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Stainless Steels

The basic austenitic composition is the familiar 18% chromium and 8% nickel alloy. Both chromium and nickel can be increased to further improve corrosion resistance and additional elements, such as molybdenum, can be added to enhance this characteristic.

Austenitic steels are non-magnetic and it is not possible to harden them by heat treatment. The only method of hardening these steels is through cold forming or deformation when strain hardening takes place rapidly. The steel can be restored to a fully softened condition by annealing, sometimes referred to as solution treatment.

Stainless Steel

Type AISI 303 S21 (form EN58AM) Colour Code: White (Austenitic - non-magnetic)
Free machining quality (contains sulphur). Good corrosion resistance and weldability is fair, but oxy-acetylene is not generally recommended. Can be cold formed but severe sharp corner bends should be avoided.
Typical application - Repetitive machining, Automatics etc.

Type AISI 304 S15 (form. EN58E) Colour Code: Yellow (Austenitic - non-magnetic)
General purpose stainless, machineability is fair, has good general corrosion resistance, weldability is good. (Oxy-acetylene is not generally recommended). Cold forming is very good; also has good polishing qualities. Non-magnetic when annealed, slightly magnetic when cold worked.
Typical application - Suitable for General Engineering, hospital, laundry etc.

Type AISI 316 S16 (form. EN58J) Colour Code: Red (Austenitic - non-magnetic)
High corrosion resistance, especially salt water and acid. Machineability fair. Weldability good. Cold forming good. Non-magnetic when annealed, slightly magnetic when cold worked.
Typical application - Petro-Chemical, Marine, Hospital, Catering Equipment.

Type AISI 321 S20 (form. EN58B) Colour Code: Blue (Austenitic - Non-magnetic)
Good corrosion and oxidisation resistance. Weldability very good, machineability fair. Cold forming good. Non-magnetic when annealed, slightly magnetic when cold worked.
Typical application - General Engineering, Petro-Chemical Engineering.

Summary Of Corrosion Resistance of Stainless Steel

MARTENSITIC STEEL
These steels which commonly contain 13% Chromium, have the least general resistance to corrosion of the steel family and can, therefore, be used where corrosive conditions are relatively light. A typical example would be cutlery.

FERRITIC STEELS
The most common ferritic steel is B.S. 1449 : 430S17 containing 17% chromium and this offers improved resistance to corrosion over martensitic steels. Although not up to the standard of austenitic steels it can be used for motor car trim, and domestic decorative fittings such as trim on refrigerators, gas cookers etc.

AUSTENITIC STEEL
A group of steels which are by far the most important and consequently the most widely used. The 18/8 type of steel resists corrosion under a wide range of circumstances and is typically used in food, dairy, brewery and other processing industries, together with certain kinds of chemical plant.

MOLYBDENUM
Molybdenum can be added to the 18/8 type of steel to give even more enhanced corrosion resistance, and thus type 316 steels containing between 2.0% and 3.0% of molybdenum are principally used in the chemical and petrochemical industries where resistance to, for example, corrosion media containing chlorides is required. The point should be made, however, that even these steels are not immune to all kinds of chemical attack from such reducing solutions as hydrochloric or oxalic acid, particularly when these acids are hot and/ or highly concentrated.

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Analysis & Application

Type	Obsolete EN MO	Description	Typical Usage
Martensitic : Magnetic, hardenable, moderate corrosion resistance			
410	**56A**	12% chromium.	Pump and gas turbine parts, general engineering.
416	**56AM**	Free machining form of 410. Sulphur bearing. Available in bar form only.	Knifes blades, valves.
420	**56B**	Heat resistant.	
431	**57**	17% chromium. 2 1/2% nickel. Available in bar form only.	
Ferritic : Magnetic, chromium steel, immune to chloride stress corrosion cracking			
430	**60**	17% chromium.	Sinks, decoration, automotive trim, washing machine drums. Automotive trim - below the waist and wiper blades.
434	**61**	17% chromium,1% molybdenum. Resistant to atmospheric and pitting corrosion.	Automotive exhaust system
409		12% chromium plus titanium. Weldable up to 2.5mm thick.	Structural, bulk handling chutes, hoppers & railway wagons, transport, mining.
4003		Modified form of 409, weldable in heavy section.	
Austenitic : Non-magnetic, chromium/nickel steels, good weldability. Good general corrosion resistance			
301		17% chromium, 7% nickel. High work hardening rate. Formability.	Structural, springs, wheel covers, wear plates.
302		18% chromium, 9% nickel. Good formability.	Similar to 304
303	**58A 58AM**	Free machining form of 302. Available in bar form only.	
304	**58E**	18% chromium, 9% nickel. Good formability.	Sinks, architecture, automotive exhausts, cutlery, holloware and flatware, water tubing.
304L		Low carbon form of 304.	Brewery, dairy, food and pharmaceutical production plant. Sinks, holloware.
304DDQ		Deep drawing quality of 304.	Eyelets, spun parts.
305		18% chromium, 12% nickel. Good formability.	Similar to 310
309		23% chromium, 14% nickel. High oxidation resistance.	
310	**58J**	25% chromium, 20% nickel. Very high oxidation resistance.	Furnaces, heat exchanges, metallurgical plant. Service temp up to 1100°C.
316		17% chromium, 11% nickel, 2.5% molybdenum. High corrosion resistance.	Chemical and petrochemical process plant architecture, brewery plant.
316L		Low carbon form of 316.	
317	**58B+C**	18% chromium, 12%nickel, 2.5% molybdenum plus titanium. Very high corrosion resistance.	Chemical and petrochemical process plant, acetic acid distillation.
317L		Low carbon form of 317.	
321		18% chromium, 10% nickel plus titanium.	Heating elements, aircraft parts, chemical and petrochemical process plant.
325	**58BM**	Free machining form of 321. Sulphur bearing. Available in bar form only.	
347	**58F+G**	18% chromium, 10% nickel plus niobium. Resistant to sensitisation and hot concentrated nitric acid.	Process plant, aircraft parts.

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Mechanical Properties

Mechanical Properties of Austenitic Stainless Steel Fasteners ISO 3506 Steel Grade A2 and A4

		Bolts Screws & Studs		Nuts	
Property Class	Diameter Range	Tensile Strength N/mm^2 min	Yield Stress N/mm^2 min	Ductility (Total Elongation)	Proof Load Stress N/mm^2 min
70	up to M20	700	450	0.4d	700

- Property values are determined on finished products - not on machine tested pieces.
- Tensile stress values are calculated in terms of the nominal (mean) tensile stress area of the thread.
- Yield stress is defined as the stress to give 0.2% permanent strain.
- Total elongation is the increase in total length at fracture after tensile loading expressed as a factor of the thread diameter.
- d = nominal thread diameter
- Above M20, the higher strength property classes should have the property values specifically agreed upon between user and manufacturer because at the tensile strength factors given, alternative values of stress at 0.2% permanent strain may occur.

Inch/Metric Conversion Table

Inch		mm	Inch		mm	Inch		mm	Inch		mm
1/32	0.031	0.794	9/32	0.281	7.144	17/32	0.531	13.494	25/32	0.781	19.844
1/16	0.063	1.587	5/16	0.312	7.937	9/16	0.562	14.287	13/16	0.812	20.637
3/32	0.094	2.381	11/32	0.343	8.731	19/32	0.593	15.081	27/32	0.843	21.431
1/8	0.125	3.175	3/8	0.375	9.525	5/8	0.625	15.875	7/8	0.875	22.225
5/32	0.156	3.968	13/32	0.406	10.319	21/32	0.656	16.669	29/32	0.906	23.019
3/16	0.187	4.762	7/16	0.437	11.112	11/16	0.687	17.462	15/16	0.937	23.812
7/32	0.218	5.556	15/32	0.468	11.906	23/32	0.718	18.256	31/32	0.968	24.606
1/4	0.250	6.350	1/2	0.500	12.700	3/4	0.750	19.050	1	1.000	25.400

in.	mm	in.	mm	in.	mm	in.	mm
0.001	0.0254	0.190	4.826	0.460	11.684	0.730	18.542
0.002	0.0508	0.200	5.080	0.470	11.938	0.740	18.796
0.003	0.0762	0.210	5.334	0.480	12.192	0.750	19.050
0.004	0.1016	0.220	5.588	0.490	12.446	0.760	19.304
0.005	0.1270	0.230	5.842	0.500	12.700	0.770	19.558
0.006	0.1524	0.240	6.096	0.510	12.954	0.780	19.812
0.007	0.1778	0.250	6.350	0.520	13.208	0.790	20.066
0.008	0.2032	0.260	6.604	0.530	13.462	0.800	20.320
0.009	0.2286	0.270	6.858	0.540	13.716	0.810	20.574
0.010	0.2540	0.280	7.112	0.550	13.970	0.820	20.828
0.020	0.5080	0.290	7.366	0.560	14.224	0.830	21.082
0.030	0.7620	0.300	7.620	0.570	14.478	0.840	21.336
0.040	1.0160	0.310	7.874	0.580	14.732	0.850	21.590
0.050	1.2700	0.320	8.128	0.590	14.986	0.860	21.844
0.060	1.5240	0.330	8.382	0.600	15.240	0.870	22.098
0.070	1.7780	0.340	8.636	0.610	15.494	0.880	22.352
0.080	2.0320	0.350	8.890	0.620	15.748	0.890	22.606
0.090	2.2860	0.360	9.144	0.630	16.002	0.900	22.860
0.100	2.5400	0.370	9.398	0.640	16.256	0.910	23.114
0.110	2.7940	0.380	9.652	0.650	16.510	0.920	23.368
0.120	3.0480	0.390	9.906	0.660	16.764	0.930	23.622
0.130	3.3020	0.400	10.160	0.670	17.018	0.940	23.876
0.140	3.5560	0.410	10.414	0.680	17.272	0.950	24.130
0.150	3.8100	0.420	10.668	0.690	17.526	0.960	24.384
0.160	4.0640	0.430	10.922	0.700	17.780	0.970	24.638
0.170	4.3180	0.440	11.176	0.710	18.034	0.980	24.892
0.180	4.5720	0.450	11.430	0.720	18.288	0.990	25.146

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Mechanical Properties

Softening Temperatures & Details of Intergranular Corrosion Test of Austenitic Stainless Steel

Steel Grade	Proof Stress Rp0.2, min N/mm²	Proof Stress Rp01.0, min N/mm²	Tensile Strength R_m•min N/mm²	*Elongation Test A.min	Hardness HV.max. †	Condition	Softening Temperature Range Min	Softening Temperature Range Max	Sensitisation Time For Intergranular Corrosion Test min
284S16	300	335	630	40%	220	Softened	1000°C	1120°C	Nil
301S21	215	250	540	40%	220	Softened	1000°C	1120°C	Nil
304S11	180	215	480	40%	135	Softened	1000°C	1120°C	30
304S15	195	230	500	40%	190	Softened	1000°C	1120°C	15
304S16	195	230	500	40%	190	Softened	1000°C	1120°C	15
304S31	195	230	500	40%	190	Softened	1000°C	1120°C	Nil
305S19	185	220	490	40%	185	Softened	1000°C	1120°C	NIl
309S24	205	240	510	40%	205	Softened	1000°C	1120°C	Nil
310S24	205	240	510	40%	205	Softened	1000°C	1120°C	Nil
315S16	205	240	510	40%	205	Softened	1000°C	1120°C	15
316S11	190	225	490	40%	195	Softened	1000°C	1120°C	30
316S13	190	225	490	40%	195	Softened	1000°C	1120°C	30
316S31	205	240	510	40%	205	Softened	1000°C	1120°C	15
316S33	205	240	510	40%	205	Softened	1000°C	1120°C	15
317S12	195	230	490	40%	195	Softened	1000°C	1120°C	30
317S16	205	240	510	40%	205	Softened	1000°C	1120°C	15
320S31	210	245	510	40%	205	Softened	1000°C	1120°C	30
320S33	210	245	510	40%	205	Softened	1000°C	1120°C	30
321S31	200	235	500	35%	200	Softened	1000°C	1120°C	30
347S31	205	240	510	35%	200	Softened	1000°C	1120°C	30

1 N/mm² = 1 MP_a

• = Elongation measured on flat test pieces using 50mm gauge length or 5.65$\sqrt{s_O}$. For cylindrical test pieces, a gauge length of 5.64√so is used.

† = For items of adequate thickness the Brinell hardness test may be used, applying the same limiting HB hardness values as given for HV.

