unit, the vendor shall take into account that many factors (such as piping loads, alignment at operating conditions, supporting structure, and handling during shipment and installation) may adversely affect site performance.

• **2.1.15** 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.

2.1.16 Gear units shall not require a break-in period.

• **2.1.17** The gearing shall be designed to withstand all internal and external loads inherent to geared, rotating machinery systems. The gearing shall be capable of withstanding the specified additional external loads (thrust, lube-oil piping and so forth) transmitted across the gear mesh while the unit is operating at the gear-rated power specified by the purchaser.

2.1.18 Spare and replacement parts for the machine and all furnished auxiliaries shall meet all the criteria of this standard.

• 2.2 SHAFT ASSEMBLY DESIGNATION

The purchaser shall specify the appropriate shaft assembly designation selected from the combinations listed in Table 2 and illustrated in Figure 1. The purchaser may alternatively circle one or more of the assembly designations on a copy of Figure 1 and submit the copy with the quotation request. If the shaft arrangement has not been finalized at the time of the quotation request, the purchaser will designate all of the combinations under consideration.

Note: The material for Table 2 and Figure 1 was reprinted from AGMA 6010 with permission of the publisher. Refer to Figure 1 for explanatory notes.

Table 2—Shaft Assembly Combinations

Parallel Shaft Assembly Combination (See Figure 1-A)

High-speed Shaft	Low-speed Shaft
L	R
R	L
L	L
R	R
R	LR
L	LR
LR	L
LR	R
LR	LR

Bevel Gear Assembly Combinations Horizontal Shafts (See Figure 1-B)

High-speed Shaft	Low-speed Shaft
1	L
1	R
1	LR
2	L
2	R
2	LR

Bevel Gear Assembly Combinations Vertical Low Speed Shafts (See Figure 1-C)

High-speed Shaft	Low-speed Shaft
1	U
2	U
1	D
2	D
1	UD
2	UD

2.3 SHAFT ROTATION

2.3.1 The rotational direction of high-speed and low-speed shafts is either clockwise (CW) or counterclockwise (CCW), as viewed from the coupling ends of the respective shafts.

2.3.2 On the data sheets and in drawings and tables, the shaft rotational direction shall be designated by the abbreviations CW or CCW, as indicated by the circular arrows in Figure 2.

• **2.3.3** The purchaser shall specify the rotational direction of both the high-speed and the low-speed shafts. When either or both shafts have an extension at each end, the purchaser may alternatively indicate the rotational directions on the appropriate assembly designation (see Figure 1) and submit a copy of the figure with the quotation request.

• **2.3.4** In finalizing the data for purchase, the purchaser shall prepare a sketch that shows the direction of rotation for each item in the train.

2.4 RATING

• 2.4.1 Gear-rated Power

2.4.1.1 The gear-rated power of the unit shall be specified by the purchaser. For gear units located next to the driver, the minimum gear unit rated power shall be the maximum installed power of the driver. For electric motor drivers, the gear-rated powershall be the motor nameplate rating multiplied by the motor service factor. All modes of normal and abnormal operation shall be examined. Modes of operation include the number of starts per unit of time, reduced load, removal, reversed load, reduced speed, and overload and overspeed conditions. If the maximum transmitted torque occurs at an operating speed other than the maximum continuous speed, this torque and its corresponding speed will be specified by the purchaser and shall be the basis for sizing the gear.

For gear units between two items of driven equipment, the power rating of such gears should normally be not less than items a or b below, whichever is greater.

a. 110% of the maximum power required by the equipment driven by the gear.
b. The maximum power of the driver prorated between the driven equipment, based on normal power demands.

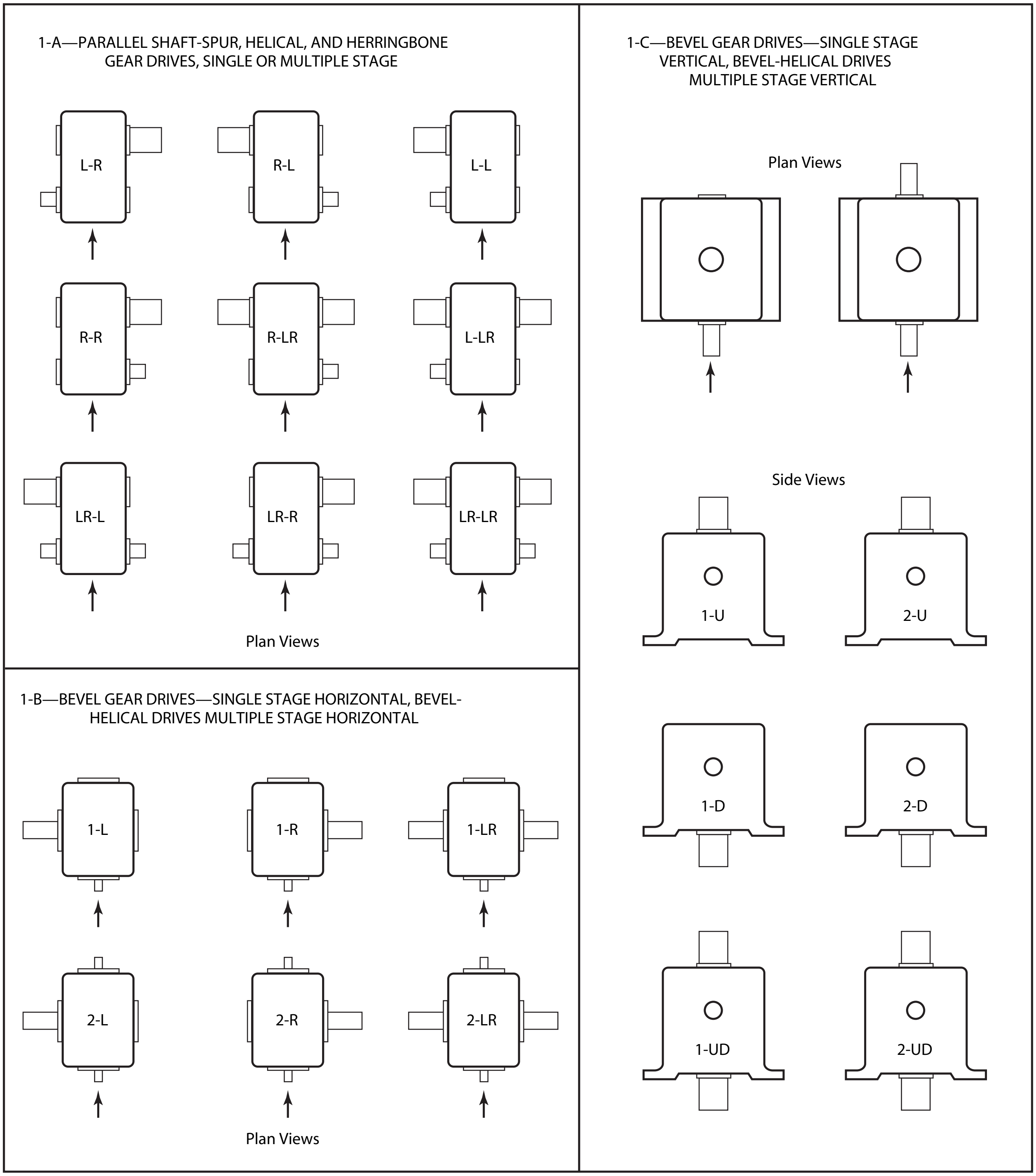
2.4.1.2 Normal Transmitted Power

For optimal gear unit design (rotordynamics, lead modification), the purchaser should specify the normal transmitted power and any special operating conditions (such as load reversals), in addition to the gear unit rated power.

2.4.1.3 Gear unit rating shall be based on the lowest of the following capacities: tooth pitting resistance, tooth bending strength, or thermal capacity.

• 2.4.2 Gear Service Factor

The minimum gear service factor (*SF*) shall be specified by the purchaser on the data sheets based on the application, as listed in Table 3.



Notes:
1. Code: L = left; R = right; U = up position-low speed shaft; D = down position-low speed shaft.
2. Arrows indicate line-of-sight to determine direction of shaft extensions.
3. Numerals preceding the hyphen refer to number of high speed shaft extensions.
4. Letters preceding the hyphen refer to number and direction of high speed shaft extensions.
5. Letters following the hyphen refer to number and direction of low speed shaft extensions.

Figure 1—Shaft Assembly Designations

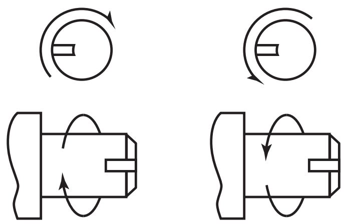


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Figure 2—Shaft Rotation Designations

Table 3—Minimum Gear Service Factors

	Prime Mover			
Driven Equipment	Motors Sync & Var.	Motors Induction	Turbine Stream & Gas	Reciprocating Engine
Agitators and mixers	1.8	1.7	1.7	2.0
Blowers				
Centrifugal	1.5	1.4	1.6	1.7
Rotary lobe	1.8	1.7	1.7	2.0
Vane	1.5	1.4	1.6	1.7
Compressors				
Rotary lobe (radial, axial, screw, and so forth)	1.8	1.7	1.7	2.0
Reciprocating	2.1	2.0	2.0	2.3
Conveyors				
Uniformly loaded and fed	1.5	1.4	1.6	1.7
Non-uniformly fed	1.8	1.7	1.7	2.0
Shaker or reciprocating	2.1	2.0	2.0	2.3
Crusher (ore or stone)	2.1	2.0	2.0	2.3
Plasticizing equipment				
Single screw extruders	1.5	1.4	—	—
Twin screw extruders				
Co-rotating	1.2	1.1	—	—
Counter-rotating	1.2	1.1	—	—
Twin screw mixers	1.3	1.2	—	—
Melt pumps	1.2	1.1	—	—
Fans				
Centrifugal	1.5	1.4	1.6	1.7
Forced draft	1.5	1.4	1.6	1.7
Induced draft	1.8	1.7	2.0	2.2
Cooling tower	2.0	2.0	2.0	—
Feeders				
General service	1.8	1.7	1.7	2.0

Table 3—Minimum Gear Service Factors (Continued)

	Prime Mover			
Reciprocating	2.1	2.0	2.0	2.3
Generators	1.3	1.3	1.3	1.7
Pumps				
Centrifugal (all service except as listed below)	1.5	1.3	1.5	1.7
Centrifugal, boiler feed	1.8	1.7	2.0	—
Centrifugal, hot oil	1.8	1.7	2.0	—
Centrifugal, water supply	1.6	1.5	1.7	2.0
Rotary, axial flow (all types)	1.6	1.5	1.5	1.8
Rotary, gear	1.6	1.5	1.5	1.8
Reciprocating	2.1	2.0	2.0	2.3

2.4.3 Tooth Pitting Index

2.4.3.1 Gear elements shall be sized on the basis of a tooth pitting index called a *K*-factor. This method includes factors to account for such considerations as the radii of curvature of the contacting tooth surfaces, extended life, high reliability, dynamic load effects, maldistribution of tooth loading across the face, and the strength of the materials in terms of pitting resistance.

Note: This simplified system for sizing the gear unit is consistent with AGMA 2101, with conservative assumptions for each variable in the more complex basic equations contained in that document.

2.4.3.2 The *K*-factor is defined as follows:

$$K = [W_t / dF_w][(R+1)/R] \tag{1}$$

In SI units:

$$W_t = [(1.91 \times 10^7)P_g]/(N_p d) \tag{2}$$

In U.S. customary units, W_t can be expressed as follows:

$$W_t = (126000 P_g)/(N_p d)$$

where

K = tooth pitting index, in MPa (lbf/in.^{2}),

W_t = transmitted tangential load at the operating pitch diameter, in N (lb),

F_w = net face width, in mm (in.),

d = pinion pitch diameter, in mm (in.),

R = number of teeth in the gear wheel divided by number of teeth in the pinion,

P_g = gear-rated power, in kw (hp),

N_p = pinion speed, in r/min.

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2.4.3.3 The allowable *K*-factor at the gear unit rated power will vary with the materials selected for the gear teeth, the tooth hardening processes used and the service factor. The allowable *K*-factor is calculated as follows:

$$K_a = I_m/(SF) \quad (3)$$

where

K_a = allowable *K*-factor,

I_m = material index number (from Table 4 and Figure 3),

SF = minimum gear service factor (from Table 3).

2.4.3.4 When rating bevel gearing, the bevel gearing must be converted to equivalent helical gearing per 2.4.3.2, calculated at the mean pitch diameter of the bevel set.

The mean pitch diameter of the pinion and gear is defined as follows:

$$MPD_p = PD_p - [(F_w)(\sin\Gamma p)] \quad (4)$$

$$MPD_g = PD_g - [(F_w)(\sin\Gamma g)] \quad (5)$$

$$Mm_n = [(MPD_p)(\cos\Psi)]/N_t$$

$$DP_n = N_t/[(MPD_p)(\cos\Psi)]$$

where

MPD_p = mean pitch diameter of bevel pinion, in mm (in.),

MPD_g = mean pitch diameter of bevel gear wheel, in mm (in.),

Mm_n = bevel module at mean pitch diameter, in mm,

DP_n = bevel normal pitch at mean pitch diameter, in 1/in.,

PD_p = bevel pinion pitch diameter, in mm (in.),

PD_g = bevel gear wheel pitch diameter, in mm (in.),

N_t = number of teeth pinion,

F_w = net face width, in mm (in.),

Γp = pitch cone angle, pinion,

Γg = pitch cone angle, gear,

ψ = spiral angle (= helix angle).

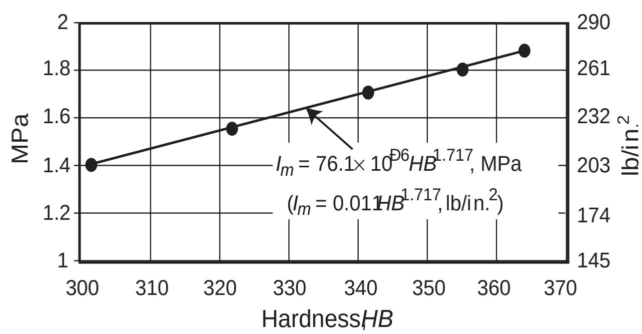
2.4.3.5 Table 4 presents material index numbers and maximum length to diameter (*L/d*) ratios for several combinations of materials in current use. The minimum material hardness is selected for the element, pinion or gear wheel, with the lowest minimum hardness. Do not extrapolate the curve specified in Table 4 (see Figure 3 and note) beyond the limits shown.

2.4.3.6 Deflections of parallel shaft helical gears with unmodified leads shall not have a total lead mismatch (combined bending and torsional deflection) of the rotors across the gear face width that is greater than 25 µm (1 mil) for through-hardened gears or greater than 18 µm (0.7 mil) for case carburized gears. The determination of rotor deformation is to be based on the rated power. The *L/d* values shown in Table 4 apply to helical gears only. The maximum face width for bevel gears is equal to 0.33 times the outer cone distance. This will result in *L/d* ratios lower than Table 4 for bevel gears.

2.4.3.7 When a higher *L/d* ratio than tabulated in Table 4 is proposed, the gear vendor shall submit justification in the proposal for using the higher *L/d* ratio. Purchaser's approval is required when *L/d* ratios exceed those in Table 4. When operating conditions other than the gear-rated power are specified by the purchaser, such as the normal transmitted power, the gear vendor shall consider in the analysis the length of time and load range at which the gear unit will operate at each condition so that lead modification can be determined. When modified leads are to be furnished, purchaser and vendor shall agree on the tooth contact patterns obtained in the checking stand, housing, and test stand.

If the rotor deformation exceeds the values limited by 2.4.3.6, regardless of the *L/d*, an analytically determined lead modification shall be applied in order to reduce the total actual mismatch to a magnitude below the limiting values in 2.4.3.6. This will facilitate a more uniform load distribution across the entire face width. Successful application of lead modifications are dependent on high gear-tooth accuracy of AGMA/ISO 1328-1 accuracy Grade 5 or better.

Note: The analysis of a gear-tooth load distribution versus lead modification is not within the scope of this standard.



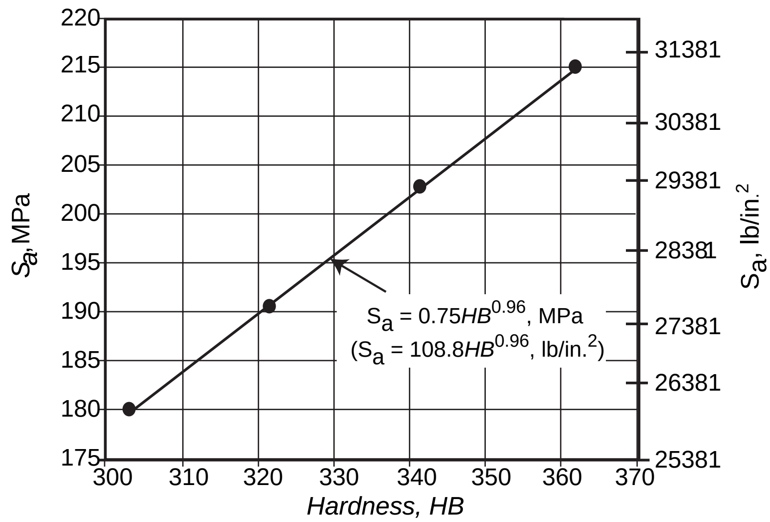
Note: Figure 3 uses the minimum specified hardness. Normal heat treating practice requires a tolerance range on hardness. The upper end of the hardness range can fall outside the limits shown in Figure 3.

Figure 3—Material Index Number, Through Hardened

Table 4—Material Index Number, I_m and Maximum *L/d* Ratios

Hardening Method	Minimum Hardness	Material Index Number, I_m MPa (lb/in.^{2})	Minimum Pinion *L/d* Ratio Double Helical	Single Helical
Through Hardening	See Figure 3	See Figure 3	2.2	1.6
Nitrided	90HR15N	2.07 (300)	2.2	1.6
Carburized	58R_c	3.03 (440)	2.0	1.6

Note: *L* = net face width plus gap, in mm (in.); *d* = pinion pitch diameter in mm (in.); BHN = Brinell hardness number; HRC = Rockwell hardness (C scale).



Note: Figure 4 uses the minimum specified hardness. Normal heat treating practice requires a tolerance range on hardness. The upper end of the hardness range can fall outside the limits shown in Figure 4.

Figure 4—Allowable Bending Stress Number, S_a

Table 5—Allowable Bending Stress Number, S_a

Minimum Hardening Method	Hardness	MPa (lb/in.^{2})	
Through-Hardened	See Figure 4	See Figure 4	
Nitrided	90HR15N	190	(27500)
Carburized	58 R_c	266	(38500)

Table 6—Overhung Load Factors Applied to Parallel Shaft and Right Angle Gears

Drive Type	Factor
Single or multiple chain	1.00
Cut pinion run with cut gear	1.25
Timing belts	1.25
Single or multiple V-belt	1.50
Flat belt	2.50

2.4.4 Tooth Size and Geometry

2.4.4.1 The size and geometry of the gear teeth shall be selected so that the bending stress number, as calculated using Equation 1, does not exceed the values in Table 5 (see Figure 4 and note). This method includes factors similar to those used to determine the allowable *K*-factor. This simplified system for sizing helical gear teeth is consistent with AGMA 2101.

2.4.4.2 The vendor shall calculate the bending stress number for both the pinion and the gear wheel. Where idlers are used, the calculated stress shall be limited to 70% of the value given in Table 5. The bending stress number for helical gears is calculated as follows:

In SI units:

$$S = [W_t/(m_n F_w)](SF)[(1.8\cos\gamma)/J] \tag{6}$$

where

S = bending stress number,

S_a = allowable bending stress number (see Table 4),

m_n = module number in mm,

γ = helix angle, in degrees,

J = geometry factor (from AGMA 908).

In U.S. customary units:

$$S = [(W_t P_{nd})/F_w](SF)[(1.8\cos\gamma)/J]$$

where

S = bending stress number,

S_a = allowable bending stress number (see Table 4),

P_{nd} = normal diametral pitch, in 1/in.,

γ = helix angle, in degrees,

J = geometry factor (from AGMA 908).

2.4.4.3 The bending stress number for bevel pinions and gears is calculated as follows:

In SI units:

$$S = [W_t/(M_{mn}F_w)](SF)[(1.8\cos\Psi)/J] \tag{7}$$

where

S = bending stress number,

S_a = allowable bending stress number,

M_{mn} = bevel module at mean pitch diameter, in mm,

ψ = spiral angle, in degrees,

J = geometry factor (from AGMA 2003).

In U.S. customary units:

$$S = [(W_t DP_n)/F_w](SF)[(1.8\cos\Psi)/J]$$

where

S = bending stress number,

S_a = allowable bending stress number,

DP_n = bevel normal pitch at mean pitch diameter, in 1/in.,

ψ = spiral angle, in degrees,

J = geometry factor (from AGMA 2003).

2.4.5 Overhung Loads

When a chain, gear, or belt drive is mounted on the input or output shaft, the overhung load shall be calculated by multiplying the transmitted force that is tangent to the pitch circle by the applicable factor from Table 6. Shafts, bearings, and bolting shall be sized according to the overhung load. All forces must be considered to be acting in the most unfavorable direction.

2.4.6 Deviations

It is recognized that special cases will exist in which it may be desirable to deviate from the rating rules specified in 2.4.1 through 2.4.5. The vendor shall describe and justify such deviations in the proposal.

2.5 CASINGS

2.5.1 Design Parameters

2.5.1.1 Gear casings shall be either cast or fabricated and shall be designed and constructed to maintain rotor alignment under all load conditions when provided with supports and installed in accordance with the vendor's written instructions.

2.5.1.2 The equipment feet shall be provided with vertical jackscrews and shall be drilled with pilot holes at two locations that are accessible for use in final doweling. Dowel hole locations shall be selected to minimize the effects of casing distortion and misalignment with connected equipment.

Note: For parallel shaft units, these locations are typically as close as possible to the vertical plane of the highest speed pinion centerline.

2.5.1.3 Casing bores shall be machined to a sufficient degree of accuracy so that spare gear sets purchased with the gearbox or at a later date will have the gear-tooth contact and power rating of the original gear set. A gear set that contacts correctly on true centers on a rotor checking stand shall also contact correctly in its own casing. Twisting the gearcase to improve contact is not allowed.

2.5.1.4 All internal piping should preferably be welded and should preferably use flanges for all connections. Any threaded piping shall be a minimum of Schedule 80 and shall be seal welded at flanges (see 2.6.2.1.d).

2.5.1.5 When tubing is used internally, it shall be stainless steel tubing in accordance with 3.5.1 and 2.5.1.6.

2.5.1.6 The design of internal piping and oil pans shall achieve proper support and protection to prevent damage from vibration or from shipment, operation, and maintenance. Cantilevered piping shall include reinforcing gussets in two planes at all pipe-to-flange connections.

2.5.1.7 Casings shall be designed to permit rapid drainage of lube-oil and to minimize oil foaming that could lead to excessive heat rise of the oil.

2.5.1.8 A replaceable filter-breather with a filtration rating of 10 micron particles ($\beta_{10} \geq 10$) or better shall be provided. The filter-breather shall be designed and located to prevent entrainment or discharge of oil to the atmosphere, pressure buildup in the casing, entrance of water during violent rainstorms, and entrance of dirt entrained in the air. The filter-breather connection shall be at least $^3/_4$ NPT.

Note: Small gearboxes may not accommodate this size filter-breather. Alternate configurations shall be as mutually agreed between the purchaser and vendor. Refer to API Std 614, Appendix E, for definition of filtration rating.

• **2.5.1.9** If specified, a non-replaceable, cleanable filter-breather shall be provided constructed of stainless steel with stainless steel or copper-nickel alloy internals, and shall be designed and located to prevent entrainment or discharge of oil to the atmosphere, pressure buildup in the casing, entrance of water during violent rainstorms, and entrance of dirt entrained in the air. The filter-breather connection shall be at least $^3/_4$ NPT, and its construction shall permit easy disassembly for inspection and cleaning.

Note: The conventional filter breather as described in this paragraph may permit contaminated air to be drawn into the gear case and contaminate the oil.

• **2.5.1.10** If specified by the purchaser and accepted by the vendor, gear unit casings shall be provided with purge oil mist to prevent casing contamination from environmental factors.

Note: This requires the oil mist lubricant to be the same as the main lubricant for the gear unit to prevent oil quality degradation. Careful consideration should be given to how the gear unit reservoir oil level, whether the reservoir is integral in the sump or on an external console, would be maintained where oil mist condensation is a possibility.

2.5.1.11 A removable, gasketed inspection cover or covers shall be provided in the gear casing to permit direct visual inspection of the full-face width of the gear elements. The inspection opening or openings shall preferably be at least one-half the width of the gear face.

2.5.1.12 Permanent coatings or paint shall not be applied to the interior of the casing unless the purchaser approves in advance the material and method of application.

2.5.1.13 On units that have pressurized oil systems with pitch line velocities above 15 m/s (3,000 ft/min), the gearbox casing shall be designed so that the gears do not dip into the oil during operation or upon shutdown. Gear units at or below 15 m/s (3,000 ft/min) pitch line velocity may dip into the oil; however, above 10 m/sec (2,000 ft/min) pitch line velocity, an oil pan shall be used to ensure rapid drainage and to minimize foaming.

2.5.2 Joints

Casing splitlines shall use a metal-to-metal joint (with a suitable joint compound) that is tightly maintained by suitable bolting. Gaskets (including string-type) shall not be used on splitlines for parallel shaft gears.

Note: Due to the interaction of the rotating elements of spiral bevel gear units, it is normally required that the element's mounting distances be adjustable to achieve proper tooth mesh contact and backlash. When the adjustment is made by shifting axially, in line with the element's shaft center line of rotation by use of a combination housing cover-bearing carrier, shim type gaskets are permitted.

2.5.3 Bolting

2.5.3.1 Case bolting may be of the through-bolt, studded, or cap-screw type. Threaded bolt holes shall not penetrate through the wall into the interior of the casing. Disassembly shall not require removal of studs.

2.5.3.2 Studded connections shall be furnished with studs installed. Blind stud holes should be drilled only deep enough to allow a preferred tap depth of $1\frac{1}{2}$ times the major diameter of the stud; the first $1\frac{1}{2}$ threads at both ends of each stud shall be removed.

2.5.3.3 Bolting shall be furnished as follows:

a. The details of threading shall conform to ISO 261, ISO 262, ISO 724, ISO 965 (to ASME B1.1).
b. Adequate clearance shall be provided at bolting locations to permit the use of socket or box wrenches.
c. Internal socket-type, slotted-nut, or spanner-type bolting shall not be used unless specifically approved by the purchaser.

2.5.3.4 Manufacturers' markings shall be located on all fasteners 6 mm ($\frac{1}{4}$ in.) and larger (excluding washers and set screws). For studs the marking should be on the nut end of the exposed stud end.

Note: A set screw is a headless screw with an internal hex opening on one end.

2.5.4 Assembly and Disassembly

It shall be possible to lift the upper half of horizontally split casings without disturbing the piping of the main oil supply to the gearbox.

2.5.4.1 Lifting lugs or eyebolts shall be provided for lifting the top half of the casing. Lifting lugs or eyebolts not capable of lifting the entire casing shall be clearly and permanently marked on the casing. Methods of lifting the assembled machine shall be specified by the vendor.

2.5.4.2 Mounting surfaces shall meet the following criteria:

a. They shall be machined to a finish of 6 µm (25 µin.) arithmetic average roughness (Ra) or better.
b. To prevent a soft foot, they shall be in the same horizontal plane within 25 µm (1 mil).
c. Each mounting surface shall be machined within a flatness of 42 µm per linear m (0.5 mils per linear ft) of mounting surface.
d. Different mounting planes shall be parallel to each other within 50 µm (2 mils).
e. The upper machined or spot faced surface shall be parallel to the mounting surface.

Hold-down bolts holes shall be drilled perpendicular to the mounting surface or surfaces, machined or spot faced to a diameter three times that of the bolt diameter and to allow for equipment alignment, be 15 mm ($\frac{1}{2}$ in.) larger in diameter than the hold-down bolt.

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Table 7—Drain Pipe Sizes

Inlet Flow Rate		Minimum Drain Size	
Liters per Minute	Gallons per Minute	Millimeters	NPS[a]
26	7	75	3
56	15	100	4
170	45	150	6
380	100	200	8

Note: [a]Nominal pipe size.

2.6 CASING CONNECTIONS

2.6.1 Service and Size Criteria

2.6.1.1 General-purpose gear casings usually have a self-contained lube-oil system. When the lube-oil system is external and provided by the purchaser, a single supply and a single drain connection from the gear casing shall be provided by the vendor. The minimum drain pipe size for external systems shall be based on the total inlet flow to the gear casing, according to Table 7.

2.6.1.2 Openings for piping connections shall be DN 20 ($^3/_4$ NPS) or larger and in accordance with ISO 6708. Sizes DN 32, DN 65, DN 90, DN 125, DN 175, and DN 225, ($1^1/_4$, $2^1/_2$, $3^1/_2$, 5, 7, and 9 NPS) shall not be used.

