INTERNATIONAL STANDARD

ISO 13691

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Petroleum and natural gas industries — High-speed special-purpose gear units

Industries du pétrole et du gaz naturel — Engrenages à grande vitesse pour applications particulières

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13691 was prepared by Technical Committee ISO/TC 60, *Gears*, Subcommittee SC 2, *Gear capacity calculation*.

ISO 13691 is based on API 613 and is intended to give ratings similar to those found when using API 613.

Annexes A to G of this International Standard are for information only.

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Introduction

This International Standard is based on the accumulated knowledge and experience of manufacturers and users of gear units. It has been developed to satisfy the requirements of the petroleum, petrochemical and natural gas industries, but its use is not restricted to these industries.

The purpose of this International Standard is to establish minimum requirements for design and construction so that the equipment is suitable for the purpose for which it is required.

Energy conservation and protection of the environment are matters of concern and are important in all aspects of equipment design, application and operation. The manufacturers and users of equipment should aggressively pursue alternative, innovative approaches which improve energy utilization and/or minimize the environmental impact, without sacrificing safety or reliability. Such approaches should be thoroughly investigated and purchase options should increasingly be based on the estimation of whole-life costs and the environmental consequences rather than acquisition costs alone.

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

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

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A bullet (●) at the beginning of a paragraph indicates that either a decision is required or further information is to be provided by the purchaser. This information should be indicated on the data sheets; otherwise it should be stated in the quotation request or in the order.

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Petroleum and natural gas industries — High-speed special-purpose gear units

1 Scope

This International Standard specifies the minimum requirements for enclosed, precision, single and double helical, one- and two-stage speed increasers and reducers of parallel shaft design with pinion speeds of 3000 min^{-1} or greater, or pitch line velocities of 25 m/s or greater, for special purpose applications. Such applications will typically be required to operate continuously for extended periods, without installed spare equipment and are critical to the continued operation of the installation. By agreement this International Standard may be used for other services.

This International Standard also specifies a method of rating gears which meet the following criteria:

a) gear accuracy

— teeth accuracy: accuracy grade 4 or better as given in ISO 1328-1:1995, for both single pitch deviation, f_{pt}, and total cumulative pitch deviation, F_p,

— total helix deviation F_β between the helices of the pinion and wheel: accuracy grade 4 or better as given in ISO 1328-1:1995;

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b) range of the transverse contact ratios: $1{,}2 < \varepsilon_\alpha < 2{,}0$;

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c) overlap ratio $\varepsilon_\beta \geqslant 1{,}0$;

d) helix angle: $5 \leqslant \beta \leqslant 35°$;

e) working flanks of the pinion or gear: provided with profile modifications to obtain a good conjugate tooth load distribution along the path of contact;

f) working flanks of pinion or gear: modified as necessary to compensate for both torsional and bending deflections and, when necessary for gears with pitch line velocities in excess of 100 m/s, also for thermal distortions;

g) gear lubrication: straight mineral oil, viscosity grade VG-32 or VG-46 (see ISO 3448);

h) material of the gear teeth: quality MQ or better, in accordance with ISO 6336-5:1996.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 7-1, *Pipe threads where pressure-tight joints are made on the threads — Part 1: Dimensions, tolerances and designation*

ISO 261, *ISO general-purpose metric screw threads — General plan*

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ISO 262, *ISO general-purpose metric screw threads — Selected sizes for screws, bolts and nuts*

ISO 724, *ISO general-purpose metric screw threads — Basic dimensions*

ISO 965-1, *ISO general-purpose metric screw threads — Tolerances — Part 1: Principles and basic data*

ISO 965-2, *ISO general- purpose metric screw threads — Tolerances — Part 2: Limits of sizes for general purpose external and internal screw threads — Medium quality*

ISO 965-3, *ISO general-purpose metric screw threads — Tolerances — Part 3: Deviations for constructional screw threads*

ISO 1122-1, *Vocabulary of gear terms — Part 1: Definitions related to geometry*

ISO 1328-1:1995, *Cylindrical gears — ISO system of accuracy — Part 1: Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth*

ISO 1940-1:1986, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Determination of permissible residual unbalance*

ISO 2953, *Mechanical vibration — Balancing machines — Description and evaluation*