Softening Temperatures Ferritic & Martensitic Steels

Steel Grade	Proof stress, $R_{po.2}$, N/mm²	Tensile Strength R_m,min N/mm²	Elongation* A.min	Hardness HV, max.† Plate	Hardness HV, max.† Sheet/ Strip	Condition	Temperature Range Softening Min	Softening Max	Hardening‡ Min	Hardening‡ Max	Tempering Min	Tempering Max
Ferritic Steels												
403S17	245	420	20%	190	175	Softened	700°C	780°C	—	—	—	—
405S17	245	420	20%	190	175	Softened	700°C	780°C	—	—	—	—
409S19	200	350	20%	190	175	Softened	700°C	950°C	—	—	—	—
430S17	245	430	20%	190	175	Softened	750°C	820°C	—	—	—	—
434S17	245	430	20%	—	185	Softened	750°C	820°C	—	—	—	—
Martensitic Steels												
410S21	—	—	—	190	185	Softened ‡Hardened &Tempered	700°C	780°C	950°C	1020°C	650°C	750°C
420S45	—	—	—	230	220	Softened ‡Hardened &Tempered	700°C	780°C	950°c	1050°C	150°C	250°C

1N/mm² = 1 MP_a

* = Elongation measured on flat test piece using 50mm gauge length or 5.65$\sqrt{s_O}$. for cylindrical test pieces, a gauge length of 5.65 $\sqrt{s_O}$. is used.

† = For items of adequate thickness the Brinell hardness test may be used, applying the same limiting HB hardness values as given for HV.

‡ = For guidance only

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Fabrication Data

Working Information

	301S1	302S25	304S16	304S12	305S19	303S21	303S41	309S24	310S24	316S16
Blanking	B	B	B	B	B	—	—	B	B	B
Brake Forming	B	A	A	A	A	—	—	A	A	A
Brazing	B	B	B	B	B	B	D	B	B	B
Buffing	A	A-B	A-B	B	A-B	B	D	B	B	B
Coining	B-C	B	B	B	A-B	A	D	B	B	B
Deep Drawing	A-B	A	A	A	B	—	—	B	B	B
Drilling	C-D	C	C	C	C	B-C	B	C	C	C
Embossing	B-C	B	B	B	B	—	C	B	B	B
Forging-Cold	C	B	B	B	B	B	D	B-C	B-C	B
Forging-Hot	B	B	B	B	B	B	B	B	B	B
Hardening By Cold Work										
a) Annealed 1000psi	115.00	90.00	85..00	82.00	80.00	—	—	90.00	95.00	90.00
kg/mm²	80.80	63.30	59.70	58.00	56.20	—	—	63.30	66.80	63.30
b) 25% Red. 1000psi	169.00	142.00	138.00	140.00	130.00	—	—	130.00	126.00	134.00
kg/mm²	119.00	100.00	97.00	98.00	91.00	—	—	91.00	89.00	94.00
c) 50% Red. 1000psi	220.00	180.00	178.00	182.00	170.00	—	—	169.00	165.00	165.00
kg/mm²	155.00	127.00	125.00	128.00	119.00	—	—	119.00	116.00	116.00
Hardening By Heat Treatment	No	No	No	No	No	No	No	No	No	No
Heading-Cold	C	B	B	B	A-B	A	A	—	A-B	B
Heading-Hot	A	A	A	A	A	A	A	—	A	A
Machining	C	C	C	C	C	B-C	B-C	C	C	C
Magnetic	Not	Not	Not	Not	Nott	Nott	Not	Not	Nott	Not
Punching	C	B	B	B	B	—	—	B	B	B
Polishing	A	A	A	A	A	A	D	B	B	B
Roll-Forming	B	A	A	A	A	—	—	B	A	A
Sawing	C	C	C	C	C	C	B	C	C	C
Shearing	B	B	B	B	B	B	C	B	B	B
Soldering	B	B	B	B	B	B	C-D	B	B	B
Spinning	D	B-C	B-C	B-C	A	—	—	B-C	B	B
Spot Welding (resistance)	A	A	A	A	A	B	D	A	A	A
Welding (coated electrodes)	B	A-B	A	A	A	B	D	B	B	A
Welding (oxy-acetylene)	D	D	D	D	D	D	D	D	D	D
Welding Metal Inert Gas Arc	A-B	A-B	A	A	A	B-C	D	A	A	A
Welding Tungsten Inert Gas Arc	A	A	A	A	A	B	D	A	A	A

A = Excellent **B** = Good **C** = Fair **D** = Not generally recommended
† = Develops magnetism after cold reduction **††** = Develops less magnetism after cold reduction
***** = Severe sharp bends to be avoided

970 PART 1 (1983) WROUGHT STEEL

Standard B.S.	Old EN~	C	Si	Min	P	S	Cr	Mo	Ni	Others	German Standard
302 S 31	—	≤ 0.12%	≤ 1.00%	≤ 2.00%	≤ 0.045%	≤ 0.030%	17.0%-19.0%	—	8.0%-10.0%	—	—
303 S 31	—	≤ 0.12%	≤ 1.00%	≤ 2.00%	≤ 0.060%	0.15%-0.35%	17.0%-19.0%	≤ 1.00%	8.0%-10.0%	—	—
303 S 42	—	≤ 0.12%	≤ 1.00%	≤ 2.00%	≤ 0.060%	≤ 0.060%	17.0%-19.0%	≤ 1.00%	8.0%-10.0%	Se0.15%0.35%	—
304 S 11	—	≤ 0.03%	≤ 1.00%	≤ 2.00%	≤ 0.045%	≤ 0.030%	17.0%-19.0%	—	9.0%-12.0%	—	1.4306
304 S 15	58E	≤ 0.06%	≤ 1.00%	≤ 2.00%	≤ 0.045%	≤ 0.030%	17.5%-19.0%	—	8.0%-11.0%	—	1.4301
304 S 31	—	≤ 0.07%	≤ 1.00%	≤ 2.00%	≤ 0.045%	≤ 0.030%	17.0%-19.0%	—	8.00%-11.0%	—	1.4301
310 S 31	—	≤ 0.15%	≤ 1.50%	≤ 2.00%	≤ 0.045%	≤ 0.030%	24.0%-26.0%	—	19.0%-22.0%	—	—
316 S 11	—	≤ 0.03%	≤ 1.00%	≤ 2.00%	≤ 0.045%	≤ 0.030%	16.5%-18.5%	2.00%-2.50%	11.0%-14.0%	—	1.4404/1.4435
316 S 13	—	≤ 0.03%	≤ 1.00%	≤ 2.00%	≤ 0.045%	≤ 0.030%	16.5%-18.5%	2.50%-3.00%	11.5%-14.5%	—	—
316 S 31	—	≤ 0.07%	≤ 1.00%	≤ 2.00%	≤ 0.045%	≤ 0.030%	16.5%-18.5%	2.00%-2.50%	10.5%-13.5%	—	1.4401/1.4436
316 S 33	—	≤ 0.07%	≤ 1.00%	≤ 2.00%	≤ 0.045%	≤ 0.030%	16.5%-18.5%	2.50%-3.00%	11.0%-14.0%	—	1.4401/1.4436
320 S 31	—	≤ 0.08%	≤ 1.00%	≤ 2.00%	≤ 0.045%	≤ 0.030%	16.5%-18.5%	2.00%-2.50%	11.0%-14.0%	Ti5XC-0.80%	1.4571
321 S 31	—	≤ 0.08%	≤ 1.00%	≤ 2.00%	≤ 0.045%	≤ 0.030%	17.0%-19.0%	—	9.0%-14.0%	Ti5XC-0.80%	—
325 S 31	—	≤ 0.12%	≤ 1.00%	≤ 2.00%	≤ 0.045%	0.15%-0.35%	17.0%-19.0%	—	8.0%-11.0%	Ti5XC-0.90%	—
347 S 31	—	≤ 0.08%	≤ 1.00%	≤ 2.00%	≤ 0.045%	≤ 0.030%	17.0%-19.0%	—	9.0%-12.0%	Nb10xC1.00%	1.4550
403 S 17	—	≤ 0.08%	≤ 1.00%	≤ 1.00%	≤ 0.040%	≤ 0.030%	12.0%-14.0%	—	≤ 0.5%	—	1.4000
410 S 21	56A	0.09%-0.15%	≤ 1.00%	≤ 1.00%	≤ 0.040%	≤ 0.030%	11.5%-13.5%	—	≤ 1.0%	—	1.4006
416 S 21	56AM	0.09%-0.15%	≤ 1.00%	≤ 1.50%	≤ 0.060%	0.15%-0.35%	11.5%-13.5%	≤ 0.60%	≤ 1.0%	—	1.4005
416 S 29	56 BM	0.14%-0.20%	≤ 1.00%	≤ 1.50%	≤ 0.060%	0.15%-0.35%	11.5%-13.5%	≤ 0.60%	≤ 1.0%	—	—
416 S 37	56CM	0.20%-0.28%	≤ 1.00%	≤ 1.50%	≤ 0.060%	0.15%-0.35%	12.0%-14.0%	≤ 0.60%	≤ 1.0%	—	—
416 S 41	56 AM	0.09%-0.15%	≤ 1.00%	≤ 1.50%	≤ 0.060%	≤ 0.060%	11.5%-13.5%	≤ 0.60%	≤ 1.0%	Se0.15%0.35%	—
420 S 29	56 B	0.14%-0.20%	≤ 1.00%	≤ 1.00%	≤ 0.040%	≤ 0.030%	11.5%-13.5%	—	≤ 1.0%	—	1.4024
420 S 37	56 C	0.20%-0.28%	≤ 1.00%	≤ 1.00%	≤ 0.040%	≤ 0.030%	12.0%-14.0%	—	≤ 1.0%	—	1.4021
430 S 17	—	≤0.08%	≤ 1.00%	≤ 1.00%	≤ 0.040%	≤ 0.030%	16.0%-18.0%	—	≤ 0.5%	—	1.4016
431 S 29	57	0.12%-0.20%	≤ 1.00%	≤ 1,00%	≤0.040%	≤ 0.030%	15.0%-18.0%	—	2.0%-3.0%	—	1.4057

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Shaft Strengths and Rotations

MATERIAL TYPE		SHAFT DIAMETER (mm) Ø6	Ø10	Ø12	Ø15	Ø17	Ø20	Ø25	Ø30	Ø40	Ø50	Ø75	Ø100
Nm	MILD STEEL EN15A EN3 35,000 KN/m²	1.5	6.6	11.5	23	34	55	105	180	440	840	2800	6600
Nm	EN8 EN32 EN58 45,000 KN/m²	1.9	8.5	15	28	43	70	135	230	550	1000	3600	8500
Nm	EN16 EN19 EN24 EN36 60,000 KN/m²	2.5	12	20	39	56	95	180	310	750	1500	4800	12000

$$\text{Torque (Nm)} = \frac{9550 \times \text{Kw}}{\text{Rpm}}$$

KW = HP x 0.746

All chart figures shown in this book are only meant as a guide and no responsibility can be taken by ondrives for the use thereof.

SHAFT ROTATION - H.P. TRANSMITTED FOR GIVEN RPM AND Nm

H.P.

Nm / RPM	0.1	0.5	1	2	5	8	10	15	20	25	30	50	100	200	500	1000
5								0.010	0.014	0.017	0.022	0.035	0.07	0.15	0.35	0.70
10						0.011	0.014	0.020	0.028	0.035	0.041	0.070	0.15	0.28	0.70	1.40
20					0.014	0.023	0.028	0.040	0.056	0.070	0.085	0.140	0.28	0.55	1.40	2.80
50				0.014	0.035	0.055	0.070	0.100	0.140	0.170	0.210	0.350	0.70	1.40	3.50	7.00
100			0.014	0.028	0.070	0.115	0.140	0.210	0.280	0.350	0.410	0.700	1.45	2.80	7.00	14.00
200		0.014	0.028	0.055	0.140	0.230	0.280	0.420	0.570	0.700	0.850	1.500	2.90	5.60	14.00	28.00
300		0.021	0.042	0.082	0.210	0.350	0.410	0.620	0.850	1.050	1.250	2.100	4.20	8.50	21.00	42.00
400		0.028	0.055	0.110	0.280	0.450	0.550	0.850	1.100	1.400	1.700	2.800	5.60	11.00	28.00	56.00
500		0.035	0.070	0.140	0.350	0.560	0.700	1.050	1.400	1.750	2.100	3.500	7.00	14.00	35.00	70.00
750	0.010	0.051	0.100	0.210	0.520	0.850	1.050	1.600	2.100	2.700	3.100	5.200	10.40	21.00	52.00	107.00
1000	0.015	0.070	0.140	0.280	0.700	1.150	1.400	2.100	2.800	3.500	4.200	7.000	14.00	28.00	70.00	140.00
1500	0.022	0.100	0.210	0.400	1.000	1.700	2.100	3.100	4.200	5.100	6.200	10.500	21.00	41.00	100.00	210.00
2000	0.029	0.140	0.280	0.550	1.400	2.300	2.800	4.100	5.500	7.000	8.400	14.000	28.00	56.00	140.00	280.00
3000	0.044	0.210	0.420	0.820	2.100	3.500	4.200	6.200	8.500	10.000	12.500	21.000	43.00	85.00	210.00	420.00
4000	0.060	0.270	0.560	1.100	2.800	4.500	5.500	8.500	11.000	14.000	18.000	28.000	58.00	110.00	280.00	560.00
5000	0.072	0.350	0.700	1.400	3.500	5.600	7.000	10.500	14.000	17.000	21.000	35.000	70.00	140.00	350.00	700.00
8000	0.120	0.550	1.100	2.300	5.500	9.200	11.000	17.000	23.000	28.000	34.000	56.000	115.00	230.00	550.00	1150.00
10000	0.150	0.700	1.400	2.800	7.000	11.500	14.000	21.000	29.000	35.000	42.000	71.000	140.00	280.00	700.00	1400.00