2.6.2 Lube-oil Connections

• **2.6.2.1** Lube-oil inlet and drain connections, oriented as specified, shall be at least DN 20 ($^3/_4$-in. NPS) and shall be flanged or machined and studded. Where flanged or machined and studded openings are impractical, threaded openings in sizes DN 20 (NPS $^3/_4$) through DN 40 (NPS $1^1/_2$) are permissible. These threaded openings shall be installed as specified as follows:

a. A pipe nipple, preferably not more than 150 mm (6 in.) long, shall be screwed into the threaded opening.

b. Pipe nipples shall be a minimum of Schedule 160 seamless for DN 25 (NPS 1) and smaller and a minimum of Schedule 80 for DN 40 (NPS $1^1/_2$).

c. The pipe nipple shall be provided with a welding-neck or socket-weld flange.

d. The threaded connection shall be seal welded; however, seal welding is not permitted on cast iron equipment, for instrument connections, or where disassembly is required for maintenance. Seal-welded joints shall be in accordance with ASME B31.3.

e. Tapped openings and bosses for pipe threads shall conform to ISO 7-1 (ASME B16.5).

f. Pipe threads shall be taper threads conforming to ASME B1.20.1.

2.6.2.2 Tapped openings not connected to piping shall be plugged with solid plugs furnished in accordance with ASME B16.11. Plugs that may later require removal shall be of corrosion-resistant material. Threads shall be lubricated. Tape shall not be applied to threads of plugs inserted into oil passages. Plastic plugs are not permitted.

• **2.6.2.3** Flanges shall conform to ISO 7005-1, Series 1, including Annex D & E or ISO 7005-2, Series 1 or ASME B16.1, B16.5, and B16.42 as specified, except as specified in 2.6.2.3.2 and 2.6.2.3.3.

Note 1: ISO 7005-1 (steel flanges) PN 20, 50, 110, 150, 260, 420 are designed to be interchangeable with ASME B16.5 and MSS SP-44 flanges, ISO 7005-1 flanges are not identical to ASME B16.5 and MSS SP 44 but are deemed to comply with the dimensions specified in ASME B16.5 and MSS SP 44.

Note: ISO 7005-2 (cast iron) flanges PN 20, 50 are designed to be interchangeable with ANSI/ASME B16.1 (gray cast iron) and B16.42 (ductile cast iron) but they are not identical. They are deemed to comply with dimensions specified in ASME B16.1 (gray cast iron) and B 16.42 (ductile cast iron).

Note 2: ISO PN 2.5, 6 do not have a corresponding ASME class and ASME Class 75, 400 & 800 do not have corresponding ISO PN designation. The use of these PN and Class flange ratings are therefore not recommended.

2.6.2.3.1 When ISO 7005-1 has been specified materials shall be in accordance with Annex D-1 (DIN) or Annex D-2 (ASTM), as specified. The pressure temperature ratings in Appendix E shall correspond to the materials specified.

Note: ISO 7005-1 Annex E Table 1-4 covers D-1 materials and Table 5-21 covers D-2 materials.

• **2.6.2.3.2** Gray, malleable, ductile, and cast iron flanges shall be flat faced and conform to the dimensional requirements of ISO 7005-2, ASME B16.1 or 16.42, as specified. PN 20 (Class 125) flanges shall have a minimum thickness equal to PN 50 (Class 250) for sizes DN 200 (8 NPS) and smaller.

Flanges other than those covered in 7005-2, shall conform to the dimensional requirements of the flanges specified in 2.6.2.3.

• **2.6.2.3.3** Purchaser connections other than those covered by ISO 7005-1, ISO 7005-2, ASME B16.1 or ASME B16.5 require purchaser's approval. When specified, mating parts shall be furnished by the vendor.

• **2.6.2.4** Machined and studded connections shall conform to the facing and drilling requirements of ISO 7005-1, ISO 7005-2, ASME B16.1, B16.5 or B16.42, as specified. Studs and nuts shall be provided installed. The first $1^1/2$ threads at both ends of each stud shall be removed.

Machined and studded connections and flanges not in accordance with ISO 7005-1, 7005-2, ASME B16.1, B16.5, B16.42 require purchaser's approval. Unless otherwise specified, the vendor shall supply mating flanges, studs and nuts for these nonstandard connections.

2.6.2.5 Flanges shall be full faced or spot faced on the back and shall be designed for through bolting.

2.6.2.6 The flange gasket contact surface shall not have mechanical damage which penetrates the root of the grooves for a radial length of more than 30% of the gasket contact width.

For all steel flanges, imperfections in the flange face finish shall not exceed that permitted in ASME 16.5.

2.6.2.7 Alternative flange connections (e.g., those of SAE) are permitted for nonpurchaser connections unless otherwise specified.

2.6.2.8 All of the purchasers connections shall be accessible for disassembly without requiring the machine, or any major part of the machine, to be moved.

2.6.2.9 The concentricity of the bolt circle and the bore of all casing flanges shall be such that the area of the machined gasket-seating surface is adequate to accommodate a complete standard gasket without protrusion of the gasket into the fluid flow.

2.7 GEAR ELEMENTS

2.7.1 General

2.7.1.1 Gear-teeth profiles shall be manufactured by the generating, shaping, or form process. Gears and pinions with pitch line velocities below 15 m/s (3,000 ft/min) may be finished unassembled with their shafts. Helical gears and pinions with pitch line velocities at or above 15 m/s shall be finish cut or ground assembled with their respective shafts. Shaving and shaping cutters shall have a hunting tooth combination with the work piece.

2.7.1.2 For pitch line velocities up to 15 m/s (3,000 ft/min), gear teeth shall be of ISO 1328 Grade 8 accuracy or better. For pitch line velocities between 15 and 30 m/s (3,000 and 6,000 ft/min), gear teeth shall be of ISO 1328 Grade 7 accuracy or better. For pitchline velocities between 30 and 45 m/s (6,000 and 9,000 ft/min), gear teeth shall be of ISO 1328 Grade 6 accuracy or better. For pitchline velocities above 45 m/s (9,000 ft/min), gear teeth shall be of ISO 1328 Grade 5 accuracy or better.

2.7.1.3 The tooth surface on loaded faces of completed gears shall have a finish, as measured along the pitch line, of 0.8 µm (32 µin.) Ra above a 20 m/s (4,000 ft/min) pitch line velocity limit and 1.6 µm (64 µin.) Ra at or below a 20 m/s (4,000 ft/min) minimum pitch line velocity limit. See also ISO TR 10064-1 on measuring methods.

2.7.1.4 The design of single-helical and right-angle gears shall be such that the effects of the moments on the gear elements, resulting from axial tooth reaction at the gear mesh, will not impair the expected performance of the gear unit.

2.7.1.5 Hunting tooth combinations are required. To achieve this, it may be necessary for the purchaser to adjust the exact gear ratio. If this is impractical, the purchaser and the vendor shall negotiate a solution.

2.7.1.6 Each helical gear and pinion of parallel shaft gear sets shall be supported between two bearings. Overhung designs are acceptable only below 15 m/s (3,000 ft/min) pitch line velocity and 225 kilowatts (300 horsepower).

2.7.1.7 There are two types of mountings for spiral bevel gear units, straddle and overhung. The mounting configuration is dictated by the size and ratio of the unit. When the gear diameter is large enough, one of the bearings shall be mounted inboard of the pitch cone (small end) or straddled. If the gear diameter will not permit straddle mounting, the element may be overhung. The vendor shall indicate on the data sheets the pinion mounting configuration, straddle or overhung.

2.7.2 Quality Assurance

2.7.2.1 Each pair of mating gears for parallel shaft units shall have a contact check in the gear casing at the vendor's shop. Those gear sets operating above 20 m/s (4,000 ft/min) pitch line velocity shall be checked for contact on a contact checking stand and in the job casing at the vendor's shop.

A thin coating of color transfer material (such as Prussian blue) shall be applied at three locations 120 degrees apart to four or more teeth of the dry degreased gear. With the gear elements held firmly on the correct center distance and with the shaft centerlines parallel within 42 µm per m (0.5 mils/ft) with a total misalignment of not more than 25 µm (1 mil), the coated teeth shall be rotated through the mesh with a moderate drag torque applied in a direction that will cause the teeth to contact on the normally loaded faces. The color transfer shall show evidence of contact distributed across the face as prescribed by the vendor. Prior to the contact tests, the vendor shall make available to the purchaser a contact drawing or vendor engineering specification that defines the expected and acceptable contact. Unmodified tooth profile leads shall show a minimum contact of 70% along the axis and 30% radially. Contact drawings or specifications and the results of the contact checks shall be delivered with the unit documentation. The results of the contact check shall be preserved by lifting the colors from a tooth, by applying and peeling off a strip of clear adhesive tape and then sticking the tape to an annotated sheet of paper.

2.7.2.2 Spiral bevel gear-tooth contact shall be checked per Appendix G.

• **2.7.2.3** The vendor shall have a manufacturing process control system to assure that the designed quality of gearing is produced. The process control system should include: manufacturing planning, machine tool maintenance and inspection programs, gear generating, hardening and finishing procedures, cutting tool selection and maintenance procedures, material control procedures, heat treatment control, inspection procedures, and quality assurance programs required to achieve and maintain the required gear quality.

If specified, gear elements shall be checked per ISO 1328-1 for required gear-tooth accuracy and charts shall be provided.

2.7.2.4 Gear elements shall not be modified on the basis of tooth contact checks made in the gear casing. Gear elements may be modified on the basis of results from gear checking machines or contact pattern while in the checking stand.

2.7.2.5 The gear vendor shall demonstrate the axial stability of each meshing pair of double-helical gears operating with pinion speeds above 1,800 r/min by either (a) measuring the unfiltered peak-to-peak shaft axial vibration, which shall not exceed 60 µm (2.5 mils) during full-speed testing, or (b) using indicators to make a slow rotation check. The preferred method for this slow rotation check is to hold one member (usually the gear wheel) firmly in a fixed axial position and indicate the axial movement of the other member (usually the pinion) as the parts are rotated through at least one full revolution of the gear wheel with a drag torque applied in a direction that will force the normally loaded tooth faces into contact. The total axial motion of the other member (pinion) relative to the fixed member (gear) shall not exceed 40 µm (1.5 mils) for gear units having a 20 m/s (4,000 ft/min) pitch line velocity or greater and 60 µm (2.5 mils) for gear units having less than a 20 m/sec (4,000 ft/min) pitch line velocity.

2.7.3 Shafts

2.7.3.1 Shafts shall be sized to transmit the gear-rated power within the stress limits of AGMA 6001-D97. Shafts shall be made of one-piece, heat-treated forged, or hot-rolled steel; shall be accurately machined throughout their entire length; and shall be suitably finished at their bearing surfaces.

• **2.7.3.2** If specified, or when vibration and/or axial-position probes are furnished, the rotor shaft-sensing areas to be observed by radial-vibration probes shall be concentric with the bearing journals. All shaft-sensing areas (both radial vibration and axial position) shall be free from stencil and scribe marks or any other surface discontinuity, such as an oil hole or a keyway, for a minimum of one probe-tip diameter on each side of the probe. For gear units with axial floats that exceed half of a probe tip diameter, the probe sensing area shall be long enough to cover the entire float, plus one probe tip diameter on each side. These areas shall not be metallized, sleeved, or plated. The final surface finish shall be a maximum of 0.8 µm (32 µin.) Ra, preferably obtained by honing or burnishing. These areas shall be properly demagnetized to the levels specified in API Std 670 or otherwise treated so that the combined total electrical and mechanical runout shall not exceed the following values:

a. For areas to be observed by radial-vibration probes 6.5 µm (0.25 mils), for shaft journals less than 305 mm (12 in.) and 10 µm (0.4 mils), for shaft journals 305 mm (12 in.) and greater.

b. For areas to be observed by axial-position probes, 15 µm (0.6 mils).

2.7.3.3 Electrical and mechanical runout shall be determined by rotating the rotor through the full 360 degrees supported in V-blocks at the journal centers while measuring runout with a non-contacting vibration probe and a dial indicator at the centerline of each probe location and one probe-tip diameter to either side.

Note: The rotor runout determined in V-blocks generally will not be reproduced when the rotor is installed in a machine with hydrodynamic bearings. This is due to pad orientation on tilt pad bearings and effect of lubrication in all journal bearings. The rotor will assume a unique position in the bearings based on the slow roll speed and rotor weight.

2.7.3.4 Accurate records of electrical and mechanical runout, measured in V-blocks for the full 360 degrees at each probe location, shall be included in the mechanical test report.

2.7.3.5 Coupling hubs shall have an interference fit with the shaft. The shaft end configuration shall conform to the requirements specified under 3.2.

2.8 DYNAMICS

2.8.1 General

Note: Refer to API RP 684 for more information on rotor dynamics.

In the design of rotor-bearing systems, consideration shall be given to all potential sources of periodic forcing phenomena (excitation) which shall include, but are not limited to, the following sources:

a. Unbalance in the rotor system.

b. Oil-film instabilities (whirl).

c. Internal rubs.

d. Gear-tooth meshing and side band frequencies, as well as other frequencies produced by inaccuracies in the generation of the gear teeth.

e. Coupling misalignment.

f. Loose rotor-system components.

g. Hysteretic and friction whirl.

h. Asynchronous whirl.

i. Electrical line frequency.

Notes:

1. The frequency of a potential source of excitation may be less than, equal to, or greater than the rotational speed of the rotor.
2. When the frequency of a periodic forcing phenomenon (excitation) applied to a rotor-bearing-support system coincides with a natural frequency of that system, the system will be in a state of resonance. A rotor-bearing-support-system in resonance may have the magnitude of its normal vibration amplified. The magnitude of amplification and, in the case of critical speeds, the rate of change of the phase-angle with respect to speed, are related to the amount of damping in the system.

2.8.2 Critical Speeds

• **2.8.2.1** The gear vendor shall provide a lateral critical speed analysis for any element operating at or above 7,200 r/min (3,000 r/min for overhung bevel gears) or if specified by the purchaser.

Note: Critical speeds are typically not a problem for gear elements operating at 3,700 r/min (1,800 r/min for overhung bevel gears) or below.

2.8.2.2 The vendor shall conduct an analysis to identify the undamped critical speeds and determine their mode shapes located in the range from 0% – 125% of trip speed.

2.8.2.3 At least three power levels shall be analyzed for the undamped analyses, and shall include the following:

a. The bearing-oil film, bearing structure at 10%, 50% and 100% gear unit rated power, and gear unit casing support structure stiffnesses.

b. The coupling weight to be supported by each gearbox shaft.

2.8.2.4 Unless otherwise specified, the results of the undamped analysis shall be furnished to the purchaser. The presentation of the results shall include:

a. Mode shape plots for all stiffness values specified in 2.8.2.3a (relative amplitude vs. axial position on the rotor).

b. Critical speed-support stiffness map (frequency vs. support stiffness). Superimposed on this map shall be the calculated system support stiffness; horizontal (kxx) and vertical (kyy).

2.8.2.5 Gear and bearing housing resonances shall not occur within the specified operating speed range or specified separation margins.

2.8.2.6 Three lateral critical speed modes are generally of concern with gear units: the cylindrical (translational or bouncing) mode, the conical (pivoted or rocking) mode, and the first bending mode. The frequency at which these modes occur will vary as a function of the transmitted load, primarily due to the resulting change of stiffness of the bearing-oil film (see Appendix B). The gear rotors shall meet the requirements given in 2.8.2.6.1 through 2.8.2.6.2.

2.8.2.6.1 When operating at the maximum torque, the three defined critical speeds of each rotor shall not be less than 20% above the maximum continuous speed of that rotor.

• **2.8.2.6.2** When the operating torque is in the range of 50% – 100% of the maximum torque, the separation margin above the maximum continuous speed of each rotor shall be 10% – 20% in proportion to the transmitted torque. Operating conditions at less than 50% of the maximum torque or less than 70% of maximum continuous speed shall be specified by the purchaser.

2.8.2.7 Slow-roll, start-up, and shutdown of rotating equipment shall not cause any damage as critical speeds are passed.

2.8.2.8 If the lateral critical speed as calculated or revealed during mechanical testing falls within the specified range of operating speeds or fails to meet the separation margin requirements after practical design efforts have been exhausted, the unit vendor shall demonstrate an insensitive rotor design. This insensitivity must be proven by operation on the test stand at the critical speed in question with the rotor unbalanced. The unfiltered vibration shall not exceed the limits specified in 2.8.4. Trip speed values may apply. During the sensitivity tests, the increment in vibration amplitude shall be based on the difference between the major axes of the orbits formed by synchronous x-y signals recorded during the balanced and unbalanced runs. Deflections of the rotor shall not exceed design rotor clearances or the allowable vibration limit specified in 2.8.4.2. The amount of rotor unbalance shall be calculated as follows:

In SI units:

$$UA = 2.5 \text{ (residual unbalance limit)}$$

$$UA = 2.5\ (6{,}350\ W/N)$$

In U.S. customary units:

$$UA = 2.5\ (4\ W/N)$$

where

UA = residual unbalance, in g-mm (oz-in.),

W = journal static weight load, in kg (lb),

N = maximum continuous speed, in r/min.

Modal analysis shall be used in the placement of the unbalance weights, as mutually agreed upon by the purchaser and the vendor.

• **2.8.2.9** If specified, the gear vendor shall supply to the driven-equipment vendor all necessary information for lateral and torsional vibration analyses. The driven-equipment vendor shall ensure that torsional modes of the complete unit shall be at least 10% below any operating speed or at least 10% above the trip speed or motor speed.

2.8.3 Balance

2.8.3.1 All gear elements shall be multiplane dynamically balanced after final assembly of the rotor. Rotors with single keys for couplings shall be balanced with half-keys in place. The maximum allowable residual unbalance per plane (journal) shall be calculated as follows:

In SI units:

$$U_{max} = 6{,}350\ W/N$$

In U.S. customary units:

$$U_{max} = 4\ W/N$$

where

U_{max} = residual unbalance, in 3-mm (oz-in.),

W = journal static weight load, in kg (lb),

N = maximum continuous speed, in r/min.

2.8.3.2 Balancing shall be done on a recently calibrated machine and accuracy shall be within prescribed limits of the balancing machine manufacturer. The balancing machine shall have suitable sensitivity for use with the gear elements.

• **2.8.3.3** If specified, after the final balancing of each assembled rotating element has been completed, a residual unbalance check shall be performed in accordance with the residual unbalance worksheet (see Appendix H).

2.8.4 Vibration

2.8.4.1 During the unloaded shop test of the assembled gear operating at its maximum continuous speed or at any other speed within the specified range of operating speeds, the vibration measured on the bearing caps shall not exceed the values given in Table 8.

Table 8—Casing Vibration Levels

	Velocity (rms)	Acceleration (true peak)
Frequency Range	10 Hz – 2.5 kHz	2.5 kHz – 10kHz
Overall	5 mm/s (0.2 in./s)	8 g's (g = 9.81 m/s^2) (g = 32.16 ft/s^2)
Discrete Frequencies	4 mm/s (0.15 in./s)	

Note: Discrete frequencies are to be determined from the FFT spectrum.

2.8.4.2 Where noncontacting vibration probes are specified, they shall be used during the shop test. In such cases, during the shop test of the assembled gear operating at maximum continuous speed or at any other speed within the specified operating speed range, the peak-to-peak amplitude of unfiltered vibration in any plane measured on the shaft adjacent to each radial bearing shall not exceed the following value or 50 µm (2 mils), whichever is less:

In SI units:

$$A = 25.4\ (12{,}000/N)^{0.5} \tag{8}$$

In U.S. customary units:

$$A = (12{,}000/N)^{0.5}$$

where

A = amplitude of unfiltered vibration, in µm (mils) true peak-to-peak,

N = maximum continuous speed, in r/min.

For variable speed drivers, the vibration shall not exceed the above values plus 12 µm (0.5 mil) at the trip speed. Mechanical and electrical runout for each probe area of each shaft shall be documented in accordance with API Std 670.

2.9 BEARINGS AND BEARING HOUSINGS

2.9.1 General

2.9.1.1 Radial and thrust bearings shall be of the hydrodynamic fluid film type or the oil-lubricated rolling element type.

Rolling element type bearings are subject to the limitations in Table 9.

Table 9—Maximum d_mN Numbers for Rolling Element Bearings

Type of Bearing	Method of Lubrication: Splash or Circulating Oil	Method of Lubrication: Pressurized Oil
Radial Bearings:		
Ball or Cylindrical Roller	450,000	500,000
Thrust/Radial Bearings:		
Tapered or Spherical Roller	300,000	350,000

Note: With d_m = mean bearing diameter = $(d + D)/2$ (mm) and N = shaft speed (r/min).

2.9.2 Radial Bearings

2.9.2.1 Hydrodynamic Radial Bearings

2.9.2.1.1 Hydrodynamic radial bearings shall be split for ease of assembly, precision bored, and of the sleeve or pad type, with steel-backed, babbitted replaceable liners, pads, or shells. These bearings shall be equipped with anti-rotation pins and shall be positively secured in the axial direction.

2.9.2.1.2 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 while the equipment is operating loaded or unloaded at specified operating speeds, including operation at any critical frequency.

2.9.2.1.3 The liners, pads, or shells shall be in axially split bearing housings and shall be replaceable without the removal of the coupling hub.

2.9.2.1.4 Bearings shall be designed to prevent incorrect positioning.

2.9.2.2 Rolling Element Bearings

2.9.2.2.1 Rolling element bearings shall be of a standard type and shall be selected to give six years (50,000 hours) minimum basic L_{10h} rating life per ISO 281, First Edition, 1990, with continuous operation at rated gear conditions but not less than 32,000 hours at maximum axial and radial loads and rated speed.

Note: The rating life is the number of hours at constant speed that 90% of a group of identical bearings will complete or exceed before the first evidence of failure.

2.9.2.2.2 Rolling element bearings shall be located, retained and mounted in accordance with the following:

a. Bearings shall be located on the shaft using shoulders, collars or other positive locating devices; snap rings and spring-type washers are not acceptable.
b. Bearings shall be retained on the shaft with an interference fit and fitted into the housing with a diametrical clearance, both in accordance with the recommendations of ABMA Standard 7.
c. Bearings shall be mounted directly on the shaft. Sleeves between the bearing and shaft are not acceptable.

2.9.2.2.3 Single row deep-groove ball bearings shall have greater than normal internal clearance according to ISO 5753 Group 3 (ABMA Symbol 3, as defined in ABMA Standard 20).

2.9.3 Thrust Bearings

2.9.3.1 General

2.9.3.1.1 Unless otherwise specified by the purchaser, thrust bearings shall be provided for all gear units.

2.9.3.1.2 Thrust bearings shall be sized for continuous operation under all specified operating conditions, including all external forces transmitted by the couplings. The external axial force transmitted by the coupling shall be considered as being numerically additive to any internal thrust forces.

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

2.9.3.1.4 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.

2.9.3.2 Hydrodynamic Thrust Bearings

2.9.3.2.1 Hydrodynamic thrust bearings shall be of the steel-backed, babbitt-faced type, designed for equal thrust capacity in both directions and arranged for continuous pressurized lubrication to each side. The maximum design criteria for babbit-faced hydrodynamic thrust bearings shall be 517 kPa (75 lbf/in.^{2}) for flat-faced thrust bearings and 1,034 kPa (150 lbf/in.^{2}) for tapered land thrust bearings.

2.9.3.2.2 Integral thrust collars are preferred for hydrodynamic thrust bearings. When integral thrust collars are furnished, they shall be provided with at least 3 mm ($^1/_8$ in.) of additional stock to enable refinishing if the collar is damaged. When replaceable collars are furnished (for assembly and maintenance purposes), they shall be positively locked to the shaft to prevent fretting.

2.9.3.2.3 Both faces of thrust collars for hydrodynamic thrust bearings shall have a surface finish of 0.4 µm (16 µin.) Ra, or better and after mounting the axial total indicated runout of either face shall not exceed 13 µm (0.5 mil).

2.9.3.3 Rolling Element Thrust Bearings

2.9.3.3.1 If ball-type thrust bearings are used, they shall be of the duplex, single-row, 0.7 radian (40-degree), angular-contact type (7,000 series), installed back to back. The need for preload shall be determined by the vendor to suit the application and meet the bearing life requirements of 2.9.2.2.1.

2.9.4 Bearing Housings

2.9.4.1 In this standard, the term bearing housing refers to all bearing enclosures, including the gear casing.

2.9.4.2 Bearing housings for pressure-lubricated hydrodynamic bearings shall be designed to minimize foaming. The drain system shall be adequate to maintain the oil and foam level below shaft end seals.

2.9.4.3 Gaskets shall not be used on housing end covers where the gasket thickness would affect the end play or clearance of the thrust bearing.

2.9.4.4 Bearing housings shall preferably be equipped with replaceable labyrinth-type end seals and deflectors where the shaft passes through the housing. With purchaser’s approval, lip-type seals may be used for shaft speeds at the seal area not exceeding 4 m/s (800 ft/min). The seals and deflectors shall be made of non-sparking materials. The design of the seals and deflectors shall effectively retain oil in the housing and prevent entry of foreign material into the housing.

- **2.9.4.5** If specified, bearing housings shall be designed to accommodate non-contacting vibration and axial position probes in accordance with API Std 670.

- **2.9.4.6** If specified, bearing housings shall be designed to mount acceleration or velocity transducers in accordance with API Std 670.

2.10 LUBRICATION

2.10.1 This section covers the following types of lubrication systems for enclosed gear drives:

a. Circulating (for increased thermal capacity).
b. Pressurized (to accommodate higher speeds).
c. Combined (with the driver and/or other driven equipment).

The vendor with unit responsibility shall provide a lubrication system that supplies sufficient lubrication for reliable operation.

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

Note: Synthetic lubricants may have advantages over mineral oils, particularly in certain classes of machinery operating at high temperatures and/or high pressures. A bearing designed for synthetics may not run properly on mineral oil lubricants due to cooling and space considerations. A user would need a relatively sophisticated inventory control system to prevent inadvertent mixing of mineral oils and synthetics which are chemically incompatible. Synthetic lubricants may also be incompatible with certain paints, coatings, and elastomers, and they may be difficult to dispose of.

2.10.3 Unless otherwise specified, pressurized oil systems shall conform to the requirements of API Std 614 Chapter 3 and Table 10 in 3.4. (See Appendix C for a typical pressurized lube-oil system and circulating oil system schematic.)

2.10.4 Where oil is supplied from a common system to two or more components of a machinery train (such as a compressor, a gear, and a motor), the vendor having unit responsibility shall ensure compatibility of type, grade, pressure and temperature of oil for all equipment served by the common system.

Note: The usual lubricant employed in common oil systems for turbomachinery trains is a mineral oil that corresponds to ISO 3448 Grade 32. However, at lower pitchline velocities higher viscosity grade oils may be required for gearboxes. Compatibility of lube-oil requirements needs to be mutually agreed among the user and all vendors supplying equipment served by the common system. In some cases there can be significant differences in individual component needs. For example, a refrigeration compressor may need low pour point oil, a gear may need high viscosity and a turbine may need a conventional mineral oil. In such cases it may be necessary to change the design of a component or to provide separate oil systems.

- **2.10.5** Where a wide variable speed range is anticipated (such as is encountered with continuous slow-roll operation), these speeds shall be specified, and lubrication of the gear unit shall be given special consideration.

2.10.6 The gear unit shall be designed to limit the drain-oil or sump temperature to 80°C (180°F). The oil inlet temperature for pressurized or circulating systems shall not exceed 50°C (120°F).

2.10.7 Oil flinger disks or oil rings shall have an operating submergence of 3.0 mm – 6.5 mm ($^1/_8$ in. – $^1/_4$ in.) above the lower edge of a flinger or above the lower edge of the bore of an oil ring. Oil flingers shall have mounting hubs to maintain concentricity and shall be positively secured to the shaft.

2.10.8 If specified, where a pressurized or circulating lubrication system is required by the driver and/or driven equipment, the gear oil may be supplied from that system.

2.11 MATERIALS

2.11.1 General

2.11.1.1 Except as required or prohibited by this standard or by the purchaser, materials of construction shall be selected by the manufacturer for the operating and site environmental conditions specified.

2.11.1.2 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 standards, including the material grade (see Appendix D). 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.

• **2.11.1.3** The vendor shall specify the optional tests and inspection procedures that may be necessary to ensure that materials are satisfactory for the service. Such tests and inspections shall be listed in the proposal.

Note: The purchaser may specify additional optional tests and inspections.

2.11.1.4 Materials used in gear wheel and pinion teeth shall be selected to meet the tooth pitting index and strength criteria outlined in 2.4. In selecting the material, the vendor shall consider whether the gear and pinion are to be through-hardened, carburized or nitrided. The material quality of gear teeth will, as a minimum, conform to ISO 6336-5 material quality grade MQ.

2.11.2 Welding

2.11.2.1 Welding of piping, pressure-containing parts, rotating parts and other highly stressed parts, weld repairs and any dissimilar-metal welds shall be performed and inspected by operators and procedures qualified in accordance with Section VIII, Division 1, and Section IX of the ASME Code.

2.11.2.2 All welds shall be continuous full-penetration welds. All welds shall be double welded, except when only one side is accessible; in such instances, a backup ring, a consumable insert, or an inert gas shield with an internal gas purge backup shall be used.

2.11.2.3 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.

2.11.2.4 Repair welding in the area of the gear teeth is prohibited.

2.11.3 Heat Treatment

2.11.3.1 After through-hardened gear materials have been rough machined to the approximate final contour of the blank and heat treated, the tooth area shall be checked for proper hardness. After surface-hardened gear material have been completely heat treated the surface hardness and case depth shall be checked on a representative coupon of suitable size that has accompanied the part during all heat treat processes.

2.11.3.2 Casings, whether of cast or fabricated construction, shall be stress-relieved before final machining and after any welding, including repairs.

2.11.4 Castings

• **2.11.4.1** The vendor shall specify on the data sheets the material grade of the castings.

2.11.4.2 Castings shall be sound and free from porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters, and other similar injurious defects. Surfaces of castings shall be cleaned by sandblasting, shot blasting, chemical cleaning, or any other standard method. Mold-parting fins and remains of gates and risers shall be chipped, filed, or ground flush.