ISO 3448:1992, *Industrial liquid lubricants — ISO viscosity classification*

ISO 6336-3, *Calculation of load capacity of spur and helical gears — Part 3: Calculation of tooth bending strength*

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ISO 6336-5, *Calculation of load capacity of spur and helical gears — Part 5: Strength and quality of materials*

ISO 6743-6, *Lubricants, industrial oils and related products (class L) — Classification — Part 6: Family C (Gears)*

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ISO 7005-1, *Metallic flanges — Part 1: Steel flanges*

ISO 7005-2, *Metallic flanges — Part 2: Cast iron flanges*

ISO 8501-1:1988, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 8579-1, *Acceptance code for gear units — Part 1: Test code for airborne sound*

ISO 8821, *Mechanical vibration — Balancing — Shaft and fitment key convention*

ISO 9084:2000, *Calculation of load capacity of spur and helical gears — Application to high speed gears and gears of similar requirement*

ISO/TR 10064-4, *Cylindrical gears — Code of inspection practice — Part 4: Recommendations relative to surface texture and tooth contact pattern checking*

ISO 10438-1, *Petroleum and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries — Part 1: General requirements*

ISO 10438-2, *Petroleum and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries — Part 2: Special-purpose oil systems*

ISO 10438-3, *Petroleum and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries — Part 3: General-purpose oil systems*

ISO 10441, *Petroleum and natural gas industries — Flexible couplings for mechanical power transmission — Special purpose applications*

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ISO/TR 13593, *Enclosed gear drives for industrial applications*

ISO/TR 13989-1, *Calculation of scuffing load capacity of cylindrical, bevel and hypoid gears — Part 1: Flash temperature method*

ISO/TR 13989-2, *Calculation of scuffing load capacity of cylindrical, bevel and hypoid gears — Part 2: Integral temperature method*

IEC 60079-0, *Electrical apparatus for explosive gas atmospheres — Part 0: General requirements*

API 670, *Vibration, axial position and bearing-temperature monitoring systems*

ASME B16.11, *Forged fittings, Socket-Welding and Threaded*

ASME, *Boiler and pressure vessel code — Section V*

ASME, *Boiler and pressure vessel code — Section VIII, Division 1*

ASME Y 14.2 M, *Line conventions and lettering*

ASTM A956, *Standard test method for Leeb hardness testing of steel products*

ASTM E94, *Standard guide for radiographic examination*

ASTM E125, *Standard reference photographs for magnetic particle indications on ferrous castings*

ASTM E709, *Standard guide for magnetic particle examination*

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3 Terms and definitions

For the purposes of this International Standard, the terms and definitions given in ISO 1122-1 and the following apply.

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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. This terminology should be used only by the equipment designer and the manufacturer.

3.1
axially [horizontally] split casing joint
casing joint parallel to the shaft centreline

3.2
critical speed
shaft rotational speed at which the rotor-bearing-support system is in a state of resonance with any exciting frequency associated with that speed

3.3
wheel
lower speed gear element in mesh

3.4
pinion
higher speed gear element in mesh

3.5
gear rated power
maximum power specified by the purchaser on the data sheet and stamped on the nameplate

cf. 5.2.1.

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3.6
normal transmitted power
power at which usual operation is expected and optimum efficiency is desired

NOTE The normal transmitted power may be equal to or less than the gear rated power.

3.7
mechanical rating
gear rated power (3.5) multiplied by the specified **gear selection factor** (3.17).

3.8
hunting tooth combination
⟨mating gears⟩ combination existing 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

3.9
maximum allowable speed
highest rotational speed at which the manufacturer's design will permit continuous operation

3.10
maximum continuous speed
⟨variable-speed unit⟩ rotational speed at least equal to 105 % of the rated speed

3.11
maximum continuous speed
⟨constant-speed unit⟩ rotational speed equal to the rated speed

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3.12
minimum allowable speed
lowest rotational speed at which the manufacturer's design will permit continuous operation

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3.13
rated input speed
specified (or nominal) rated speed of the driver, as designated by the purchaser

3.14
rated output speed
specified (or nominal) rated speed of the driven equipment, as designated by the purchaser.