TECHNICAL

Shaft and Bore Limits & Fits

Housing Bore Tolerances (deviation from nominal dimensions)

Nominal Diameter mm		TOLERANCE OF HOUSING SHAFT DIAMETER (Unit = 0.001mm)											
		d6		e6		f6		g5		h5		h6	
Over	Incl.	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
-	3	-20	-26	-14	-20	-6	-12	-2	-6	0	-4	0	-6
3	6	-30	-38	-20	-28	-10	-18	-4	-9	0	-5	0	-8
6	10	-40	-49	-25	-34	-13	-22	-5	-11	0	-6	0	-9
10	18	-50	-61	-32	-43	-16	-27	-6	-14	0	-8	0	-11
18	30	-65	-78	-40	-53	-20	-33	-7	-16	0	-9	0	-13
30	40	-80	-96	-50	-66	-25	-41	-9	-20	0	-11	0	-16
40	50	-80	-96	-50	-66	-25	-41	-9	-20	0	-11	0	-16
50	65	-100	-119	-60	-79	-30	-49	-10	-23	0	-13	0	-19
65	80	-100	-119	-60	-79	-30	-49	-10	-23	0	-13	0	-19
80	100	-120	-142	-72	-94	-36	-58	-12	-27	0	-15	0	-22
100	120	-120	-142	-72	-94	-36	-58	-12	-27	0	-15	0	-22
120	140	-145	-170	-85	-110	-43	-68	-14	-32	0	-18	0	-25
140	160	-145	-170	-85	-110	-43	-68	-14	-32	0	-18	0	-25
160	180	-145	-170	-85	-110	-43	-68	-14	-32	0	-18	0	-25
180	200	-170	-199	-100	-129	-50	-79	-15	-35	0	-20	0	-29
200	225	-170	-199	-100	-129	-50	-79	-15	-35	0	-20	0	-29
225	250	-170	-199	-100	-129	-50	-79	-15	-35	0	-20	0	-29
250	280	-190	-222	-110	-142	-56	-88	-17	-40	0	-23	0	-32
280	315	-190	-222	-110	-142	-56	-88	-17	-40	0	-23	0	-32
315	355	-210	-246	-125	-161	-62	-98	-18	-43	0	-25	0	-36
355	400	-210	-246	-125	-161	-62	-98	-18	-43	0	-25	0	-36
400	450	-230	-270	-135	-175	-68	-108	-20	-47	0	-27	0	-40
450	500	-230	-270	-135	-175	-68	-108	-20	-47	0	-27	0	-40

Nominal Diameter mm		TOLERANCE OF HOUSING BORE DIAMETER (Unit = 0.001mm)											
		F6		F7		G6		G7		H6		H7	
Over	Incl.	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
-	3	+12	+6	+16	+6	+8	+2	+12	+2	+6	0	+10	0
3	6	+18	+10	+22	+10	+12	+4	+16	+4	+8	0	+12	0
6	10	+22	+13	+28	+13	+14	+5	+20	+5	+9	0	+15	0
10	18	+27	+16	+34	+16	+17	+6	+24	+6	+11	0	+18	0
18	30	+33	+20	+41	+20	+20	+7	+28	+7	+13	0	+21	0
30	40	+41	+25	+50	+25	+25	+9	+34	+9	+16	0	+25	0
40	50	+41	+25	+50	+25	+25	+9	+34	+9	+16	0	+25	0
50	65	+49	+30	+60	+30	+29	+10	+40	+10	+19	0	+30	0
65	80	+49	+30	+60	+30	+29	+10	+40	+10	+19	0	+30	0
80	100	+58	+36	+71	+36	+34	+12	+47	+12	+22	0	+35	0
100	120	+58	+36	+71	+36	+34	+12	+47	+12	+22	0	+35	0
120	140	+68	+43	+83	+43	+39	+14	+54	+14	+25	0	+40	0
140	160	+68	+43	+83	+43	+39	+14	+54	+14	+25	0	+40	0
160	180	+68	+43	+83	+43	+39	+14	+54	+14	+25	0	+40	0
180	200	+79	+50	+96	+50	+44	+15	+61	+15	+29	0	+46	0
200	225	+79	+50	+96	+50	+44	+15	+61	+15	+29	0	+46	0
225	250	+79	+50	+96	+50	+44	+15	+61	+15	+29	0	+46	0
250	280	+88	+56	+108	+56	+49	+17	+69	+17	+32	0	+52	0
280	315	+88	+56	+108	+56	+49	+17	+69	+17	+32	0	+52	0
315	355	+98	+62	+119	+62	+54	+18	+75	+18	+36	0	+57	0
355	400	+98	+62	+119	+62	+54	+18	+75	+18	+36	0	+57	0
400	450	+108	+68	+131	+68	+60	+20	+83	+20	+40	0	+63	0
450	500	+108	+68	+131	+68	+60	+20	+83	+20	+40	0	+63	0

	SURFACE FINISH CONVERSION CHART	
Micro Inch (Cla)	Metric (microns) Equivalent (Ra)	European
1	0.025	N1
2	0.050	N2
4	0.100	N3
8	0.200	N4
16	0.400	N5
32	0.810	N6
63	1.600	N7
125	3.180	N8
250	6.350	N9
500	12.700	N10
1000	25.400	N11

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Shaft and Bore Limits & Fits

Housing Bore Tolerances (deviation from nominal dimensions)

Nominal Diameter mm		TOLERANCE OF HOUSING SHAFT DIAMETER (Unit = 0.001mm)											
		h7		h8		h9		h10		j5		j6	
Over	Incl.	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
-	3	0	-10	0	-14	0	-25	0	-40	+2	-2	+4	-2
3	6	0	-12	0	-18	0	-30	0	-48	+3	-2	+6	-2
6	10	0	-15	0	-22	0	-36	0	-58	+4	-2	+7	-2
10	18	0	-18	0	-27	0	-43	0	-70	+5	-3	+8	-3
18	30	0	-21	0	-33	0	-52	0	-84	+5	-4	+9	-4
30	40	0	-25	0	-39	0	-62	0	-100	+6	-5	+11	-5
40	50	0	-25	0	-39	0	-62	0	-100	+6	-5	+11	-5
50	65	0	-30	0	-46	0	-74	0	-120	+6	-7	+12	-7
65	80	0	-30	0	-46	0	-74	0	-120	+6	-7	+12	-7
80	100	0	-35	0	-54	0	-87	0	-140	+6	-9	+13	-9
100	120	0	-35	0	-54	0	-87	0	-140	+6	-9	+13	-9
120	140	0	-40	0	-63	0	-100	0	-160	+7	-11	+14	-11
140	160	0	-40	0	-63	0	-100	0	-160	+7	-11	+14	-11
160	180	0	-40	0	-63	0	-100	0	-160	+7	-11	+14	-11
180	200	0	-46	0	-72	0	-115	0	-185	+7	-13	+16	-13
200	225	0	-46	0	-72	0	-115	0	-185	+7	-13	+16	-13
225	250	0	-46	0	-72	0	-115	0	-185	+7	-13	+16	-13
250	280	0	-52	0	-81	0	-130	0	-210	+7	-16	+16	-16
280	315	0	-52	0	-81	0	-130	0	-210	+7	-16	+16	-16
315	355	0	-57	0	-89	0	-140	0	-230	+7	-18	+18	-18
355	400	0	-57	0	-89	0	-140	0	-230	+7	-18	+18	-18
400	450	0	-63	0	-97	0	-155	0	-250	+7	-20	+20	-20
450	500	0	-63	0	-97	0	-155	0	-250	+7	-20	+20	-20

Nominal Diameter mm		TOLERANCE OF HOUSING BORE DIAMETER (Unit = 0.001mm)									
		H8		H9		H10		J6		J7	
Over	Incl.	High	Low	High	Low	High	Low	High	Low	High	Low
-	3	+14	0	+25	0	+40	0	+2	-4	+4	-6
3	6	+18	0	+30	0	+48	0	+5	-3	+6	-6
6	10	+22	0	+36	0	+58	0	+5	-4	+8	-7
10	18	+27	0	+43	0	+70	0	+6	-5	+10	-8
18	30	+33	0	+52	0	+84	0	+8	-5	+12	-9
30	40	+39	0	+62	0	+100	0	+10	-6	+14	-11
40	50	+39	0	+62	0	+100	0	+10	-6	+14	-11
50	65	+46	0	+74	0	+120	0	+13	-6	+18	-12
65	80	+46	0	+74	0	+120	0	+13	-6	+18	-12
80	100	+54	0	+87	0	+140	0	+16	-6	+22	-13
100	120	+54	0	+87	0	+140	0	+16	-6	+22	-13
120	140	+63	0	+100	0	+160	0	+18	-7	+26	-14
140	160	+63	0	+100	0	+160	0	+18	-7	+26	-14
160	180	+63	0	+100	0	+160	0	+18	-7	+26	-14
180	200	+72	0	+115	0	+185	0	+22	-7	+30	-16
200	225	+72	0	+115	0	+185	0	+22	-7	+30	-16
225	250	+72	0	+115	0	+185	0	+22	-7	+30	-16
250	280	+81	0	+130	0	+210	0	+25	-7	+36	-16
280	315	+81	0	+130	0	+210	0	+25	-7	+36	-16
315	355	+89	0	+140	0	+230	0	+29	-7	+39	-18
355	400	+89	0	+140	0	+230	0	+29	-7	+39	-18
400	450	+97	0	+155	0	+250	0	+33	-7	+43	-20
450	500	+97	0	+155	0	+250	0	+33	-7	+43	-20

TOLERANCE BAND IN MICRONS (0.001mm) UNITS			
over	incl.	m6	S7
0	3	+2 / +8	-6 / -16
3	6	+4 / +12	-10 / -22
6	10	+6 / +15	-13 / -28
10	18	+7 / +18	-16 / -34
18	30	+8 / +21	-20 / -41
30	50	+9 / +25	-25 / -50
50	80	+11 / +30	-30 / -60

TECHNICAL

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Inertia and the Use of Inertia Figures to Aid Selection

Example Gearbox
3:1 ratio, 90% efficient, 0.52kg cm^2 (0.000052kg m^2) relflected inertia at input

So, if acceleration = 10 radians per sec per sec

Input torque needed = inertia (in kg m^2) x acceleration (in radians per second)

Input torque needed = 0.000052 kg m^2 x 10 radians per second = 0.00052Nm

Also, if inertia of load 0.0062 kg m^2 (62 kg cm^2) at output of unit
Reflected inertia at input will go upto 0.00817 kg m^2 (81.7kg cm^2)
Torque now will need to be 0.0817Nm.

Using the calculations below :-

$$J_T = J_M + \frac{J_L}{R^2\, n}$$

J_T (kg m^2) x acceleration at input (radians per second) = acceleration torque needed Nm

J_T = total reflected inertia at input of gearbox unit (kg m^2)
J_M = reflected inertia of gearbox (kg m^2)
J_L = inertia of load at gearbox output (kg m^2)
R = ratio :1
n = efficiency %

Deceleration can be done but the in efficency should help slow the load down but using the same formula should be okay as a guide . Then next you would also look at required running torques also and make sure the gearbox unit and the couplings and motors are large enough to handle the required torques. Also using the basic inertia x acceleration you can check the acceleration torque required for different couplings if using minature technology ie very light applications with small motors.

With J_T you can add any inertias before the gearbox in like inertia of the motor etc. as long as no other reduction is before the unit if so you will need to do more calculation than are shown.:-

1 radian (rad) = 57.5928°
1 kg m^2 = 10,000 kg cm^2
1 kg m^2 = 1,000,000,000 g mm^2
1 m^2 = 1,000,000 mm^2
1 m^2 = 10,000 cm^2

$1.0 \times 10^{-2} = 0.01$
$1.0 \times 10^{-3} = 0.001$
$1.0 \times 10^{-4} = 0.0001$
$1.0 \times 10^{-5} = 0.00001$
$1.0 \times 10^{-6} = 0.000001$
$1.0 \times 10^{-7} = 0.0000001$

Torsional Stiffness

When looking at couplings and objects that need zero or low backlash, you also need to know how stiff they are, as when you put a load/torque on the object it will twist and to know movement you will experience you can work it out from the torsional stiffness figure.

Eg. MHW-63C has a stiffness of 5000 Nm/Rad

So if we know you are putting 5Nm through the coupling as torque we can us the below calculation to show in minutes how much movement you will get between each end of the coupling.

(5/5000) x 3437.75 = 3.438' (0.057°)

$$\frac{\text{torque Nm used}}{\text{torsional stiffness Nm/rad}} \times 3437.75 = \text{answer in minutes of movment (')}$$

1 radian = 3437.75'
1 radian = 57.2958°

So by looking at tosional stiffness figures, making sure you are using Nm/rad against Nm/rad if not convert to give the same relationship you can see how stiff an assembly is and if you need to be aware of any compensations you need to input into your devices.

