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Design Data

Data Book of Engineers



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Material	Specific Weight N/cc	Melting Point °C	Modulus of Elasticity E, N/mm ²	Modulus of Rigidity G, N/mm ²	Thermal Conductivity k, cal/s cm °C	Coefficient of Linear Expansion α μm/m °C	Poisson's Ratio ν
Aluminium	0.027	660	0.675×10^4	0.260×10^4	0.530	23.8	0.34
Beryllium	0.0182	1280	2.938×10^4		0.380	12.3	
Brass	0.0845	900—950	0.970×10^4	0.350×10^4	0.310	16.7	0.30—0.40
Bronze	0.0873	910—1040	1.110×10^4		0.160	17.3	
Cast Iron	0.072	1150—1300	1.000×10^4	0.350×10^4	0.130	9.0	0.23
Copper	0.0896	1083	1.230×10^4	0.390×10^4	0.940	16.2	0.26
Lead	0.1134	327	0.160×10^4	0.076×10^4	0.083	28.3	0.45
Monel Metal	0.0858	1315—1350	1.590×10^4	0.670×10^4	0.060	14.0	0.32
Steel C 15	0.0785	1510	2.080×10^4	0.790×10^4	0.120	11.1	
Steel C 35	0.0784	1490	2.060×10^4	to	0.120	11.1	0.30
Steel C 60	0.0783	1470	2.040×10^4	0.890×10^4	0.110	11.1	
Titanium	0.0454	1800	1.050×10^4		0.041	11.8	
Tungsten	0.1930	3410	4.153×10^4	1.770×10^4	0.480	4.5	0.17
Zirconium	0.0650	≈ 1850	0.697×10^4		0.040	10.0	

INTERPRETATION OF INDIAN STANDARD DESIGNATION OF STEEL AND ALUMINIUM

1. STRUCTURAL STEEL:

St 32 K

St, structural steel
32, minimum tensile strength of 320 N/mm²
K, special limit for phosphorus or sulphur content

2. PLAIN CARBON STEEL:

C 45 *

C, Plain Carbon Steel
45, Average carbon content in hundredths of a per cent
*, any of the following:
W, Fusion weldable
W_p, pressure "
W_r, resistance "
W_s, spot "

3. ALLOY STEEL:

20 Cr 18 Ni 25 Mn 25 *

20, 0.2% Carbon
Cr 18, 18% Chromium
Ni 25, 2.5% Nickel
Mn 25, 0.25% Manganese

*, any of the following symbols:
J_b, bright drawn or rolled
J_p, precision ground
A, non aging quality
D, killed deoxidised
G, grain size controlled
H, hardenability "
M, structural homogeneity

4. TOOL STEEL

T 90 *

T, Tool steel
90, average carbon content in hundredths of a per cent
*, any of the symbols listed below
a, annealed
c, case carburised
d, cold drawn
h, hot rolled
n, normalised
o, spheroidised
p, patented
q, hardened & tempered
s, stress relieved
t, tempered

5. WROUGHT ALUMINIUM (5 DIGIT SYSTEM)

64423

6, 1st digit, major alloying element
1 for unalloyed
2 for copper
3 for Manganese
4 for Silicon
5 for Magnesium
6 for Magnesium Silicide
7 for Zinc
8 for other elements (Ni, Ti, Cr)
4, 2nd digit indicates rounded off mean value in per cent of the major alloying element except elements 4 & 6.
423, 3rd, 4th & 5th digits identify the minor alloying elements in the descending order of their percentage

6. CAST ALUMINIUM (4 DIGIT SYSTEM)

4680

4, 1st digit, major alloying element
6, second digit indicates rounded off half the mean value in percent of the major alloying element
80, 3rd and 4th digits identify the minor alloying elements in the descending order of percentage

MEEHANITE CASTINGS : Properties

Type	Tensile strength	Yield strength N/mm ²	Young's modulus	BHN
HEAT RESISTING:				
HR (carbide/pearlitic)	280	—	147000	>300
HS (Nodular graphite/ferritic)	420—700	310—520	160000	200
HSV (nod. graph/pearlitic)	700—840	—	35 to 56 × 10 ⁴	200
HE (flake graph/pearlitic)	170	—	70000	170
WEAR RESISTING:				
W1 (Carbide/pearlitic)	350—420	—	—	500—600
W2 (" /martensitic)	350—420	—	—	500—600
W4 (" /austenitic)	420—560	—	—	400—700
WSH (nod. graph/ ")	700	520	168000	350—500
CORROSION RESISTING:				
CC (Flake graphite/pearlitic)	280	—	—	200
CR (Flake graphite/Ni austenitic)	170	—	—	130—180
CRS (nod. graphite/ Ni austenitic)	380	210	—	140—200
GENERAL:				
GM 60 (flake graphite/sorbo pearlitic)	380	170	150000	>230
GA 50 (" / pearlitic)	350	140	140000	>220
GC 40 (" / ")	280	90	115000	160
GE 30 (" / ")	210	70	90000	180
GF 20 (" / " ferritic)	140	60	63000	160
AQ (" / " bainitic)	350	—	—	280
SF 60 (Nodular graphite/ferritic)	420	310	160000	160
SP 80 (" / pearlitic/ferritic)	560—700	500	175000	200
SH 100 (" / pearlitic)	630	450	165000	240
AQS (" / pearlitic bainitic)	560—1260	500—950	—	225—500

CAST IRON CASTINGS : PROPERTIES AND USES

ISI Grade	Overseas nearest equivalent	Sectional thickness in castings mm	diameter of test bar mm	Tensile strength (min) N/mm ²	Brinell Hardness	USES
GCI 15	CSN 42 24 18	4 to 8	13	190	149 to 197	where bending stress is limited to 1 kgf/mm ² ; pressure limited to 5 kgf/cm ² ; columns, pedestals, beds, covers, housings, arms, Sliding tables & c.,
		8 to 15	20	170		
		15 to 30	30	150		
		30 to 50	45	130		
GCI 20	SAE 111	8 to 15	20	220	179 to 223	where bending stress is limited to 3 kgf/mm ² ; pressure < 10 kgf/cm ² ; Beds, columns, gears, guideways, housings, pulleys & c.,
	DIN 1691/GG22	15 to 30	30	200		
	BS 1452/Gr 12	30 to 50	45	170		
	CSN 42 24 21					
GCI 25	SAE 120	15 to 30	30	250	197 to 241	Bending stress < 5 kgf/mm ² pressure < 20 kgf/cm ² columns, chucks, gears, ways, hyd. cylinders, pump body, HP valves, work table, flywheels, & c.,
	DIN 1681/GG26	30 to 50	45	220		
	BS 1452/Gr 14					
	CSN 42 24 24					
Malleable CI		<8	9	280		
MCI B	CSN 42 25 08	8 to 13	12	320	Max. 149	Faceplate, chuck body, Vices, clamps levers, handwheels, turret body, tool post & c.,
		>13	15	350		
MCI A		<8	9	360		
		8 to 13	12	400		
		>13	15	420		

- NOTE: 1. damping capacity decreases with increase in tensile strength.
 2. MCI B can be replaced by CI Grade 3 B (IS 1865), nodular CI.

SPHEROIDAL GRAPHITE OR NODULAR GRAPHITE IRON : Properties

Grade	Tensile strength N/mm ²	Proof Stress, 0.2% N/mm ²	Elongation %	Impact Strength (charpy) Joule or Nm	BHN	Predominant Structure
SG 800/2	800	430	2	—	245—350	pearlite or tempered
SG 700/2	700	440	2	—	225—300	pearlite
SG 600/3	600	370	3	—	190—270	pearlite & ferrite
SG 500/7	500	320	7	—	170—240	ferrite & pearlite
SG 400/12	400	250	12	—	max 200	ferrite
SG 370/17	370	230	17	13	max. 180	ferrite

IS 1865 — 1974

GREY IRON CASTINGS FOR GENERAL USE

ISI Grade	Tensile strength N/mm ²	BHN
30	270 — 310	207 — 241
35	320 — 350	207 — 241
40	370 — 400	241 — 320

MECHANICAL PROPERTIES OF HIGH TENSILE CAST STEEL

CHARACTERISTIC	GRADE & DESIGNATION				
	1	2	3	4	5
	CS 65	CS 71	CS 85	CS 105	CS 125
Tensile Strength, kgf/mm ² , min.	65	71	85	105	125
Yield Strength (0.5% Proof stress), kgf/mm ² , min.	40	57	71	87	102
Reduction in area, %, min.	37	35	30	22	12
Elongation, %, min.	17	15	12	8	5
Brinell Hardness, HB, min.	190	207	248	311	363
*Izod Impact Strength, kgf m, min.	3.5	3.5	2.8	2.0	—

*Where due to mass design, it is not practicable to liquid quench the castings, it may not be possible to achieve the specified impact properties. In such cases the values to be obtained should be agreed to between the purchaser and the manufacturer at the time of enquiry and order.

CARBON STEEL CASTINGS : GENERAL USE

	GRADE & DESIGNATION				
	20—40	23—45	26—52	27—54	30—57
Yield strength, N/mm ²	200	230	260	270	300
Tensile strength, N/mm ²	400	450	520	540	570
Elongation, %	25	22	18	16	15
Reduction in area, %	40	31	25	23	21
Impact value, Nm	30	25	22	20	18

1 kgf = 10N

CARBON STEEL CASTINGS SUBJECTED TO PRESSURE & HIGH TEMPERATURE : (IS—2856—1974)

Grade	CHEMICAL COMPOSITION%					ultimate tensile strength N/mm ²	Yield strength N/mm ²	Elongation %	Impact value (charpy) Nm
	C	Si	Mn	S	P				
CSW—C 25(A)	0.25	0.6	0.7	0.05	0.05	420	210	20	25
CSW—C 25(B)	0.25	0.6	1.2	0.05	0.05	520	280	19	20
(working temperature not to exceed 425 °C)									

ALLOY STEEL CASTINGS SUBJECTED TO PRESSURE & HIGH TEMPERATURE (IS 3038—1965)

Properties	Gr 1*	Gr 2	Gr 3	Gr 4	Gr 5	Gr 6	Gr 7
tensile strength, N/mm ²	550	470	520	490	520	630	630
yield strength, (0.5% Proof stress) N/mm ²	350	250	310	280	310	430	430
elongation, %	17	17	15	17	17	15	15
Izod impact value, Nm	—	—	—	34.5	—	27.6	—
stress relieving temp. °C	600—650	600—650	690—710	600—650	660—690	600—650	600—650
Uses	upto 400°C	turbine castings upto 450°C	turbine castings upto 510°C	valves, pressure vessels upto 510°C	turbine casting upto 580°C	chemical, petroleum industries upto 600°C	Chemical, petroleum industries upto 650°C

*For chemical composition, refer IS. 3038.

CORROSION RESISTANT STEEL CASTINGS : IS 3444—1966)

Grade	Chemical composition, %						tensile strength N/mm ²	Yield Strength N/mm ²	Elongation %	BHN
	C	Mn	Si	Ni	Cr	Mo				
Gr 1	0.15	1	1.5	1	11.5 to 14	0.4	550	380	20	241
Gr 2	0.12 to 0.2	1	1	1	-do-	0.5	630	460	18	241
Gr 3	0.2 to 0.3	1	1	1	-do-	0.5	710	480	15	255
Gr 4	0.3	1	1	2	18 to 21	—	460	210	—	241
Gr 5	0.5	1	1	4	26 to 30	—	390	—	—	255

Heat Treatment: For Gr 1 to 3 : Heat to 1000°C, Air cool and temper at 600°C or anneal at 800°C
 For Gr 4 & 5 : Heat to 800°C, air cool or furnace cool.

HEAT RESISTANT ALLOY STEEL CASTINGS : IS 4522 — 1968

Grade	Chemical composition, %							tensile strength N/mm ²	Yield strength N/mm ²	Elongation %	BHN	Young's mod $\times 10^{-5}$ N/mm ²
	C	Si	Mn	Cr	Ni	S	P					
4	0.2—0.5	2	1	26—30	4—7	0.05	0.05	600	400	14	190	1.9
5	0.2—0.5	2	2	18—20	8—10	0.05	0.05	600	320	32	165	1.97
6	0.2—0.5	2	2	26—30	8—10	0.05	0.05	670	320	18	200	1.76
7 (Type 1)	0.2—0.5	2	2	23—27	11—14	0.05	0.05	560	350	22	185	1.9

CARBON STEELS WITH SPECIFIED CHEMICAL COMPOSITION AND RELATED MECHANICAL PROPERTIES

Designation	% C	% Mn	Tensile strength kgf/mm ²	% Minimum Elongation (Gauge length $5.65 \sqrt{a^*}$, Cylindrical test piece)	Yield stress kgf/mm ²	Izod impact value min. (If specified) kgf m	Brinell hardness (If specified) HB
C 07	0.12 max	0.50 max	32–40	27	20	—	—
C 10†	0.15 max	0.30–0.60	34–42	26	21	5.5	—
C 14†	0.10–0.18	0.40–0.70	37–45	26	22	5.5	137
C 15	0.20 max	0.30–0.60	37–49	25	24	—	137
C 15 Mn 75	0.10–0.20	0.60–0.90	42–50	25	25	—	163
C 20	0.15–0.25	0.60–0.90	44–52	24	26	—	156
C 25	0.20–0.30	0.30–0.60	44–54	23	28	—	170
C 25 Mn 75	0.20–0.30	0.60–0.90	47–57	22	28	—	207
C 30⊕	0.25–0.35	0.60–0.90	50–60	21	30	5.5	179
C 35	0.30–0.40	0.30–0.60	52–62	20	31	—	187
C 35 Mn 75⊕	0.30–0.40	0.60–0.90	55–65	20	32	5.5	223
C 40⊕	0.35–0.45	0.60–0.90	58–68	18	33	4.1	217
C 45⊕	0.40–0.50	0.60–0.90	63–71	15	36	4.1	229
C 50⊕	0.45–0.55	0.60–0.90	66–78	13	38	—	241
C 50 Mn 1	0.45–0.55	1.10–1.40	72 min	11	40	—	255
C 55 Mn 75⊕	0.50–0.60	0.60–0.90	72 min	13	40	—	265
C 60	0.55–0.65	0.50–0.80	75 min	11	42	—	255
C 65	0.60–0.70	0.50–0.80	75 min	10	43	—	255

* a, area of cross section

† STEELS FOR CASE CARBURISING

⊕ STEELS FOR HARDENING AND TEMPERING

Mn 75 : average content of Mn is 0.75%

1 kgf = 10 N

Properties given are for bars and forgings in the oil hardened and tempered condition

TYPICAL USES OF CARBON STEELS

Steel Designation	Typical uses
C07, C10	Used for cold forming and deep drawing. Rimming quality used for Automobile bodies, cold heading wires and rivets. Killed quality used for forging and heat treating applications.
C10 and C14	Case hardening steels used for making camshafts, cams, light duty gears, worms, gudgeon pins, selector forks, spindles, pawls, ratchets, chain wheels, tappets, etc.
C15	Used for lightly stressed parts. The material, although easily machinable is not designed specifically for rapid cutting, but is suitable where cold work, such as bending and riveting may be necessary.
C15Mn75, C20, C25 and C25Mn75 C30	General purpose steels for low stressed components. Used for cold formed levers - Hardened and tempered tie rods, cables, sprockets, hubs and bushes - steel tubes.
C35	Steel for low stressed parts, automobile tubes and fasteners.
C35Mn75	Steel for making low stressed parts in machine structures, cycle and motorcycle frame tubes, fish plates for rails and fasteners.
C40	Steel for crankshafts, shafts, spindles, automobile axle beams, push rods, connecting rods, studs, bolts, lightly stressed gears, etc.
C45	Steel for spindles of machine tools, bigger gears, bolts and shafts.
C50	Steel for making keys, shafts, cylinders, machine components requiring moderate wear resistance. In surface hardened condition it is also suitable for large-pitch worms and gears.
C50Mn1	Rail steel. Also used for making spike bolts, gear shafts, rocking levers and cylinder liners.
C55 and C55Mn75	Steels used for making gears, cylinders, cams, keys, crank shafts, sprockets and machine parts requiring moderate wear resistance for which toughness is not of primary importance.
C60	Steel for making spindles for machine tools, hardened screws and nuts, couplings, crank shafts, axles and pinions.
C65	High tensile structural steel for making locomotive carriage and wagon tyres. Typical uses of this steel in the spring industry include engine valve springs, small washers and thin stamped parts.

CARBON STEELS : PROPERTIES

Designation	condition	tensile strength N/mm ²	yield strength N/mm ²	Izod Impact value, Nm
C 07	sheets, cold rolled and annealed	300—380		
C 10	—do—	320—400		
	Case hardened—refined & quenched	500		55
	bars, cold drawn upto 20 diam	500		
	20—40 "	460		
	40—63 "	420		
	over 63 "	340		
C 14	Case hardened—refined & quenched	500		55
	tubes, cold drawn and annealed;	340	190	
	cold drawn and tempered;	440	380	
C 15	tubes cold drawn and annealed	340	190	
	Cold drawn & tempered	440	380	
	sheets, cold rolled & annealed	320—440		
C 15 Mn 75	bars, cold drawn			
	upto 20 dia	520		
	20—40 "	480		
	40—63 "	440		
	Over 63 "	420		
	tubes, cold drawn & annealed	340	190	
	" & tempered	440	380	
C 20	bars, cold drawn			
	upto 20 diam	560		
	20—40 "	540		
	40—63 "	480		
	Over 63 "	440		
	sheets, cold rolled & annealed	390—510		
	tubes, cold drawn & annealed	370	220	
	cold drawn & tempered	520	420	
C 25	tubes, cold drawn & annealed	390		250
	cold drawn & tempered	560		460
C 25 Mn 75	tubes, cold drawn & annealed	390		250
	" & tempered	560		460
C 30	bars & forgings:			
	hardened & tempered	600—750	400	55
	bars: upto 20 diam	620		
	20—40 "	580		
	40—63 "	540		
	Over 63 "	500		
C 35	tubes, cold drawn & annealed	440	280	
	" & tempered	620	500	

CARBON STEEL : PROPERTIES (Contd.)

Designation	Condition	tensile strength N/mm ²	yield strength N/mm ²	Izod impact Nm
C 35 Mn 75	bars & forgings			
	hardened & tempered	600—750	400	55
	tubes, cold drawn & annealed	440	280	
	„ & tempered	620	500	
C 40	bars, cold drawn			
	upto 20 diam	680		
	20—40 „	640		
	40—63 „	600		
	Over 63 „	580		
	bars & forgings, hardened and tempered	600—750	380	41
C 45	bars & forgings, hardened & tempered	600—750	380	41
	tubes, cold drawn & annealed	520	340	
	„ & tempered	700	600	
C 50	bars, cold drawn			
	upto 20 dia.	740		
	20—40 „	700		
	40—63 „	680		
	Over 63 „	660		
	bars & forgings, hardened & tempered	700—850	460	—
	tubes, cold drawn & annealed	520	340	
	„ & tempered	700	600	
C 55 Mn 75	bars, cold drawn	720—780		
	bars & forgings, hardened & tempered	700—850	460	—
C 55 Cr 75	Wear resisting, hardened & tempered	900—1050	660	35 (BHN 255 — 311)

TENSILE STRENGTH OF STRUCTURAL STEELS : N/mm²

grade	St 30	St 32	St 34	St 37	St 39	St 42	St 44	St 47	St 50	St 52	St 55	St 58	St 63	St 88
tensile strength	300 to 380	320 to 440	340 to 460	370 to 490	390 to 510	420 to 540	440 to 540	470 to 570	500 to 600	520 to 620	550 to 650	580 to 680	630 to 710	880 to 1000

COMPOSITION AND RELATED MECHANICAL PROPERTIES OF ALLOY STEELS

Designation	% C	% Si	% Mn	% Ni	% Cr	% Mo	Tensile strength kgf/mm ²	Yield strength kgf/mm ²	% Min Elongation l=5.65 √A [⊙]	Min. Izod impact value kgf m	Brinell hardness number HB
20 Mn 2*	0.16–0.24	0.1–0.35	1.3–1.7	—	—	—	60–75	44	18	4.8	170–217
							70–85	50	16	4.8	201–248
27 Mn 2*	0.22–0.32	0.1–0.35	1.3–1.7	—	—	—	60–75	44	18	4.8	170–217
							70–85	50	16	4.8	201–248
37 Mn 2*	0.32–0.42	0.1–0.35	1.3–1.7	—	—	—	60–75	44	18	4.8	170–217
							70–85	54	18	4.8	201–248
							80–95	60	16	4.8	229–277
							90–105	70	15	4.1	255–311
35 Mn 2 Mo 28*	0.3–0.4	0.1–0.35	1.3–1.8	—	—	0.2–0.35	70–85	54	18	5.5	201–248
							80–95	60	16	5.5	229–277
							90–105	70	15	5.5	255–311
							100–115	80	13	4.8	285–341
35 Mn 2 Mo 45*	0.3–0.4	0.1–0.35	1.3–1.8	—	—	0.35–0.55	80–95	60	16	5.5	229–277
							90–105	70	15	5.5	255–311
							100–115	80	13	4.8	285–341
40 Cr 1*	0.35–0.45	0.1–0.35	0.6–0.9	—	0.9–1.2	—	70–85	54	18	5.5	201–248
							80–95	60	16	5.5	229–277
							90–105	70	15	5.5	255–311

* Steels for Hardening and Tempering

† Steels for Nitriding

‡ Creep Resisting Steels

⊙ a, Area of Cross Section

1 kgf = 10 N

COMPOSITION AND RELATED MECHANICAL PROPERTIES OF ALLOY STEELS (Contd.)

Designation	% C	% Si	% Mn	% Ni	% Cr	% Mo	Tensile strength kgf/mm ²	Yield strength kgf/mm ²	% Min Elongation l=5.65 √A [○]	Min. izod impact value kgf m	Brinell hardness number HB
40 Cr 1 Mo 28*	0.35-0.45	0.1-0.35	0.5-0.8	—	0.9-1.2	0.2-0.35	70-85 80-95 90-105 100-115	54 60 70 80	18 16 15 13	5.5 5.5 5.5 4.8	201-248 229-277 255-311 285-341
15 Cr 3 Mo 55*†	0.1-0.2	0.1-0.35	0.4-0.7	0.3 max	2.9-3.4	0.45-0.65	70-85	54	18	5.5	201-248
25 Cr 3 Mo 55*†	0.2-0.3	0.1-0.35	0.4-0.7	0.3 max	2.9-3.4	0.45-0.65	80-95 90-105 100-115 110-125 155 min	60 70 80 88 130	16 15 13 12 8	5.5 5.5 4.8 4.1 1.4	229-277 255-311 285-341 311-363 444 min
40 Cr 3 Mo 1 V 20*†	0.35-0.45	0.1-0.35	0.4-0.7	0.3 max	3.0-3.5	0.9-1.1	135 min 155 min	112 130	8 8	2.1 1.4	363 min 444 min
40 Cr 2 Al 1 Mo 18*†	0.35-0.45	0.1-0.45	0.4-0.7	0.3 max	1.5-1.8	0.1-0.25	70-85 80-95 90-105	54 60 70	18 16 15	5.5 5.5 4.8	201-248 229-277 255-311
40 Ni 3*	0.35-0.45	0.1-0.35	0.5-0.8	3.2-3.6	0.3 max	—	80-95 90-105	60 70	16 15	5.5 5.5	229-277 255-311
35 Ni 1 Cr 80*	0.3-0.40	0.1-0.35	0.6-0.9	1.0-1.5	0.45-0.75	—	70-85 80-95 90-105	54 60 70	18 16 15	5.5 5.5 5.5	201-248 229-277 255-311
30 Ni 4 Cr 1*	0.26-0.34	0.1-0.35	0.4-0.7	3.9-4.3	1.1-1.4	—	155 min	130	8	1.4	444 min

*, †, §, ○ see foot note on page 1.13

1 kgf = 10 N

COMPOSITION AND RELATED MECHANICAL PROPERTIES OF ALLOY STEELS (Contd.)

Designation	% C	% Si	% Mn	% Ni	% Cr	% Mo	Tensile strength kgf/mm ²	Yield strength kgf/mm ²	% Min Elongation l = 5.65 √A ₀	Min. izod impact value kgf m	Brinell hardness number HB
40 Ni 1 Cr 1 Mo <u>15</u> *	0.35-0.45	0.1-0.35	0.4-0.7	1.2-1.6	0.9-1.3	0.1-0.2	80-95	60	16	5.5	229-277
							90-105	70	15	5.5	255-311
							100-115	80	13	4.8	285-341
							110-125	88	11	4.1	311-363
40 Ni 2 Cr 1 Mo <u>28</u> *	0.35-0.45	0.1-0.35	0.4-0.7	1.25-1.75	0.9-1.3	0.2-0.35	80-95	60	16	5.5	229-277
							90-105	70	15	5.5	255-311
							100-115	80	13	4.8	285-341
							110-125	88	11	4.1	311-363
							120-135	100	10	3.0	341-401
31 Ni 3 Cr 65 Mo <u>55</u> *	0.27-0.35	0.1-0.35	0.4-0.7	2.25-2.75	0.5-0.8	0.4-0.7	155 min	130	6	1.1	444 min
							90-105	70	15	5.5	255-311
							100-115	80	12	4.8	285-341
							110-125	80	11	4.1	311-363
							120-135	100	10	3.5	341-401
40 Ni 3 Cr 65 Mo <u>55</u>	—	—	—	—	—	—	155 min	130	8	1.4	444 min
							100-115	80	12	4.8	285-341
							110-125	88	11	4.1	311-363
							120-135	100	10	3.5	341-401
							155 min	130	8	1.4	444 min
55 Si 2 Mn <u>90</u>	0.5-0.6	1.5-2	0.8-1.0	—	—	—	160-200	150	6	—	440-510
50 Cr 1 V <u>23</u>	0.45-0.55	0.1-0.35	0.5-0.8	—	0.9-1.2	—	190-240	180	4	—	500-580

*, †, §, © see foot note on page 8.

1 kgf = 10 N

**CARBON AND CARBON-MANGANESE FREE CUTTING STEELS WITH SPECIFIED
CHEMICAL COMPOSITION AND RELATED MECHANICAL PROPERTIES**

Designation	% C	% Si	% Mn	% S	% P (max)	Tensile Strength kgf/mm ²	Minimum Elongation % (gauge length 5.65√a)*
10 S 11 [✓]	0.15 Max	0.05—0.30	0.60—0.90	0.08—0.13	0.060	37—49	24
14 Mn 1 S 14	0.10—0.18	0.05—0.30	1.20—1.50	0.10—0.18	0.060	44—54	22
25 Mn 1 S 14	0.20—0.30	0.25 Max	1.00—1.50	0.10—0.18	0.060	50—60	20
40 S 18 [⊕]	0.35—0.45	0.25 Max	0.80—1.20	0.14—0.22	0.060	55—65	17
13 S 25	0.08—0.18	0.10 Max	0.80—1.20	0.20—0.30	0.060	37—49	22
40 Mn 2 S 12 [⊕]	0.35—0.45	0.25 Max	1.30—1.70	0.08—0.15	0.060	60—70	15

* a, area of cross section

1 kgf = 10 N

✓ Steels for Case Carburising

⊕ Steels for Hardening and Tempering

TYPICAL USES OF ALLOY STEELS

Designation	Uses
20 Mn 2 } 27 Mn 2 }	Welded structures, crank shafts steering, levers, shafting, spindles, etc.
37 Mn 2	Axles, shafts, crank shafts, connecting rods etc.
35 Mn 2 Mo 28 } 35 Mn 2 Mo 45 }	Crank shafts, bolts, levers, connecting rods etc.
40 Cr 1	Gears, connecting rods, wear resistant plates etc.
40 Cr 1 Mo 28	Shafts, gears, high tensile bolts and studs.
15 Cr 3 Mo 55 } 25 Cr 3 Mo 55 }	Components requiring medium to high tensile strength in the nitrided condition for parts requiring high surface hardness and wear resistance.
40 Cr 3 Mo 1 V 20	Components requiring high tensile strength.
40 Cr 2 Al 1 Mo 18	Nitrided — components requiring high surface hardness and core strength
40 Ni 3	Cold tough steel - used at low temperatures such as in refrigerators and compressors. For heavy forgings, turbine blades, highly stressed screws, bolts and nuts.
35 Ni 1 Cr 60	Aircrafts and heavy vehicle components.
30 Ni 4 Cr 1	Highly stressed gears and other components requiring ultimate tensile strength of the order of 160 kgf/mm ² and where minimum distortion in heat treatment is essential.
40 Ni 1 Cr 1 Mo 15	General machine parts like bolts, gears etc.
40 Ni 2 Cr 1 Mo 28	High strength machine parts like collets, spindles, bolts, gears etc.
31 Ni 3 Cr 65 Mo 55	Highly stressed bolts, shafts, gears, mandrels, aircraft power units and for low temperature service.
14 Mn 1 S 14	Parts where good machinability and finish are important.
40 Mn 2 S 12	Heat treated axles and shafts (not recommended for forgings in which transverse properties are important.)
17 Mn 1 Cr 95	Small gear wheels, shafts, cardan joints and chain wheels.
15 Ni 2 Cr 1 Mo 15	Heavy duty components, gears and super charger gears.
13 Ni 3 Cr 80	Heavy duty gears, pinions etc. Very highly stressed machine parts which are to be hardened with high strength and toughness in core after hardening.
55 Si 2 Mn 90 } 50 Cr 1 V 23 }	Used for springs in the hardened and tempered condition.

ALLOY STEELS : Properties (I S : 1570)

Designation	condition	tensile strength N/mm ²	yield strength N/mm ²	Izod value Nm	BHN
07 Cr 13 (stainless & heat resisting steel)	bars & forgings, hardened & tempered " softened sheet & strip, softened cold drawn & softened	600 to 1050 550 450 500—700	440 to 700 240	14 to 62 69	170—311
10 Mo 55	Creep resisting bars, forgings & plates, normalised	420—540	240		
11 Mn 2	Plates, bars, forgings : hot rolled or normalised case hardened, refined and quenched (core property)	470 to 570 600	260	55	
15 Cr 65	case hardened, refined & quenched	600		48	
15 Cr 90 Mo 55	Creep resisting, bars & plates, normalised and tempered bars & forgings, normalised and tempered tubes, creep resisting	500 to 640 440	300 240	55	
15 Cr 3 Mo 55	creep resisting; bars & forgings normalised & tempered tubes	600 to 740 480	440 260	48	
15 Cr 13 (stainless & heat resisting)	bars & forgings: hardened and tempered sheets, strips: " softened " hardened & tempered tubes, annealed " hardened & tempered	600 to 1050 500 700—1000 450 600	440 to 700 500—760 300 500	14 to 62	170—311
16 Ni 80 Cr 60	case hardened, refined & quenched (core)	700		41	
17 Mn 1 Cr 95	—do—	800		35	
20 Mn Cr 1	—do—	1000		38	
20 Mo 55	creep resisting forgings, bars & plates, normalised	480—620	280	55	
20 Cr 5 Mo 55	creep resisting forgings & bars, air hardened & tempered	700—850	540	41	
20 Mo 55	tubes, creep resisting	460	250		

ALLOY STEEL : Properties (Contd)

Designation	Condition	tensile strength N/mm ²	yield strength N/mm ²	Izod value Nm	BHN
20 Mn 2	Plates, bars, forgings: hot rolled or normalised	500 to 650	290 to 360		
	bars: cold drawn	700—800			
	Sheets and strips: softened	480			
	hot rolled or normalised or normalised & tempered	550			
	hardened & tempered	800—1000			
	tubes: annealed	480	280		
20 Cr 18 Ni 2 (stainless & heat resisting)	cold drawn & tempered	560 to 720	460 to 600		
	bars & forgings, hardened and tempered	900 to 1050	700	21 to 35	255 to 311
	Sheet & strip, " softened	650			
	" hardened & tempered	900	660		
	wires, cold drawn	700—850			
	" softened	650—800			
21 Cr 1 Mo 28	Sheets, strips; hardened & tempered	1150—1350	1000		
	" cold rolled & tempered	800—1000	620		
	tubes: normalised & tempered	560—800	460—650		
	hardened & tempered	1200	1000		
22 Cr 13 (Stainless & heat resisting)	Sheet, hardened & tempered	700—900	500—760		
	" softened	550			
	Wire, —do—	800—950			
22 Cr 13 S 28 (Stainless)	bars & forgings, hardened & tempered	600—950	440—600	28—35	170—277
27 Mn 2	Plates; bars & forgings hot rolled or normalised	550 to 680	300 to 360		
	Tubes; cold drawn & tempered	560 to 640	460 to 520		
30 Ni 4 Cr 1	Tube, hardened & tempered	1100—1300	900—1100		
30 Cr 13 (Stainless & heat resisting)	bars & forgings, hardened & tempered	600—1050	440—700	14—62	170—311
	Sheet, softened	600			
	" hardened & tempered	1600			
	Wire, cold drawn	700—850			
	" softened,	650—800			
31 Ni 3 Cr 65 Mo 55	Tube, hardened & tempered	1200	1000		
35 Cr 1 Mo 65 V 25	Creep resisting, bars & forgings, normalised & tempered	900—1050	700	48	

ALLOY STEELS : Properties (Contd.)

Designation	Condition	tensile strength N/mm ²	yield strength N/mm ²	Izod Impact Nm	BHN
40 Cr 1	Tube, hardened & tempered	1100	900		
40 Cr 1 Mo 28	Tube, " or cold drawn & tempered	720	600		
40 Cr 1 Mo 60	Creep resisting, bars & forgings, oil hardened & tempered	900—1150	700—800	48—55	
40 Cr Ni 14W 3 Si 2	Valve Steel, softened			21	269
45 Cr 9 Si 4	Valve steel, hard & tempered				255—293
47 Mn 2	Sheet & strip, cold rolled & tempered " hardened & "	900—1100 1150—1350	750 1000		
55 Cr 70	Wear resisting, hardened and tempered	900 to 1050	660	35	255—311
80 Cr 20 Si 2 Ni 1	Valve steel, hardened & tempered				269—302

TOOL STEELS : Hardness in the annealed condition (max)

Designation	BHN	Designation	BHN
For cold work			
T 118	210	T 90 Mn 2 W 50 Cr 45	230
T 70	200	T 50 Cr 1 V 23	230
T 60	240	T 55 Ni 2 Cr 65 Mo 30	255
T 85	240	T 30 Ni 4 Cr 1	255
T 105 Cr 1 Mn 60	230	T 75 W 18 Co 6 Cr 4 V 1 Mo 75	269
T 105 Cr 1	230	T 83 Mo W 6 Cr 4 V 2	248
T 215 Cr 12	260	For Hot Work	
T 160 Cr 12	260	T 35 Cr 5 Mo V 1	229
T 140 W 4 Cr 50	250	T 35 Cr 5 Mo W 1 V 30	229
T 111 W 2 Cr 1	230		

CHEMICAL COMPOSITION OF TOOL STEELS

Designation	% C	% Si	% Mn	% Ni	% Cr	% Mo	% V	% W
T 118	1.1-1.25	0.1-0.3	0.2-0.35	—	—	—	—	—
T 70	0.65-0.75	0.1-0.3	0.2-0.35	—	—	—	—	—
T 60	0.55-0.65	0.1-0.35	0.5-0.8	—	—	—	—	—
T 85	0.8-0.9	0.1-0.35	0.5-0.8	—	—	—	—	—
T 105 Cr 1 Mn <u>60</u>	0.9-1.2	0.1-0.35	0.4-0.8	—	1.0-1.6	—	—	—
T 105 Cr 1	0.9-1.2	0.1-0.35	0.2-0.4	—	1.0-1.6	—	—	—
T 215 Cr 12	2.0-2.3	0.1-0.35	0.25-0.5	—	11.0-13.0	0.8 Max	0.8 Max	—
T 160 Cr 12	1.5-1.7	0.1-0.35	0.25-0.5	—	11.0-13.0	0.8 Max	0.8 Max	—
T 140 W4 Cr <u>50</u>	1.3-1.5	0.1-0.35	0.25-0.5	—	0.3-0.7	—	—	3.5-4.2
T 110 W2 Cr 1	1.0-1.2	0.1-0.35	0.9-1.3	—	0.9-1.3	—	—	1.25-1.75
T 90 Mn 2 W <u>50</u> Cr <u>45</u>	0.85-0.95	0.1-0.35	1.25-1.75	—	0.3-0.6	—	0.25 Max	0.4-0.6
T 50 Cr 1 V <u>23</u>	0.45-0.55	0.1-0.35	0.5-0.8	—	0.9-1.2	—	0.15-0.3	—
T 55 Ni 2 Cr <u>65</u> Mo <u>30</u>	0.5-0.6	0.1-0.35	0.5-0.8	1.25-1.75	0.5-0.8	0.25-0.35	—	—
T 30 Ni 4 Cr 1	0.26-0.34	0.1-0.35	0.4-0.7	3.9-4.3	1.1-1.4	—	—	—
T 35 Cr 5 Mo V 1	0.3-0.4	0.8-1.2	0.25-0.5	—	4.75-5.25	1.2-1.6	1.0-1.2	—
T 35 Cr 5 Mo W1 V <u>30</u>	0.3-0.4	0.8-1.2	0.25-0.5	—	4.75-5.25	1.2-1.6	0.2-0.4	1.2-1.6
T 75 W 18 Co 6 Cr 4 } V 1 Mo <u>75</u> }	0.7-0.8	0.1-0.35	0.2-0.4	—	4.0-4.5	0.5-1.0	1.0-1.5	17.5-19.0
T 83 Mo W 6 Cr 4 V 2	0.75-0.9	0.1-0.35	0.2-0.4	—	3.75-4.5	5.5-6.5	1.75-2.0	5.5-6.5
T 10 Cr 5 Mo <u>75</u> V <u>23</u>	0.15 Max	0.1-0.35	0.25-0.5	—	4.75-5.25	0.5-1.0	0.15-0.3	—

TOOL STEELS AND THEIR USES

Type	Designation	Uses
Carbon Tool Steels	T 118 } T 70 } T 60 and T 85	Engraving tools, files, razors, shaping tools, drills, shear blades, chisels, press tools etc. Die blocks, hand tools, garden and agricultural tools
Carbon - Chromium Tool Steels	T 105 Cr 1 Mn <u>80</u> } T 105 Cr 1	Cold forming rolls, lathe centres, knurling tools, press tools
High Carbon, High Chromium Tool Steels	T 215 Cr 12 } T 160 Cr 12 }	High quality press tools, drawing and cutter dies, shear blades, thread rollers, cold rolls etc.
Fast Finishing Tool Steels	T 140 W4 Cr <u>50</u>	Finishing tools with light feeds, marking tools etc.
Non - Deforming Tool Steels	T 110 W 2 Cr 1 } T 90 Mn 2 W <u>50</u> Cr <u>45</u> }	Engraving tools, press tools, gauge, tape, hard reamers, milling cutters, cold punches, knives, etc.
Shock Resisting Tool Steels	T 50 Cr 1 V <u>23</u>	Chisels, rivet shape shear blades, scarfing tools, trimming dies, heavy duty punches, pneumatic chisels, etc.
Nickel - Chromium - Moly b - denum Tool Steels	T 55 Ni 2 Cr <u>65</u> Mo <u>80</u> } T 30 Ni 4 Cr 1	Cold punches, trimming dies, shear blades, scarfing tools, pneumatic chisels
Hot Work Tool Steels	T 35 Cr 5 Mo V 1 } T 35 Cr 5 Mo W 1 V <u>30</u> }	Dies for extrusion, stamping dies, casting dies for light alloys, forging dies etc.
High - Speed Tool Steels	T 75 W 18 Co 6 Cr 4 } V 1 Mo <u>75</u> } T 83 Mo W 6 Cr 4 V <u>2</u> }	Drills, reamers, broaches, form cutters, milling cutters, deep hole drills, slitting saws, and other high speed and heavy cut tools.
Carburising Steels	T 10 Cr 5 Mo <u>75</u> V <u>23</u>	Used after case hardening for moulds for plastic material

INDIAN STANDARD STEELS FOR MACHINE TOOLS AND THEIR EQUIVALENT IN OTHER COUNTRIES

IS INDIAN	CSN CZECH	DIN GERMAN	BS BRITISH	ASTM AMERICAN	JIS JAPANESE	GOST RUSSIAN	UNI ITALIAN	AFNOR FRENCH
14Mn1S14*	11110	15S20	En 1A	C 1113	SUM2	A12	—	15 F2
40Mn2S12*	11140	45S20	En 8M	C 1140	SUM5	A40G	—	35MF 4
C40	12040	C35 K	—	—	S35C-D	—	—	—
C 45*	12050	CK 45	En 8D	1040	S45C	MCr6	C 40	XC45F
C 75	12081	2076	En 42	—	—	—	—	—
17Mn1Cr95	14220	16MnCr5	—	5115	—	20XGA	16MC5	16MC5
T50Cr1V23	15260	50CrV4	En 47	6150	SUP10	50XFA	50CV4	50CV4
15Ni2Cr1Mo15*	16220	—	En 325	4317	SNCM22	—	17NCD7	18NCD6
40Ni2Cr1Mo 28*	16341	36CrNiMo4	En 24	4340	SNCM8	40HXMA	40NCD7	—
13Ni3Cr80	16420	ECN35	En 36	3315	SNC22	12HX3A	15NC11	14NC12
30Ni4Cr1	16640	VCN45	En 30A	—	—	—	—	35NC15
T215Cr12	19436	210Cr46	—	—	SKD1	X12	UX200C13	Z200C12
T110W2Cr1	19710	105WCr6	—	—	SKS31	XBG	U100WC	105WC15.04
T83MoW6Cr4V2	19800	DMo 5	—	M 2	SKH9	—	UX82WD65	Z85WD0606
T123W14Co5CrV4	19810	EV4Co	—	—	—	P14F4	—	Z125WV15-03
T75W18Co6Cr4								
V1Mo75	19885	E18Co5	—	T 4	SKH3	P18VK5F2	UX80WK185	Z85WK1805

* Preferred Steels.

INDIAN STANDARD STEELS AND THEIR NEAREST EQUIVALENTS OF OTHER COUNTRIES

IS INDIAN	CSN CZECH	DIN GERMAN	BS BRITISH	ASTM AMERICAN	JIS JAPANESE	GOST RUSSIAN	UNI ITALIAN	AFNOR FRENCH
St 50	11500	St 50-2-1623	—	A 306 Gr 70 A-15-A160 A-408 In.Gr.	G 3101 Class 3 SS 50	380 Gr CT 5	—	—
St 58	11600	17100/1623 St 60 St 60-2	—	—	—	380 Gr CT 6	—	—
C 14	12020	1654 C 15 17210 C 15	En 32 B & C	A 179 A 192 A 226	G 3102 S 15 CK	1050 Gr 15 K w	—	—
C 40	12040	C 35 K	970 En 8 K	A 108 Gr 1040	S 35 C-D	1050 Gr 40r	—	—
C 45	12050	CK 45	En 8D (≈ En 9)	1040	S 45 C	M Cr 6	C 40	X C 45 F
C 55	12060	17222 C 53	En 9 & En 9 K	A 57 Class A	G 3102 Class 10 S 55 C	1050 Gr 55	—	—
C 60	12061	17200 C 60 & C K 60	1449 Part 3 AHS60 Part 3 BCS60	A107 Gr 1060	G 3506 Class 4B SWRH 4B	1050 Gr 60	—	—
C 85	12090	—	1429 En 42 D	A 421	G 3502 Class 3B SW R S 3 B	1050 Gr 85	—	—
17 Mn 1 Cr 95	14220	16MnCr5	—	5115	—	20XGA	—	—
15 Ni 2Cr1 Mo 15	16220	—	En 354	4317	SNCM 22	—	17 NCD 6	18 NCD6
13 Ni 3 Cr 80	16420	ECN 35	En 36	3315	SNC 22	12HX3A	15 NC 11	14 NC 12
15 Ni 4 Cr 1	16520	—	970 En 39A	A 331 Gr E 9310	G 4102 Class 22 SNC 22	4543 Gr12X12H4A	—	—

INDIAN STANDARD STEELS AND THEIR NEAREST EQUIVALENTS OF OTHER COUNTRIES (Contd.)

IS INDIAN	CSN CZECH	DIN GERMAN	BS BRITISH	ASTM AMERICAN	JIS JAPANESE	GOST RUSSIAN	UNI ITALIAN	AFNOR FRENCH
15 Cr 65	14120	17210 15 Cr 3	970 En 206	5015 SAE-AISI		5058 Gr 12 X	—	—
40 Ni 2 Cr 1 Mo 28	16341	36 Cr Ni Mo 4	En 24	4340	SNCM 8	40 H X MA	40 NCD 7	—
35 Ni 1 Cr 60	16240	—	970 En 111	3140 SAE AISI A 322—332 Gr 3140	G 4102 Class 1 SNCL	4543 Gr 40 X H	—	—
30 Ni 4 Cr 1	16640	VCN 45	En 30A	—	—	—	—	35 NC 15
40 Ni 3	16440	—	970 En 22	A 322 Gr 8615	—	37 H X 3 A	—	—
105 Cr 1	14100	E 52 100 105 Cr 4 (W ₂)	970 En 31	A295 Type B 51100	G 4805 Class 1 SUJ 1	801 Gr W X 15	—	—
105 Cr 1 Mn 60	14200	105 Cr 4 (W ₂)	En 31	52100	G 4805 Class 2 SUJ 2	801 Gr W X 15	—	—
40 Cr 2 Al 1 Mo 18	15340	—	En 41B	A 355 Class A	SACM 1 Gr 4202 Class 1	38 X M 1-0 A	—	—

PROPERTIES OF BRASSES OF DIFFERENT CHEMICAL COMPOSITIONS

CHEMICAL COMPOSITION			Tensile Strength kgf/mm ²	% Elongation*	Brinell Hardness HB
% Cu	% Pb	% Zn			
54-47	upto 2.5	Rest	> 45	10	110
57-59.5	1.0-3.0	Rest	37-68	2 to 25	90-170
59.5-62	upto 0.3	Rest	34-59	3 to 30	80-170
62-65	upto 0.2	Rest	30-70	5 to 45	70-160
66-69	upto 0.1	Rest	29-54	5 to 45	70-160
69.5-73	upto 0.07	Rest	28-53	5 to 44	70-155

* Gauge Length

5.8 $\sqrt{a}$ Round test piece;

a, Area of cross section

CHEMICAL COMPOSITION & PROPERTIES OF TIN BRONZE

CHEMICAL COMPOSITION					MECHANICAL PROPERTIES		
%Cu	%Sn	%Zn	%Pb	%P	Tensile Strength kgf/mm ²	% Elongation Gauge length 5.8 $\sqrt{a}$ *	Brinell Hardness HB
96	4	—	—	<0.4	32-45	10-55	65-120
94	6	—	—	<0.4	35-50	12-60	70-130
92	8	—	—	<0.4	40-55	20-60	80-150
91	8.5	—	—	0.3	55	5	150
90	10	—	—	—	22	15	60
88	12	—	—	—	24-28	8	80-95
86	14	—	—	—	20	3	85
85	5	7	3	—	15-25	10-12	60-75
86	10	4	—	—	20	10	65

*a, area of cross section, round.