NOTE In selecting the number of teeth for the pinion and gear, it is often impracticable for the vendor to match exactly both the rated input and the rated output speeds designated on the data sheets. The purchaser therefore indicates 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). The letter S is used to indicate the specified speed, and the letter N to indicate the nominal speed. The purchaser also indicates on the data sheets the allowable percentage of variation in the designed gear ratio.

3.15
contact stress number
σ_H
contact stress calculated based on the Hertzian contact pressure

3.16
bending stress number
σ_F
bending stress calculated from the resistance to fatigue cracking at the tooth root fillet

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3.17
gear selection factor
K_{SL}
factor applied to the calculated contact stress number and the calculated bending stress number, depending on the characteristics of the driver and the driven equipment, to account for potential overload, shock load and/or continuous oscillatory torque characteristics

3.18
trip speed
rotational speed at which the independent emergency overspeed device operates to shut down a prime mover

NOTE 1 For fixed-frequency alternating current motor drives, the trip speed is taken to be the speed corresponding to the synchronous speed of the motor at the highest supply frequency.

NOTE 2 For steam turbines and reciprocating engines, the trip speed is at least 110 % of the maximum continuous speed. For gas turbines, the trip speed is at least 105 % of the maximum continuous speed.

3.19
special-purpose application
application for which the equipment is designed for uninterrupted, continuous operation in critical service and for which there is usually no spare equipment

3.20
total indicated runout
total indicator reading
TIR
runout of a diameter or face determined by measurement with a dial indicator

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NOTE The indicator reading implies an out-of-squareness equal to the reading or an eccentricity equal to half the reading.

3.21
Gauss level

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magnetic field level of a component measured with a "Hall effect" probe with no interference from adjacent magnetic parts or structures

3.22
unit responsibility
responsibility for coordinating the technical aspects of the equipment and all auxiliary systems included in the scope of the order

NOTE Responsibility for 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 is included.

3.23
purchaser
individual or organization that issues the order and specification to the vendor

NOTE The purchaser may be the owner of the plant in which the equipment is to be installed, or the owner´s agent (often the vendor of the equipment to be driven by the gear).

3.24
vendor
organization that supplies the equipment

NOTE The vendor may be the manufacturer of the equipment or the manufacturer´s agent and is normally responsible for service support.

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4 Symbols and abbreviated terms

See Table 1.

Table 1

Symbol	Meaning or term	Unit
a	centre distance	mm
b	facewidth	mm
b_B	facewidth of one helix on a double helical gear	mm
B	total facewidth of a double helical gear including the gap width	mm
$d_{1,2}$	reference diameter of pinion, wheel	mm
$D_{1,2}$	shaft diameter at coupling of pinion, wheel	mm
f_{pt}	single pitch deviation	µm
F_p	total cumulative pitch deviation	µm
F_t	(nominal) transverse tangential force at reference cylinder	N
F_R	external force (coupling)	N
F_β	total helix deviation	µm
HBW	Brinell hardness	—
HRC	Rockwell hardness number (C scale)	—
K_v	dynamic factor	—
$K_{F\beta}$	face load factor (root stress)	—
$K_{H\beta}$	face load factor (contact stress)	—
K_{SL}	selection factor	—
m_n	normal module	mm
$n_{1,2}$	rotational speed of pinion, of wheel, nominal	min^{-1}
P	gear rated power	kW
Ra	arithmetic average roughness value	µm
u	gear ratio $z_2/z_1 \geqslant 1$	—
v	pitch line velocity at reference cylinder	m/s
Y_F	form factor	—
Y_S	stress correction factor	—
Y_β	helix angle factor (root stress)	—
z_1, z_2	number of teeth of pinion, of wheel	—
Z_E	elasticity factor	$\sqrt{N/mm^2}$
Z_H	zone factor	—
Z_β	helix angle factor (contact stress)	—
Z_ε	contact ratio factor (contact stress)	—
α_n	normal pressure angle	°
α_t	transverse pressure angle	°
α_{wt}	pressure angle at the pitch cylinder	°
β	helix angle at the reference cylinder	°
β_b	base helix angle	°

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Table 1 *(continued)*

Symbol	Meaning or term	Unit
ε_α	transverse contact ratio	—
ε_β	overlap ratio	—
σ_F	calculated bending stress number	N/mm^2
σ_{FAD}	allowable design bending stress number	N/mm^2
σ_H	calculated contact stress number	N/mm^2
σ_{HAD}	allowable design contact stress number	N/mm^2

5 Basic design

5.1 General

5.1.1 The equipment (including auxiliaries) covered by this International Standard shall be designed and constructed for a minimum service life of 20 years and at least three years of uninterrupted operation. It is recognized that this is a design criterion.