No repsonsibility is accepted for formulas / calculations shown in our catalogue. You must check against known ISO and British Standards to satisfy your own needs and also you may still need to test in use to make sure products have adequate life and fulfill the requirements of your equipment / machine.

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Alignment Adjustment

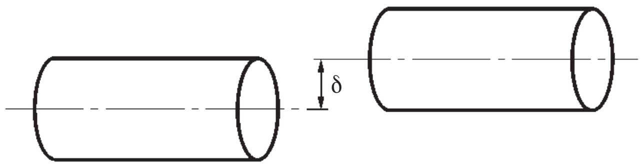
① Flexible couplings transmit torque and rotational angle while absorning misalignment. When the misalignment exceeds allowable values, vibration may result or the life of the coupling may become shortened. Make sure to adjust the alignment accordingly.

② There are three types of shaft misalignment, namely in terms of parallel misalignment, angular misalignment and shaft end play. Adjust the alignment to be below allowable values listed in the specification table of each product listed in the catalogue (where applicable).

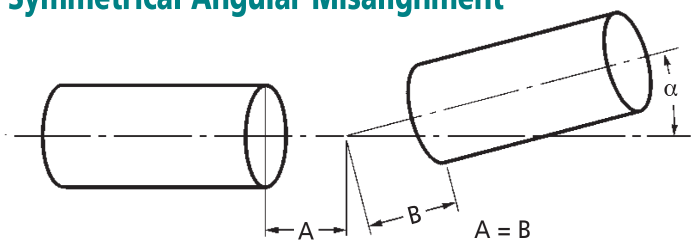
③ The maximum misalignment listed is the allowable value when only one of the misalignments exists. In case two or more misalignments exist at the same time, the allowable values will be less than ½ of the maximum misalignment listed in the specification tables.

④ Misalignments are sometimes caused not only by equipment assembly, but also by vibration, heat expansion, wear of bearings, etc. during operation. Therefore, it is recommended to adjust the shaft misalignment to be below ⅓ of maximum values.

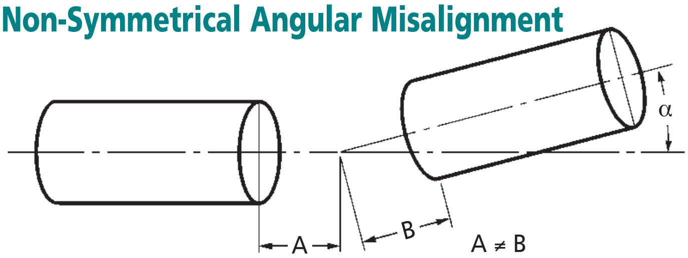
Parallel Offset Misalignment



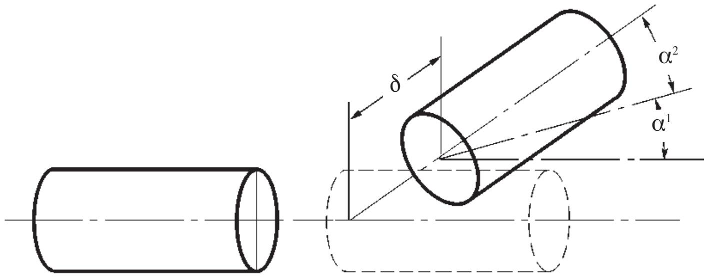
Symmetrical Angular Misalignment



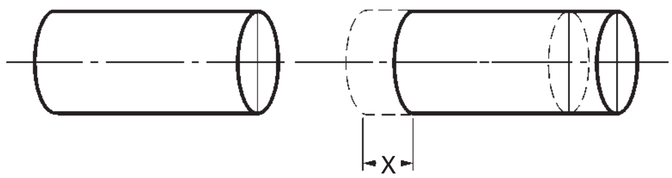
Non-Symmetrical Angular Misalignment



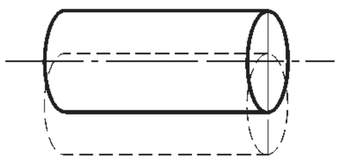
Combined Angular-Offset Misalignment



End-Play



Run Out



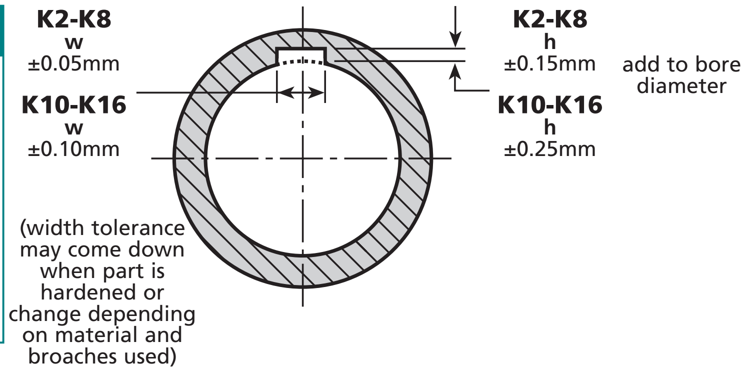
TECHNICAL

Keyway Sizes & Tapping Drill Sizes

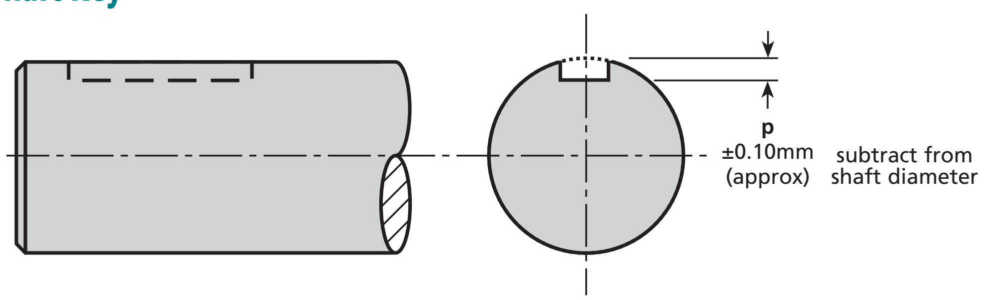
Keyway Sizes

Ref	w mm	h mm	P mm
K2	2	1.07	1.25
K3	3	1.50	1.85
K4	4	1.86	2.55
K5	5	2.35	3.05
K6	6	2.83	3.55
K8	8	3.34	4.10
K10	10	3.34	5.10
K12	12	3.35	5.10
K14	14	3.80	5.50
K16	16	4.30	6.00

Ondrives standard on most products (Free Fit)



Shaft Key



Other keyway tolerance standards
(we may be able to quote on some of these depending on product type - tooling costs may be charged extra).

On width values only (not depth)

Free Fit	Normal Fit	Close Fit
H9 D10	N9 Js9	P9

Bore or Shaft Ø over	up to & incl.	Keyway	Pin Hole Dia.	Grub Screw
4	6	-	1.50	M3
6	8	K2	2.00	M3
8	10	K3	3.00	M3
10	12	K4	4.00	M4
12	17	K5	5.00	M5
17	22	K6	6.00	M6
22	30	K8	8.00	M8
30	38	K10	10.00	M10
38	44	K12	10.00	M10
44	50	K14	10.00	M12
50	58	K16	10.00	M12

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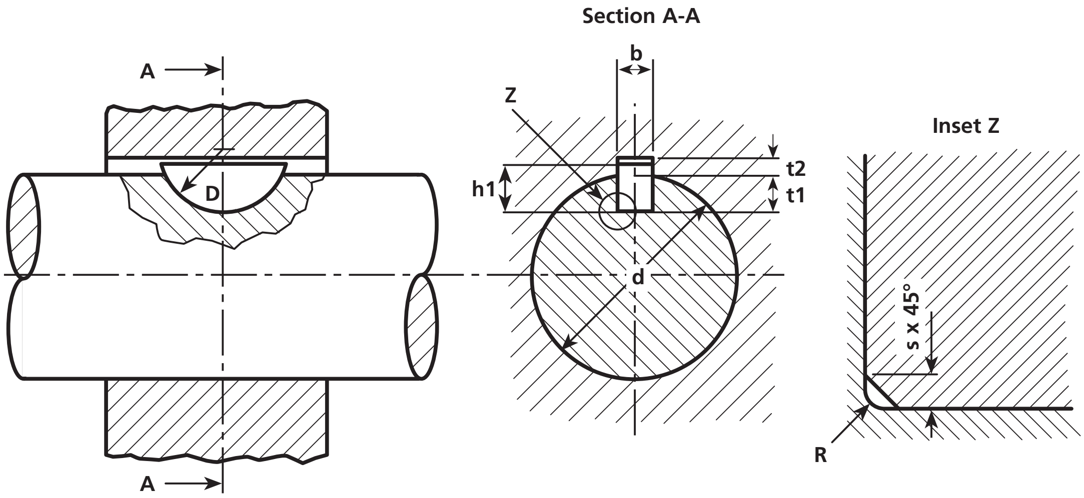
Woodruff Keys And Keyways

Metric Sizes

Key size for nominal b x h1 x D or equivalent Whitney form	Width b				Depth				Radius R	
	Nominal	Tolerance			Shaft t1		Hub t2			
		Normal Fit		Close Fit						
		Shaft (N9)	Hub (Js9)	Shaft & Hub (P9)	Nom.	Tol.	Nom.	Tol.	Max.	Min.
1.0 x 1.4 x 4	1.0				1.0		0.6		0.16	0.08
1.5 x 2.6 x 7	1.5				2.0	+0.1	0.8		0.16	0.08
2.0 x 2.6 x 7	2.0	-0.004	+0.012	-0.006	1.8	-0.0	1.0		0.16	0.08
2.0 x 3.7 x 10	2.0	-0.029	-0.012	-0.031	2.9		1.0		0.16	0.08
2.5 x 3.7 x 10	2.5				2.7		1.2	+0.1	0.16	0.08
3.0 x 5.0 x 13	3.0				3.8		1.4	-0.0	0.16	0.08
3.0 x 6.5 x 16	3.0				5.3		1.4		0.16	0.08
4.0 x 6.5 x 16	4.0				5.0	+0.2	1.8		0.25	0.16
4.0 x 7.5 x 19	4.0				6.0	-0.0	1.8		0.25	0.16
5.0 x 6.5 x 16	5.0				4.5		2.3		0.25	0.16
5.0 x 7.5 x 19	5.0	+0.000	+0.015	-0.012	5.5		2.3		0.25	0.16
5.0 x 9.0 x 22	5.0	-0.030	-0.015	-0.042	7.0		2.3		0.25	0.16
6.0 x 9.0 x 22	6.0				6.5	+0.3	2.8		0.25	0.16
6.0 x 11.0 x 28	6.0				7.5	-0.0	2.8	+0.2	0.25	0.16
8.0 x 11.0 x 28	8.0	+0.000	+0.018	-0.015	8.0		3.3	-0.0	0.40	0.25
10.0 x 13.0 x 32	10.0	-0.036	-0.018	-0.051	10.0		3.3		0.40	0.25

Woodruff Keys and Keyways, Metric Sizes



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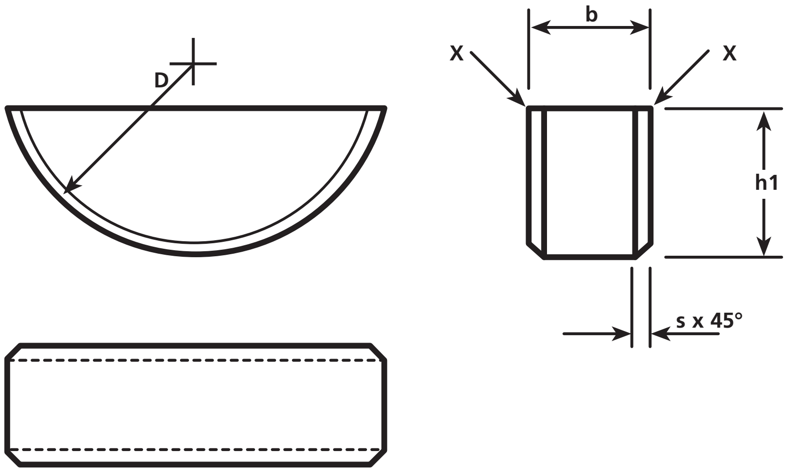
Woodruff Keys And Keyways