1 kgf = 10 N

CHEMICAL COMPOSITION OF ANTI-FRICTION BEARING ALLOYS

GRADE	ALLOY	ALLOYING ELEMENTS, %							IMPURITIES, % MAX.							Total of Indicated Impurities Percent
		Sn	Sb	Pb	Cu	Ni	Cd	As	Zn	Fe	As	Al	Bi	Zn	Cd	
90	Sn Sb 7 Cu 3	90 Min	6.5—7.5	0.3 Max	2.5—3.5	—	—	—	—	0.08	0.10	0.005	0.05	0.008	0.05	0.15
84	Sn Sb 10 Cu 5	84 Min	9—11	0.3 Max	5—6	—	—	—	—	0.08	0.10	0.005	0.05	0.008	0.10	0.17
75	Sn 75 Sb 11 Pb	74—76	10—12	Remain-der	2.75—3.25	—	—	—	—	0.08	0.10	0.005	0.05	0.008	0.10	0.17
69	Sn 69 Zn 30	68—70	0.2 max	0.3 Max	1.0—1.4	—	—	—	29—31	0.10	0.15	0.005	0.08	—	0.10	0.22
60	Sn 60 Sb 11 Pb	59—61	11—12	Remain-der	2.5—3.5	—	—	—	—	0.10	0.15	0.005	0.08	0.01	0.10	0.22
20	Sn 20 Sb 15 Pb	19—21	14—16	Remain-der	1.25—1.75	—	—	—	—	0.10	0.20	0.005	0.10	0.01	0.10	0.26
10	Sn 10 Sb 14 Pb	9.5—10.5	13—15	Remain-der	0.5—1.0	—	—	—	—	0.10	0.20	0.005	0.10	0.01	0.10	0.28
6	Sn 6 Sb 15 Pb	5—7	14—16	Remain-der	0.8—1.2	0.8—1.5	0.7—1.5	0.3—0.8	—	0.10	—	0.005	0.10	0.01	—	0.15
5	Sn 5 Sb 15 Pb	4.5—5.5	14—16	Remain-der	0.3—0.7	—	—	—	—	0.10	0.25	0.005	0.10	0.01	0.10	0.28
1	Sn 1 Sb 15 Pb	0.75—1.25	15—16	Remain-der	0.5 Max	—	—	0.8—1.1	—	0.10	—	0.005	0.10	0.01	0.10	0.28

POURING TEMPERATURE RANGES AND TYPICAL USES OF ANTI-FRICTION BEARING ALLOYS

Grade	Pouring Temperature °C	Typical Uses
90 84	340 to 390 } 430 to 460 }	For lining of petrol and diesel engine bearing, cross-heads in steam engine and other bearings used at high speeds. (As tin content drops in these alloys, their resistance to shock and load increases)
75	360 to 400	Mostly used for repair jobs in mills and marine installations. (Because of its long plastic range, it can be spread in as a wipe joint)
69	500 approx	For under water applications as a bearing alloy and gland packings.
60	370 to 400	For lining of bearings required for medium speeds, such as Centrifugal pumps, Circular saws, Convertors, Dynamos and electrical motors.
20 } 10 }	370 to 410	For low speed bearings, such as pulp Crushers, Concrete mixers and rope conveyors.
6	500 to 530	Heavy duty bearings, rolling mill bearings in sugar, rubber, paper, steel industries etc. Bearings for diesel engines, Cross-heads in steam engines, turbines etc. Generally for heavy duty jobs.
5	350 to 390	For mill shaftings, railway Carriage and wagon bearings.
1	—	Used as a thin line overlay on steel strips where the white metal lining material is 0.076 mm thick.

COMPOSITION AND USES OF DIE CASTING ALLOYS

Description	% Zn	% Al	% Cu	% Mg	% Fe	% Pb	% Cd	% Sn	% Si	% Mn	% Ni	Other Elements	Uses
Zn base	Re- mainder	3.9— 4.3	0.03	0.03— 0.06	0.075	0.003	0.003	0.001	—	—	—	—	High grade die castings such as automotive parts, pad locks, toys etc.
Al-Si Alloys	0.01	Re- mainder	0.1	—	0.6	0.05	—	—	10—13	0.5	0.1	Ti=0.2 Sn=0.04	Sand, gravity and pressure die castings and miscellaneous fittings.
Al-Mg Alloys	—	Re- mainder	0.15	9.5— 11.0	0.3	—	—	—	0.25	—	—	Ti+Mn +Ca=0.25	Sand or gravity die castings where high strength with ductility and shock resistance is required such as oscillating levers, stressed brackets etc.

CHEMICAL COMPOSITION OF WROUGHT ALUMINIUM & ALUMINIUM ALLOYS FOR GENERAL ENGINEERING PURPOSES

IS : 733

Designation	Aluminium	Copper	Magnesium	Silicon	Iron	Manganese	Zinc	Titanium and/or other refining Elements	Chromium	Condition	SIZE		0.2 percent proof stress N/mm ²	Tensile strength N/mm ²	Elongation percent min	Remarks
											Over	upto and including				
19000	99min	0.1	0.2	0.5	0.7	0.1	0.1	—	—	*M	—	—	—	65	18	Cu+Mg+Si+Fe+Mn+Zn = 1.0
19500	99.5min	0.05	—	0.3	0.4	0.05	0.1	—	—	*M	—	—	—	65	23	Cu+Si+Fe+Mn+Zn=0.5
24345	Remainder	3.8 to 5.0	0.2 to 0.8	0.5 to 1.2	0.7	0.3 to 1.2	0.2	0.3*	0.3*	W	—	10	225	375	10	
											10	75	235	385	10	
											75	150	235	385	8	
											150	200	225	375	8	
										WP	—	10	375	430	6	
											10	25	400	460	6	
											25	75	420	480	6	
											75	150	405	460	6	
											150	200	380	430	6	
											—	10	220	375	10	
24534	Remainder	3.5 to 4.7	0.4 to 1.2	0.2 to 0.7	0.4 to 1.2	0.2	0.2	0.3	—	W	10	75	235	385	10	
											75	150	235	385	8	
											150	200	225	375	8	
43000	Remainder	0.1	0.2	4.5 to 6.00	0.6	0.5	0.2	—	—	*M	—	10	—	110	18	
46000	Remainder	0.1	0.2	10.0 to 13.0	0.6	0.5	0.2	—	—	*M	—	10	—	150	10	
52000	Remainder	0.1	1.7 to 2.6	0.6	0.5	0.5	0.2	0.2	0.25	*M	—	150	—	170	14	Cr+Mn=0.5
53000	Remainder	0.1	2.8 to 4.0	0.6	0.5	0.5	0.2	0.2	0.25	*M	—	50	100	215	14	Cr + Mn = 0.5
											50	150	100	200	14	
54300	Remainder	0.1	4.0 to 4.9	0.4	0.7	0.5 to 1.0	0.2	0.2	0.25	O *M	—	150	125	265	13	
											—	150	130	275	11	

CHEMICAL COMPOSITION OF WROUGHT ALUMINIUM AND ALUMINIUM ALLOYS FOR GENERAL ENGINEERING PURPOSES—(Continued)

Designation	Aluminium	Copper	Magnesium	Silicon	Iron	Manganese	Zinc	Titanium or other Elements	Chromium	Condition	SIZE		0.2 percent proof stress N/mm ²	Tensile strength N/mm ²	Elongation percent min	Remarks
											OVER	upto and including				
63400	Remainder	0.1	0.4— 0.9	0.3— 0.7	0.6	0.3	0.2	0.2	0.1	*M or O W P WP	All sizes	—	—	110	13	
											—	150	80	140	14	
											150	200	80	125	13	
											—	3	140	170	7	
											3	12	110	150	7	
64423	Remainder	0.5 to 1.0	0.5 to 1.3	0.7 to 1.3	0.8	1.0	—	—	—	*M or O W WP	—	—	—	120	10	
											—	—	155	265	13	
											6.3	—	265	330	7	
											—	150	120	185	14	
											150	200	100	170	12	
64430	Remainder	0.1	0.4— 1.2	0.6— 1.3	0.6	0.4— 1.0	1.0	0.2	0.25	*M or O W WP	All sizes	—	—	110	12	
											—	150	120	185	14	
											150	200	100	170	12	
											—	5	235	295	7	
											5	75	270	310	7	
65032	Remainder	0.15— 0.4	0.7— 1.2	0.4— 0.8	0.7	0.2— 0.8	0.2	0.2	0.15— 0.35	*M or O W WP	All sizes	—	—	110	12	Either Mn or Cr shall be present
											—	150	115	185	14	
											150	200	100	170	12	
											—	150	235	280	7	
											150	200	200	245	6	
74530	Remainder	0.2	1.0— 1.5	0.4— 0.8	0.7	0.2— 0.7	4— 5	0.2	0.2	W (Naturally aged for 30 days) WP	—	6.3	220	255	9	
											6.3	75	230	275	9	
											75	150	220	260	9	
											—	6.3	245	285	7	
											6.3	75	260	310	7	
											75	150	245	290	7	

*Properties in M temper are only typical values and are given for information only.

CHARACTERISTICS AND USES OF TYPICAL WROUGHT ALUMINIUM ALLOYS

Designation	Characteristics	Available Forms	Typical Uses
19000	Commercially pure aluminium. Very ductile in annealed or extruded condition. Excellent resistance to corrosion.	Sheet, plate, Extrusion, Tube, wire and Forgings.	Panelling and moulding, Refrigeration tubing, Equipment for chemical, food and brewing industries; packing, cooking utensils, Sheet metal work, builders hardware, spun / pressed hollow ware, deep drawn parts, cladding, welding wire, electrical appliances.
19500	High purity aluminium more resistant to corrosion than other alloys.	Sheet, plate, Extrusion, tube, wire, rolled rod and forgings.	Corrosion resistant cladding on Stronger alloys; impact extruded containers, food, chemical, brewing and processing equipment; tank and pipes; marine fittings, reflectors; pressed and anodized utility items, jewellery and cable sheathing.
24345	Combines high strength with fair ductility in the solution treated condition, when forming can be done and parts subsequently aged.	Sheet, plate, Extrusion tube, wire and forging.	Heavy duty forgings, structures where high mechanical properties are of utmost importance, aircraft application of clad sheets, extrusions and armaments.
24534	Strong alloy that is aged naturally at room temperature after solution treatment and has fair ductility in this condition.	Extrusion, tube, wire, rolled rod and forgings	Stressed parts in aircraft and other structures where high strength is of primary consideration.
43000	It is easily formed and blends itself well to welding, brazing and soldering	Wire and rolled rod	Filler wire for welding.
46000	—do—	—do—	Filler wire for brazing.
52000	Ductile in soft condition, but work hardens rapidly, becoming extremely tough, Have high resistance to corrosive attack, especially in marine atmosphere	Sheet, plate, Extrusion, tube, wire and forgings	Panelling and structures, sheet metal work and domestic appliances, marine applications like sheathing/lining of boat bottom.

CHARACTERISTICS AND USES OF TYPICAL WROUGHT ALUMINIUM ALLOYS — (Contd)

Designation	Characteristics	Available forms	Typical Uses
53000	as for 52000	Sheet, plate, Extrusion, Tube and wire and rolled rod	Ship building; rivets; pressure vessels and other processing tanks; cryogenics and welded structures.
54300	—do—	Sheet, plate, extrusion and forgings.	Welded structures, cryogenic applications, structural and marine applications, rail and road tank cars, rivets and missile components
63400	Suitable for intricate extruded sections of medium strength. Forms well in W condition. Highly corrosion resistant.	Extrusion, Tube, wire, rolled rod and forgings.	Window and door frames, wall facings, partitions, hand rails etc., and similar application where surface finish is important and medium strength sufficient.
64423	Stronger than 64430 and has superior machinability.	Extrusions	Applications involving good strength and machinability such as textile machinery components.
64430	Medium strength alloy with good mechanical properties, corrosion resistance & weldability.	Sheet, plate, Extrusion, tube, wire and forgings.	Structural applications of all kinds such as rail and road transport vehicles, bridges, cranes, roof trusses, rivets, cargo containers, milk containers, deep drawn containers and flooring.
65032	Medium strength alloy similar to 64430.	—do—	Similar to 64430.
74530	Medium strength self-ageing weldable alloy. It does not require heat treatment after hot working/after welding; Excellent welding characteristics and good formability, good corrosion resistance when compared with other high strength aluminium Zinc alloys.	Sheet, plate, extrusion and forgings.	Stressed structural applications requiring weldings such as bridges, chequered plates, dump-truck bodies, pressure vessels and rail coaches, etc.

CHEMICAL COMPOSITION AND MECHANICAL PROPERTIES OF CAST ALUMINIUM ALLOYS

IS designation	Chemical composition, per cent												Mechanical Properties				
	Cu	Mg	Si	Fe	Mn	Ni	Zn	Ti	Ti+ Nb	Pb	Sn	Al	σ_u N/mm ²	Elongation %	Brinell hardness	Test Piece	Condi- tion
2447	6—8	0.15	2—4	1.0	0.6	0.5	2—4	—	—	0.3	0.2	Rest	126 157	— —	— —	Sand Chill	M
4520	0.7— 2.5	0.3	9.0— 11.5	1.0	0.5	1.0	1.2	0.2	—	0.3	0.2	Rest	126 150	— —	— —	Sand Chill	M
4223	2.0— 4.0	0.15	4.0— 6.0	0.8	0.3— 0.7	0.3	0.5	0.2	—	0.1	0.05	Rest	142 157	2 2	— —	Sand Chill	M
5230	0.1	3.0— 6.0	0.3	0.6	0.3— 0.7	0.1	0.1	—	0.2	0.05	0.05	Rest	142 173	3 5	— —	Sand Chill	M
4600	0.1	0.1	10.0— 13.0	0.6	0.5	0.1	0.1	—	—	0.1	0.05	Rest	165 189	5 7	— —	Sand Chill	M
4250	0.1	0.3— 0.8	3.5— 6.0	0.6	0.5	0.1	0.1	—	0.2	0.1	0.05	Rest	126 165	2 3	— —	Sand Chill	M
4635	0.1	0.2— 0.6	10.0 13.0	0.6	0.3— 0.7	0.1	0.1	—	0.2	0.1	0.05	Rest	173 236	1.5 2	— —	Sand Chill	M
5500	0.1	9.5— 11.0	0.25	0.35	0.1	0.1	0.1	—	0.2	0.05	0.05	Rest	283 315	8 12	— —	Sand Chill	W
2280	4.0— 5.0	0.1	0.25	0.25	0.1	0.1	0.1	—	0.05— 0.1	0.05	0.05	Rest	220 268	7 13	— —	Sand Chill	W
2585	9.0— 10.5	0.15— 0.35	2.0	0.5— 1.5	0.6	0.5	0.1	—	—	0.1	0.1	Rest	—	—	100		WP

CHEMICAL COMPOSITION AND MECHANICAL PROPERTIES OF CAST ALUMINIUM ALLOYS (CONT'D)

IS designation	Chemical composition, per cent												Mechanical Properties				
	Cu	Mg	Si	Fe	Mn	Ni	Zn	Ti	Ti+Nb	Pb	Sn	Al	σ_u N/mm ²	Elongation %	Brinell hardness	Test piece	Condi- tion
4685	0.5—	0.8—	11.0—	0.8	0.5	2.0—	0.1	—	0.2	0.1	0.1	Rest	173	—	100	Sand	WP
	1.3	1.5	13.0			3.0							252	—	100	Chill	
2285	3.5—	1.2—	0.6	0.6	0.6	1.8—	0.1	0.2	—	0.05	0.05	Rest	220	—	100	Sand	WP
	4.5	1.7				2.3							283	—	100	Chill	
4225	1.0—	0.4—	4.5—	0.6	0.5	0.25	0.1	—	—	0.05	0.05	Rest	173	2	—	Sand	W
	1.5	0.6	5.5										205	3	—	Chill	
4300	0.1	0.1	4.5—	0.6	0.5	0.1	0.1	—	0.2	0.1	0.05	Rest	118	3	—	Sand	M
			6.0										142	4	—	Chill	
4223	2.8—	0.05	4.0—	0.7	0.3—	0.15	0.15	—	0.1	0.05	0.05	Rest	252	8	—	Chill	W
	3.8		6.0		0.6												
4420	3.0—	0.1	7.5—	1.3	0.5	0.5	1.0	—	—	0.3	0.2	Rest	181	1.5	—	Chill	M
	4.0		9.5														

M— As cast condition

P— Precipitation treated

W— Solution treated

WP— Solution and precipitation treated.

CAST ALUMINIUM ALLOYS — CHARACTERISTICS & APPLICATIONS

IS designation	BS designation	Characteristics	Typical applications	Recommended method of casting
2447	LM 1	Fair fluidity; a general purpose low cast alloy with moderate strength and good machinability.	Crank cases, cam shaft housings, chain covers, gear boxes, automotive timing gears, brake positioners, cylinder head covers, household and industrial fittings and brackets, washing machine agitators, assembly jigs, patterns, electric switch gears etc.	Mainly used as gravity die casting.
4520	LM 2	Excellent fluidity and pressure tightness, suitable for intricate castings machinability and hardness better than A-6 alloy.	Motor housings, Camera and meter cases, portable electric tools, window frames etc.	Mainly used as pressure die casting.
4223	LM 4	General purpose alloy with moderate strength, good fluidity, pressure tightness and machinability weldable.	Automotive cylinder heads, crank cases, junction boxes, gear boxes, clutch cases, switch switch gear covers, instrument cases, tool cases, tool handles, ornamental grills etc.	Suitable as sand castings and gravity and pressure die castings.
5230	LM 5	Medium strength alloy, excellent resistance to corrosion and tarnish, with good machinability, suitable for anodising.	Utensils, sewage and chemical equipment, ornamental hardware, furniture, fittings, for cars, marine and pipes etc.	Mainly used as sand castings gravity die castings.
4600	LM 6	Excellent fluidity and pressure tightness; good resistance to corrosion; suitable for intricate castings, weldable.	Water cooled manifolds and jackets, motor car and road transport fittings, motor housings, meter cases and switch boxes, typewriter frames, chemical and die industry castings, food and domestic castings etc.	Suitable as sand castings and gravity and pressure die castings.
4250	LM 8	Good fluidity, pressure tightness and resistance to corrosion, suitable for intricate castings, weldable.	Aircraft pump parts fitting and control parts, automotive transmission cases, water cooled cylinder blocks, marine hardware, valve bodies and fittings, truck axle housings and wheels, large fan blades, pneumatic tools, etc. suitable for application in chemical and food industries.	Mainly used as sand castings and gravity die castings.
4635	LM 9	Used where fluidity and corrosion resistance of A-6 alloy together with high strength and hardness required.	Engine and crank case for motor car, ship, aircraft, etc.	Mainly used as sand castings and gravity die castings.
5500	LM 10	Combines best mechanical properties with good impact strength, machinability and corrosion resistance, susceptible to stress-corrosion cracking; suffers loss of ductility at elevated temperatures, needs special foundry techniques.	Highly stressed aircraft castings, marine fittings, mining equipment, rail road and passenger car frames.	Mainly used as sand castings and gravity die castings.

CAST ALUMINIUM ALLOYS — CHARACTERISTICS & APPLICATIONS (Contd.)

IS designation	BS designation	Characteristics	Typical applications	Recommended method of casting
2280	LM 11	Combines high strength, ductility and machining characteristics, suitable for stressed castings and for components with shock resistance.	Aircraft wheel fittings and crank cases, bus wheels and rear axle housings, drier shafts, flywheel housing, peripheral fitting parts, power transmission cable accessories, wrenches, type-writer key levers, etc.	Mainly used as sand casting and gravity die castings.
2585	LM 12	Has good strength and hardness at elevated temperature with resistance to wear and machinability.	Air-cooled cylinder heads, automotive pistons, bushings, bearing caps, electric iron sole plates, castings for hydraulic brake systems, etc.	Mainly used as sand castings and gravity die castings for pistons.
4685	LM 13	Good fluidity, high temperature strength and low coefficient of thermal expansion, good resistance to wear.	Heavy duty automotive and diesel piston, pulleys, sheaves, etc.	Mainly used as sand castings and gravity die castings for pistons.
2285	LM 14	One of 'Y' alloy series suitable for excellent strength and hardness at elevated temperature.	Aircraft, diesel and heavy duty engine pistons, air cooled cylinder heads, aircraft generator housings, aircraft structural castings, high duty gear boxes, etc.	Mainly used as sand castings and gravity die castings.
4225	LM 16	Excellent fluidity, pressure tightness with resistance to corrosion, usable at elevated temperatures, weldable.	Aircraft supercharger covers, fuel pump bodies, air compressor pistons, liquid cooled cylinder heads, valve bodies liquid cooled aircraft engine crank cases, accessory housings, aircraft fittings, water jackets, blower housings, cylinder blocks, fire hose couplings, etc.	Mainly used as sand castings and gravity die castings.
4300	LM 18	General purpose alloy with excellent fluidity and pressure tightness, resistance to corrosion and good ductility but low strength properties, weldable.	Used for marine fittings, manifold water jackets, meter cases, utensils, steam iron, electric floor polishers, vacuum cleaners, etc.	Mainly used as sand castings and gravity die castings.
4223	LM 22	Has good shock resistance and strength.	For heavy duty service in road transport vehicles namely cross-beaters and other structural components.	Used as gravity die castings.
4420	LM 24	General purpose die casting alloy of medium strength with poor corrosion resistance.	Suitable for general purpose die castings applications.	Used as pressure die castings.

CONVERSION OF HARDNESS NUMBERS AND THEIR CORRELATION WITH TENSILE STRENGTH

Brinell Hardness Number		Rockwell Hardness Number			Diamond pyramid hardness number	Shore Scleroscope hardness number	Tensile strength N/mm ²		
Impression dia, mm	Hardness number	Scale					Carbon Steel	Chromium Steel	Nickel and Chrome Nickel Steel
		C	A	B					
2.2	780	72	89	—	1224	—	—	—	
2.25	745	70	87	—	1116	—	—	—	
2.30	712	68	86	—	1022	—	—	—	
2.35	682	66	85	—	941	90	—	—	
2.40	653	64	84	—	868	86	—	—	
2.45	627	62	83	—	804	84	—	—	
2.50	601	60	82	—	746	81	—	—	
2.55	578	58	81	—	694	78	—	—	
2.60	555	56	79	—	649	75	—	—	
2.65	534	54	78	—	606	71	—	—	
2.70	514	52	77	—	587	69	—	—	
2.75	495	50	76	—	551	66	1780	1730	
2.80	477	49	76	—	534	65	1720	1670	
2.85	461	48	75	—	502	64	1650	—	
2.90	444	46	74	—	473	61	1600	1560	
2.95	429	45	73	—	460	59	1550	1500	
3.00	415	44	72	—	435	58	1490	1450	
3.02	409	43	72	—	423	57	1470	1430	
3.05	401	42	71	—	412	56	1440	1395	
3.10	388	41	71	—	401	55	1395	1360	
3.15	375	40	70	—	390	53	1350	1315	
3.20	363	39	70	—	380	52	1305	1270	
3.25	352	38	69	—	361	51	1265	1230	
3.30	341	37	68	—	344	50	1225	1190	
3.35	331	36	68	—	335	49	1195	1165	
3.40	321	35	67	—	320	48	1155	1120	
3.45	311	34	67	—	312	47	1115	1085	
3.50	302	33	67	—	305	46	1085	1055	
3.55	293	31	66	—	291	43	1055	1025	
3.60	286	30	66	—	285	42	1030	1005	
3.65	277	29	65	—	278	41	995	970	
3.70	269	28	65	—	272	40	970	940	
3.75	262	27	64	—	261	39	945	920	
3.80	255	26	64	—	255	38	920	890	
3.85	248	25	63	—	250	37	895	870	
3.90	241	24	63	100	240	36	870	845	
3.95	235	23	62	99	235	35	845	825	
4.00	228	22	62	98	226	34	825	800	
4.05	223	21	61	97	221	33	800	775	
4.10	217	20	61	97	217	33	780	760	
4.15	212	19	60	96	213	32	760	740	
4.20	207	18	60	95	209	32	745	725	
4.25	202	16	59	94	201	31	720	710	
4.30	196	15	58	93	197	31	705	685	
4.35	192	15	58	92	190	30	690	670	

CONVERSION OF HARDNESS NUMBERS AND THEIR CORRELATION WITH TENSILE STRENGTH (Contd)

Brinell Hardness Number		Rockwell Hardness Number			Diamond pyramid hardness number	Shore Scleroscope hardness number	Tensile strength N/mm ²		
Impression dia, mm	Hardness Number	Scale					Carbon Steel	Chromium Steel	Nickel and Chrome Nickel Steel
		C	A	B					
4.40	187	—	57	91	186	—	675	655	635
4.45	183	—	56	89	183	—	660	640	625
4.50	179	—	56	88	177	—	640	625	605
4.55	174	—	55	87	174	—	625	610	590
4.60	170	—	—	86	171	—	610	595	580
4.65	166	—	—	85	165	—	600	585	570
4.70	163	—	—	84	162	—	585	570	555
4.75	159	—	—	83	159	—	575	555	545
4.80	156	—	—	82	154	—	560	545	530
4.85	153	—	—	81	152	—	550	535	520
4.90	149	—	—	80	149	—	535	520	505
4.95	146	—	—	78	147	—	525	510	500
5.00	143	—	—	76	144	—	510	495	485
5.05	140	—	—	76	—	—	500	490	475
5.10	137	—	—	75	—	—	495	480	465
5.15	134	—	—	74	—	—	486	470	455
5.20	131	—	—	72	—	—	470	455	445
5.25	128	—	—	71	—	—	462	447	435
5.30	126	—	—	69	—	—	450	435	425
5.35	124	—	—	69	—	—	440	430	420
5.40	121	—	—	67	—	—	435	425	410
5.45	118	—	—	66	—	—	425	415	400
5.50	116	—	—	65	—	—	417	407	393
5.55	114	—	—	64	—	—	412	402	387
5.60	112	—	—	62	—	—	405	395	385
5.65	109	—	—	61	—	—	390	—	—
5.70	107	—	—	59	—	—	385	—	—
5.75	105	—	—	58	—	—	380	—	—
5.80	103	—	—	57	—	—	370	—	—
5.85	101	—	—	56	—	—	365	—	—
5.90	99	—	—	54	—	—	355	—	—
5.95	97	—	—	53	—	—	350	—	—
6.00	96	—	—	52	—	—	345	—	—
6.10	92	—	—	49.5	—	—	330	—	—
6.20	88	—	—	47	—	—	320	—	—
6.36	84	—	—	43.5	—	—	300	—	—
6.48	80	—	—	40.5	—	—	290	—	—
6.56	78	—	—	38.5	—	—	280	—	—

APPROXIMATE RELATIONSHIP BETWEEN TENSILE STRENGTH AND HARDNESS FOR NON-FERROUS METALS

Material	Cu, Ni, Bronze (cold worked)	Cu, Ni, Bronze (annealed)	Cast bronze	Al-Cu-Mg alloy	Al-Mg alloy	Cast aluminium
tensile strength σ_{ut} kgf/mm ²	0.4 BHN	0.55 BHN	0.23 BHN	0.35 BHN	0.44 BHN	0.26 BHN

MATERIALS FOR GEARS

Material	IS Specification	Tensile strength N/mm ²	Brinell hardness number
Grey Cast Iron	Grade 25	250	197
Phosphor Bronze	Sand Cast	160	60
	Chill Cast	240	70
	Centrifugally Cast	270	90
Cast steel	Grade 1	550	145
Constructional Steel	St 58	580—680	160—190
Plain Carbon Steel	C 60	600—700	180—200
Carbon steel for surface hardening	C 45	700	145 Core
	C 55	720	460 Case
			200 Core
			520 Case
Carbon steel for case hardening	C 14	500—750	650 Case
Direct hardening	40 Ni 2 Cr 1 Mo <u>28</u>	1550	444
Alloy steels	30 Ni 4 Cr 1	1000—1150	400—500
	35 Ni 1 Cr <u>60</u>	1150	400—500
	40 Ni 3	750—1050	400—500
Alloy Steels for case hardening	17 Mn 1 Cr <u>95</u>	800—1100	650 Case
	15 Ni 2 Cr 1 Mo <u>15</u>	1040	630 Case
	13 Ni 3 Cr <u>80</u>	900—1200	600—620 Case
	15 Ni 4 Cr 1	1200—1500	600—650 Case
	15 Cr <u>65</u>	600—850	650 Case
Nitriding Alloy steel	40 Cr 2 Al 1 Mo <u>18</u>	>660	750—800 Case

TYPICAL PROPERTIES OF A FEW PLASTICS

Material	Type	Condition	Tensile strength N/mm ²	Compressive strength N/mm ²	Flexure strength N/mm ²	Rockwell hardness	$E \times 10^{-3}$ N/mm ²	Specific Gravity	Trade names
Phenolformaldehyde	TS	L Sheet	98	245	162	M 100	28— 140	1.35	Bakelite, durez, Formica, textolite, Micarta, Synthane durite.
Urea formaldehyde	TS	M	63	175	70	M 118	105	1.45	Beetle, sylplast, plaskon
Poly vinyl Chloride	TP	M	56	70	—	R 65	21	1.2	Geon, Vinylite, Marvinol
Poly Vinyl Chloride (Unplasticized)	TP	M	56	91	—	M 70	56	1.41	Exon, pliovic, ulttron.
Poly methyl methacrylate	TP	M	56	98	63	M 100	28	1.16	Lucite, plexiglass, perspex
Polystyrene	TP	M	35	80	42	M 85	3.5	1.06	Lustrex, Styron, styrene, pliolite
Polyamide	TP	M	82	35	95	R 118	24	1.14	Nylon, Zetol
Cellulose Acetate	TP	M	32	140	—	R 100	14	1.27	Plastacele, Celanese, Kodapak.
Polyethylene	TP	M	12	2.8	12	R 11	1	0.92	Dylon, Alathon, Orizon
Polytetrafluoroethylene	TP	M	26	12	14	R 20	4	2.2	Teflon, (PTFE)
Polyvinylidene Chloride	TP	M	35	14	—	M 55	5	1.7	Saron
Polychlorotrifluoroethylene	TP	M	42	35	—	R 110	17	2.1	Kel-F fluorobene

NOTE: TS — Thermosetting
 TP — Thermoplastic
 L — Laminated
 M — Moulded

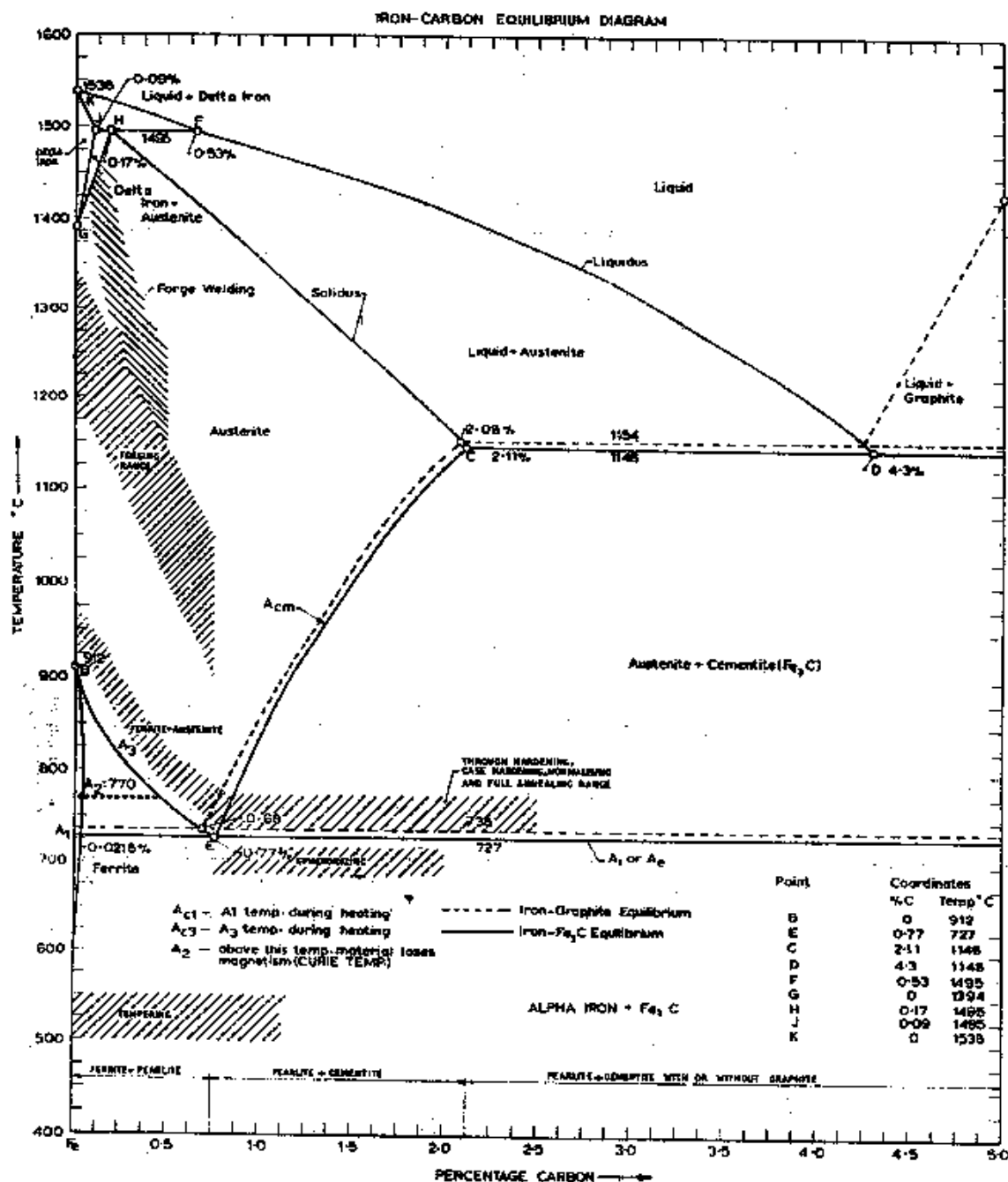
APPROXIMATE VALUES OF ENDURANCE LIMIT FOR STEELS:

Loading	Reversed cycle	Repeated cycle
Tension-compression	$\sigma_{-1t} = 0.36 \sigma_u$	$\sigma_{0t} = 0.5 \sigma_u \leq \sigma_y$
Bending	$\sigma_{-1b} = 0.46 \sigma_u$	$\sigma_{0b} \approx 0.6 \sigma_u \leq \sigma_y$
Torsion	$\tau_{-1} = 0.22 \sigma_u$	$\tau_0 = 0.3 \sigma_u \leq \sigma_y$

APPROXIMATE RELATIONSHIP BETWEEN ENDURANCE LIMITS FOR DIFFERENT MATERIALS:

Material	Relationship
Steels (Generally)	$\sigma_{-1t} = (0.7 \text{ to } 0.8) \sigma_{-1b}; \tau_{-1} = (0.55 \text{ to } 0.58) \sigma_{-1b}$
Carbon Steels	$\sigma_{0b} = 1.5 \sigma_{-1b}; \sigma_{0t} = 1.6 \sigma_{-1b}; \tau_0 = (1.8 \text{ to } 2) \tau_{-1}$
Alloy Steels	$\sigma_{-1t} = 0.95 \sigma_{-1b}; \sigma_{0b} = 1.6 \sigma_{-1b}; \tau_0 = (1.8 \text{ to } 2) \tau_{-1}$ $\sigma_{0t} = (1.5 \text{ to } 1.6) \sigma_{-1t}$
Copper Alloys	$\tau_{-1} = 0.58 \sigma_{-1b}; \tau_0 = (1.4 \text{ to } 2) \tau_{-1}$
Aluminium Alloys	$\sigma_{0b} = 1.8 \sigma_{-1b}; \sigma_{-1t} = 0.7 \sigma_{-1b}; \tau_{-1} = (0.55 \text{ to } 0.58) \sigma_{-1b}$ $\tau_0 = (1.4 \text{ to } 2) \tau_{-1}$
Grey Cast Iron	$\sigma_{-1t} = (0.6 \text{ to } 0.7) \sigma_{-1b}; \sigma_{0b} = (1.2 \text{ to } 1.5) \sigma_{-1b}; \frac{\sigma_{-1b}}{\sigma_u} \approx 0.38$ $\tau_{-1} = (0.75 \text{ to } 0.9) \sigma_{-1b}; \tau_0 = (1.2 \text{ to } 1.3) \tau_{-1}$
Endurance strength for finite life $\sigma'_{-1} = \sigma_{-1} \left(\frac{10^6}{N} \right)^{0.09}$ where N is the required life in cycles.	

HEAT TREATMENT - 2

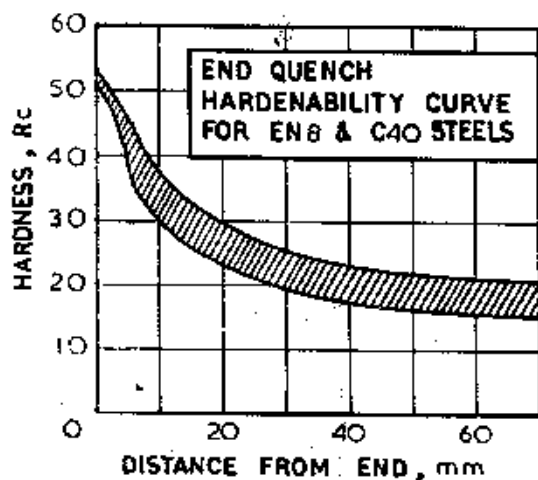
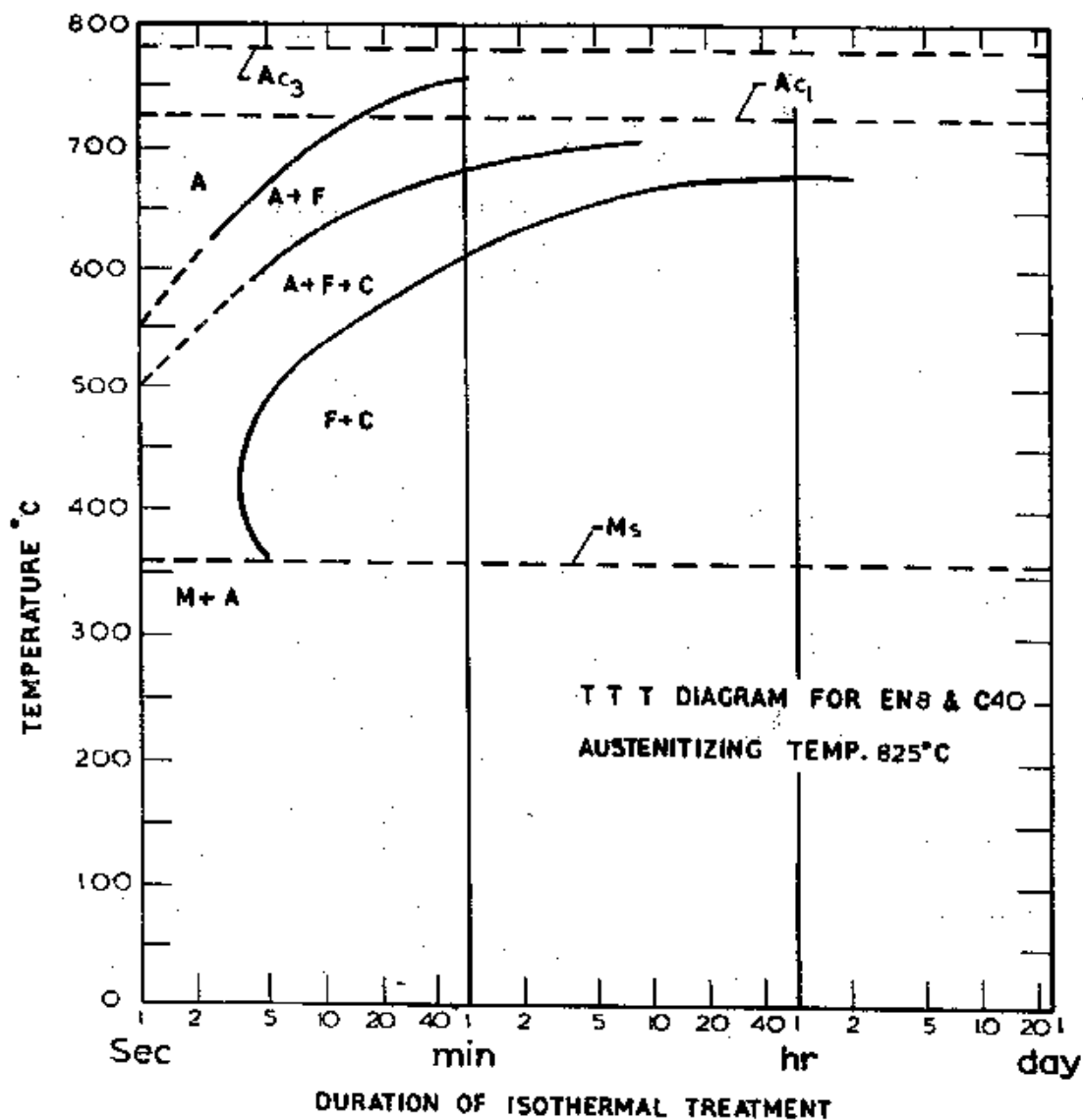


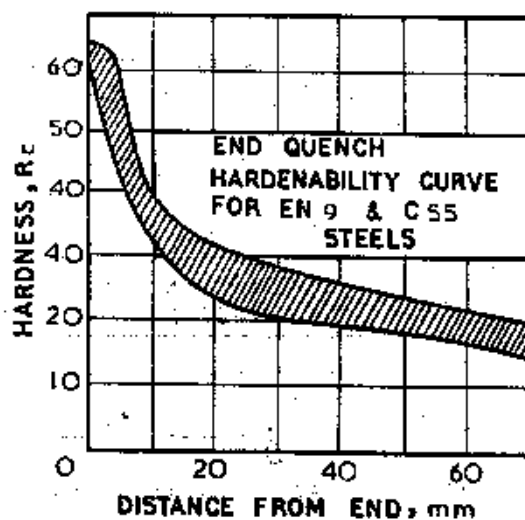
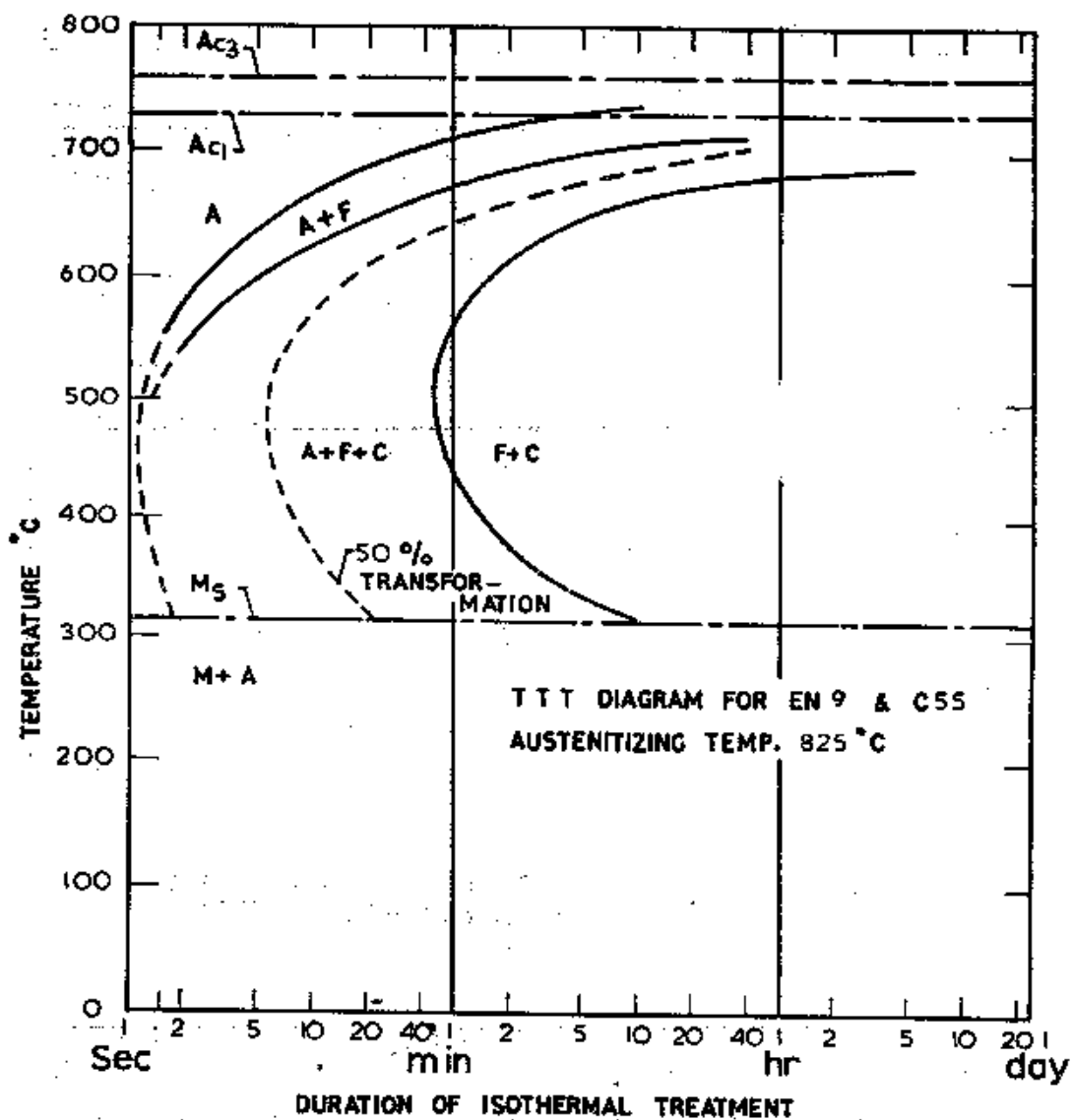
STRUCTURAL CONSTITUENTS OF IRON-CARBON ALLOYS

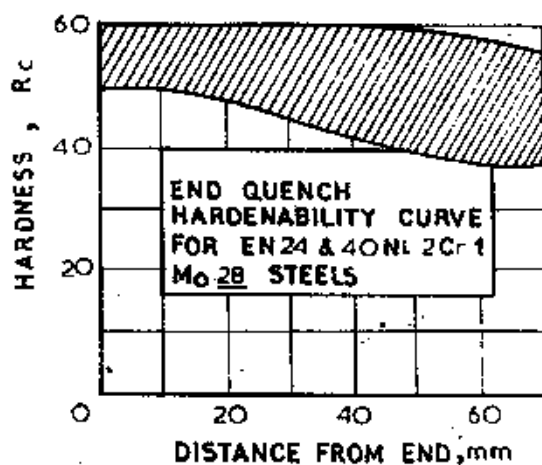
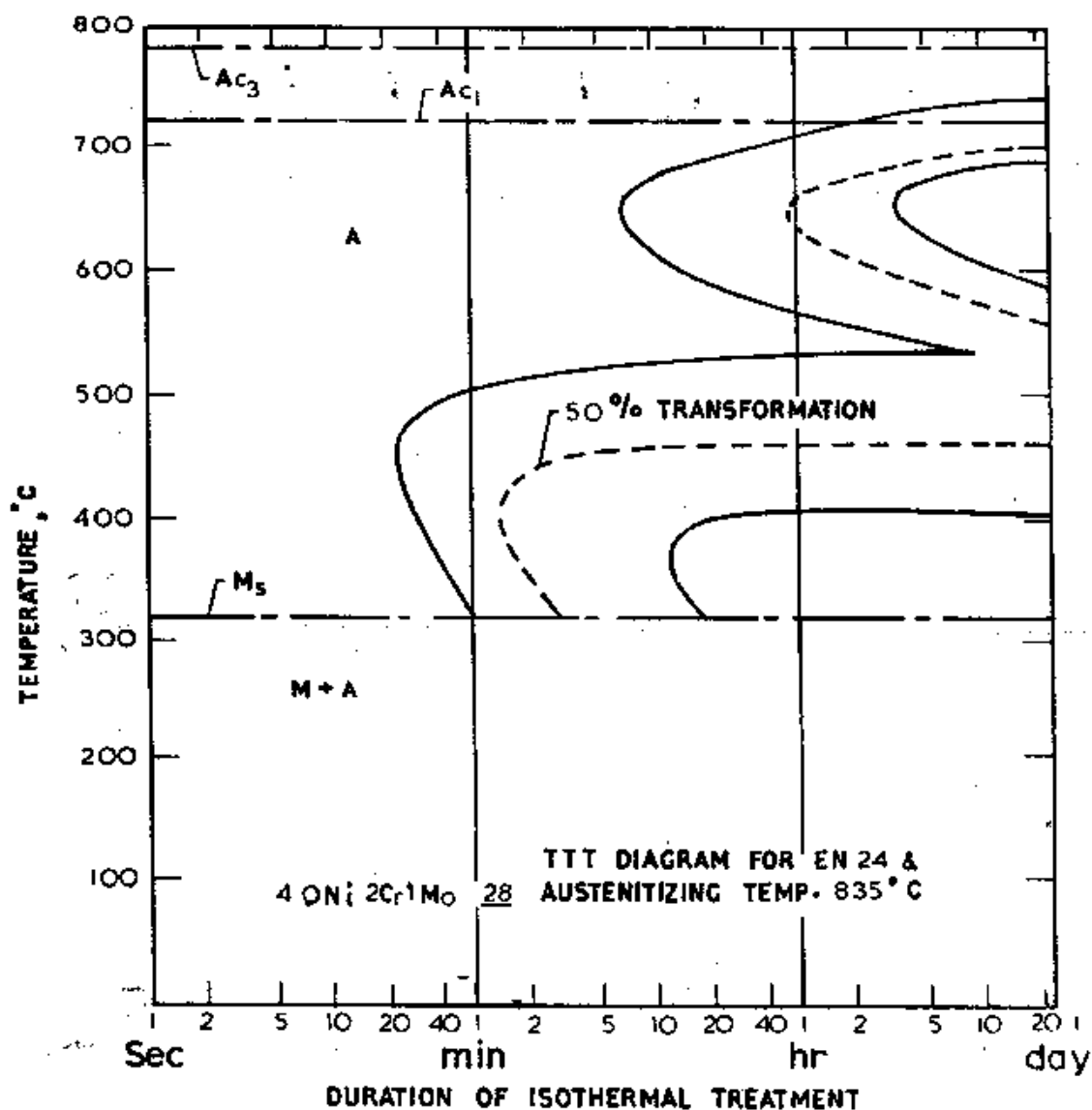
Structure	Definition	Conditions of formation	Stable at temp. °C	Physical Properties	BHN
Austenite	Solid solution of carbon and other elements in gamma iron Carbon Content upto 2%	on heating above critical points.	Above AC ₃ , AC _m and AC ₁ AC ₁ = 723 AC ₃ = 910—723 AC _m = 723—1130	Soft, non-magnetic malleable but poorly ductile. High elec. resistance.	170—220
Ferrite	Solid solution of Carbon and other elements in alpha iron Carbon content upto 0.04%	Rejected by austenite on slow cooling of hypoeutectoid steel below Ar ₃	Below AC ₃	Soft, Very malleable magnetic	60—100
Cementite	Chemical combination of iron Carbon. Iron carbide Fe ₃ C contains 6.67% Carbon.	Rejected by liquid and solutions on slow cooling	—	Hard, brittle Magnetic upto 210°C. On heating above 210°C becomes non magnetic	820
Pearlite	Eutectoid mixture of Cementite and ferrite	Formed on decay of austenite.	Below 723	Harder and stronger than ferrite but less ductile Magnetic	160—230
Martensite	Solid solution of Carbon and other elements in alpha iron with distorted lattice.	Formed on very rapid of austenite from above its critical temperatures.	Below 150	Brittle, hard. Hardness depends on Carbon content. Magnetic; heat & elect conductivities are low	650—700
Troostite	Highly dispersed mixture of ferrite and Carbides	Formed on heating of martensite in the 250—400°C range or on slow Cooling of austenite.	Upto 400°	Magnetic. Less stronger more ductile and higher in elec. conductivity than martensite	330—400
Bainite (acicular troostite)	—do—	Formed on iso thermal transformation of austenite in the 250—400 °C range.	Upto 500	Hard, fairly ductile, magnetic	Harder than troostite.
Sorbite	Fine mixture of ferrite & Cementite	Formed on heating of martensite in the 400 °C—AC ₁ range or on very slow cooling of austenite.	Upto AC ₁	Ductile and resilient Less stronger and harder than troostite; Magnetic	270—320
Ledeburite	An austenite—Cementite eutectic mixture; 4.3%C	Formed on solidification of liquid alloys containing >2%C	below 1130°	Brittle	—

CHOICE OF ANNEALING TREATMENTS

Type of annealing	Steels subject to the process	Heating temp °C	Cooling rate	Purpose
Full annealing	Hypoeutectoid, eutectoid, small and medium size steel castings.	$AC_3 + 20$ to 30 $AC_1 + 20$ to 30	Down to 500–600 °C at a rate i) 50–100 °C/hr for carbon steels ii) 20–60 °C/hr for alloy steels	1) Softening 2) Stress relieving 3) Structure improvement
Process annealing	Hypoeutectoid	Between AC_1 and AC_3	—do—	1) softening 2) stress relieving
Spheroidizing (globular pearlitic annealing)	Hyper-eutectoid	$AC_1 + 10$ to 20	Down to 500–600 °C at a rate 20–30 °C per hour	1) Softening 2) Improvement of machinability 3) Improvement of cold broaching 4) Preparation of structure for subsequent hardening.
Isothermal annealing	Chiefly for alloy steels	1. $AC_3 + 20$ to 30 2. $AC_1 - 20$ to 30	Rapid cooling down to A_{r1} —20–30 °C holding at the said temperature followed by air cooling	Same as for full annealing.
Inter-diffusion annealing (homogenisation)	Large steel castings and ingots	$AC_3 + 150$ to 250	In the furnace	To eliminate coarse cast structure and segregation
High tempering (Low temperature annealing)	Hyper-eutectoid and high alloy Structural steels	$AC_1 - 15$ to 30	In the furnace or air	1) Softening 2) Stress Relieving 3) Improvement of machinability.
Recrystallisation annealing	All grades of steel following cold working	—	—	Regeneration of structure after cold working.