2.11.4.3 Fully-enclosed cored voids, including voids closed by plugging, are prohibited.

2.12 NAMEPLATES AND ROTATION ARROWS

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

2.12.2 Rotation arrows shall be cast in or attached at a readily visible location. Nameplates and rotation arrows (if attached) shall be of AISI Standard Type 300 stainless steel or of nickel-copper alloy (Monel or its equivalent). Attachment pins shall be of the same material. Welding is not permitted.

2.12.3 The following data shall be clearly stamped on the nameplate:

a. The vendor's name.
b. The size and type of the gear unit.
c. The gear ratio.
d. The serial number.
e. The gear-rated power.
f. The rated input speed, in r/min.

g. The rated output speed, in r/min.
h. The gear service factor, as defined in this standard.
i. The purchaser's item number.
j. ISO 3448 lubricant viscosity grade.

3 Accessories

• 3.1 GENERAL

The purchaser shall specify on the data sheets the accessories to be supplied by the vendor.

3.2 COUPLINGS AND GUARDS

3.2.1 Unless otherwise specified, non-lubricated flexible element couplings and guards between drivers and driven equipment shall be supplied by the manufacturer of the driven equipment.

3.2.2 The power rating of the coupling-to-shaft juncture shall be at least equal to the driver's rated power times the coupling service factor for the application per AGMA 9002. The make, type, and mounting arrangement of the couplings shall be agreed upon by the purchaser and the vendors of the driver and driven equipment. A spacer coupling with a minimum 125-mm (5-in.) spacer shall be used, unless otherwise specified. Couplings shall be forged steel and designed to allow the necessary end float caused by expansion and other end movements of the shaft and shall meet the requirements of API Std 671.

3.2.3 Information on shafts, key way dimensions (if any), and shaft end movements due to end play and thermal effects shall be furnished to the vendor supplying the coupling.

• **3.2.4** Flexible coupling hubs shall be keyed to the shaft. Keys, key ways, and fits shall conform to AGMA 9002, Commercial Class. Flexible couplings with cylindrical bores shall have the interference fit specified in ISO/R286, Tolerance N8, and shafting in accordance with ISO/ R755 (AGMA 9002). If specified for shaft diameters greater than 64 mm (2.5 in.), the hub shall be mounted with a taper fit. Taper for keyed couplings shall be 1 in 10 long series conical in accordance with ISO/R755 or alternately 1 in 16 (0.75 in./ft., Diametral). Other mounting methods shall be agreed upon by the purchaser and the vendor. Coupling hubs shall be furnished with tapped puller holes at least 10 mm ($^3/_8$ in.) in size to aid in removal.

Note: Appropriate assembly and maintenance procedures must be used to assure that taper fit coupling have an interference fit.

3.2.5 To assure accurate alignment of connected machinery, the total indicator reading of coupling registration and alignment surfaces shall be controlled as specified in 3.2.5.1 and 3.2.5.2.

3.2.5.1 The coupling surfaces normally used for checking alignment shall be concentric to the axis of coupling hub rotation within the following limits: 13 µm (0.5 mils) TIR per 25 mm (1 in.) of shaft diameter, with a minimum applicable tolerance of 25 µm (1 mil) TIR and a maximum of 75 µm (3 mils) TIR. All other diameters not used for location, registration, or alignment shall conform to the coupling manufacturer's standard, provided that dynamic balance requirements are met.

3.2.5.2 The shaft end shall be machined such that when the coupling is mounted the run out of the coupling shall not exceed the limits of 3.2.5.1.

3.2.6 An easily removable coupling guard shall be placed over all exposed couplings furnished by the vendor. The coupling guard shall be of sufficiently rigid design to withstand deflection and consequent rubbing as a result of bodily contact and shall extend to within 13 mm (0.5 in.) of the stationary housing.

3.3 MOUNTING PLATES

3.3.1 General

3.3.1.1 Unless otherwise specified, the gear unit shall be furnished for mounting on a baseplate.

3.3.1.2 In 3.3.1.2.1 through 3.3.1.2.10, the term mounting plate refers to both baseplates and soleplates.

3.3.1.2.1 The surfaces on which the gear mounts (mounting pads) and the multiple mounted pads on the baseplate shall be machined coplanar within 50 µm (2 mils).

3.3.1.2.2 The mounting plate or plates shall be furnished with horizontal (axial and lateral) jackscrews, the same size or larger than the vertical jackscrews. The lugs holding these jackscrews shall be attached to the mounting plates in such a manner that they do not interfere with the installation of the equipment, jackscrews or shims. Precautions shall be taken to prevent vertical jackscrews in the equipment feet from marring the shimming surfaces. If the equipment is too heavy to use jackscrews, other means shall be provided.

3.3.1.2.3 Machinery supports shall be designed to limit the relative displacement of the shaft end caused by the worst combination of pressure, torque and allowable piping stress, to 50 µm (2 mils).

3.3.1.2.4 Mounting plates shall contain the following:

a. Mounting plates shall not be drilled for equipment to be mounted by others.
b. Mounting plates shall be supplied with leveling screws.
c. Outside corners of mounting plates which are in contact with the grout shall have 50 mm (2 in.) minimum radiused outside corners (in the plan view).
d. All machinery mounting surfaces shall be treated with a rust preventive immediately after machining.
e. Mounting plates shall extend at least 25 mm (1in.) beyond the outer three sides of the equipment feet.
f. Mounting plates shall be machined to a finish of 63 µm (250 µin) arithmetic average roughness (Ra) or better.

Note:
1. Item c: Radiused corners are recommended to prevent the potential of cracking the grout.
2. Item e: This requirement allows handing of shims and mounting level or laser type instruments to check alignment.

3.3.1.2.5 The vendor shall blast-clean all grout contact surfaces of the mounting plates in accordance with ISO 8501 Grade Sa2 (SSPC SP6), and coat those surfaces with a grout-compatible coating in preparation for epoxy grout.

3.3.1.2.6 Anchor bolts shall not be used to fasten machinery to the mounting plates. There shall be a 6 mm ($^1/_4$ in.) diametrical clearance between the anchor bolts and the anchor bolt holes in the mounting plate.

3.3.1.2.7 Unless otherwise specified, anchor bolts will be furnished by the purchaser.

3.3.1.2.8 When the mounting plate is supplied by the vendor, the vendor shall also supply hold-down bolts used to attach the equipment to the mounting plates and all jackscrews.

3.3.1.2.9 Equipment shall be designed for installation in accord with API RP 686.

3.3.1.2.10 The alignment shims shall be provided by the vendor in accordance with API RP 686 Chapter 7 and shall straddle the hold-down bolts and vertical jackscrews and be at least 6 mm ($^1/_4$ in.) larger on all sides than the equipment feet. Gearbox manufacturer shall specify the minimum shim contact area required.

• **3.3.1.3** If specified, the baseplate shall be suitable for column mounting (that is, of sufficient rigidity to be supported at specified points) without continuous grouting under structural members. The baseplate design shall be mutually agreed upon by the purchaser and the vendor.

3.3.1.4 The baseplate shall be provided with lifting lugs for a four-point lift. Lifting the baseplate complete with all equipment mounted shall not permanently distort or otherwise damage the baseplate or the equipment mounted on it.

3.3.1.5 The bottom of the baseplate between structural members shall be open. When the baseplate is installed on a concrete foundation, it shall be provided with at least one grout hole having a clear area of at least 0.01 m^2 (19 in.^{2}) and no dimension less than 75 mm (3 in.) in each bulkhead section. These holes shall be located to permit grouting under all load-carrying structural members. Where practical, the holes shall be accessible for grouting with the equipment installed. The holes shall have 15-mm ($^1/_2$-in.) raised-lip edges, and if located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of 16 gauge shall be provided. Vent holes at least 15-mm ($^1/_2$-in.) in size shall be provided at the highest point in each bulkhead section of the baseplate.

3.3.1.6 Unless otherwise specified, nonskid metal decking covering all walk and work areas shall be provided on the top of the baseplate.

3.3.1.7 All baseplate mounting surfaces shall meet the following criteria:

a. Surfaces shall be machined after the baseplate is fabricated to a finish of 63 µm (250 µin.) Ra or better.
b. Surfaces shall be in the same horizontal plane within 25 µm (1 mil) to prevent a soft foot.
c. Each mounting surface shall be machined within a flatness of 42 µm per m (0.5 mils/linear ft) of mounting surface.
d. With different mounting planes, mounting surfaces shall be parallel to each other within 50 µm (2 mils).

e. The upper machined or spot faced surface shall be parallel to the mounting surface.
f. Hold-down bolts shall be drilled perpendicular to the mounting surface or surfaces; machined or spot faced to a diameter three times that of bolt and to allow for equipment alignment; and shall be 15 mm ($^1/_2$ in.) larger in diameter than the hold-down bolt.

The above tolerances shall be recorded and verified by inspection in unrestrained condition on a flat machined surface at the place of manufacture.

Note: The surfaces being discussed are those on which the equipment is mounted and on the bottom of the baseplate.

• **3.3.1.8** If specified, sub-sole plates shall be provided by the vendor.

3.4 CONTROLS AND INSTRUMENTATION

3.4.1 General

3.4.1.1 Unless otherwise specified, controls and instrumentation shall be designed for outdoor installation and shall meet the requirements of IP65 as detailed in IEC 60034-5 (NEMA Publication 250).

3.4.1.2 Instrumentation and installation for gearbox manufacturer supplied oil systems for gearboxes and auxiliaries such as general-purpose turbines shall conform to the purchaser's specifications. Unless otherwise specified, instrumentation and installation shall conform to the requirements of API Std 614 for general-purpose oil systems and shall include the items indicated for the applicable system in Appendix C.

3.4.1.3 Instrumentation and controls shall be designed and manufactured for use in the area classification (class, group, and division or zone) specified.

3.4.1.4 Thermometers, thermocouples, or resistance temperature detectors, as specified by the purchaser, shall be provided.

3.4.1.5 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.

• 3.4.2 Vibration and Position Detectors

If specified, vibration and axial-position transducers shall be supplied, installed and calibrated in accordance with API Std 670.

3.5 PIPING AND APPURTENANCES

3.5.1 Unless otherwise specified, lube-oil piping and appurtenances shall conform to the requirement of API Std 614 Chapter 1 and 3.

3.5.2 The vendor shall include in the quotation all integral piping considered necessary for the successful operation of the gear unit or units, as well as all integral piping in accordance with Appendix C and items indicated on the data sheets.

3.6 SPECIAL TOOLS

3.6.1 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 purchase and the vendor. These or similar special tools shall be used during shop assembly and post-test disassembly of the equipment.

3.6.2 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.

4 Inspection, Testing, and Preparation for Shipment

4.1 GENERAL

4.1.1 The vendor shall provide sufficient advance notice to the purchaser before conducting any inspection and test outlined in the purchase order or other agreements. After advance notification of the vendor by the purchaser, the purchaser's representative shall have entry to all vendor plants and sub vendor plants where manufacturing, testing, or inspection of the equipment is in progress. It shall be the responsibility of the vendor to notify subvendors of the purchaser's inspection requirements.

4.1.2 In each instance, the actual number of calendar days for notification prior to inspection shall be established by mutual consent of the purchaser and the vendor.

• **4.1.3** The purchaser shall specify the extent of his/her participation in the inspection and testing.

a. Witnessed means that a hold shall be applied to the production schedule and that the inspection or test shall be carried out with the purchaser or his/her representative in attendance. For mechanical running or performance tests, this requires written notification of a successful preliminary test.
b. Observed means that the purchaser will be notified of the timing of the inspection or test; however, the inspection or test is performed as scheduled, and if the purchaser or his/her representative is not present, the vendor shall proceed to the next step. (The purchaser should expect to be in the factory longer than for a witnessed test.)

4.1.4 Equipment for the specified inspection and tests shall be provided by the vendor.

4.1.5 During assembly of the gear and oil system and before testing, each component (including cast-in passages of these components) and all piping and appurtenances shall be cleaned by pickling or by another appropriate method to remove foreign materials, corrosion products, and mill scale.

• **4.1.6** If specified, the purchaser may inspect for cleanliness of the equipment and all piping and appurtenances furnished by or through the vendor before piping is finally assembled.

• **4.1.7** If specified, the hardness of parts, welds, and heat-affected zones shall be verified as being within the allowable values by testing of the parts, welds, or heat-affected zones. The method, extent, documentation, and witnessing of the testing shall be mutually agreed upon by the purchaser and the vendor.

4.1.8 The purchaser's representative shall have access to the vendor's quality control program for review.

4.2 INSPECTION

4.2.1 General

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

a. Necessary or specified certification of materials, such as mill test reports.
b. Test data and results to verify that the requirements of the specification have been met.
c. Fully identified records of all heat treatment whether performed in the normal course of manufacture or as part of a repair procedure.
d. Results of all quality control tests and inspections.
e. Details of all repairs.
f. Final assembly, maintenance, and running clearances.
g. Gear and bearing rating calculations.
h. Other data specified by the purchaser or required by applicable codes and regulations.

4.2.1.2 Pressure-containing parts shall not be painted until specified inspection of the parts is complete.

4.2.1.3 The purchaser may specify the following:

a. Parts that shall be subjected to surface and subsurface examination.
b. The type of examination required, such as magnetic particle, liquid penetrant, radiographic, and ultrasonic.

4.2.2 Material Inspection

4.2.2.1 General

4.2.2.1.1 When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the recommended practices in 4.2.2.2 through 4.2.2.5 shall apply unless other corresponding procedures and acceptance criteria have been specified. Cast iron may be inspected only in accordance with 4.2.2.4 and/or 4.2.2.5. Welds, cast steel, and wrought material shall be inspected in accordance with 4.2.2.2 through 4.2.2.5.

Note: Radiographic and ultrasonic inspection are not appropriate for cast iron due to differences in accurate interpretation.

4.2.2.1.2 Acceptance standards for 4.2.2.2 through 4.2.2.5 shall be mutually agreed upon by the purchaser and vendor.

4.2.2.2 Radiography

4.2.2.2.1 Radiography shall be in accordance with ASTM E 94.

4.2.2.3 Ultrasonic Inspection

4.2.2.3.1 Ultrasonic inspection shall be based upon the procedures ASTM A 609 (castings), ASTM A 388 (forgings), or ASTM A 578 (plate).

4.2.2.4 Magnetic Particle Inspection

4.2.2.4.1 Both wet and dry methods of magnetic particle inspection shall be in accordance with ASTM E 709.

4.2.2.5 Liquid Penetrant Inspection

4.2.2.5.1 Liquid penetrant inspection shall be based upon the procedures of ASTM E 165.

4.2.2.6 Regardless of the generalized limits in 4.2, the vendor shall be responsible for the review of the design limits of the equipment in the event that more stringent requirements are necessary.

4.2.2.7 Defects that exceed the limits agreed to by the vendor and purchaser shall be removed to meet the agreed to quality standard.

4.2.2.8 Welds in Fabricated Rotating Elements

4.2.2.8.1 All welds in rotating elements, including those attaching gears to shafts, shall receive 100% inspection. Accessible surfaces of welds shall be inspected on completion and again after final post weld heat treatment. Magnetic particle inspection is preferred. Other methods, such as dye penetrant, ultrasonic, or radiography, are acceptable only as mutually agreed upon by the purchaser and the vendor.

4.2.2.8.2 Indications less than 1.5 mm (0.06 in.) are not interpretable. Nonrelevant indications may be present, such as caused by flux leakage at the depression at the side of a weld or particles attached to rust or scale. Relevant indications 1.5 mm (0.06 in.) or greater may be removed by grinding and feathering if material removal does not impair the function of the welded area. Indications requiring weld repair shall be reported to the purchaser. A retest shall be performed after any weld repair.

4.2.2.9 Material Inspection for Rotating Elements

4.2.2.9.1 Forgings and hot rolled bar stock used for rotating elements shall be free from cracks, seams, laps, shrinkage, and other similar injurious defects.

• **4.2.2.9.2** If specified, ultrasonic inspection of forgings and hot rolled bar stock for rotating elements shall be performed. Indications producing a “peaked” signal greater than 2 mm (0.08 in.) FBH (flat-bottom hole) are unacceptable. Traveling flaws or groups of flaws with centers within 20 mm (0.8 in.) or less of each other and giving a peaked signal greater than 2 mm (0.08 in.) FBH are unacceptable. However, centerline pipe may be acceptable provided it is within 10% of the shaft diameter, its cumulative length does not exceed 20% of the length of any section of constant outside diameter, and its peaked signal does not exceed 3 mm (0.1 in.) FBH and they are not clustered indications of five or more in a 40 mm (1.6 in.) or smaller cube.

• **4.2.2.9.3** If specified, wet (fluorescent) magnetic particle inspection of gear teeth and shaft surfaces shall be performed. Any fluorescent magnetic particle indications less than 1.5 mm (0.06 in.) are not interpretable. Any crack indication on flanks or roots of gear teeth or on stress carrying shaft surfaces is unacceptable. Any nonmetallic inclusion greater than 40 mm (1.6 in.) in length is unacceptable. Other nonmetallic inclusions will be evaluated and disposition will be agreed to by vendor and purchaser. It is acceptable to use dye penetrant inspection to help confirm if an indication is a crack or a nonmetallic inclusion.

4.2.2.10 Inspection of Gear Casing

• **4.2.2.10.1** If specified, dry magnetic particle inspection of gear casings shall be performed to check oil tightness. Indications less than 1.5 mm (0.06 in.) are not interpretable. Nonrelevant indications may be present, such as caused by flux leakage at the depression at the side of a weld or particles attached to rust or scale. Relevant indications 1.5 mm (0.06 in.) or greater may be removed by grinding and feathering if material removal does not impair the function of the welded area. Indications requiring weld repair shall be reported to the purchaser. A retest shall be performed after any weld repair.

Note: Gear casings are normally not pressure containing vessels and do not require testing to verify pressure capability.

• **4.2.2.10.2** If specified, the gear casing shall be given a fluid fill leak check to test for oil tightness. Casing interior and exterior shall not be painted prior to the test. Test is performed by blocking all openings in the casing and filling the casing with a low viscosity fluid such as kerosene. After a 1-hour soak period, any evidence of leakage through the casing shall be considered unacceptable.

4.2.2.11 Inspection of Babbitt Lined Journal Bearings

• **4.2.2.11.1** If specified steel backed babbitt lined journal bearings shall be inspected to verify the bond between the steel backing material and the babbitt lining. Ultrasonic inspection may be specified and/or liquid penetrant inspection of any exposed interface surfaces may be specified.

4.3 TESTING

4.3.1 General

4.3.1.1 Gears shall be tested in accordance with 4.3.2 and 4.3.3. Other tests that may be specified by the purchaser are described in 4.3.4.

• **4.3.1.2** The purchaser reserves the right to observe the testing, dismantling, inspection, and reassembly of equipment, as specified. The purchaser shall specify tests that will be witnessed.

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

4.3.1.4 At least six weeks before the first scheduled running test, the vendor shall submit to the purchaser, for his/her review and comment, detailed procedures for the mechanical running test and all specified running optional tests (see 4.3.4), including acceptance criteria for all monitored parameters.

4.3.1.5 Test-stand oil filtration shall be in accordance with 2.10.3. Oil system components downstream of the filters shall meet the cleanliness requirements of API Std 614 before any test is started.

4.3.1.6 Bearings intended to be lubricated by an oil mist system shall be pre-lubricated.

4.3.2 Pressure Test

4.3.2.1 Pressurized oil systems and associated piping shall be tested either hydrostatically or dynamically with liquid at a minimum of 1.5 times the maximum allowable working pressure but not less than 1.4 bar gauge (20 lbf/in.^{2} gauge). The test liquid should be at a minimum temperature of 15.6°C (60°F) when testing carbon steels.

4.3.2.2 Tests shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The test shall be considered satisfactory when no leaks are observed for a minimum of 30 minutes.

4.3.3 Mechanical Running Test

4.3.3.1 The mechanical running test of the gear shall be conducted by operating at maximum continuous speed for not less than 1 hour after bearing temperature and lube-oil temperatures have stabilized for three consecutive readings taken five minutes apart.

• **4.3.3.2** If specified, an extended mechanical running test of the gear shall be conducted in the following sequence:

a. The gear shall be operated at maximum continuous speed for four hours after bearings and lube-oil temperatures have stabilized.

b. The speed shall be increased to 110% of maximum continuous speed and run for a minimum of 15 minutes.

c. Testing at any additional speeds, the duration of testing at each speed, and the data to be recorded will be specified by the purchaser at the time of the purchase.

4.3.3.3 The requirements of 4.3.3.3.1 through 4.3.3.3.6 shall be met before the mechanical running test is performed.

4.3.3.3.1 The contract bearings shall be used in the machine for the mechanical running test.

4.3.3.3.2 All oil flows, pressures, viscosities, and temperatures shall be within the range of operating values recommended in the vendor's operating instructions for the specific unit being tested.

4.3.3.3.3 All joints and connections shall be checked for tightness and any leaks shall be corrected.

4.3.3.3.4 All warning, protective and control devices used during the test shall be checked and adjusted, as required.

• **4.3.3.3.5** Testing with the contract coupling or couplings is preferred. If this is not possible, mass shall be added to the shaft end or ends (using moment simulators in accordance with API Std 671, such that the effective overhanging moment is not less than 10% greater than the effective moment with the contract coupling.

If specified, after all testing is completed, the idling adapters shall be furnished to the purchaser as part of the special tools.

4.3.3.3.6 The mechanical running tests shall be made with a job lube system, if such a system has been purchased with the gear unit or units.

4.3.3.4 During the running tests, the mechanical operation of all equipment being tested and the operation of the test instrumentation shall be satisfactory. The measured unfiltered vibration shall not exceed the limits of 2.7.2.5 and 2.8.4 and shall be recorded throughout the testing speed range.

4.3.3.5 Vibration measurements shall be made with a recently calibrated measuring device operating within its frequency range, which shall include the frequency range covered in 2.8.4.1.

4.3.3.6 All purchased vibration probes and oscillation-demodulators shall be in use during the tests. If vibration probes are not furnished by the vendor or the purchased probes are not compatible with shop readout facilities, then shop probes and readouts that meet the accuracy requirements of API Std 670 shall be used. Runout, with phase angle reference, should be measured at 500 r/min or less and recorded in the mechanical test report.

4.3.3.7 After the mechanical running tests are completed, the tooth mesh shall be inspected for surface damage and proper contact pattern. (See 2.7.2.1 for contact-pattern acceptance criteria.)

• **4.3.3.8** If specified, all hydrodynamic bearings shall be removed, inspected, and reassembled after the mechanical running tests are completed.

4.3.3.9 If replacement or modification of bearings or seals or dismantling of the case to replace or modify other parts is required to correct mechanical or performance deficiencies, the initial test will not be acceptable, and the final shop tests shall be run after these replacements or corrections are made.

4.3.3.10 When spare gear elements are ordered to permit concurrent manufacture, each spare element shall also be given mechanical running tests in accordance with the requirements of this standard.

4.3.3.11 The vendor shall keep a detailed log of the final tests, making entries at 15-minute intervals for the duration of the tests. Each entry shall include the following information:

a. Oil temperatures and inlet pressures.
b. Outlet oil (drain) temperature, when available.
c. Vibration amplitude, unfiltered and filtered 1 time for operating speed of each rotor.
d. Bearing temperatures (when measurements are available).

• 4.3.4 Optional Tests

The purchaser shall specify in the inquiry or in the order whether any of the shop tests specified in 4.3.4.1 through 4.3.4.2 shall be performed.

4.3.4.1 Full-speed/Full- or Part-load Test

The gear unit shall be tested to transmit partial or full-rated power, as agreed upon by the purchaser and the vendor, at its rated input speed. The load shall be applied by a mechanical or hydraulic method (such as dynamometers and pony brakes) until the bearing temperatures and lube-oil temperatures have stabilized. Details of the test, including vibration limits, shall be negotiated before the order.

4.3.4.2 Sound-level Test

The vendor shall provide typical noise data at rated load conditions. The data can be developed by test or analytical methods. If specified, a sound-level test shall be performed in accordance with AGMA 6025-D98 or other agreed standard such as ISO 3744.

4.4 PREPARATION FOR SHIPMENT

• **4.4.1** Equipment shall be prepared for the type of shipment specified, including blocking of the rotor when necessary. Blocked rotors shall be identified by means of corrosion resistant tags attached with stainless steel wire. The preparation shall make the equipment suitable for six months of outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings and seals. If storage for a longer period is contemplated, the purchaser will consult with the vendor regarding the recommended procedures to be followed.

4.4.2 The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up, as described in Chapter 3 of API RP 686.

4.4.3 The equipment shall be prepared for shipment after all testing and inspection have been completed and the equipment has been released by the purchaser. The preparation shall include that specified in 4.4.3.1 through 4.4.3.11.

4.4.3.1 Except for machined surfaces, all exterior surfaces that may corrode during shipment, storage or in service, shall be given at least one coat of the manufacturer's standard paint. The paint shall not contain lead or chromates.

Note: Austenitic stainless steels are typically not painted.

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

4.4.3.3 The interior of the gear unit shall be clean; free from scale, welding spatter and foreign objects; and sprayed or flushed with a rust preventive that can be removed with solvent. The rust preventive shall be applied through all openings while the rotor is rotated.

4.4.3.4 Internal surfaces of bearing housings and carbon steel oil systems' components shall be coated with an oil-soluble rust preventive that is compatible with the lubricating oil.

4.4.3.5 Flanged openings shall be provided with metal closures at least 5-mm ($^{3}/_{16}$-in.) thick with elastomer gaskets and at least four full-diameter bolts. For studded openings, all nuts needed for the intended service shall be used to secure closures. Each opening shall be car sealed so that the protective cover cannot be removed without the seal being broken.

4.4.3.6 Threaded openings shall be provided with steel caps or round-head steel plugs. In no case shall non-metallic (such as plastic) caps or plugs be used.

Note: These are shipping plugs; permanent plugs are covered in 2.6.2.2.

4.4.3.7 Lifting points and lifting lugs shall be clearly identified on the equipment or equipment package. The recommended lifting arrangement shall be described in the installation manual.

4.4.3.8 The equipment shall be identified with item and serial numbers. Material shipped separately shall be identified with securely affixed, corrosion-resistant metal tags indicating the item and serial number of the equipment for which it is intended. Crated equipment shall be shipped with duplicate packing lists, one inside and one on the outside of the shipping container.

• **4.4.3.9** Spare gear elements, if purchased, shall be prepared for unheated indoor storage for a period of at least 3 years. The gear set shall be treated with a rust preventive and shall be housed in a vapor-barrier envelope with a slow-release volatile-corrosion inhibitor. The gear shall be crated for domestic or export shipment, as specified. A purchaser-approved resilient material 3-mm ($^{1}/_{8}$-in.) thick (not tetrafluoroethylene [TFE] or polytetrafluoroethylene [PTFE]) shall be used between the rotor and the cradle at the support areas. The rotor shall not be supported on journals. If designed for vibration probes, mark the probe target area barriers with the words "Probe Area—Do Not Cut." When specified, the rotor shall be prepared for vertical storage. It shall be supported from its coupling end with a fixture designed to support 1.5 times the rotor's weight without damaging the shaft. Instructions on the use of the fixture shall be included in the installation, operation and maintenance manuals.

Note: TFE and PTFE are not recommended as cradle support liners since they cold flow and impregnate into the surface.

4.4.3.10 Critical shaft areas such as journals, end seal areas, probe target areas, and coupling fit areas shall be protected with a corrosion barrier followed by a separate barrier material to protect against incidental mechanical damage.

4.4.3.11 Loose components shall be dipped in wax or placed in plastic bags and contained by cardboard boxes. Loose boxes are to be securely blocked in the shipping container.

4.4.4 Auxiliary piping connections furnished on the purchased equipment shall be impression stamped or permanently tagged to agree with the vendor's connection table or general arrangement drawing. Service and connection designations shall be indicated.

4.4.5 Bearing assemblies shall be fully protected from the entry of moisture and dirt. If vapor-phase-inhibitor crystals in bags are installed in large cavities to absorb moisture, the bags must be attached in an accessible area for ease of removal. Where applicable, bags shall be installed in wire cages attached to flanged covers and bag locations shall be indicated by corrosion-resistant tags attached with stainless steel wire.

4.4.6 One copy of the manufacturer's standard installation instructions shall be packed and shipped with the equipment.

4.4.7 Connections on auxiliary piping, removed for shipment, shall be match-marked for ease of reassembly.

• **4.4.8** If specified, the fit-up and assembly of machine-mounted piping, intercoolers, etc., shall be completed in the vendor's shop prior to shipment.

5 Vendor's Data

5.1 GENERAL

5.1.1 The information to be furnished by the vendor is specified in 5.2 and 5.3. The vendor shall complete and forward the Vendor Drawing and Data Requirements (VDDR) form (see Appendix E) to the address or addresses noted on the inquiry or order. This form shall detail the schedule for transmission of drawings, curves, and data as agreed to at the time of the order, as well as the number and type of copies required by the purchaser.

5.1.2 The data shall be identified on transmittal (cover) letters and in title blocks or title pages with the following information:

a. The purchaser/user's corporate name.
b. The job/project number.
c. The equipment item number and service name.
d. The inquiry or purchase order number.
e. Any other identification specified in the inquiry or purchase order.
f. The vendor's identifying proposal number, shop order number, serial number, or other reference required to identify return correspondence completely.

5.2 PROPOSALS

5.2.1 General

The vendor shall forward the original proposal and the specified number of copies to the addressee specified in the inquiry documents. As a minimum, the proposal shall include the data specified in 5.2.2 through 5.2.4, as well as a specific statement that the system and all its components are in strict accordance with this standard. If the system and components are not in strict accordance, the vendor shall provide details to enable the purchaser to evaluate any proposed alternative designs. All correspondence shall be clearly identified in accordance with 5.1.2.