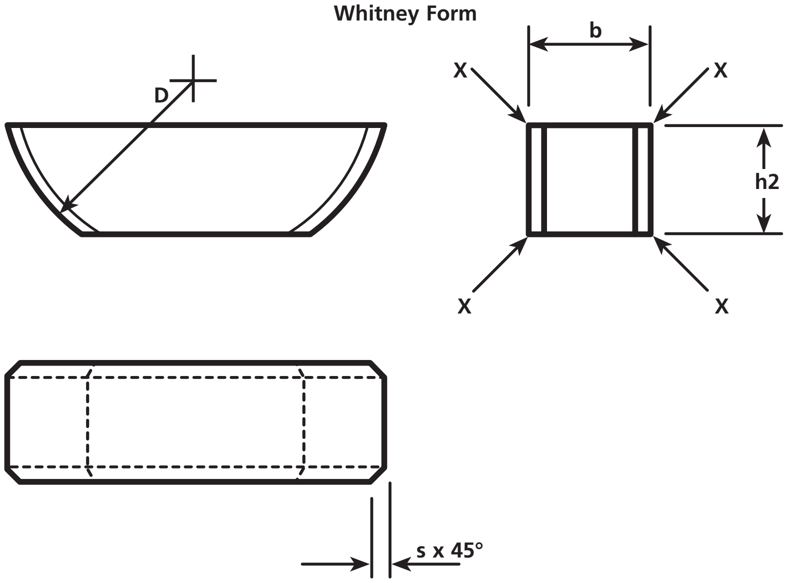
Metric Sizes

Width b		Height h1		Diameter D		Chamfer s	
Nominal	Tolerance (h9)	Nominal	Tolerance (h11)	Nominal	Tolerance (h11)	Min.	Max.
					+0.000		
1.0		1.4	+0.000	4	-0.120	0.16	0.25
1.5		2.6	-0.060	7		0.16	0.25
2.0	+0.000	2.6		7	+0.000	0.16	0.25
2.0	-0.025	3.7	+0.000	10	-0.150	0.16	0.25
2.5		3.7	-0.075	10		0.16	0.25
3.0		5.0		13	+0.000	0.16	0.25
3.0		6.5		16	-0.180	0.16	0.25
4.0		6.5		16		0.25	0.40
4.0		7.5		19	+0.000	0.25	0.40
					-0.210		
					+0.000		
5.0		6.5	+0.000	16	-0.180	0.25	0.40
5.0		7.5	-0.090	19		0.25	0.40
5.0	+0.000	9.0		22	+0.000	0.25	0.40
6.0	-0.030	9.0		22	-0.210	0.25	0.40
6.0		10.0		25		0.25	0.40
8.0	+0.000	11.0	+0.000	28		0.40	0.60
10.0	-0.036	13.0	-0.110	32	+0.000	0.40	0.60
					-0.250		

Dimensions and Tolerances for Woodruff Keys



Whitney Form



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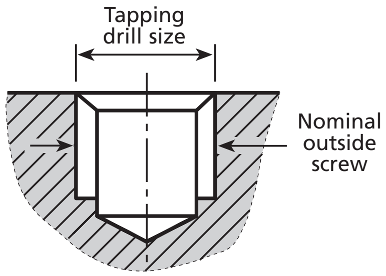
Threads, Fixings & Tolerances

Recommended Tapping Drill Sizes (when cold forming using DIN 371 cold forming taps)

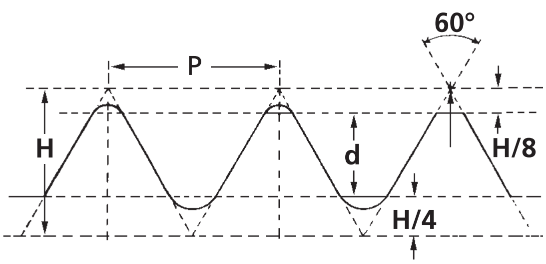
Note: Larger drills must only be used if cold forming (rolling). Check with your tool supplier. Normally only done on malleable materials such as aluminium, bronze, soft steels etc.

Tap	Drill Size mm	Pitch mm
M3	Ø2.80	0.50
M4	Ø3.70	0.70
M5	Ø4.65	0.80
M6	Ø5.55	1.00
M8	Ø7.40	1.25
M10	Ø9.30	1.50
M12	Ø11.20	1.75

Basic Thread Forms (cut): ISO Metric and Unified Thread



Tapping Drill Ø mm	Thread	Pitch mm	Outside Ø mm
1.60	M2	0.40	2.00
2.05	M2.5	0.45	2.50
2.50	M3	0.50	3.00
3.30	M4	0.70	4.00
4.20	M5	0.80	5.00
5.00	M6	1.00	6.00
6.00	M7	1.00	7.00
6.80	M8	1.25	8.00
8.50	M10	1.50	10.00
10.20	M12	1.75	12.00
12.00	M14	2.00	14.00
14.00	M16	2.00	16.00
15.50	M18	2.50	18.00
17.50	M20	2.50	20.00
19.50	M22	2.50	22.00
21.00	M24	3.00	24.00



The basic form is derived from an equilateral triangle which is truncated 1/8 of the height at the major diameter and 1/4 of the height at the minor diameter. The corresponding flats have a width of P/8 and P/4 respectively. In practice, clearance is provided beyond the P/8 flat on internal threads and beyond the P/4 flat on external threads.
These clearances are usually rounded but may be flat.

H = angular depth = 0.866025P
H/8 = shortening of major diameter = 0.108253P
H/4 = shortening of minor diameter = 0.216506P
d = 5/8 in H = 0.541266P
P = pitch = $\frac{1}{\text{No. of threads per inch}}$

Metric Drill and Tap Reference Data						
Thread	Pitch		Tap Drill	Clearance Hole		
m	Course	Fine	Diameter	Tight	Normal	Loose
2.00	0.40	0.25	1.60	2.20	2.40	2.60
2.50	0.45	0.35	2.05	2.70	2.90	3.10
3.00	0.50	0.35	2.50	3.20	3.40	3.60
3.50	0.60	0.35	2.90	3.70	3.90	4.20
4.00	0.70	0.50	3.30	4.30	4.50	4.80
5.00	0.80	0.50	4.20	5.30	5.50	5.80
6.00	1.00	0.75	5.00	6.40	6.60	7.00
7.00	1.00	0.75	6.00	7.40	7.60	8.00
8.00	1.25	1.00	6.80	8.40	9.00	10.00
10.00	1.50	1.25	8.50	10.50	11.00	12.00
12.00	1.75	1.25	10.20	13.00	13.50	14.50

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Linear Slides - Preload

Purpose of preload

A clearance may be given to linear motion rolling guides, when the load is small and very smooth motion is required. However, in many cases, preload is preferred, because it eliminates play in the guide mechanism and increases the rigidity of rolling guide. Preload is given by applying an internal stress in advance to the contact area between raceways and rolling elements. When load is applied on the preloaded rolling guide, elastic deformation due to load is smaller compared to that without preload by the effect of this internal stress, and the rigidity of rolling guide is increased (see Fig. 7).

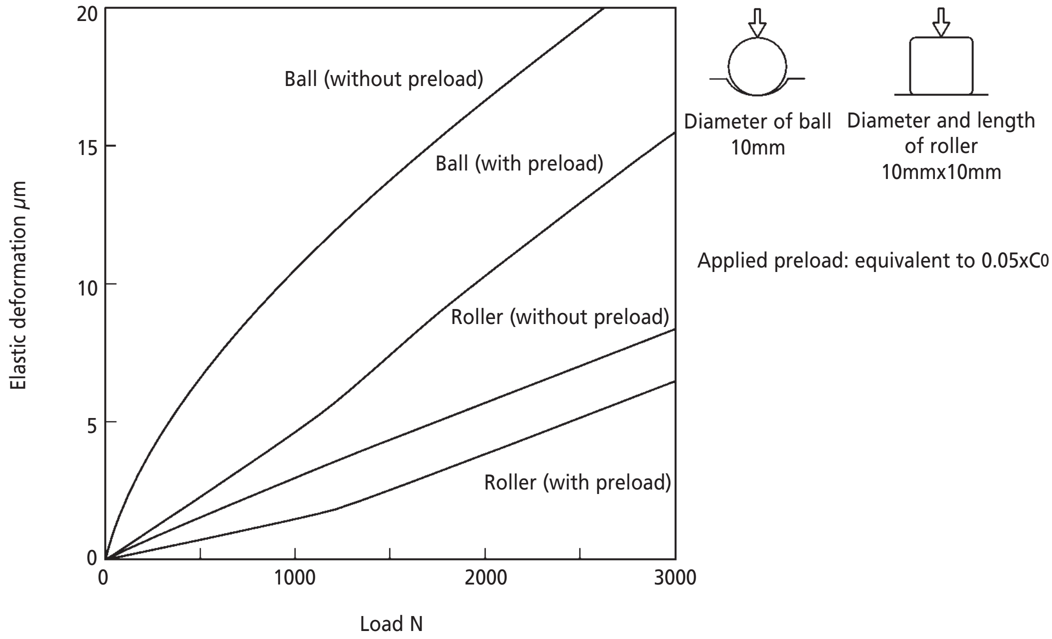

Fig. 7 Effect of preload on elastic deformation due to load

Setting preload

The preload amount is determined by considering the characteristics of the machines and equipment on which the rolling guide is mounted and the nature of load acting on the roller guide. The standard mount of preload for linear motion rolling guides is, in general, approx. ⅓ of load when the rolling elements are balls (steel balls) and approx. ½ of load when they are rollers (cylindrical rollers). If the rolling guides are required to have very high rigidity to withstand vibration of fluctuating load, a larger preload may be applied.

Cautions on Preload Selection

Even when high rigidity must be obtained, excessive preload should be avoided, because it will produce an excessive stress between rolling elements and raceways, and eventually result in short life of rolling guides. It is important to apply a proper amount of preload, considering the operation conditions. When linear motion rolling guides must be used with a large preload. Linear Bushing and Stroke Rotary Bushing should never be given a large amount of preload.

Linear Slides - Friction

Friction of Linear Motion Rolling Guides

The static friction (start-up friction) of linear motion rolling guides is much lower than that of conventional plain guides. Also, the difference between static friction and dynamic friction is small, and friction varies little when velocity changes. These are excellent features of linear motion rolling guides, and account for their ability to reduce power consumption, suppress operating temperature rise, and increase travelling speed. Since frictional resistance and variation are small, high speed response to motor commands and high accuracy positioning can be achieved.

Friction co-efficient

The frictional resistance of rolling guides varies with their type, load, travelling speed and lubricant used. Generally speaking, lubricants or seals are major factors in determining the frictional resistance in light load and high speed applications, while the magnitude of load is the major factor in heavy load and low speed applications. The frictional resistance of rolling guides actually depends on various factors, but the following formula is used for practical purposes.

Table 11
Friction coefficient

Series	Dynamic friction coefficient μ ([1])
Linear Way	0.0040 ~ 0.0060
Linear Roller Way	0.0020 ~ 0.0040
Linear Ball Spline	0.0020 ~ 0.0040
Crossed Roller Way	0.0010 ~ 0.0030
Precision Linear Slide	0.0010 ~ 0.0020
Linear Bushing	0.0020 ~ 0.0030
Stroke Rotary Bushing	0.0006 ~ 0.0012
Roller Way	0.0020 ~ 0.0040
Flat Roller Cage	0.0010 ~ 0.0030

Note ([1]): These friction coefficients do not include the seal friction.

$$F = \mu P \text{ ....} \quad (1.7)$$

where, F : Frictional resistance, N
μ : Dynamic friction coefficient
P : Load, N

For sealed guides, seal resistance is added to the above value, but this resistance varies greatly with the interference amount of seal lip and lubrication conditions. Where the methods of lubrication and mounting are correct and the load is moderate, the friction coefficients of linear motion rolling guide in operation within the range shown in Table 11. Generally, friction coefficient is large under small load. Fig. 8 gives typical examples of this relationship.

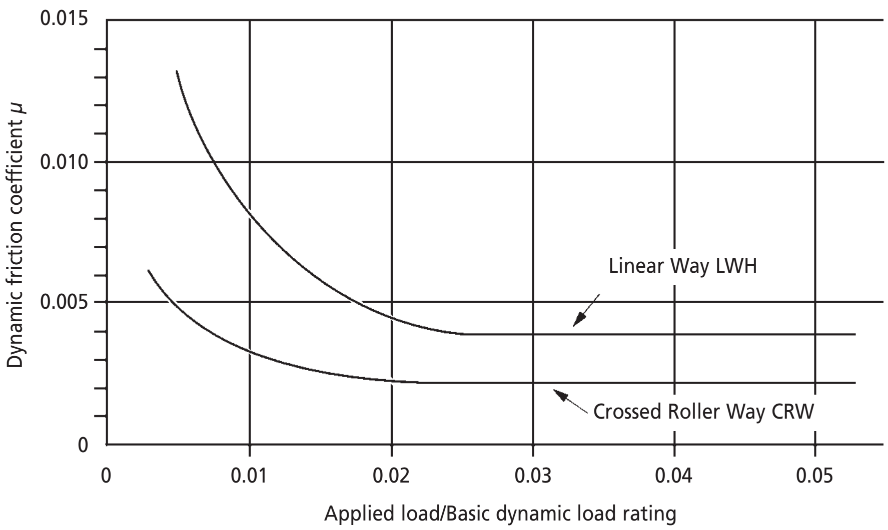

Fig. 8 Relationship between load and friction coefficient

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Linear Slides - Preload

The average amount of preload for Linear Way and Linear Roller Way is shown in Table 4. When both rigidity and vibration characteristics are important, the standard preload amount is 1/3 of the applied load for Linear Way and 1/2 for Linear Roller Way. A summary of applicable preload types is shown in Table 5. For details, see the description of each series.