5.1.2 The vendor shall assume responsibility for the engineering coordination of the equipment and all auxiliary systems included in the scope of the order.

- **5.1.3** Control of the sound pressure level (SPL) of all equipment furnished shall be a joint effort of the purchaser and the vendor. Unless otherwise specified, the equipment furnished by the vendor shall conform to the requirements of ISO 8579-1 and to the maximum allowable sound pressure level specified by the purchaser.

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5.1.4 Equipment shall be designed to run safely to the trip speed setting. Unless otherwise agreed, rotors for turbine driven gear units shall be designed to operate safely at momentary speeds up to 130 %of the rated speed.

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5.1.5 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.

- **5.1.6** Electrical components and installations shall be suitable for the area classification (class, group and division) specified and shall comply with the requirements of IEC 60079-0 and with any local codes specified and furnished by the purchaser.

5.1.7 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.

5.1.8 The gear shall perform on the test stand and on its permanent foundation within the specified acceptance criteria. After installation, the performance of the combined units shall be the joint responsibility of the purchaser and the vendor who has unit responsibility.

- **5.1.9** Many factors (such as piping loads, alignment at operating conditions, supporting structure, handling during shipment, and handling and assembly at the site) may adversely affect site performance. To minimize the influence of these factors, the vendor shall review and comment on the purchaser's baseplate and foundation drawings. In addition, the vendor's representative may be requested to check alignment at the operating temperature and may be requested to be present during the initial alignment check and the tooth contact check.

- **5.1.10** The purchaser shall specify whether the installation is indoors (heated or unheated) or outdoors (with or without a roof) as well as the weather and environmental conditions in which the equipment must operate (including maximum and minimum temperatures, unusual humidity and dusty or corrosive conditions).

5.1.11 Unless otherwise agreed, gear units shall not require a running-in period at reduced speed and load in the field.

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It is recognized that under certain conditions a running-in period may be requested. If a running-in period is required, the vendor shall specify in the proposal the required load, speed and duration of the period. The vendor shall also specify in the proposal any additional field inspection and commissioning required during the break-in period.

- **5.1.12** 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 external loads (thrust, lube-oil piping, and so forth) while the unit is operating at the gear rated power specified by the purchaser.

5.1.13 All equipment shall be designed to permit rapid and economical maintenance. Major parts such as casing components and bearing housings shall be designed (shouldered or cylindrical dowelled) and manufactured to ensure accurate alignment on reassembly. Where practical, components should be dowelled, keyed or shouldered asymmetrically to prevent incorrect assembly.

5.1.14 Spare parts for the machine and all furnished auxiliaries shall meet all the criteria of this International Standard.

- **5.1.15** 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 shall designate all of the combinations under consideration.

Table 2 — Shaft assembly combinations

High-speed shaft	Low-speed shaft
L	R
R	L
L	L
R	R
R	LR
L	LR
LR	L
LR	R
LR	LR

NOTE L = left; R = right. The letters refer to the number and direction of shaft extensions (see Figure 1).

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5.1.16 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 shaft.

5.1.16.1 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.

- **5.1.16.2** 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.