SALT MIXTURES FREQUENTLY USED FOR HEATING IN SALT BATHS FOR HARDENING

Mixture components	Chemical formula	Weight %	Melting point °C	Recommended temp. range °C
Common Salt	NaCl	50	560	590 — 900*
Soda ash	Na ₂ CO ₃	50		
Common Salt	NaCl	50	595	630 — 850
Calcium chloride	CaCl ₂	50		
Common Salt	NaCl	22.5	635	665 — 870
Barium Chloride	BaCl ₂	77.5		
Common Salt	NaCl	44	660	720 — 900
Potassium Chloride	KCl	56		
Common Salt	NaCl	100	800	830 — 1100
Barium Chloride	BaCl ₂	100	962	1100 — 1350

COMPOSITIONS & OPERATING TEMPERATURES FOR SALT BATHS USED IN HEAT TREATMENT

Composition of bath, %									Operating temp. °C	Furning temp. °C
Sodium Nitrite	Sodium Nitrate	Potassium Nitrate	Sodium Carbonate	Sodium chloride	Potassium chloride	Barium chloride	Calcium chloride			
37—50	0—10	50—60	—	—	—	—	—	163 to 595	635	
—	45—57	45—57	—	—	—	—	—	285 to 595	650	
				10—15	25—30	40—45	15—20	550—755	790	
			45—55	—	45—55	—	—	620—930	940	
			15—25	20—32	50—60	—	—	595—900	940	

APPROXIMATE HEATING TIME FOR STEELS IN VARIOUS TYPES OF FURNACES

	Furnace Temp °C	Heating time per mm dia or thickness of article, sec		
		Round section	Square Section	Rectangular Section
Electric Furnace	800	40—50	50—60	60—75
Oil Furnace	800	35—40	45—50	55—60
Salt Bath	800	12—15	15—18	18—22
Lead Bath	800	6—8	8—10	10—12
Salt Bath	1300	6—8	8—10	10—12

CHARACTERISTICS OF COMMON METALS WITH THEIR ANNEALING AND HOT WORKING TEMPERATURES

Metal	Workability at room temperature	Lowest re-crystallisation temperature °C	Usual annealing temperature after cold-working °C	Usual hot-working temperature range °C
Aluminium	Very good	150	350	320-480
Brass	Very good	200	540-680	590-900
Bronze	Fair	400	540-680	590-900
Copper	Very good	200	540-760	430-1040
Duralumin	Good	260	340-355	320-455
Gold	Excellent	200	260-540	*
Iron	Good	450	590-760	820-1320
Lead	Excellent	Below room temperature	Anneals itself	*
Monel-Metal	Fair	430	730-790	870-1150
Nickel	Fair	590	590-950	870-1260
High carbon steel	Poor	540	590-760	760-1090
Silver	Excellent	200	260-540	*
Tin	Excellent	Below room temperature	Anneals itself	*
Tungsten	Poor	1200	1205-1370	590-1590
Wrought iron	Poor	480	Not cold-worked	900-1340

* Heating not necessary.

HARDENING AND TEMPERING TREATMENTS FOR CARBON AND ALLOY STEELS

(Hot Working Temperature Range for all the following Steels is 1200°—850°C
except for those underlined below)

Designation	Normalising °C	Hardening °C	Quenching Medium	Tempering °C
C30	860–890	860–890	Water or Oil	550–660
C35 Mn <u>75</u>	850–880	840–880	Water or Oil	530–760
C40	830–860	830–860	Water or Oil	550–660
C45	830–860	830–860	Water or Oil	530–670
C50	810–840	810–840	Oil	550–660
C55 Mn <u>75</u>	810–840	810–840	Oil	550–660
40 S <u>18</u>	830–860	830–860	Oil	550–660
40 Mn 2 S <u>12</u>	840–870	840–870	Oil	550–660
20 Mn 2	860–900	860–900	Water or Oil	550–660
27 Mn 2	840–880	840–880	Water or Oil	550–660
37 Mn 2	850–870	850–870	Water or Oil	550–660
40 Cr 1	850–880	850–880	Oil	550–700
35 Mn 2 Mo <u>28</u>	—	840–860	Water or Oil	550–600
35 Mn 2 Mo <u>45</u>	—	840–860	Oil	550–660
40 Cr 1 Mo <u>28</u>	850–880	850–880	Oil	550–720
40 Ni 3	830–860	830–860	Oil	550–650
35 Ni 1 Cr <u>60</u>	—	820–850	Water or Oil	550–660
40 Ni Cr 1 Mo <u>15</u>	—	830–850	Oil	550–660
40 Ni 2 Cr 1 Mo <u>28</u>	—	830–850	Oil	550–660* or 150–200
31 Ni 3 Cr <u>65</u> Mo <u>55</u>	—	830–850	Oil	up to 660
30 Ni 4 Cr 1	—	810–830	Air or Oil	Above 250
15 Cr 3 Mo <u>55</u>	—	890–910	Oil	550–700*
25 Cr 3 Mo <u>55</u>	—	890–910	Oil	550–700*
40 Cr 3 Mo 1 V <u>20</u>	—	900–940	Oil	570–650
40 Cr 2 Al 1 Mo <u>18</u>	—	850–900	Oil	550–700
55 Cr <u>70</u>	800–850	800–850	Oil	500–700
105 Cr 1	—	820–860	Water or Oil	Above 150 in Oil
105 Cr 1 Mn <u>60</u>	—	800–840	Water or Oil	130–180

* Stabilisation 550°C

COLOUR CODING FOR STEEL, IS — 2049 — 1963

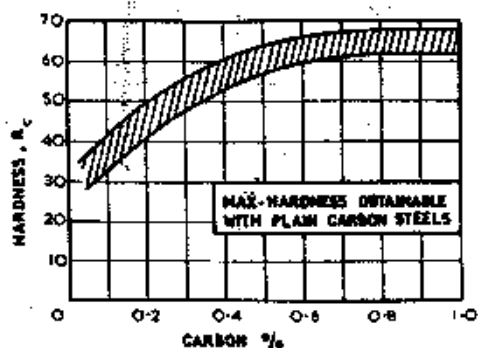
Material	Colour
C45 (EN 8, En 9)	RED
14Mn 1 5 14 (Free Cutting)	YELLOW
40 Ni 2 Cr 1 Mo 28 (En 24)	BLUE
15 Ni 2 Cr 1 Mo 15 (En 36)	GREY
Carbon Tool Steel	GREEN
High speed steel	GREEN & GREY
Stainless steel	ORANGE
Die steel	WHITE

COLOUR OF HEATED STEELS & THEIR TEMPERATURE

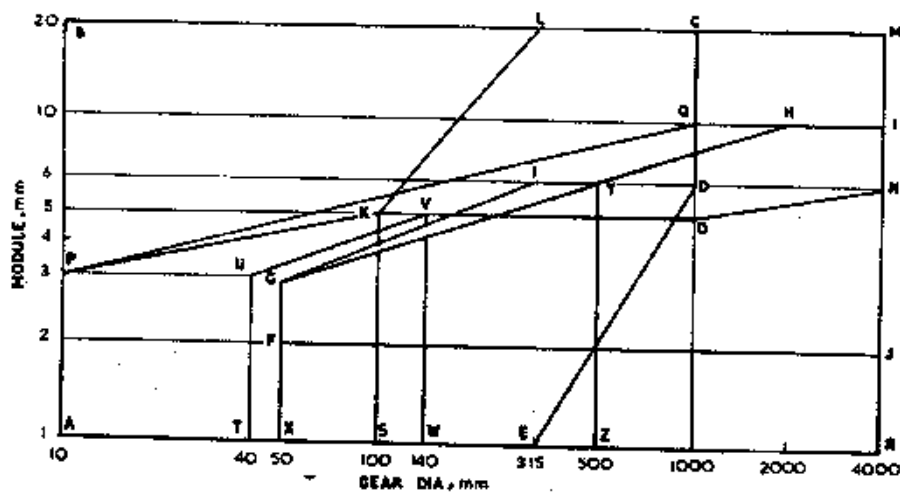
Colour of Steel	Black Red	Blood Red	Dark Red	Dark Cherry Red	Full Red	Light Red	Orange	Light Orange	Yellow	Light yellow	WHITE
Temp. Range °C	550—580	580 to 650	650 to 730	730 to 770	770 to 800	800 to 830	830 to 900	900 to 1050	1050 to 1150	1150 to 1250	1250 to 1300

COLOUR OF STEEL DURING TEMPERING

Colour	Pale yellow	Straw yellow	Yellow Brown	Spotted Red Brown	Light purple	Dark purple	Dark Blue	Pale Blue	Grey
Temp. °C	220	240	255	265	275	285	295	315	330



SURFACE HARDENING PROCESSES FOR GEARS

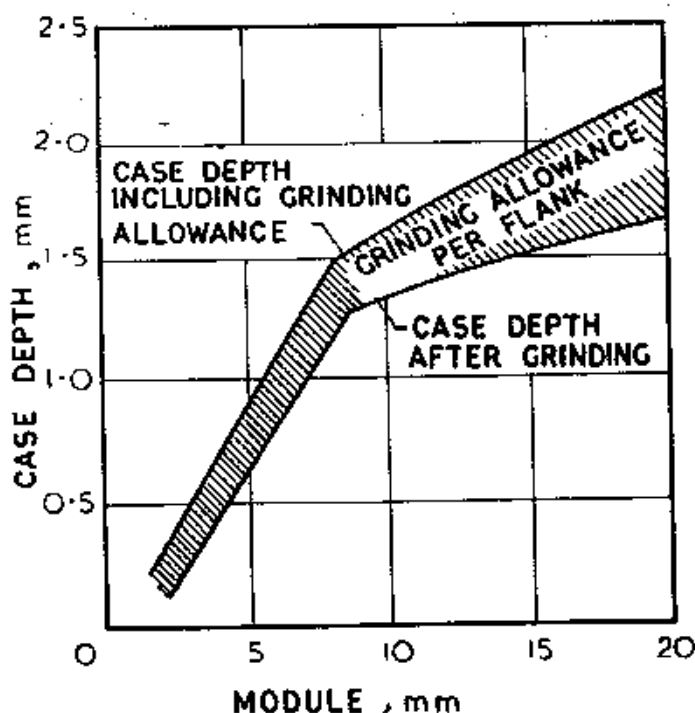


ABCDE = Case hardening
 FGHIJ = HF progressive hardening
 (single tooth)
 KLMNO = MF
 APQIR = Nitriding

APKS = HF-spin hardening
 TUVW = MF
 XGYZ = Flame

SURFACE HARDNESS OBTAINABLE BY FLAME OR INDUCTION HARDENING OF STEELS

Designation	Rockwell hardness Rc
C 30	45 — 50
C 35 Mn <u>75</u>	51 — 57
C 45	55 — 61
C 55	57 — 62
T 70	60 — 63
37 Mn 2	53 — 59
47 Mn 2	54 — 60
40 Mn 2 S <u>12</u>	53 — 59
35 Mn 2 Mo <u>28</u>	53 — 59
35 Mn 2 Mo <u>45</u>	53 — 59
40 Cr 1	54 — 60
50 Cr 1	57 — 62
50 Cr 1 V <u>23</u>	57 — 62
40 Cr 1 Mo <u>28</u>	54 — 60
40 Ni 3	54 — 60
35 Ni 1 Cr <u>60</u>	54 — 60
40 Ni 1 Cr 1 Mo <u>13</u>	54 — 60
40 Ni 2 Cr 1 Mo <u>28</u>	54 — 60
31 Ni 3 Cr <u>65</u> Mo <u>55</u>	49 — 54



SELECTION OF HEAT TREATMENT FOR FERROUS COMPONENTS

REQUIREMENT	PROCESS											APPLICATION	
	Annealing	Normalising	Hardening	tempering	Aus-tempering	Mar-tempering	Flame hardening	Induction hardening	Carburising	Cyaniding	Nitriding		colouring
improvement in general mechanical properties.		x	x	x	x	x	x	x	x	x	x		Crankshafts, gears, springs, spindles.
Stress relieving, machinability, ductility.	x												Castings, deep drawn components.
increased notch-toughness at a given high hardness without crack.					x								Springs, fasteners, levers, chain links, socket wrench, cylinder liner, pins
minimum distortion during quenching						x							for parts with section thickness less than 5 mm.
toughness for the hardened component				x									full hardened, surface or case hardened parts.
hardness & wear resistance of surface			x			x	x	x	x	x	x		gears, rocker arms, m/c beds. followed by hardening
anti galling property				x							x		
Corrosion & fatigue resistance				x							x	x	

OPERATING DATA FOR PROGRESSIVE INDUCTION TEMPERING

Section size, mm	Material	Frequency Hz	Power kW	Total heating time, sec.	Scan time sec/cm	Work temp. °C		Production kg/hr	Operating efficiency kgf/kWh	Inductor input kW/cm ²
						Entering coil	Leaving coil			
12.5 (round)	30Cr1Mo21	9600	11.0	17.0	0.4	50	560	90	8.2	0.06
18 (round)	C35	9600	12.7	30.6	0.7	50	510	113	8.9	0.05
25 (round)	C40	9600	18.7	44.0	1.0	50	560	140	7.5	0.03
28 (round)	C40	9600	20.6	51.0	1.2	50	560	152	7.4	0.03
16 (Flat)	C40	60	88.0	123.0	0.6	40	290	1430	16.3	0.013
18 (Flat)	C40	60	100.0	164.0	0.8	40	315	1560	15.6	0.012
20 (Flat)	C45	60	98.0	312.0	1.5	40	290	1600	16.4	0.008
25 (Flat)	C35	60	85.0	254.0	1.2	40	290	1360	16.4	0.011
28 (Flat)	C35	60	90.0	328.0	1.6	40	290	1480	16.3	0.009
16-31.5 (irregular)	C37	9600	192.0	64.0	0.9	65	550	2200	11.5	0.04

COMPOSITION OF SOLID CARBURISERS

Type	Ingredients, % by weight							Remarks
	Charcoal	Barium carbonate	Sodium Carbonate	Calcium Carbonate	Peat coke	Activated bituminous coke	Fuel oil	
I	74—78	12—15	1—1.5	3—5	—	—	4.5—5	Ready made
II	90	—	10	—	—	—	—	to be prepared
III	90	10	—	—	—	—	—	"
IV	—	10—15	—	—	—	90—85	—	"
V	—	—	10—15	—	90—85	—	—	Ready made

LIQUID NITRIDING

MATERIAL	Time, minutes		Temp. °C	Case depth, microns	
	min.	Max		min	max
Carbon & low alloy steels	60	120	566	5	13
Die steel	30	180	538—566	3	8
Tool steel	5	30	538	—	3
Corrosion & heat resistant steels	60	120	566	5	15
Spheroidal, malleable & grey cast iron	120	240	566	3	8

COMPOSITION OF SALTS BY WIEGHT FOR NITRIDING AT 565 °C

for general Purpose		for tool steels
*Sodium salt	60 — 70%	NaCN—30%; Na ₂ CO ₃ or K ₂ CO ₃ —25% max.
+Potassium salt	40 — 30%	moisture — 2%; other activators — 4% max.
		KCl — remainder.

* Constituents:

NaCN — 96.5%; Na₂ CO₃ — 2.5%
NaCNO — 0.5%

+KCN — 96%; K₂ CO₃ — 0.6%;
KCNO — 0.75%; KCl — 0.5%.

PROCESSES OF HEAT-TREATMENT FOR ALUMINIUM ALLOY CASTINGS

Heat-treating process	Alloy, %	Hardening		Age-hardening or annealing		Brinell Hardness
		Temp. °C	Holding time, hours	Temp. °C	Holding time, hours	
Ageing without preliminary hardening	5Si, 1.5—3.5 Cu, 0.2—0.8Mg	—	—	180	5	70
	0.2—0.8 Mn	—	—	178	15	70
	—do—	—	—	180	15	65
Annealing	5Si, 1.5 Cu, 0.5 Mg	—	—	290	2—4	65
	5Si, 2Cu, 0.2—0.8 Mg, 0.2—0.8 Mn	—	—	290	3	45
	5Si, 2—3 Cu	—	—	—	—	—
Hardening	4—5 Cu	515	10—15	—	—	60
	9.5 — 11.5 Mg	440	15—20	—	—	60
	7Si, 0.2—0.4 Mg	535	12	—	—	50
Hardening & partial ageing	7Si, 10—14 Zn, 0.1—0.3Mg	515	2—4	220	2—4	95
	5Si, 2 Cu, 0.2—0.8 Mg, 0.2—0.8 Mn	515	4—6	180	5	75
	5Si, 1.5 Cu, 0.5 Mg	525	4	180	5	70
	4—5 Cu	515	10—15	150	2—4	70
	7Si, 0.2—0.4 Mg	535	12	150	1—3	60
Hardening and full ageing	9Si, 0.17—0.3 Mg, 0.25 — 0.5 Mn	535	2—6	175	15	70
Hardening and stabilising	9 — 11 Cu	515	10—15	150	2—4	100
	5Si, 2Cu, 0.2—0.8 Mg, 0.2 — 0.8 Mn	525	4—6	230	5	70
Hardening and tempering	5Si, 1.5 Cu, 0.5 Mg	525	4	230	5	65
	5Si, 2 Cu, 0.2 — 0.8 Mg, 0.2 — 0.8 Mn	500	5—6	330	3	65

TYPICAL STRESS RELIEVING TEMPERATURES FOR WROUGHT COPPER ALLOYS

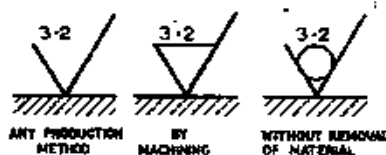
ALLOYS	Commercial Bronze, 90%	Red Brass 85%	Low Brass 80%	Cartridge brass, 70%	Yellow Brass 65%	Muntz metal 60%	Free cutting brass,	Phosphor Bronze,	Cupro- Nickel	Nickel Silver.
STRESS RELIEVING TEMP °C for one hour holding	200	225	250	260	260	200	250	190	250	250

DEFECTS IN HEAT-TREATMENT OF STEELS

Defect	Chief cause	Measures to prevent and correct the defect
1. Annealing and Normalising Defects of Steels		
Low ductility, the fracture being relatively fine-grained	Underheat. Annealing temp. below that required or insufficient holding.	Repeat annealing or normalising at normal temperatures
Coarse-grained fracture. Low ductility and, particularly, impact strength	Overheat. Considerable overheating or excessive holding time.	Repeat annealing or normalising at normal temperature. In case of considerable overheating use double annealing, the first one at a temperature by 50–150°C above the normal.
Very coarse and bright fracture	Overheat. Heating of steel in an oxidising atmosphere at high temperatures, in the proximity of the melting point.	No remedy.
High hardness	Excessive cooling rate	Repeat annealing at the required cooling rate.
2. Defects in Annealing of Tool and High-Speed Steels		
High hardness	1 Underheat. 2 Excessive cooling rate in normal annealing or insufficient holding in isothermal annealing.	Repeat annealing at a requisite temperature and follow strictly the prescribed cooling schedule, or temper at high temperature.
Carbide lattice	Heating above A_{cm}	Normalising or hardening with subsequent tempering at 670–700°C, holding time not less than 2 hrs.
Cracking	Stresses caused by changes in volume arising from transformation of austenite to martensite at temperatures below 250°C.	Irreparable defect. Preventive measures. 1. Whenever possible use step-hardening, as well as intermittent hardening in two quenching media. 2. Avoid manufacturing parts with acute angles sharp changes in section; when this is unavoidable, use only alloy steel. 3. No water should be present in the oil quenching tank.

FITS AND TOLERANCES - 3

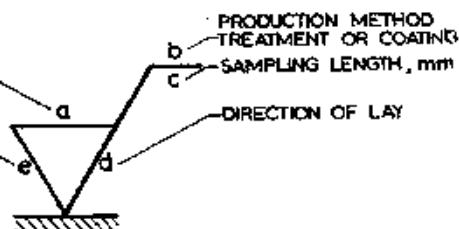
SPECIFIED ROUGHNESS TO BE OBTAINED BY



MACHINING SYMBOL :

ROUGHNESS VALUE R_a IN MICRONS or ROUGHNESS GRADE SYMBOL N1 to N12

MACHINING ALLOWANCE in mm



SYMBOLS USED TO DENOTE SURFACE ROUGHNESS

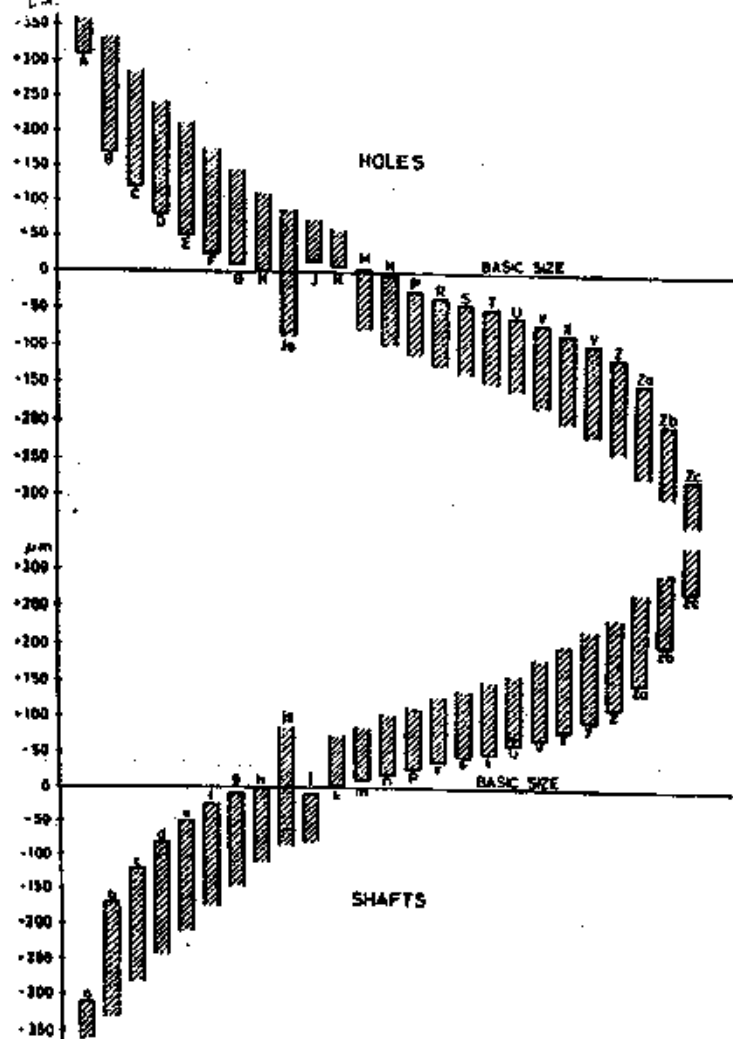
OLD METHOD														
PRESENT METHOD	in μm	0.012	0.025	0.05	0.1	0.2	0.4	0.8	1.6	3.2	6.3	12.5	25	50
	in GRADES	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12	

SYMBOL	INTERPRETATION	
—	PARALLEL TO THE PLANE OF PROJECTION OF THE VIEW IN WHICH THE SYMBOL IS USED	
⊥	PERPENDICULAR TO THE PLANE OF PROJECTION OF THE VIEW IN WHICH THE SYMBOL IS USED	
X	CROSSED IN TWO SLANT DIRECTIONS RELATIVE TO THE PLANE OF PROJECTION OF THE VIEW IN WHICH THE SYMBOL IS USED	
M	MULTI-DIRECTIONAL	
C	APPROXIMATELY CIRCULAR RELATIVE TO THE CENTRE OF THE SURFACE TO WHICH THE SYMBOL IS APPLIED	
R	APPROXIMATELY RADIAL RELATIVE TO THE CENTRE OF THE SURFACE TO WHICH THE SYMBOL IS APPLIED	

OBTAINABLE RANGE OF SURFACE ROUGHNESS, R_a IN MICRONS

Manufacturing Process		with Difficulty	Normally	Roughing
CASTING	Sand casting		6.3 — 12.5	12.5 — 25
	permanent mould	0.8 — 1.6	1.6 — 6.3	
	Die casting		0.8 — 3.2	
FORMING	Forging	1.6 — 3.2	3.2 — 25	
	Extrusion	0.4 — 0.8	0.8 — 6.3	
	Rolling	0.4 — 0.8	0.8 — 3.2	
MANUAL	Flame Cut		25 — 50	
	Hack Saw Cut		6.3 — 50	
	Bandsaw, Chipping		3.2 — 50	
	Filing	0.8 — 1.6	1.6 — 12.5	
	Emery Polish	0.1 — 0.4	0.4 — 1.6	1.6 — 3.2
SURFACE PROCESS	Shot Blast	1.6 — 3.2	3.2 — 50	
	Tumbling		0.2 — 12.5	
	Abrasive Belt		0.1 — 6.3	
	Fibre Wheel brushing	0.1 — 0.2	0.2 — 0.8	0.8 — 1.
	Cloth buffing	0.012 — 0.05	0.05 — 0.1	
MACHINING	SHELL MILLING	1.6 — 3.2	3.2 — 25	25 — 50
	DRILLING	3.2 — 6.3	6.3 — 25	
	PLANING & SHAPING		1.6 — 12.5	
	FACE MILLING	0.8 — 1.6	1.6 — 12.5	12.5 — 50
	TURNING	0.2 — 1.6	1.6 — 6.3	6.3 — 50
	BORING	0.2 — 1.6	1.6 — 6.3	6.3 — 50
	REAMING	0.4 — 0.8	0.8 — 6.3	6.3 — 12.5
	CYL. GRINDING	0.025 — 0.4	0.4 — 3.2	3.2 — 6.3
	CENTRELESS GRINDING	0.05 — 0.4	0.4 — 3.2	
	INTERNAL GRINDING	0.025 — 0.4	0.4 — 3.2	3.2 — 6.3
	SURFACE GRINDING	0.025 — 0.4	0.4 — 3.2	3.2 — 6.3
	BROACHING	0.2 — 0.8	0.8 — 3.2	3.2 — 6.3
	SUPER FINISHING	0.025 — 0.1	0.1 — 0.4	
	HONING	0.025 — 0.1	0.1 — 0.4	
GEAR MANUFACTURE	LAPPING	0.006 — 0.05	0.05 — 0.4	
	MILLING, SPIRAL BEVEL	1.56 — 3.2	3.2 — 12.5	12.5 — 25
	MILLING with FORM CUTTER	1.6 — 3.2	3.2 — 12.5	12.5 — 50
	HOBGING	0.8 — 3.2	3.2 — 12.5	12.5 — 50
	SHAPING	0.4 — 1.6	1.6 — 12.5	12.5 — 250
	PLANING	0.4 — 1.6	1.6 — 12.5	12.5 — 50
	SHAVING	0.4 — 0.8	0.8 — 3.2	
	GRINDING, Criss Cross	0.4 — 0.8	0.8 — 1.6	
	GRINDING	0.1 — 0.4	0.4 — 0.8	
	LAPPING	0.05 — 0.2	0.2 — 0.8	

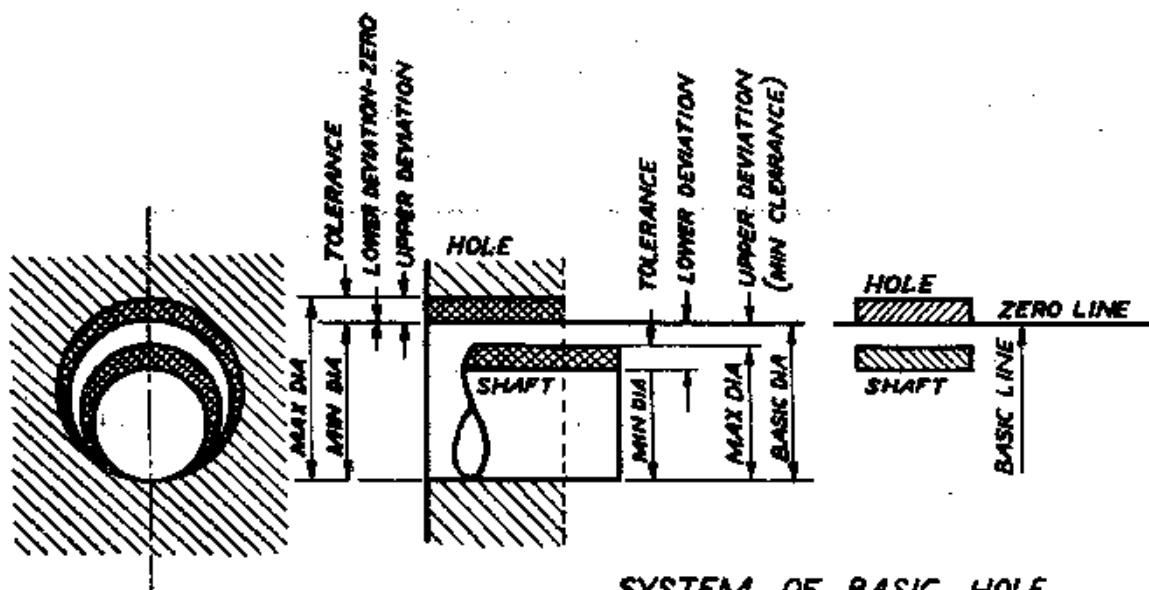
LETTER SYMBOLS FOR TOLERANCES



FUNDAMENTAL TOLERANCES OF GRADES IT, H AND h TO 16

Diameter Steps in mm	Values of Tolerances in Microns (1 micron = 0.001 mm)															
	Tolerance Grades															
	IT	H	1	2	3	4	5	6	7	8	9	10	11	12	13	14*
To and inc 3	0.3	0.5	0.8	1.2	2	3	4	6	10	14	25	40	60	100	140	250
Over 3	0.4	0.6	1	1.5	2.5	4	5	8	12	18	30	48	75	120	180	300
To and inc 6	0.4	0.6	1	1.5	2.5	4	6	9	15	22	36	58	90	150	220	360
Over 6	0.5	0.8	1.2	2	3	5	8	11	18	27	43	70	110	180	270	430
To and inc 10	0.6	1	1.5	2.5	4	6	9	13	21	33	52	84	130	210	330	520
Over 10	0.8	1.2	2	3	5	8	11	16	25	39	62	100	160	250	390	620
To and inc 18	0.8	1.2	2	3	5	8	11	16	25	39	62	100	160	250	390	620
Over 18	1	1.5	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870
To and inc 30	1	1.5	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870
Over 30	1.2	2	3	5	8	12	18	25	40	63	100	160	250	400	630	1000
To and inc 50	1.2	2	3	5	8	12	18	25	40	63	100	160	250	400	630	1000
Over 50	1.5	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870	1400
To and inc 80	1.5	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870	1400
Over 80	2	3	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600
To and inc 120	2	3	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600
Over 120	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200
To and inc 180	2.5	4	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200
Over 180	3	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500
To and inc 250	3	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500
Over 250	4	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200	3500
To and inc 315	4	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200	3500
Over 315	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500	4000
To and inc 400	5	8	12	18	25	40	63	100	160	250	400	630	1000	1600	2500	4000
Over 400	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200	3500	5400
To and inc 500	6	10	15	22	35	54	87	140	220	350	540	870	1400	2200	3500	5400

*Up to 1 mm, Grades 14 to 16 are not provided.



SYSTEM OF BASIC HOLE

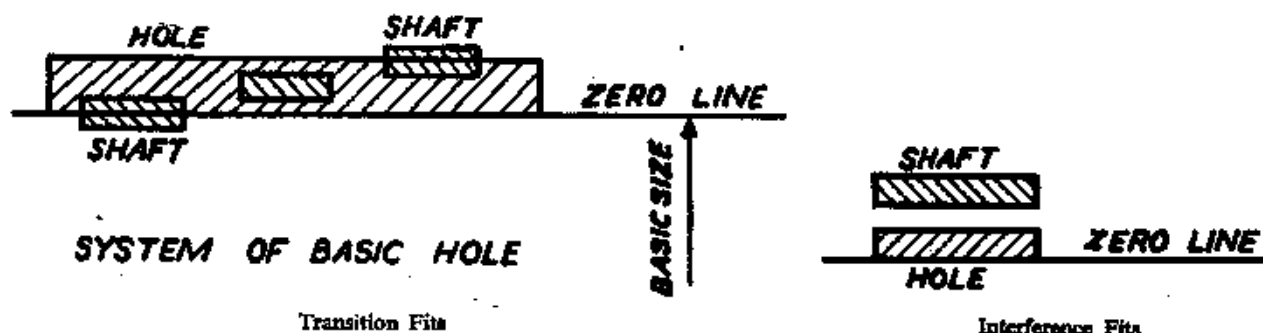
RUNNING AND SLIDING FITS

Combination of Hole and shaft	Quality of fit	Typical uses
H6 g5 Fine H7 g6 Normal H8 g7 Coarse	Precision	Small clearance-used in precision equipment under very light load-Bearings for accurate link work and for piston and slide valves-Also used for spigot or location fits.
H6 f6 Fine H7 f7 Normal H8 f8 Coarse	Close running	Widely used as grease or oil lubricated bearings having low temperature differences-bearings for gear shafts, small electric motor shafts and pump shafts.
H7 e7 Fine H8 e8 Normal H9 e9 Coarse	Normal running	Used for properly lubricated bearings with appreciable clearance. Finer grades for high speeds and heavy loads-Turbo generator and large electric motor bearings.
H8 d8 Fine H8 d9 Normal H9 d9 Coarse	Loose running	For plummer block bearings and loose pulleys.
H8 c8 } H8 b8 } Fine H9 a9 } H9 c9 } H11 c11 } Normal H11 e9 } H11 b9 } Coarse H11 a9 }	Slack running or positional fit	Large clearance-not widely used.

LOCATIONAL AND ASSEMBLY FITS

Combination of Hole and Shaft	Quality of fit	Typical uses
H6 h5	Precision location	All these fits are widely used for non running parts, for normal location and spigot fits—In finer grades, used as a precision sliding fit.
*H6 h6		
H7 h6	Close location	
*H7 h7		
H8 h7	Normal location	
*H8 h8		
H9 h8	Loose location	
*H9 h9		
*H11 h9	Slack assembly	
*H11 h11		
*H8 b9	Positional fits	
*H8 a9		

* Preferred combinations.



TRANSITION AND INTERFERENCE FITS

Combination of Hole and Shaft	Quality of fit	Typical uses
H6 j5 Fine	Clearance transition	Very small clearance is obtained - used for fits where a slight interference is permissible - coupling spigots and recesses, gear rings clamped to steel hubs.
H7 j6 Normal		
H8 j7 Coarse		
H6 k5 Fine	True transition	Fits averaging no clearance where slight interference can be tolerated, with the object of eliminating vibration - ball bearing races of light duty
H7 k6 Normal		
H8 k7 Coarse		
H6 m5 Fine	Interference transition	Fits averaging slight interference - used for ball bearing races of medium duty.
H7 m6 Normal		
H8 m7 Coarse		

TRANSITION AND INTERFERENCE FITS (Contd.)

Combination of hole and shaft	Quality of fit	Typical uses
H6 p5 Fine H7 p6 Normal	Press fit	Light press fit for nonferrous parts which can be dismantled when required-bearing bushes-press fit for steel, cast iron or brass to steel assemblies-bush in a gear.
H6 r5 Fine H7 r6 Normal	Drive fit	Medium drive fit for ferrous parts and light drive fit for non-ferrous parts that can be dismantled.
H6 s5 Fine H7 s6 Normal	"	Permanent or semi permanent assemblies of steel and cast iron with considerable gripping force-collars pressed on to shafts, valve seatings etc. For light alloys this gives a press fit.
H6 u5 Fine H7 u6 Normal	Force or shrink fit	High interference fit. A thorough investigation into the degree of grip and the stresses in the part must be made.

For Grades 5 to 16, standard tolerance unit i , is $i = 0.45 \sqrt[3]{D} + 0.001 D$
 i in microns ; D in mm.

IT GRADE	5	6	7	8	9	10	11	12	13	14	15	16
Values	7i	10i	16i	25i	40i	64i	100i	160i	250i	400i	640i	1000i

Grades of Holes	MANUFACTURING PROCESS USED
H5	FINE BORING, FINE GRINDING, HONING
H6	FINE BORING, HONING, HAND REAMING
H7	INT. GRINDING, BROACHING, REAMING
H8	BORING, MACHINE REAMING
H9	BORING & REAMING
H10	Not for diameter fits; used for milled widths, drilled holes.
H11	Not used in fits; punching, coarse drilling drawn recesses.