Table 4 : Preload amount

Preload type \ Item	Symbol	Preload amount N	Application
Clearance	Tc	0 (1)	• Very smooth motion • To absorb slight misalignment
	T0	0 (2)	• Very smooth motion
Standard	(No symbol)	0 (3)	• Smooth and precise motion
Light preload	T1	0.02 C_0	• Minimum vibration • Load is evenly balanced. • Smooth and precise motion
Medium preload	T2	0.05 C_0	• Medium vibration • Medium overhung load
Heavy preload	T3	0.08 C_0	• Vibration and/or shocks • Large overhung load • Heavy cutting

Note (1) : Clearance of about 10μm
(2) : Zero or minimal amount of clearance.
(3) : Zero or minimal amount of preload.

Remarks: Co means the basic static load rating.

Table 5 : Preload type

Series	Classification (symbol)	Clearance (Tc)	Clearance (T0)	Standard (No symbol)	Light preload (T1)	Minimum preload (T2)	Heavy preload (T3)
Linear Way L	Interchangeable specification	–	–	O	–	–	–
	Non-interchangeable specification	–	O	O	O	–	–
Linear Way E	Interchangeable specification	O	–	O	O	–	–
	Non-interchangeable specification	O	–	O	O	–	–
Linear Way H	Interchangeable specification	–	–	O	O	–	–
	Non-interchangeable specification	–	O(1)	O	O	O(2)	O(2)
Linear Way F		–	–	O	O	O	–
Linear Roller Way	Interchangeable specification	–	–	O	O	O	O
Super X	Non-interchangeable specification	–	–	O	O	O	O
Linear Roller Way X		–	–	O	O	O	O

Note (1) : It applies to LWHT8 to LWHT12 and LWHD8 and LWHD12
(2) : It does not apply to LWHT8 to LWHT12 and LWHD8 to LWHD12.

Linear Slides - Preload

Linear Way and Linear Roller Way of the special specifications shown in Table 6 are available. In some cases, however, special specifications may not be applicable. For details, see the description of each series. When a special specification is required, add the applicable supplemental code to the end of the identification number. When a combination of several special specifications is required, arrange their supplemental codes in alphabetical order.

Table 6 : Special specifications for Linear Way and Linear Roller Way

Special specifications	Supplemental Code	Linear Way L	Linear Way E	Linear Way H	Linear Way F	Linear Roller Way Super X	Linear Roller Way X	Linear Way M(1)
Butt-jointing track rails (Non-interchangeable specification)	A	o	o	o	o	o	o	o
Stainless steel end plates	BS	o	o	o	–	–	–	–
Chamfered reference surface	C	–	–	–	o	–	–	–
Opposite reference surfaces arrangement	D	o	o	o	o	o	o	–
Specified rail mounting hole positions	E	o	o	o	o	o	o	o
Caps for rail mounting holes	F	–	o	o	o	o	o	o
Changed pitch of slide unit middle mounting holes	GE	–	–	–	–	o	–	–
Half pitch of track rail mounting holes	HP	–	–	–	–	o	–	–
Inspection sheet (Non-interchangeable specification)	I	o	o	o	o	o	o	o
Female threads for bellows	J	–	o	o	o	o	o	–
Black chrome surface treatment	L	o	o	o	o	o	o	o
Fluorine black chrome surface treatment	LF	–	o	o	o	o	o	o
Change of mounting hole and female thread sizes	M	o	o	–	–	–	–	–
No end seal	N	o	o	o	o	–	–	–
Rail cover plate (Non-interchangeable specifications)	PS	–	–	o	–	o	–	–
Capillary plate (Non-interchangeable specification)	Q	o	o	o	–	o	–	–
Seal for special environment	RE	–	o	o	–	–	–	–
Track rail with stopper pins (Non-interchangeable specification)	S	o	–	–	–	–	–	–
Butt-joining interchangeable track rail (Interchangeable specification)	T	–	o	o	–	o	–	–
Under seals	U	o	o	–	o	–	–	–
Double end seals	V	–	o	o	o	o	–	–
Matched sets to be used as an assembled group	W	o	o	o	o	o	o	o
Specified grease	Y	o	o	o	o	o	o	o
Scrapers	Z	–	o	o	o	o	o	–

Note (1): Including Linear Way LM and Linear Roller Way M

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Linear Slides - Lubrication

Purpose of lubrication

The purpose of lubrication for linear motion rolling guides is to keep raceways, rolling elements, etc. from direct metal-to-metal contact, and thereby reduce friction and wear and prevent heat generation seizure. When an adequate oil film is formed between the raceways and rolling elements of the rolling contact area, the contact stress due to load can be moderated. Lubrication is important for ensuring the reliability of linear motion rolling guides.

Selection of lubricant

To obtain the full performance of linear motion rolling guides, it is necessary to select an appropriate lubricant and lubrication method by considering the type, load and speed of each linear motion rolling guide. However, as compared with plain guides, lubrication of linear motion rolling guides is much simpler. Only a small amount of lubricant is needed and the replenishment interval is longer, so maintenance can be greatly reduced. Oil and grease are the two most commonly used lubricants for linear motion rolling guides.

Grease Lubrication

For grease lubrication of linear motion rolling guides, lithium-soap base grease (Consistency No. 2 of JIS) is commonly used. For rolling guides operating under heavy load conditions, grease containing extreme pressure activities is recommended. In clean and high-vacuum environments, where low dust generation performance and low vapourisation characteristics are required, greases containing a synthetic base oil or a soap other than the lithium-soap base are used. For applications in these environments, due consideration is necessary to select a grease type that is suitable for the special operating conditions and achieves satisfactory lubrication performance at the same time.

Grease Replenishment Interval

The quality of any grease will gradually deteriorate as operating time passes. Therefore, periodic relubrication is necessary. The relubrication interval varies depending on the operating conditions of the rolling guides. A six month interval is generally recommended and, if the machine operation consists of reciprocating motions with many cycles and long strokes, relubrication every three months is recommended.

Grease Replenishment Method

New grease must be supplied through a grease feed device such as a grease nipple until old grease is discharged. After grease is replenished, running in is performed and excess grease will be discharged from the inside of rolling guide. Discharged grease must then be removed before starting the operation. The amount of grease required for standard replenishment is about 1/3 to 1/2 of the free space inside the linear motion rolling guide. when grease is supplied from a grease nipple for the first time, there will be grease lost in the replenishment path. The amount lost should be taken into consideration. Generally, immediately after grease is replenished, frictional resistance tends to increase. If running in is performed for 10 to 20 reciprocating cycles after excess grease is discharged, frictional resistance becomes small and stable. For applications where low frictional resistance is required, the replenishment amount of grease may be reduced, but it must be kept to an appropriate level so as not to give a bad influence on the lubrication performance.

Linear Slides - Lubrication

Mixing of Different Grease Types

Mixing different types of greases may result in changing the properties of base oil, soap base or additives used and in some cases, severely deteriorate the lubrication performance or cause problems due to chemical changes of additives. Old grease should therefore be removed thoroughly before filling with new grease.

Grease Bands for Linear Motion Rolling Guides

Name		Base Oil	Thickener	Service range °C	Remarks
ALVANIA GREASE EP2	SHELL	Mineral oil	Li	– 20~+110	General applications, contains extreme pressure additives.
ALVANIA GREASE 2	SHELL	Mineral oil	Li	– 25~+120	General applications.
MULTEMP PS2	KYODO OIL	Synthetic oil, Mineral oil	Li	– 50~+130	General applications.
CG2	NIPPON THOMPSON	Synthetic oil	Urea	– 40~+200	For clean environment, long life.
DEMNUM GREASE L-200 (1)	DAIKIN	Synthetic oil	Ethylene tetra-fluoride	– 60~+300	For clean environment
FOMBLIN YVAC2(1)	AUSIMONT	Synthetic oil	Ethylene tetra-fluoride	– 20~+200	For vacuum.
6459 GREASE N	SHELL	Mineral oil	Poly-urea	–	Fretting-proof.

Note (1): Set a little shorter replenishment interval.
Remark: When using a grease type, check the selected type according to the manufacturer's catalogue of grease. Please consult us for other applications than those described above.

Oil lubrication

For oil lubrication, heavy loads require a higher oil viscosity and higher operating speeds require a lower viscosity. Generally, for linear motion rolling guides operating under heavy loads, lubrication oil with a viscosity of about 68 mm^2/s is used. For linear motion rolling guides under light loads at high speeds lubrication oil with a viscosity of about 13 mm^2/s is used.

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Linear Slides - Load Rating

The load rating of Linear Way and Linear Roller Way are defined for downward load. Some description of load ratings are given below. For details of load rating definitions and load calculations, see "General description".

Basic dynamic load rating C

The basic dynamic load rating is defined as the constant load both in direction and magnitude under which a group of identical Linear Ways or Linear Roller Ways are individually operated and 90% of the units in the group can travel 50×10^3 metres free from material damage due to rolling contact fatigue.

Basic static load rating C0

The basic static load rating is defined as the static load that gives a prescribed constant contact stress at the centre of the contact area between the rolling element and raceway receiving the maximum load.

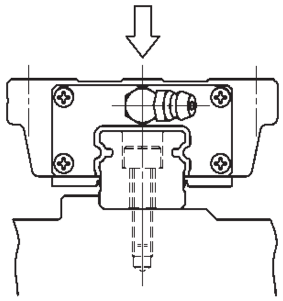

Fig. 1 Direction of load rating

Static moment rating To, Tx, Ty

The static moment rating is defined as the static moment load that gives a prescribed constant contact stress at the centre of the contact between the rolling element and raceway receiving the maximum load when a moment is loaded.

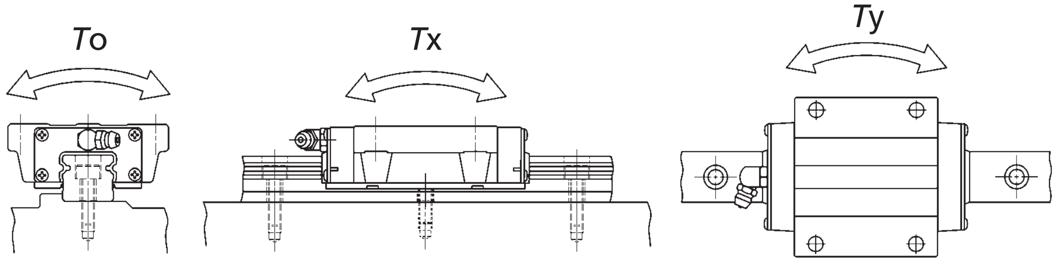

Fig. 2 Static moment rating direction

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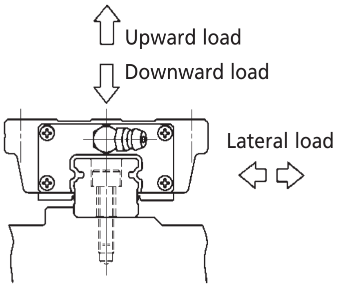
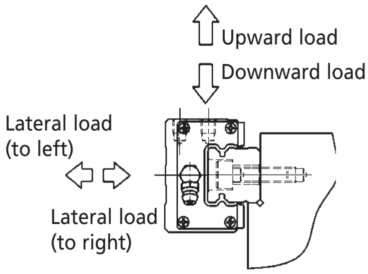
Linear Slides - Load Rating

Since the load ratings of Linear Way and Linear Roller Way given in the table of dimensions are for downward load, they must be corrected for the load direction for upward or lateral loads. The corrected basic dynamic load ratings and basic static load ratings are shown in Table 1.

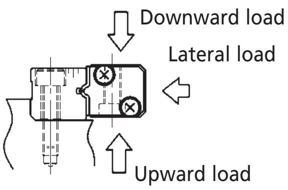
Table 1
Load ratings corrected for the load direction



Linear Way and Linear Roller Way



Linear Way H Side Mounting type



Linear Way LM
Linear Way M
Linear Roller Way M

Series and Size	Load rating and load direction	Basic dynamic load rating – Load direction: Downward	Upward	Lateral	Basic static load rating – Load direction: Downward	Upward	Lateral
Linear Way L	Ball retained type	C	C	0.88C	C_0	C_0	0.84C
	Ball non-retained type	C	C	1.13C	C_0	C_0	1.19C
Linear Way E	15 ~ 30	C	C	C	C_0	C_0	C_0
	35 ~ 45	C	0.88C	0.84C	C_0	0.84C	0.78C
Linear Way H	8 ~ 12	C	C	0.88C	C_0	C_0	0.84C
	15 ~ 30	C	C	C	C_0	C_0	C_0
	35 ~ 65	C	0.88C	0.84C	C_0	0.84C	0.78C
	85	C	0.78C	0.81C	C_0	0.70C	0.75C
Linear Way H	15 ~ 30	C	C	C	C_0	C_0	C_0
Slide mounting type	35 ~ 65(1)	C	C	1.19C 1.05C	C_0	C_0	1.28C 1.07C
Linear Way F		C	C	C	C_0	C_0	C_0
Linear Way FH		C	0.88C	0.84C	C_0	0.84C	0.78C
Linear Roller Way Super X		C	C	C	C_0	C_0	C_0
Linear Roller Way X		C	C	C	C_0	C_0	C_0
Linear Way LM		C	C	1.44C	C_0	C_0	1.68C
Linear Way M	1 ~ 5	C	0.88C	1.37C	C_0	0.84C	1.56C
	6	C	0.78C	1.32C	C_0	0.70C	1.49C
Linear Roller Way M		C	C	1.71C	C_0	C_0	2C

Note (1): The lateral load ratings side mounting type LWH are different for loads to the right and to the left. The upper value in the column indicates the load rating to the right and the lower value indicates the load rating to the left. (See the figure above).