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

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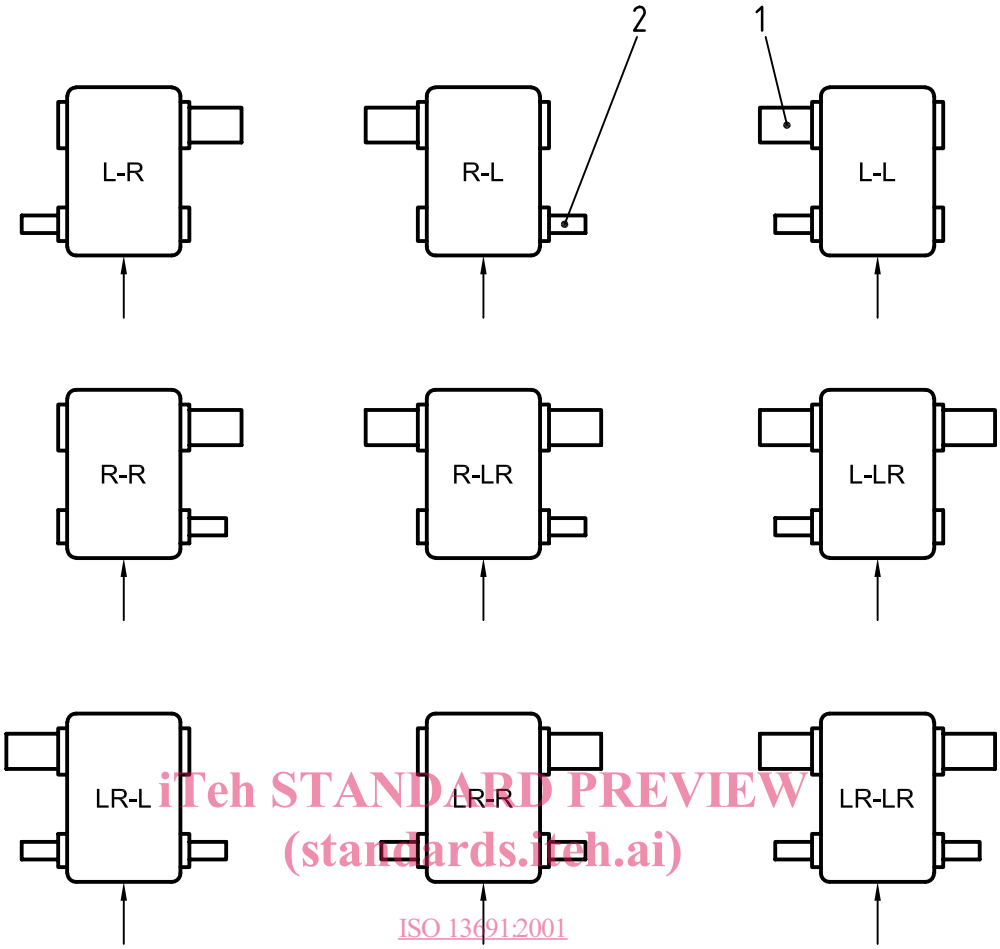

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Key

1 Low-speed shaft
2 High-speed shaft

NOTE 1 L = left; R = right

NOTE 2 Arrows indicate the line of sight used to determine the direction of the shaft extensions. (The figure depicts plan views.)

NOTE 3 The letter(s) before the hyphen refer to the number and direction of high-speed shaft extensions; the letter(s) after the hyphen refer to the number and direction of low speed shaft extensions.

NOTE 4 The material for this figure was extracted from AGMA 6010-F97 with permission of the publisher.

Figure 1 — Shaft assembly designations (for parallel-shaft, single- and double-helical one- and two-stage speed increasers and reducers)

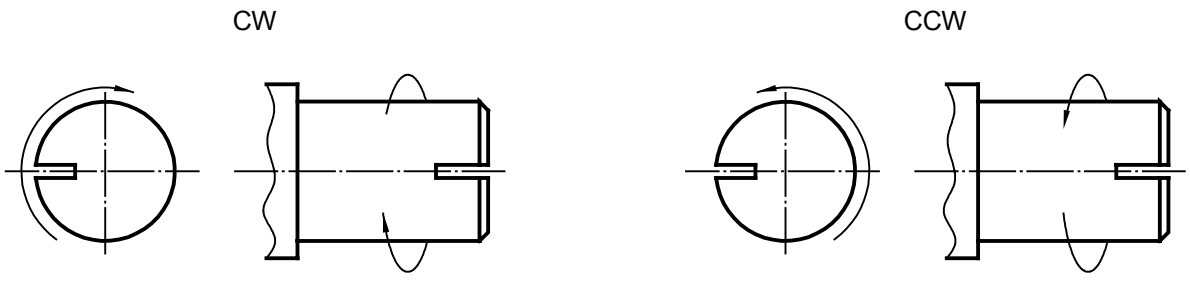

Figure 2 — Shaft rotation designations

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