		Diameter Steps, mm																							
Over To		3	6	10	18	24	30	40	50	65	80	100	120	140	160	180	200	225	250	280	315	355	400	450	500
j5	G	+02	+03	+04	+05	+05	+06	+06	+06	+06	+06	+06	+07	+07	+07	+07	+07	+07	+07	+07	+07	+07	+07	+07	+07
	N	-02	-02	-02	-03	-04	-05	-07	-09	-11	-11	-11	-11	-11	-11	-11	-13	-13	-16	-16	-18	-18	-20	-20	-20
j8	G	+04	+06	+07	+08	+09	+11	+12	+13	+13	+13	+13	+14	+14	+14	+14	+16	+16	+16	+16	+18	+18	+20	+20	+20
	N	-02	-02	-02	-03	-04	-05	-07	-09	-11	-11	-11	-11	-11	-11	-11	-13	-13	-15	-15	-18	-18	-20	-20	-20
j7	G	+06	+08	+10	+12	+13	+15	+18	+20	+22	+22	+22	+22	+22	+22	+22	+25	+25	+26	+26	+29	+29	+31	+31	+31
	N	-04	-04	-05	-06	-08	-10	-12	-15	-18	-18	-18	-18	-18	-18	-18	-21	-21	-26	-26	-28	-28	-32	-32	-32
k5	G	+04	+06	+07	+09	+11	+13	+15	+18	+21	+21	+21	+21	+21	+21	+21	+24	+24	+27	+27	+29	+29	+32	+32	+32
	N	+00	+01	+01	+01	+02	+02	+02	+02	+03	+03	+03	+03	+03	+03	+03	+04	+04	+04	+04	+04	+04	+05	+05	+05
k6	G	+06	+09	+10	+12	+15	+18	+21	+25	+28	+28	+28	+28	+28	+28	+28	+33	+33	+36	+36	+40	+40	+45	+45	+45
	N	+00	+01	+01	+01	+02	+02	+02	+02	+03	+03	+03	+03	+03	+03	+03	+04	+04	+04	+04	+04	+04	+05	+05	+05
k7	G	+10	+13	+16	+19	+23	+27	+32	+38	+43	+43	+43	+43	+43	+43	+43	+50	+50	+56	+56	+61	+61	+66	+66	+66
	N	+00	+01	+01	+01	+02	+02	+02	+02	+03	+03	+03	+03	+03	+03	+03	+04	+04	+04	+04	+04	+04	+05	+05	+05
m5	G	+06	+09	+12	+15	+17	+20	+24	+28	+33	+33	+33	+33	+33	+33	+33	+37	+37	+43	+43	+46	+46	+50	+50	+50
	N	+02	+04	+06	+07	+08	+09	+11	+13	+15	+15	+15	+15	+15	+15	+15	+17	+17	+20	+20	+21	+21	+23	+23	+23
m6	G	+08	+12	+15	+18	+21	+25	+30	+35	+40	+40	+40	+40	+40	+40	+40	+46	+46	+52	+52	+57	+57	+63	+63	+63
	N	+02	+04	+06	+07	+08	+09	+11	+13	+15	+15	+15	+15	+15	+15	+15	+17	+17	+20	+20	+21	+21	+23	+23	+23
m7	G	+14	+16	+21	+25	+29	+34	+41	+48	+55	+55	+55	+55	+55	+55	+55	+63	+63	+72	+72	+78	+78	+86	+86	+86
	N	+02	+04	+06	+07	+08	+09	+11	+13	+15	+15	+15	+15	+15	+15	+15	+17	+17	+20	+20	+21	+21	+23	+23	+23
n5	G	+08	+13	+16	+20	+24	+28	+33	+38	+45	+45	+45	+45	+45	+45	+45	+51	+51	+57	+57	+62	+62	+67	+67	+67
	N	+04	+08	+10	+12	+15	+17	+20	+23	+27	+27	+27	+27	+27	+27	+27	+31	+31	+34	+34	+37	+37	+40	+40	+40
n6	G	+10	+16	+19	+23	+28	+33	+39	+45	+52	+52	+52	+52	+52	+52	+52	+60	+60	+66	+66	+73	+73	+80	+80	+80
	N	+04	+08	+10	+12	+15	+17	+20	+23	+27	+27	+27	+27	+27	+27	+27	+31	+31	+34	+34	+37	+37	+40	+40	+40
p5	G	+10	+17	+21	+26	+31	+37	+45	+52	+61	+61	+61	+61	+61	+61	+61	+70	+70	+79	+79	+87	+87	+95	+95	+95
	N	+08	+12	+15	+18	+22	+26	+32	+37	+43	+43	+43	+43	+43	+43	+43	+50	+50	+56	+56	+62	+62	+68	+68	+68
p6	G	+12	+20	+24	+29	+35	+42	+51	+59	+68	+68	+68	+68	+68	+68	+68	+79	+79	+90	+90	+98	+98	+108	+108	+108
	N	+06	+12	+15	+18	+22	+26	+32	+37	+43	+43	+43	+43	+43	+43	+43	+50	+50	+56	+56	+62	+62	+68	+68	+68
r5	G	+14	+20	+25	+31	+37	+45	+54	+56	+66	+69	+69	+81	+83	+86	+97	+100	+104	+117	+121	+133	+139	+159	+159	+159
	N	+10	+15	+19	+23	+28	+34	+41	+43	+51	+54	+54	+63	+65	+68	+77	+80	+84	+94	+98	+108	+114	+128	+132	+132
r6	G	+16	+23	+28	+34	+41	+50	+60	+62	+73	+76	+88	+90	+93	+106	+109	+113	+126	+130	+144	+150	+166	+172	+172	+172
	N	+10	+15	+19	+23	+28	+34	+41	+43	+51	+54	+63	+65	+68	+77	+80	+84	+94	+98	+108	+114	+126	+132	+132	+132
r7	G	+20	+27	+34	+41	+49	+59	+71	+73	+86	+89	+103	+105	+108	+123	+126	+130	+146	+150	+165	+171	+189	+195	+195	+195
	N	+10	+15	+19	+23	+28	+34	+41	+43	+51	+54	+63	+65	+68	+77	+80	+84	+94	+98	+108	+114	+126	+132	+132	+132
s5	G	+18	+24	+29	+36	+44	+54	+66	+72	+86	+94	+110	+118	+126	+142	+150	+160	+181	+193	+215	+233	+259	+279	+279	+279
	N	+14	+19	+23	+28	+35	+43	+53	+59	+71	+79	+92	+100	+108	+122	+130	+140	+158	+170	+190	+208	+232	+252	+252	+252
s6	G	+20	+27	+32	+39	+48	+59	+72	+78	+93	+101	+117	+125	+133	+151	+159	+169	+190	+202	+226	+244	+272	+292	+292	+292
	N	+14	+19	+23	+28	+35	+43	+53	+59	+71	+79	+92	+100	+108	+122	+130	+140	+158	+170	+190	+208	+232	+252	+252	+252
t7	G	+28	+35	+43	+51	+62	+73	+79	+96	+105	+126	+139	+162	+174	+186	+212	+226	+242	+270	+292	+325	+351	+393	+423	+423
	N	+18	+23	+28	+33	+41	+48	+54	+66	+75	+91	+104	+122	+134	+146	+166	+180	+196	+216	+240	+268	+294	+330	+360	+360
u5	G	+22	+28	+34	+41	+50	+71	+81	+100	+115	+139	+159	+188	+208	+228	+256	+278	+304	+338	+373	+415	+460	+517	+567	+567
	N	+18	+23	+28	+33	+41	+60	+70	+87	+102	+124	+144	+170	+190	+210	+236	+258	+284	+315	+350	+390	+435	+490	+540	+540
u6	G	+24	+31	+37	+44	+54	+76	+88	+106	+121	+146	+166	+195	+215	+235	+265	+287	+313	+347	+382	+426	+471	+530	+580	+580
	N	+18	+23	+28	+33	+41	+60	+70	+87	+102	+124	+144	+170	+190	+210	+236	+258	+284	+315	+350	+390	+435	+490	+540	+540

Note:- G- Go; N- No go; Tolerances in microns 1 micron = 0.001mm = 1×10^{-6} m

TABLE OF TOLERANCES

		Diameter steps, mm																											
Over To		3	6	10	18	24	30	40	50	65	80	100	120	140	160	180	200	225	250	280	315	355	400	450	500				
A9	N	+295	+300	+318	+333	+352	+372	+382	+414	+434	+467	+497	+560	+620	+680	+775	+855	+935	+1050	+1180	+1340	+1490	+1655	+1805					
	G	+270	+270	+280	+290	+300	+310	+320	+340	+360	+380	+410	+460	+520	+580	+660	+740	+820	+920	+1050	+1200	+1350	+1500	+1650					
B9	N	+165	+170	+186	+193	+212	+232	+242	+264	+274	+307	+327	+360	+380	+410	+455	+495	+535	+610	+670	+740	+820	+915	+995					
	G	+140	+140	+150	+150	+160	+170	+180	+190	+200	+220	+240	+260	+280	+310	+340	+380	+420	+480	+540	+600	+680	+760	+840					
C9	N	+85	+100	+116	+138	+162	+182	+192	+214	+224	+257	+267	+300	+310	+330	+355	+375	+395	+430	+460	+500	+540	+595	+635					
	G	+60	+70	+80	+95	+110	+120	+130	+140	+150	+170	+180	+200	+210	+230	+240	+260	+280	+300	+330	+360	+400	+440	+480					
E8	N	+28	+38	+47	+59	+73	+89		+106		+126		+148			+172			+191		+214		+232						
	G	+14	+20	+25	+32	+40	+50		+60		+72		+85			+100			+110		+125		+135						
F7	N	+16	+22	+26	+34	+41	+50		+60		+71		+83			+96			+108		+119		+131						
	G	+06	+10	+13	+16	+20	+25		+30		+36		+43			+50			+56		+62		+68						
G7	N	+12	+16	+20	+24	+28	+34		+40		+47		+54			+61			+69		+75		+83						
	G	+02	+04	+05	+06	+07	+09		+10		+12		+14			+15			+17		+18		+20						
H5	N	+04	+05	+06	+08	+09	+11		+13		+15		+18			+20			+23		+25		+27						
	G	00	00	00	00	00	00		00		00		00			00			00		00		00						
H6	N	+06	+08	+09	+11	+13	+16		+19		+22		+25			+29			+32		+36		+40						
	G	00	00	00	00	00	00		00		00		00			00			00		00		00						
H7	N	+10	+12	+15	+18	+21	+25		+30		+35		+40			+46			+52		+57		+63						
	G	00	00	00	00	00	00		00		00		00			00			00		00		00						
H8	N	+14	+18	+22	+27	+33	+39		+46		+54		+63			+72			+81		+89		+97						
	G	00	00	00	00	00	00		00		00		00			00			00		00		00						
H9	N	+25	+30	+36	+43	+52	+62		+74		+87		+100			+115			+130		+140		+155						
	G	00	00	00	00	00	00		00		00		00			00			00		00		00						
H10	N	+40	+48	+58	+70	+84	+100		+120		+140		+160			+185			+210		+230		+250						
	G	00	00	00	00	00	00		00		00		00			00			00		00		00						
H11	N	+60	+75	+90	+110	+130	+160		+190		+220		+250			+290			+320		+360		+400						
	G	00	00	00	00	00	00		00		00		00			00			00		00		00						
J7	N	+04	+06	+08	+10	+12	+14		+18		+22		+26			+30			+36		+39		+43						
	G	-06	-06	-07	-08	-09	-11		-12		-13		-14			-16			-16		-18		-20						
K6	N	+00	+02	+02	+02	+02	+03		+04		+04		+04			+05			+05		+07		+08						
	G	-06	-06	-07	-09	-11	-13		-15		-18		-21			-24			-27		-29		-32						
K7	N	+00	+03	+05	+06	+06	+07		+09		+10		+12			+13			+16		+17		+18						
	G	-10	-09	-10	-12	-15	-18		-21		-25		-28			-33			-36		-40		-45						
M7	N	-02	00	00	00	00	00		00		00		00			00			00		00		00						
	G	-12	-12	-15	-18	-21	-25		-30		-35		-40			-46			-52		-57		-63						
N7	N	-04	-04	-04	-05	-07	-08		-09		-10		-12			-14			-14		-16		-17						
	G	-14	-16	-19	-23	-28	-33		-39		-45		-52			-60			-66		-73		-80						
P7	N	-06	-08	-09	-11	-14	-17		-21		-24		-28			-33			-36		-41		-45						
	G	-16	-20	-24	-29	-35	-42		-51		-59		-68			-79			-88		-96		-103						
S6	N	-14	-16	-20	-25	-31	-38		-47	-53	-64	-72	-85	-93	-101	-113	-121	-131	-149	-161	-179	-197	-219	-239					
	G	-20	-24	-29	-36	-44	-54		-66	-72	-86	-94	-110	-118	-126	-142	-150	-160	-181	-193	-215	-233	-259	-279					
S7	N	-14	-15	-17	-21	-27	-34		-42	-48	-58	-66	-77	-85	-93	-105	-113	-123	-138	-150	-169	-187	-209	-229					
	G	-24	-27	-32	-39	-48	-59		-72	-78	-93	-101	-117	-125	-133	-151	-159	-169	-190	-202	-226	-244	-272	-292					

MEAN FIT AND VARIATION ABOUT THE MEAN FIT HOLE-BASIS

Tolerance unit = 0.001 mm

		HOLE SIZE, mm																			
		1	3	6	10	18	24	30	40	50	65	80	100	120	140	160	180	200	250	300	350
		3	6	10	18	24	30	40	50	65	80	100	120	140	160	180	200	250	300	350	400
Running and Sliding Fits	Over to & including	+11	+14	+17	+20.5	+24	+29.5	+34.5	+40.5	+46.5	+53	+60	+67	+74	+81	+88	+95	+102	+110	+118	+126
	Precision H7/g6	+8	+10	+12	+14.5	+17	+20.5	+24.5	+28.5	+33	+38	+43	+48	+53	+58	+63	+68	+73	+78	+83	+88
	Close Running H7/h7	+16	+22	+28	+34	+41	+50	+60	+71	+83	+96	+110	+126	+143	+160	+178	+195	+212	+230	+248	+266
	Normal Running H8/h8	+26	+38	+47	+59	+72	+89	+106	+126	+148	+172	+197	+223	+250	+278	+306	+334	+362	+390	+418	+446
	Loose Running H9/d9	+39.5	+54	+69	+85	+102.5	+120.5	+140	+160	+180.5	+202	+224	+246	+268	+290	+312	+334	+356	+378	+400	+422
	Positional fits or Slotted Running H9/d9	+85	+100	+116	+138	+162	+182	+214	+224	+257	+267	+300	+310	+330	+356	+375	+395	+430	+460	+500	+540
	Positional fits or Slotted Running H7/h7	+120	+145	+170	+205	+240	+280	+330	+390	+460	+540	+620	+700	+780	+860	+940	+1020	+1100	+1180	+1260	+1340
	Positional fits or Slotted Running H7/h7	+60	+75	+90	+110	+130	+160	+190	+220	+260	+300	+340	+380	+420	+460	+500	+540	+580	+620	+660	+700
	Precision Location H6/h6	+7	+8	+9	+11	+13	+16	+18	+22	+25	+28	+32	+35	+40	+45	+50	+55	+60	+65	+70	+75
	Close Location H7/h7	+9	+12	+15	+18	+21	+26	+30	+35	+40	+45	+50	+55	+60	+65	+70	+75	+80	+85	+90	+95
Location and Assembly Fits	Normal Location H6/h6	+14	+16	+22	+27	+33	+39	+46	+54	+63	+72	+81	+90	+100	+110	+120	+130	+140	+150	+160	+170
	Loose Location H9/h9	+25	+30	+36	+43	+52	+62	+74	+87	+100	+115	+130	+145	+160	+175	+190	+205	+220	+235	+250	+265
	Slack Assembly H11/h11	+42.5	+52.5	+63	+76.5	+91	+111	+132	+153.5	+175	+200	+225	+250	+275	+300	+325	+350	+375	+400	+425	+450
	Slack Assembly H11/h11	+80	+75	+90	+110	+130	+160	+190	+220	+250	+280	+310	+340	+370	+400	+430	+460	+490	+520	+550	+580
	Positional fits H8/g8	+130.5	+164	+179	+199	+202.5	+220.5	+230.5	+260	+290.5	+310.5	+341.5	+361.5	+395	+433.5	+473.5	+513.5	+553.5	+593.5	+633.5	+673.5
	Positional fits H8/g8	+195	+24	+29	+35	+42.5	+50.5	+60	+70	+80	+90.5	+101.5	+111.5	+124	+134.5	+145.5	+156.5	+167.5	+178.5	+189.5	+200.5
	Positional fits H8/g8	+260.5	+294	+309	+325	+342.5	+360.5	+370.5	+400	+420	+450.5	+480.5	+511.5	+541.5	+571.5	+601.5	+631.5	+661.5	+691.5	+721.5	+751.5
	Positional fits H8/g8	+190	+24	+29	+35	+42.5	+50.5	+60	+70	+80	+90.5	+101.5	+111.5	+124	+134.5	+145.5	+156.5	+167.5	+178.5	+189.5	+200.5
	Clearance Transition H7/js	+2	+3	+5	+6.5	+8	+9.5	+12.5	+15.5	+18.5	+21.5	+24.5	+27.5	+30.5	+33.5	+36.5	+39.5	+42.5	+45.5	+48.5	+51.5
	True Transition H7/js	-	-	+2	+2.5	+2	+2.5	+2.5	+3.5	+3.5	+4.5	+4.5	+5.5	+5.5	+6.5	+6.5	+7.5	+7.5	+8.5	+8.5	+9.5
Interference Fits	Interference Transition H7/m6	-1	-2	-3	-3.5	-4	-4.5	-5	-5.5	-6.5	-7.5	-8.5	-9.5	-10.5	-11.5	-12.5	-13.5	-14.5	-15.5	-16.5	-17.5
	Press H7/p6	-8	-10	-12	-14.5	-18	-21.5	-26	-30.5	-35.5	-40.5	-45.5	-50.5	-55.5	-60.5	-65.5	-70.5	-75.5	-80.5	-85.5	-90.5
	Drive H7/r6	-11	-13	-16	-19.5	-24	-28.5	-33.5	-39	-44.5	-50.5	-56.5	-62.5	-68.5	-74.5	-80.5	-86.5	-92.5	-98.5	-104.5	-110.5
	Drive H7/s6	-12	-17	-20	-24.5	-31	-36.5	-43	-50.5	-58.5	-66.5	-74.5	-82.5	-90.5	-98.5	-106.5	-114.5	-122.5	-130.5	-138.5	-146.5
	Force H7/u6	-17	-21	-25	-29.5	-37	-44	-52.5	-61.5	-70.5	-79.5	-88.5	-97.5	-106.5	-115.5	-124.5	-133.5	-142.5	-151.5	-160.5	-169.5
	Force H7/u6	-8	-10	-12	-14.5	-18	-21.5	-26	-30.5	-35.5	-40.5	-45.5	-50.5	-55.5	-60.5	-65.5	-70.5	-75.5	-80.5	-85.5	-90.5
	Force H7/u6	-11	-13	-16	-19.5	-24	-28.5	-33.5	-39	-44.5	-50.5	-56.5	-62.5	-68.5	-74.5	-80.5	-86.5	-92.5	-98.5	-104.5	-110.5
	Force H7/u6	-12	-17	-20	-24.5	-31	-36.5	-43	-50.5	-58.5	-66.5	-74.5	-82.5	-90.5	-98.5	-106.5	-114.5	-122.5	-130.5	-138.5	-146.5
	Force H7/u6	-17	-21	-25	-29.5	-37	-44	-52.5	-61.5	-70.5	-79.5	-88.5	-97.5	-106.5	-115.5	-124.5	-133.5	-142.5	-151.5	-160.5	-169.5
	Force H7/u6	-8	-10	-12	-14.5	-18	-21.5	-26	-30.5	-35.5	-40.5	-45.5	-50.5	-55.5	-60.5	-65.5	-70.5	-75.5	-80.5	-85.5	-90.5

MEAN FIT AND VARIATION ABOUT THE MEAN FIT

Tolerance units=0.001mm

SHAFT BASIS LIMIT SYSTEM						
Basic Sizes		Interference	Transition	Normal Running	Positional Fits or Slack Running	Positional Fits or Slack Running
Over	To & Incl.	h8 S7	h8 K7	h8 E8	h8 B9	h8 A9
mm	mm					
1	3	- 10.5 ± 11.5	—	+ 28 ± 14	+ 159.5 ± 19.5	+ 289.5 ± 19.5
3	6	- 12 ± 15	—	+ 38 ± 18	+ 164 ± 24	+ 294 ± 24
6	10	- 13.5 ± 18.5	+ 8.5 ± 18.5	+ 47 ± 22	+ 179 ± 29	+ 309 ± 29
10	18	- 16.5 ± 22.5	+ 10.5 ± 22.5	+ 59 ± 27	+ 185 ± 35	+ 325 ± 35
18	30	- 21 ± 27	+ 12 ± 27	+ 73 ± 33	+ 202.5 ± 42.5	+ 342.5 ± 42.5
30	40	- 27 ± 32	+ 14 ± 32	+ 89 ± 39	+ 220.5 ± 50.5	+ 360.5 ± 50.5
40	50	- 27 ± 32	+ 14 ± 32	+ 89 ± 39	+ 230.5 ± 50.5	+ 370.5 ± 50.5
50	65	- 34 ± 38	+ 17 ± 38	+ 106 ± 48	+ 250 ± 60	+ 400 ± 60
65	80	- 40 ± 38	+ 17 ± 38	+ 106 ± 48	+ 260 ± 60	+ 420 ± 60

* This Fit gives a small clearance at one extreme

RELATION BETWEEN GEOMETRY TOLERANCES AND MACHINING PROCESSES

ORDER OF TOLERANCE								
Machining Process	Roundness (circularity) of cylinders *	Expressed as mm/mm length of surface or cylinder						
		Flatness of Surfaces	Parallelism of cylinders on dia	Straightness of cylinders, gaps, and tongues	Angularity			
					Flat surfaces		cylinders, gaps, tongues	
					Parallelism Squaresness	Any other angle **	Parallelism Squaresness	Any other angle **
Drill	—	—	—	—	—	—	$\frac{1}{10^3}$	$\frac{1}{10^3}$
Mill, Slot, Plane	—	$\frac{5}{10^5}$	—	$\frac{1}{10^6}$	$\frac{1}{10^4}$	$\frac{3}{10^6}$	$\frac{1}{10^4}$	$\frac{3}{10^4}$
Turn, Bore	IT4	$\frac{5}{10^5}$	$\frac{1}{10^6}$	$\frac{1}{10^6}$	$\frac{1}{10^4}$	$\frac{3}{10^6}$	$\frac{1}{10^4}$	$\frac{3}{10^6}$
Fine turn Fine bore	IT2	$\frac{3}{10^5}$	$\frac{4}{10^8}$	$\frac{4}{10^8}$	$\frac{5}{10^5}$	$\frac{3}{10^6}$	$\frac{5}{10^5}$	$\frac{3}{10^4}$
Cylindrical grind	IT3	—	$\frac{5}{10^8}$	$\frac{5}{10^8}$	—	—	$\frac{5}{10^8}$	$\frac{3}{10^4}$
Fine cylindrical grind	IT1	—	$\frac{2}{10^8}$	$\frac{2}{10^8}$	—	—	$\frac{2}{10^8}$	$\frac{1}{10^6}$
Surface grind	—	$\frac{3}{10^5}$	—	—	$\frac{5}{10^5}$	$\frac{3}{10^6}$	$\frac{5}{10^5}$	$\frac{3}{10^6}$
Fine surface grind	—	$\frac{1}{10^5}$	—	—	$\frac{2}{10^5}$	$\frac{1}{10^6}$	$\frac{2}{10^5}$	$\frac{1}{10^6}$

* A Roundness tolerance of 0.012 corresponds to a permissible diametral variation of 0.024 (ovality).

** These tolerances are dependent upon auxiliary equipments such as jigs, fixtures, dividing heads etc, used on the machine tool. The values quoted are for good class of equipment in good condition. Twice or thrice the above tolerances may have to be allowed for worn machine tools.

PREFERRED BASIC & DESIGN SIZES

ANGULAR DIMENSIONS unit: degree

PRIORITY	PREFERRED ANGLES									
1	1	3	5	10	15	30	45	60	90	120
2	2	4.5	8	12	20					

LINEAR DIMENSIONS unit: mm

HOLE BASIS				SHAFT BASIS	
PRIORITY				PRIORITY	
1	2	3		A	B
1.0	56.0	1.2	58.0	1.6	5.0
1.6	63.0	2.0	65.0	2.5	8.0
2.5	71.0	3.2	75.0	4.0	12.0
4.0	80.0	4.5	85.0	6.0	14.0
5.0	90.0	5.5	95.0	10.0	18.0
6.0	100.0	7.0	105.0	16.0	20.0
8.0	110.0	8.0	115.0	25.0	22.0
10.0	125.0	11.0	120.0	40.0	32.0
12.0	140.0	13.0	130.0	63.0	50.0
14.0	160.0	15.0	135.0	100.0	80.0
16.0	180.0	17.0	150.0		
18.0	200.0	19.0	170.0		
20.0	220.0	21.0	190.0		
22.0	250.0	25.0	210.0		
25.0	280.0	26.0	230.0		
28.0	320.0	30.0	240.0		
32.0	360.0	34.0	260.0		
36.0	400.0	38.0	270.0		
40.0	450.0	42.0	300.0		
45.0	500.0	48.0	340.0		
50.0		53.0			

ANGULAR DIMENSIONS (unit: degree)

PREFERRED ANGLES	
PRIORITY	
1	2
1	2
3	4
6	5
10	8
15	12
30	20
45	
60	
90	
120	

STANDARD TOLERANCES FOR GEOMETRY

1. FOR LINEAR DIMENSIONS unit: mm

	0.0010	0.010	0.10	1.0
	0.0012	0.012	0.12	1.2
	0.0016	0.016	0.16	1.6
0.0002	0.0020	0.020	0.20	2.0
	0.0025	0.025	0.25	2.5
	0.0032	0.032	0.32	3.2
0.0004	0.0040	0.040	0.40	4.0
	0.0050	0.050	0.50	5.0
0.0006	0.0060	0.060	0.60	6.0
0.0008	0.0080	0.080	0.80	8.0

2. FOR ANGULAR DIMENSIONS

0° 1'	1°
0° 2'	2°
0° 3'	3°
0° 6'	5°
0° 10'	
0° 15'	
0° 30'	
0° 45'	

3. FOR TAPERS mm/mm

	0.0016	0.015
0.0003	0.0030	0.030
0.0006	0.0060	0.060
0.0010	0.0100	0.100

SYMBOLS FOR GEOMETRY OF FORM & POSITION

TOLERANCE OF FORM	CHARACTERISTICS TO BE TOLERANCED	SYMBOLS
	STRAIGHTNESS	—
	FLATNESS	
	CIRCULARITY	○
	ACCURACY OF ANY PROFILE	C
	ACCURACY OF ANY SURFACE	

TOLERANCE OF POSITION	CHARACTERISTICS TO BE TOLERANCED	SYMBOLS
	PARALLELISM	//
	PERPENDICULARITY	⊥
	ANGULARITY	∠
	POSITION	⊕
	CONCENTRICITY OR COAXIALITY	⊙
	SYMMETRY	≡

ROLLING ELEMENT BEARINGS - 4

BALL AND ROLLER BEARINGS

Designation	Application	Type and Figure
Deep groove ball bearing	Can carry considerable thrust load apart from radial load—high speed	
Self aligning ball bearing	Minor angular displacements of shafts will not affect	
Single row angular contact ball bearing	*For heavy axial loads	
Double row angular contact ball bearing	Can carry radial loads with heavy thrust in both directions	
Spherical roller bearing	High carrying capacity, self aligning—for heavy radial loads with considerable axial load in both directions	
Cylindrical roller bearing	For heavy radial loads at high speeds—permit slight axial displacement	
Taper roller bearing	*For combined radial and axial loads	
Single thrust ball bearing	For axial load in one direction only	
Double thrust ball bearing	For axial loads acting on both directions	
Spherical roller thrust bearing	For heavy axial loads—high speed—self aligning	

*Note: Always adjusted towards another bearing capable of carrying axial load in the opposite direction.

BALL AND ROLLER BEARINGS

Nomenclature :

F_r — radial load, kgf
 F_a — axial load, kgf
 C — basic dynamic capacity, kgf
 C_0 — basic static capacity, kgf
 P — equivalent load, kgf
 S — service factor
 X — radial factor
 Y — thrust factor
 F_m — cubic mean load (axial or radial)
 n — revolutions
 t — time

mr = million revolutions

L — required life of the bearing in million revolutions

L_{10} — Life of the bearing for 90% survival at 1 mr

P — probability of survival

P_{10} — probability of survival for 90% or 0.9

L_{50} — median life based on 50% survival

Service factors for bearings carrying geared shafts:

	S
Rotary M/c with no impact	1.1–1.5
Reciprocating m/c	1.3–1.9
M/c with pronounced impact, hammer mills etc.	1.6–4

Equivalent Load :

$$P = (XF_r + YF_a)S$$

Dynamic Capacity :

$$C = \left(\frac{L}{L_{10}} \right)^{1/K} P$$

$L_{10} = 1$ mr, $K=3$ for ball bearings

$K=10/3$ for roller bearings

C/P may also be obtained direct from the charts on pages 185 and 186

Probability of survival:

$$\frac{L}{L_{10}} = \left[\frac{\ln(1/p)}{\ln(1/p_{10})} \right]^{1/b}$$

L — required life of bearing in mr

L_{10} — calculated life of selected bearing, for the given load, for 90% survival

& $\ln(1/p_{10}) = \ln(1/0.9) = 0.1053$

$b = 1.17$ for a median life $= 5L_{10}$

$b = 1.34$ for a median life $= 4.08 L_{10}$ (for deep groove ball bearings)

For a system having x bearings each having the probability as p , the survival probability, $P_{system} = p^x$

Cubic mean load: (F_a or F_r)

$$F_m = \left[\frac{F_1^3 n_1 + F_2^3 n_2 + \dots}{\sum n} \right]^{1/3} \quad \text{OR} \quad F_m = \left[\frac{F_1^3 t_1 + F_2^3 t_2 + \dots}{\sum t} \right]^{1/3}$$

(revolutions varying) (time varying)

Decrease in carrying capacity at high temperatures:

Bearing temp. °C	— 125	150	175	200	225	250
Decrease in capacity	— 5%	10%	15%	25%	35%	40%

NEEDLE BEARINGS :

$$L_h = \frac{16666}{n} \left(\frac{C}{P} \right)^p$$

(The life expectancy in hours, L_h can be obtained from the nomogram given for Roller Bearings, p. 4.7)

ROLLING BEARINGS FOR LINEAR MOVEMENT :

$$L = \left(\frac{C}{P} \right)^{\frac{10}{3}} \text{ in } 10^6 \text{ metres}$$

$$L_h = \frac{833 L}{H n} \text{ in hours}$$

$$P = \sqrt[p]{\frac{1}{T} \int_0^T F^p(t) dt}$$

$$\approx 0.76 P_{max}$$

For variable speed and load use equations given on p 4.2 with the index $p = \frac{10}{3}$ instead of 3

$$p = \frac{10}{3} \text{ for line contact}$$

L , nominal life in 10^6 metres

C , dynamic load capacity, kgf

P , equivalent bearing load, kgf

H , single stroke length, m

n , frequency of oscillation in strokes/min

T , duration in seconds with periodically varying load or total time of operation with non-periodically varying load

$$p = \frac{10}{3} \text{ for needle bearings}$$

F_{max} , max load in the periodic load

RECOMMENDED LIFE VALUES :

Type of operation	Life, L_h in operating hours
Infrequently operated	500
Brief operation only	4000 to 8000
Intermittent operation	8000 to 15000
One shift operation	15000 to 30000
Continuous operation	30000 to 60000
—do— with high production capacity	100 000

EQUIVALENT BEARING LOAD

Type of Bearing	Series (SKF)	$\frac{F_a}{F_r} \leq e$		$\frac{F_a}{F_r} > e$		e
		X	Y	X	Y	
Deep groove ball bearing	Series EL, R				2	0.22
	160, 60, 62, 63				1.8	0.24
	64, EE, RLS,				1.6	0.27
	RMS	1	0	0.56	1.4	0.31
					1.2	0.37
					1.0	0.44
Angular contact ball bearing	72B, 73B	1	0	0.35	0.57	1.14
	72 BG, 73 BG [⊕]	1	0	0.35	0.57	1.14
	72 BG, 73 BG [†]	1	0.55	0.57	0.93	1.14
	32, 33	1	0.73	0.62	1.17	0.86
Self aligning ball bearing	2200—2204		1.3		2	0.5
	05— 07		1.7		2.6	0.37
	08— 09	1	2	0.65	3.1	0.31
	10— 13		2.3		3.5	0.28
	14— 20		2.4		3.8	0.26
	21— 22		2.3		3.5	0.28
	2301		1		1.6	0.63
	2302—2304		1.2		1.9	0.52
	05— 10	1	1.5	0.65	2.3	0.43
Spherical roller bearing	11— 18		1.6		2.5	0.39
	22205C—22207C		2.1		3.1	0.32
	08C 09C	1	2.5	0.67	3.7	0.27
	10C 20C		2.9		4.4	0.23
Taper roller bearing	22C 44C		2.6		3.9	0.26
	32206— 208				1.6	0.37
	09— 22	1	0	0.4	1.45	0.41
	24— 30				1.35	0.44

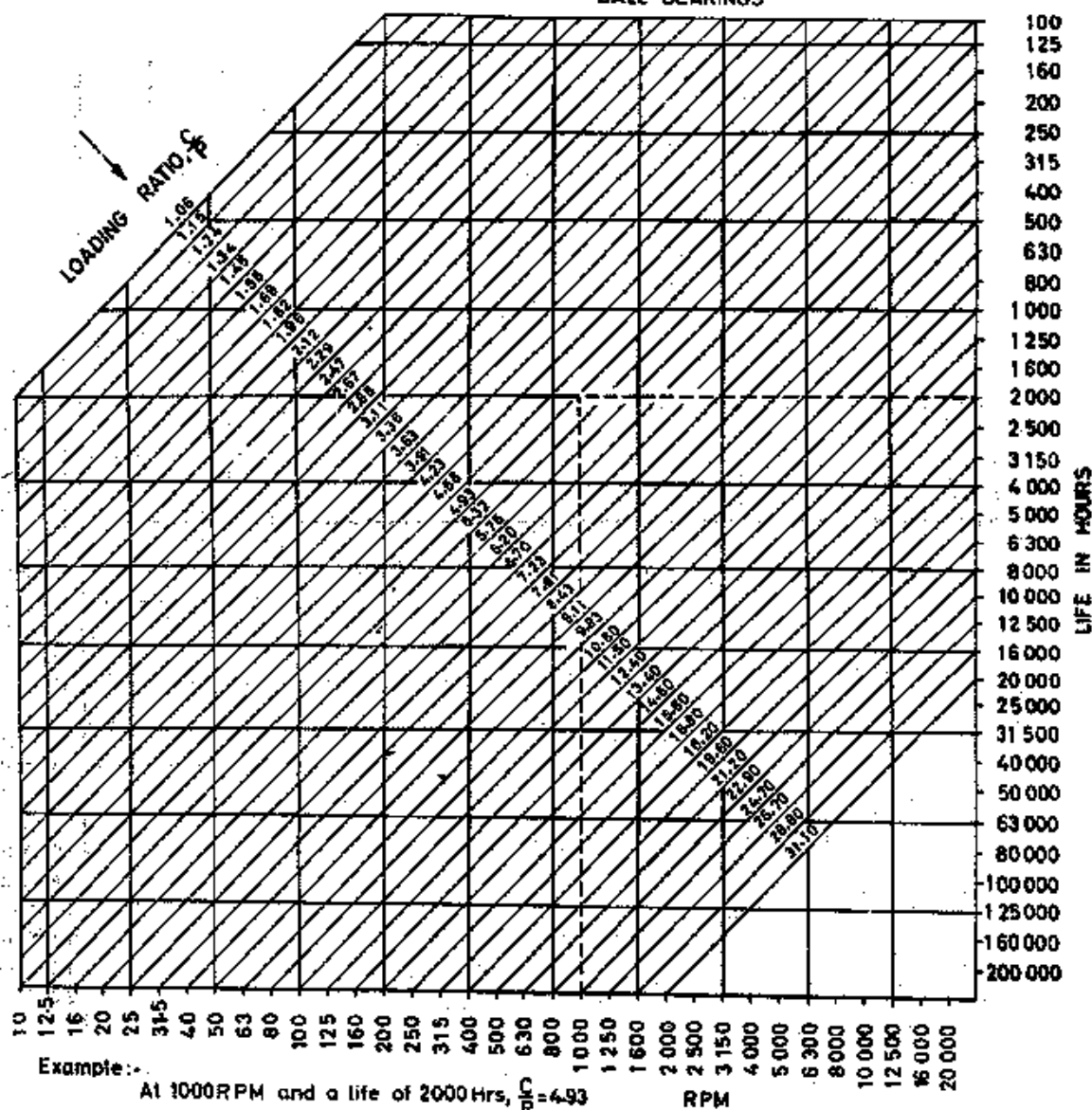
⊕ A pair of bearings mounted in tandem.

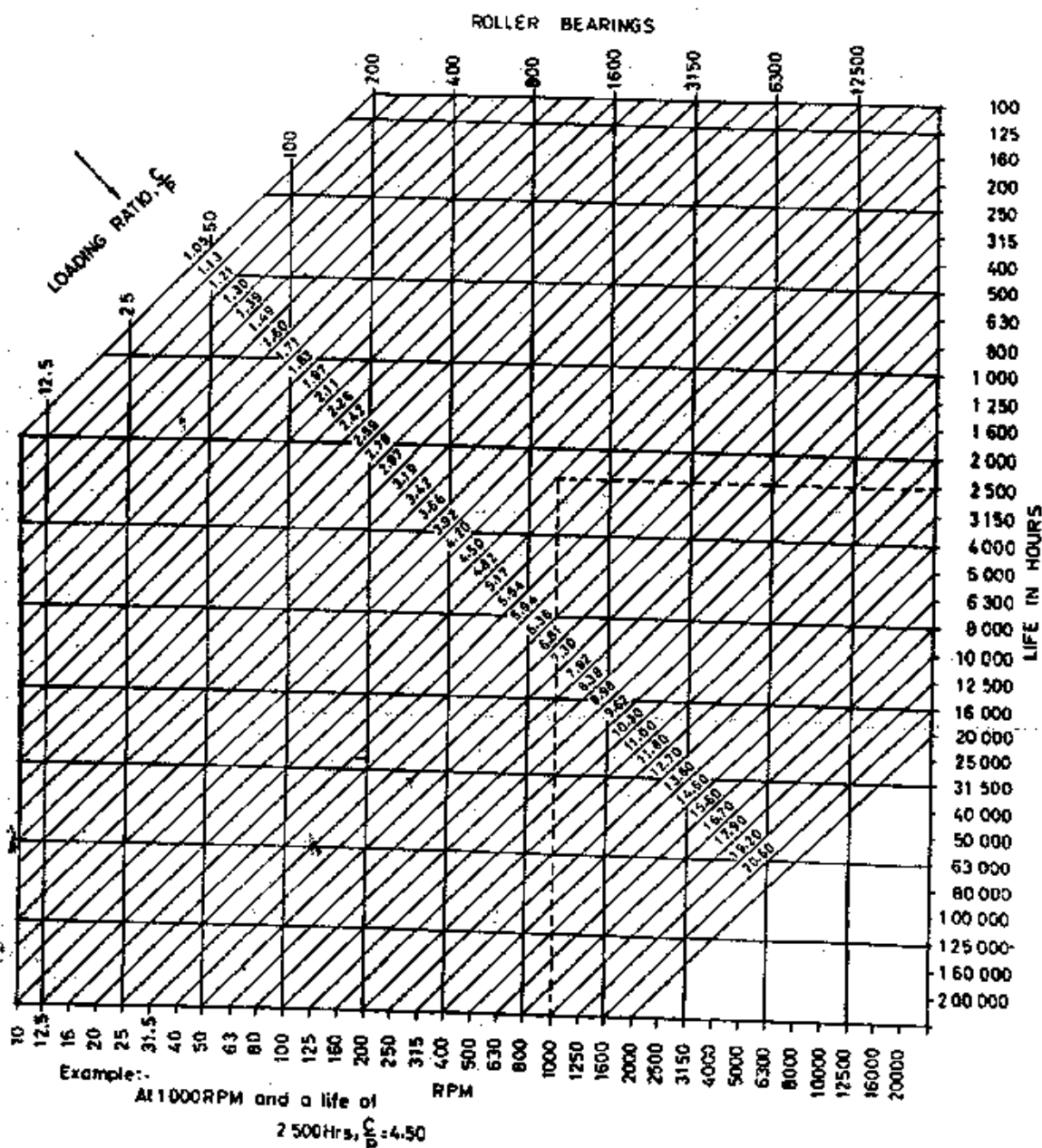
† A pair of bearings mounted back to back or face to face.

LIFE OF BEARINGS

Class of Machines	Bearing Life Working Hours
Instruments and apparatus that are used only rarely e.g. Demonstration apparatus, sliding door mechanism	500
Machines used for short periods or intermittently and whose break-down would not have serious consequences e.g. hand tools, lifting tackle, agricultural machines, domestic appliances	4000 to 8000
Machines working intermittently and whose break-down would have serious consequences e.g. Auxiliary machines in powerstations, conveyor plants, lifts, m/c tools used infrequently	8000 to 12000
Machines for use 8 hrs/day and not always fully used e.g. Stationary electric motors, general purpose gear units	12000 to 20000
Machines for use 8hrs/day and fully utilised e.g. machines for engg. industry - cranes of bulk goods, ventilating fans, counter shaft in gear box.	20000 to 30000
Machines for continuous use 24 hrs/day e.g. Separators, compressors, pumps, mine hoists, stationary electric machines, on-board naval vessel machines.	40000 to 60000
Machines required to work with a high degree of reliability for 24 hrs/day e.g. pulp and paper making machinery, public power plants, mine pumps, water works, on-board merchant ship machines	100000 to 200000

BALL BEARINGS





SELECTION OF FIT

Shaft seating for radial bearings

		Shaft diameter, mm			Tolerance	
Conditions	Examples	Ball bearing	Cylind. & taper roller brg.	Spher. roller bearing		
<i>Bearings with Cylindrical Bore</i>						
Stationary inner ring load	Easy axial displacement of inner race on shaft desirable	Wheels on non rotating axles	All diameters		g6	
	Easy axial displacement of inner race on shaft unnecessary	Tension pulley rope sheaves	All diameters		h6	
Rotating inner ring load or direction of loading indeterminate	Light and variable loads	Electrical apparatus,	≤ 18	—	—	h5
			18—100	≤ 40	≤ 40	j6
		M/c Tools, pumps	100—200	40—140	40—100	k6
			—	140—200	100—200	m6
	Normal and heavy loads	General application,	≤ 18	—	—	j5
			18—100	≤ 40	≤ 40	k5
		elec. motor,	100—140	40—100	40—65	m5
		pumps,	140—200	100—140	65—100	m6
		compressors,	200—280	140—200	100—140	n6
		I. C. Engines	—	200—400	140—280	p6
			—	—	280—500	r6
			—	—	> 500	r7
	Heavy and shock loads	Railway axle, traction motors	—	50—140	50—100	n6
			—	140—200	100—140	p6
			—	—	140—200	r6
			—	—	200—500	r7
Purely axial loads — All kinds of bearings — all diameters					j6	
<i>Bearings with Taper Bore and Sleeve</i>						
Loads of all kinds	Bearings in general, railway axle boxes	All diameters			h9	
	Line shafting	All diameters			h10	
Shaft seating for thrust bearings						
Conditions					Tolerance	
Purely axial load	Thrust ball bearing, spherical roller thrust bearing			All diameters	j6	
Combined load on spherical roller thrust bearing	Stationary load on shaft washer					
	Rotating load on shaft or direction of loading indeterminate			d ≤ 200	k6	
				200—400	m6	
				> 400	n6	

Housing seatings for radial bearings—selection of fit (Contd.)

		Conditions	Examples	Tolerance
Solid Housing	Rotating Outer Race load	Heavy loads on bearings in thin walled housing—shock loads	Big end bearing	P7
		Normal and heavy loads	Big end bearing	N7
		Light and variable loads	Conveyor rollers, rope sheaves, belt tension pulleys	M7
	Direction of Loading Indeterminate	Heavy shock loads	Elec. traction motors	M7
		Heavy and normal loads—axial movement of outer race unnecessary	Medium size electrical machines, crankshaft main bearings	K7
		Normal and light loads	Electrical machines, pumps, crank main bearings	J7
Split or solid Housing	Stationary Outer Ring load	Shock loads	Railway axle boxes	J7
		All loads	Bearing—general application	H7
		Normal and light loads	Line shafting	H8
		Heat conduction through shaft	Drying cylinders	G7
Solid Housing		Accurate and silent running desirable	Roller bearing for machine tool spindle	K6
			Ball bearings for grinding spindles	J6
			Small Electrical motors	H6

Housing seatings for thrust bearings

		Conditions		Tolerance
Purely axial load		Thrust ball bearings		H8
		Spherical roller thrust bearings where another bearing is taking care of location		—
Combined load on spherical roller thrust bearings		Stationary load on housing		J7
		Rotating load on housing washer	Heavy radial load	M7
			Generally	K7

RADIAL BEARING — TOLERANCES ON INNER RACE

Nominal Bore Dia, mm	over to	2.5 10	10 18	18 30	30 50	50 80	80 120	120 180	180 250
STANDARD BEARING — tolerances in microns									
BORE	*on mean dia	-8 0	-8 0	-10 0	-12 0	-15 0	-20 0	-25 0	-30 0
	Circularity	-10 + 2	-11 + 3	-13 + 3	-15 + 3	-19 + 4	-25 + 5	-31 + 6	-38 + 8
Width,		0 -120	0 -120	0 -120	0 -120	0 -150	0 -200	0 -250	0 -300
Width (error in form)		15	20	20	20	25	25	30	30
Radial runout		10	10	13	15	20	25	30	40

CLASS P6 Bearings

BORE	*on mean dia	-7 0	-7 0	-8 0	-10 0	-12 0	-15 0	-18 0	-22 0
	Circularity	-8 +1	-8 +1	-9 +1	-11 +1	-14 + 2	-18 + 3	-21 + 3	-26 + 4
Width		0 -120	0 -120	0 -120	0 -120	0 -150	0 -200	0 -250	0 -300
Width (error in form)		15	20	20	20	25	25	30	30
Radial runout		6	7	8	10	10	13	18	20

CLASS P5 Bearings

BORE	*on mean dia	-5 0	-5 0	-6 0	-8 0	-9 0	-10 0	-13 0	-15 0
	Circularity	"	"	"	"	"	"	"	"
Width		0 -40	0 -80	0 -120	0 -120	0 -150	0 -200	0 -250	0 -300
Width (error in form)		5	5	5	5	6	7	8	10
Radial runout		3.5	3.5	4	5	5	6	8	10
Side/axial runout		7	7	8	8	8	9	10	11

CLASS P4 Bearings

BORE	*on mean dia	-4 0	-4 0	-5 0	-6 0	-7 0	-8 0	-10 0	-12 0
	Circularity	"	"	"	"	"	"	"	"
Width		0 -40	0 -80	0 -120	0 -120	0 -150	0 -200	0 -250	0 -300
Width (error in form)		2.5	2.5	3	4	4	5	6	8
Side/axial runout		3	3	4	4	5	5	6	7

* Use this value for deciding the fit on the shaft.

RADIAL BEARING — TOLERANCES ON OUTER RACE

Nominal Bore Dia, mm	Over to	2.5 10	10 18	18 30	30 50	50 80	80 120	120 180	180 250

STANDARD BEARING

tolerances in microns

OUTSIDE DIAMETER	*on mean dia	0 -8	0 -9	0 -11	0 -13	0 -15	0 -18	0 -25	0 -30
	Circularity	+2 -10	+2 -11	+3 -14	+4 -17	+5 -20	+6 -24	+7 -32	+8 -38
RADIAL RUN OUT		15	15	20	25	35	40	45	50

CLASS P6 BEARINGS

OUTSIDE DIAMETER	*on mean dia	0 -7	0 -8	0 -9	0 -11	0 -13	0 -15	0 -18	0 -20
	Circularity	+1 -8	+1 -9	+2 -11	+2 -13	+2 -15	+3 -18	+3 -21	+4 -24
RADIAL RUN OUT		8	9	10	13	18	20	23	25

CLASS P5 BEARINGS

OUTSIDE DIAMETER	*on mean dia	0 -5	0 -6	0 -7	0 -9	0 -10	0 -11	0 -13	0 -15
	Circularity	0 -5	0 -6	0 -7	0 -9	0 -10	0 -11	0 -13	0 -15
Width (Error in form)		5	5	5	6	8	8	8	10
Radial runout		5	6	7	8	10	11	13	15
Side/Axial runout		8	8	8	10	11	13	14	15

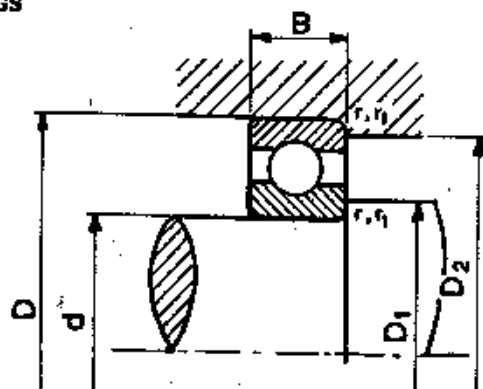
CLASS P4 BEARINGS

OUTSIDE DIAMETER	*on mean dia	0 -4	0 -5	0 -6	0 -7	0 -8	0 -9	0 -10	0 -11
	Circularity	"	"	"	"	"	"	"	"
Width (Error in form)		2.5	2.5	2.5	3	4	5	5	7
Radial runout		4	4	4	4	5	5	5	7
Side/axial runout		5	5	5	5	6	7	8	10

Width tolerance is the same for outer and inner ring. See p. 4.10.

* Use this value for deciding the fit in the housing.

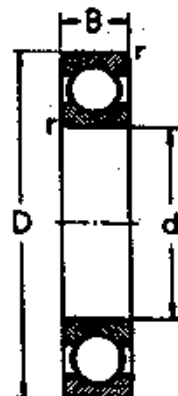
DEEP GROOVE BALL BEARINGS



Series 60

Bearing of basic design No. (SKF)	d mm	D _i mm	D mm	D _e mm	B mm	r mm	r ₁ mm	Basic capacity, kgf Static C ₀	Dynamic C	Max. permissible speed-rpm
6000	10	12	26	24	8	0.5	0.3	190	360	20000
01	12	14	28	26	8	0.5	"	220	400	20000
02	15	17	32	30	9	0.5	"	255	440	20000
6003	17	19	35	33	10	0.5	"	285	465	20000
04	20	23	42	36	12	1	0.6	450	735	16000
05	25	28	47	44	12	1	"	520	780	16000
6006	30	35	55	50	13	1.5	1.0	710	1040	13000
07	35	40	62	57	14	1.5	"	880	1250	13000
08	40	45	68	63	15	1.5	"	980	1320	10000
6009	45	50	75	70	16	1.5	"	1270	1630	10000
10	50	55	80	75	16	1.5	"	1370	1700	8000
11	55	61	90	84	18	2	"	1800	2200	8000
6012	60	66	95	89	18	2	"	1930	2280	8000
13	65	71	100	94	18	2	"	2120	2400	8000
14	70	76	110	104	20	2	"	2550	3000	6000
6015	75	81	115	109	20	2	"	2800	3100	6000
16	80	86	125	119	22	2	"	3350	3750	6000
17	85	91	130	124	22	2	"	3600	3900	5000
6018	90	97	140	133	24	2.5	1.5	4150	4550	5000
19	95	102	145	138	24	2.5	"	4500	4750	5000
20	100	107	150	143	24	2.5	"	4500	4750	4000
6021	105	114	160	151	26	3	2	5400	5700	4000
22	110	119	170	161	28	3	"	6100	6400	4000
24	120	129	180	171	28	3	"	6550	6700	3000
6026	130	139	200	191	33	3	"	8300	8300	3000
28	140	149	210	201	33	3	"	9000	8650	3000
30	150	160	225	215	35	3.5	"	10400	9800	2500
6032	160	170	240	230	38	3.5	"	11800	11200	2500
34	170	180	260	250	42	3.5	"	14300	13200	2500
36	180	190	280	270	46	3.5	"	16600	15000	2000
6038	190	200	290	280	46	3.5	"	18000	15300	2000
40	200	210	310	300	51	3.5	"	20000	17000	2000

DEEP GROOVE BALL BEARINGS (Contd.)

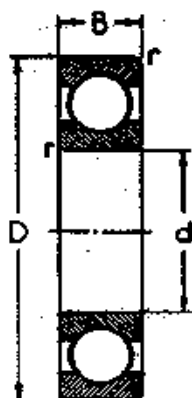


Series 62

ISI No.	Bearing of basic design No. (SKF)	d mm	D ₁ min	D mm	D ₂ max	B mm	r mm	r ₁ mm	Basic capacity, kgf		Max. permissible speed rpm
									Static C ₀	Dynamic C	
10BC02	6200	10	14	30	26	9	1	0.6	224	400	20000
12BC02	01	12	16	32	28	10	1	"	300	540	20000
15BC02	02	15	19	35	31	11	1	"	355	610	16000
17BC02	6203	17	21	40	36	12	1	"	440	750	16000
20BC02	04	20	26	47	41	14	1.5	1.0	655	1000	16000
25BC02	05	25	31	52	46	15	1.5	"	710	1100	13000
30BC02	6206	30	36	62	56	16	1.5	"	1000	1530	13000
35BC02	07	35	42	72	65	17	2	"	1370	2000	10000
40BC02	08	40	47	80	73	18	2	"	1600	2280	10000
45BC02	6209	45	52	85	78	19	2	"	1830	2550	8000
50BC02	10	50	57	90	83	20	2	"	2120	2750	8000
55BC02	11	55	64	100	91	21	2.5	1.5	2600	3400	8000
60BC02	6212	60	69	110	101	22	2.5	"	3200	4050	6000
65BC02	13	65	74	120	111	23	2.5	"	3550	4400	6000
70BC02	14	70	79	125	116	24	2.5	"	3900	5400	5000
75BC02	6215	75	84	130	121	25	2.5	"	4250	5200	5000
80BC02	16	80	91	140	129	26	3	2.0	4550	5700	5000
85BC02	17	85	96	150	139	28	3	"	5500	6550	4000
90BC02	6218	90	101	160	149	30	3	"	6300	7500	4000
95BC02	19	95	107	170	158	32	3.5	"	7200	8500	4000
100BC02	20	100	112	180	168	34	3.5	"	8150	9650	3000
105BC02	6221	105	117	190	178	36	3.5	"	9300	10400	3000
110BC02	22	110	122	200	188	38	3.5	"	10400	11200	3000
120BC02	24	120	132	215	203	40	3.5	"	10400	11400	3000
	6226	130	144	230	216	40	4	2.5	11600	12200	2500
	28	140	154	250	236	42	4	"	12900	12900	2500
	30	150	164	270	256	45	4	"	14300	13700	2500
	32	160	174	290	276	48	4	"	15600	14300	2000
	6234	170	187	310	293	52	5	3.0	19000	16600	2000
	36	180	197	320	303	52	5	"	20400	17600	1600
	38	190	207	340	323	55	5	"	24000	20000	1600
	40	200	217	360	343	58	5	"	26500	21200	1600

D₁, abutment diam. on shaftD₂, abutment diam. on housingr₁, corner radii on shaft & housing.