5.2.2 Drawings

5.2.2.1 The drawings indicated on the vendor drawings and data requirement form (see Appendix E) shall be included in the proposal. If typical drawings, schematics, and bills of material are used, they shall be marked to indicate the applicable weight and dimension data and to reflect the actual equipment and scope proposed. As a minimum, the following data shall be furnished:

a. An outline drawing for the system showing overall dimensions, maintenance clearance dimensions, overall weights, and the direction of rotation.
b. Cross-sectional drawings showing the details of the proposed equipment.
c. Schematics of all auxiliary systems such as lube-oil, which are in the vendor's scope of supply.

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5.2.3 Technical Data

The following data shall be included in the proposal:

a. The purchaser's data sheets, with complete vendor's information entered thereon.

b. Noise data sheet in the form requested by the purchaser.

c. The VDDR form (see Appendix E) indicating the schedule according to which the vendor agrees to transmit all the data specified as part of the contract.

d. A schedule for shipment of the equipment, in weeks after receipt of the order.

e. A list of major wearing components, showing interchangeability with the purchaser's other units.

f. A list of spare parts recommended for start-up and normal maintenance purposes.

g. A list of the special tools furnished for maintenance. The vendor shall identify any metric items included in the offering.

h. A statement of any special weather protection and winterization required for start-up, operation, and periods of idleness under the site conditions specified on the data sheets. The list shall show the protection to be furnished by the purchaser, as well as that included in the vendor's scope of supply.

i. A complete tabulation of utility requirements, such as those for steam, water, electricity, air, gas and lube-oil, including the quantity of lube-oil required and the supply pressure, the heat load to be removed by the oil, and the nameplate power rating and operating power requirements of auxiliary drivers. (Approximate data shall be defined and clearly indicated as such.)

j. A description of the tests and inspection procedures for materials, as required by 2.11.1.3.

k. A description of any special requirements specified in the purchaser's inquiry and as outlined in 2.4.6, 2.11.1.3, and 4.1.7.

l. Any start-up, shutdown, or operating restrictions required to protect the integrity of the equipment.

m. If *L/d* exceeds the ratio allowed as specified in Table 4, a typical analytic justification shall be included in accordance with 2.4.3.7.

5.2.4 Options

The vendor shall furnish a list of the procedures for any special or optional tests that have been specified by the purchaser or proposed by the vendor.

5.3 CONTRACT DATA

5.3.1 General

5.3.1.1 The contract data to be furnished is specified in Appendix E. Each drawing, bill of material, and data sheet shall have a title block in its lower right-hand corner that shows the date of certification, a reference to all identification data specified in 5.1.2, the revision number and date, and the title.

5.3.1.2 The purchaser will promptly review the vendor's data when received and notify the vendor of results; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing. After the data have been reviewed, the vendor shall furnish certified copies in the quantity specified.

5.3.1.3 A complete list of vendor data shall be included with the first issue of the major drawings. This list shall contain titles, drawing numbers, and a schedule for transmission of all the data the vendor will furnish (see Appendix E).

5.3.2 Drawings

The drawings and data furnished by the vendor shall contain sufficient information so that together with the manuals specified in 5.3.6, the purchaser can properly install, operate and maintain the equipment covered by the purchase order. All contract drawings and data shall be clearly legible (8-point minimum font size even if reduced from a larger size drawing), shall cover the scope of the agreed VDDR form and shall satisfy the applicable detailed descriptions in Appendix E.

5.3.3 Technical Data

The data shall be submitted in accordance with Appendix E and identified in accordance with 5.3.1.1. Any comments on the drawings or revisions of the specifications that necessitate a change in the data shall be noted by the vendor. These notations will result in the purchaser's issue of completed, corrected data sheets as part of the order specifications.

5.3.4 Progress Reports

The vendor shall submit progress reports to the purchaser at the intervals specified on the VDDR form (see Appendix E). The reports shall include engineering, purchasing, manufacturing, and testing schedules for all major components. Planned and actual dates and the percentage completed shall be indicated for each milestone in the schedule.

5.3.5 Parts Lists and Recommended Spares

5.3.5.1 The vendor shall submit complete parts lists for all equipment and accessories supplied. The lists shall include manufacturer's unique part numbers, materials of construction, and delivery times. Materials shall be identified as specified in 2.11.1.2. Each part shall be completely identified and shown on cross-sectional or assembly-type drawings so that the purchaser may determine the interchangeability of the part with other equipment. Parts that have been modified from standard dimensions and/or finish to satisfy specific performance requirements shall be uniquely identified by part number for interchangeability and future duplication purposes. Standard purchased items shall be identified by the original manufacturer's name and part number.

5.3.5.2 The vendor shall indicate on the above parts lists which parts are recommended spares for startup and which parts are recommended for normal maintenance (see item f of 5.2.3). The vendor shall forward the lists to the purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of the parts before field start-up. The transmittal letter shall be identified with data specified in 5.1.2.

5.3.6 Installation, Operation, Maintenance, and Technical Data Manuals

5.3.6.1 General

The vendor shall provide sufficient written instructions and a list of all drawings to enable the purchaser to correctly install, operate, and maintain all of the equipment ordered. This information shall be compiled in a manual or manuals with a cover sheet that contains all reference-identifying data specified in 5.1.2, an index sheet that contains section titles, and a complete list of referenced and enclosed drawings by title and drawing number. The manual shall be prepared for the specified installation; a generic manual is not acceptable.

5.3.6.2 Installation Manual

Any special information required for proper installation design that is not on the drawings shall be compiled in a manual that is separate from the operating and maintenance instructions. This manual shall be forwarded at a time that is mutually agreed upon in the order but not later than the final issue of prints. The manual shall contain information such as special alignment and grouting procedures, utility specifications (including quantities), and all other installation design data, including the drawings and data specified in 5.2.2 and 5.2.3. The manual shall also include sketches that show the location of the center of gravity and rigging provisions to permit the removal of the top half of the casings, rotors, and any subassemblies that weigh more than 135 kg (300 lb).

5.3.6.3 Operating and Maintenance and Technical Data Manual

The manual containing operating and maintenance and technical data shall be provided at the time of shipment. This manual shall include a section that provides special instructions for operation at specified extreme environmental conditions, such as temperatures. As a minimum, the manual shall also include all of the data listed in Appendix E.

APPENDIX A—GENERAL-PURPOSE GEAR DATA SHEETS

GENERAL PURPOSE GEAR UNITS
API 677 THIRD EDITION
PARALLEL SHAFT
DATA SHEET
SI UNITS

Job No. ________ Item No. ________
P.O No. ________ Date ________
Requisition No. ________
Inquiry No. ________
Revision ____ Date ______ By ______

Applicable To: ○ Proposal ○ Purchase ○ As Built

For ________ Manufacturer ________
Site ________ Model No. ________
Unit ________ Serial No. ________
Service ________ Driver Type ________
No. Required ________ Driven Equipment ________

NOTE: Numbers Within ( ) Refer to Applicable API Standard 677 Paragraphs:
○ Information to be completed by purchaser. ☐ Information to be completed by manufacturer.

Driven Equip. Power (2.1.4 Normal ______ Max ______
Driver Power: Rated ______ Max ______
Gear Rated Power (2.4.1) ______
Torque @ Max. Cont. Speed ______ kg·m
Max.Torque (2.4.1) ______ kg·m ______ r/min
Rated Speed, RPM (1.4):
Input ______ ○ Specified ○ Nominal
Output ______ ○ Specified ○ Nominal
Allow. Var. In Gear Ratio (1.4)(+)(-) ______ %
Max Continuous Speed (1.4) ______ r/min
Trip Speed (1.4) ______ r/min
Gear Service Factor (2.4.2) ______ (Min)
Pin/Gear Hardness (Table 4) ______ / ______
Shaft Assembly Designation (2.2) ______
HS Shaft Rotation Facing Cpl'g. End (2.3.3): ○ CW ○ CCW
LS Shaft Rotation Facing Cpl'g. End (2.3.3): ○ CW ○ CCW
HS Shaft End: ○ Cylindrical ○ Taper ○ Hyd.Taper
○ 1-Key ○ 2-Keys ○ Integral Flange
LS Shaft End: ○ Cylindrical ○ Taper ○ Hyd.Taper
○ 1-Key ○ 2-Keys ○ Integral Flange
External Loads (2.1.17) ______
Other Operating Conditions (2.8.2.6)(2.10.5) ______

○ **INSTALLATION DATA**

○ Indoor ○ Heated ○ Under Roof
○ Outdoor ○ Unheated ○ Partial Sides
○ Grade ○ Mezzanine ○ ______
○ Winterization Req'd ○ Tropicalization Req'd
Electrical Area (2.1.10) Class ____ Grp ____ Div ____
Max Allow SPL (2.1.6) ______ dBA @ ____ m
Elevation ______ m Barometer ______ (kPa) (BAR)
Range Of Ambient Temperatures:

	Dry Bulb	Wet Bulb
Normal	______ C	______ C
Maximum	______ C	______ C
Minimum	______ C	______ C

Unusual Conditions (2.1.15): ○ Dust ○ Fumes ○ ______
Notes: ______

☐ **BASIC GEAR DATA**

Mechanical Rating ______ kW ______ r/min
Thermal Rating ______ kW ______ r/min
Full Load Horsepower Loss ______
Mechanical Efficiency ______ %
Pitch Line Velocity ______ m/s
Tooth Pitting Index, "K" (2.4.3):
Actual ______ Allowable ______
Tangential Load, "Wt" (2.4.3.2) ______ N
Bending Stress Number, "St" (2.4.4.2)

	Pinion	Gear
Actual	______	______
Allowable	______	______

Material Index Number (Fig 3, Table 4) ______
Anticipated Sound Press Level ______ dBA @ ____ m
Journal Static Weight Loads:
Pinion ______ kg Gear ______ kg
WR2 Referred to LS Shaft ______ kg·m^2
Breakaway Torque ______ kg·m @Low Speed Shaft
Overhung Load Factor (Table 6) ______

☐ **CONSTRUCTION FEATURES**

TYPE OF GEAR ☐ Reducer ☐ Increaser
☐ Single Stage ☐ Double Stage
☐ Single Helical ☐ Double Helical
☐ Other ______

TEETH
Number Of Teeth: Pinion ______ Gear ______
Gear Ratio ______ Center Distance ______ mm
Pitch Dia. mm Pinion ______ Gear ______
Finish ______ (RA) AGMA Geometry Factor "J":
Pinion ______ Gear ______
Helix Angle ______ Deg Normal Press Angle ______ Deg
Net Face Width, "F" ______ mm Pinion L / D ______
Normal Diametral Pitch, "PND" ______ Backlash ____ mm

MANUFACTURING METHODS	Pinion	Gear
Teeth Generating Process		
Teeth Finishing Process		
Teeth Hardening Method		

Pinion to Shaft ☐ Integral ☐ Shrunk-On
Gear to Shaft ☐ Integral ☐ Shrunk-On

GENERAL PURPOSE GEAR UNITS
API 677 THIRD EDITION
PARALLEL SHAFT
DATA SHEET
SI UNITS

Job No. ________ Item No. ________
Date ________ By ________
Revision No. ________ By ________

○ **ADDITIONAL REQUIREMENTS**

MOUNTING PLATES (3.3)
○ Gear Furnished With (3.3.1):
○ Baseplate ○ Soleplate
○ Baseplate Suitable for Column Mounting (3.3.1.3)
○ Grout Type (3.3.1.2.5): ○Epoxy ○Other ________

● **PAINTING** (4.4.3.1) ○ ________

MISCELLANEOUS
○ Torsional Analysis By (2.8.1.8): ○ Gear Vendor ○Other
○ Lateral Analysis By (2.8.1.3) (2.8.1.8) :
○ Gear Vendor ○ Other
○ Spare Set of Gear Rotors
○ Orientation of Oil Inlet And Drain Connections (2.6.2.1):
____

○ **VIBRATION DETECTORS (3.4.5)**
Per API 670, except where indicated otherwise below.

RADIAL (2.7.3.2) (2.9.4.5)
Manufacturer ________
○ No. At Each Shaft Bearing ____ Total No. ____
○ Oscillator-Demodulators Supplied By ________
○ Manufacturer ________
○ Monitor Supplied By ________
○ Location ________ Enclosure ________
○ Manufacturer ________
○ Alarm ________ Shutdown ________

AXIAL (2.7.3.2) (2.9.4.5)
○ Manufacturer ________ No. Required ____
○ Location ________ ________
○ Oscillator-Demodulators Supplied By ________
○ Manufacturer ________
○ Shutdown: Time Delay ________ Seconds
○ Monitor Supplied By ________
○ Location ________ Enclosure ________
○ Manufacturer ________
○ Alarm ________ Shutdown ________
○ Shutdown: Time Delay ________ Seconds

ACCELEROMETER (2.9.4.6)
○ Manufacturer ________ No. Required ____
○ Location ________
○ Monitor Supplied By ________

Notes: ________

☐ **RADIAL BEARINGS**

	Pinion	Gear
Type		
Diameter, mm		
Length, mm		
Journal Velocity, m/s		
Loading, kPa		
Clearance (min-max), mm		
Span, mm		
L10 , Hrs (Roller Elm't)		

☐ **THRUST BEARINGS**

Location		
Manufacturer		
Type		
Size		
Area, mm^2		
Loading, kPa		
Rating, kPa		
L10 , Hrs (Roller Elm't)		
Int.Thrust Load, N (+)(-)		
Ext.Thrust Load, N (+)(-)		

☐ **COUPLINGS**

Manufacturer		
Model		
Cplg.Rating, kW/100 r/min		
Cylindrical / 1-Key	☐	☐
Cylindrical / 2-Keys	☐	☐
Tapered / 1-Key	☐	☐
Tapered / 2-Keys	☐	☐
Tapered / Keyless	☐	☐

☐ **MATERIALS**

Gear Casing ________ Oil Seals ________
Radial Bearings ________
Thrust Bearing(s) ________
HS Shaft ________ LS Shaft ________
Pinion(s) ________ Hardness ________
Gear Rim(s) ________ Hardness ________

☐ **PIPING CONNECTIONS**

Service	No.	Size	Type
Lube Oil Inlet			
Lube Oil Outlet			
Casing Drain			
Vent			
Casing Purge			

Notes: ________

GENERAL PURPOSE GEAR UNITS
API 677 THIRD EDITION
PARALLEL SHAFT
DATA SHEET
SI UNITS

Job No. ____________ Item No. ____________
Date ____________ By ____________
Revision No. ____________ By ____________

○ INSTRUMENTS

- ○ Low Oil Pressure Alarm Switch ____________
- ○ High Oil Temp. Alarm Switch ____________
- ○ Temperature Measuring Devices (3.4.1.4): ____________
  - ○ Thermometers ____________
  - ○ Thermocouples ____________
  - ○ Resistance Temp. Detectors ____________
  - ○ Liquid Filled Pressure Gages (3.4.4) ____________
- ○ Thermal Relief Valves (3.4.6.2) ____________

○ CONTRACT DATA

- ○ Test Data Prior To Shipment ____________
- ○ Progress Reports (5.3.4) ____________

○ SHIPMENT (4.4.1)

	Contract Unit	Spares
Export Boxing	○	○
Domestic Boxing	○	○
Outdoor Storage Over 6 Months	○	○
Fit-Up & Assembly of Mounted Accessories (4.4.8)	○	○

○ COUPLINGS AND GUARDS

	High Speed	Low Speed
Coupling Furnished By		
Coupling Type		
Cplg Rating kW/100 r/min		
Coupling manufacturer		
Coupling Lubrication		
Mount Cplg Halves (3.2.4)		
Taper, mm/m		
Taper gauge furnished by		
Limited End Float		
Cplg Guard Furnished By		

Notes: ____________

○ LUBRICATION REQUIREMENTS (2.10)

- ○ Oil System Furnished By:
  - ○ Gear Vendor ○ Other ____________
- ○ Oil Visc.: _____ cP @ 40 C _____ cP @ 100 C (2.10.4)
- ○ Lubrication Requirements: ○ Fig. C-1 ○ Fig. C-2
- ○ Standby Oil Pump MFGR _______ Type _______
- ○ Oil Pump Casing: ○ Cast Iron ○ Steel
- ○ Oil Cooler ○ Water Cooled ○ Air Cooled
- ○ Heaters Required:
  - ○ Electric With Thermostats ○ Steam
- ○ Duplex Filters

☐ LUBRICATION REQUIREMENTS

- System Type (2.10.1) ☐ ____________
  - ☐ Circulating ☐ Pressurized
- ☐ Filters, Micron Rating ____________
- ☐ Minimum Startup Oil Temperature ____________ C
- ☐ Oil Flow ____________ m^3/ hr
- ☐ Oil Pressure ____________ kPa
- ☐ Unit Power Loss ____________ kW
- Reservoir: ☐ Gear Casing ☐ Separate
- ☐ Lube Oil Inlet Size ____________ mm
- ☐ Lube Oil Outlet Size ____________ mm

☐ WEIGHTS AND DIMENSIONS

- Net Weight: Gear _____ kg ☐ Auxiliaries _____ kg
- Max. Maintenance Weight (Identify) ____________ kg
- Total Shipping Weight(s) ____________ kg
- Total Shipping Dimensions ____ X ____ X ____

Notes: ____________

GENERAL PURPOSE GEAR UNITS
API 677 THIRD EDITION
PARALLEL SHAFT
DATA SHEET
SI UNITS

Job No. ____________ Item No. ____________
Date ____________ By ____________
Revision No. ____________ By ____________

○ **INSPECTIONS AND TESTS** (4.1.3)

	Req'd	Wit-nessed	Ob-served	Test Log
Shop Inspection (4.1.3)	○	○	○	
Cleanliness Inspection (4.1.6)	○	○	○	
Hardness Verification Inspection (4.1.7)	○	○	○	○
Mag. Particle Inspection (4.2.4.1)	○	○	○	
Ultrasonic Inspection (4.2.4.2.2)	○	○	○	
Weld Inspection (4.2.3.1)	○	○	○	
Dismantle-Reassembly Inspection	○	○	○	
Contact Check (2.7.2.1)	●	○	○	○
Contact Check Tape Lift (2.7.2.1)	○	○	○	○
Bearing Visual Check (4.3.3.8)	○	○	○	○
Axial Stability Check (2.7.2.4)	●	○	○	○
Residual Unbalance Check (2.8.2.3)	○	○	○	○
Mechanical Run Test (4.3.3)	●	○	○	○
Extended Mechanical Run Test (4.3.3.2)	○	○	○	○
Mechanical Run Test (Spare Rotors) (4.3.3.10)	●	○	○	○
Part Or Full Load And Full Speed Test (4.3.4.1)	○	○	○	○
Full Torque, Slow Roll Test (4.3.4.2)	○	○	○	○
Full Torque Static Test (4.3.4.3)	○	○	○	○
Sound Level Test (4.3.4.4)	○	○	○	○
Mechanical Run Test Coupling (4.3.3.3.5):				
Couplings Installed	○	○	○	○
Couplings Hubs With Idlers	○	○	○	○
Use Shop Lube System (4.3.3.3.2) (4.3.3.11)	○	○	○	○
Use Job Lube System (4.3.3.3.2) (4.3.3.11) (4.3.3.3.6)	○	○	○	○
Use Shop Vibration Probes,Etc.(4.3.3.6)	○	○	○	
Use Job Vibration Probes, Etc.(4.3.3.6)	○	○	○	
Final Assembly, Maintenance & Running Clearance (4.2.1.e)	○	○	○	○
Oil System Cleanliness	●	○	○	
Oil System-Casing Joint Tightness (4.3.3.3.3)	●	○	○	
Warning And Protection Devices (4.3.3.3.4)	●	○	○	
Oil System Leak Test (4.3.2.2)	●	○	○	

Notes: ____________

Notes: ____________

--`,`,,,,`,,,`,,`,`,``,`,,`,``-`-`,,`,,`,`,,`---

GENERAL PURPOSE GEAR UNITS
API 677 THIRD EDITION
PARALLEL SHAFT
DATA SHEET
U.S. CUSTOMARY UNITS

Job No. ____________ Item No. ____________
P.O No. ____________ Date ____________
Requisition No. ____________
Inquiry No. ____________
Revision ______ Date ______ By ______

Applicable To: ○ Proposal ○ Purchase ○ As Built

For ____________ Manufacturer ____________
Site ____________ Model No. ____________
Unit ____________ Serial No. ____________
Service ____________ Driver Type ____________
No. Required ____________ Driven Equipment ____________

NOTE: Numbers Within ( ) Refer To Applicable API Standard 677 Paragraphs:
○ Information to be completed by purchaser. ☐ Information to be completed by manufacturer.

Driven Equip. Power (2.1.4): Normal ______ Max ______
Driver Power: Rated ______ Max ______
Gear Rated Power (2.4.1) ______
Torque @ Max. Cont. Speed ______ lb ft
Max.Torque (2.4.1) ______ lb ft @ ______ r/min
Rated Speed, RPM (1.4):
Input ______ ○ Specified ○ Nominal
Output ______ ○ Specified ○ Nominal
Allow. Var. In Gear Ratio (1.4)(+)(-) ______ %
Max Continuous Speed (1.4) ______ r/min
Trip Speed (1.4) ______ r/min
Gear Service Factor (2.4.2) ______ (Min)
Pin/Gear Hardness (Table 4) ______ / ______
Shaft Assembly Designation (2.2) ______
HS Shaft Rotation Facing Cpl'g. End (2.3.3): ○ CW ○ CCW
LS Shaft Rotation Facing Cpl'g. End (2.3.3): ○ CW ○ CCW
HS Shaft End: ○ Cylindrical ○ Taper ○ Hyd.Taper
○ 1-Key ○ 2-Keys ○ Integral Flange
LS Shaft End: ○ Cylindrical ○ Taper ○ Hyd.Taper
○ 1-Key ○ 2-Keys ○ Integral Flange
External Loads (2.1.16) ______
Other Operating Conditions (2.8.1.6)(2.10.5) ______

○ INSTALLATION DATA

○ Indoor ○ Heated ○ Under Roof
○ Outdoor ○ Unheated ○ Partial Sides
○ Grade ○ Mezzanine ○ ______
○ Winterization Req'd ○ Tropicalization Req'd
Electrical Area (2.1.10) Class ______ Grp ______ Div ______
Max Allow SPL (2.1.6) ______ dBA @ ______ ft
Elevation ______ ft Barometer ______ psia
Range Of Ambient Temperatures:

	Dry Bulb	Wet Bulb
Normal	______ F	______ F
Maximum	______ F	______ F
Minimum	______ F	______ F

Unusual Conditions (2.1.15):
○ Dust ○ Fumes ○ ______

Notes: ______

☐ BASIC GEAR DATA

Mechanical Rating ______ hp @ ______ r/min
Thermal Rating ______ hp @ ______ r/min
Full Load Horsepower Loss ______
Mechanical Efficiency ______ %
Pitch Line Velocity ______ ft/min
Tooth Pitting Index, "K" (2.4.3) :
Actual ______ Allowable ______
Tangential Load, "Wt" (2.4.3.2) ______ lb
Bending Stress Number, "St" (2.4.4.2)

	Pinion	Gear
Actual	______	______
Allowable	______	______

Material Index Number (Fig 3, Table 4) ______
Anticipated Sound Press Level ______ dBA @ ______ ft
Journal Static Weight Loads:
Pinion ______ lb Gear ______ lb
WR^2 Referred To LS Shaft ______ lb ft^2
Breakaway Torque ______ ft lb @ LS Shaft
Overhung Load Factor (Table 6) ______

☐ CONSTRUCTION FEATURES

TYPE OF GEAR
☐ Reducer ☐ Increaser
☐ Single Stage ☐ Double Stage
☐ Single Helical ☐ Double Helical
☐ Other ______

TEETH
Number Of Teeth: Pinion ______ Gear ______
Gear Ratio ______ Center Distance ______ in.
Pitch Dia. In.: Pinion ______ Gear ______
Finish ______ (RA) AGMA Geometry Factor "J" :
Pinion ______ Gear ______
Helix Angle ______ Deg Normal Press Angle ______ Deg
Net Face Width, "F" ______ In Pinion L / D ______
Normal Diametral Pitch, "PND" ______ Backlash ______ in.

MANUFACTURING METHODS	Pinion	Gear
Teeth Generating Process		
Teeth Finishing Process		
Teeth Hardening Method		

Pinion to Shaft ☐ Integral ☐ Shrunk-On
Gear to Shaft ☐ Integral ☐ Shrunk-On

GENERAL PURPOSE GEAR UNITS
API 677 THIRD EDITION
PARALLEL SHAFT
DATA SHEET
U.S. CUSTOMARY UNITS

Job No. ______ Item No. ______
Date ______ By ______
Revision No. ______ By ______

ADDITIONAL REQUIREMENTS

MOUNTING PLATES (3.3.)

- Gear Furnished With (3.3.1):
  - Baseplate
  - Soleplate
- Baseplate Suitable for Column Mounting (3.3.1.3)
- Grout Type (3.3.1.2.5): Epoxy / Other ______

● **PAINTING** (4.4.3.1) ______

MISCELLANEOUS

- Torsional Analysis By (2.8.2.9): Gear Vendor / Other
- Lateral Analysis By (2.8.2.9):
  - Gear Vendor
  - Other
- Spare Set of Gear Rotors
- Orientation of Oil Inlet And Drain Connections (2.6.2.1):

______

VIBRATION DETECTORS (3.4.5)

Per API 670, except where indicated otherwise below.

RADIAL (2.7.3.2) (2.9.4.5)

Manufacturer ______

- No. At Each Shaft Bearing ______ Total No. ______
- Oscillator-Demodulators Supplied By ______
  - Manufacturer ______
- Monitor Supplied By ______
  - Location ______ Enclosure ______
  - Manufacturer ______
  - Alarm ______ Shutdown ______

AXIAL (2.7.3.2) (2.9.4.5)

- Manufacturer ______ No. Required ______
- Location ______
- Oscillator-Demodulators Supplied By ______
  - Manufacturer ______
  - Shutdown: Time Delay ______ Seconds
- Monitor Supplied By ______
  - Location ______ Enclosure ______
  - Manufacturer ______
  - Alarm ______ Shutdown ______
  - Shutdown: Time Delay ______ Seconds

ACCELEROMETER (2.9.4.6)

- Manufacturer ______ No. Required ______
- Location ______
- Monitor Supplied By ______

Notes: ______

RADIAL BEARINGS

	Pinion	Gear
Type		
Diameter, In		
Length, In		
Journal Velocity, ft/s		
Loading, PSI		
Clearance (min-max), in.		
Span, In		
L10 , Hrs (Roller Elm't)		

THRUST BEARINGS

	Pinion	Gear
Location		
Manufacturer		
Type		
Size		
Area, in.^{2}		
Loading, psi		
Rating, psi		
L10 , Hrs (Roller Elm't)		
Int.Thrust Load, Lb (+)(-)		
Ext.Thrust Load, Lb(+)(-)		

COUPLINGS

	Pinion	Gear
Manufacturer		
Model		
Cplg.Rating,HP/100 r/min		
Cylindrical / 1-Key	☐	☐
Cylindrical / 2-Keys	☐	☐
Tapered / 1-Key	☐	☐
Tapered / 2-Keys	☐	☐
Tapered / Keyless	☐	☐

MATERIALS

Gear Casing ______ Oil Seals ______
Radial Bearings ______
Thrust Bearing(s) ______
HS Shaft ______ LS Shaft ______
Pinion(s) ______ Hardness ______
Gear Rim(s) ______ Hardness ______

PIPING CONNECTIONS

	No.	Size	Type
Service			
Lube Oil Inlet			
Lube Oil Outlet			
Casing Drain			
Vent			
Casing Purge			

Notes: ______

GENERAL PURPOSE GEAR UNITS
API 677 THIRD EDITION
PARALLEL SHAFT
DATA SHEET
U.S. CUSTOMARY UNITS

Job No. ______ Item No. ______
Date ______ By ______
Revision No. ______ By ______

INSTRUMENTS

- Low Oil Pressure Alarm Switch: ______
- High Oil Temp. Alarm Switch: ______
- Temperature Measuring Devices (3.4.1.4):
  - Thermometers ______
  - Thermocouples ______
  - Resistance Temp. Detectors ______
  - Liquid Filled Pressure Gages (3.4.4) ______
- Thermal Relief Valves (3.4.6.2) ______

CONTRACT DATA

- Test Data Prior To Shipment ______
- Progress Reports (5.3.4) ______

______

SHIPMENT (4.4.1)

	Contract Unit	Spares
Export Boxing	○	○
Domestic Boxing	○	○
Outdoor Storage Over 6 Months	○	○
Fit-Up & Assembly of Mounted Accessories (4.4.8)	○	○

COUPLINGS AND GUARDS

	High Speed	Low Speed
Coupling Furnished By		
Coupling Type		
Cplg Rating HP/100 r/min		
Coupling Manufacturer		
Coupling Lubrication		
Mount Cplg Halves (3.2.4)		
Taper		
Taper Gauge Furnished By		
Limited End Float		
Cplg Guard Furnished By		

Notes: ______

LUBRICATION REQUIREMENTS (2.10)

- Oil System Furnished By:
  - Gear Vendor ○ Other ______
- Oil Visc.: ______ SSU@100 F ______ SSU@210 F (2.10.4)
- Lubrication Requirements: ○ Fig. C-1 ○ Fig. C-2
- Standby Oil Pump MFGR ______ Type ______
- Oil Pump Casing: ○ Cast Iron ○ Steel
- Oil Cooler ○ Water Cooled ○ Air Cooled
- Heaters Required:
  - Electric With Thermostats ○ Steam
- Duplex Filters

LUBRICATION REQUIREMENTS

System Type (2.10.1) : ☐ ______
☐ Circulating ☐ Pressurized
☐ Filters, Micron Rating ______
☐ Minimum Startup Oil Temperature ______ F
☐ Oil Flow ______ gal/min
☐ Oil Pressure ______ psig
☐ Unit Power Loss ______ hp
Reservoir: ☐ Gear Casing ☐ Separate
☐ Lube Oil Inlet Size ______ in.
☐ Lube Oil Outlet Size ______ in.