TECHNICAL

Linear Slides - Accuracy

Five classes of accuracy, Ordinary, High, Precision, Super Precision, and Ultra Precision are specified for Linear Way and Linear Roller Way. Table 2 summarises applicable accuracy classes for each series, and Tables 3.1 to 3.3 show accuracy of each series. For details of applicable classes, see the description of each series. For the accuracy of series other than those shown in Table 2, please consult us for further information.

Table 2
Accuracy classes

Series	Classification (symbol)	Ordinary (No symbol)	High (H)	Precision (P)	Super Precision (SP)	Ultra Precision (UP)
Linear Way L	Interchangeable specification	–	o	o	–	–
	Non-interchangeable specification	–	o	o	–	–
Linear Way E	Interchangeable specification	o	o	o	–	–
	Non-interchangeable specification	o	o	o	–	–
Linear Way H	Interchangeable specification	–	o	o	–	–
	Non-interchangeable specification	–	o	o	o(1)	–
Linear Way F		–	o	o	o	–
Linear Roller Way	Interchangeable specification	–	o	o	o	–
Super X	Non-interchangeable specification	–	o	o	o	o
Linear Roller Way X		–	o	o	o	o
Linear Way Module		–	o	o	o	–

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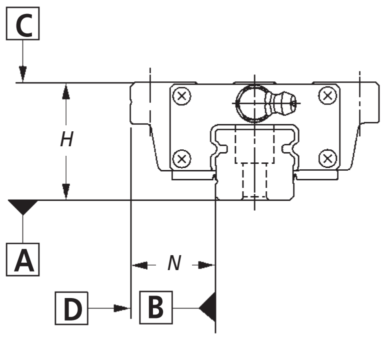
Linear Slides - Accuracy

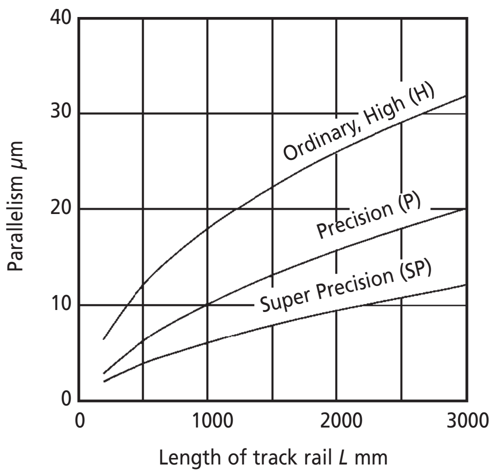
Table 3.1
Accuracy of Linear Way and Linear Roller Way

Item \ Classification (symbol)	Ordinary (No symbol)	High (H)	Precision (P)	Super Precision (SP)	Ultra Precision (UP)
Dim. ***H*** tolerance	±0.080	±0.040	±0.020	±0.010	±0.008
Dim. ***N*** tolerance	±0.100	±0.050	±0.025	±0.015	±0.010
Dim. variation of ***H*** ([1])	0.025	0.015	0.007	0.005	0.003
Dim. variation of ***N*** ([1])	0.030	0.020	0.010	0.007	0.003
Dim. variation of H for multiple assembled sets ([2])	0.045	0.035	0.025	–	–
Parallelism in operation of C to A	See Fig. 3.1				
Parallelism in operation of D to B	See Fig. 3.1				

Note ([1]): It means the size variation between slide units mounted on the same track rail.
([2]): It applies to the interchangeable specification products.

Remarks 1: The accuracy of Linear Way L, LWHT8 to LWHT12, and LWHD8 to LWHD12 is shown in Table 3.2.
2: The accuracy of Linear Way Module is shown in Table 3.3.





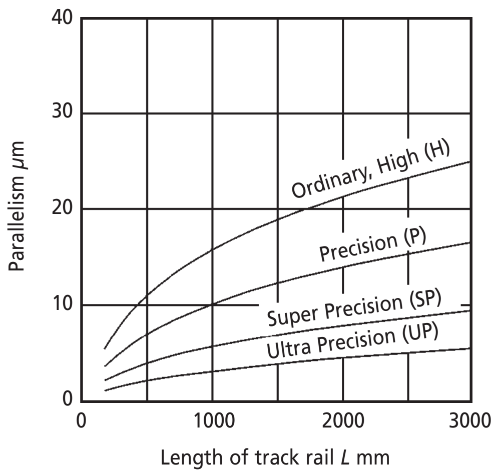


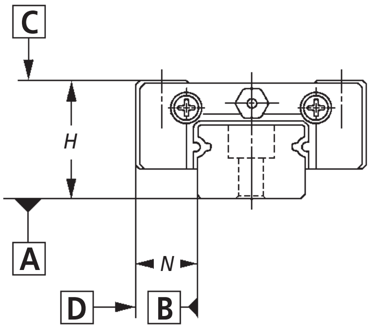
Fig. 3.1 Parallelism in operation of Linear Way and Linear Roller Way

TECHNICAL

Linear Slides - Accuracy

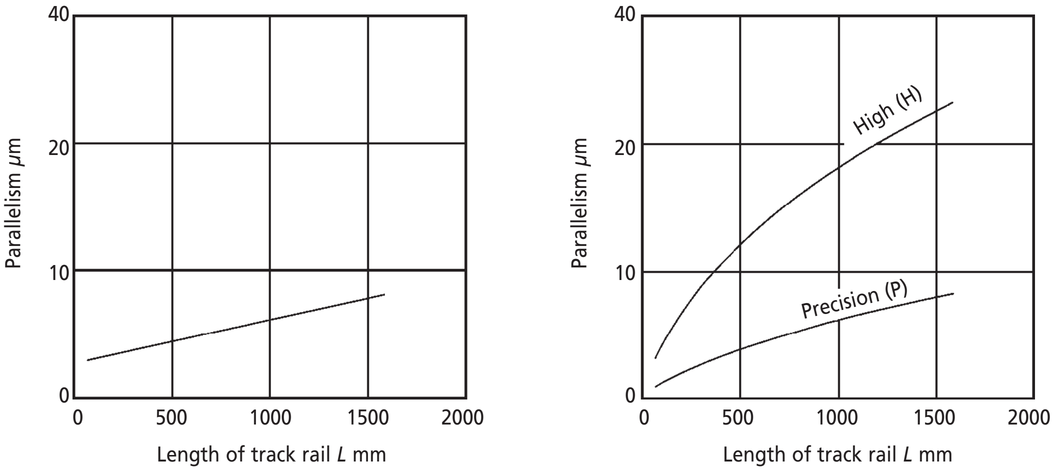
Table 3.2
Accuracy of Linear Way L

Item \ Classification (symbol)	High (H)	Precision (P)
Dim. ***H*** tolerance	±0.020	±0.010
Dim. ***N*** tolerance	±0.025	±0.015
Dim. variation of ***H*** (1)	0.015	0.007
Dim. variation of ***N*** (1)	0.020	0.010
Dim. variation of H for multiple assembled sets (2)	0.030	0.020
Parallelism in operation of C to A	See Fig. 3.3	
Parallelism in operation of D to B	See Fig. 3.3	



Note (1): It means the size variation between slide units mounted on the same track rail.
(2): It applies to the interchangeable specification products.

Remark The accuracy given in this table also applies to LWHT8 to LWHT12 and LWHD8 and LWHD12.



(a) Linear Way L Interchangeable specification

(b) Linear Way L Non-interchangeable specification

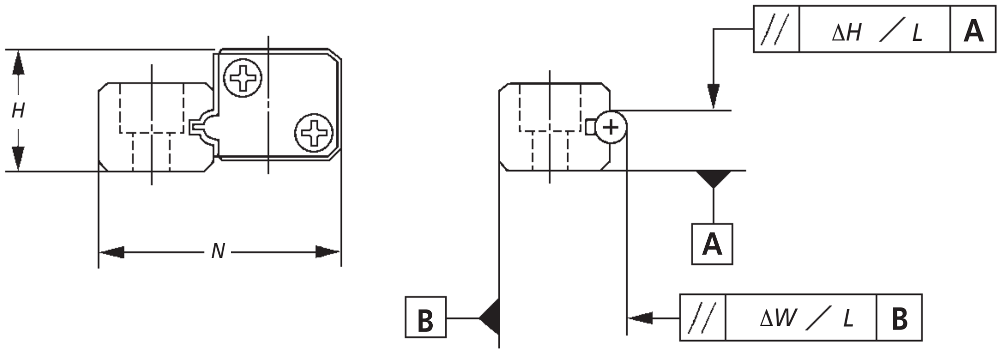
Fig. 3.2 Parallelism in operation of Linear Way L

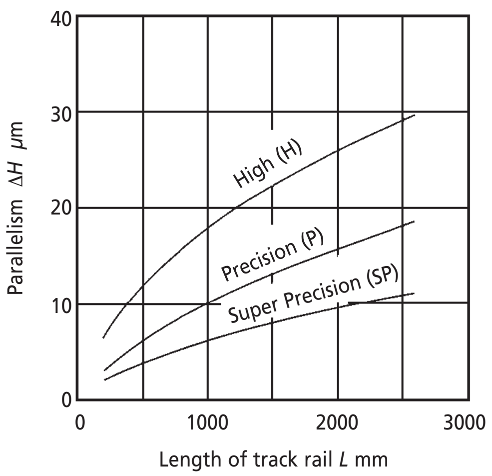
Table 3.3
Accuracy of Linear Way Module

Item \ Classification (symbol)	High (H)	Precision (P)	Super Precision (SP)
Dim. ***H*** tolerance	±0.040	±0.020	±0.010
Dim. ***N*** tolerance	±0.050	±0.025	±0.015
Dim. variation of ***H*** (1)	0.015	0.007	0.005
Dim. variation of ***N*** (1)	0.020	0.010	0.007
Dim. variation of H for multiple assembled sets (2)			
Parallelism in operation of C to A	See Fig. 3.1		
Parallelism in operation of D to B	See Fig. 3.1		

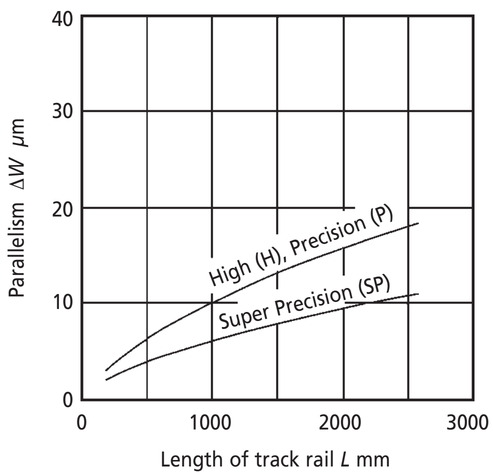
Note (1): It means the size variation between slide members mounted on the same track rail.