Series 63



DEEP GROOVE BALL BEARINGS (Contd.)

Series 63

ISI No.	Bearing of basic design No. (SKF)	d mm	D _i mm	D mm	D _o mm	B mm	r mm	r ₁ mm	Basic Capacity, kgf		Max permissible speed rpm
									Static C _s	Dynamic C	
10BC03	6300	10	14	35	31	11	1	0.6	360	630	16000
12BC03	01	12	18	37	31	12	1.5	1	430	765	16000
15BC03	02	15	21	42	36	13	1.5	"	520	880	16000
17BC03	6303	17	23	47	41	14	1.5	"	630	1060	13000
20BC03	04	20	27	52	45	15	2	"	765	1250	13000
25BC03	05	25	32	62	55	17	2	"	1040	1660	10000
30BC03	6306	30	37	72	65	19	2	"	1460	2200	10000
35BC03	07	35	44	80	71	21	2.5	1.5	1760	2600	8000
40BC03	08	40	49	90	81	23	2.5	"	2200	3200	8000
45BC03	6309	45	54	100	91	25	2.5	"	3000	4150	8000
50BC03	10	50	61	110	99	27	3	2.0	3550	4800	6000
55BC03	11	55	66	120	109	29	3	"	4250	5600	6000
60BC03	6312	60	72	130	118	31	3.5	"	4800	6400	5000
65BC03	13	65	77	140	128	33	3.5	"	5500	7200	5000
70BC03	14	70	82	150	138	35	3.5	"	6300	8150	5000
75BC03	6315	75	87	160	148	37	3.5	"	7200	9000	4000
80BC03	16	80	92	170	158	39	3.5	"	8000	9650	4000
85BC03	17	85	99	180	166	41	4	2.5	8800	10400	4000
90BC03	6318	90	104	190	176	43	4	"	9800	11200	3000
95BC03	19	95	109	200	186	45	4	"	11200	12000	3000
100BC03	20	100	114	215	201	47	4	"	13200	13700	3000
105BC03	6321	105	119	225	211	49	4	"	14300	14300	2500
110BC03	22	110	124	240	226	50	4	"	16600	16000	2500
120BC03	24	120	134	260	246	55	4	"	17000	16300	2500
	6326	130	147	280	263	58	5	3	19600	18000	2500
	28	140	157	300	283	62	5	"	22400	20000	2000
	30	150	167	320	303	65	5	"	25500	21600	2000

D_i, abutment diam. on shaft

D_o, abutment diam. on shaft and housing

r₁, corner radii on shaft and housing.

Series 64 DEEP GROOVE BALL BEARINGS

(Nomenclature same as other series)

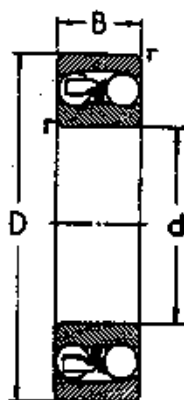
All dimensions in mm

No.	d	D _i min	D	D _i max	B	r	r ₁	Basic capacity, kgf Static C ₀	Dynamic C	Max speed rpm
6403	17	26	62	53	17	2	1	1280	1800	10000
6404	20	29	72	63	19	"	"	1660	2400	8000
6405	25	36	80	69	21	2.5	1.5	2000	2825	7100
6406	30	41	90	79	23	"	"	2400	3350	6300
6407	35	46	100	89	25	"	"	3250	4300	5600
6408	40	53	110	97	27	3	2	3800	5000	5000
6409	45	58	120	107	29	"	"	4650	5850	4500
6410	50	64	130	116	31	3.5	"	5300	7000	4000
6411	55	69	140	126	33	"	"	6400	7850	4000
6412	60	74	150	136	35	"	"	7100	8450	3600
6413	65	79	160	146	37	"	"	8000	9150	3200
6414	70	86	180	164	42	4	2.5	9100	10000	2800
6415	75	91	190	174	45	"	"	10160	12000	2800
6416	80	96	200	184	48	"	"	12800	13000	2500
6417	85	105	210	190	52	5	3	13800	13800	2500
6418	90	110	225	205	54	"	"	16600	15200	2200

Series 2 DEEP GROOVE BALL BEARINGS (with filling slots)

203	17	21	40	36	12	1	0.6	640	950	16000
204	20	26	47	41	14	1.5	1	950	1400	14000
205	25	31	52	46	15	"	"	1140	1300	12000
206	30	36	62	56	16	"	"	1570	2100	10000
207	35	42	72	65	17	2	"	2100	2800	8000
208	40	47	80	73	18	"	"	2600	3300	7100
209	45	52	85	78	19	"	"	2820	3500	7100
210	50	57	90	83	20	"	"	3000	3650	6300
211	55	64	100	91	21	2.5	1.5	3860	4450	5600
212	60	69	110	101	22	"	"	4750	5400	5000
213	65	74	120	111	23	"	"	5700	6400	4500
214	70	79	125	116	24	"	"	6100	6700	4500
215	75	84	130	121	25	"	"	6500	7000	4000
216	80	91	140	129	26	3	2	7750	8200	4000

SELF-ALIGNING BALL BEARINGS

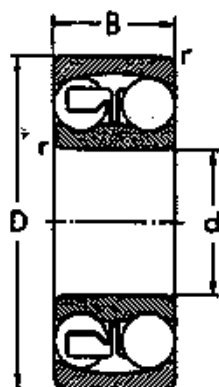


Bearing with cylindrical bore No. (SKF)	Bearing with *taper bore No. (SKF)	d	D	B	r	Basic capacity, kgf		Max. permissible speed rpm
		mm	mm	mm	mm	Static C_0	Dynamic C	
2200		10	30	14	1	180	570	20000
01		12	32	14	1	200	585	20000
02		15	35	14	1	216	600	16000
2203		17	40	16	1	280	765	16000
04	2204 K	20	47	18	1.5	390	980	16000
05	05 K	25	52	18	1.5	425	980	13000
2206	2206 K	30	62	20	1.5	560	1200	13000
07	07 K	35	72	23	2	800	1700	10000
08	08 K	40	80	23	2	915	1760	10000
2209	2209 K	45	85	23	2	1020	1800	8000
10	10 K	50	90	23	2	1080	1800	8000
11	11 K	55	100	25	2.5	1270	2080	8000
2212	2212 K	60	110	28	2.5	1600	2650	6000
13	13 K	65	120	31	2.5	2040	3400	6000
14	—	70	125	31	2.5	2160	3450	5000
2215	2215 K	75	130	31	2.5	2240	3450	5000
16	16 K	80	140	33	3	2500	3800	5000
17	17 K	85	150	36	3	3000	4550	4000
2218	2218 K	90	160	40	3	3600	5500	4000
19	19 K	95	170	43	3.5	4300	6550	4000
20	20 K	100	180	46	3.5	5100	7650	3000
2221	—	105	190	50	3.5	5600	8500	3000
22	2222 K	110	200	53	3.5	6400	9800	3000

* Taper 1 : 12 on diameter.

Note: Abutment diameters D_1 , D_2 and corner radii r_1 , r_2 are the same as for 62 series.

SELF-ALIGNING BALL BEARINGS (Contd.)

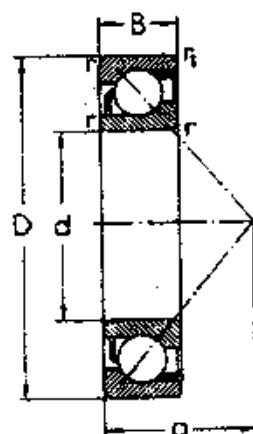


Bearing with cylindrical bore No. (SKF)	Bearing with taper bore No. (SKF)	d mm	D mm	B mm	r mm	Basic capacity, kgf		Max. permissible speed rpm
						Static C_0	Dynamic C	
2301		12	37	17	1.5	300	915	16000
02		15	42	17	1.5	335	930	13000
03		17	47	19	1.5	415	1120	13000
2304	2304 K	20	52	21	2	550	1400	10000
05	05 K	25	62	24	2	765	1900	10000
06	06 K	30	72	27	2	1020	2450	8000
2307	2307 K	35	80	31	2.5	1320	3050	8000
08	08 K	40	90	33	2.5	1600	3550	6000
09	09 K	45	100	36	2.5	1960	4250	6000
2310	2310 K	50	110	40	3	2400	5000	5000
11	11 K	55	120	43	3	2850	5850	5000
12	12 K	60	130	46	3.5	3350	6800	4000
2313	2313 K	65	140	48	3.5	3900	7500	4000
14	—	70	150	51	3.5	4500	8500	4000
15	15 K	75	160	55	3.5	5200	9500	3000
16	16 K	80	170	58	3.5	5850	10600	3000
2317	2317 K	85	180	60	4	6200	11000	2500
18	18 K	90	190	64	4	6950	11800	2500

* Taper 1:12 on diameter.

Note: Abutment diameters D_1 , D_2 and corner radii r_1 are the same as for 63 series

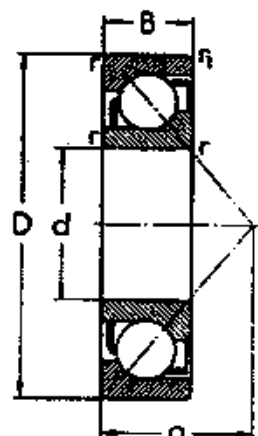
SINGLE ROW ANGULAR CONTACT BALL BEARINGS



ISI No.	Bearing No. (SKF)	d mm	D mm	B mm	r mm	r ₁ mm	α °	Basic capacity, kgf		Max. permissible speed rpm
								Static C ₀	Dynamic C	
15BA02	7202 B	15	35	11	1	0.5	16	375	630	13000
17BA02	03 B	17	40	12	1	0.8	18	475	780	13000
20BA02	04 B	20	47	14	1.5	0.8	21	655	1040	10000
25BA02	7205 B	25	52	15	1.5	0.8	24	780	1160	10000
30BA02	06 B	30	62	16	1.5	0.8	27	1120	1600	10000
35BA02	07 B	35	72	17	2	1	31	1530	2120	8000
40BA02	7208 B	40	80	18	2	1	34	1900	2500	8000
45BA02	09 B	45	85	19	2	1	37	2160	2800	6000
50BA02	10 B	50	90	20	2	1	39	2360	2900	6000
55BA02	7211 B	55	100	21	2.5	1.2	43	3000	3650	6000
60BA02	12 B	60	110	22	2.5	1.2	47	3650	4400	5000
65BA02	13 B	65	120	23	2.5	1.2	50	4300	5000	5000
70BA02	7214 B	70	125	24	2.5	1.2	53	4750	5400	5000
75BA02	15 B	75	130	25	2.5	1.2	56	5000	5600	4000
80BA02	16 B	80	140	26	3	1.5	59	5700	6300	4000
85BA02	7217 B	85	150	28	3	1.5	64	6550	7100	4000
90BA02	18 B	90	160	30	3	1.5	67	7650	8300	4000
95BA02	19 B	95	170	32	3.5	2	71	8800	9500	3000
100BA02	7220 B	100	180	34	3.5	2	76	9300	10200	3000
105BA02	21 B	105	190	36	3.5	2	80	10400	11000	2500
110BA02	22 B	110	200	38	3.5	2	84	11600	12000	2500

Note: Abutment diameters D_1 , D_2 and corner radii r_1 are the same as for 62 series.

SINGLE ROW ANGULAR CONTACT BALL BEARINGS (Contd.)

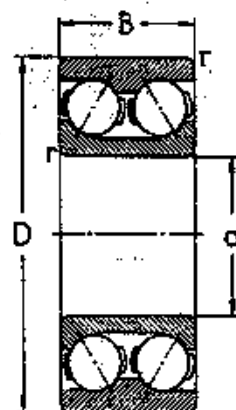


ISI No.	Bearing No. (SKF)	d	D	B	r	r ₁	a	Basic capacity, kgf		Max. permissible speed rpm
		mm	mm	mm	mm	mm	mm	Static C ₀	Dynamic C	
17BA03	7303 B	17	47	14	1.5	0.8	21	720	1160	10000
20BA03	04 B	20	52	15	2	1	23	830	1370	10000
25BA03	05 B	25	62	17	2	1	27	1250	1930	10000
30BA03	7306 B	30	72	19	2	1	31	1700	2450	8000
35BA03	07 B	35	80	21	2.5	1.2	35	2040	2850	8000
40BA03	08 B	40	90	23	2.5	1.2	39	2550	3550	6000
45BA03	7309 B	45	100	25	2.5	1.2	43	3400	4550	6000
50BA03	10 B	50	110	27	3	1.5	47	4050	5300	6000
55BA03	11 B	55	120	29	3	1.5	52	4750	6200	5000
60BA03	7312 B	60	130	31	3.5	2	55	5500	7100	5000
65BA03	13 B	65	140	33	3.5	2	60	6300	8000	5000
70BA03	14 B	70	150	35	3.5	2	64	7350	9000	4000
75BA03	7315 B	75	160	37	3.5	2	68	8150	9800	4000
80BA03	16 B	80	170	39	3.5	2	72	9150	10600	4000
85BA03	17 B	85	180	41	4	2	76	10200	11400	3000
90BA03	7318 B	90	190	43	4	2	80	11400	12200	3000
95BA03	19 B	95	200	45	4	2	84	12500	13200	2500
100BA03	20 B	100	215	47	4	2	90	15300	15000	2500
105BA03	7321 B	105	225	49	4	2	94	16600	16000	2500
110BA03	22 B	110	240	50	4	2	99	19300	17600	2500

Note: Abutment diameters D₁, D₂ and corner radii r₁, r₂ are the same as for 63 series

DOUBLE ROW ANGULAR CONTACT BALL BEARINGS

Series 33



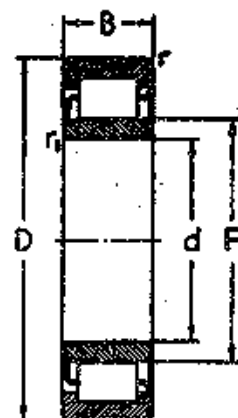
Bearing No. (SKF)	d mm	D mm	B mm	r mm	Basic capacity, kg†		Max. permissible speed rpm
					Static C ₀	Dynamic C	
3302	15	42	19	1.5	930	1400	10000
03	17	47	22.2	1.5	1290	1930	8000
04	20	52	22.2	2	1400	1930	8000
3305	25	62	25.4	2	2000	2650	6000
06	30	72	30.2	2	2750	3550	6000
07	35	80	34.9	2.5	3600	4500	5000
3308	40	90	36.5	2.5	4550	5500	5000
09	45	100	39.7	2.5	5600	6700	4000
10	50	110	44.4	3	7350	8150	4000
3311	55	120	49.2	3	8000	8800	4000
12	60	130	54	3.5	9650	10200	3000
13	65	140	58.7	3.5	11200	11800	3000
3314	70	150	63.5	3.5	12900	13700	3000
15	75	160	68.3	3.5	14000	14300	2500
16	80	170	68.3	3.5	16000	16300	2500
3317	85	180	73	4	18000	18000	2500
18	90	190	73	4	21200	20400	2500

Note: Abutment diameters D₁, D₂, and corner radii r, are the same as for 63 series

CYLINDRICAL ROLLER BEARINGS

Series NU 22

Bearing No. (SKF)	d	D	B	r	r ₁	F	Basic capacity, kgf		Max. permissible speed rpm
	mm	mm	mm	mm	mm	mm	Static C ₀	Dynamic C	
NU 2205	25	52	18	1.5	1	32	1220	1630	13000
2206	30	62	20	1.5	1	38.5	1760	2360	13000
2207	35	72	23	2	1	43.8	2800	3600	10000
NU 2208	40	80	23	2	2	50	3350	4150	10000
2209	45	85	23	2	2	55	3600	4500	8000
2210	50	90	23	2	2	60.4	3900	4650	8000
NU 2211	55	100	25	2.5	2	66.5	4650	5400	8000
2212	60	110	28	2.5	2.5	73.5	6200	7100	6000
2213	65	120	31	2.5	2.5	79.6	7500	8300	6000
NU 2214	70	125	31	2.5	2.5	84.5	8000	8800	5000
2215	75	130	31	2.5	2.5	88.5	8650	9800	5000
2216	80	140	33	3	3	95.3	10200	11200	5000
NU 2217	85	150	36	3	3	101.8	12000	12900	4000
2218	90	160	40	3	3	107	13700	15000	4000
2219	95	170	43	3.5	3.5	113.5	16600	18000	4000
NU 2220	100	180	46	3.5	3.5	120	19000	20000	3000
2222	110	200	53	3.5	3.5	132.5	23200	25000	3000
2224	120	215	58	3.5	3.5	143.5	27500	28500	3000
NU 2226	130	230	64	4	4	156	31500	30500	2500
2228	140	250	68	4	4	169	38000	36500	2500
2230	150	270	73	4	4	182	45000	43000	2500

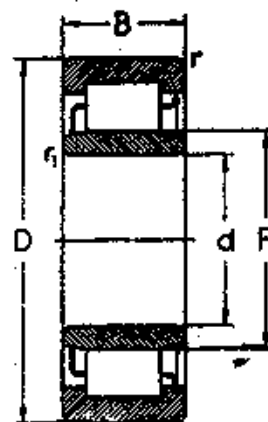


Note: Abutment diameters D_1 , D_2 and corner radii r_1 are the same as for 62 series.

CYLINDRICAL ROLLER BEARINGS (Contd.)

Bearing No. (SKF)	d mm	D mm	B mm	r mm	r ₁ mm	F mm	Basic capacity, kgf		Max. permissible speed rpm
							Static C ₀	Dynamic C	
NU 2305	25	62	24	2	2	35	2280	3200	10000
2306	30	72	27	2	2	42	2800	3750	10000
2307	35	80	31	2.5	2	46.2	3250	4500	8000
NU 2308	40	90	33	2.5	2.5	53.5	4800	6100	8000
2309	45	100	36	2.5	2.5	58.5	5700	7500	8000
2310	50	110	40	3	3	65	7500	9300	6000
NU 2311	55	120	43	3	3	70.5	8500	11000	6000
2312	60	130	46	3.5	3.5	77	10600	13200	5000
2313	65	140	48	3.5	3.5	83.5	12200	14600	5000
NU 2314	70	150	51	3.5	3.5	90	14000	16300	5000
2315	75	160	55	3.5	3.5	95.5	17300	20400	4000
2316	80	170	58	3.5	3.5	103	19000	22000	4000
NU 2317	85	180	60	4	4	108	20000	23200	4000
2318	90	190	64	4	4	115	22800	26000	3000
2319	95	200	67	4	4	121.5	26500	30000	3000
NU 2320	100	215	73	4	4	129.5	31500	34500	3000
2322	110	240	80	4	4	143	43000	46500	2500
2324	120	260	86	4	4	154	54000	57000	2500
NU 2326	130	280	93	5	5	167	65500	68000	2500
2328	140	300	102	5	5	180	73500	75000	2000
2330	150	320	108	5	5	193	83000	83000	2000

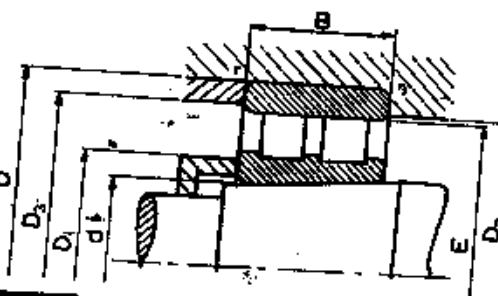
Series NU 23



Note: Abutment diameters D_1 , D_2 , and corner radii r , are the same as for 63 series

DOUBLE ROW CYLINDRICAL ROLLER BEARINGS : Series NN 30 K (with taper bore; taper 1 : 12)

All dimensions in mm

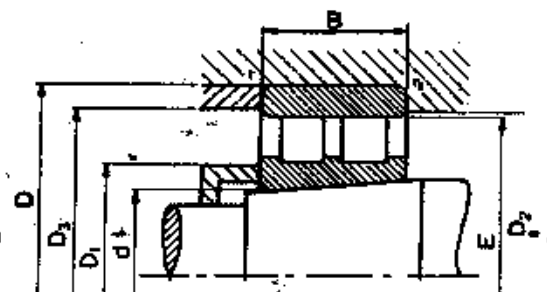


Bearing No.	d	D ₁ min	D	D ₂ min	D ₂ max	E	B	r brg	r abut	Basic Static C ₀	capacity, kgf, Dynamic C	Max. Speed rpm
NN 30 06 K	30	35	55	49	50	48.5	19	1.5	1	1600	2500	11000
07 K	35	40	62	56	57	55	20	"	"	2200	3100	10000
08 K	40	45	68	62	63	61	21	"	"	2950	3940	9000
09 K	45	50	75	69	70	67.5	23	"	"	3760	4200	8000
10 K	50	55	80	74	75	72.5	23	"	"	4080	5000	7100
11 K	55	61	90	82	84	81	26	2	"	5050	6250	6300
12 K	60	66	95	87	89	86.1	26	"	"	5780	6600	5600
13 K	65	71	100	92	94	91	"	"	"	5850	6800	5600
14 K	70	76*	110	102	104	100	30	"	"	7700	8650	5000
15 K	75	81	115	107	109	105	"	"	"	8000	8750	5000
16 K	80	86	125	115	119	113	34	"	"	9600	10500	4500
17 K	85	91	130	120	124	118	"	"	"	10400	11100	4000
18 K	90	98	140	129	132	127	37	2.5	1.5	12200	13200	4000
19 K	95	103	145	134	137	132	"	"	"	12700	13600	3600
20 K	100	108	150	139	142	137	"	"	"	13200	13800	3600
21 K	105	114	160	148	151	146	41	3	2	16400	17700	3200
22 K	110	119	170	157	161	155	45	"	"	20000	20600	3200
24 K	120	129	180	167	171	165	46	"	"	21000	21500	2800
26 K	130	139	200	184	191	182	52	"	"	27600	27600	2500

120

DOUBLE ROW CYLINDRICAL ROLLER BEARINGS : Series NN 30 K (with taper bore; taper 1 : 12)

All dimensions in mm



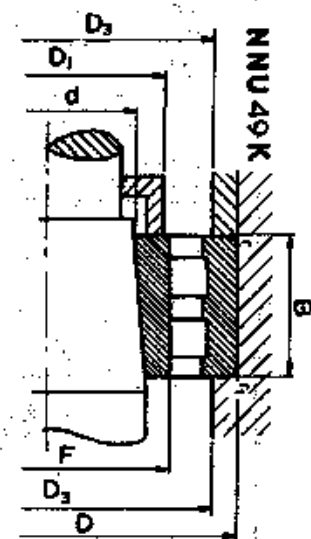
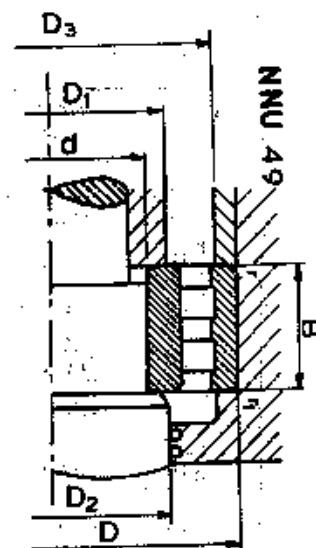
Bearing No.	d	D _i min	D	D _i min	D _e max	E	B	r brg	r abut	Basic Static C ₀	capacity, kgf. Dynamic C	Max. Speed rpm
NN 30 06 K	30	35	55	49	50	48.5	19	1.5	1	1600	2500	11000
07 K	35	40	62	56	57	55	20	"	"	2200	3100	10000
08 K	40	45	68	62	63	61	21	"	"	2950	3940	9000
09 K	45	50	75	69	70	67.5	23	"	"	3760	4200	8000
10 K	50	55	80	74	75	72.5	23	"	"	4080	5000	7100
11 K	55	61	90	82	84	81	26	2	"	5050	6250	6300
12 K	60	66	95	87	89	86.1	26	"	"	5780	6600	5600
13 K	65	71	100	92	94	91	"	"	"	5850	6800	5600
14 K	70	76	110	102	104	100	30	"	"	7700	8650	5000
15 K	75	81	115	107	109	105	"	"	"	8000	8750	5000
16 K	80	86	125	115	119	113	34	"	"	9600	10500	4500
17 K	85	91	130	120	124	118	"	"	"	10400	11100	4000
18 K	90	98	140	129	132	127	37	2.5	1.5	12200	13200	4000
19 K	95	103	145	134	137	132	"	"	"	12700	13600	3600
20 K	100	108	150	139	142	137	"	"	"	13200	13800	3600
21 K	105	114	160	148	151	146	41	3	2	16400	17700	3200
22 K	110	119	170	157	161	155	45	"	"	20000	20600	3200
24 K	120	129	180	167	171	165	46	"	"	21000	21500	2800
26 K	130	139	200	184	191	182	52	"	"	27600	27600	2500

DOUBLE ROW CYLINDRICAL ROLLER BEARINGS : NNU 49 & NNU 49 K Series

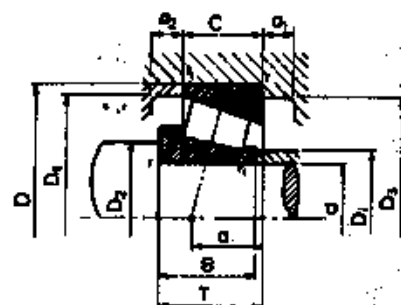
(taper for K Series 1 : 12 on the bore)

All dimensions in mm

Brg No.	d	D_1 max	D_1 min	D_1 min	D	D_3 max	F	B	r brg	r_1 abut	Basic capacity, kgf Static C_0	Dynamic C	Max Speed, rpm
NNU 4920 K	100	112	106	115	140	134	113	40	2	1	13000	11500	4000
21 K	105	117	111	120	145	139	118	"	"	"	13600	11800	3600
22 K	110	122	116	125	150	144	123	"	"	"	13800	12000	"
24 K	120	133	126	137	165	159	134.5	45	"	"	17300	15600	3200
26 K	130	145	138	148	180	172	146	50	2.5	1.5	20000	16500	2800
28 K	140	155	148	158	190	182	156	"	"	"	20500	17000	2800
30 K	150	167	159	171	210	201	168.5	60	3	2	34700	30000	2500
32 K	160	177	169	181	220	211	178.5	"	"	"	35300	30500	2200
34 K	170	187	179	191	230	221	188.5	"	"	"	36800	30750	"
36 K	180	200	189	205	250	241	202	69	"	"	44500	36600	2000
38 K	190	210	199	215	260	251	212	"	"	"	46400	37600	"
40 K	200	223	210	228	280	270	225	80	3.5	"	53700	43600	1800
44 K	220	243	230	248	300	290	245	"	"	"	57600	46400	"
48 K	240	263	250	268	320	310	265	"	"	"	61000	48200	1600
52 K	260	289	270	295	360	350	292	100	"	"	84500	68000	1400
56 K	280	309	290	315	380	370	312	"	"	"	93000	71000	"
60 K	300	335	312	342	420	408	339	118	4	2.5	125000	95000	1200
64 K	320	355	332	362	440	428	359	"	"	"	132000	98000	1100



TAPER ROLLER BEARINGS Series 322



All dimensions in mm

Brg No.	d	D ₁ max	D ₂ min	D	D ₃ min	D ₄ min	B	C	T	r brg	r ₁ brg	r ₂ abut	a ₁	a ₂	a	Basic Static C ₀	Capacity kgf dynamic C	Max speed rpm
322 06 A	30	37	36	62	52	57	20	17	21.25	1.5	0.5	1	2	4	15	3850	4380	6300
07 A	35	43	42	72	61	67	23	19	24.25	2	"	"	3	5	18	5080	5760	5000
08 A	40	48	47	80	68	78.5	"	"	24.75	"	"	"	"	5.5	19	5440	6350	4500
09 A	45	53	52	85	73	80	"	"	"	"	0.8	"	"	"	20	5760	6480	"
322 10 A	50	58	57	90	78	85	"	"	"	"	"	"	"	"	21	6480	7260	4000
11 A	55	63	64	100	87	94	25	21	26.75	2.5	"	1.5	4	"	22	7980	8900	3600
12 A	60	69	69	110	95	102	28	24	29.75	"	"	"	"	"	24	10000	10700	3200
13 A	65	75	74	120	105	112	31	27	32.75	"	"	"	"	"	26	11800	12700	2800
14 A	70	80	79	125	108	117	"	"	33.25	"	"	"	"	6	28	12700	13600	"
15 A	75	85	84	130	113	123	"	"	"	"	"	"	"	"	29	13600	14000	2500
16 A	80	90	90	140	122	132	33	28	"	3	1	2	"	7	30	15200	16100	"
17 A	85	96	95	150	130	140	36	30	38.5	"	"	"	5	8	33	17700	18350	2200
18 A	90	102	100	160	138	150	40	34	42.5	"	"	"	"	"	36	21100	21500	2000
19 A	95	108	107	170	146	158	43	37	45.5	3.5	1.2	"	"	10	38	24900	25000	"
322 20 A	100	114	112	180	155	168	46	39	49	"	"	"	"	"	41	28600	28100	1800
21 A	105	120	117	190	163	178	50	43	53	"	"	"	"	"	44	32650	32200	"
22 A	110	125	122	200	171	188	53	46	56	"	"	"	8	"	46	35400	34000	1600
24	120	135	132	215	184	203	58	50	61.5	"	"	"	9	11	52	34700	36290	"

Suffix A, denotes bearings of high load carrying capacity.

TAPER ROLLER BEARINGS : Series 323

All dimensions in mm

Brg No.	d	D ₁ max	D ₂ min	D	D ₃ min	D ₄ min	B	C	T	r brg	r ₁ brg	r abut	a ₁	a ₂	a	Basic Static C ₀	Capacity, kgf dynamic C	max speed rpm
323 06 A	30	38	37	72	61	66	27	23	28.75	2	0.8	1	2	5.5	17	5670	6600	5000
07 A	35	43	44	80	68	74	31	25	32.75	2.5	"	1.5	3	7.5	20	7255	8300	4500
08 A	40	50	49	90	76	82	33	27	35.25	"	"	"	"	8	23	8750	9800	4000
09 A	45	56	54	100	85	93	36	30	38.25	"	"	"	"	"	25	12000	12700	3600
323 10 A	50	62	60	110	94	102	40	33	42.25	3	1	2	"	9	28	14500	15100	3200
11 A	55	67	65	120	103	111	43	35	45.5	"	"	"	4	10	29	16300	17200	2800
12 A	60	73	72	130	112	120	46	37	48.5	3.5	1.2	"	"	11	31	18800	20000	2500
13 A	65	80	77	140	121	130	48	39	51	"	"	"	"	11.5	33	21500	22200	"
14 A	70	85	82	150	129	140	51	42	54	"	"	"	"	"	36	25400	25800	2200
323 15 A	75	91	87	160	138	149	55	45	58	3.5	"	"	"	12.5	38	29000	29700	2000
16	80	97	92	170	147	159	58	48	61.5	"	"	"	"	13	40	24500	26500	"
17	85	102	99	180	155	167	60	49	63.5	4	1.5	2.5	9	14	42	28600	30400	1800
18	90	108	104	190	163	177	64	53	67.5	"	"	"	"	"	44	29700	30850	"
19	95	113	109	200	171	186	67	55	71.5	"	"	"	10	"	47	36300	37600	1600
323 20	100	121	114	215	183	200	73	60	77.5	"	"	"	11	16	51	41500	41500	"
21	105	127	119	225	193	209	77	63	81.5	"	"	"	"	17	54	46300	46250	1400
22	110	135	124	240	205	222	80	65	84.5	"	"	"	12	"	56	49900	48000	"
24	120	145	134	260	219	239	86	69	90.5	"	"	"	"	18	60	56700	54500	1200

Suffix A, denotes high load carrying capacity.

SINGLE THRUST BALL BEARINGS

with flat housing washer



ISI No.	Bearing No. (SKF)	d mm	D mm	H mm	d ₂ min. mm	r mm	Basic capacity, kgf		Max. permissible speed rpm
							Static C ₀	Dynamic C	
10TA12	51200	10	26	11	10.2	1	1400	1000	10000
12TA12	01	12	28	11	12.2	1	1560	1040	8000
15TA12	02	15	32	12	15.2	1	2040	1220	8000
17TA12	51203	17	35	12	17.2	1	2200	1270	8000
20TA12	04	20	40	14	20.2	1	3100	1730	6000
25TA12	05	25	47	15	25.2	1	4150	2160	6000
30TA12	51206	30	52	16	30.2	1	4800	2280	6000
35TA12	07	35	62	18	35.2	1.5	6400	3050	5000
40TA12	08	40	68	19	40.2	1.5	7650	3450	5000
45TA12	51209	45	73	20	45.2	1.5	8650	3650	4000
50TA12	10	50	78	22	50.2	1.5	9150	3750	4000
55TA12	11	55	90	25	55.2	1.5	13200	5500	3000
60TA12	51212	60	95	26	60.2	1.5	14600	5700	3000
65TA12	13	65	100	27	65.2	1.5	15600	5850	2500
70TA12	14	70	105	27	70.2	1.5	16300	6000	2500
75TA12	51215	75	110	27	75.2	1.5	17300	6100	2500
80TA12	16	80	115	28	80.2	1.5	18000	6200	2000
85TA12	17	85	125	31	85.2	1.5	22000	7500	2000
90TA12	51218	90	135	35	90.2	2	27000	9150	2000
100TA12	20	100	150	38	100.2	2	34000	11400	1600
110TA12	22	110	160	38	110.2	2	37500	12000	1600
120TA12	51224	120	170	39	120.2	2	39000	12000	1300
130TA12	26	130	190	45	130.3	2.5	51000	16000	1300
140TA12	28	140	200	46	140.3	2.5	54000	16300	1000
150TA12	51230	150	215	50	150.3	2.5	60000	17600	1000
160TA12	32	160	225	51	160.3	2.5	62000	18000	1000
170TA12	34	170	240	55	170.3	2.5	73500	21200	800
180TA12	51236	180	250	56	180.3	2.5	76500	21600	800
190TA12	38	190	270	62	190.3	3	91500	25000	800
200TA12	40	200	280	62	200.3	3	96500	25500	600
	51244	220	300	63	220.3	3	104000	26000	600
	48	240	340	78	240.3	3.5	143000	33500	500
	51252	260	360	79	260.3	3.5	156000	34500	500
	56	280	380	80	280.3	3.5	163000	35500	400
	60	300	420	95	300.3	4	224000	45500	400
	51264	320	440	95	320.4	4	236000	46500	400
	68	340	460	96	340.4	4	245000	47500	300
	72	360	500	110	360.4	5	315000	58500	300

SINGLE THRUST BALL BEARINGS : Series 513

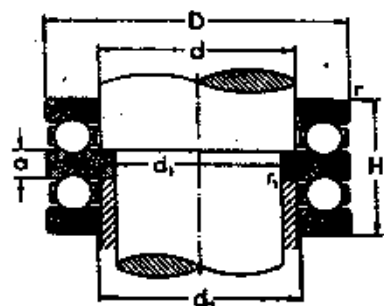
All dimensions in mm; For nomenclature refer Series 512

Brg. No.	d	D	H	d ₁ min	r as	Basic Capacity, kgf		Max. speed rpm
						Static C ₀	dynamic C	
513 05	25	52	18	27	1.5	5000	2900	3600
06	30	60	21	32	"	6350	3330	2800
07	35	68	24	37	"	8600	4370	2500
08	40	78	26	42	"	10900	5350	2000
09	45	85	28	47	"	13800	6620	"
513 10	50	95	31	52	2	16300	8000	1600
11	55	105	35	57	"	19900	9250	1400
12	60	110	"	62	"	21500	9660	"
13	65	115	36	67	"	23100	10000	"
14	70	125	40	72	"	27700	12000	1200
15	75	135	44	77	2.5	31500	13600	1100
16	80	140	"	82	"	34000	14000	"
17	85	150	49	88	"	40800	16000	1000
18	90	155	50	93	"	40800	16000	"
513 20	100	170	55	103	"	49000	18800	900
22	110	187	63	113	3	57600	21500	800
24	120	205	70	123	3.5	74000	25400	710
26	130	220	75	134	"	84300	28100	630
28	140	235	80	144	"	98000	30400	"
30	150	245	80	154	"	103000	31300	560
32	160	265	87	164	4	122500	35400	"

DOUBLE THRUST BALL BEARINGS

Flat housing washers — Series 522

Series 522



Bearing No. (SKF)	d mm	d ₁ mm	D mm	H mm	d ₁ min. mm	e mm	r mm	r ₁ mm	Basic capacity, kgf		Max. permissible speed rpm
									Static C ₀	Dynamic C	
52202	15	10	32	22	15.2	5	1	0.5	2040	1220	8000
04	20	15	40	26	20.2	6	1	0.5	3100	1730	6000
05	25	20	47	28	25.2	7	1	0.5	4150	2160	6000
52206	30	25	52	29	30.2	7	1	0.5	4800	2280	6000
07	35	30	62	34	35.2	8	1.5	0.5	6400	3050	5000
08	40	30	68	36	40.2	9	1.5	1	7650	3450	5000
09	45	35	73	37	45.2	9	1.5	1	8650	3650	4000
10	50	40	78	39	50.2	9	1.5	1	9150	3750	4000
52211	55	45	90	45	55.2	10	1.5	1	13200	5500	3000
12	60	50	95	46	60.2	10	1.5	1	14600	5700	3000
13	65	55	100	47	65.2	10	1.5	1	15600	5850	2500
14	70	55	105	47	70.2	10	1.5	1.5	16300	6000	2500
15	75	60	110	47	75.2	10	1.5	1.5	17300	6100	2500
52216	80	65	115	48	80.2	10	1.5	1.5	18000	6200	2000
17	85	70	125	55	85.2	12	1.5	1.5	22000	7500	2000
18	90	75	135	62	90.2	14	2	1.5	27000	9150	2000
20	100	85	150	67	100.2	15	2	1.5	34000	11400	1600

DOUBLE THRUST BALL BEARINGS : Series 523

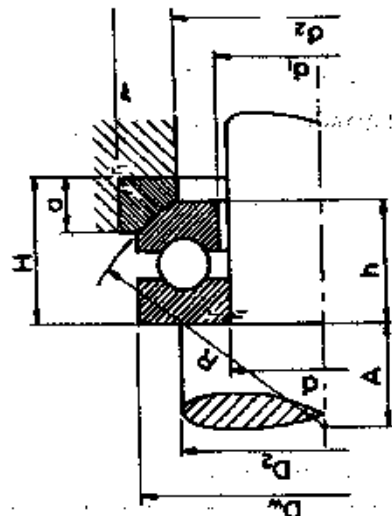
All dimensions in mm ; For nomenclature See Series 522

Brg. No.	d	d ₁	D	H	d ₃ min.	a	r	r ₁	Basic Capacity		Max. speed rpm
									Static C ₀	kgf Dynamic C	
523 05	25	20	52	34	27	8	1.5	0.5	5000	2900	3600
06	30	25	60	38	32	9	"	"	6350	3330	2800
07	35	30	68	44	37	10	"	"	8600	4370	2500
08	40	"	78	49	42	12	"	1	10900	5350	2000
09	45	35	85	52	47	"	"	"	13600	6620	"
523 10	50	40	95	58	52	14	2	"	16300	7980	1600
11	55	45	105	64	57	15	"	"	20000	9250	1400
12	60	50	110	"	62	"	"	"	21300	9600	"
13	65	55	115	65	67	"	"	"	23100	9980	"
14	70	"	125	72	72	16	"	1.5	27700	12000	1200
15	75	60	135	79	77	18	2.5	"	31500	13600	1100
16	80	65	140	"	82	"	"	"	34000	14000	"
17	85	70	150	87	88	19	"	"	40800	16100	1000
18	90	75	155	88	93	"	"	"	"	"	"
523 20	100	85	170	97	103	21	"	"	49000	18800	900
22	110	95	190	110	113	24	3	"	57600	21500	800
24	120	100	210	123	123	27	3.5	2	73900	25400	710
26	130	110	225	130	134	30	"	"	84300	28100	630
28	140	120	240	140	144	31	"	"	98000	30400	"

THRUST BALL BEARINGS : Series 532 and 532 U
(with spherical housing washer and seating ring U)

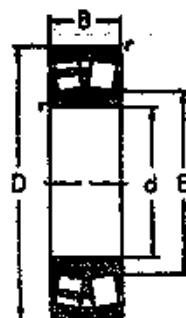
All dimensions in mm

Brg. No.	d	d ₁	D ₂	h	r	d ₁	D ₂	a	H	D ₂ min	r ₁ max abut	R	A	Basic Static C ₀	Basic capacity kgf dynamic C	Max speed rpm
532 05U	25	27	47	16.7	1	36	50	5.5	19	38	0.6	40	19	4080	2170	4000
06U	30	32	52	17.8	"	42	55	"	20	43	"	45	22	4700	2270	3600
07U	35	37	62	19.9	1.5	48	65	7	22	51	1.0	50	24	6350	3040	2800
08U	40	42	68	20.3	"	55	72	"	23	57	"	56	28.5	8000	3700	2500
09U	45	47	73	21.3	"	60	78	7.5	24	62	"	"	26	8750	3920	2200
10U	50	52	78	23.5	"	62	82	1.4	26	67	"	64	32.5	9800	4220	2000
11U	55	57	90	27.3	"	72	95	9	30	76	"	72	35	13600	5670	1800
12U	60	62	95	28	"	78	100	"	31	81	"	"	32.5	14520	6000	1600
13U	65	67	100	28.7	"	82	105	"	32	86	"	80	40	15420	6080	"
14U	70	72	105	28.8	"	88	110	"	"	91	"	"	38	16100	6210	1400
15U	75	77	110	28.4	"	92	115	9.5	"	96	"	90	49	17000	6350	"
16U	80	82	115	29.5	"	98	120	10	33	101	"	"	46	18100	6490	"
17U	85	88	125	31.1	"	105	130	11	37	109	"	100	52	22700	8300	1200
18U	90	93	130	38.5	2	110	140	13.5	42	117	"	"	45	27900	10160	1100
20U	100	103	150	40.9	"	125	155	14	45	130	"	112	52	34000	12250	1000
22U	110	113	160	40.2	"	135	165	"	"	140	"	125	63	38500	12930	900
24U	120	123	170	40.8	"	145	175	15	46	150	"	"	61	40000	"	"
26U	130	133	187	47.9	2.5	160	195	17	53	166	1.5	140	67	50800	16330	800
28U	140	143	197	48.6	"	170	210	"	55	176	"	160	87	53500	16550	710
30U	150	153	212	53.3	"	180	225	20.5	60	189	"	"	79	58500	18370	"
32U	160	163	222	54.7	"	190	235	21	61	199	"	"	74	62140	18820	630



SPHERICAL ROLLER BEARINGS

Series 222 C and 222 CK



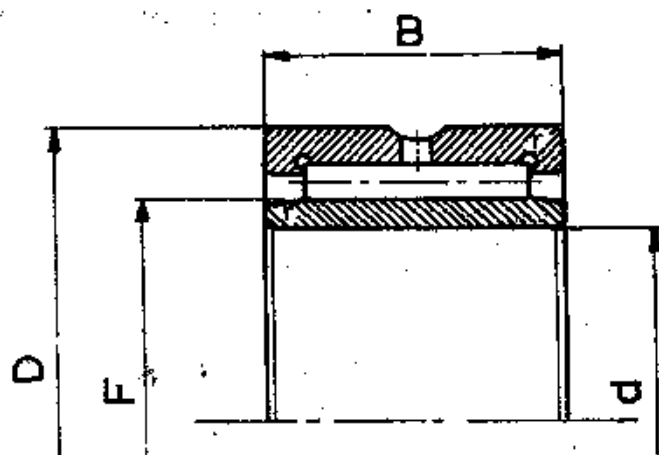
Bearing with cylindrical bore	d	D	B	E	r	Basic capacity, kgf		Maximum permissible speed rpm
	mm	mm	mm	mm	mm	Static C ₀	Dynamic C	
*22205 C	25	52	18	32	1.5	2200	3000	8000
*06 C	30	62	20	38	1.5	3100	4500	6000
07 C	35	72	23	44	2	4050	5200	6000
22208 C	40	80	23	50	2	4800	6200	5000
09 C	45	85	23	55	2	5200	6400	5000
10 C	50	90	23	60	2	5500	6700	4000
22211 C	55	100	25	66	2.5	6800	8300	4000
12 C	60	110	28	73	2.5	8500	10000	4000
13 C	65	120	31	79	2.5	10200	11800	3000
22214 C	70	125	31	84	2.5	10800	12200	3000
15 C	75	130	31	90	2.5	11200	12700	3000
16 C	80	140	33	95	3	14000	15300	2500
22217 C	85	150	36	100	3	16300	18000	2500
18 C	90	160	40	107	3	19600	20800	2500
19 C	95	170	43	113	3.5	22800	24500	2000
22220 C	100	180	46	120	3.5	25500	27000	2000
22 C	110	200	53	132	3.5	34500	34500	2000
24 C	120	215	58	143	3.5	40000	40000	1600
22226 C	130	230	64	153	4	48000	46500	1600
28 C	140	250	68	167	4	54000	53000	1600
30 C	150	270	73	179	4	65500	64000	1300
22232 C	160	290	80	191	4	78000	73500	1300
34 C	170	310	86	204	5	90000	83000	1000
36 C	180	320	86	213	5	95000	88000	1000
22238 C	190	340	92	226	5	102000	95000	1000
40 C	200	360	98	238	5	116000	108000	800
44 C	220	400	108	264	5	143000	129000	800

Note: For bearings with taper bore add K-Example 22208 CK. Taper 1:12 on diameter.

* Not available with taper bore.

Abutment diameters D_1 , D_2 and corner radii r_1 , r_2 are the same as for 62 series.

NEEDLE BEARINGS
NA 49 SERIES

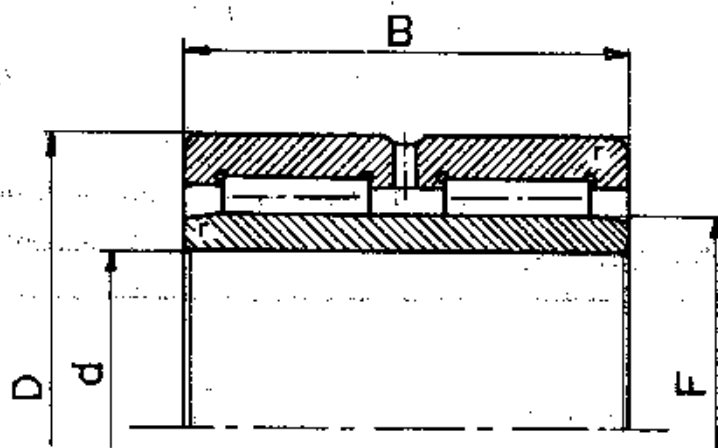


All dimensions in mm

Brg. No.	d	F	D	B	r	Basic Static Capacity, kgf C_0	dynamic C	Max. speed rpm
NA 49/02	15	20	28	13	0.5	780	940	20000
03	17	22	30	13	"	820	970	18000
04	20	25	37	17	"	1490	1850	16000
49/22	22	28	39	17	"	1690	2010	14000
05	25	30	42	17	"	1790	2080	13000
49/28	28	32	45	17	"	1890	2150	12000
06	30	35	47	17	"	1990	2210	11000
49/32	32	40	52	20	1	2650	2700	10000
07	35	42	55	20	"	2750	2800	9000
08	40	48	62	22	"	3700	3750	8000
09	45	52	68	22	"	3950	3900	8000
49/10	50	58	72	"	"	4250	4050	7000
12	60	68	85	25	1.5	5700	5200	6000
14	70	80	100	30	"	8400	7400	5000
16	80	90	110	30	"	9400	7800	4000
18	90	105	125	35	2	13400	10000	4000
20	100	115	140	40	"	14400	11200	3000
24	120	135	165	45	"	21000	15900	3000

* If lubricating groove and hole are required, please add ASR I to the bearing designation.