WEIGHTS AND DIMENSIONS

Net Weight: Gear ______ lb ☐ Auxiliaries ______ lb
Max. Maintenance Weight (Identify) ______ lb
Total Shipping Weight(s) ______ lb
Total Shipping Dimensions ______ X ______ X ______

Notes: ______

GENERAL PURPOSE GEAR UNITS
API 677 THIRD EDITION
PARALLEL SHAFT
DATA SHEET
U.S. CUSTOMARY UNITS

Job No.		Item No.	
Date		By	
Revision No.		By	

○ **INSPECTIONS AND TESTS** (4.1.3)

	Req'd	Wit-nessed	Ob-served	Test Log
Shop Inspection (4.1.3)	○	○	○	
Cleanliness Inspection (4.1.6)	○	○	○	
Hardness Verification Inspection (4.1.7)	○	○	○	○
Mag. Particle Inspection (4.2.4.1)	○	○	○	
Ultrasonic Inspection (4.2.4.2.2)	○	○	○	
Weld Inspection (4.2.3.1)	○	○	○	
Dismantle-Reassembly Inspection	○	○	○	
Contact Check (2.7.2.1)	●	○	○	○
Contact Check Tape Lift (2.7.2.1)	○	○	○	○
Bearing Visual Check (4.3.3.8)	○	○	○	○
Axial Stability Check (2.7.2.4)	●	○	○	○
Residual Unbalance Check (2.8.2.3)	○	○	○	○
Mechanical Run Test (4.3.3)	●	○	○	○
Extended Mechanical Run Test (4.3.3.2)	○	○	○	○
Mechanical Run Test (Spare Rotors) (4.3.3.10)	●	○	○	○
Part Or Full Load And Full Speed Test (4.3.4.1)	○	○	○	○
Full Torque, Slow Roll Test (4.3.4.2)	○	○	○	○
Full Torque Static Test (4.3.4.3)	○	○	○	○
Sound Level Test (4.3.4.4)	○	○	○	○
Mechanical Run Test Coupling (4.3.3.3.5):				
Couplings Installed	○	○	○	○
Couplings Hubs With Idlers	○	○	○	○
Use Shop Lube System (4.3.3.3.2) (4.3.3.11)	○	○	○	○
Use Job Lube System (4.3.3.3.2) (4.3.3.11) (4.3.3.3.6)	○	○	○	○
Use Shop Vibration Probes, Etc.(4.3.3.6)	○	○	○	
Use Job Vibration Probes, Etc.(4.3.3.6)	○	○	○	
Final Assembly, Maintenance & Running Clearance (4.2.1.e)	○	○	○	○
Oil System Cleanliness	●	○	○	
Oil System-Casing Joint Tightness (4.3.3.3.3)	●	○	○	
Warning And Protection Devices (4.3.3.3.4)	●	○	○	
Oil System Leak Test (4.3.2.2)	●	○	○	

Notes:

Notes:

GENERAL PURPOSE GEAR UNITS
API 677 THIRD EDITION
BEVEL MOUNTED
DATA SHEET
SI UNITS

Job No. ________ Item No. ________
P.O No. ________ Date ________
Requisition No. ________
Inquiry No. ________
Revision ____ Date ____ By ____

Applicable To: ○ Proposal ○ Purchase ○ As Built

For	Manufacturer
Site	Model No.
Unit	Serial No.
Service	Driver Type
No. Required	Driven Equipment

NOTE: Numbers Within ( ) Refer to Applicable API Standard 677 Paragraphs:
○ Information to be completed by purchaser. ☐ Information to be completed by manufacturer.

Driven Equip. Power (2.1.4 Normal ____ Max ____
Driver Power: Rated ____ Max ____
Gear Rated Power (2.4.1) ____ kW
Torque @ Max. Cont. Speed ____ kg· m
Max.Torque (2.4.1) ____ kg· m ____ r/min
Rated Speed, r/min (1.4):
Input ____ ○ Specified ○ Nominal
Output ____ ○ Specified ○ Nominal
Allow. Var. In Gear Ratio (1.4)(+)(-) ____ %
Max Continuous Speed (1.4) ____ r/min
Trip Speed (1.4) ____ r/min
Gear Service Factor (2.4.2) ____ (Min)
Pin/Gear Hardness (Table 4) ____ / ____
Shaft Assembly Designation (2.2) ____
HS Shaft Rotation Facing Cpl'g. End (2.3.3): ○ CW ○ CCW
LS Shaft Rotation Facing Cpl'g. End (2.3.3): ○ CW ○ CCW
HS Shaft End: ○ Cylindrical ○ Taper/Keyed
○ 1-Key ○ 2-Keys
LS Shaft End: ○ Cylindrical ○ Taper/Keyed
○ 1-Key ○ 2-Keys
External Loads (2.1.17) ____
Other Operating Conditions (2.8.2.6)(2.10.3) ____

○ INSTALLATION DATA

○ Indoor (2.1.15) ○ Heated ○ Under Roof
○ Outdoor ○ Unheated ○ Partial Sides
○ Grade ○ Mezzanine ○ ____
○ Winterization Req'd ○ Tropicalization Req'd
Electrical Area (2.1.9) Class ____ Grp ____ Div ____
Max Allow SPL (2.1.5) ____ dBA @ ____ m
Elevation ____ m Barometer ____ kPa abs
Range of Ambient Temperatures:

	Dry Bulb	Wet Bulb
Normal	____ C	____ C
Maximum	____ C	____ C
Minimum	____ C	____ C

Unusual Conditions (2.1.15) (2.11.1.3)
○ Dust ○ Fumes ○ ____

Notes:

☐ BASIC GEAR DATA

Mechanical Rating ____ kW ____ r/min
Thermal Rating ____ kW ____ r/min
Full Load Horsepower Loss ____ kW
Mechanical Efficiency ____ %
Pitch Line Velocity ____ m/s
Tooth Pitting Index, "K" (2.4.3.2 and 2.4.3.4)
Actual ____ Allowable ____
Tangential Load, "Wt" (2.4.3.2 and 2.4.3.4) ____ kg
Bending Stress Number, "St" (2.4.4.3)

	Pinion	Gear
Actual		
Allowable		

Material Index Number (Fig 3, Table 4) ____
Anticipated Sound Press Level ____ dBA @ ____ m
Mounting of Bevel Gears (2.7.1.7): ☐ Straddle ☐ Overhung
Journal Static Weight Loads
Pinion ____ kg Gear ____ kg
WR^2 Referred to LS Shaft ____ kg· m^2
Breakaway Torque ____ N· m
Overhung Load Factor (Table 6) ____

☐ CONSTRUCTION FEATURES

TYPE OF GEAR ☐ Reducer ☐ Increaser
☐ Single Stage ☐ Double Stage
Other ____

TEETH
Number of Teeth: Pinion ____ Gear ____
Gear Ratio ____ Mounting Distance ____ mm
Pitch Dia. mm: Pinion ____ Gear ____
Finish ____ (RA) AGMA Geometry Factor "J":
Pinion ____ Gear ____
Helix Angle ____ Deg Transverse Press Angle ____ Deg
Face Width, "F" ____ mm Pinion L/D (2.4.3.6) ____
Normal Diametral Pitch, "PND" ____ Backlash ____ mm

MANUFACTURING METHODS	Pinion	Gear
Teeth Generating Process		
Teeth Finishing Process		
Teeth Hardening Method		

Pinion to Shaft ☐ Integral ☐ Shrunk-On
Gear to Shaft ☐ Integral ☐ Shrunk-On

GENERAL PURPOSE GEAR UNITS
API 677 THIRD EDITION
BEVEL MOUNTED
DATA SHEET
SI UNITS

Job No. ________ Item No. ________
Date ________ By ________
Revision No. ________ By ________

○ ADDITIONAL REQUIREMENTS

MOUNTING PLATES (3.3)
○ Gear Furnished With (3.3.1):
○ Baseplate ○ Soleplate
○ Baseplate Suitable For Column Mounting (3.3.1.3)
○ Grout Type (3.3.1.2.5): ○ Epoxy ○ Other ________
MOUNTING FLANGES
○ Clearance Fit With Jackbolts
○ Register Fit
● **PAINTING** (4.4.3.1) ○ ________
MISCELLANEOUS
○ Torsional Analysis By (2.8.2.9): ○ Gear Vendor ○ Other
○ Lateral Analysis By (2.8.2.9):
○ Gear Vendor ○ Other
○ Spare Set of Gear Rotors
○ Orientation of Oil Inlet and Drain Connections (2.6.2.1):

○ VIBRATION DETECTORS (3.4.2)

Per API 670, except where indicated otherwise below.

ACCELEROMETER (2.9.4.6)
○ Manufacturer ________ No. Required ________
○ Location ________
○ Monitor Supplied By

○ INSTRUMENTS

○ Low Oil Pressure Alarm Switch: ________
○ High Oil Temp. Alarm Switch: ________
○ Temperature Measuring Devices (3.4.1.4): ________
○ Thermometers ________
○ Thermocouples ________
○ Resistance Temp. Detectors ________
○ Liquid Filled Pressure Gauges ________
○ Thermal Relief Valves ________

○ CONTRACT DATA

○ Test Data Prior to Shipment ________
○ Progress Reports (5.3.4) ________

○ SHIPMENT (4.4.1)

	Contract Unit	Spares
Export Boxing (4.4.3.9)	○	○
Domestic Boxing (4.4.3.9)	○	○
Outdoor Storage Over 6 Months	○	○
Fit-Up & Assembly of Mounted Accessories (4.4.8)	○	○

Notes: ________

☐ RADIAL BEARINGS

	Pinion	Gear
Manufacturer		
Type		
Class		
Cage Speed, m/s		
☐ B10 ☐ L10 Hours		

NOTES ________

☐ THRUST BEARINGS

	Pinion	Gear
Manufacturer		
Type		
Class		
Cage Speed, m/s		
☐ B10 ☐ L10 Hours		
Down Thrust Capacity, N		
Up Thrust Capacity, N		

NOTES ________

☐ COUPLINGS

Manufacturer		
Model		
Cplg.Rating,kW/100 r/min		
Cylindrical / 1-Key	☐	☐
Cylindrical / 2-Keys	☐	☐
Tapered / 1-Key	☐	☐
Tapered / 2-Keys	☐	☐
Tapered / Keyless	☐	☐

☐ MATERIALS

Gear Casing ________ Oil Seals ________
Radial Bearings ________
Thrust Bearing(s) ________
HS Shaft ________ LS Shaft ________
Pinion(s) ________ Hardness ________
Gear Rim(s) ________ Hardness ________

☐ PIPING CONNECTIONS

Service	No.	Size	Type
Lube Oil Inlet			
Lube Oil Outlet			
Casing Drain			
Vent			
Casing Purge			

Notes: ________

GENERAL PURPOSE GEAR UNITS
API 677 THIRD EDITION
BEVEL MOUNTED
DATA SHEET
SI UNITS

Job No. ________ Item No. ________
Date ________ By ________
Revision No. ________ By ________

○ COUPLINGS AND GUARDS

	High Speed	Low Speed
Coupling Furnished By		
Coupling Type		
Cplg Rating kW/100 r/min		
Coupling Manufacturer		
Coupling Lubrication		
Mount Cplg Halves (3.2.1)		
Taper		
Taper Gauge Furnished By		
Limited End Float		
Cplg Guard Furnished By		

Notes: ________

○ LUBRICATION REQUIREMENTS (2.10)

○ Oil System Furnished By (2.10.4):
○ Gear Vendor ○ Other ________
○ Oil Visc.:_____ cP @40 C _____ cP@100 C (2.10.4)
○ Lubrication Requirements: ○ Fig. C-1 ○ Fig. C-2
● Main Oil Pump: ○ Shaft Driven ○ Motor Driven
○ Standby Oil Pump MFGR_____ Type _____
Oil Pump Casings: ○ Cast Iron ○ Steel
● Oil Cooler ○ Water Cooled ○ Air Cooled
○ Heaters Required:
○ Electric With Thermostats ○ Steam
○ Duplex Filters

○ INSPECTIONS AND TESTS (4.1.3)

	Req'd	Wit-nessed	Ob-served	Test Log
Shop Inspection (4.1.3)	○	○	○	
Cleanliness Inspection (4.1.6)	○	○	○	
Hardness Verification Inspection (4.1.7)	○	○	○	○
Mag. Particle Inspection (4.2.2.9.3)	○	○	○	
Ultrasonic Inspection (4.2.2.9.2)	○	○	○	
Weld Inspection (4.2.2.8)	○	○	○	
Dismantle-Reassembly Inspection	○	○	○	
Contact Check (2.7.2.2)	●	○	○	○
Contact Check Tape Lift (2.7.2.2)	○	○	○	○
Bearing Visual Check (4.3.3.8)	○	○	○	○
Bevel Backlash Check (Appendix G)	○	○	○	○
Residual Unbalance Check (2.8.3.3)	○	○	○	○
Mechanical Run Test (4.3.3)	●	○	○	○
Extended Mechanical Run Test (4.3.3.2)	○	○	○	○
Mechanical Run Test (Spare Rotors) (4.3.3.10)	●	○	○	○
Sound Level Test (4.3.4.2)	○	○	○	○
Mechanical Run Test Coupling (4.3.3.3.5):				
Couplings Installed	○	○	○	○
Coupling Hubs With Idlers	○	○	○	○

☐ LUBRICATION REQUIREMENTS

System Type: ☐ ________
☐ Circulating ☐ Pressurized
☐ Filters, Micron Rating ________
☐ Cooler Not Required
☐ Minimum Startup Oil Temperature ________ C
☐ Oil Flow ________ GPM m^3/hr
☐ Oil Pressure ________ kPa
☐ Unit Power Loss ________ kW
Reservoir: ☐ Gear Casing ☐ Separate
☐ Lube Oil Inlet Size ________ mm
☐ Lube Oil Outlet Size ________ mm

☐ WEIGHTS AND DIMENSIONS

Net Weight: Gear _____ kg ☐ Auxiliaries _____ kg
Max. Maintenance Weight (Identify) ________ kg
Total Shipping Weight(s) ________ kg
Total Shipping Dimensions _____ X _____ X _____

○ INSPECTIONS AND TESTS (4.1.3)

Use Shop Lube System (4.3.3.3.2) (4.3.3.11)	○	○	○	○
Use Job Lube System (4.3.3.3.2) (4.3.3.11) (4.3.3.3.6)	○	○	○	○
Final Assembly, Maintenance & Running Clearance (4.2.1f)	○	○	○	○
Oil System Cleanliness	●	○	○	
Oil System-Casing Joint Tightness (4.3.3.3.3)	●	○	○	
Warning And Protection Devices (4.3.3.3.4)	●	○	○	
Oil System Leak Test (4.3.2.2)	●	○	○	

Notes: ________

GENERAL PURPOSE GEAR UNITS
API 677 THIRD EDITION
BEVEL MOUNTED
DATA SHEET
U.S. CUSTOMARY UNITS

Job No. ________ Item No. ________
P.O No. ________ Date ________
Requisition No. ________
Inquiry No. ________
Revision ____ Date ________ By ________

1	Applicable To: ○ Proposal ○ Purchase ○ As Built	
2	For ________	Manufacturer ________
3	Site ________	Model No. ________
4	Unit ________	Serial No. ________
5	Service ________	Driver Type ________
6	No. Required ________	Driven Equipment ________
7	NOTE: Numbers Within ( ) Refer To Applicable API Standard 677 Paragraphs:	
8	○ Information to be completed by purchaser.	☐ Information to be completed by manufacturer.
9	Driven Equip. Power (2.1.4): Normal ____ Max ____	☐ **BASIC GEAR DATA**
10	Driver Power: Rated ____ Max ____	Mechanical Rating ____ hp @ ____ r/min
11	Gear Rated Power (2.4.1) ____	Thermal Rating ____ hp @ ____ r/min
12	Torque @ Max. Cont. Speed ____ lb ft	Full Load Horsepower Loss ____
13	Max.Torque (2.4.1) ____ lb ft @ ____ r/min	Mechanical Efficiency ____ %
14	Rated Speed, r/min (1.4):	Pitch Line Velocity ____ FPM
15	Input ____ ○ Specified ○ Nominal	Tooth Pitting Index, "K" (2.4.3.2 and 2.4.3.4) **:**
16	Output ____ ○ Specified ○ Nominal	Actual ____ Allowable ____
17	Allow. Var. In Gear Ratio (1.4)(+)(-) ____ **%**	Tangential Load, "Wt" (2.4.3.2 and 2.4.3.4) ____ lb
18	Max Continuous Speed (1.4) ____ r/min	Bending Stress Number, "St" (2.4.4.3)
19	Trip Speed (1.4) ____ r/min	Pinion Gear
20	Gear Service Factor (2.4.2) ____ (Min)	Actual ____ ____
21	Pin/Gear Hardness (Table 3) ____ / ____	Allowable ____ ____
22	Shaft Assembly Designation (2.2) ____	Material Index Number (Fig 3, Table 3) ____
23	HS Shaft Rotation Facing Cpl'g. End (2.3.3): ○ CW ○ CCW	Anticipated Sound Press Level ____ dBA @ ____ ft
24	LS Shaft Rotation Facing Cpl'g. End (2.3.3): ○ CW ○ CCW	Mounting of Bevel Gears (2.7.1.6): ☐ Straddle ☐ Overhung
25	HS Shaft End: ○ Cylindrical ○ Taper/Keyed	Journal Static Weight Loads**:**
26	○ 1-Key ○ 2-Keys	Pinion ____ lb Gear ____ lb
27	LS Shaft End: ○ Cylindrical ○ Taper/Keyed	WR^2 Referred To LS Shaft ____ lb ft^2
28	○ 1-Key ○ 2-Keys	Breakaway Torque ____ ft lb @ LS Shaft
29	External Loads (2.1.16) ____	Overhung Load Factor (Table 4) ____
30	Other Operating Conditions (2.8.1.5)(2.10.3) ____	
31		☐ **CONSTRUCTION FEATURES**
32	○ **INSTALLATION DATA**	**TYPE OF GEAR** ☐ Reducer ☐ Increaser
33	○ Indoor (2.1.15) ○ Heated ○ Under Roof	☐ Single Stage ☐ Double Stage
34	○ Outdoor ○ Unheated ○ Partial Sides	☐ Other ____
35	○ Grade ○ Mezzanine ○ ____	**TEETH**
36	○ Winterization Req'd ○ Tropicalization Req'd	Number of Teeth: Pinion ____ Gear ____
37	Electrical Area (2.1.9) Class ____ Grp ____ Div ____	Gear Ratio ____ Mounting Distance ____ in.
38	Max Allow SPL (2.1.5) ____ dBA @ ____ ft	Pitch Dia. In**:** Pinion ____ Gear ____
39	Elevation ____ ft Barometer ____ psia	Finish ____ (RA) AGMA Geometry Factor "J" **:**
40	Range of Ambient Temperatures:	Pinion ____ Gear ____
41	Dry Bulb Wet Bulb	Helix Angle ____ Deg Transverse Press Angle ____ Deg
42	Normal ____ F ____ F	Face Width, "F" ____ in. Pinion L/D (2.4.3.6) ____
43	Maximum ____ F ____ F	Normal Diametral Pitch, "PND" ____ Backlash ____ in.
44	Minimum ____ F ____ F	
45	Unusual Conditions (2.1.14):	**MANUFACTURING METHODS** Pinion | Gear
46	○ Dust ○ Fumes ○ ____	Teeth Generating Process ____ | ____
47	Notes: ____	Teeth Finishing Process ____ | ____
48	____	Teeth Hardening Method ____ | ____
49	____	Pinion To Shaft ☐ Integral ☐ Shrunk-On
50		Gear To Shaft ☐ Integral ☐ Shrunk-On

GENERAL PURPOSE GEAR UNITS
API 677 SECOND EDITION
BEVEL MOUNTED
DATA SHEET
U.S. CUSTOMARY UNITS

Job No.	________	Item No.	________
Date	________	By	________
Revision No.	________	By	________

○ ADDITIONAL REQUIREMENTS

MOUNTING PLATES (3.3)

○ Gear Furnished With (3.3.1):
○ Baseplate ○ Soleplate
○ Baseplate Suitable For Column Mounting (3.3.1.3)
○ Grout Type (3.3.1.2.5): ○ Epoxy ○ Other ________

MOUNTING FLANGES

○ Clearance Fit With Jackbolts
○ Register Fit

● **PAINTING** (4.4.3.1) ○ ________

MISCELLANEOUS

○ Torsional Analysis By (2.8.1.8): ○ Gear Vendor ○ Other
○ Lateral Analysis By (2.8.1.3) (2.8.1.8):
○ Gear Vendor ○ Other
○ Spare Set Of Gear Rotors
○ Orientation Of Oil Inlet And Drain Connections (2.6.2.1):

○ VIBRATION DETECTORS (3.4.5)

Per API 670, except where indicated otherwise below.

ACCELEROMETER (2.9.4.4)

○ Manufacturer ________ No. Required ________
○ Location ________
○ Monitor Supplied By

○ INSTRUMENTS

○ Low Oil Pressure Alarm Switch: ________
○ High Oil Temp. Alarm Switch: ________
○ Temperature Measuring Devices (3.4.1.4):
○ Thermometers ________
○ Thermocouples ________
○ Resistance Temp. Detectors ________
○ Liquid Filled Pressure Gages ________
○ Thermal Relief Valves ________

○ CONTRACT DATA

○ Test Data Prior To Shipment ________
○ Progress Reports (5.3.4) ________

○ SHIPMENT (4.4.1)

	Contract Unit	Spares
Export Boxing (4.4.3.9)	○	○
Domestic Boxing (4.4.3.9)	○	○
Outdoor Storage Over 6 Months	○	○
Fit-Up & Assembly Of Mounted Accessories (4.4.8)	○	○

Notes: ________

☐ RADIAL BEARINGS

	Pinion	Gear
Manufacturer		
Type		
Class		
Cage Speed, ft/min		
☐ B10 ☐ L10 Hours		

Notes: ________

☐ THRUST BEARINGS

	Pinion	Gear
Manufacturer		
Type		
Class		
Cage Speed, ft/min		
☐ B10 ☐ L10 Hours		
DownThrust Capacity, lb		
Up Thrust Capacity, lb		

Notes: ________

☐ COUPLINGS

Manufacturer		
Model		
Cplg.Rating,HP/100 r/min		
Cylindrical / 1-Key	☐	☐
Cylindrical / 2-Keys	☐	☐
Tapered / 1-Key	☐	☐
Tapered / 2-Keys	☐	☐
Tapered / Keyless	☐	☐

☐ MATERIALS

Gear Casing ________ Oil Seals ________
Radial Bearings ________
Thrust Bearing(s) ________
HS Shaft ________ LS Shaft ________
Pinion(s) ________ Hardness ________
Gear Rim(s) ________ Hardness ________

☐ PIPING CONNECTIONS

Service	No.	Size	Type
Lube Oil Inlet			
Lube Oil Outlet			
Casing Drain			
Vent			
Casing Purge			

Notes: ________

GENERAL PURPOSE GEAR UNITS
API 677 THIRD EDITION
BEVEL MOUNTED
DATA SHEET
U.S. CUSTOMARY UNITS

Job No. ______ Item No. ______
Date ______ By ______
Revision No. ______ By ______

○ COUPLINGS AND GUARDS

	High Speed	Low Speed
Coupling Furnished By		
Coupling Type		
Cplg Rating HP/100 RPM		
Coupling Manufacturer		
Coupling Lubrication		
Mount Cplg Halves (3.2.1)		
Taper		
Taper Gauge Furnished By		
Limited End Float		
Cplg Guard Furnished By		

Notes: ______

○ LUBRICATION REQUIREMENTS (2.10)

○ Oil System Furnished By (2.10.4) :
○ Gear Vendor ○ Other ______
○ Oil Visc.: ______ SSU@100 F ______ SSU@210 F (2.10.4)
○ Lubrication Requirements ○ Fig. C-1 ○ Fig. C-2
● Main Oil Pump ○ Shaft Driven ○ Motor Driven
○ Standby Oil Pump MFGR ______ Type ______
Oil Pump Casings: ○ Cast Iron ○ Steel
● Oil Cooler ○ Water Cooled ○ Air Cooled
○ Heaters Required:
○ Electric With Thermostats ○ Steam
○ Duplex Filters

○ INSPECTIONS AND TESTS (4.1.3)

	Req'd	Witnessed	Observed	Test Log
Shop Inspection (4.1.3)	○	○	○	
Cleanliness Inspection (4.1.6)	○	○	○	
Hardness Verification Inspection (4.1.7)	○	○	○	○
Mag. Particle Inspection (4.2.2.9.3)	○	○	○	
Ultrasonic Inspection (4.2.2.9.2)	○	○	○	
Weld Inspection (4.2.2.8)	○	○	○	
Dismantle-Reassembly Inspection	○	○	○	
Contact Check (2.7.2.2)	●	○	○	○
Contact Check Tape Lift (2.7.2.2)	○	○	○	○
Bearing Visual Check (4.3.3.8)	○	○	○	○
Bevel Backlash Check (Appendix G)	○	○	○	○
Residual Unbalance Check (2.8.3.3)	○	○	○	○
Mechanical Run Test (4.3.3)	●	○	○	○
Extended Mechanical Run Test (4.3.3.2)	○	○	○	○
Mechanical Run Test (Spare Rotors) (4.3.3.10)	●	○	○	○
Sound Level Test (4.3.4.2)	○	○	○	○
Mechanical Run Test Coupling (4.3.3.3.5):				
Couplings Installed	○	○	○	○
Coupling Hubs With Idlers	○	○	○	○

☐ LUBRICATION REQUIREMENTS

System Type: ☐ ______
☐ Circulating ☐ Pressurized
☐ Filters, Micron Rating ______
☐ Cooler Not Required
☐ Minimum Startup Oil Temperature ______ F
☐ Oil Flow ______ gal/min
☐ Oil Pressure ______ psig
☐ Unit Power Loss ______ hp
Reservoir: ☐ Gear Casing ☐ Separate
☐ Lube Oil Inlet Size ______ in.
☐ Lube Oil Outlet Size ______ in.