Linear Slides - Accuracy



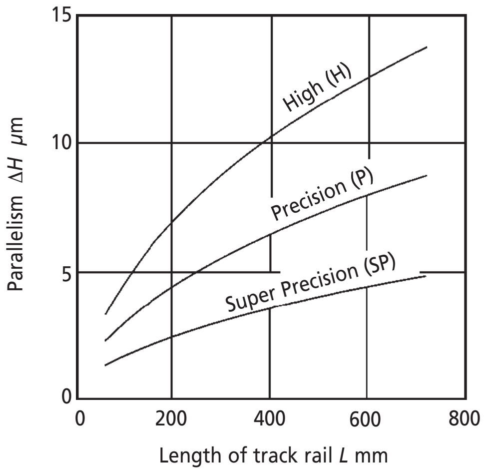


(a) Parallelism ΔH

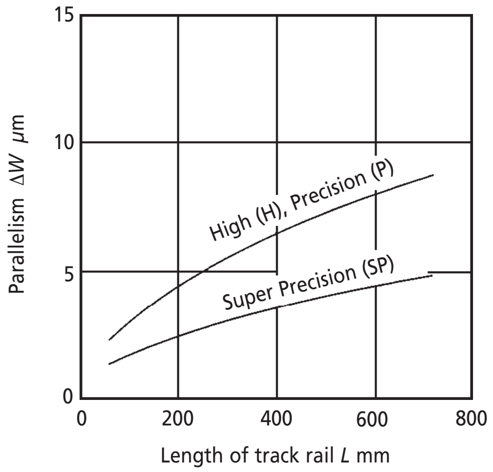


(b) Parallelism ΔW

Fig. 3.3 Parallelism of Linear Way M and Linear Roller Way M



(a) Parallelism ΔH



(b) Parallelism ΔW

Fig. 3.4 Parallelism of Linear Way LM

TECHNICAL

International Specifications

Material Equivalents

En.	B.S.	Workstoff	AFNOR (France)	DIN	USA
1A	220M7	1.0711	AF37C12XC18	9521	1212
	080M15	1.0401	AF42C20XC25	C15	1015
3A	070M20	1.0402	AF55C35XC38	C22	1020
5C	080A32	1.0501	AF50C30	C35	1035
	070M26	1.0406		C25	1025
6	080M30		AF60C40		
8	080M40	1.0511	AF55C34XC38	C40	1040
8A & 8B	080A35/37	1.0501	XC42H1	C822	1035
8C	080A40	1.1186	35MF6	CK40	1040
8M	212M36	1.0726	AF65C45	35S20	1140
8	080M46	1.0503		C45	1045
9	070M55	1.0535	32C4	C55	1055
18B	530A32	1.7033	42CD4	34Cr4	5132
19A	708M40	1.7225	35CD4	42CrMo4	4140;4142
19B	708A37	1.7220	35NCD6	34CrMo4	4135;4137
24	817M40	1.6582	35NCD14	34CrNiMo6	4340
26	0826M40	1.6746	35NCD16	32NiCrMo145	
30B	835M30	1.6747	100C6	30NiCrMo166	
31	535A99	1.3505		100Cr6	52100
202	214M15		AF34C10XC10		
32A	045M10	1.0301		C10	1010
32M	212M15	1.0723	12NC15	15S20	
36A	655M13	1.5752	16NCD17	14NiCr14	3415, 3310, 9314
39B	835M15	1.6723	30CD12		
40B	722M24	1.7361	XC48H1	32CrMo12	
43A	080M50	1.1206	Z12CF13	CK50	1050
56	416S21	1.4005	Z10CNF18.09	X12CrS13	416
58	303S21/3	1.4305	Z6CND17.12	X10CrNiS189	303
58J	316S16	1.4436		X5CrNiMo17133	316

Material Strengths

Material Spec. B.S. 970	Condition	Tensile Stress lbf/in^2	Surface Stress Factor Sc	Bending Stress Factor Sb	Tensile Strength N/mm^2	Elongation After Fracture	0.2% Proof Stress N/mm^2
Nylon 66		9,500		3,900	0.62-0.82	20% - 200%	—
Delrin (polyacetal)		10,117			69	75%	—
Tufnol	CARP	16,000	560	4,500	—	—	—
Cast Iron	GR17 (260)	35800	1,400	9,000	260	—	—
Aluminium	HR15N		500	13,000	295	6% - 8%	230
Alloy Aluminium	7016	CA 102	900	9,000	420-720	18% - 40%	140 - 660
Phosphor Bronze	PB2	26,800	700	7,000	360-500	6.25%	170 - 280
(EN32) 045M10		71,680	1,400	17,000	430	18%	—
(EN32) 045M10	CASE HARDENED	71,680	9,200	40,000	—	—	—
(EN8) 080M40		78,400	1,400	19,000	510-550	16% - 17%	—
(EN8) 080M40	INDUCTION/ THROUGH	78,400	2,800	17,000	—	—	—
(EN24) 817M40		112,000	3,000	32,000	850-1550	5% - 13%	635 - 1125
(EN24) 817M40	INDUCTION/ THROUGH	112,000	5,000	26,500	—	—	—
EN(36) 655M13	CASE HARDENED	123,200	11,000	50,000	—	—	—
(EN58AM)303S21		78,400	1,800	20000	480-510	35% - 40%	180 - 200

TECHNICAL

General Information

SI Units & Conversions for Characteristics of Mechanical Fasteners

Property	Unit	Symbol	Conversion From	Conversion To	Conversion Multiply by	Approx. Equivalent
Length	metre centimetre millimetre	m cm mm	inch inch foot	mm cm mm	25.40 2.54 304.80	25mm = 1in. 300mm = 1ft. 1m = 39.37in.
Mass	kilogram gram tonne (megagram)	kg g t	ounce pound ton (2240lb)	g kg kg	28.35 0.4536 984.20	28g = 1oz. 1kg = 2.2lb = 35oz. 1t = 2205lbs.
Density	kilogram per cub. metre	kg/m^3	pounds per cu. ft.	kg/m^3	16.02	$16kg/m^3 = 1lb/ft^3$
Temp.	deg. Celsius	°C	deg. Fahr.	°C	(°F-32) x5/9	0°C = 32°F 100°C = 212°F
Area	square metre square millimetre	m^2 mm^2	sq. inch sq. ft.	mm^2 m^2	645.20 0.0929	$645mm^2 = 1in^2$ $1m^2 = 11\ ft^2$
Volume	cubic metre cubic centimetre cubic millimetre	m^3 cm^3 mm^3	cu. in. cu. ft. cu. yd.	mm^3 m^3 m^3	16387 0.02832 0.7645	$16400mm^3 = 1in^3$ $1m^3 = 35ft^3$ $1m^3 = 1.3yd^3$
Force	newton kilonewton meganewton	N kN Mn	ounce (Force) pound (Force) Kip	N kN MN	0.278 0.00445 0.00445	1N = 3.6 ozf 4.4N = 1 lbf 1kN = 225 lbf
Stress	megapascal newtons/sq.mm	Mpa N/m^2	$pounds/in^2$ (psi) Kip/in^2 (ksi)	MPa MPa	0.0069 6.895	1MPa = 145 psi 7MPa = 1 ksi
Torque	newton-metres	N-m	inch-ounce	N-m	0.00706	1N-mm = 0.1416119 oz.in.
			inch-pound	N-m	0.113	1N-m = 8.8507 lb.in.
			foot-pound	N-m	1.356	1N-m = 0.7375621 lb.ft. 1.4 N-m = 1 ft.lb.

Rockwell • Brinell • Tensile Conversion

Rockwell "C" Scale	Brinell Hardness Number	Approx. Tensile Strength MPa	Approx. Tensile Strength KSI	Rockwell "C" Scale	Rockwell "B" Scale	Brinell Hardness Number	Approx. Tensile Strength MPa	Approx. Tensile Strength KSI
60	654	2320	336	34	-	318	1030	150
59	634	2260	328	33	-	309	1010	147
58	615	2200	319	32	-	301	980	142
57	595	2140	310	31	-	294	960	139
56	577	2080	301	30	-	285	940	136
55	560	2010	292	29	-	279	910	132
54	543	1950	283	28	-	272	890	129
53	524	1890	274	27	-	265	870	126
52	512	1830	265	26	-	259	850	123
51	500	1770	257	25	-	253	830	120
50	488	1720	249	24	-	247	810	118
49	476	1660	241	23	-	241	790	115
48	464	1610	233	22	100	235	770	112
47	453	1550	225	21	99	230	760	110
46	442	1510	219	20	98	225	740	107
45	430	1460	212	(19)	-	220	720	104
44	419	1420	206	(18)	97	215	710	103
43	408	1380	200	(17)	-	210	700	102
42	398	1340	194	(16)	96	206	690	100
41	387	1300	188	(15)	-	201	680	99
40	377	1250	181	(14)	95	197	670	97
39	367	1210	176	(13)	94	193	660	96
38	357	1170	170	(12)	93	190	640	93
37	347	1140	165	(11)	-	186	630	91
36	337	1100	160	(10)	92	183	620	90
35	327	1070	155	(8)	90	179	600	87

TECHNICAL

SI Units

Symbols & Names

System \ Units	Length	Mass	Time	Temp.	Acceleration	Force	Stress	Pressure	Energy	Power
SI	m	kg	s	K, °C	m/s^2	N	Pa	Pa	J	W
CGS	cm	g	s	°C	Gal	dyn	dyn/cm^2	dyn/cm^2	erg	erg
Engineering Unit	m	$kgf \bullet S^2/m$	s	°C	m/s^2	kgf	kgf/m^2	kgf/m^2	kgf•m	kgf•ms

Parameter	SI Units: Names of Units	SI Units: Symbols	Units other than SI: Name of Units	Units other than SI: Symbols	Conversion Factors from SI Units
Angle	Radian	rad	Degree	°	$180/\pi$
			Minute	′	$10\ 800/\pi$
			Second	″	$648\ 000/\pi$
Length	Metre	m	Micron	μ	10^6
			Angstrom	Å	10^{10}
Area	Square metre	m^2	Acre	a	10^{-2}
			Hectare	ha	10^{-4}
Volume	Cubic metre	m^3	Litre	l, L	10^3
			Decilitre	dl, dL	10^4
Frequency	Hertz	Hz	Cycle	s^{-1}	1
Speed of Rotation	Revolution per sec.	s^{-1}	Revolution per minute	rpm	60
Speed	Metre per second	m/s	Kilometer per hour	km/h	3 600/1 000
			Knot	kt	3 600/1 852
Acceleration	Metre per sec./sec.	m/s^2	g	g	1/ 9.806 65
Mass	Kilogram	kg	Ton	t	10^{-3}
Force	Newton	N	Kilogram-force	kgf	1/ 9.806 65
			Ton-force	tf	$1/9.806\ 65 \times 10^3$
			Dyne	dyn	105
Torque or Moment	Newton-metre	N•m	Kilogram-force metre	kgf•m	1/ 9.806 65
Stress	Pascal	Pa	Kilogram-force per sq. cm	kgf/cm^2	$1/9.806\ 65 \times 10^4$
		(N/m^2)	Kilogram-force per sq. mm	kgf/mm^2	$1/9.806\ 65 \times 10^6$

Multiples	Prefix	Symbols	Multiples	Prefix	Symbols
10^{18}	Exa	E	10^{-1}	Deci	d
10^{15}	Peta	P	10^{-2}	Centi	c
10^{12}	Tera	T	10^{-3}	Milli	m
10^9	Giga	G	10^{-6}	Micro	μ
10^6	Mega	M	10^{-9}	Nano	n
10^3	Kilo	k	10^{-12}	Pico	p
10^2	Hecto	h	10^{-15}	Femto	f
10^1	Deca	da	10^{-18}	Ato	a

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TECHNICAL

SI Units

Symbols & Names

Parameter	SI Units: Names of Units	SI Units: Symbols	Units other than SI: Name of Units	Units other than SI: Symbols	Conversion Factors from SI Units
Pressure	Pascal	Pa	Kilogram-force per sq. metre	kgf/m2	1/9.806 65
	(Newton per sq. metre)	(N/m2)	Water Column	mH2O	$1/(9.806\ 65 \times 10^{3})$
			Mercury Column	mmHg	$760/(1.013\ 25 \times 10^{5})$
			Torr	Torr	$760/(1.013\ 25 \times 10^{5})$
			Bar	bar	10^{-5}
			Atmosphere	atm	$1/(1.013\ 25 \times 10^{5})$
Energy	Joule	J	Erg	erg	10^{7}
	(Newton-metre)	(N•m)	Calorie(International)	cal^{IT}	1/4.186 8
			Kilogram-force metre	kgf•m	1/9.806 65
			Kilowatt hour	kW•h	$1/(3.6 \times 10^{6})$
			French hourse power hour	PS•h	$\approx 3.776\ 72 \times 10^{-7}$
Work	Watt	W	Kilogram-force metre per second	kgf•m/s	1/9.806 65
	(Joule per second)	(J/s)	Kilocalorie per hour	kcal/h	1/1.163
			French horse power	PS	≈1/735.498 8
Viscosity Viscosity Index	Pascal second	Pa•s	Poise	P	10
Kinematic Viscosity Kinematic Viscosity Index	Square metre per second	m^2/s	Stokes Centistokes	St cSt	10^{4} 10^{6}
Temperature	Kelvin, Degree Celsius	K °C	Degree	°C	(see note (1))
Electric Current Magnetomotive Force	Ampere	A	Ampere	A	1
Voltage Electromotive Force	Volt	V	(Watts per ampere)	(W/A)	1
Magnetic Field Strength	Ampere per metre	A/m	Oersted	Oe	$4\pi/10^{3}$
Magnetic Flux Density	Tesla	T	Gauss Gamma	Gs γ	10^{4} 10^{9}
Electrical Resistance	Ohm	Ω	(Volts per ampere)	(V/A)	1

Note: (1) The conversion from TK into $\theta = T - 273.13$ but for a temperature difference, it is $\Delta T = \Delta\theta$. However, ΔT and $\Delta\theta$ represent temperature differences measured using the Kelvin and Celsius scales respectively.

Remarks: The names and symbols in ( ) are equivalent to those directly above them or on their left. Example of conversion 1N1/9.806 65kgf.