NEEDLE BEARINGS : Series NA 69



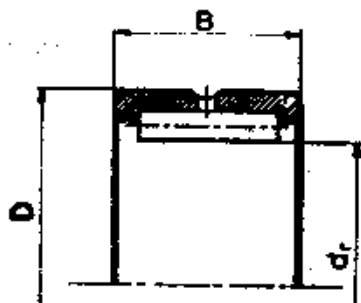
All dimensions in mm

Brg. No.	d	F	D	B	r	Basic Static C_0	Capacity, kgf dynamic C	Max. speed rpm
NA 69 02	15	20	28	23	0.5	1430	1510	20000
03	17	22	30	"	"	1610	1630	18000
04	20	25	37	30	"	2750	2950	16000
69/22	22	28	39	30	"	2950	3100	14000
05	25	30	42	"	"	3150	3250	13000
69/28	28	32	45	"	"	3350	3400	12000
06	30	35	47	"	"	3800	3650	11000

All the above are with single row of needles only.

Bearings listed below are with double row of needles.

NA 69/32	32	40	52	36	1	4550	4100	10000
07	35	42	55	"	"	4750	4200	9000
08	40	48	62	40	"	6400	5800	8000
09	45	52	68	"	"	6800	6000	8000
10	50	58	72	40	"	7400	6200	7000
12	60	68	85	45	1.5	10100	8100	6000
14	70	80	100	54	"	14500	11300	5000
16	80	90	110	"	"	16000	11900	4000
18	90	105	125	63	2	22800	15100	4000



NEEDLE BEARINGS : RNA 49 Series (without inner race)

RNA 69 Series (without inner race)

All dimensions in mm

Brg. No.	d_i	D	B	r	Basic Static C_0	capacity, kgf dynamic C	Max. speed rpm
RNA 49 01	16	24	13	0.5	640	830	25000
02	20	28	13	"	780	940	20000
03	22	30	13	"	820	970	18000
04	25	37	17	"	1490	1850	16000
49/22	28	39	"	"	1690	2010	14000
05	30	42	"	"	1790	2080	13000
49/28	32	45	"	"	1890	2150	12000
06	35	47	"	"	1990	2210	11000
49/32	40	52	20	1	2650	2700	10000
07	42	55	20	"	2750	2800	9000
08	48	62	22	"	3700	3750	8000
09	52	68	22	"	3950	3900	8000
49 10	58	72	22	"	4250	4050	7000
12	68	85	25	1.5	5700	5200	6000
14	80	100	30	"	8400	7400	5000

RNA 69 Series with two rows of needles for $d_i \geq 40$.

RNA 69/32	40	52	36	1	4550	4100	10000
69 07	42	55	36	"	4750	4200	9000
08	48	62	40	"	6400	5800	8000
09	52	68	"	"	6800	6000	8000
69 10	58	72	40	"	7400	6200	7000
12	68	85	45	1.5	10100	8100	6000
14	80	100	54	"	14500	11300	5000
16	90	110	54	"	16000	11900	4000
18	105	125	63	2	22800	15100	4000

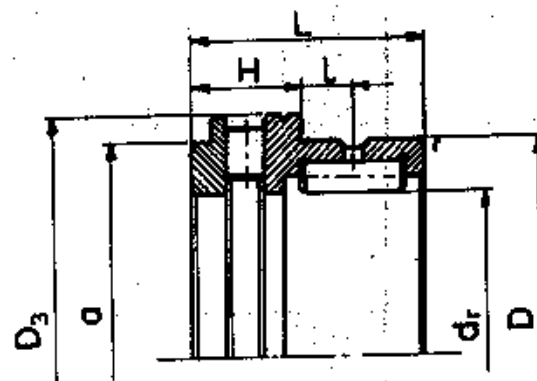
Combined NEEDLE THRUST ROLLER BEARINGS : NKXR[†] Series
(without inner race)*

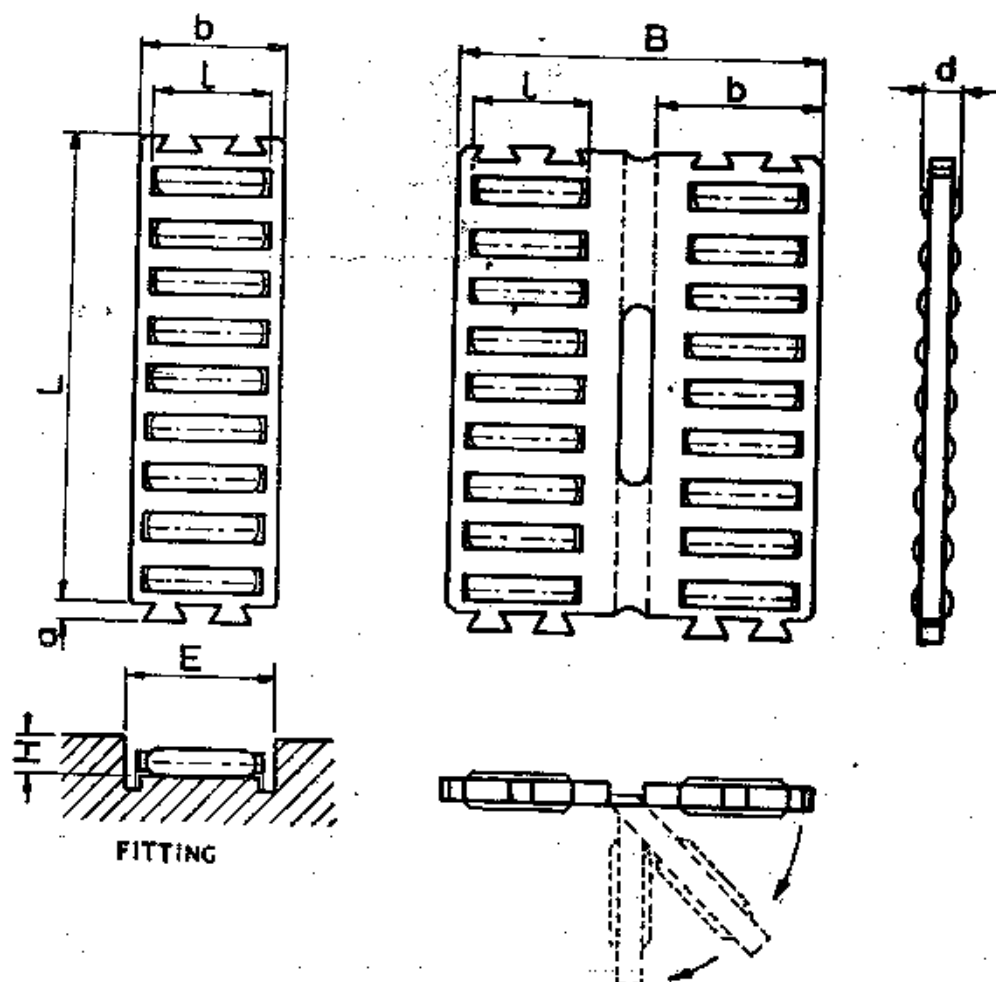
All dimensions in mm

Brg designation	d_r	D	D_2	H	L	a	l	r	Basic Capacity kgf				Max. Speed rpm
									Static radial C_0	Static axial C_{0a}	Dynamic radial C	Dynamic axial C_a	
NKXR 15	15	24	28.2	9	23	25.2	6.5	0.5	750	1210	950	1050	6500
17	17	26	30.2	"	25	27.2	8.4	"	870	1320	1050	1100	6000
20	20	30	35	10	30	30.7	10.5	"	1350	2600	1440	1910	5000
25	25	37	44	11	"	39.7	9.5	1	1680	4050	1660	2550	4000
30	30	42	49	"	"	44.7	9.5	"	1980	4500	1980	2700	3000
35	35	47	55	12	"	50.7	9	"	2270	4950	2140	3150	2500
40	40	52	67	13	32	61.7	10	"	2550	9900	2290	5300	2000
45	45	58	71.4	14	"	67.2	9	"	2850	9100	2420	"	1800
50	50	62	76.4	"	35	72.2	10	"	4000	10100	3350	5600	1600

* The inner race can be ordered separately.

† The above bearings are also available with dust shield when designated as NKXR Z

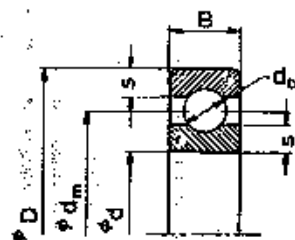




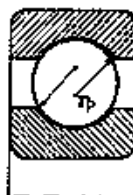
FLAT CAGES (LINEAR NEEDLE BEARINGS FOR SLIDEWAYS) Series FF & FF.....ZW

All dimensions in mm

Brg designation	b	B	L	a	No. of needles	d × l	E +0.1	H -0.2	Basic capacity, kgf C ₀ C	
FF 2010	10	—	32	2	7	2 × 6.3	10.3	1.7	870	540
2515	15	—	45	2.4	8	2.5 × 9.8	15.3	2.2	1810	1190
3020	20	—	60	3	9	3 × 13.8	20.4	2.7	3490	2430
3525	25	—	75	3.2	10	3.5 × 17.8	25.4	3.2	5900	4300
FF 2025 ZW	10	25	32	2	14	2 × 6.8	25.3	1.7	1740	930
2535 ZW	15	35	45	2.4	16	2.5 × 9.8	35.3	2.2	3620	2000
3045 ZW	20	45	60	3	18	3 × 13.8	45.4	2.7	6980	4100
3555 ZW	25	55	75	3.2	20	3.5 × 17.8	55.4	3.2	11800	7360



DEEP GROOVE BALL BEARING



FOR LARGE SIZE SKETCH

$$d_m = \frac{D+d}{2}$$

$$d_b \approx 0.3(D-d)$$

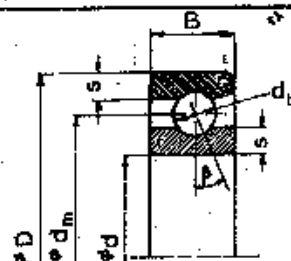
$$s \approx 0.15(D-d) = \frac{d_b}{2}$$

$$r = 0.5r$$

$$r = 0.515 d_b$$

$$Z \approx 2.9 \left(\frac{D+d}{D-d} \right)$$

d_m , mean diameter;
 s , radial thickness
 of races;
 d_b , diameter of ball;
 r_p , ball path radius;
 Z , no. of balls



ANGULAR CONTACT BEARING

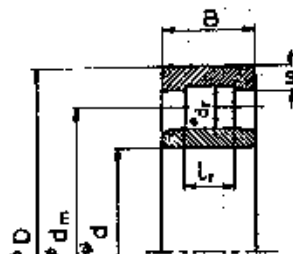
$$d_m = \frac{D+d}{2}$$

$$d_b \approx 0.3(D-d)$$

$$s \approx 0.15(D-d)$$

$$Z \approx 4.2 \frac{D+d}{D-d}$$

$$\beta = 25^\circ$$



ROLLER BEARING

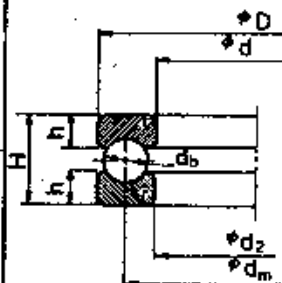
$$d_m = \frac{D+d}{2}$$

$$d_r \approx 0.25(D-d)$$

$$L_r \approx 1 \text{ or } 1.5 d_r$$

$$s \approx (0.15)(D-d)$$

General proportions for
 ANTI FRICTION BEARINGS



THRUST BEARING

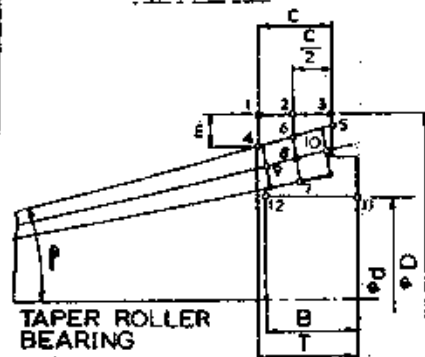
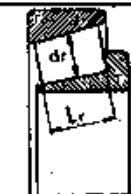
$$d_m = \frac{D+d}{2}$$

$$d_b = 0.5H; h \approx 0.3H;$$

$$r = 0.5r$$

$$Z \approx 3.56 \frac{D+d}{D-d}$$

$$r_p \approx 0.54 d_b$$



TAPER ROLLER BEARING

$$m \approx 0.2(D-d); \beta = 16^\circ$$

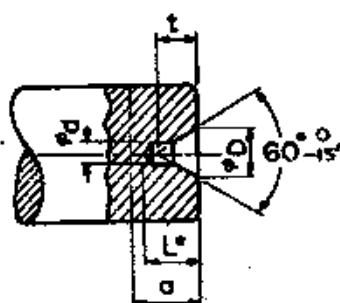
$$d_r \approx 0.25(D-d)$$

$$L_r \approx 1.6 d_r$$

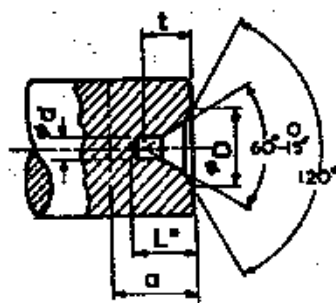
STANDARDS AND STANDARD COMPONENTS - 5

DIMENSIONS FOR CENTRE HOLES

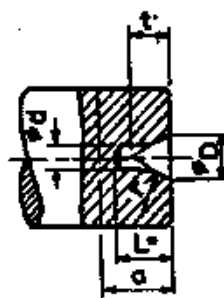
All dimensions in mm



TYPE A



TYPE B



TYPE R

d Nominal	TYPE A			TYPE B			TYPE R				
	D Nominal	t Reference	a	D Nominal	t Reference	a	D Nominal	t Reference	r Max.	r Min.	a
(0.5)	1.06	1.0	2	—	—	—	—	—	—	—	—
(0.63)	1.32	1.2	2	—	—	—	—	—	—	—	—
(0.8)	1.70	1.5	2.5	—	—	—	—	—	—	—	—
1.0	2.12	1.9	3	3.15	2.2	3.5	2.12	1.9	3.15	2.5	3
(1.25)	2.63	2.3	4	4	2.7	4.5	2.63	2.3	4.0	3.15	4
1.6	3.35	2.9	5	5	3.4	5.6	3.35	2.9	5.0	4.0	5
2.0	4.25	3.7	6	6.3	4.3	6.6	4.25	3.7	6.3	5.0	6
2.5	5.30	4.6	7	8	5.4	8.3	5.3	4.6	8.0	6.3	7
3.15	6.70	5.9	9	10	6.8	10.0	6.7	5.8	10.0	8.0	9
4.0	8.50	7.4	11	12.5	8.6	12.7	8.5	7.4	12.5	10.0	11
(5.0)	10.60	9.2	14	16	10.8	15.6	10.6	9.2	16.0	12.5	14
6.3	13.20	11.5	18	18	12.9	20.0	13.2	11.4	20.0	16.0	18
(8.0)	17.00	14.8	22	22.4	16.4	25.0	17.0	14.7	25.0	20.0	22
10.0	21.20	18.4	28	28	20.4	31.0	21.2	18.3	31.5	25.0	28

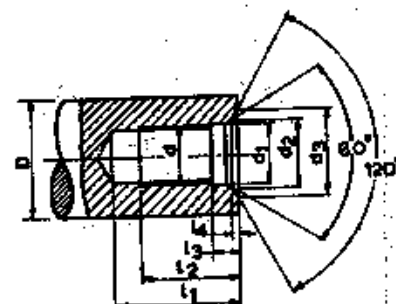
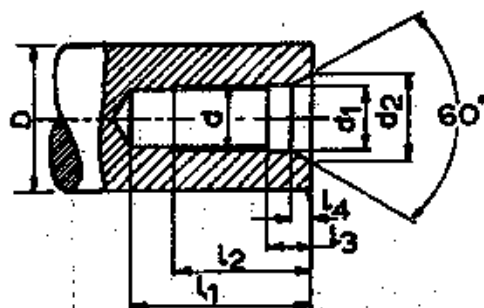
- NOTE :
- Sizes given in brackets are not preferred.
 - *Dimension L depends upon IS : 6709 — 1972. L should be greater than t.
 - a denotes parting off dimension if the centre hole is to be removed from the workpiece.
- IS : 2473 — 1975

RECOMMENDED CENTRE HOLES FOR DIFFERENT SIZES OF SHAFTS

Diameter of workpiece	Over	—	4	6	10	16	40	Weight of Workpiece	
	upto	4	6	10	16	40	80	1000 kgf	4000 kgf
d, Nominal		0.5	0.8	1.0	1.6	2.5	4	6.3	10

DIMENSIONS OF THREADED CENTRE-HOLES

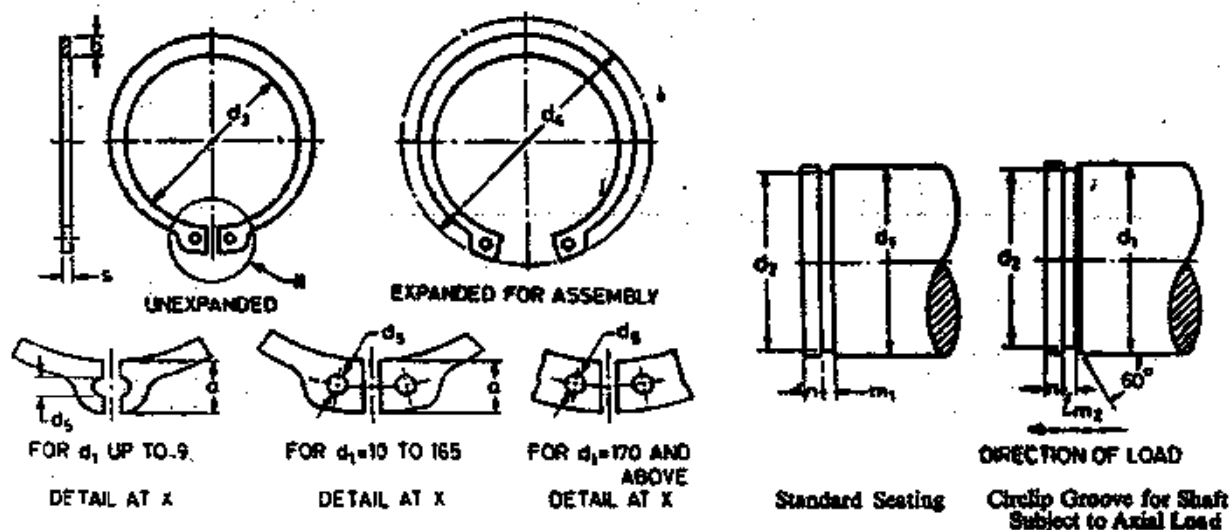
All dimensions in mm



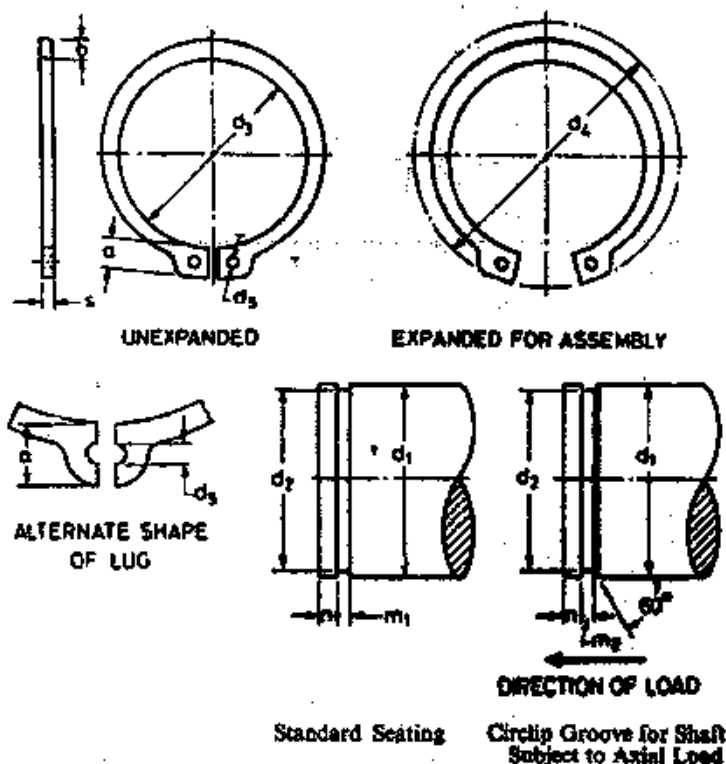
THREADED CENTRE-HOLES WITHOUT PROTECTED EDGES								THREADED CENTRE-HOLES WITH PROTECTED EDGES							
Nominal Size d	d ₁	d ₂	l ₁ min	l ₂	l ₃	l ₄	Recommended minimum workpiece diameter, D	d ₁	d ₂	d ₃	l ₁	l ₂	l ₃	l ₄	Recommended minimum workpiece diameter, D
M4	4.3	6.5	13	9	3.5 ^{+0.5}	2	—	—	—	—	—	—	—	—	—
M5	5.3	8	16	12	4.0 ^{+0.5}	2.5	10	5.3	7.4	9	16	12	4	0.5	10
M6	6.4	10	20	16	4.5 ^{+0.5}	2.5	14	6.4	9.4	11	20	16	4.5	0.5	14
M8	8.4	12	25	20	5.5 ^{+0.1.0}	3.2	17	8.4	10.8	14.5	25	20	5.5	1	17
M10	10.5	15	30	24	7.0 ^{+1.0}	4.0	22	10.5	13.8	17.5	30	24	7	1	22
M12	13	18	36	28	8.0 ^{+1.0}	4.5	30	13	16.8	20.5	36	28	8	1	30
M16	17	24	40	32	10.0 ^{+1.0}	6.0	38	17	21.7	28.5	40	32	10	2	38
M20	21	29	50	40	12.0 ^{+1.0}	7.0	50	21	26.7	33.5	50	40	12	2	50
M24	25	35	63	50	14.0 ^{+1.0}	9.0	85	25	32.7	39.5	63	50	14	2	85
M30	31	44	80	65	18.0 ^{+1.0}	11.0	130	31	41.7	48.5	80	65	18	2	130

DIMENSIONS FOR EXTERNAL CIRCLIPS, TYPE A

Light Series



Heavy Series



Designation:

A circlip of light series in type A for shaft diameter d_1 equal to 50 mm shall be designated as: Circlip, Light A 50 IS: 3075-1965

DIMENSIONS FOR EXTERNAL CIRCLIPS, TYPE A—LIGHT SERIES

All dimensions in millimetres

Shaft Dia d_1	CIRCLIP								SHAFT GROOVE				Axial Force kgf
	h 11	a Max.	b Approx.	d_3	Tol. on d_3	d_4 Expanded	d_5 Min.	d_6	Tol. on d_6	m_1 H13	m_2 Min.	n Min.	
8	0.8	3.2	1.5	7.4	+0.09	15.2	—	7.6	—	0.9	1.0	—	120
9	—	—	1.7	8.4	-0.18	16.4	1.2	8.6	—	—	—	—	138
10	—	3.3	—	9.3	+0.15	17.6	—	9.6	—	—	—	0.6	153
11	—	—	1.8	10.2	-0.30	—	1.5	10.5	—	—	—	—	210
12	—	—	—	11	—	18.6	—	11.5	h11	—	—	0.75	230
13	1	3.4	2	11.9	—	20.8	—	12.4	1.1	1.2	—	—	300
14	—	3.5	2.1	12.9	—	22	—	13.4	—	—	—	0.9	325
15	—	3.6	—	13.8	+0.18	23.2	1.7	14.3	—	—	—	—	400
16	—	3.7	2.2	14.7	-0.36	24.4	—	15.2	—	—	—	1.1	490
17	—	3.8	2.3	15.7	—	25.6	—	16.2	—	—	—	1.2	520
18	—	—	2.4	16.5	—	26.8	—	17	—	—	—	—	690
19	—	3.9	2.5	17.5	—	27.8	—	18	—	—	—	—	725
20	—	4	2.6	18.5	—	29	—	19	—	—	—	1.5	770
21	1.2	4.1	2.7	19.5	—	30.2	—	20	—	—	—	—	805
22	—	4.2	2.8	20.5	—	31.4	—	21	1.3	1.4	—	—	845
24	—	4.4	3	22.2	—	33.8	2	22.9	—	—	—	—	1 010
25	—	—	—	23.2	+0.21	34.8	—	23.9	—	—	—	—	1 060
26	—	4.5	3.1	24.2	-0.42	36	—	24.9	—	—	—	1.7	1 100
28	—	4.7	3.2	25.9	—	38.4	—	26.6	—	—	—	—	1 500
29	—	4.8	3.4	26.9	—	39.6	—	27.6	—	—	—	—	1 560
30	—	5	3.5	27.9	—	41	—	28.6	—	—	—	2.1	1 620
32	1.5	5.2	3.6	29.6	—	43.4	—	30.3	1.6	1.7	—	—	2 100
34	—	5.4	3.8	31.5	—	45.8	—	32.3	—	—	—	2.6	2 220
35	—	—	3.9	32.2	+0.25	47.2	—	33	—	—	—	—	2 670
36	—	5.6	4	33.2	-0.50	48.2	—	34	—	—	—	—	2 760
38	—	5.8	4.2	35.2	—	50.6	—	36	h12	—	—	3	2 910
40	—	6	4.4	36.5	—	53	—	37.5	—	—	—	—	3 810
42	1.75	6.5	4.5	38.5	—	56	—	39.5	1.85	2	—	—	4 000
45	—	6.7	4.7	41.5	+0.39	59.4	—	42.5	—	—	—	3.8	4 300
48	—	6.9	5	44.5	-0.78	62.8	2.5	45.5	—	—	—	—	4 600
50	—	6.9	5.1	45.8	—	64.8	—	47	—	—	—	—	5 700
52	—	7	5.2	47.8	—	67	—	49	—	—	—	—	5 950
55	—	7.2	5.4	50.8	—	70.4	—	52	—	—	—	—	6 300
56	—	—	5.5	51.8	—	71.6	—	53	2.15	2.3	—	—	6 400
58	2	7.3	5.6	53.8	—	73.6	—	55	—	—	—	—	6 650
60	—	7.4	5.8	55.8	+0.46	75.8	—	57	—	—	—	4.5	6 900
62	—	7.5	6	57.8	-0.92	78	—	59	—	—	—	—	7 100
63	—	7.6	6.2	58.8	—	79.2	—	60	—	—	—	—	7 250

DIMENSIONS FOR EXTERNAL CIRCLIPS, TYPE A—LIGHT SERIES (Contd.)

Shaft Dia d_1	CIRCLIP					SHAFT GROOVE					Axial Force kgf		
	h	a Max.	b Approx.	d_2	Tol. on d_2	d_4 Expanded	d_5 Min.	d_1	Tol. on d_2	m_1 H13		m_2 Min.	n Min.
65		7.8	6.3	60.8		81.6		62					7 500
68		8	6.5	63.5		85		65					7 840
70		8.1	6.6	65.5		87.2		67					8 050
72	2.5	8.2	6.8	67.5	+0.46	89.4	3	69		2.65	2.8	4.5	8 300
75		8.4	7	70.5	-0.92	92.8		72					8 600
78			7.3	73.5		96.2		75					9 000
80		8.6	7.4	74.5		98.2		76.5	h12				10 700
82			7.6	76.5		101		78.5					11 000
85		8.7	7.8	79.5		104		81.5					11 400
88			8	82.5		107		84.5				5.3	11 900
90	3	8.8	8.2	84.5		109		86.5		3.15	3.3		12 100
95		9.4	8.6	89.5		115		91.5					12 800
100		9.6	9	94.5		121	3.5	96.5					13 500
105		9.9	9.3	98	+0.54	126		101					16 200
110			9.6	103	-1.08	132		106					17 000
115		10.6	9.8	108		138		111					17 800
120		11	10.2	113		143		116					18 500
125		11.4	10.4	118		149		121				6	19 300
130		11.6	10.7	123		155		126					20 100
135		11.8	11	128		160		131					20 900
140		12	11.2	133		165		136					21 700
145		12.2	11.5	138		171		141					22 500
150			11.8	142		177		145					28 900
155	4	13	12	146		182		150		4.15	4.3		30 000
160		13.3	12.2	151	+0.63	188		155					31 000
165		13.5	12.5	155.5	-1.26	193		160					32 000
170			12.9	160.5		197		165					32 900
175			Max	165.5		202	4	170	h13			7.5	33 800
180			13.5	170.5		208		175					34 800
185			Max	175.5		213		180					33 800
190				180.5		219		185					33 500
195				185.5		224		190					32 700
200				190.5		229		195					31 900
210			14	198		239		204					48 800
220			Max	208	+0.72	249		214					51 200
230				218	-1.44	259		224				9	53 500
240				228		269		234					52 900
250				238		279		244					50 300
260	5			245		293		252		5.15	5.3		54 400
270				255		303		262					52 500
280			16	265	+0.81	313	5	272				12	50 800
290			Max	275	-1.62	323		282					49 100
300				285		333		292					47 300

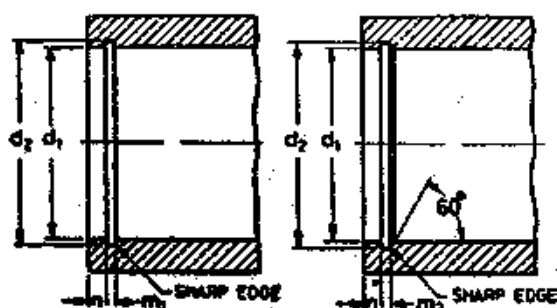
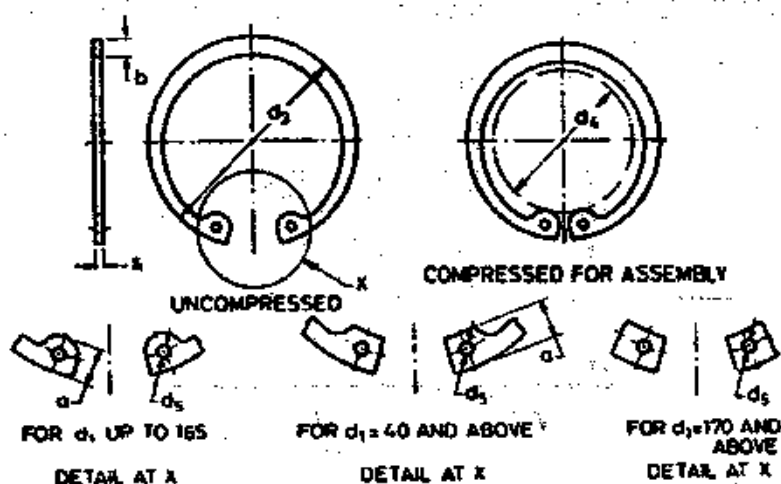
DIMENSIONS FOR EXTERNAL CIRCLIPS, TYPE A—HEAVY SERIES*

All dimensions in millimetres

Shaft Dia d_1	CIRCLIP							SHAFT GROOVE					
	s h 11	a Max.	b Approx.	d_2	Tol. on d_2	d_3 Expanded	d_4 Min.	d_5	Tol. on d_5	m_1 H13	m_2 Min.	n Min.	Axial Force kgf
15		4.8	2.4	13.8		25.5		14.3				1.1	400
16	1.5	5	2.5	14.7	+0.18	27.5		15.2				1.2	490
17			2.6	15.7	-0.36	28.5		16.2	h11	1.6	1.7		520
18		5.1	2.7	16.3		29.5		17					690
20		5.5	3	18.5		32.5		19				1.5	770
22	1.75	6	3.1	20.5		35.5	2	21		1.85	2		845
24		6.3	3.2	22.2	+0.21	38		22.9				1.7	1 010
25		6.4	3.4	23.2	-0.42	39		23.9					1 060
28			3.5	25.9		42.5		26.6					1 500
30	2	6.5		27.9		44.5		28.6		2.15	2.3	2.1	1 620
32			4.1	29.6		46.5		30.3				2.6	2 100
34		6.6		31.5	+0.25	49		32.3					2 220
35		6.7	4.2	32.2	-0.50	50		33				3	2 640
38		6.8	4.3	35.2		53		36					2 880
40	2.5	7	4.4	36.5		55.5		37.5		2.65	2.8		3 840
42		7.2	4.5	38.5		58		39.5				3.8	4 000
45		7.5	4.7	41.5	+0.39	61.5	2.5	42.5	h12				4 300
48		7.8	5	44.5	-0.78	65		45.5					4 600
50		8	5.1	45.8		68		47					5 700
52		8.2	5.2	47.8		70		49					5 950
55	3	8.5	5.4	50.8		73.5		52		3.15	3.3		6 300
58		8.8	5.6	53.8		77		55				4.5	6 650
60		9	5.8	55.8		79		57					6 900
65		9.3	6.3	60.8	+0.46	85		62					7 500
70		9.5	6.6	65.5	-0.92	90.5	3	67					8 050
75		9.7	7	70.5		96		72					8 600
80	4	9.8	7.4	74.5		101		76.5		4.15	4.3		10 700
85		10	7.8	79.5		106.5		81.5				5.3	11 400
90		10.2	8.2	84.5	+0.54	112	3.5	86.5					12 100
100		10.5	9	94.5	-1.08	124		96.5					13 500

*Please refer page 5.3 for figure.

DIMENSIONS FOR INTERNAL CIRCLIPS, TYPE B **Light Series**

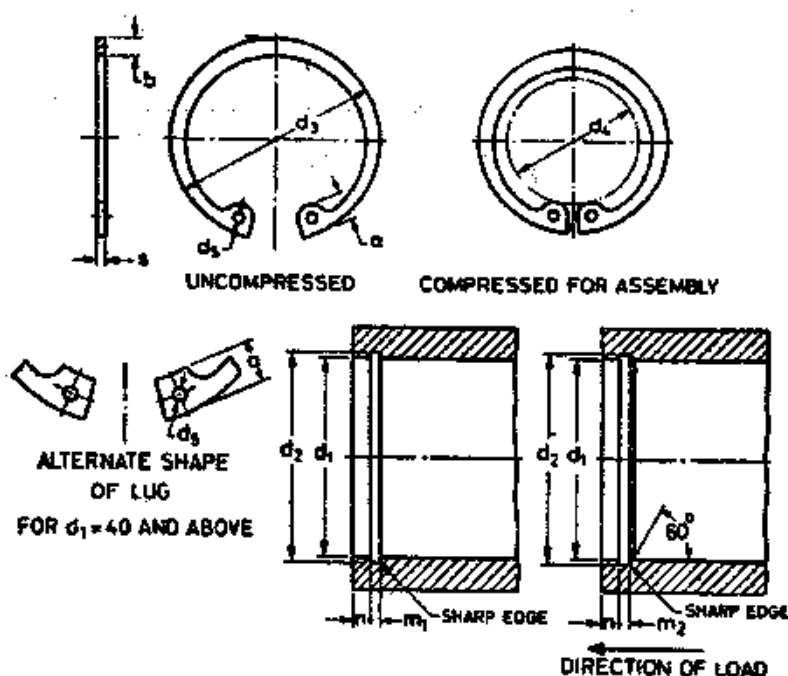


DIRECTION OF LOAD

Standard Seating

Circlip Groove for Bore Subject to Axial Load

Heavy Series



Standard Seating

Circlip Groove for Bore Subject to Axial Load

DIMENSIONS FOR INTERNAL CIRCLIPS, TYPE-B LIGHT SERIES

All dimensions in millimetres

Bore Dia d_1	CIRCLIP				Tol. on d_2	d_3 Com- pressed	d_4 Min.	d_5	BORE GROOVE					Axial Force kgf
	b H11	Max.	Approx.	d_2					Tol. on d_5	m_1 H13	m_2 Min.	n Min.		
8	0.8	2.4	1.1	8.7	+0.36 -0.18	2.8	1	8.4	H11	1.1	1.2	1.1	0.6	128
9		2.5	1.3	9.8		3.5		9.4						144
10		3.2	1.4	10.8		3.1		10.4						160
11		3.3	1.5	11.8		3.9		11.4						176
12	1	3.4	1.7	13	+0.42 -0.21	4.7	1.7	12.5						240
13		3.6	1.8	14.1		5.3		13.6						314
14		3.7	1.9	15.1		6		14.6						336
15		3.8	2	16.2		7		15.7						422
16		3.9	2.1	17.3		7.7		16.8						515
17		4.1	2.2	18.3		8.4		17.8						547
18		4.2	2.3	19.5		8.9		19						725
19		4.4	2.4	20.5		9.8		20						764
20		4.5	2.5	21.5		10.6		21						805
21		4.7	2.6	22.5		11.6		22						845
22	1.2	4.8	2.7	23.5	+0.50 -0.25	12.6	2	23		1.3	1.4	2.1	1.8	882
24		4.9	2.8	25.9		14.2		25.2						1160
25		5.1	2.9	26.9		15		26.2						1200
26		5.2	3	27.9		15.6		27.2						1250
28		5.4	3.1	30.1		17.4		29.4						1580
30		5.6	3.2	32.1		19.4		31.4						1690
32		5.8	3.3	34.4		20.2		33.7						2200
34		6.0	3.4	36.5		22.2		35.7						2320
35		6.2	3.5	37.8		23.2		37						2820
36		6.4	3.6	38.8		24.2		38		H12	1.85	2	3.8	2900
37	6.6	3.7	39.8	25	39	3070								
38	6.8	3.8	40.8	26	40	4050								
40	7.0	3.9	43.5	27.4	42.5	4250								
42	7.2	4.1	45.5	29.2	44.5	4520								
45	7.4	4.3	48.5	31.6	47.5	4720								
47	7.6	4.4	50.5	33.2	49.5	4820								
48	7.8	4.5	51.5	34.6	50.5	6070								
50	8.0	4.6	54.2	36	53	6300								
52	8.2	4.7	56.2	37.6	55	6650								
55	8.4	5	59.2	40.4	58	6750								
56	2	8.6	5.1	60.2	+0.92 -0.46	41.4	3	59		2.15	2.3	4.5	5.3	7000
58		8.8	5.2	62.2		43.2		61						7250
60		9.0	5.4	64.2		44.4		63						7480
62		9.2	5.5	66.2		46.4		65						7580
63		9.4	5.6	67.2		47.4		66						7820
65		9.6	5.8	69.2		48.8		68						8170
68		9.8	6.1	72.5		51.4		71						8420
70		10.0	6.2	74.5		53.4		73						8650
72		10.2	6.4	76.5		55.4		75		2.65	2.8			9000
75	10.4	6.6	79.5	+1.08 -0.54	58.4	3	78	9350						
78	10.6	6.8	82.5		60		81	11200						
80	10.8	7	85.5		62		83.5	11500						
82	11.0	7.2	87.5		64		85.5							

DIMENSIONS FOR INTERNAL CIRCLIPS, TYPE B—LIGHT SERIES (Contd.)

Bore Dia. d_1	CIRCLIP				Bore Groove								Axial Force kgf
	a h II	a Max.	b Approx.	d_2	Tol. on d_2	d_3 Com- pressed	d_4 Min.	d_5	Tol. on d_5	m_1 H13	m_2 Min.	n Min.	
85			7.2	90.5		66.8		88.5					11 900
88		8.6	7.4	93.5		69.8		91.5					12 300
90			7.6	95.5		71.8		93.5					12 600
92	3	8.7	7.8	97.5		73.6		95.5	H12	3.15	3.3	5.3	12 900
95		8.8	8.1	100.5		76.4		98.5					13 300
98		9	8.3	103.5	+1.08	79		101.5					13 700
100			8.4	105.5	-0.54	81	3.5	103.5					14 000
102		9.2	8.5	108		82.6		106					16 300
105			8.7	112		85.6		109					16 800
108		9.5	9	115		88		112					17 300
110		10.4	9	117		88.2		114					17 600
112		10.5	9.1	119		90		116					17 900
115			9.3	122		93		119					18 400
120			9.7	127		97		124				6	19 200
125		11	10	132		102		129					19 900
130			10.2	137		107		134					20 700
135			10.5	142		112		139					21 500
140		11.2	10.7	147	+1.26	117		144					22 300
145		11.4	10.9	152	-0.63	122		149					23 100
150		12	11.2	158		125		155					30 000
155	4		11.4	164		130		160		4.15	4.3		30 900
160		13	11.6	169		133		165					31 900
165			11.8	174.5		138		170					32 900
170			12.2	179.5		145		175					33 900
			Max										
175			12.7	184.5		149	4	180	H13			7.5	34 800
			Max										
180			13.2	189.5		153		185					34 500
			Max										
185			13.7	194.5	+1.44	157		190					35 000
			Max		-0.72	162		195					34 000
190			13.8	199.5		167		200					33 000
195			Max	204.5		171		205					32 500
200				209.5		171		205					49 800
210				222		181		216					52 200
220			14	232		191		226					54 900
230			Max	242		201		236				9	52 500
240				252		211		246					50 500
250				262		221		256					54 000
260	5			275	+1.62	227		268		5.15	5.3		51 800
270				285	-0.81	237		278					50 000
280			16	295		247	5	288				12	48 200
290			Max	305		257		298					46 500
300				315		267		308					

DIMENSIONS FOR INTERNAL CIRCLIPS, TYPE B—HEAVY SERIES*

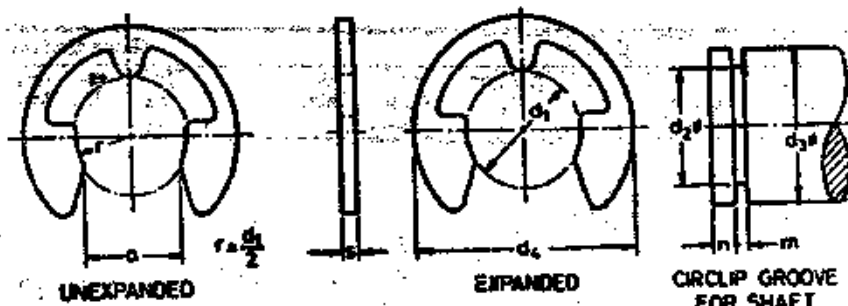
All dimensions in millimetres

Bore Dia d_1	Circle							Boss Groove					Axial Force kgf
	s h II	a Max.	b Approx.	d_2	Tol. on d_2	d_3 Com- pressed	d_4 Min.	d_5	Tol. on d_5	m_2 H/3	m_3 Min.	n Min.	
20		4.5	2.4	21.5		10		21				1.5	805
22		4.7	2.8	23.5		11.6		23					882
24		4.9	3	25.9	+0.42	13.2		25.2					1 160
25	1.5	5	3.1	26.9	-0.21	14	2	26.2		1.6	1.7	1.8	1 200
26		5.1		27.9		14.8		27.2					1 250
28		5.3	3.2	30.1		16.4		29.4					1 580
30		5.5	3.3	32.1		18		31.4				2.1	1 690
32		5.7	3.4	34.4		19.6		33.7					2 200
34		5.9	3.7	36.5	+0.50	21.2		35.7				2.6	2 320
35	1.75	6	3.8	37.8	-0.25	22		37					2 820
37		6.2	3.9	39.8		23.6		39		1.85	2	3	2 980
38		6.3		40.8		24.4		40					3 070
40		6.5		43.5		26		42.5					4 050
42	2	6.7	4.1	45.5	+0.78	27.6	2.5	44.5					4 250
45		7	4.3	48.5	-0.39	30		47.5		2.15	2.3	3.8	4 520
47		7.2	4.4	50.5		31.6		49.9	H12				4 720
50		7.5	4.6	54.2		34		53					6 070
52	2.5	7.7	4.7	56.2		35.6		55		2.65	2.8		6 300
55		8	5	59.2		38		58					6 650
60		8.5	5.4	64.2		42		63					7 250
62		8.6	5.5	66.2	+0.92	43.8		65					7 480
65		8.7	5.8	69.2	-0.46	46.6		68				4.5	7 820
68	3	8.8	6.1	72.5		49.4		71		3.15	3.3		8 170
70		9	6.2	74.5		51		73					8 420
72		9.2	6.4	76.5		52.6	3	75					8 650
75		9.3	6.6	79.5		55.5		78					9 000
80		9.5	7	85.5		60		83.5					11 200
85		9.7	7.2	90.5		64.6		88.5					11 900
90	4	10	7.6	95.5	+1.08	69		93.5		4.15	4.3	5.3	12 600
95		10.3	8.1	100.5	-0.54	73.4	3.5	98.5					13 300
100		10.5	8.4	105.5		78		103.5					14 000

*Refer page 5.7 for figure.

DIMENSIONS FOR EXTERNAL CIRCLIPS, TYPE C

All dimensions in millimetres



Nominal Size d_1	CIRCLIP				SHAFT GROOVE					
	d_2 Expanded	a H10	s	Tol. on s	d_3 From	To	d_2 h 11	m	Tol. on m	n Min.
0.8	2	0.58	0.2		1	1.4	0.8	0.24		0.4
1.2	3	1.01	0.3		1.4	2	1.2	0.34	± 0.02	0.6
1.5	4	1.28	0.4		2	2.5	1.5	0.44		0.8
1.9	4.5	1.61	0.5		2.5	3	1.9	0.54		1
2.3	6	1.94	0.6	± 0.02	3	4	2.3	0.64		1
3.2	7	2.70	0.6		4	5	3.2	0.64		1
4	9	3.34	0.7		5	7	4	0.74	± 0.03	1.2
5	11	4.11	0.7		6	8	5	0.74		1.2
6	12	5.26	0.7		7	9	6	0.74		1.2
7	14	5.84	0.9		8	11	7	0.94		1.5
8	16	6.52	1.0		9	12	8	1.05		1.8
9	18.5	7.63	1.1		10	14	9	1.15		2
10	20	8.32	1.2		11	15	10	1.25		2
12	23	10.45	1.3	± 0.03	13	18	12	1.35	± 0.06	2.5
15	29	12.61	1.5		16	24	15	1.55		3.0
19	37	15.92	1.75		20	31	19	1.80		3.5
24	44	21.88	2.0		25	38	24	2.05		4.0

IS : 3075 - 1965

DIMENSIONS FOR CYLINDRICAL PINS

All dimensions in millimetres.



1-8-2
7.98
7.98

d Nom		1.6	2	2.5	3	4	5	6	8	10	12	16	20	25	32	40	50
d m6	Max	1.61	2.01	2.51	3.01	4.01	5.01	6.01	8.02	10.02	12.02	16.02	20.02	25.02	32.02	40.02	50.02
	Min	1.60	2.00	2.50	3.00	4.00	5.00	6.00	8.01	10.01	12.01	16.01	20.01	25.01	32.01	40.01	50.01
d h8	Max	1.60	2.00	2.50	3.00	4.00	5.00	6.00	8.00	10.00	12.00	16.00	20.00	25.00	32.00	40.00	50.00
	Min	1.59	1.99	2.49	2.99	3.98	4.98	5.98	7.98	9.98	11.97	15.97	19.97	24.97	31.96	39.96	49.96
d h11	Max	1.60	2.00	2.50	3.00	4.00	5.00	6.00	8.00	10.00	12.00	16.00	20.00	25.00	32.00	40.00	50.00
	Min	1.54	1.94	2.44	2.94	3.92	4.92	5.92	7.91	9.91	11.89	15.89	19.87	24.87	31.84	39.84	49.84
a Max		0.2	0.25	0.3	0.4	0.5	0.63	0.8	1	1.2	1.6	2	2.5	3	4	5	6.3
r Nom		1.6	2	2.5	3	4	5	6	8	10	12	16	20	25	32	40	50

Designation: A cylindrical pin of nominal diameter 10 mm, tolerance h8 and nominal length 20 mm shall be designated as:
Cylindrical Pin 10 h8 x 20 IS: 2393-1963.