☐ WEIGHTS AND DIMENSIONS

Net Weight: Gear ______ lb ☐ Auxiliaries ______ lb
Max. Maintenance Weight (Identify) ______ lb
Total Shipping Weight(s) ______ lb
Total Shipping Dimensions ______ X ______ X ______

○ INSPECTIONS AND TESTS (4.1.3)

Use Shop Lube System (4.3.3.3.2) (4.3.3.11)	○	○	○	○
Use Job Lube System (4.3.3.3.2) (4.3.3.11) (4.3.3.3.6)	○	○	○	○
Final Assembly, Maintenance & Running Clearance (4.2.1.1f)	○	○	○	○
Oil System Cleanliness	●	○	○	
Oil System-Casing Joint Tightness (4.3.3.3.3)	●	○	○	
Warning And Protection Devices (4.3.3.3.4)	●	○	○	
Oil System Leak Test (4.3.2.2)	●	○	○	

Notes: ______

APPENDIX B—LATERAL CRITICAL SPEED MAP AND MODE SHAPES FOR A TYPICAL ROTOR

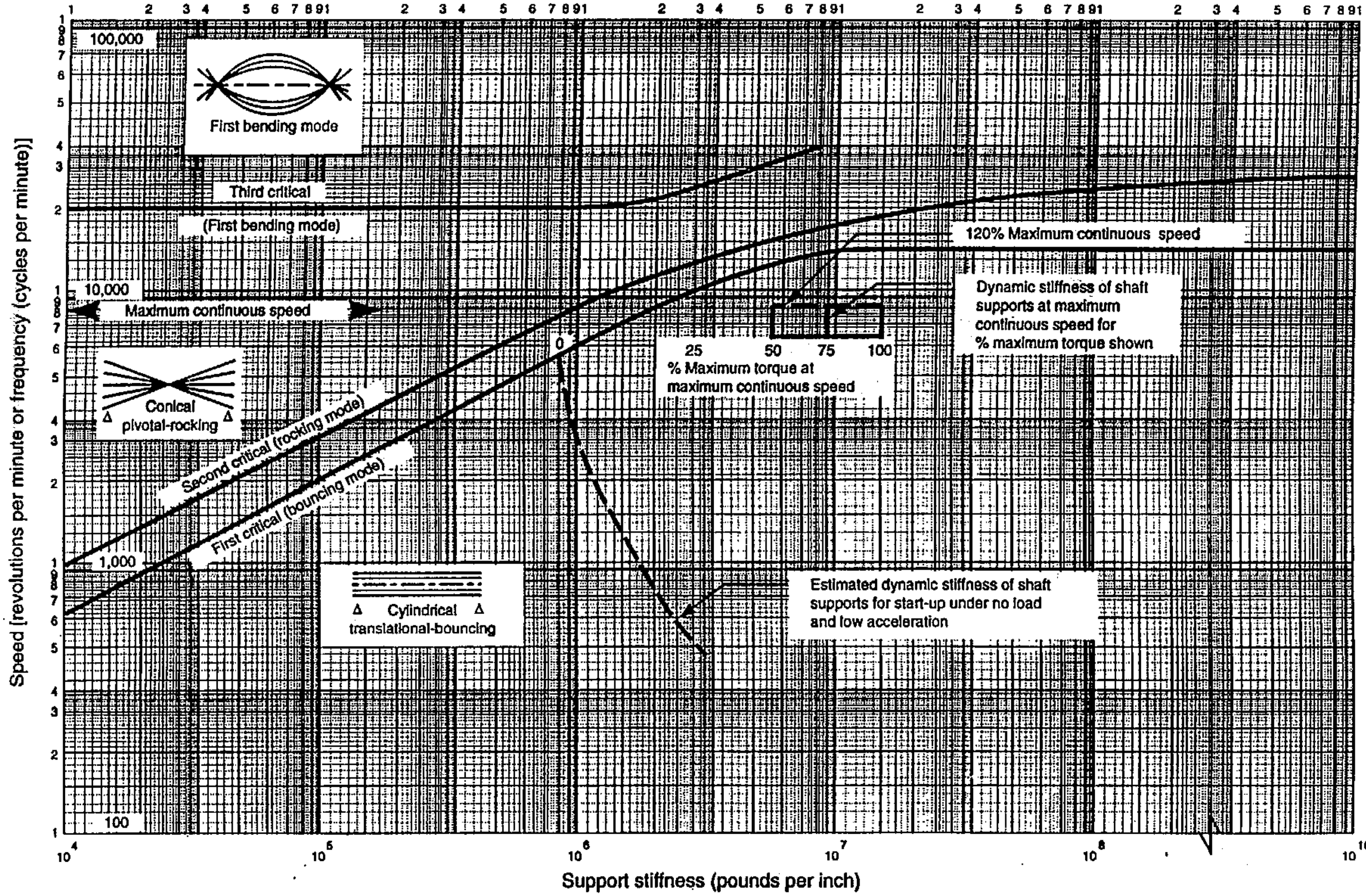
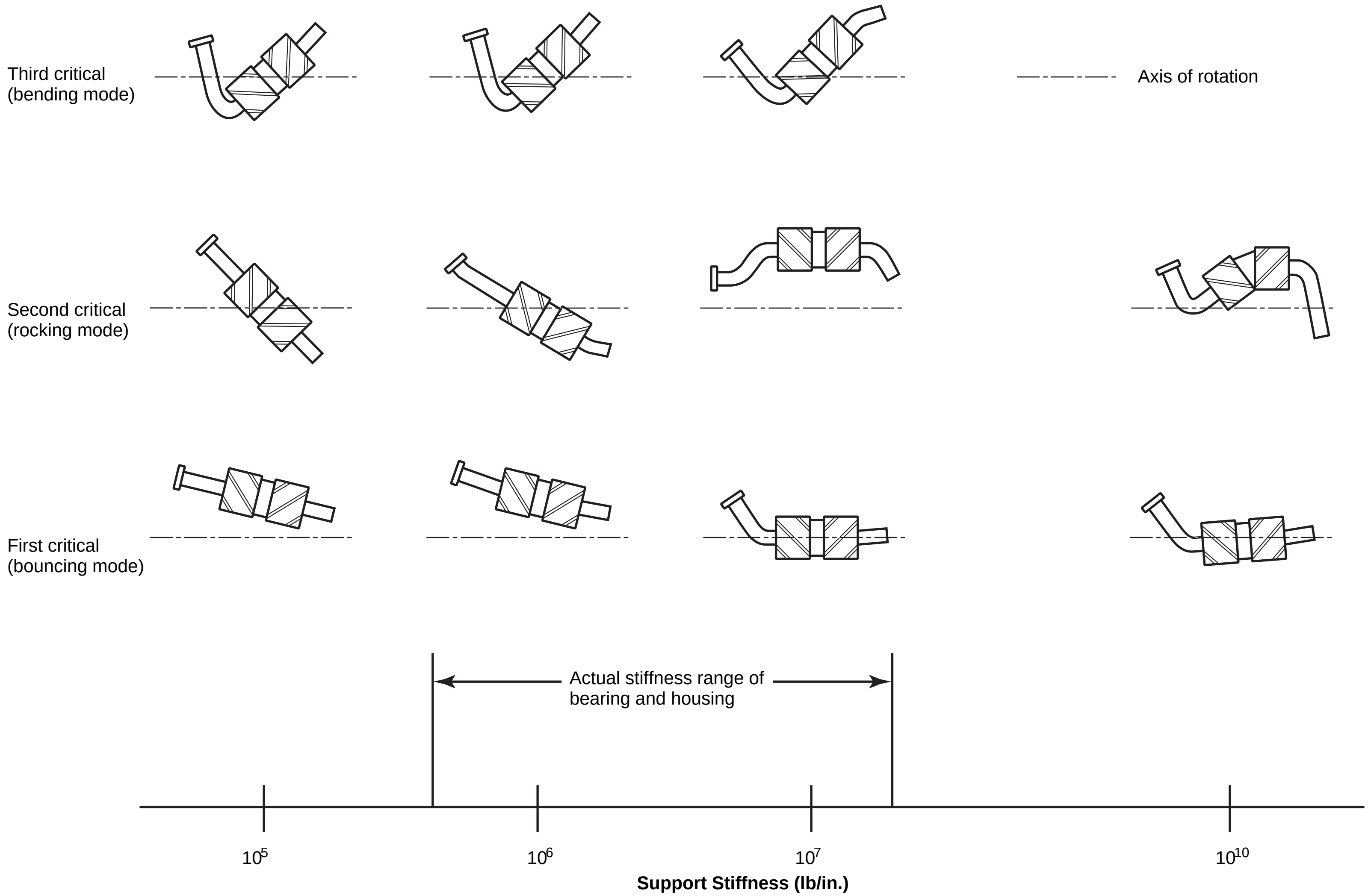


Figure B-1—Lateral Critical Speed Map for a Typical Rotor



Note: The mode shapes in this figure are normalized, which exaggerates the deflections of the rotor. The actual maximum deflection may be so small that it is insignificant. These mode shapes apply only to operation directly on a critical speed. Mode shapes will vary with the geometry of the rotor.

Figure B-2—Mode Shapes versus Support Stiffness for a Typical Rotor

--`,,`,,,,`,`,,,`,,`,`,`,,`,`,`,`,,`,,`,`,,`---

APPENDIX C—TYPICAL LUBE-OIL SYSTEMS

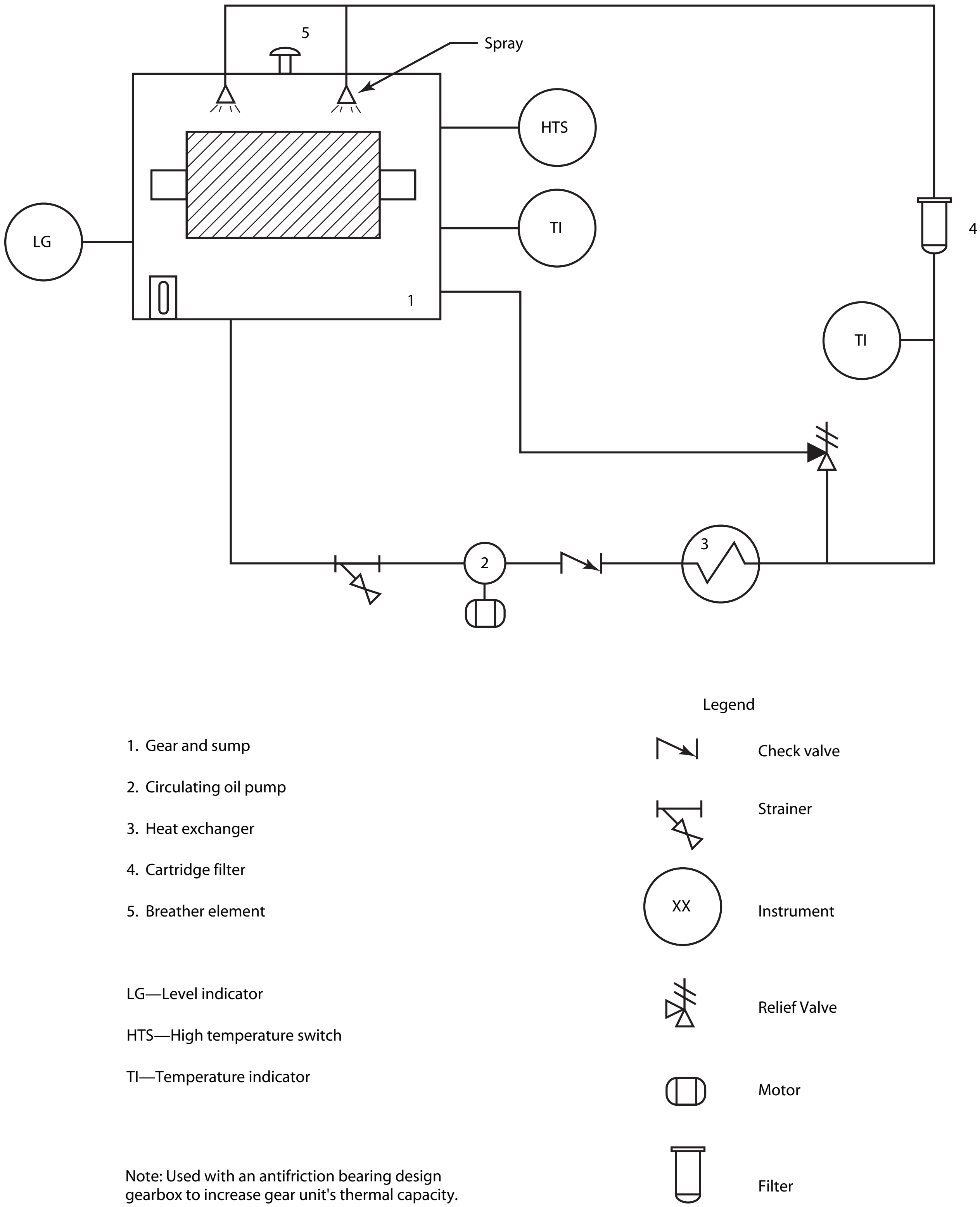
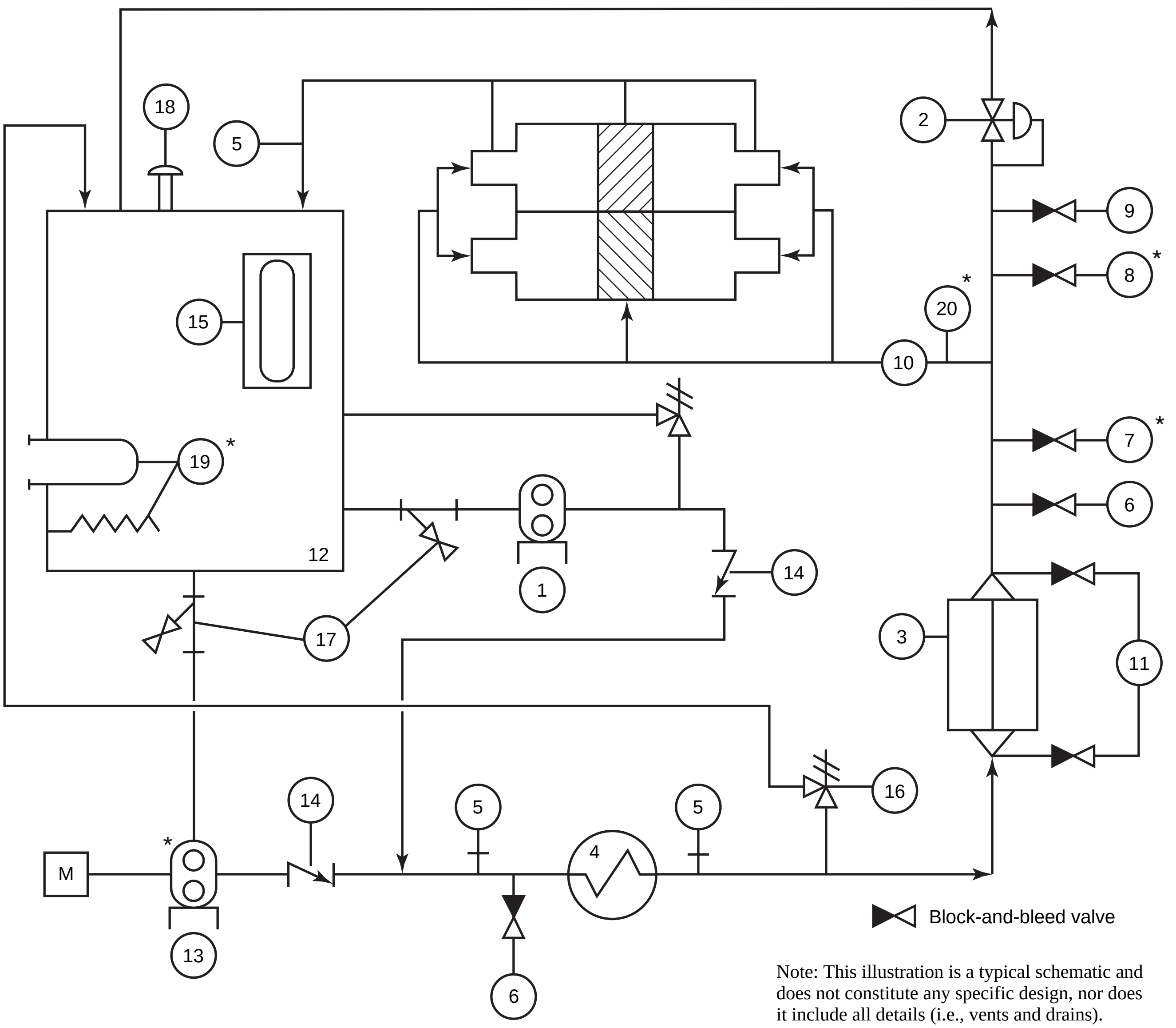


Figure C-1—Typical Circulating Lube-oil System for Gear Units



1. Shaft driven main oil pump
2. Pressure regulating valve
* 3. Duplex full flow filter
4. Oil cooler
5. Temperature gauge
6. Pressure gauge
* 7. Low-pressure alarm
* 8. Low-pressure auxiliary oil pump start-up
9. Low-pressure trip
10. Sight flow indicator
11. Pressure differential indicator
12. Oil reservoir (separate)
* 13. Auxiliary oil pump
14. Check valve
15. Oil-level indicator
16. Relief valve
17. Suction strainer
18. Filler/breather
* 19. Sump heater
* 20. High oil temperaturealarm

* Optional items

Figure C-2—Typical Pressurized Lube-oil System for Hydrodynamic Bearings in Gear Units

APPENDIX D—MATERIAL SPECIFICATIONS FOR GENERAL-PURPOSE GEAR UNITS

Table D-1—Gear Unit Housings

Cast	Material[a,b]
Cast	ASTM A 27 Grade 65-35
Cast	ASTM A 48 Class 30 Minimum
Cast	EN JL1040
Cast	EN JL1050
Cast	EN JL1030
Cast	EN JL1015
Fabricated	**Material[a,b]**
Hot-rolled Bars	ASTM A 575, A 576
Plate	ASTM A 131
Plate	ASTM A 283
Plate	ASTM A 284, Grade B
Plate	ASTM A 285
Plate	ASTM A 516
Plate or Shape	ASTM A 6
Plate or Shape	ASTM A 36
Plate or Shape	AISI 1010
Plate or Shape	AISI 1020
	EN C45E
	EN C15E
	EN S235JRG

Table D-2 —Shafts, Pinions[c], & Gear Wheels[c]

Heat Treatment	Material[a,b]
Through-Hardened	AISI 4140
	AISI 4145
	AISI 4340
	EN 42CrMo4
	EN 34CrNiMo6
	EN 30CrNiMo8
	EN 36CrNiMo16
Nitrided	SAE/AMS 6470
	SAE/AMS 6475
	EN 18CrMoV12-9
	EN 31CrMoV9
	EN 32CrMoV12-9
Carburized	AISI 3310
	AISI 4320
	AISI 9310
	EN 12NiCrMo7
	EN 18CrNiMo7-6

Note: [a]Descriptions of AISI designations can be found in ASTM DS 56B. For alloy steel the material chemistry shown can be both standard and "H." Also,sometime the designation "E" is shown in front of the AISI number to indicate electric furnace melted and is also acceptable. For instance, when 4340 is the listed material, 4340, 4340H, E4340 and E4340H are all acceptable materials.
[b]Descriptions of EN or Euronorm designations can be found in EN10083 & EN10084 & EN1561 & EN1563.
[c]Forgings and hot rolled bar stock used on gear wheels, gear wheel rims, & pinions shall as a minimum be electric furnace melted and vacuum degassed and meet the requirements of ANSI/AGMA/ISO 6336-5 quality grade M.

--`,,`,,,,`,`,,,`,,`,`,`,,`,`,`-`-`,,`,,`,`,,`---

Table D-3—Fabricated Gears

Web	Material[a,b]
Plate Plate Plate or Shapes	ASTM A 283, Grade B ASTM A 285, Grade B&C ASTM A 36 EN C45E EN C15E EN S235JRG
Hub	**Material[a,b]**
	AISI 1020 AISI 4140 AISI 4340 EN C45E EN C15E EN S235JRG
Rim[c]	**Material[a,b]**
Through-Hardened	AISI 4130 AISI 4135 AISI 4140 AISI 4145 AISI 4340 EN 42CrMo4 EN 34CrNiMo6 EN 30CrNiMo8 EN 36CrNiMo16
Nitrided	SAE/AMS 6470 SAE/AMS 6475 EN 18CrMoV12-9 EN 31CrMoV9 EN 32CrMoV12-9
Carburized	AISI 3310 AISI 4320 AISI 9310 EN 12NiCrMo7 EN 18CrNiMo7-6

APPENDIX E—VENDOR DRAWING AND DATA REQUIREMENTS

--`,,,`,,,,`,`,,,`,,`,`,`,,`,`,``,`-`-`,,`,,`,`,,`---

SPECIAL PURPOSE GEAR UNITS VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ______ ITEM NO. ______
PURCHASE ORDER NO. ______ DATE ______
REQUISITION NO. ______ DATE ______
INQUIRY NO. ______ DATE ______
PAGE 1 OF 2 BY ______
REVISION ______
UNIT ______
NO. REQUIRED ______

FOR ______
SITE ______
SERVICE ______

Proposal[a] Bidder shall furnish ____ copies of data for all items indicated by an X.

Review[b] Vendor shall furnish ____ copies and ____ electronic files of drawings and data indicated.

Final[c] Vendor shall furnish ____ copies and ____ electronic files of drawings and data indicated.
Vendor shall furnish ____ copies and ____ electronic files of operating and maintenance manuals.

DISTRIBUTION RECORD

Final-Receive from vendor
Final-Due from vendor[c]
Review-Returned to vendor
Review-Received from vendor
Review-Due from vendor[c]

Proposal	Review	Final	DESCRIPTION	Review-Due from vendor	Review-Received from vendor	Review-Returned to vendor	Final-Due from vendor	Final-Receive from vendor
			1. Certified dimensional outline drawing and list of connections.					
			2. Cross-sectional drawings and part numbers.[d]					
			3. Rotor assembly drawings and part numbers.[d]					
			4. Thrust-bearing assembly drawing and part numbers.[d]					
			5. Journal-bearing assembly drawings and bills of materials.					
			6. Coupling assembly drawing and bill of materials.[d,e]					
			7. Lube-oil schematic and bill of materials.					
			8. Lube-oil arrangement drawing and list of connections.[e]					
			9. Lube-oil component drawings and data.[d]					
			10. Electrical and instrumentation schematics and bills of materials.					
			11. Electrical and instrumentaion arrangement drawing and list of connections.					
			12. Tooth-contact drawing and specifications.[d]					
			13. Tooth-contact check records.					
			14. Record of deviations from manufacturing process control system.[f]					
			15. Mass elastic data.					
			16. Lateral critical speed analysis report.[f]					
			17. Torsional analysis report.[f]					
			18. Input and output shaft position diagram.					
			19. Weld procedures.[f]					
			20. Hydrostatic test logs (oil system).					
			21. Mechanical running test logs.[f]					
			22. Rotor balancing logs.					
			23. Rotor mechanical and electrical runout.[f]					
			24. As-built data sheets.					
			25. As-built dimensions or data.[d]					
			26. Installation manual.					
			27. Operating, maintenance, and technical manual.					
			28. Spare parts recommendation and price list.					
			29. Progress reports and delivery schedule.					

[a]Proposal drawings and data do not have to be certified or as-built.
[b]Purchaser will indicate in this column the desired time frame for submission of materials, using the nomenclature given at the end of the form.
[c]Bidder shall complete this column to reflect his/her actual distribution schedule and shall include this form with this proposal.
[d]These items are normally provided only in instruction manuals.
[e]If furnished by the vendor.
[f]If specified.

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SPECIAL PURPOSE GEAR UNITS VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ______ ITEM NO. ______
PAGE 2 OF 2 BY ______
DATE ______ REVISION ______

Proposal[a] Bidder shall furnish ____ copies of data for all items indicated by an X.

Review[b] Vendor shall furnish ____ copies and ____ electronic files of drawings and data indicated.

Final[c] Vendor shall furnish ____ copies and ____ electronic files of drawings and data indicated.
Vendor shall furnish ____ copies and ____ electronic files of operating and maintenance manuals.

DISTRIBUTION RECORD

Final-Receive from vendor
Final-Due from vendor[c]
Review-Returned to vendor
Review-Received from vendor
Review-Due from vendor[c]

Proposal	Review	Final	DESCRIPTION	Review-Due from vendor	Review-Received from vendor	Review-Returned to vendor	Final-Due from vendor	Final-Receive from vendor
			30. Preservation, packaging, and shipping procedures.					
			31. List of special tools furnished for maintenance.					
			32. Material safety data sheets (OSHA Form 20).					
			33. Nondestructive and performance test procedures and acceptance criteria.					
			34. Quality data manual					

[a]Proposal drawings and data do not have to be certified or as-built.
[b]Purchaser will indicate in this column the desired time frame for submission of materials, using the nomenclature given at the end of the form (S, F, or D).
[c]Bidder shall complete this column to reflect his actual distribution schedule and shall include this form with the proposal.
[d]These items are normally provided only in instruction manuals.
[e]If furnished by the vendor.
[f]If specified.

Notes:

1. Where necessary to meet the scheduled shipping date, the vendor shall proceed with manufacture upon receipt of the order and without awaiting the purchaser's approval of drawings.
2. The vendor shall send all drawings and data to the following:

   ____

3. All drawings and data shall show project, purchase order, and item numbers as well as plant location and unit. One set of the drawings and instructions necessary for field installation, in addition to the copies specified above, shall be fowarded with shipment.
4. See the descriptions of required items that follow.
5. All of the information indicated on the distributuion schedule shall be received before final payment is made.

Nomenclature:
S number of weeks before shipment.
F number of weeks after firm order.
D number of weeks after receipt of approved drawings.

Vendor ______________________________

Date ____________ Vendor Reference ______________________________

Signature ______________________________

(Signature acknowledges receipt of all instructions)

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Description

1. Certified dimensional outline drawing and list of connections including the following:
    a. The size, rating, and location of all customer connections.
    b. Approximate overall and handling weights.
    c. Overall dimensions, and maintenance and dismantling clearances.
    d. Centerline height of each shaft.
    e. Dimensions of baseplates (if furnished) complete with diameters, number, and locations of bolt holes and the thicknesses of sections through which the bolts must pass, and recommended clearances.
    f. Grouting details.
    g. Center of gravity and lifting points.
    h. Shaft end separation and alignment data.
    i. Direction of rotation for each shaft.
    j. Winterization, tropicalization, and/or noise attenuation details, when required.
2. Cross-sectional drawings and part numbers.
3. Rotor assembly drawings and part numbers.
4. Thrust-bearing assembly drawing and part numbers.
5. Journal-bearing asembly drawings and bills of materials.
6. Coupling assembly drawings and bills of materials (where applicable).
7. Lube-oil schematic and bill of materials including the following (where applicable):
    a. Oil flows, temperatures, and pressures at each use point.
    b. Control, alarm, and trip settings (pressure and recommended temperatures).
    c. Total heat loads.
    d. Utility requirements, including electrical, water, and air.
    e. Pipe, valve, and orifice sizes.
    f. Instrumentation, safety devices, control schemes, and wiring diagrams.
8. Lube-oil arrangement drawing and list of connections.
9. Lube-oil component drawings and data including the following:
    a. Pumps and drivers.
    b. Coolers, filters, and reservoir.
    c. Instrumentation.
    d. Spare parts lists and recommendations.
10. Electrical and instrumentation schematics and bills of materials including the following:
    a. Vibration alarm and shutdown limits.
    b. Bearing temperature alarm and shutdown limits.
    c. Lube-oil temperature alarm and shutdown limits.
    d. Driver.
11. Electrical and instrumentation arrangement drawing and list of connections.
12. Tooth-contact drawing and specifications.
13. Tooth-contact check records.
14. Record of deviations from manufacturing process control system.
15. Mass electric data.
16. Lateral critical speed analysis report.
17. Torsional analysis report.
18. Input and output shaft position diagram.

19. Weld procedures.
20. Hydrostatic test logs (oil system).
21. Mechanical running test logs.
22. Rotor balancing logs.
23. Rotor mechanical and electrical runout.
24. As-built data sheets.
25. As-built dimensions and data.
26. Installation manual—including the following as a minimum:
    a. Storage procedures.
    b. Foundation plan.
    c. Grouting.
    d. Setting equipment, rigging procedures, component weights, and lifting diagram.
    e. Shaft alignment diagram.
    f. Piping recommendations.
    g. Composite outline drawing for driven equipment/gear/driver train, including anchor bolt locations.
    h. Dismantling clearances.
27. Operating, maintenance, and technical manual-including the following as a minimum:

Section 1—Operation:

a. Start-up including tests and checks before start-up.
b. Routine operational procedures.
c. Lube-oil recommendations.

Section 2—Disassembly and assembly:

a. Gears in casing.
b. Journal bearings.
c. Thrust bearings (including clearance and preload on antifriction bearings).
d. Seals.
e. Thrust collars, if applicable.
f. Allowable wear of running clearances.
g. Fits and clearances for rebuilding.
h. Bolt torque values.
i. Illustrated maintenance procedures and intervals.

Section 3—Vibration data:

a. Vibration analysis data.
b. Lateral critical speed analysis.
c. Torsional critical speed analysis.

Section 4—As-built data:

a. As-built data sheets.
b. As-built dimensions or data (see item 25).
c. Noise data sheets.
d. Performance data.

Section 5—Drawings and data:

a. A drawing list, including latest revision numbers and dates.
b. Certified dimensional outline drawing and list of connections.
c. Cross-sectional drawing and bill of materials.
d. Shaft seal drawing and bill of materials.

e. Rotor assembly drawings and bills of materials.
f. Thrust-bearing assembly drawings and bills of materials.
g. Journal-bearing assembly drawings and bills of materials.
h. Lube-oil schematic and bills of materials.
i. Lube-oil arrangement drawing and list of connections.
j. Lube-oil component drawings and data, and bill of materials.
k. Electrical and instrumentation schematics, wiring diagrams, and bills of materials.
l. Electrical and instrumentation arrangement drawing and list of connections.
m. Coupling assembly drawing and bill of materials.
n. Complete parts list referenced to cross-section drawings.

28. Spare part recommendations and price list.
29. Progress reports and delivery schedule.
30. Preservation, packaging, and shipping procedures.
31. List of special tools furnished for maintenance.
32. Material safety data sheets (OSHA Form 20).
33. Non-destructive test procedures and acceptance criteria.
34. Quality data manual.

Section 1—Vibration data:

a. Vibration test data logs.
b. Lateral critical speed analysis report.
c. Torsional critical speed analysis report, if specified.
d. Mass elastic data.

Section 2—As-built data:

a. As-built data sheets.
b. As-built clearances.
c. Rotor balance logs and 6-point residual unbalance check.
d. Noise data sheets.
e. Input and output shaft position diagram.
f. Welding procedures.
g. Gear checker charts (lead, profile and spacing).
h. Tooth contact blue transfer tapes (checking stand).
i. Tooth contact blue transfer tapes (contract housing).
j. Mechanical run test logs and vibration data.
k. Rotor mechanical and electrical runout.
l. As-built dimensions or data.

APPENDIX F—REFERENCED SPECIFICATIONS

API

Std 613	*Special Purpose Gear Units for Petroleum, Chemical and Gas Industry Services*
Std 614	*Lubrication, Shaft-sealing and Control-oil Systems and Auxiliaries for Petroleum, Chemical and Gas Industry Services*
Std 670	*Machinery Protection Systems*
Std 671	*Special Purpose Couplings for Petroleum, Chemical and Gas Industry Services*
Publ 684	*Tutorial on the API Standard Paragraphs Covering Rotor Dynamics and Balance (An Introduction to Lateral Critical and Train Torsional Analysis and Rotor Balancing)*
RP 686	*Machinery Installation and Installation Design*
MPMS	*Manual of Petroleum Measurement Standards Chapter 15*

ABMA[1]

Std 7	*Shaft and Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plans*
Std 9	*Load Ratings and Fatigue Life for Ball Bearings*
Std 11	*Load Ratings and Fatigue Life for Roller Bearings*
Std 20	*Radial Bearings of Ball, Cylindrical Roller and Spherical Roller Types, Metric Design; Basic Plan for Boundary Dimensions, Tolerances an Identification Code*

AGMA[2]

908 Information Sheet	*Geometry Factors for Determining the Pitting Resistance and Bending Strength of Spur, Helical and Herringbone Gear Teeth*
2101	*Fundamental Rating Factors and Calculation Methods for Involute Spur and Helical Gear Teeth (Metric Units)*
6010	*Standard for Spur, Helical, Herringbone and Bevel Enclosed Drives*
6011	*Specification for High Speed Helical Gear Units*
6001-D97	*Design and Selection of Components for Enclosed Gear Drives*
6025-D98	*Sound for Enclosed Helical, Herringbone and Spiral Bevel Gears*
9002	*Bores and Keyways for Flexible Couplings*

ASME[3]

B1.1	*Unified Screw Threads (UN and UNR Thread Form)*
B1.20.1	*Pipe Threads, General Purpose (Inch)*
B16.1	*Cast Iron Pipe Flanges and Flange Fittings, Classes 25, 125 and 250*
B16.5	*Pipe Flanges and Flanged Fittings NPS* $^1/_2$ *Through NPS 250*
B16.42	*Ductile Iron Pipe Flanges and Flanged Fittings, Classes 150 and 300*
B31.3	*Chemical Plant and Petroleum Refinery Piping*
Boiler and Pressure Vessel Code:	
	Section VIII Rules for Construction of Pressure Vessels
	Section IX Qualification Standard for Welding and Brazing Qualifications

ASTM[4]

A 388	*Standard Practice for Ultrasonic Examination of Heavy Steel Forgings*
A 578	*Standard Specification for Straight-Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications*
E 94	*Standard Guide for Radiographic Examination*
E 165	*Standard Test Methods for Liquid Penetrant Examination*
A 609	*Standard Practice for Castings, Carbon, Low-alloy, and Martinsetic Stainless Steel, Ultrasonic Examination Thereof*

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[1]American Bearing Manufacturers Association, 2111 West Plum Street, Suite 274, Aurora, Illinois 60506, www.abma.org.
[2]American Gear Manufacturers Association, 500 Montgomery Street, Suite 350, Alexandria, Virginia 22314-1581, www.agma.org.
[3]ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org.
[4]ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, www.astm.org.