PREFERRED LENGTH DIAMETER COMBINATIONS FOR CYLINDRICAL PINS

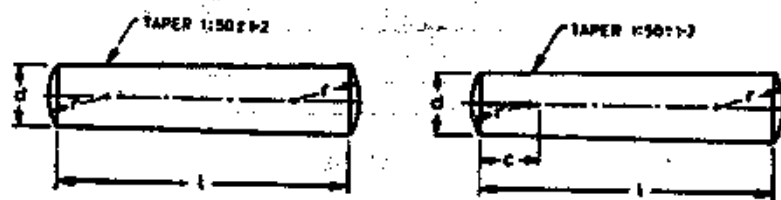
All dimensions in millimetres

Length, <i>l</i> (J15)			d, Nom.															
Nom	Max	Min	1.6	2	2.5	3	4	5	6	8	10	12	16	20	25	32	40	50
4	4.24	3.76	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	5.24	4.76	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	6.24	5.76	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
8	8.29	7.71	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
10	10.3	9.71	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
12	12.4	11.6	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
14	14.4	13.6	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
16	16.4	15.6	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-
20	20.4	19.6	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-
25	25.4	24.6	-	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-
30	30.4	29.6	-	-	+	+	+	+	+	+	+	+	+	-	-	-	-	-
35	35.5	34.5	-	-	-	+	+	+	+	+	+	+	+	-	-	-	-	-
40	40.5	39.5	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-	-
45	45.5	44.5	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-	-
50	50.5	49.5	-	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-
55	55.6	54.4	-	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-
60	60.6	59.4	-	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-
65	65.6	64.4	-	-	-	-	-	-	+	+	+	+	+	+	+	+	-	-
70	70.6	69.4	-	-	-	-	-	-	+	+	+	+	+	+	+	+	-	-
75	75.6	74.4	-	-	-	-	-	-	+	+	+	+	+	+	+	+	-	-
80	80.6	79.4	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	-
90	90.7	89.3	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	-
100	101	99.3	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+
110	111	109	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+
120	121	119	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+
130	131	129	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
140	141	139	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
150	151	149	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
160	161	159	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+
170	171	169	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+
180	181	179	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+
190	191	189	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+
200	201	199	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+

NOTE — For lengths beyond 200 mm, steps of 20 mm may be used.

DIMENSIONS FOR SOLID AND SPLIT TAPER PINS

All dimensions in millimetres



($r=d$ approx)
Solid Taper Pin

($r=d$ approx, and split length $C=0.2 l$)
Split Taper Pin

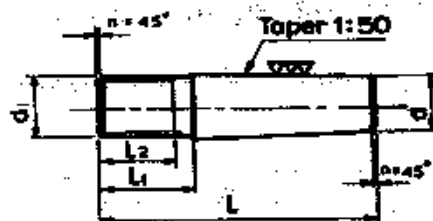
d Nom	1.6	2	2.5	3	4	5	6	8	10	12	16	20	25	32	40	50
d Max (h10)	1.60	2.00	2.50	3.00	4.00	5.00	6.00	8.00	10.00	12.00	16.00	20.00	25.00	32.00	40.00	50.00
d Min	1.54	1.96	2.46	2.94	3.95	4.95	5.95	7.94	9.94	11.93	15.93	19.92	24.92	31.90	39.90	49.90

Preferred Length Diameter Combinations

Length, l (J15)			d, Nom.															
Nom	Max	Min	1.6	2	2.5	3	4	5	6	8	10	12	16	20	25	32	40	50
8	8.29	7.71	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	10.3	9.71	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	12.4	11.6	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
14	14.4	13.6	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
16	16.4	15.6	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
20	20.4	19.6	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
25	25.4	24.6	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
30	30.4	29.6	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-
35	35.5	34.5	-	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-
40	40.5	39.5	-	-	-	+	+	+	+	+	+	+	-	-	-	-	-	-
45	45.5	44.5	-	-	-	-	+	+	+	+	+	+	+	-	-	-	-	-
50	50.5	49.5	-	-	-	-	-	+	+	+	+	+	+	+	-	-	-	-
55	55.6	54.4	-	-	-	-	-	+	+	+	+	+	+	+	+	-	-	-
60	60.6	59.4	-	-	-	-	-	+	+	+	+	+	+	+	+	+	-	-
65	65.6	64.4	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	-
70	70.6	69.4	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+
75	75.6	74.4	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+
80	80.6	79.4	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+
90	90.7	89.3	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+
100	101	99.3	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+
110	111	109	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+
120	121	119	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+
130	131	129	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+
140	141	139	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+
150	151	149	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+
160	161	159	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
170	171	169	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
180	181	179	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+
190	191	189	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+
200	201	199	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+

NOTE — For lengths above 200 mm, steps of 20 mm may be used.

Designation: A solid taper Pin of 10 mm diameter and 50 mm nominal length shall be designated as: Solid Taper Pin 10×50 IS: 2393 - 1963.

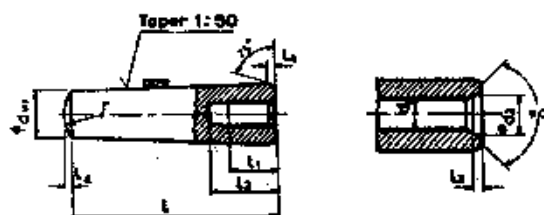


▽ (▽▽)

EXTERNALLY THREADED TAPER PINS

All dimensions in mm

SIZE d	5	6	8	10	12	16	20
d ₁	M5	M6	M8	M10	M12	M16	M20
L ₁	11	12.5	15	18	22	28	30
L ₂	8	10	12	15	18	22	25
n	1	1	1	2	2	3	3
l	20—40	25—50	40—65	50—85	50—120	65—140	120—160



▽ (▽▽)

DIMENSIONS OF INTERNAL THREADED TAPER PINS

All dimensions in mm

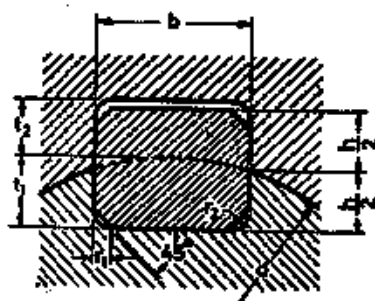
d h10	6	8	10	12	16	20
d ₁	M4	M5	M6	M8	M10	M12
d ₂	4.3	5.3	6.4	8.4	10.5	13
L ₁	6	8	10	12	16	20
L ₂	10	13	16	18	23	27
L ₃	1	1.2	1.2	1.2	1.6	1.6
L ₄ max	0.9	1.2	1.5	2	2.5	3
r approx	6	10	10	16	16	20

IS : 3524

Material : Medium Carbon Steel.

DIMENSIONS OF PARALLEL KEYS AND KEYWAYS

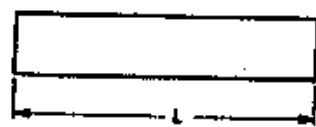
All dimensions in millimetres



CHAMFER OR RADIUS
OF KEY



KEYWAY RADIUS
IN SHAFT AND HUB



For shaft diameters	Above Up to	6	8	10	12	17	22	30	38	44	50	58	65	75	85	95	110	130	150	170	200	230	260	290	330	380	440
Key cross section	Width b	2	3	4	5	6	8	10	12	14	16	18	20	22	25	28	32	36	40	45	50	56	63	70	80	90	100
	Height h	2	3	4	5	6	7	8	8	9	10	11	12	14	14	16	18	20	22	25	28	32	32	36	40	45	50
Keyway depth (nominal)	in Shaft t_1	1.2	1.8	2.5	3	3.5	4	5	5	5.5	6	7	7.5	8.5	9	10	11	12	13	15	17	19	20	22	25	28	31
	in hub t_2	1	1.4	1.8	2.3	2.8	3.3	3.3	3.3	3.8	4.3	4.4	4.9	5.9	5.4	6.4	7.4	8.4	9.4	10.4	11.4	13.4	12.4	14.4	15.4	17.4	19.5
Tolerance on keyway depth	r_1	+0.1		+0.2										+0.3													
	r_2	+0.1				+0.2								+0.3													
Chamfer or radius of key r_1	Max	0.25		0.35				0.55						0.80				1.30				2.00				2.95	
	Min	0.16		0.25				0.40						0.60				1.00				1.60				2.50	
Keyway radius r_2	Max	0.16		0.25				0.40						0.60				1.00				1.60				2.50	
Length of key L	Min	6	6	8	10	14	18	22	28	36	45	50	56	63	70	80	90	100	110	125	140	160	180	200	220	250	280
	Max	20	36	45	56	70	90	110	140	160	180	200	220	250	280	320	360	400	400	400	400	400	400	400	400	400	400

Designation : A Parallel Key of width 10 mm height 8 mm and length 50 mm shall be designated as: Parallel Key 10×8×50 IS: 2048-1962

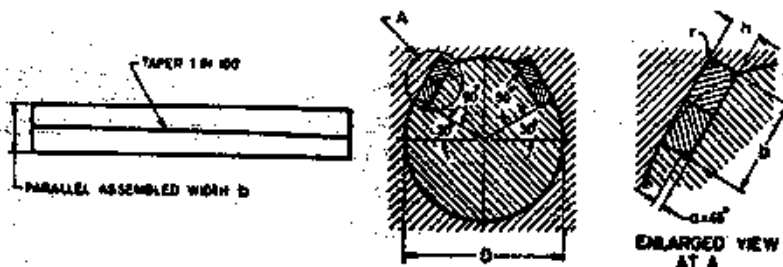
PREFERRED LENGTHS OF PARALLEL KEYS

Width (b), mm	2	3	4	5	6	8	10	12	14	16	18	20	22	25	28	32	36	40	45	50	56	63	70	80	90	100
Height (h), mm	2	3	4	5	6	7	8	8	9	10	11	12	14	14	16	18	20	22	25	28	32	32	36	40	45	50
6	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
8	8	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
10	10	10	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12	12	12	12	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
14	14	14	14	14	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	16	16	16	16	16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18	18	18	18	18	18	18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	20	20	20	20	20	20	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	22	22	22	22	22	22	22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	25	25	25	25	25	25	25	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	28	28	28	28	28	28	28	28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	32	32	32	32	32	32	32	32	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	36	36	36	36	36	36	36	36	36	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	40	40	40	40	40	40	40	40	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	45	45	45	45	45	45	45	45	45	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	50	50	50	50	50	50	50	50	50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	56	56	56	56	56	56	56	56	56	56	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	63	63	63	63	63	63	63	63	63	63	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	70	70	70	70	70	70	70	70	70	70	70	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	80	80	80	80	80	80	80	80	80	80	80	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	90	90	90	90	90	90	90	90	90	90	90	90	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	90	90	90	90	90	90	90	90	90	90	90	90	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	100	100	100	100	100	100	100	100	100	100	100	100	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	110	110	110	110	110	110	110	110	110	110	110	110	110	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	125	125	125	125	125	125	125	125	125	125	125	125	125	—	—	—	—	—	—
—	—	—	—	—	—	—	—	140	140	140	140	140	140	140	140	140	140	140	140	140	140	—	—	—	—	—
—	—	—	—	—	—	—	—	—	160	160	160	160	160	160	160	160	160	160	160	160	160	160	—	—	—	—
—	—	—	—	—	—	—	—	—	—	180	180	180	180	180	180	180	180	180	180	180	180	180	180	—	—	—
—	—	—	—	—	—	—	—	—	—	—	180	180	180	180	180	180	180	180	180	180	180	180	180	180	—	—
—	—	—	—	—	—	—	—	—	—	—	—	200	200	200	200	200	200	200	200	200	200	200	200	200	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	220	220	220	220	220	220	220	220	220	220	220	220	220	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	250	250	250	250	250	250	250	250	250	250	250	250	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	280	280	280	280	280	280	280	280	280	280	280	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	320	320	320	320	320	320	320	320	320	320	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	360	360	360	360	360	360	360	360	360	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	400	400	400	400	400	400	400	400	—

Preferred Length (L), mm

DIMENSIONS OF TANGENTIAL KEYS AND KEYWAYS

All dimensions in millimetres



Shaft Dia D	Keyway			Key	Shaft Dia D	Keyway			Key
	Height	Width	Radius	Chamfer		Height	Width	Radius	Chamfer
	h	b	r	a		h	b	r	a
100	10	30	2	3	460	46	138	4	5
110	11	30	2	3	480	48	144	5	6
120	12	36	2	3	500	50	150	5	6
130	13	39	2	3	520	52	156	5	6
140	14	42	2	3	540	54	162	5	6
150	15	45	2	3	560	56	168	5	6
160	16	48	2	3	580	58	174	5	6
170	17	51	2	3	600	60	180	6	7
180	18	54	2	3	620	62	186	6	7
190	19	57	2	3	640	64	192	6	7
200	20	60	2	3	660	66	198	6	7
210	21	63	2	3	680	68	204	6	7
220	22	66	2	3	700	70	210	6	7
230	23	69	3	4	720	72	216	6	7
240	24	72	3	4	740	74	222	6	7
250	25	75	3	4	760	76	228	6	7
260	26	78	3	4	780	78	234	6	7
270	27	81	3	4	800	80	240	6	7
280	28	84	3	4	820	82	246	6	7
290	29	87	3	4	840	84	252	6	7
300	30	90	3	4	860	86	258	6	7
320	32	96	3	4	880	88	264	8	9
340	34	102	3	4	900	90	270	8	9
360	36	108	3	4	920	92	276	8	9
380	38	114	4	5	940	94	282	8	9
400	40	120	4	5	960	96	288	8	9
420	42	126	4	5	980	98	294	8	9
440	44	132	4	5	1000	100	300	8	9

Note 1—The dimensions of the keys are based on the formula :
width = 0.3 shaft dia. and thickness = 0.1 shaft dia.

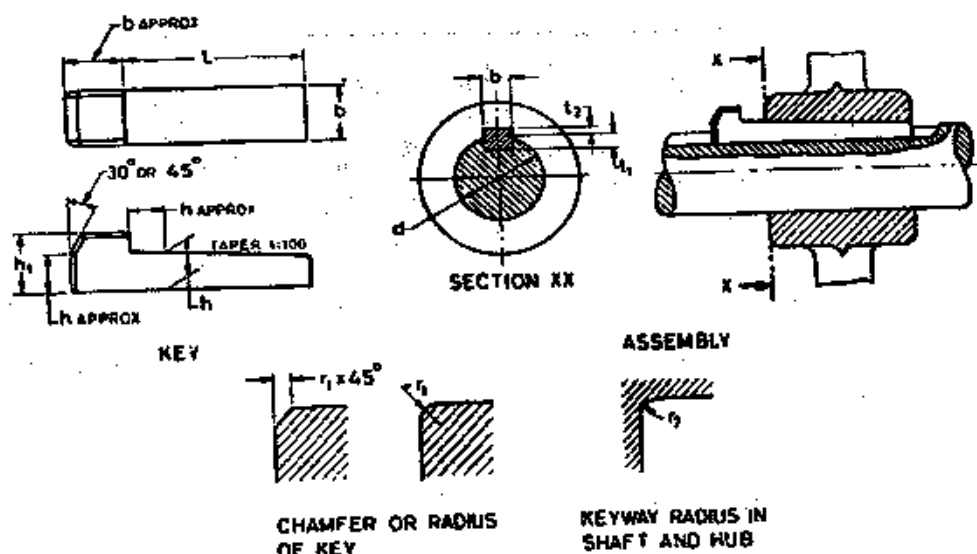
2—If it is not possible to fix the keys at 120°, they may be fixed at 180°.

3—It is recommended that for an intermediate diameter of shaft, the key section shall be the same as that for the next larger size of shaft in this table.

Designation: A tangential key for shaft diameter 500 mm shall be designated as: Tangential key 500 IS: 2291 – 1963.

GIB-HEAD KEYS AND KEYWAYS

All dimensions in millimetres



SHAFT DIAMETER, d		KEY					KEYWAY IN SHAFT AND HUB					
Above	Up to and Including	Width b (h9)	Height h (Nominal)	Tol. on h	Height of Gib-head h1	Chamfer or Radius r1 (Min)	Width of Keyway (D10)	Depth in Shaft t1	Tol. on t1	Depth in Hub t2	Tol. on t2	Radius at Bottom of Keyway r2 (max)
10	12	4	4		7	0.16	4	2.5		1.2		0.16
12	17	5	5	+0.1	8		5	3		1.7		
17	22	6	6		10	0.25	6	3.5		2.1		0.25
22	30	8	7		11		8	4	+0.1	2.5	+0.1	
30	38	10	8		12		10	5		2.5		
38	44	12	8		12		12	5		2.5		
44	50	14	9		14	0.40	14	5.5		2.9		0.40
50	58	16	10		16		16	6		3.4		
58	65	18	11	+0.2	18		18	7		3.3		
65	75	20	12		20		20	7.5		3.8		
75	85	22	14		22		22	8.5		4.8		
85	95	25	14		22	0.60	25	9		4.3	+0.15	0.60
95	110	28	16		25		28	10		5.3		
110	130	32	18		28		32	11		6.2		
130	150	36	20		32		36	12		7.2		
150	170	40	22		36	1.00	40	13	+0.15	8.2		1.00
170	200	45	25		40		45	15		9.2		
200	230	50	28		45		50	17		10.1		
230	260	56	32	+0.3	50		56	19		11.1		
260	290	63	32		56	1.60	63	20		12.1		1.60
290	330	70	36		63		70	22		13.1	+0.3	
330	380	80	40		70		80	25		14.1		
380	440	90	45		75	2.50	90	28		16.1		2.50
440	500	100	50		80		100	31		18.1		

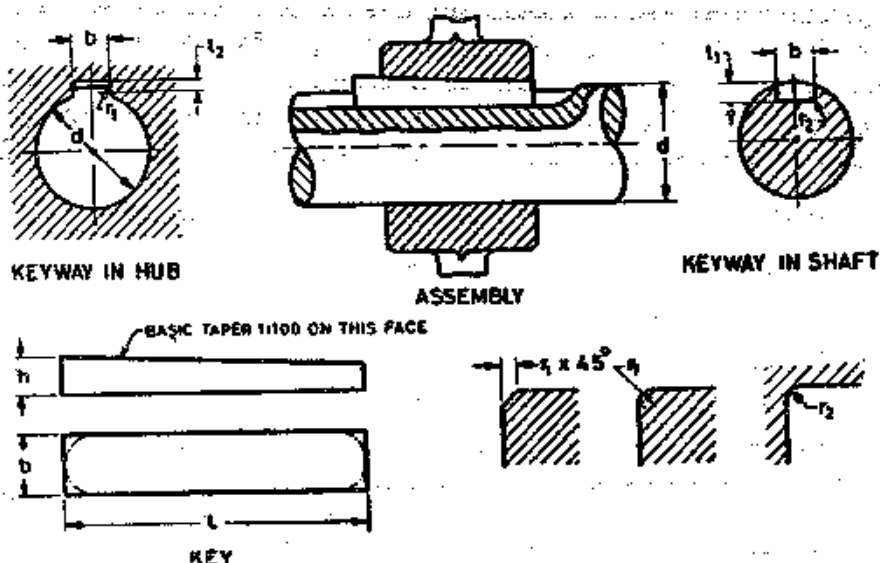
IS 2293-1963

PREFERRED LENGTHS OF GIB-HEAD KEYS

Width (b) mm	4	5	6	8	10	12	14	16	18	20	22	25	28	32	36	40	45	50
	4	5	6	7	8	8	9	10	11	12	14	14	16	18	20	22	25	28
Height (h) mm	4	5	6	7	8	8	9	10	11	12	14	14	16	18	20	22	25	28
14	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	16	16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
18	18	18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
20	20	20	20	20	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22	22	22	22	22	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25	25	25	25	25	25	—	—	—	—	—	—	—	—	—	—	—	—	—
28	28	28	28	28	28	—	—	—	—	—	—	—	—	—	—	—	—	—
32	32	32	32	32	32	32	—	—	—	—	—	—	—	—	—	—	—	—
36	36	36	36	36	36	36	—	—	—	—	—	—	—	—	—	—	—	—
40	40	40	40	40	40	40	40	—	—	—	—	—	—	—	—	—	—	—
45	45	45	45	45	45	45	45	45	—	—	—	—	—	—	—	—	—	—
—	50	50	50	50	50	50	50	50	50	—	—	—	—	—	—	—	—	—
—	56	56	56	56	56	56	56	56	56	56	—	—	—	—	—	—	—	—
—	—	63	63	63	63	63	63	63	63	63	63	—	—	—	—	—	—	—
—	—	71	71	71	71	71	71	71	71	71	71	71	—	—	—	—	—	—
—	—	—	80	80	80	80	80	80	80	80	80	80	80	—	—	—	—	—
—	—	—	90	90	90	90	90	90	90	90	90	90	90	90	—	—	—	—
—	—	—	—	100	100	100	100	100	100	100	100	100	100	100	100	—	—	—
—	—	—	—	110	110	110	110	110	110	110	110	110	110	110	110	110	—	—
—	—	—	—	—	125	125	125	125	125	125	125	125	125	125	125	125	125	—
—	—	—	—	—	140	140	140	140	140	140	140	140	140	140	140	140	140	140
—	—	—	—	—	—	160	160	160	160	160	160	160	160	160	160	160	160	160
—	—	—	—	—	—	—	180	180	180	180	180	180	180	180	180	180	180	180
—	—	—	—	—	—	—	—	200	200	200	200	200	200	200	200	200	200	200
—	—	—	—	—	—	—	—	—	220	220	220	220	220	220	220	220	220	220
—	—	—	—	—	—	—	—	—	—	250	250	250	250	250	250	250	250	250
—	—	—	—	—	—	—	—	—	—	—	280	280	280	280	280	280	280	280
—	—	—	—	—	—	—	—	—	—	—	—	315	315	315	315	315	315	315
—	—	—	—	—	—	—	—	—	—	—	—	—	355	355	355	355	355	355
—	—	—	—	—	—	—	—	—	—	—	—	—	—	400	400	400	400	400

TAPER KEYS AND KEYWAYS

All dimensions in millimetres

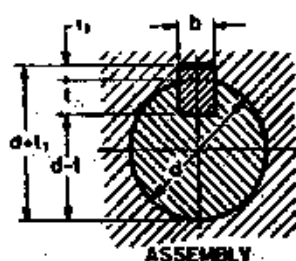


Shaft Diameter d		Key		Keyway in Shaft and Hub						Length				
Above	Up to and including	Cross Section Width, b (h9)	Height h	Chamfer or Radius r ₁ (Min)	Keyway width b (D10)	Depth in Shaft t ₁	Tol. on t ₁	Depth in Hub t ₂	Tol. on t ₂	Radius r ₂ Max	Mio.	Max.		
6	8	2	2	0.16	2	1.2	+0.05	0.5		0.16	6	20		
8	10	3	3		3	1.8		0.9			8	36		
10	12	4	4		4	2.5		1.2			10	45		
12	17	5	5	0.25	5	3.0		1.7	+0.1	0.25	12	56		
17	22	6	6		6	3.5		2.1			16	70		
22	30	8	7		8	4.0		2.5			20	90		
30	38	10	8		10	5.0	+0.1	2.5			25	110		
38	44	12	8		12	5.0		2.5			32	140		
44	50	14	9		14	5.5		2.9			40	160		
50	58	16	10		16	6.0		3.4			45	180		
58	65	18	11		18	7.0		3.3			50	200		
65	75	20	12		20	7.5		3.8			56	220		
75	85	22	14	0.60	22	8.5		4.8			63	250		
85	95	25	14		25	9.0		4.3			+0.2	0.60	70	280
95	110	28	16		28	10.0		5.3			80	315		
110	130	32	18		32	11.0		6.2			90	355		
130	150	36	20		36	12.0		7.2			100	400		
150	170	40	22		40	13.0		8.2			110	400		
170	200	45	25	1.00	45	15.0	+0.15	9.2		1.00	125	400		
200	230	50	28		50	17.0		10.1			140	400		
230	260	56	32		56	19.0		12.1						
260	290	63	32	1.6	63	20.0		11.1		1.6				
290	330	70	36		70	22.0		13.1			+0.3			
330	380	80	40		80	25.0		14.1						
380	440	90	45	2.5	90	28.0		16.1		2.5				
440	500	100	50		100	31.0		18.1						

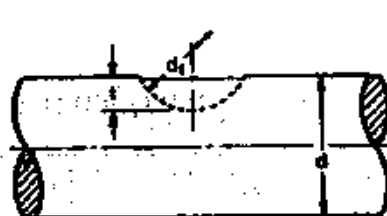
PREFERRED LENGTHS OF TAPER KEYS

Width (b) mm	2	3	4	5	6	8	10	12	14	16	18	20	22	25	28	32	36	40	45	50
Height (h) mm	2	3	4	5	6	7	8	8	9	10	11	12	14	14	16	18	20	22	25	28
Preferred Length (L), mm	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	8	8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	10	10	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	12	12	12	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	14	14	14	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	16	16	16	16	16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	18	18	18	18	18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	20	20	20	20	20	20	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	22	22	22	22	22	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	25	25	25	25	25	25	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	28	28	28	28	28	28	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	32	32	32	32	32	32	32	—	—	—	—	—	—	—	—	—	—	—	—
	—	36	36	36	36	36	36	36	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	40	40	40	40	40	40	40	—	—	—	—	—	—	—	—	—	—	—
	—	—	45	45	45	45	45	45	45	45	—	—	—	—	—	—	—	—	—	—
	—	—	—	50	50	50	50	50	50	50	50	—	—	—	—	—	—	—	—	—
	—	—	—	56	56	56	56	56	56	56	56	56	—	—	—	—	—	—	—	—
	—	—	—	—	63	63	63	63	63	63	63	63	63	—	—	—	—	—	—	—
	—	—	—	—	70	70	70	70	70	70	70	70	70	70	—	—	—	—	—	—
	—	—	—	—	—	80	80	80	80	80	80	80	80	80	80	—	—	—	—	—
	—	—	—	—	—	90	90	90	90	90	90	90	90	90	90	90	—	—	—	—
	—	—	—	—	—	—	100	100	100	100	100	100	100	100	100	100	100	—	—	—
	—	—	—	—	—	—	110	110	110	110	110	110	110	110	110	110	110	110	—	—
	—	—	—	—	—	—	—	125	125	125	125	125	125	125	125	125	125	125	125	—
	—	—	—	—	—	—	—	140	140	140	140	140	140	140	140	140	140	140	140	140
	—	—	—	—	—	—	—	—	160	160	160	160	160	160	160	160	160	160	160	160
	—	—	—	—	—	—	—	—	—	180	180	180	180	180	180	180	180	180	180	180
	—	—	—	—	—	—	—	—	—	—	200	200	200	200	200	200	200	200	200	200
	—	—	—	—	—	—	—	—	—	—	—	220	220	220	220	220	220	220	220	220
	—	—	—	—	—	—	—	—	—	—	—	—	250	250	250	250	250	250	250	250
	—	—	—	—	—	—	—	—	—	—	—	—	—	280	280	280	280	280	280	280
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	315	315	315	315	315	315
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	355	355	355	355	355
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	400	400	400	400

WOODRUFF KEYS AND KEYSLOTS

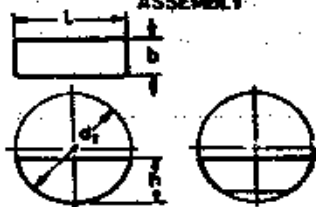


ASSEMBLY



KEYSLOT IN SHAFT

All dimensions in
millimetres



KEY
FLAT BOTTOM
OPTIONAL



CHAMFER OR RADIUS
OF KEY KEYWAY RADIUS
IN
SHAFT AND HUB

KEY SECTION RANGE OF SHAFT DIA, d						KEY				KEYSLOT IN SHAFT			KEYSLOT IN HUB			RADIUS, r		
b (b9)	h (h12)	Group I		Group II		Dia- meter of Key d ₁	Tol- erance on d ₁	Cham- fer or Radi- us r	Tol- erance on r	Length L	Depth, t			Depth, t ₁			Nom.	Tol
		Over	Up to and In- cluding	Over	Up to and In- cluding						Series A	Series B	Tol.	Series A	Series B	Tol.		
1	1.4	3	4	6	8	4.0		0.2		3.82	1.0	1.0		0.6	0.6		0.2	
1.5	2.6	4	6	8	10	7.0		0.2		6.76	2.0	2.0		0.8	0.8		0.2	
2	2.6	6	8	10	12	7.0		0.2		6.76	1.8	1.8		1.0	1.0		0.2	
2	3.7	6	8	10	12	10.0		0.2		9.66	2.9	2.9		1.0	1.0		0.2	
2.5	3.7	8	10	12	17	10.0		0.2		9.66	2.9	2.9		1.0	1.0		0.2	
3	3.7	8	10	12	17	10.0		0.2		9.66	2.5	2.8		1.4	1.1		0.2	
3	5	8	10	12	17	13.0		0.2	+0.1	12.65	3.8	4.1	+0.1	1.4	1.1		0.2	
3	6.5	—	—	16	17	16.0		0.2		15.72	5.3	5.6		1.4	1.1		0.2	
4	5	10	12	17	22	13.0	-0.1	0.2		12.65	3.5	4.1		1.7	1.1		0.2	
4	6.5	10	12	17	22	16.0		0.2		15.72	5.0	5.6		1.7	1.1		0.2	
4	7.5	—	—	17	22	19.0		0.2		18.57	6.0	6.6		1.7	1.1		0.2	
5	6.5	12	17	22	30	16.0		0.2		15.72	4.5	5.4		2.2	1.3	+0.1	0.2	
5	7.5	12	17	22	30	19.0		0.2		18.57	5.5	6.4		2.2	1.3		0.2	
5	9	—	—	22	30	22.0		0.2		21.63	7.0	7.9	+0.2	2.2	1.3		0.2	
6	7.5	17	22	30	38	19.0		0.4		18.57	5.1	6.0		2.6	1.7		0.4	
6	9	17	22	30	38	22.0		0.4		21.63	6.6	7.5	+0.1	2.6	1.7		0.4	
6 (10)	—	17	22	30	38	25.0		0.4		24.49	7.6	8.5		2.6	1.7		0.4	
6	11	—	—	30	38	28.0	-0.2	0.4		27.35	8.6	9.5		2.6	1.7		0.4	
8	9	22	30	38	—	22.0	-0.1	0.4	+0.2	21.63	6.2	7.5		3.0	1.7		0.4	
8	11	22	30	38	—	28.0		0.4		27.35	8.2	9.5	+0.2	3.0	1.7		0.4	
8	13	—	—	38	—	32.0		0.4		31.43	10.2	11.5		3.0	1.7		0.4	
10	11	30	38	38	—	28.0	-0.2	0.4		27.35	7.8	9.1		3.4	2.1		0.4	
10	13	30	38	38	—	32.0		0.4		31.43	9.8	11.1		3.4	2.1		0.4	
10	16	—	—	38	—	45.0		0.4		43.08	12.8	14.1		3.4	2.1		0.4	

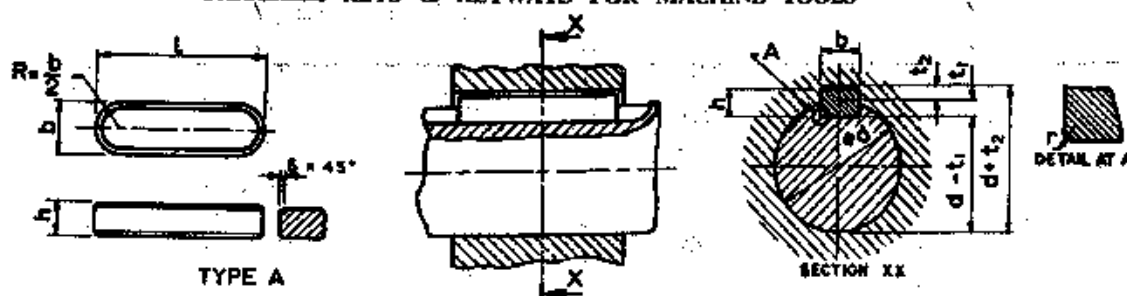
Note 1—The dimensions d-t and d+t1 may be specified on workshop drawings

Note 2—The key size 6x10 is non-preferred

Note 3—The key size 2.5x3.7 shall be used in automobile industries only

IS 2291-1

PARALLEL KEYS & KEYWAYS FOR MACHINE TOOLS



All dimensions in mm

TYPE A

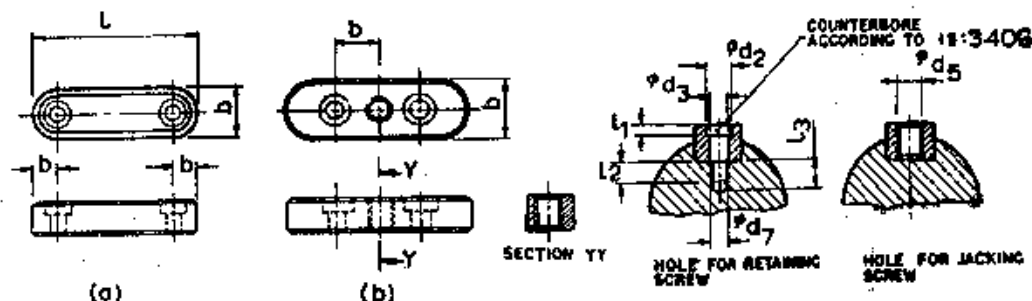
SECTION XX

DETAIL AT A

KEY										KEYWAY													
Shaft diam	Width	Tol on b	height h	Tol on h	Chamfer S		Length l		Tol. on b					t ₁	tol on t ₁	t ₂	tol on t ₂	r					
					min	max	min	max	Running Fit		Light drive Fit		Force Fit					min	max				
									Shaft	Hub	Shaft	hub								Shaft & hub			
above	upto	b					min	max															
10	12	4	h9	h9	0.16	0.25	10	45	+0.03	0	+0.078	+0.03	0	-0.03	+0.015	-0.015	-0.012	3	+0.1	1.1	+0.1	0.08	0.16
12	17	5			0.25	0.40	12	56	+0.03	0	+0.078	+0.03	0	-0.03	+0.015	-0.015	-0.012	3.8	+0.1	1.3	+0.1	0.16	0.25
17	22	6			0.25	0.40	16	70	+0.03	0	+0.078	+0.03	0	-0.03	+0.015	-0.015	-0.012	4.4	0	1.7	0	"	"
22	30	8			0.25	0.40	20	90	+0.036	0	+0.098	+0.04	0	-0.036	+0.018	-0.018	-0.015	5.4	+0.2	1.7	+0.2	"	"
30	38	10		0.40	0.60	25	110	+0.036	0	+0.098	+0.04	0	-0.036	+0.018	-0.018	-0.015	6.0	2.1		0.25		0.40	
38	44	12		"	"	32	140	+0.036	0	+0.098	+0.04	0	-0.036	+0.018	-0.018	-0.015	6.0	2.1		"		"	
44	50	14		"	"	40	160	+0.036	0	+0.098	+0.04	0	-0.036	+0.018	-0.018	-0.015	6.5	2.6		"		"	
50	58	16		"	"	45	180	+0.043	0	+0.12	+0.05	0	-0.043	+0.021	-0.021	-0.018	7.5	2.6		"		"	
58	65	18		"	"	50	200	+0.043	0	+0.12	+0.05	0	-0.043	+0.021	-0.021	-0.018	8.0	3.1		"		"	
65	75	20		"	"	56	220	+0.043	0	+0.12	+0.05	0	-0.043	+0.021	-0.021	-0.018	8.0	4.1		0.40		0.60	
75	85	22		"	"	63	250	+0.052	0	+0.149	+0.065	0	-0.052	+0.026	-0.026	-0.022	10	4.1		"		"	
85	95	25		"	"	70	250	+0.052	0	+0.149	+0.065	0	-0.052	+0.026	-0.026	-0.022	10	4.1	"	"			
95	110	28		"	"	80	250	+0.052	0	+0.149	+0.065	0	-0.052	+0.026	-0.026	-0.022	11	5.1	"	"			

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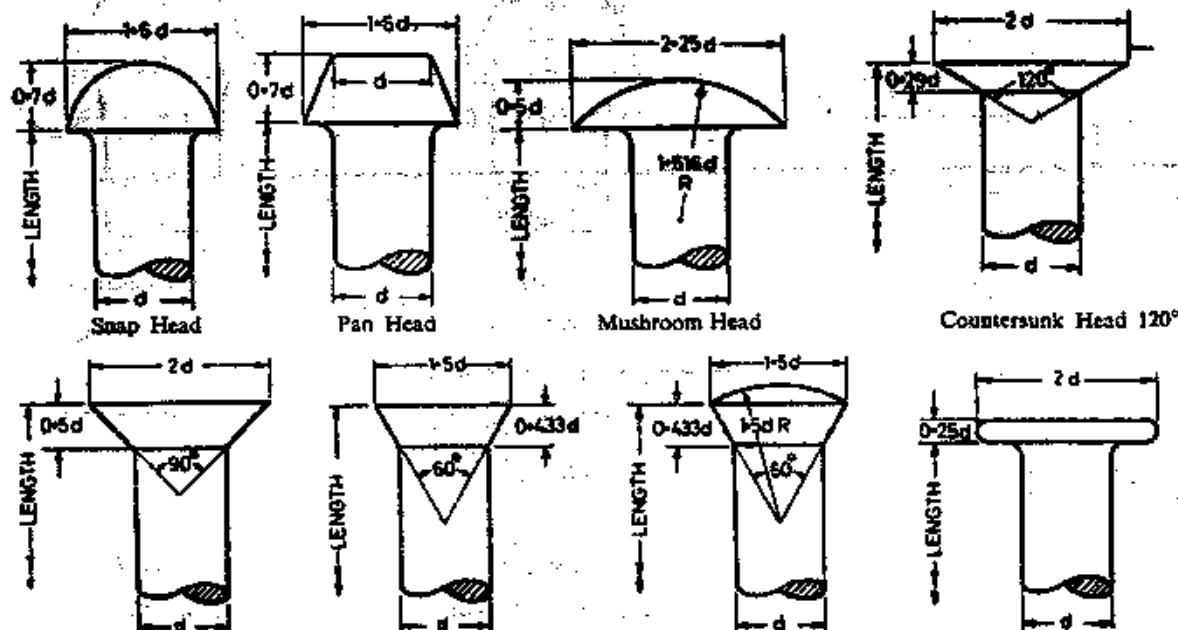
RETAINING & JACKING SCREWS FOR PARALLEL KEYS



All dimensions in mm

Size of key $b \times h$	KEY				SHAFT			Retaining Screw Length
	d_3	d_4	d_5	l_1	d_1	l_2	l_3	
8 × 7	3.4	6	M3	2.4	M3	4	7	8
10 × 8	"	6	"	"	"	5	8	10
12 × 8	4.5	8	M4	3.2	M4	6	10	"
14 × 9	5.5	10	M5	4.1	M5	"	"	"
16 × 10	"	"	"	"	"	"	"	"
18 × 11	6.6	11	M6	4.8	M6	"	11	12
20 × 12	"	"	"	"	"	"	"	"
22 × 14	"	"	"	"	"	8	13	16
25 × 14	9.0	14	M8	6.0	M8	9	15	"
28 × 16	11.0	18	M10	7.3	M10	"	16	"
32 × 18	"	"	"	"	"	10	17	20

RIVETS FOR GENERAL PURPOSES (Below 12 mm diameter)



Flat Countersunk Head 90° Flat Countersunk Head 60° Round Countersunk Head 60°

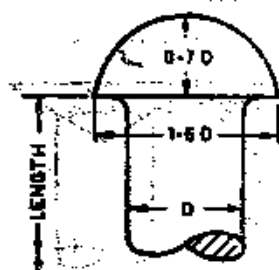
Flat Head

PREFERRED LENGTH AND DIAMETER COMBINATIONS FOR RIVETS

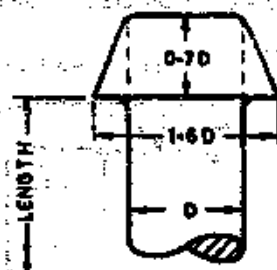
Length mm	Rivet Diameter, mm									
	1.6	2	2.5	3	4	5	6	8	10	
5	+	-	-	-	-	-	-	-	-	
6	+	+	+	+	-	-	-	-	-	
7	+	+	+	+	-	-	-	-	-	
8	+	+	+	+	+	-	-	-	-	
9	+	+	+	+	+	-	-	-	-	
10	+	+	+	+	+	+	-	-	-	
12	-	+	+	+	+	+	+	-	-	
14	-	-	+	+	+	+	+	+	-	
16	-	-	+	+	+	+	+	+	-	
18	-	-	-	+	+	+	+	+	+	
20	-	-	-	+	+	+	+	+	+	
22	-	-	-	+	+	+	+	+	+	
24	-	-	-	+	+	+	+	+	+	
26	-	-	-	+	+	+	+	+	+	
28	-	-	-	+	+	+	+	+	+	
30	-	-	-	+	+	+	+	+	+	
35	-	-	-	+	+	+	+	+	+	
40	-	-	-	-	+	+	+	+	+	
45	-	-	-	-	+	+	+	+	+	
50	-	-	-	-	-	-	+	+	+	
55	-	-	-	-	-	-	+	+	+	
60	-	-	-	-	-	-	-	+	+	
65	-	-	-	-	-	-	-	+	+	
70	-	-	-	-	-	-	-	-	-	

Preferred combinations are indicated by +
IS 2155 - 1962

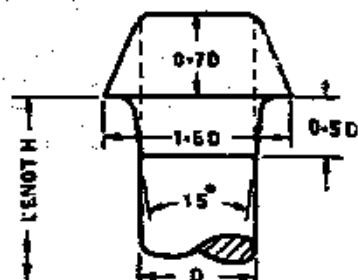
RIVETS FOR GENERAL PURPOSES (12 to 48 mm diameter)



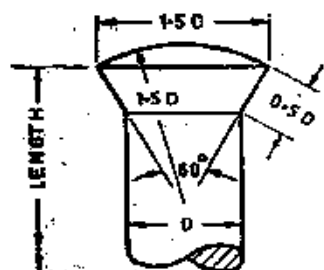
Soap Head



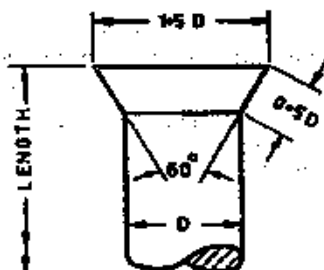
Pan Head



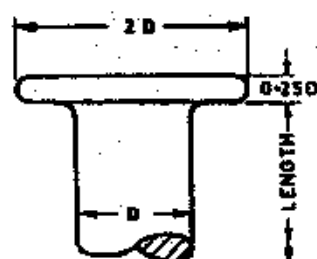
Pan Head with Tapered Neck



Rounded Countersunk Head



Flat Countersunk Head



Flat Head

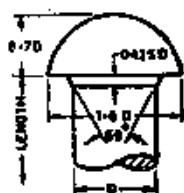
PREFERRED LENGTH AND DIAMETER COMBINATIONS FOR RIVETS

Length mm	Diameter, mm													
	12	14	16	18	20	22	24	27	30	33	36	39	42	48
28	+	-	-	-	-	-	-	-	-	-	-	-	-	-
31.5	+	+	-	-	-	-	-	-	-	-	-	-	-	-
35.5	+	+	+	-	-	-	-	-	-	-	-	-	-	-
40	+	+	+	+	-	-	-	-	-	-	-	-	-	-
45	+	+	+	+	+	-	-	-	-	-	-	-	-	-
50	+	+	+	+	+	+	-	-	-	-	-	-	-	-
56	+	+	+	+	+	+	+	-	-	-	-	-	-	-
63	+	+	+	+	+	+	+	+	-	-	-	-	-	-
71	+	+	+	+	+	+	+	+	+	-	-	-	-	-
80	+	+	+	+	+	+	+	+	+	+	-	-	-	-
85	-	+	+	+	+	+	+	+	+	+	+	-	-	-
90	-	+	+	+	+	+	+	+	+	+	+	+	-	-
95	-	+	+	+	+	+	+	+	+	+	+	+	+	-
100	-	-	+	+	+	+	+	+	+	+	+	+	+	-
106	-	-	+	+	+	+	+	+	+	+	+	+	+	+
112	-	-	+	+	+	+	+	+	+	+	+	+	+	+
118	-	-	-	+	+	+	+	+	+	+	+	+	+	+
125	-	-	-	-	+	+	+	+	+	+	+	+	+	+
132	-	-	-	-	-	+	+	+	+	+	+	+	+	+
140	-	-	-	-	-	+	+	+	+	+	+	+	+	+
150	-	-	-	-	-	-	+	+	+	+	+	+	+	+
160	-	-	-	-	-	-	+	+	+	+	+	+	+	+
180	-	-	-	-	-	-	-	+	+	+	+	+	+	+
200	-	-	-	-	-	-	-	-	+	+	+	+	+	+
224	-	-	-	-	-	-	-	-	-	+	+	+	+	+
250	-	-	-	-	-	-	-	-	-	-	-	-	+	+

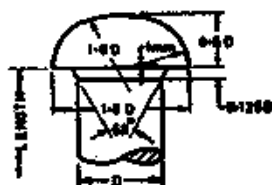
Preferred combinations are indicated by +

IS 1929-1961

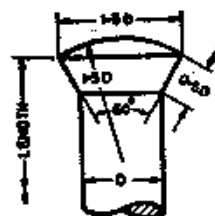
BOILER RIVETS (12 to 48 mm diameter)



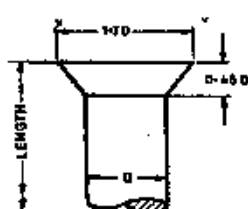
Snap Head



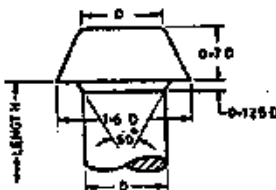
Ellipsoid Head



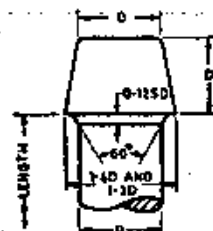
Rounded Countersunk Head



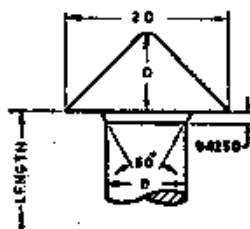
Countersunk Head



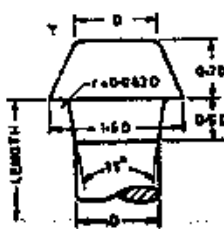
Pan Head Type 1



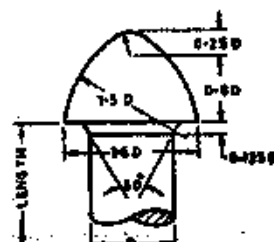
1.4D for Rivets under 24 mm
1.3D for Rivets 24 mm and over
Pan Head Type 2



Steeple Head



Pan Head with Tapered Neck



Conical Head

Designation:

A pan head rivet of 20 mm diameter having a length of 100 mm shall be designated as:
Pan head rivet 20×100, IS: 1928—1961

Rivets of other types shall be designated in a similar manner.

BOILER RIVETS (Contd.)