E 709	*Standard Practice for Magnetic Particle Examination*
CEN[5]	
EN 1561 (BS)	*Foundary—Grey Cast Irons*
EN 1563 (BS)	*Foundary—Spherodial Graphite Cast Irons*
EN 10083	*Quenched and Tempered Steels*
EN 10084	*Case Hardened Steels*
IEC[6]	
60034-5	*Degrees of Protection Provided by the Integral Design of Rotating Electrical Machines (IP Code)*
60079-0	*Electrical Apparatus for Explosive Gas Atmospheres*
ISO[7]	
7-1	*Pipe threads where pressure-tight joints are made on the threads*
261	*ISO general-purpose metric screw threads—General plan*
262	*ISO general-purpose metric screw threads —Selected sizes for screws, bolts and nuts*
281	*Rolling Bearings—Dynamic Load Ratings and Rating Life*
R286	*ISO system of Limits and Fits—Parts 1 & 2*
724	*ISO general-purpose metric screw threads—Tolerances*
965	*ISO general purpose metric screw threads—Tolerances*
1328-1	*Cylindrical Gears—ISO System of Accuracy—Part 1: Definitions and Allowable Values of Deviations Relevant to Corresponding Flanks of Gear Teeth*
3448	*Industrial liquid lubricants—ISO viscosity classification*
3744	*Determination of Sound Power Levels of Noise Sources Using Sound Pressure— Engineering Method in an Essentially Free Field Over a Reflecting Plane*
5753	*Rolling Bearings-Radial Internal Clearances*
6336-5	*Calculation of load capacity of spur and helical gears—Part 5: Strength and quality of materials*
6708	*Pipework components—Definition and Selection of DN (Nominal Sizes)*
7005-1	*Metallic Flanges—Part 1: Steel Flanges*
7005-2	*Metallic Flanges—Part 2: Cast Iron Flanges*
8501	*Preparation of steel substrates before application of paints and related products*
TR 10064-1	*Cylindrical gears—Code of inspection practice Part 1: Inspection of corresponding flanks of gear teeth*
NEMA[8]	
SM23	*Steam Turbines for Mechanical Drive*
Publ 250	*Enclosures for Electrical Equipment (1000 Volts Maximum)*
NFPA[9]	
NFPA 70	*National Electrical Code, Articles 500, 501, 502 and 504*
SSPC[10]	
SP6	*Commercial Blast Cleaning*

[5]CEN European Committee for Standardization, 36 rue de Stassart, B-1050 Brussels, www.cenorm.be/cenorm/index.htm.
[6]International Electrochemical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211, Geneva 20, Switzerland,www.iec.ch.
[7]International Organization for Standardization, ISO publications are available from the American National Standards Institute (ANSI), 25 West 43rd Street, 4 Floor, New York, New York 10036, www.iso.org, www.ansi.org.
[8]National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1847, Rosslyn, Virginia 22209, www.nema.org.
[9]National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169, www.nfpa.org.
[10]The Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburgh, Pennsylvania 15222-4656, www.sspc.org.

APPENDIX G—SPIRAL BEVEL GEAR-TOOTH CONTACT ARRANGEMENT REQUIREMENTS FOR INSPECTION

G.1 General Information

Spiral bevel gearing requires attention to the orientation of the bevel tooth contact patterns of the gear set at the manufacturer. An inspector in the final testing and assembly will need to recognize the proper gear-tooth contact-bearing patterns to ensure that the gear set is properly aligned and ready for installation with the driven equipment (i.e., fan, blower or agitator, etc.). Determining the gear set contact-bearing surface patterns requires an understanding of gear-tooth nomenclature. There are nine basic elements of the gear tooth, which are described in Figure G-1, that will aid in certifying that a gear set is properly manufactured and assembled. This nomenclature will be used for all the exhibits and narratives in this appendix.

The TOE of a bevel gear tooth is the portion of the tooth surface at the inner end.

The HEEL of a bevel gear tooth is the portion of the tooth surface at the outer end.

The TOP of a gear tooth is the upper or addendum portion of the tooth surface.

The FLANK of a gear tooth is the lower or dedendum portion of the tooth surface.

The TOP LAND of a gear tooth is the surface of the top of the tooth.

The TOP SIDE of a tooth.

The BOTTOM SIDE of a tooth.

The CLEARANCE is the distance from the bottom of a tooth space to the top of a mating tooth.

The WORKING AREA is all that portion of the tooth surface above the clearance.

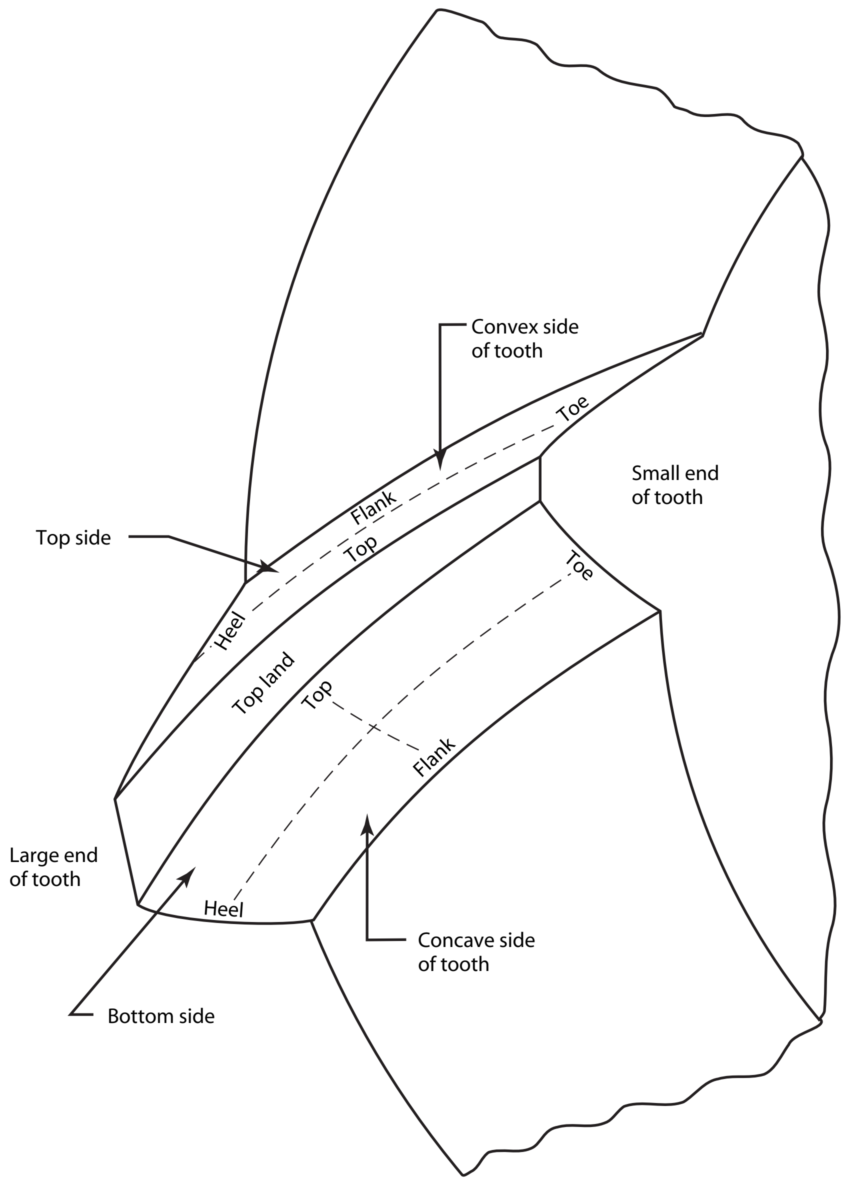

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Figure G-1—Gear-tooth Nomenclature

G.2 Mounting Distance

The quality of performance that is designed and manufactured into a set of bevel gears can only be achieved by correct mounting. Each gear and pinion must be positioned relative to the other to provide proper tooth contact pattern and backlash. Desirable tooth contact patterns and improper contact patterns are illustrated. Typical corrective adjustments (not dimensioned) are indicated in Figure G-2.

The axial position of a bevel gear and pinion in assembly is given by a dimension called the mounting distance (MD) as shown in Figure G-2. This measurement is the linear dimension from the axial locating surface of a given member to the crossing point[11] which is the point of intersection of the pinion and gear axes. Normally, the back of the pinion or gear is used to establish MD; however, for convenience in assembling some gears, a front surface may be used. In all cases, the distance will be given to a flat surface square with the axis of the gear or pinion. The MD is then etched on the surface of the gear set.

G.3 Positioning Gear and Pinion in Bevel Gear Drives

The pinion shaft assembly, including bearings, is usually contained in a cylindrical cartridge. Pinion MD is set by adjusting thickness of shims between cartridge flange and gear drive housing. A gauge is used to set the pinion member to its proper MD. This

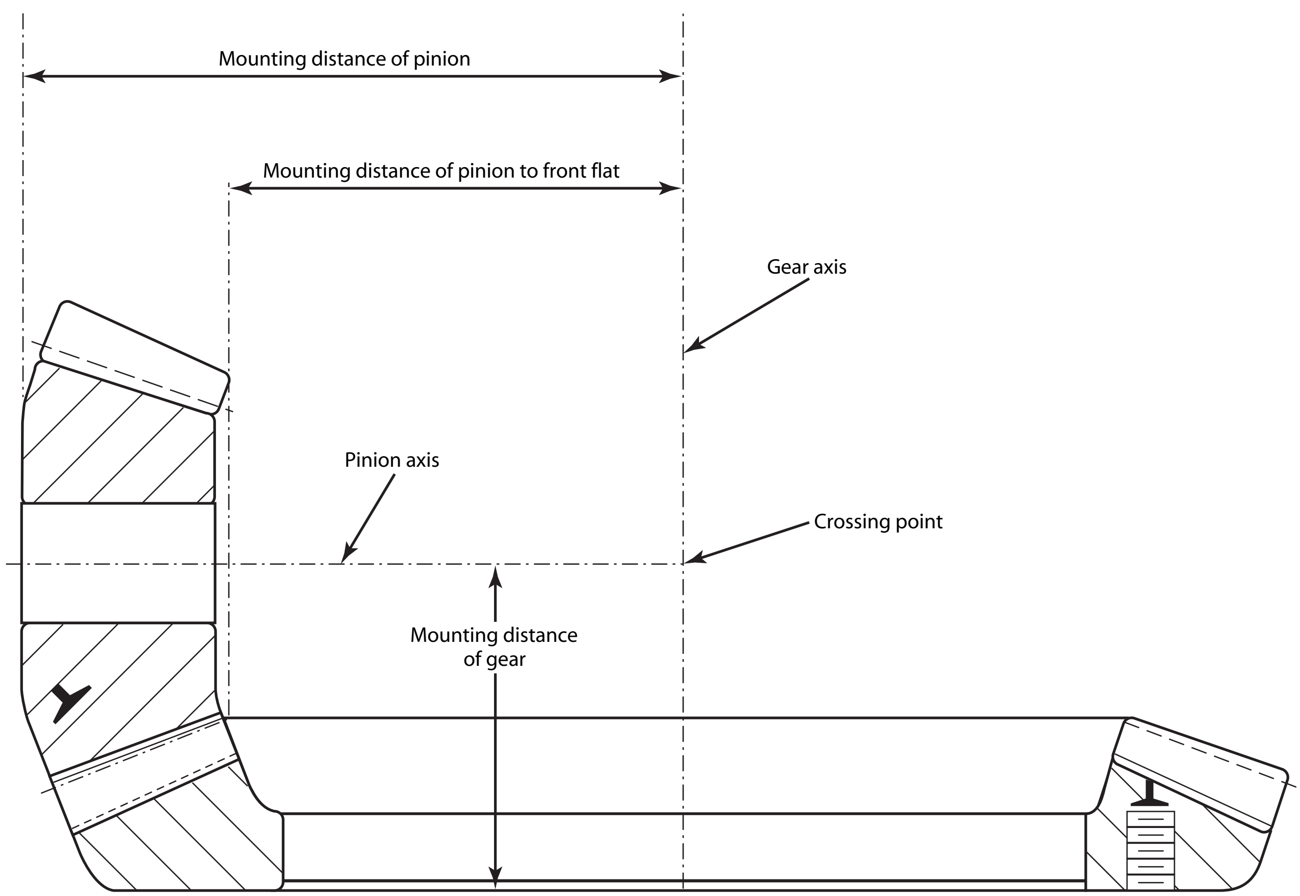

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Figure G-2—Determining Mounting Distances

[11]Crossing point is the apparent point of intersection of the gear and pinion axis on a drawing showing the two axes. For bevel gears, it is the point of intersection of the two axes.

MD is measured by means of a special gauge manufactured for this purpose. This gauge is provided by the manufacturer and is a special shop tool. Reference points for measuring distances are shown in Figure G-3.

In the case of large bevel gears where direct measurement of MD is difficult, a flat is hand-ground on the back cone surfaces (back angles) of the gear and pinion when in proper position on the testing machine. When the gears are assembled, they must be positioned so that the hand-ground flats on the back cone surfaces are flush. These surfaces are marked "X" and must be assembled in a manner similar to that used for lapped gears.

The gear member will now be positioned by either of two methods. Once the pinion is positioned, proper location of the gear may now be determined by measuring the backlash. If the backlash does not conform to specifications, the gear member must be repositioned axially.

To adjust, the caps are removed from the housing at the shaft ends and shims are removed from one end as needed, and equivalent thickness shims are added to the opposite end. Caps are then replaced. This procedure allows repositioning of gear/shaft assembly while maintaining bearing clearances.

G.4 Positioning Gear and Pinion in Bevel Gear Drives

G.4.1 Backlash is the difference in width of the gear tooth and the gear-tooth space in the mating gear (see Figure G-4). It is measured at the tightest point of mesh.

Backlash is necessary to achieve correct operation of the gears and varies with the size of the tooth and the operating conditions. Bevel gears are cut to have a definite amount of backlash when correctly assembled together. Excessive or insufficient backlash can result in noise, excessive wear, and damage. Backlash can be changed by changing the position of one or both members.

Setting the correct backlash is an important part of the gear assembly procedure. Unless specified otherwise by purchaser, the normal backlash is etched or stamped on one or both of the members. Table G-1 shows recommended values but in many cases, manufacturing or operating conditions make it necessary to go outside these values. Deviations to the normal backlash settings will be discussed with purchaser during the engineering of the gear. Values are given for normal backlash at the tightest point of mesh. Normal backlash is measured in a direction normal to the surface of the tooth. It can be checked by locking the pinion against rotation, placing a dial indicator against the gear tooth perpendicular to the tooth surface at the extreme heel of the tooth, and rotating the gear. To establish backlash in the transverse plane rotation, the normal backlash must be divided by the cosine of the spiral angle and the cosine of the pressure angle of the gear teeth. Transverse rotation is approximately 30% higher than normal backlash (see Figure G-5).

The graph in Figure G-6 illustrates the amount of axial movement necessary for either the pinion or gear member to obtain a change in backlash.

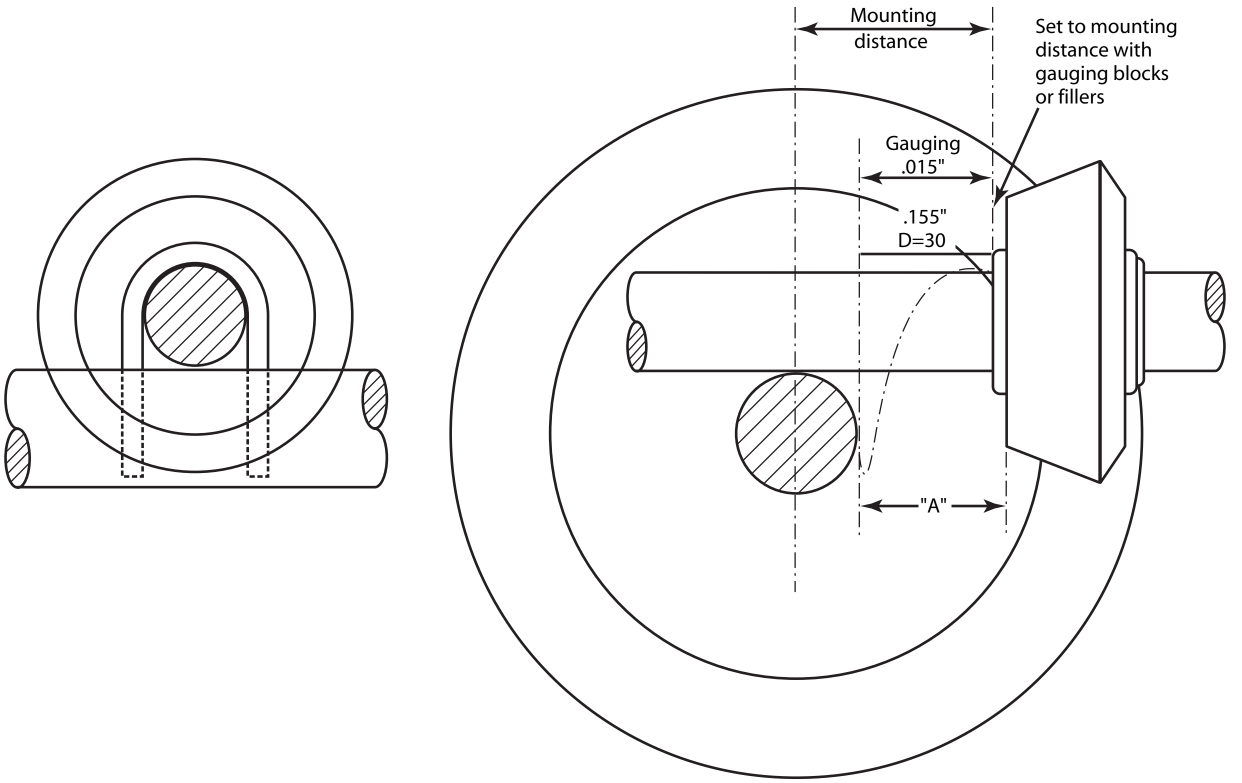

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Figure G-3—Reference Points in Bevel Gear Drives

Table G-1–Recommended Values of Normal Backlash at Tight Points of Mesh (All Values in Inches)

Diametral Pitch	Normal Backlash at Tight Points of Mesh
1.00 – 1.25	0.020 – 0.030
1.25 – 1.50	0.018 – 0.026
1.50 – 1.75	0.016 – 0.022
1.75 – 2.00	0.014 – 0.018
2.00 – 2.50	0.012 – 0.016
2.50 – 3.00	0.010 – 0.013
3.00 – 3.50	0.008 – 0.011
3.50 – 4.00	0.007 – 0.009
4.00 – 5.00	0.006 – 0.008
5.00 – 6.00	0.005 – 0.007
6.00 – 8.00	0.004 – 0.006
8.00 – 10.00	0.003 – 0.005
10.00 – 16.00	0.002 – 0.004
16.00 – 20.00	0.001 – 0.003

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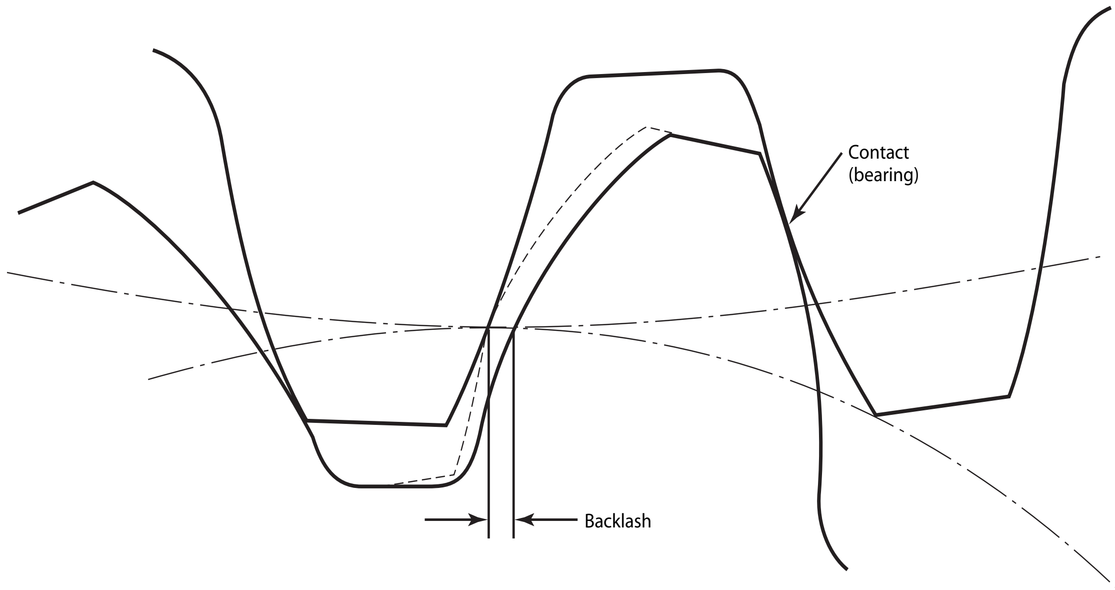

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Figure G-4—Backlash in the Plane of Rotation

G.4.2 ASSEMBLING BEVEL GEARS, AXIAL MOVEMENT VS. BACKLASH

The amount of axial movement for either pinion or gear member necessary to obtain a change in backlash may be determined by the following formulas:

$$\Delta P = \frac{\Delta B_P}{2\tan\phi\sin\gamma}$$

$$\Delta G = \frac{\Delta B_g}{2\tan\phi\sin\Gamma}$$

where

ΔB_p = change of backlash for pinion (mm/mil),

ΔB_g = change of backlash for gear (mm/mil),

ΔP = axial movement of pinion (mm/mil),

ΔG = axial movement of gear (mm/mil),

ϕ = pressure angle,

γ = pitch angle pinion,

Γ = pitch angle gear.

G.5 Tooth Contact for Bevel Gears

Inspection of the gear-tooth contact surfaces is much more critical in bevel and spiral bevel gear units than in parallel shaft gear units due to the interaction of backlash and bearing patterns. Identifying on the test stand the contact pattern acceptability is an important part of ensuring that any gear unit will provide good dependable service. An inspector should be familiar with the desired tooth contact patterns that will be seen during a gear test procedure. Acceptable contact can be identified and improper alignments can be corrected prior to shipment of the gear unit. Acceptable tooth contact for both bevel and parallel shaft units are presented as guide to inspectors.

Determining tooth contact in bevel and spiral bevel gear units shall be done in the manufacturer's facility on a suitable bevel gear test machine. This machine should permit adjustment of the MD of both gear members to duplicate mounting in the job housing. If a test machine is not available, tooth contact shall be checked in the job housing.

Using a suitable marking compound, check the tooth contact pattern. Suitable compounds include coating one member with Prussian blue, copper sulfate, or finely ground red lead in oil. If the markings on the gear set have been followed, the bearing pattern will conform to accepted standards. A permanent record of tooth-bearing contact can be established by using clear cellophane tape. A tape transfer showing the bearing contact may be lifted directly from the tooth profile and attached to a notated sheet of white paper.

Gears are cut with a contact pattern that will cover about half the length of the tooth, the location will slightly favor the toe end of the tooth (see Figures G-7 and G-8). Under a load condition, the bearing pattern will shift somewhat toward the heel of the tooth, thus becoming more central on the gear teeth. There is no ideal no-load pattern that will guarantee a perfect contact in the full load condition, but if a no-load contact pattern falls within the constraints shown in Figure G-7 an acceptable full-load contact pattern can be expected. Although the constraints shown are approximate and can be deviated from, depending on the known pattern movement from load, under no circumstances should the no-load contact pattern show indications of running off the tooth flank in any direction.

Situations where tooth contact patterns are not centrally located on the gear will lead to premature failure of the gear in the field. The types of patterns where the tooth contact is not central to the gear teeth implies that the gear members are not mounted correctly in relation to each other. The types of mounting errors will produce different types of tooth contact patterns on the gear mesh teeth. Three common types of contact error (see Figure G-9) are:

a. Profile error (pinion axial position error).
b. Cross contact error.
c. Shaft angle error.

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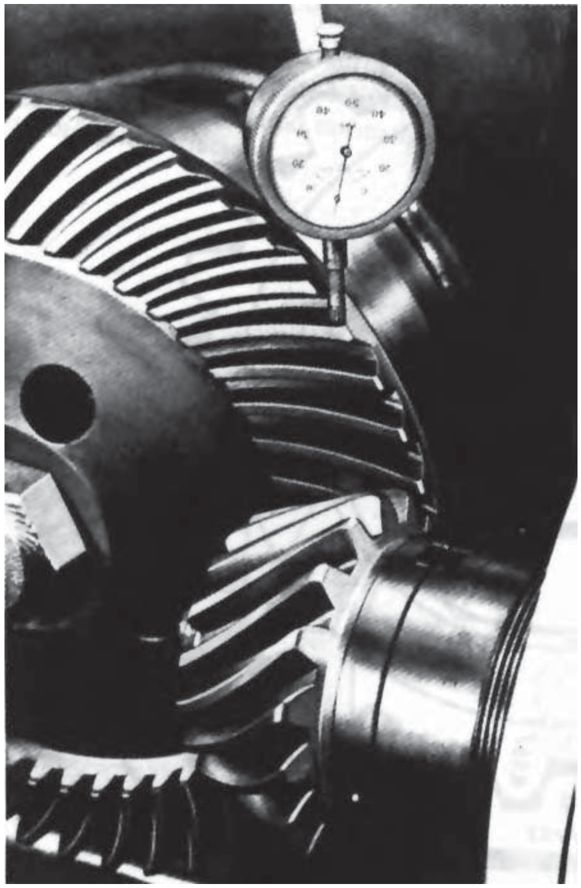

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Figure G-5—Measurement of Normal Backlash

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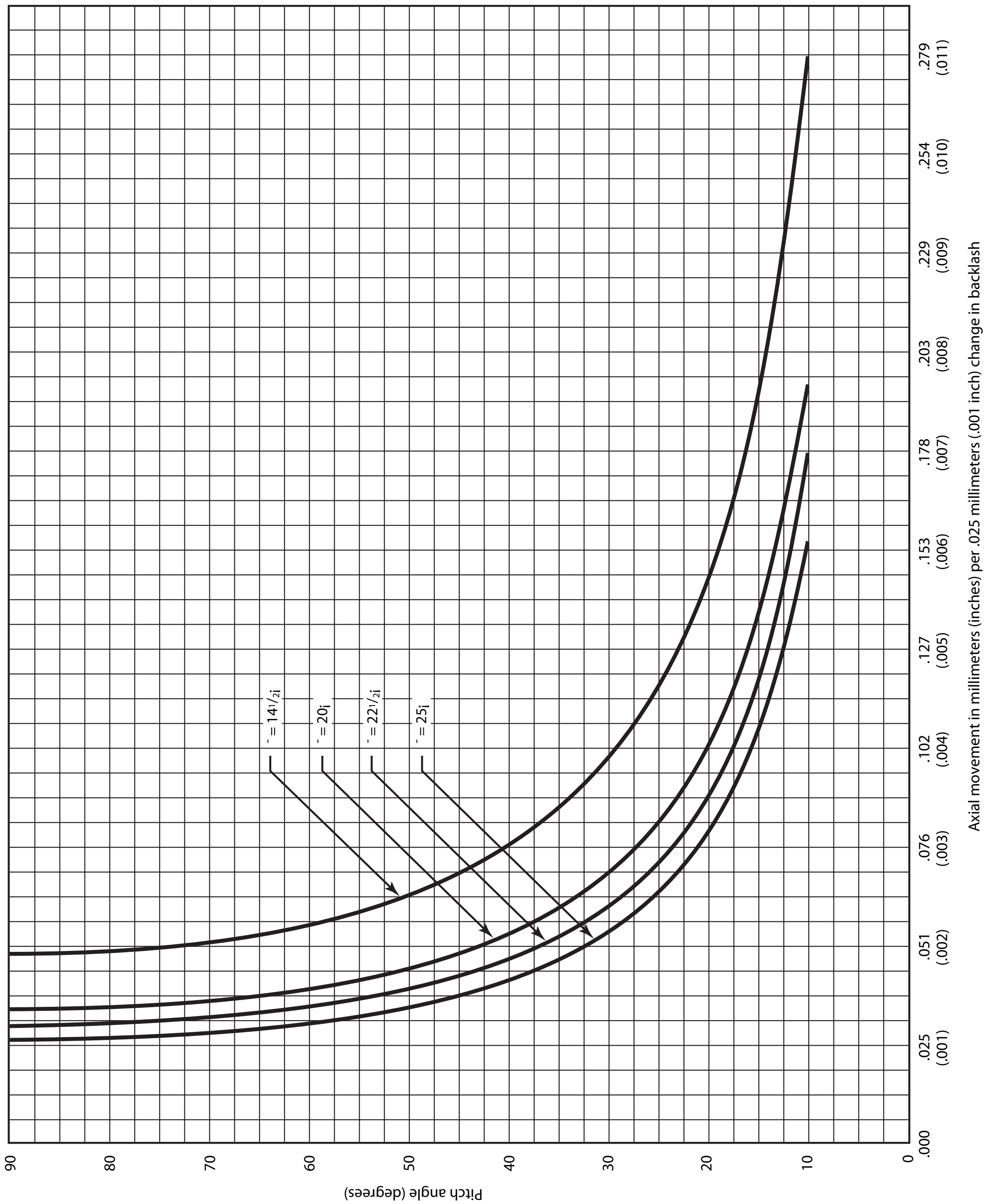

Figure G-6—Axial Movement Necessary to Obtain a Change in Backlash

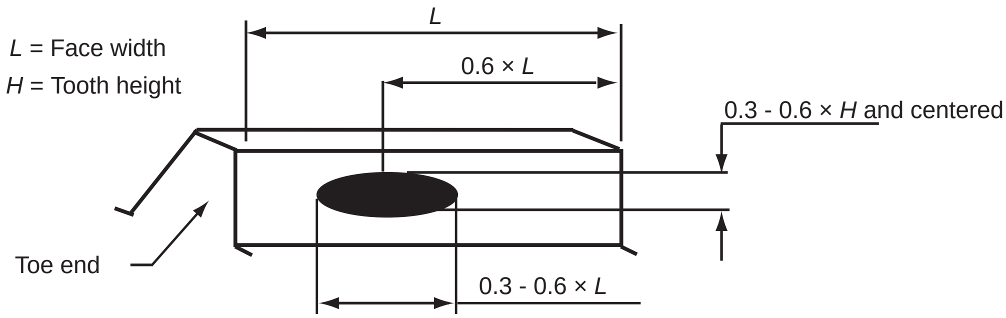

Figure G-7—Typical No Load Tooth Contact Pattern

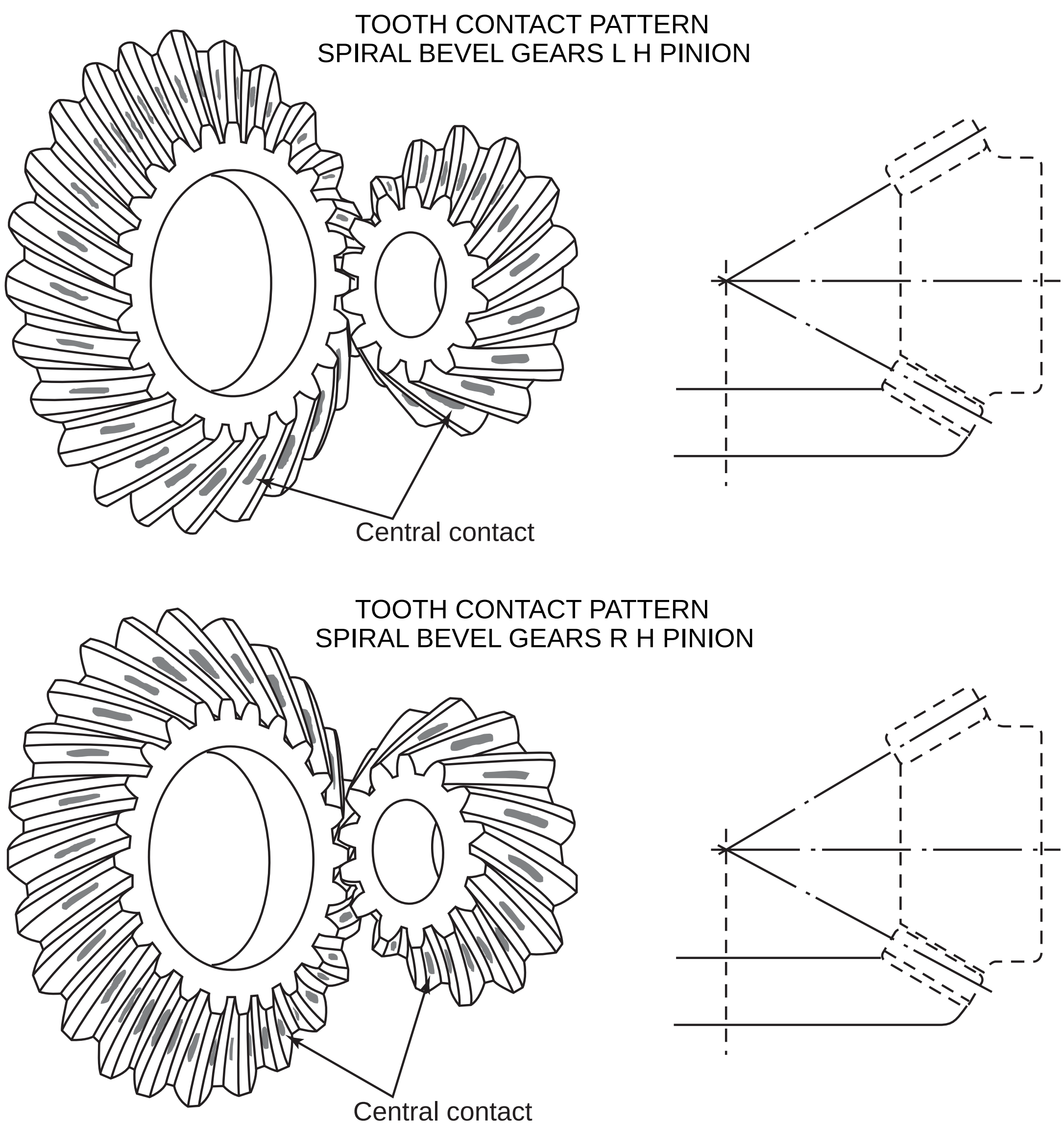

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Figure G-8—Preferred Contact Resulting from Correct Mounting Position

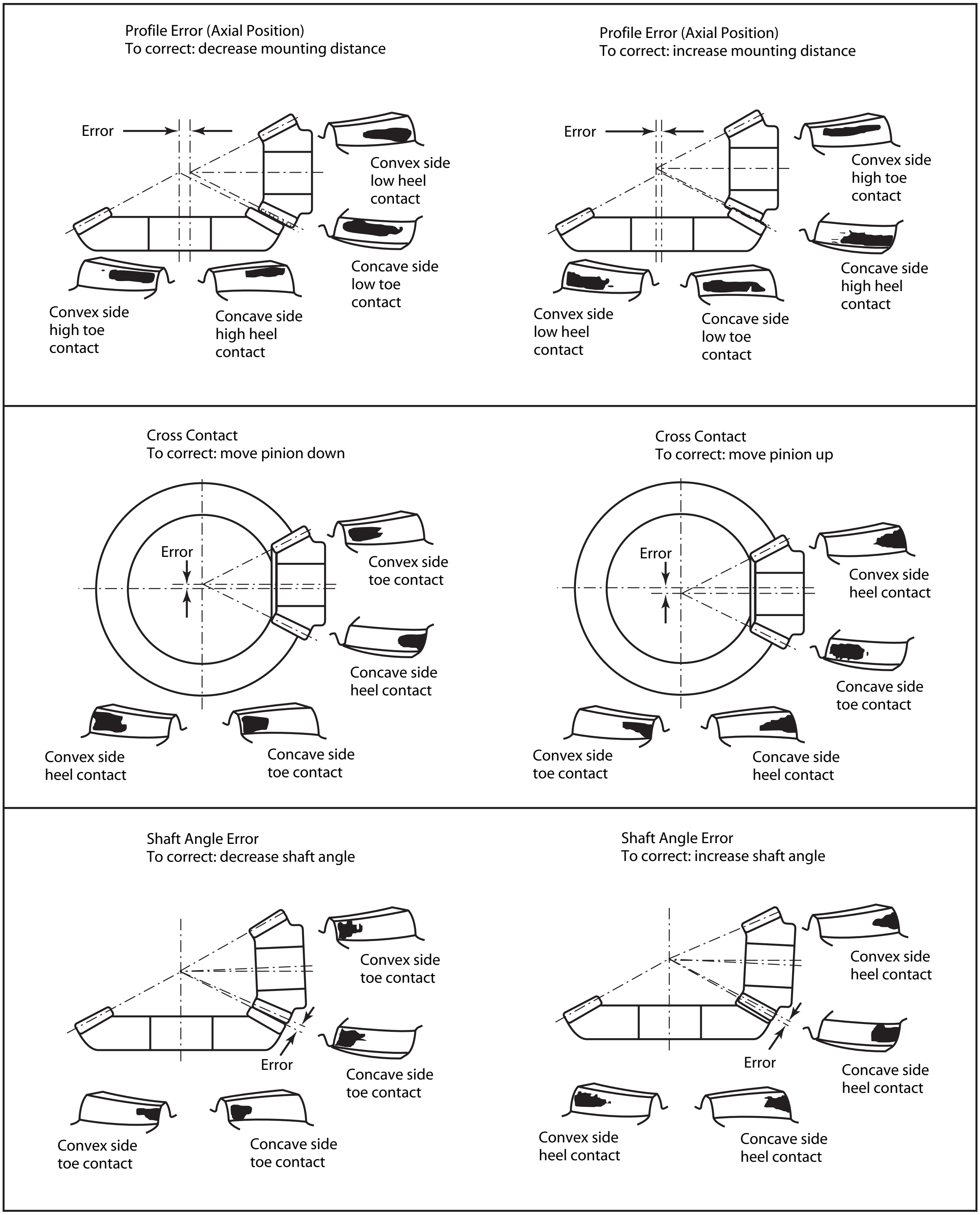


Figure G-9—Common Types of Contact Error

APPENDIX H—RESIDUAL UNBALANCE WORKSHEETS

--`,`,,,,`,`,,,`,,`,`,``,`,,`,```-`-`,,`,,`,`,,`---

Customer: ______
Job/Project Number: ______
OEM Equipment S/N: ______
Rotor Identification Number: ______
Repair Purchase Order Number: ______
Vendor Job Number: ______
Correction Plane (Left or Right)—use sketch: ______ (plane)

Balancing Speed ______ (rpm)
Maximum Rotor Operating Speed (N) ______ (rpm)
Static Journal Weight Closest to This Correction Plane (W) ______ (kg) ______ (lb.)
Trial Weight Radius (R)—the radius at which the trial weight will be placed ______ (mm) ______ (in.)

Calculate Maximum Allowable Residual Unbalance (U_{max}):

SI Units:

$U_{max} = \frac{(6350) \times (W)}{(N)} = \frac{(6350) \times \boxed{}}{\boxed{}} = \boxed{}$ (g-mm)

Customary Units:

$U_{max} = \frac{(113.4) \times (W)}{(N)} = \frac{(113.4) \times \boxed{}}{\boxed{}} = \boxed{}$ (g-in.)

Calculate the trial unbalance(TU):

Trial Unbalance (TU) is between ($1 \times U_{max}$) and ($2 \times U_{max}$) (1×) to (2×) (Selected Multiplier is) ______

SI Units: ______ to ______ = ______ (g-mm)
Customary Units: ______ to ______ = ______ (g-in.)

Calculate the trial weight (TW):

Trial Weight (TW) = $\frac{U_{max}}{R}$ = $\frac{\boxed{}\ \text{g-mm}}{\boxed{}\ \text{mm}}$ or $\frac{\boxed{}\ \text{g-in.}}{\boxed{}\ \text{in.}}$ = ______ (g)

Conversion Information:
1 kg = 2.2046 lb. 1 oz. = 28.345 g

Obtain the test data and complete the table:

Test Data

Position	Trial Weight Angular Location on Rotor (degrees)	Balancing Mach Readout	
		Amplitude (grams)	Phase Angle (degrees)
1	0		
2	60		
3	120		
4	180		
5	240		
6	300		
Repeat 1	0		

Sketch the rotor configuration:

Rotor Sketch

PROCEDURE:

Step 1: Plot the balancing machine amplitude versus trial weight angular location on the polar chart (Figure H-2) such that the largest and smallest values will fit.
Step 2: The points located on the polar chart should closely approximate a circle. If it does not, then it is probably that the recorded data it is in error and the test should be repeated.
Step 3: Determine the maximum and minimum balancing machine amplitude readings.
Step 4: Using the worksheet,(Figure H-2), determine the Y and Z values required for the residual unbalance calculation.
Step 5: Using the worksheet,(Figure H-2), calculate the residual unbalance remaining in the rotor.
Step 6: Verify that the determined residual unbalance is equal to or less than the maximum allowable residual unbalance (U_{max}).

Half Keys Used for Rotor Balancing
(add sketch for clarification if necessary)

Location	Weight

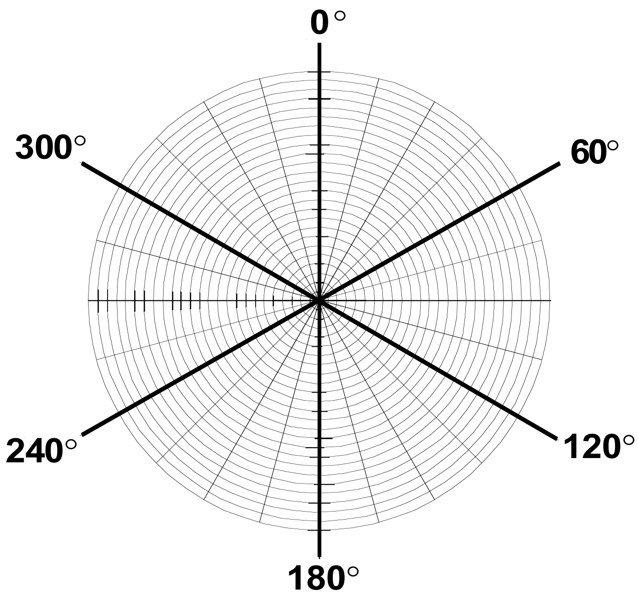
NOTES:
1) The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor. The preferred location is the location of the once-per-revolution mark (for the phase reference transducer).
2) The balancing machine amplitude readout for the Repeat of 1 should be the same as Position 1, indicating repeatability.
3) A primary source for error is not maintaining the same radius for each trial weight location.

Balanced By: ______ Date: ______
Approved By: ______ Date: ______

Figure H-1—Residual Unbalance Worksheet

Customer: ____________
Job/Project Number: ____________
OEM Equipment S/N: ____________
Rotor Identification Number: ____________
Repair Purchase Order Number: ____________
Vendor Job Number: ____________
Correction Plane (Left or Right)—use sketch: ____________

RESIDUAL UNBALANCE POLAR PLOT



Rotor Rotation: ☐ CCW ☐ CW   Phase is layed out: ☐ CCW ☐ CW

Calculate *Y* and *Z* values:

Maximum amplitude value is:	[ ]	g	Minimum amplitude value is:			[ ]
Y = (Maximum – Minimum)/2 (	[ ]	–	[ ]	) / 2	=	[ ]
Z = (Maximum + Minimum)/2 (	[ ]	+	[ ]	) / 2	=	[ ]

Residual Unbalance Left in Rotor =	(*TU*)	×	(*Y*)	/	(*Z*)			
SI Units:	[ ]	×	[ ]	/	[ ]	=	[ ]	
Customary Units:	[ ]	×	[ ]	/	[ ]	=	[ ]	

Allowable Unbalance Tolerance = U_{max} = [ ] gm-mm [ ] gm-in.

RESULT: Residual unbalance left in the rotor is equal to or less than the allowable unbalance tolerance?

☐ PASS ☐ FAIL

☐ As Received ☐ Final ☐ Other: ____________

Balanced By: ____________ Date: ____________
Approved By: ____________ Date: ____________

Figure H-2—Residual Unbalance Polar Plot Worksheet

--`,,`,`,,,,`,`,,,`,,`,`,`,,`,``-`-`,,`,,`,`,,`---

Customer:	ABC Refining Co.
Job/Project Number:	00 – 1234
OEM Equipment S/N:	C – 1234
Rotor Identification Number:	1234 – C – 4320
Repair Purchase Order Number:	PO 12345678
Vendor Job Number:	Shop – 00 – 1234
Correction Plane (Left or Right)—use sketch:	Left (plane)

Balancing Speed	800	(rpm)		
Maximum Rotor Operating Speed (*N*)	6900	(rpm)		
Static Journal Weight Closest to This Correction Plane (*W*)	530.7	(kg)	1170	(lb.)
Trial Weight Radius (*R*)—the radius at which the trial weight will be placed	381	(mm)	15	(in.)

Calculate Maximum Allowable Residual Unbalance (U_{max}):

SI Units:

$$U_{max} = \frac{(6350) \times (W)}{(N)} = \frac{(6350)}{6900} \times 530.7 = 488.4 \text{ (g-mm)}$$

Customary Units:

$$U_{max} = \frac{(113.4) \times (W)}{(N)} = \frac{(113.4)}{6900} \times 1170 = 19.2 \text{ (g-in.)}$$

Calculate the trial unbalance (*TU*):

Trial Unbalance (*TU*) is between ($1 \times U_{max}$) and ($2 \times U_{max}$)

	(1×)	to	(2×)	(Selected Multiplier is)	1.6
SI Units	488.4	to	976.8	is	781.4 (g-mm)
Customary Units:	19.2	to	38.5	is	30.8 (g-in.)

Calculate the trial weight (*TW*):

$$\text{Trial Weight } (TW) = \frac{U_{max}}{R} = \frac{781 \text{ g-mm}}{381 \text{ mm}} \text{ or } \frac{31 \text{ g-in.}}{15 \text{ in.}} = 2.1 \text{ (g)}$$

Conversion Information:

1 kg = 2.2046 lb.   1 oz. = 28.345 g

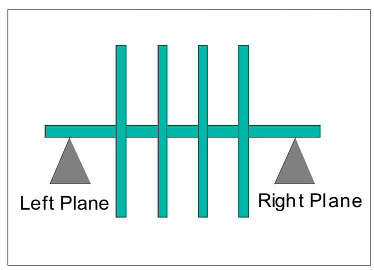
Obtain the test data and complete the table:

Test Data

Position	Trial Weight Angular Location on Rotor (degrees)	Balancing Mach Readout Amplitude (grams)	Balancing Mach Readout Phase Angle (degrees)
1	0	1.60	358
2	60	1.11	59
3	120	1.58	123
4	180	2.21	182
5	240	3.00	241
6	300	2.30	301
Repeat 1	0	1.58	359

Sketch the rotor configuration:

Rotor Sketch



PROCEDURE:

Step 1: Plot the balancing machine amplitude versus trial weight angular location on the polar chart (Figure H-4) such that the largest and smallest values will fit.

Step 2: The points located on the polar chart should closely approximate a circle. If it does not, then it is probably that the recorded data it is in error and the test should be repeated.

Step 3: Determine the maximum and minimum balancing machine amplitude readings.

Step 4: Using the worksheet, (Figure H-4), determine the *Y* and *Z* values required for the residual unbalance calculation.

Step 5: Using the worksheet, (Figure H-4), calculate the residual unbalance remaining in the rotor.

Step 6: Verify that the determined residual unbalance is equal to or less than the maximum allowable residual unbalance (U_{max}).

Half Keys Used for Rotor Balancing
(add sketch for clarification if necessary)

Location	Weight

NOTES:

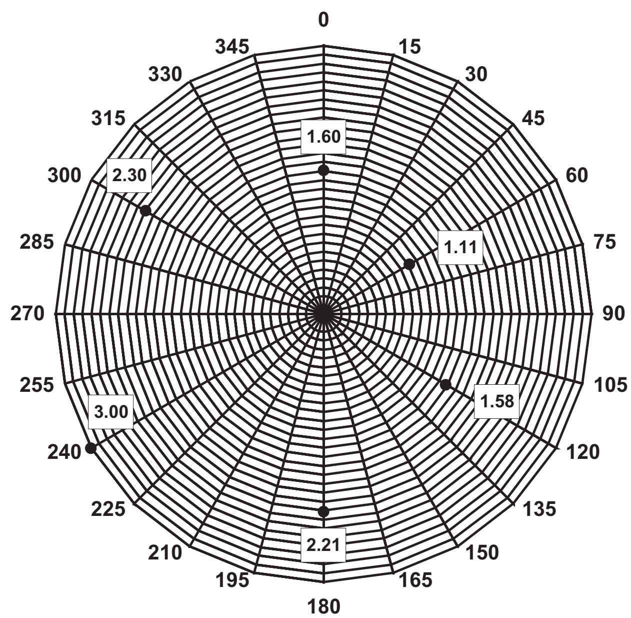
1) The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor. The preferred location is the location of the once-per-revolution mark (for the phase reference transducer).
2) The balancing machine amplitude readout for the Repeat of 1 should be the same as Position 1, indicating repeatability.
3) A primary source for error is not maintaining the same radius for each trial weight location.

Balanced By:	CJ, TR, & RC	Date:	05/24/00
Approved By:	CC	Date:	05/24/00

Figure H-3—Sample Residual Unbalance Worksheet for Left Plane

Customer:	ABC Refining Co.
Job/Project Number:	00 – 1234
OEM Equipment S/N:	C – 1234
Rotor Identification Number:	1234 – C – 4320
Repair Purchase Order Number:	PO 12345678
Vendor Job Number:	Shop – 00 – 1234
Correction Plane (Left or Right)—use sketch:	Left (plane)

RESIDUAL UNBALANCE POLAR PLOT



Rotor Rotation: ☒ CCW ☐ CW Phase is layed out: ☐ CCW ☒ CW

Calculate *Y* and *Z* values:

Maximum amplitude value is:		3.00	g	Minimum amplitude value is:			1.11 g
Y = (Maximum – Minimum)/2	(	3.00	–	1.11	) /2	=	0.9
Z = (Maximum + Minimum)/2	(	3.00	+	1.11	) /2	=	2.1

Residual Unbalance Left in Rotor =	(*TU*)	×	(*Y*)	/	(*Z*)	=		
SI Units:	781	×	0.95	/	2.06	=	359	g-mm
Customary Units:	31	×	0.95	/	2.06	=	14.1	g-in.

Allowable Unbalance Tolerance = U_{max} = 488.4 g-mm 19.2 g-in.

RESULT: Residual unbalance left in the rotor is equal to or less than the allowable unbalance tolerance? PASS

☐ As Received ☐ Final ☒ Other: w/o trim hardware

Balanced By:	CJ, TR & RC	Date:	05/24/00
Approved By:	CC	Date:	05/24/00

Figure H-4—Sample Residual Unbalance Polar Plot Worksheet for Left Plane

Customer:	ABC Refining Co.
Job/Project Number:	00 – 1234
OEM Equipment S/N:	C – 1234
Rotor Identification Number:	1234 – C – 4320
Repair Purchase Order Number:	PO 12345678
Vendor Job Number:	Shop – 00 – 1234
Correction Plane (Left or Right)—use sketch:	Right (plane)

Balancing Speed	800	(rpm)		
Maximum Rotor Operating Speed (N)	6900	(rpm)		
Static Journal Weight Closest to This Correction Plane (W)	571.5	(kg)	1260	(lb.)
Trial Weight Radius (R)—the radius at which the trial weight will be placed	203	(mm)	8	(in.)

Calculate Maximum Allowable Residual Unbalance (U_{max}):

Si Units:

$$U_{max} = \frac{(6350) \times (W)}{(N)} = \frac{(6350) \times 571.5}{6900} = 525.9 \text{ (g-mm)}$$

Customary Units:

$$U_{max} = \frac{(113.4) \times (W)}{(N)} = \frac{(113.4) \times 1260}{6900} = 20.7 \text{ (g-in.)}$$

Calculate the trial unbalance (TU) :

Trial Unbalance (TU) is between $(1 \times U_{max})$ and $(2 \times U_{max})$

	(1×)	to	(2×)	(Selected Multiplier is)	1.6	
SI Units:	525.9	to	1051.9	is	841.5	(g-mm)
Customary Units:	20.7	to	41.4	is	33.1	(g-in.)

Calculate the trial weight (TW):

$$\text{Trial Weight } (TW) = \frac{U_{max}}{R} = \frac{842 \text{ g-mm}}{203 \text{ mm}} \text{ or } \frac{33 \text{ g-in.}}{8 \text{ in.}} = 4.1 \text{ (g)}$$

Conversion Information:

1 kg = 2.2046 lb. 1 oz. = 28.345 g

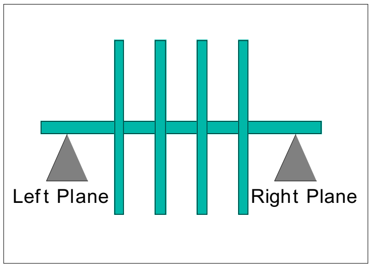
Obtain the test data and complete the table:

Test Data

Position	Trial Weight Angular Location on Rotor (degrees)	Balancing Mach Readout Amplitude (grams)	Balancing Mach Readout Phase Angle (degrees)
1	0	4.60	3
2	60	4.20	58
3	120	4.70	121
4	180	5.20	180
5	240	5.80	235
6	300	5.10	301
Repeat 1	0	4.60	2

Sketch the rotor configuration:

Rotor Sketch



PROCEDURE:

Step 1: Plot the balancing machine amplitude versus trial weight angular location on the polar chart, (Figure H-6) such that the largest and smallest values will fit.

Step 2: The points located on the polar chart should closely approximate a circle. If it does not, then it is probably that the recorded data it is in error and the test should be repeated.

Step 3: Determine the maximum and minimum balancing machine amplitude readings.

Step 4: Using the worksheet, (Figure H-6), determine the Y and Z values required for the residual unbalance calculation.

Step 5: Using the worksheet, (Figure H-6), calculate the residual unbalance remaining in the rotor.

Step 6: Verify that the determined residual unbalance is equal to or less than the maximum allowable residual unbalance (U_{max}).

Half Keys Used for Rotor Balancing
(add sketch for clarification if necessary)

Location	Weight

NOTES:

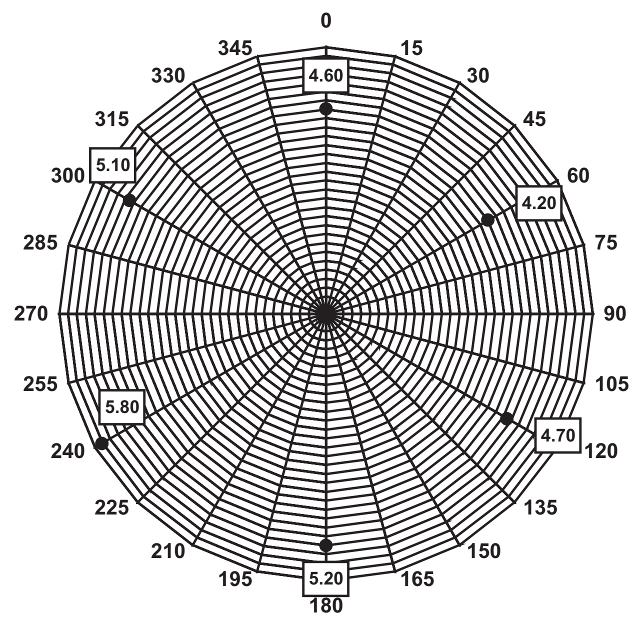
1) The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor. The preferred location is the location of the once-per-revolution mark (for the phase reference transducer).
2) The balancing machine amplitude readout for the Repeat of 1 should be the same as Position 1, indicating repeatability.
3) A primary source for error is not maintaining the same radius for each trial weight location.

Balanced By:	CJ, TR, & RC	Date:	05/24/00
Approved By:	CC	Date:	05/24/00

Figure H-5—Sample Residual Unbalance Worksheet for Right Plane

Customer:	ABC Refining Co.
Job/Project Number:	00 – 1234
OEM Equipment S/N:	C – 1234
Rotor Identification Number:	1234 – C – 4320
Repair Purchase Order Number:	PO 12345678
Vendor Job Number:	Shop – 00 – 1234
Correction Plane (Left or Right)—use sketch:	Right (plane)

RESIDUAL UNBALANCE POLAR PLOT



Rotor Rotation: ☒ CCW ☐ CW

Phase is layed out: ☐ CCW ☒ CW

Calculate *Y* and *Z* values:

Maximum amplitude value is:	5.80		Minimum ampltude value is:			4.20	g
Y = (Maximum – Minimum)/2	(5.80	–	4.20)	/2	=	0.8	
Z = (Maximum + Minimum)/2	(5.80	+	4.20)	/2	=	5.0	

Residual Unbalance Left in Rotor =	(*TU*)	×	(*Y*)	/	(*Z*)	=		
SI Units:	842	×	0.8	/	5	=	134.6	g-mm
Customary Units:	33	×	0.8	/	5	=	5.3	g-in.

Allowable Unbalance Tolerance = U_{max} = 525.9 g-mm 20.7 g-in.

RESULT: Residual unbalance left in the rotor is equal to or less than the allowable unbalance tolerance? PASS

☐ As Received ☐ Final ☒ Other: w/o trim hardware

Balanced By:	CJ, TR & RC	Date:	05/24/00
Approved By:	CC	Date:	05/24/00

Figure H-6—Sample Residual Unbalance Polar Plot Worksheet for Right Plane

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