PREFERRED LENGTH AND DIAMETER COMBINATIONS FOR RIVETS

Length mm	Rivet Diameter, mm													
	12	14	16	18	20	22	24	27	30	33	36	39	42	48
28	+	-	-	-	-	-	-	-	-	-	-	-	-	-
31.5	+	+	-	-	-	-	-	-	-	-	-	-	-	-
35.5	+	+	+	-	-	-	-	-	-	-	-	-	-	-
40	+	+	+	+	-	-	-	-	-	-	-	-	-	-
45	+	+	+	+	+	-	-	-	-	-	-	-	-	-
50	+	+	+	+	+	+	-	-	-	-	-	-	-	-
56	+	+	+	+	+	+	+	-	-	-	-	-	-	-
63	+	+	+	+	+	+	+	+	-	-	-	-	-	-
71	+	+	+	+	+	+	+	+	+	-	-	-	-	-
80	+	+	+	+	+	+	+	+	+	-	-	-	-	-
85	-	+	+	+	+	+	+	+	+	+	-	-	-	-
90	-	+	+	+	+	+	+	+	+	+	-	-	-	-
95	-	+	+	+	+	+	+	+	+	+	+	-	-	-
100	-	-	+	+	+	+	+	+	+	+	+	-	-	-
106	-	-	+	+	+	+	+	+	+	+	+	+	-	-
112	-	-	+	+	+	+	+	+	+	+	+	+	-	-
118	-	-	-	+	+	+	+	+	+	+	+	+	+	-
125	-	-	-	-	+	+	+	+	+	+	+	+	+	+
132	-	-	-	-	-	+	+	+	+	+	+	+	+	+
140	-	-	-	-	-	+	+	+	+	+	+	+	+	+
150	-	-	-	-	-	-	+	+	+	+	+	+	+	+
160	-	-	-	-	-	-	+	+	+	+	+	+	+	+
180	-	-	-	-	-	-	-	+	+	+	+	+	+	+
200	-	-	-	-	-	-	-	-	+	+	+	+	+	+
224	-	-	-	-	-	-	-	-	-	+	+	+	+	+
250	-	-	-	-	-	-	-	-	-	-	-	-	+	+

Preferred combinations are indicated by +

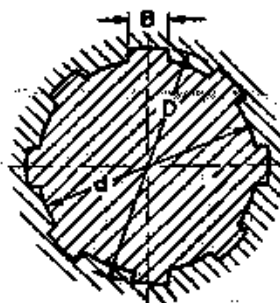
RIVET HOLE DIAMETERS

Diameter of Rivet, mm	12	14	16	18	20	22	24	27	30	33	36	39	42	48
Rivet Hole Diameter mm (Min.)	13	15	17	19	21	23	25	28.5	31.5	34.5	37.5	41	44	50

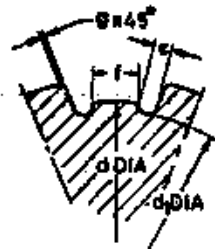
DIMENSIONS FOR STRAIGHT SIDED SPLINES FOR GENERAL ENGINEERING USE

Straight sided splines

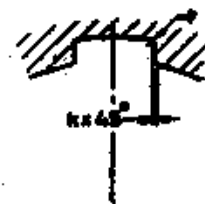
All dimensions in millimetres



Splined shaft and hub profile



Splined shaft



Splined hub

Nominal Size $N \times d \times D$	No of Splines N	Minor Dia d	Major Dia D	Width B	d^*_{Min}	e^*_{Max}	f^*	g_{Max}	k_{Max}	r_{Max}	Centering on
Light duty series											
6 × 23 × 26	6	23	26	6	22.1	1.25	3.54	0.3	0.3	0.2	Inside* diameter
6 × 26 × 30	6	26	30	6	24.6	1.84	3.85	0.3	0.3	0.2	
6 × 28 × 32	6	28	32	7	26.7	1.77	4.03	0.3	0.3	0.2	
8 × 32 × 36	8	32	36	6	30.4	1.89	2.71	0.4	0.4	0.3	Inside† diameter or flanks
8 × 36 × 40	8	36	40	7	34.5	1.78	3.46	0.4	0.4	0.3	
8 × 42 × 46	8	42	46	8	40.4	1.68	5.03	0.4	0.4	0.3	
8 × 46 × 50	8	46	50	9	44.6	1.61	5.75	0.4	0.4	0.3	
8 × 52 × 58	8	52	58	10	49.7	2.72	4.89	0.5	0.5	0.5	
8 × 56 × 62	8	56	62	10	53.6	2.76	6.38	0.5	0.5	0.5	
8 × 62 × 68	8	62	68	12	59.8	2.48	7.31	0.5	0.5	0.5	
10 × 72 × 78	10	72	78	12	69.6	2.54	5.45	0.5	0.5	0.5	
10 × 82 × 88	10	82	88	12	79.3	2.67	8.62	0.5	0.5	0.5	
10 × 92 × 98	10	92	98	14	89.4	2.36	10.08	0.5	0.5	0.5	
10 × 102 × 108	10	102	108	16	99.9	2.23	11.49	0.5	0.5	0.5	
10 × 112 × 120	10	112	120	18	108.8	3.23	10.72	0.5	0.5	0.5	

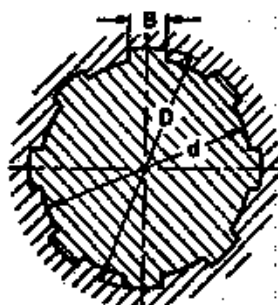
STRAIGHT SIDED SPLINES (Contd.)

Nominal Size N × d × D	No. of Splines N	Minor Dia d	Major Dia D	Width B	d ₁ * Min	c* Max	f* Max	g Max	k Max	r Max	Centering on
Medium duty series											
6 × 11 × 14	6	11	14	3	9.9	1.55	—	0.3	0.3	0.2	Inside* diameter
6 × 13 × 16	6	13	16	3.5	12.0	1.50	0.32	0.3	0.3	0.2	
6 × 16 × 20	6	16	20	4	14.5	2.10	0.16	0.3	0.3	0.2	
6 × 18 × 22	6	18	22	5	16.7	1.95	0.45	0.3	0.3	0.2	
6 × 21 × 25	6	21	25	5	19.5	1.98	1.95	0.3	0.3	0.2	
6 × 23 × 28	6	23	28	6	21.3	2.30	1.34	0.3	0.3	0.2	
6 × 26 × 32	6	26	32	6	23.4	2.94	1.65	0.4	0.4	0.3	
6 × 28 × 34	6	28	34	7	25.9	2.94	1.70	0.4	0.4	0.3	Inside† diameter or flanks
8 × 32 × 38	8	32	38	6	29.4	3.30	0.15	0.4	0.4	0.3	
8 × 36 × 42	8	36	42	7	33.5	3.01	1.02	0.4	0.4	0.3	
8 × 42 × 48	8	42	48	8	39.5	2.91	2.57	0.4	0.4	0.3	
8 × 46 × 54	8	46	54	9	42.7	4.10	0.86	0.5	0.5	0.5	
8 × 52 × 60	8	52	60	10	48.7	4.00	2.44	0.5	0.5	0.5	
8 × 56 × 65	8	56	65	10	52.2	4.74	2.50	0.5	0.5	0.5	
8 × 62 × 72	8	62	72	12	57.8	5.00	2.40	0.5	0.5	0.5	
10 × 72 × 82	10	72	82	12	67.4	5.43	—	0.5	0.5	0.5	
10 × 82 × 92	10	82	92	12	77.1	5.40	3.00	0.5	0.5	0.5	
10 × 92 × 102	10	92	102	14	87.3	5.20	4.50	0.5	0.5	0.5	
10 × 102 × 112	10	102	112	16	97.7	4.90	6.30	0.5	0.5	0.5	
10 × 112 × 125	10	112	125	18	106.3	6.40	4.40	0.5	0.5	0.5	

*These values are based on the generating process.

†Inside centering is not always possible with generating process.

TOLERANCES FOR STRAIGHT SIDED SPLINES



Assembly of Splined Hub and Shaft

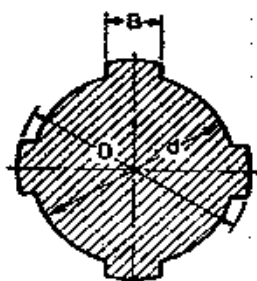
				TOLERANCE ON			
				Width of Hub B	Minor dia. of Hub d	Major dia. of Hub D	
				Soft	Hard- ened	Soft or hardened	Soft or hardened
Splined Hub	For Centering on Inner Diameter or Flanks	Shaft sliding or fixed		D9	F10	H7	H11
Splined Shaft	For Centering on Inner Diameter	Shaft sliding inside hub		h8	e8	f7	a11
		Shaft fixed in hub		p6	h6	j6	a11
	For Centering on Flanks	Shaft sliding inside hub		h8	e8	—	a11
		Shaft fixed in hub		u6	k6	—	a11

Designation

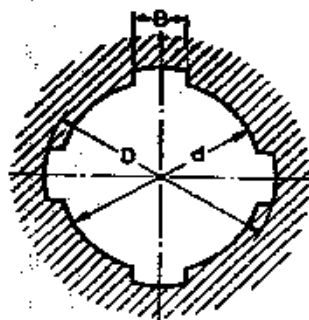
A 6-splined shaft or hub with minor diameter of 28 mm and major diameter of 32 mm shall be designated as : Spline 6×28×32 IS : 2327-1963

DIMENSIONS FOR STRAIGHT SIDED SPLINES FOR MACHINE TOOLS

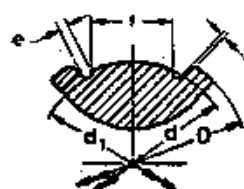
Straight sided splines—4 splines



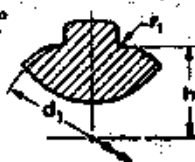
External Spline Profile



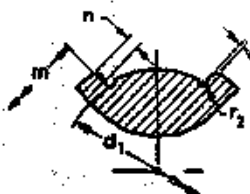
Internal Spline Profile



Type A



Type B
(External Splines)

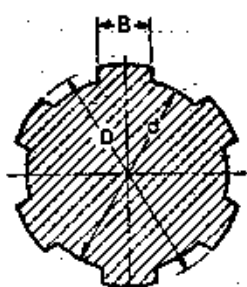


Type M

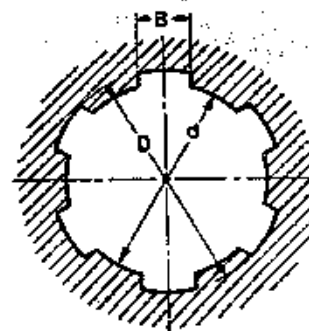


Internal Spline

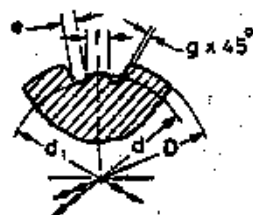
Straight sided splines—6 splines



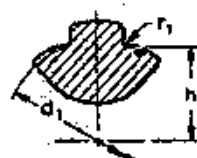
External Spline Profile



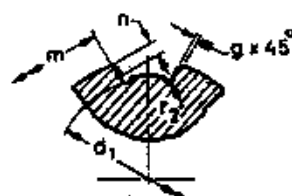
Internal Spline Profile



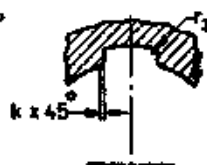
Type A



Type B
(External Splines)



Type M



Internal Spline

Designation

A 6—splined (straight sided) shaft or hub for machine tools with minor diameter of 28 mm and major diameter of 34 mm shall be designated as:

Straight Sided Spline 6×28×34 IS : 2610—1964

DIMENSIONS FOR STRAIGHT SIDED SPLINES FOR MACHINE TOOLS

Undercut, chamfers, and radii for straight sided splines—4 splines

All dimensions in millimetres

Designation N×d×D	External Splines									Internal Splines	Projected Tip Width of Hob	Minor Dia d	Major Dia D	Width B	
	Type A*			Type B**		Type M‡									
	d ₁ §	Min	g ₁ † Max	f Min	h	r ₁ † Max	m	n	r ₂						k Max
4×11×15	9.6	0.2	1.50		5.0	0.10	2.82	1.70	0.3	0.2	0.15	0.5	11	15	3
4×13×17	11.8	0.2	2.37		5.5	0.10	3.76	1.70	0.3	0.2	0.15	0.5	13	17	4
4×16×20	15.0	0.3	2.87		6.7	0.15	5.64	1.70	0.3	0.3	0.25	0.7	16	20	6
4×18×22	16.9	0.3	4.35		7.7	0.15	5.64	1.70	0.3	0.3	0.25	0.7	18	22	6
4×21×25	20.1	0.3	5.00		8.9	0.15	7.52	1.70	0.6	0.3	0.25	0.7	21	25	8
4×24×28	23.0	0.3	7.30		10.4	0.15	7.52	1.70	0.6	0.3	0.25	0.7	24	28	8
4×28×32	26.8	0.5	7.39		12.1	0.25	9.40	1.63	0.6	0.5	0.40	1.0	28	32	10
4×32×38	30.3	0.5	9.56		14.2	0.25	9.40	2.55	0.6	0.5	0.40	1.0	32	38	10
4×36×42	34.5	0.5	11.03		15.9	0.25	11.28	2.55	0.6	0.5	0.40	1.0	36	42	12
4×42×48	40.2	0.5	15.41		19.0	0.25	11.28	2.55	1.0	0.5	0.40	1.0	42	48	12
4×46×52	44.4	0.5	16.79		20.7	0.25	13.16	2.55	1.0	0.5	0.40	1.3	46	52	14
4×52×60	49.5	0.5	21.63		23.7	0.25	13.16	3.40	1.0	0.5	0.40	1.3	52	60	14
4×56×65	56.2	0.5	23.26		26.4	0.25	15.04	2.98	1.0	0.5	0.40	1.6	56	65	16
4×62×70	59.5	0.5	23.61		28.3	0.25	15.04	3.40	1.0	0.5	0.40	1.6	62	70	16
4×68×78	64.4	0.5	27.57		31.2	0.25	15.04	4.25	1.0	0.5	0.40	1.6	68	78	16

* Type A is obtained only by hobbing

** Type B is obtained by straddle milling

§ These values are based on the generating process

§ If the flanks are to be ground, Type M undercut is produced by milling the roots of the splines as shown.

‡ Rounding in place of chamfer is permissible

DIMENSIONS FOR STRAIGHT SIDED SPLINES FOR MACHINE TOOLS

Undercuts, chamfers and radii for straight sided splines—6 splines

All dimensions in millimetres

Designation N × d × D	External Splines								Internal Splines		Projected Tip Width of Hob	Minor Dia	Major Dia	Width B
	Type A*			Type B**			Type M‡							
	d ₁ Min	g ₁ Max	f Min	h	r ₁ Max	m	n	r ₂	k Max	r ₃ Max				
6 × 21 × 25	19.50	0.3	1.95	9.7	0.15	4.70	1.70	0.6	0.3	0.2	0.7	21	25	5
6 × 23 × 28	21.30	0.3	1.34	11.0	0.15	5.64	2.13	0.6	0.3	0.2	0.7	23	28	6
6 × 26 × 32	23.40	0.4	1.65	11.8	0.15	5.64	2.55	0.6	0.4	0.3	1.0	26	32	6
6 × 28 × 34	25.90	0.4	1.70	12.9	0.25	6.58	2.55	0.6	0.4	0.3	1.0	28	34	7
6 × 32 × 38	29.90	0.5	2.83	14.8	0.25	7.52	2.55	0.6	0.5	0.4	1.0	32	38	8
6 × 36 × 42	33.70	0.5	4.95	16.5	0.25	7.52	2.55	0.6	0.5	0.4	1.0	36	42	8
6 × 42 × 48	39.94	0.5	6.02	19.3	0.25	9.40	2.55	1.0	0.5	0.4	1.0	42	48	10
6 × 46 × 52	44.16	0.5	5.81	21.1	0.25	11.28	2.55	1.0	0.5	0.4	1.3	46	52	12
6 × 52 × 60	49.50	0.5	5.89	23.9	0.25	13.16	3.40	1.0	0.5	0.4	1.3	52	60	14
6 × 58 × 65	55.74	0.5	8.29	26.7	0.25	13.16	2.98	1.0	0.5	0.4	1.6	58	65	14
6 × 62 × 70	59.50	0.5	8.03	28.6	0.25	15.04	3.40	1.0	0.5	0.4	1.6	62	70	16
6 × 68 × 78	64.40	0.5	9.73	31.4	0.25	15.04	4.25	1.0	0.5	0.4	1.6	68	78	16
6 × 72 × 82	68.30	0.5	12.67	33.4	0.25	15.04	4.25	1.6	0.5	0.4	2.0	72	82	16
6 × 78 × 90	73.00	0.5	13.07	36.2	0.25	15.04	5.10	1.6	0.5	0.4	2.0	78	90	16
6 × 82 × 95	76.60	0.5	13.96	38.0	0.25	15.04	5.53	1.6	0.5	0.4	2.0	82	95	16
6 × 88 × 100	82.90	0.5	17.84	41.3	0.25	15.04	5.10	1.6	0.5	0.4	2.0	88	100	16
6 × 92 × 105	87.10	0.6	15.96	43.1	0.3	18.80	5.53	1.6	0.6	0.5	2.0	92	105	20
6 × 98 × 110	93.40	0.6	19.22	46.4	0.3	18.80	5.10	2.0	0.6	0.5	2.0	98	110	20
6 × 105 × 120	98.80	0.6	19.25	49.2	0.3	18.80	6.38	2.0	0.6	0.5	2.4	105	120	20
6 × 115 × 130	108.4	0.6	24.75	54.2	0.3	18.80	6.38	2.5	0.6	0.5	2.4	115	130	20
6 × 130 × 145	123.9	0.6	29.20	61.8	0.3	22.56	6.38	2.5	0.6	0.5	2.4	130	145	24

* Type A is obtained only by hobbing.

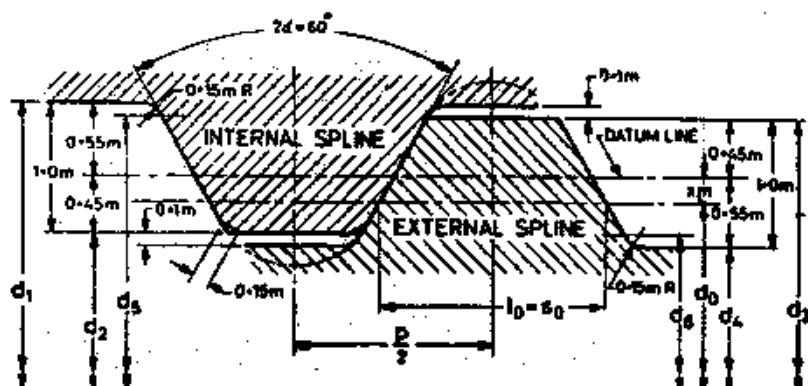
** Type B is obtained by straddle milling.

§ These values are based on the generating process.

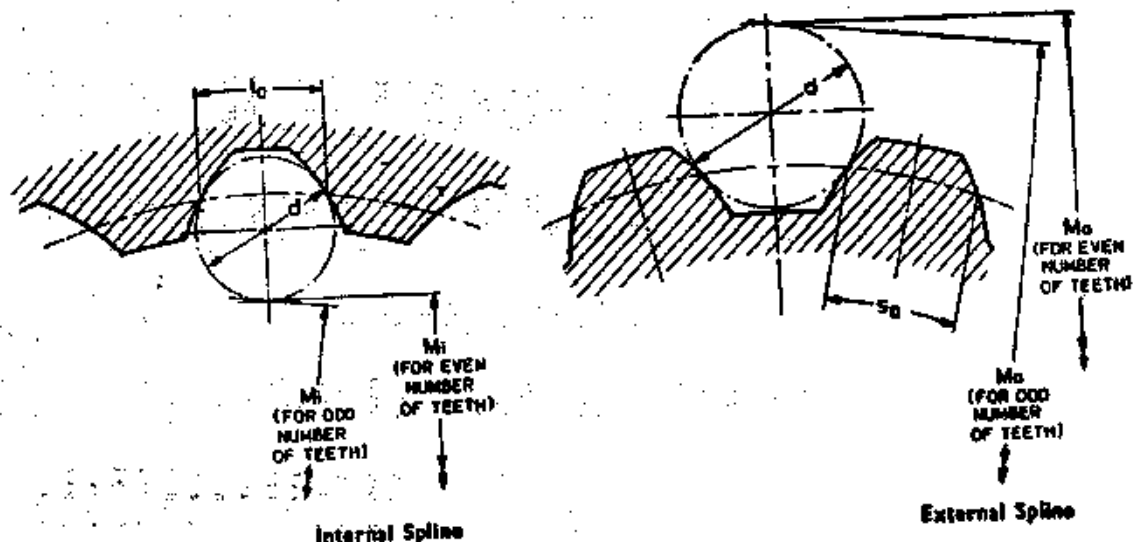
‡ If the flanks are to be ground, Type M undercut is produced by milling the roots of the splines as shown.

§ Rounding in place of chamfer is permissible.

DIMENSIONS FOR INVOLUTE SIDED SPLINES



Reference Profile



Internal Spline Measurement between Pins and Measurement Over Pins

IS: 3665-1966

DIMENSIONS FOR INVOLUTE SIDED SPLINES OF MODULE 2 All dimensions in millimetres

All dimensions in millimetres

Nominal Size	INTERNAL SPLINE										EXTERNAL SPLINE						
	Pin Dia	Measure-ment Between Pins	Devia-tion Factor	Pin Dia	Measure-ment Over Pins	Devia-tion Factor	Tooth Thickness Over z' Teeth	Tooth thickness deviation factor 0.866									
$d_1 \times d_2$	z	d_o	d_b	d_g	d_i	d_s Min	d_s Max	xm	$l_o = s_o$	d	Mi	fi	d	Ma	fa	z'	
15 × 11	6	12	10.392	14.6	10.6	14.68	10.92	+0.4	3.603	3.5	7.629	2.42	5.5	22.212	1.11	2	9.121
17 × 13	7	14	12.124	16.6	12.6	16.68	12.92	+0.4	3.603	3.5	9.324	2.19	5.0	22.695	1.13	2	9.214
18 × 14	7	14	12.124	17.6	13.6	17.68	13.92	+0.9	4.181	3.5	10.379	1.61	6.0	25.588	1.06	2	9.714
20 × 16	8	16	13.856	19.6	15.6	19.68	15.92	+0.9	4.181	3.5	12.736	1.66	6.0	28.206	1.11	2	9.807
22 × 18	9	18	15.588	21.6	17.6	21.68	17.92	+0.9	4.181	3.5	14.460	1.64	5.5	28.790	1.13	—	—
25 × 21	11	22	19.053	24.6	20.6	24.68	20.92	+0.4	3.603	3.5	17.478	1.96	4.5	29.898	1.28	—	—
28 × 24	12	24	20.785	27.6	23.6	27.68	23.92	+0.9	4.181	3.5	20.738	1.68	5.0	34.161	1.23	3	15.621
30 × 26	14	28	24.249	29.6	25.6	29.69	25.91	-0.1	3.026	3.5	22.484	2.41	4.0	34.144	1.46	3	14.807
32 × 28	14	28	24.249	31.6	27.6	31.69	27.91	+0.9	4.181	3.5	24.738	1.69	4.5	37.016	1.30	3	15.807
35 × 31	16	32	27.713	34.6	30.6	34.69	30.91	+0.4	3.603	3.5	27.711	1.88	4.0	39.000	1.42	3	15.493
37 × 33	17	34	29.445	36.6	32.6	36.69	32.91	+0.4	3.603	3.5	29.571	1.86	4.0	40.857	1.42	4	21.028
38 × 34	18	36	31.177	37.6	33.6	37.69	33.91	-0.1	3.026	3.5	30.566	2.15	4.0	42.181	1.50	3	15.179
40 × 36	18	36	31.177	39.6	35.6	39.69	35.91	+0.9	4.181	3.5	32.739	1.70	4.5	45.137	1.35	4	21.621
42 × 38	20	40	34.641	41.6	37.6	41.69	37.91	-0.1	3.026	3.5	34.589	2.08	4.0	46.193	1.52	4	20.807
45 × 41	21	42	36.373	44.6	40.6	44.69	40.91	+0.4	3.603	3.5	37.604	1.84	4.0	48.938	1.46	4	21.400
47 × 43	22	44	38.105	46.6	42.6	46.69	42.91	+0.4	3.603	3.5	39.720	1.84	4.0	51.074	1.47	4	21.493
48 × 44	22	44	38.105	47.6	43.6	47.69	43.91	+0.9	4.181	3.5	40.740	1.70	4.0	51.912	1.43	5	27.435
50 × 46	24	48	41.569	49.6	45.6	49.69	45.91	-0.1	3.026	3.5	42.621	2.00	4.0	54.218	1.54	4	21.179
(52 × 48)	24	48	41.569	51.6	47.6	51.69	47.91	+0.9	4.181	3.5	44.740	1.71	4.0	55.939	1.44	5	27.621
55 × 51	26	52	45.033	54.6	50.6	54.70	50.90	+0.4	3.603	3.5	47.724	1.82	4.0	59.109	1.50	5	27.307
(58 × 54)	28	56	48.497	57.6	53.6	57.70	53.90	-0.1	3.026	3.5	50.642	1.95	4.0	62.235	1.56	5	26.993
60 × 56	28	56	48.497	59.6	55.6	59.70	55.90	+0.9	4.181	3.5	52.740	1.71	4.0	63.984	1.47	6	33.435
(62 × 58)	30	60	51.962	61.6	57.6	61.70	57.90	-0.1	3.026	3.5	54.650	1.93	4.0	66.242	1.57	5	27.179
65 × 61	31	62	53.694	64.6	60.6	64.70	60.90	+0.4	3.603	3.5	57.648	1.80	4.0	69.058	1.53	6	33.214
(68 × 64)	32	64	55.426	67.6	63.6	67.70	63.90	+0.9	4.181	3.5	60.740	1.71	4.0	72.021	1.49	6	33.807
70 × 66	34	68	58.890	69.6	65.6	69.70	65.90	-0.1	3.026	3.5	62.663	1.90	4.0	74.253	1.59	6	32.993
(72 × 68)	34	68	58.890	71.6	67.6	71.70	67.90	+0.9	4.181	3.5	64.740	1.71	4.0	76.036	1.50	7	39.435
75 × 71	36	72	62.354	74.6	70.6	74.70	70.90	+0.4	3.603	3.3	67.729	1.79	4.0	79.166	1.55	7	39.121
(78 × 74)	38	76	65.818	77.6	73.6	77.70	73.90	-0.1	3.026	3.5	70.672	1.88	4.0	82.263	1.60	7	38.807
80 × 76	38	76	65.818	79.6	75.6	79.70	75.90	+0.9	4.181	3.5	72.740	1.72	4.0	84.063	1.52	7	39.807
(82 × 78)	40	80	69.282	81.6	77.6	81.70	77.90	-0.1	3.026	3.5	74.676	1.87	4.0	86.267	1.61	7	38.993

Note:- Values within brackets are non-preferred.

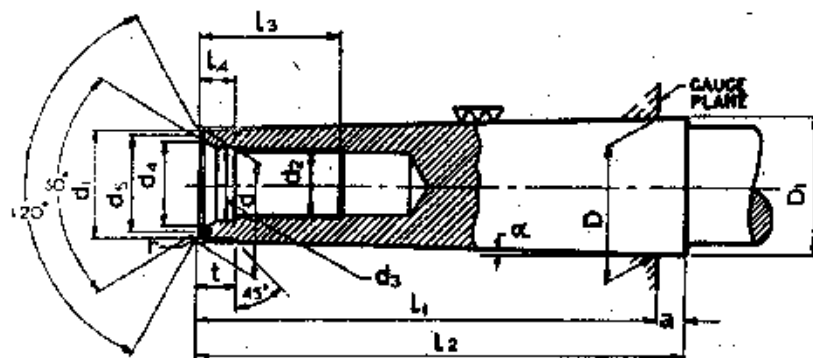
DIMENSIONS FOR INVOLUTE SIDED SPLINES OF MODULE 2.5

All dimensions in millimetres

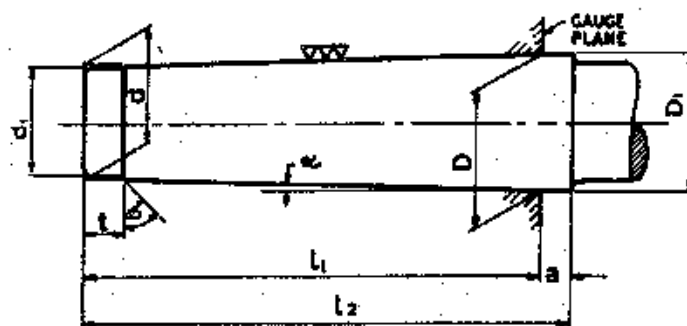
Nominal Size											INTERNAL SPLINE			EXTERNAL SPLINE				Tooth thickness deviation factor 0.866
											Pin Dia	Measure- ment Between Pins	Devia- tion Factor	Pin Dia	Measure- ment Over Pins	Devia- tion Factor	Tooth Thickness Over z' , Teeth	
	$d_1 \times d_f$	z	d_o	d_p	d_g	d_s	d_s Min	d_s Max	x_m	$l_o = s_o$	d	M_i	f_i	d	M_a	f_a	z	
20 × 15	6	15.0	12.990	19.5	14.5	19.58	14.92	+1.125	5.226	4.5	10.552	1.71	9.0	33.258	1.03	2	12.026	
22 × 17	7	17.5	15.155	21.5	16.5	21.58	16.92	+0.875	4.937	4.5	12.105	1.85	7.0	30.558	1.08	2	11.892	
25 × 20	8	20.0	17.321	24.5	19.5	24.58	19.92	+1.125	5.226	4.5	15.552	1.72	7.0	34.113	1.13	2	12.259	
28 × 23	10	25.0	21.651	27.5	22.5	27.58	22.92	+0.125	4.071	4.25	19.116	2.30	5.0	33.006	1.37	2	11.491	
30 × 25	10	25.0	21.651	29.5	24.5	29.58	24.92	+1.125	5.226	4.5	20.552	1.72	6.5	38.151	1.19	3	19.293	
32 × 27	11	27.5	23.816	31.5	26.5	31.59	26.91	+0.875	4.937	4.5	22.265	1.81	6.0	38.835	1.23	3	19.160	
35 × 30	12	30.0	25.981	34.5	29.5	34.59	29.91	+0.125	5.226	4.5	25.552	1.72	6.0	42.093	1.25	3	19.526	
37 × 32	13	32.5	28.146	36.5	31.5	36.59	31.91	+0.875	4.937	4.5	27.308	1.80	5.5	42.764	1.30	3	19.392	
38 × 33	14	35.0	30.311	37.5	32.5	37.59	32.91	+0.125	4.071	4.5	28.316	2.26	5.0	43.096	1.43	3	18.759	
40 × 35	14	35.0	30.311	39.5	34.5	39.59	34.91	+1.125	5.226	4.5	30.552	1.72	6.0	47.204	1.28	3	19.759	
42 × 37	15	37.5	32.476	41.5	36.5	41.59	36.91	+0.875	4.937	4.5	32.340	1.79	5.5	47.881	1.33	3	19.625	
45 × 40	16	40.0	34.641	44.5	39.5	44.59	39.91	+1.125	5.226	4.5	35.552	1.73	5.5	51.035	1.33	4	26.793	
47 × 42	17	42.5	36.806	46.5	41.5	46.59	41.91	+0.875	4.937	4.5	37.365	1.78	5.5	52.974	1.36	4	26.660	
48 × 43	18	45.0	38.971	47.5	42.5	47.59	42.91	+0.125	4.071	4.5	38.387	2.07	5.0	53.156	1.47	4	26.026	
50 × 45	18	45.0	38.971	49.5	44.5	49.59	44.91	+1.125	5.226	4.5	40.552	1.73	5.5	56.100	1.36	4	27.026	
(52 × 47)	19	47.5	41.136	51.5	46.5	51.59	46.91	+0.875	4.937	4.5	42.384	1.78	5.5	58.052	1.38	4	26.892	
55 × 50	20	50.0	43.301	54.5	49.5	54.59	49.91	+1.125	5.226	4.5	45.552	1.73	5.5	61.157	1.38	4	27.259	
(58 × 53)	22	55.0	47.631	57.5	52.5	57.60	52.90	+0.125	4.071	4.5	48.424	1.99	5.0	63.198	1.51	4	26.491	
60 × 55	22	55.0	47.631	59.5	54.5	59.60	54.90	+1.125	5.226	4.5	50.552	1.73	5.5	66.206	1.40	5	34.293	
(62 × 57)	23	57.5	49.796	61.5	56.5	61.60	56.90	+0.875	4.937	4.5	52.413	1.77	5.0	66.846	1.45	5	34.160	
65 × 60	24	60.0	51.962	64.5	59.5	64.60	59.90	+1.125	5.226	4.5	55.552	1.73	5.0	69.924	1.44	5	34.526	
(68 × 63)	26	65.0	56.292	67.5	62.5	67.60	62.90	+0.125	4.071	4.5	58.448	1.94	5.0	73.229	1.53	5	33.759	
70 × 65	26	65.0	56.292	69.5	64.5	69.60	64.90	+1.125	5.226	4.5	60.552	1.73	5.0	74.954	1.46	5	34.759	
(72 × 67)	27	67.5	58.457	71.5	66.5	71.60	66.90	+0.875	4.937	4.5	62.434	1.77	5.0	76.920	1.48	5	34.625	
75 × 70	28	70.0	60.622	74.5	69.5	74.60	69.90	+1.125	5.226	4.5	65.552	1.73	5.0	79.961	1.47	6	41.793	
(78 × 73)	30	75.0	64.952	77.5	72.5	77.60	72.90	+0.125	4.071	4.5	68.464	1.90	5.0	83.253	1.55	6	41.026	
80 × 75	30	75.0	64.952	79.5	74.5	79.60	74.90	+1.125	5.226	4.5	70.552	1.73	5.0	85.004	1.48	6	42.026	
(82 × 77)	31	77.5	67.117	81.5	76.5	81.60	76.90	+0.875	4.937	4.5	72.449	1.76	5.0	86.978	1.50	6	41.892	
85 × 80	32	80.0	69.282	84.5	79.5	84.60	79.90	+1.125	5.226	4.5	75.552	1.73	5.0	90.026	1.49	6	42.259	
(88 × 83)	34	85.0	73.612	87.5	82.5	87.60	82.90	+0.125	4.071	4.5	78.476	1.88	5.0	93.273	1.57	6	41.491	
90 × 85	34	85.0	73.612	89.5	84.5	89.60	84.90	+1.125	5.226	4.5	80.552	1.73	5.0	95.045	1.50	7	49.293	
(92 × 87)	35	87.5	75.777	91.5	86.5	91.60	86.90	+0.875	4.937	4.5	82.461	1.76	5.0	97.024	1.52	7	49.160	
95 × 90	36	90.0	77.942	94.5	89.5	94.60	89.90	+1.125	5.226	4.5	85.552	1.73	5.0	100.063	1.51	7	49.526	
(98 × 93)	38	95.0	82.272	97.5	92.5	97.60	92.90	+0.125	4.071	4.5	88.485	1.86	5.0	103.288	1.58	7	48.759	
100 × 95	38	95.0	82.272	99.5	94.5	99.60	94.90	+1.125	5.226	4.5	90.552	1.73	5.0	105.079	1.52	7	49.759	
105 × 100	40	100.0	86.603	104.5	99.5	104.60	99.90	+1.125	5.226	4.5	95.552	1.73	5.0	110.094	1.53	8	56.793	

NOTE:- Values within brackets are non-preferred.

DIMENSIONS OF EXTERNAL SELF HOLDING TAPERS FOR TAPPED OR PLAIN END SHANKS



SHANKS WITH TAPPED ENDS

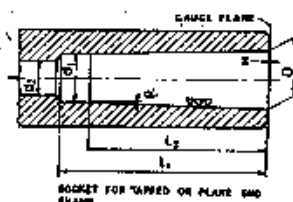


SHANKS WITH PLAIN ENDS

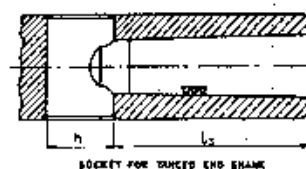
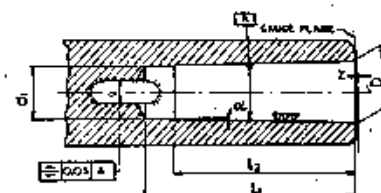
११ (१११)

All dimensions in mm

Designation of Taper	TAPER ON DIAMETER	α	a	D ¹	D ₁ Approx	d Approx	d ₁ max	d ₁	d ₂	d ₂ max	d ₂ max	l ₂ max	l ₂ max	l ₂ max	l ₂ max	l ₂ max	r
Metric 4	1:20=0.05	1°25' 56"	2.0	4.000	4.1	2.9	2.5	—	—	—	—	23.0	25	—	2	—	0.2
Metric 6	1:20=0.05	1°25' 56"	3.0	6.000	6.2	4.4	4	—	—	—	—	32.0	35	—	3	—	0.2
Morse 0	1:19.212=0.05205	1°29' 27"	3.0	9.045	9.2	6.4	6	—	—	—	—	50.0	53	—	4	—	0.2
Morse 1	1:20.047=0.04988	1°25' 43"	3.5	12.065	12.2	9.4	9	M6	6.4	8	8.5	53.5	57	16	5	4	0.2
Morse 2	1:20.020=0.04995	1°25' 50"	5.0	17.780	18.0	14.6	14	M10	10.5	12.5	13.2	64.0	69	24	5	5	0.2
Morse 3	1:19.922=0.05020	1°26' 16"	5.0	23.825	24.1	19.8	19	M12	13	15	17	81.0	86	28	7	6	0.6
Morse 4	1:19.254 =0.05194	1°29' 15"	6.5	31.267	31.6	25.9	25	M16	17	20	22	102.5	109	32	9	8	1.0
Morse 5	1:19.002=0.05263	1°30' 26"	6.5	44.399	44.7	37.6	35.7	M20	21	26	30	129.5	136	40	10	11	2.5
Morse 6	1:19.189=0.05214	1°29' 36"	8.0	63.348	63.8	53.9	51	M24	25	31	36	182.0	190	50	16	12	4
Metric 80	1:20=0.05	1°25' 56"	8.0	80.000	80.4	70.2	67	M30	31	38	45	196.0	204	65	24	14	5
Metric 100	1:20=0.05	1°25' 56"	10.0	100.000	100.5	88.4	85	M36	37	45	52	232.0	242	80	30	16	5
Metric 120	1:20=0.05	1°25' 56"	12.0	120.000	120.6	106.6	102	M36	37	45	52	268.0	280	80	36	16	6
Metric 160	1:20=0.05	1°25' 56"	16.0	160.000	160.8	143.0	138	M48	50	60	68	340.0	356	100	48	20	8
Metric 200	1:20=0.05	1°25' 56"	20.0	200.000	201.0	179.4	174	M48	50	60	68	412.0	432	100	60	20	10



DIMENSIONS OF INTERNAL SELF HOLDING TAPERS



SOCKET FOR TAPERED END SHAFT

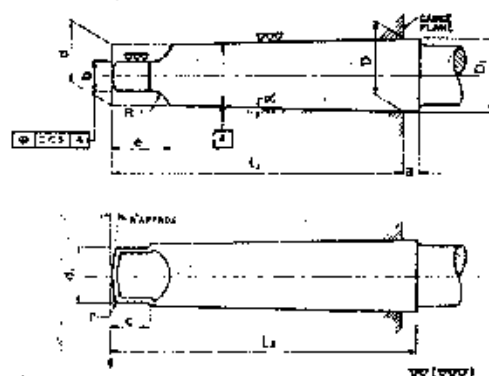
mm (inches)

All dimensions in mm

Designation of Taper	Taper on diameter	α	$\frac{g}{\text{tol A 13}}$	D	d_1 H11	d_1	l_1 min	l_1 Approx	l_2	b	Z*
Metric 4	1:20=0.05	1°25'56"	2.2	4.000	3.0	—	25	20	21	8	0.5
Metric 6	1:20=0.05	1°25'56"	3.2	6.000	4.6	—	34	28	29	12	0.5
Morse 0	1:19.212=0.05205	1°29'27"	3.9	9.045	6.7	—	52	45	49	15	1.0
Morse 1	1:20.047=0.04988	1°25'43"	5.2	12.065	9.7	7	56	47	52	19	1.0
Morse 2	1:20.020=0.04995	1°25'50"	6.3	17.780	14.9	11.5	67	58	62	22	1.0
Morse 3	1:19.922=0.05020	1°26'16"	7.9	23.825	20.2	14	84	72	78	27	1.5
Morse 4	1:19.254=0.05194	1°29'15"	11.9	31.267	26.5	18	107	92	98	32	1.5
Morse 5	1:19.002=0.05263	1°30'26"	15.9	44.399	38.2	23	135	118	125	38	2.0
Morse 6	1:19.180=0.05214	1°29'36"	19.0	63.348	54.6	27	188	164	177	47	2.0
Metric 80	1:20=0.05	1°25'56"	26.0	80.000	71.5	33	202	170	186	52	2.0
Metric 100	1:20=0.05	1°25'56"	32.0	100.000	90.0	39	240	200	220	60	2.0
Metric 120	1:20=0.05	1°25'56"	38.0	120.000	108.5	39	276	230	254	70	2.0
Metric 160	1:20=0.05	1°25'56"	50.0	160.000	145.5	52	350	290	321	90	3.0
Metric 200	1:20=0.05	1°25'56"	62.0	200.000	182.5	52	424	350	388	110	3.0

* Z is the maximum permissible deviation, outwards only of the position of gauge plane D from the nominal position of coincidence of leading face.

DIMENSIONS FOR EXTERNAL SELF HOLDING TAPERS WITH TANGED END SHANKS



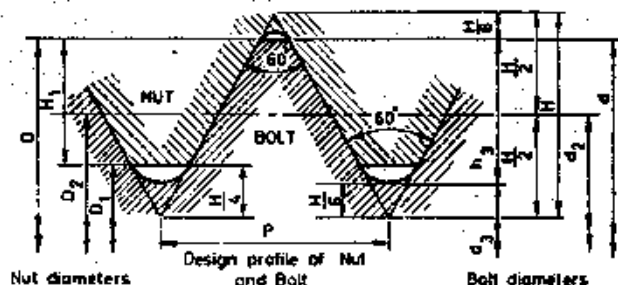
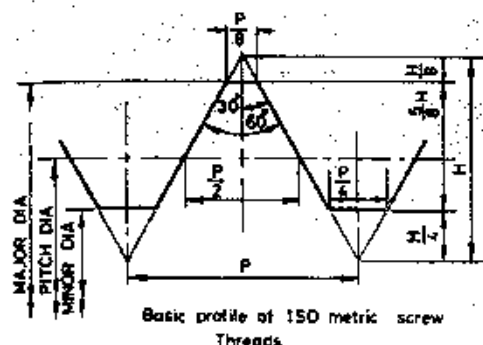
All dimensions in mm

Designation of Taper	Taper on Diameter	α	a	b h 13	D dia	D ₁ Approx	d Approx	d ₁ Max	l ₁	Tolerance	l ₂ Max	C	e Max	R Max	r
Morse 0	1:19.212=0.05205	1° 29' 27"	3.0	3.9	9.045	9.2	6.1	6.0	56.5	-1.0	59.5	6.5	10.5	4	1.0
Morse 1	1:20.047=0.04988	1° 25' 43"	3.5	5.2	12.065	12.2	9.0	8.7	62.0	-1.0	65.5	8.5	13.5	5	1.2
Morse 2	1:20.020=0.04995	1° 25' 50"	5.0	6.3	17.780	18	14.0	13.5	75.0	-1.0	80.0	10	16	6	1.6
Morse 3	1:19.922=0.05020	1° 26' 16"	5.0	7.9	23.825	24.1	19.1	18.5	94.0	-1.0	99.0	13.0	20	7	2.0
Morse 4	1:19.254=0.05194	1° 29' 15"	6.5	11.9	31.267	31.6	25.2	24.5	117.5	-1.5	124.0	16.0	24	8	2.5
Morse 5	1:19.002=0.05263	1° 30' 26"	6.5	15.9	44.399	44.7	36.5	35.7	149.5	-1.5	156.0	19.0	29	10	3.0
Morse 6	1:19.180=0.05214	1° 29' 36"	8.0	19	63.348	63.8	52.4	51.0	210.0	-2.0	218.0	27.0	40	13	4.0
Metric 80	1:20=0.05	1° 25' 56"	8.0	26	80.000	80.4	69.0	67.0	220.0	-2.0	228.0	24.0	48	24	5.0
Metric 100	1:20=0.05	1° 25' 56"	10.0	32	100.00	100.5	87.0	85.0	260.0	-2.0	270.0	28.0	58	30	5.0
Metric 120	1:20=0.05	1° 25' 56"	12.0	38	120.00	120.6	105.0	102.0	300.0	-2.0	312.0	32.0	68	36	6.0
Metric 160	1:20=0.05	1° 25' 56"	16.0	50	160.00	160.8	141.0	138.0	380.0	-3.0	396.0	40.0	88	48	8.0
Metric 200	1:20=0.05	1° 25' 56"	20.0	62	200.00	201	177.0	174	460.0	-3.0	480.0	48.0	108	60	10.0

IS 1715 — 1973

THREADS FOR BOLTS AND NUTS

Coarse and Fine Series



$$H = 0.86603 P$$

$$H_1 = 0.54127 P$$

$$h_3 = 0.61343 P$$

$$r = 0.14434 P$$

	Size	Pitch P	Major Diameter d = D	Pitch Diameter d ₂ = D ₂	Minor Diameter		Depth of Thread h ₃	Max. Depth of Engage- ment, H ₁	Stress Area, S mm ²
					Bolt, d ₃	Nut, d ₁			
Coarse Series	M 2.5	0.45	2.5	2.208	1.948	2.013	0.276	0.244	3.39
	M 3	0.5	3	2.675	2.387	2.459	0.307	0.271	5.03
	M 4	0.7	4	3.545	3.141	3.242	0.429	0.379	8.78
	M 5	0.8	5	4.480	4.019	4.134	0.491	0.433	14.2
	M 6	1	6	5.350	4.773	4.918	0.613	0.541	20.1
	M 8	1.25	8	7.188	6.466	6.647	0.767	0.677	36.6
	M 10	1.5	10	9.026	8.160	8.376	0.920	0.812	58.0
	M 12	1.75	12	10.863	9.853	10.106	1.074	0.947	84.3
	M 16	2	16	14.701	13.546	13.835	1.227	1.083	157
	M 20	2.5	20	18.376	16.933	17.294	1.534	1.353	245
	M 24	3	24	22.051	20.320	20.752	1.840	1.624	353
	M 30	3.5	30	27.727	25.706	26.211	2.147	1.894	561
	M 33	3.5	33	30.727	28.706	29.211	2.147	1.894	694
	M 36	4	36	33.402	31.093	31.67	2.454	2.165	817
Fine Series	M 8 × 1	1	8	7.350	6.773	6.918	0.613	0.541	39.2
	M 10 × 1.25	1.25	10	9.188	8.466	8.647	0.767	0.677	61.2
	M 12 × 1.25	1.25	12	11.188	10.466	10.647	0.767	0.677	92.1
	M 16 × 1.5	1.5	16	15.026	14.16	14.376	0.920	0.812	167
	M 20 × 1.5	1.5	20	19.026	18.16	18.376	0.920	0.812	272
	M 24 × 2	2	24	22.701	21.546	21.835	1.227	1.083	384
	M 30 × 2	2	30	28.701	27.546	27.835	1.227	1.083	621
	M 36 × 3	3	36	34.051	32.32	35.752	1.840	1.624	865

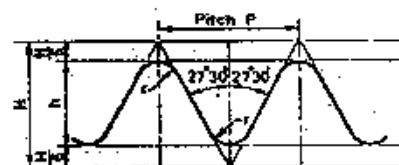
$$\text{Stress area} = \frac{\pi}{4} \left(\frac{d_2 + d_3}{2} \right)^2$$

Designation: A fine series screw of major diameter 8 mm and pitch 1 mm shall be designated as M8 × 1.

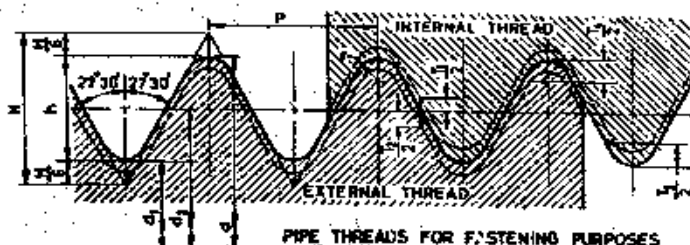
A coarse series screw of major diameter 6 mm and pitch 1 mm shall be designated as M 6.

IS : 4218-1967

STANDARD PIPE THREADS



PARALLEL PIPE THREAD



PIPE THREADS FOR FASTENING PURPOSES

$$H = 0.961 P \quad h = 0.640 P \quad r = 0.137 P$$

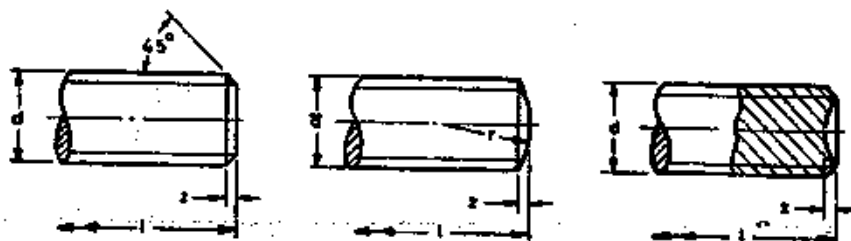
Tolerances T_1 , T_2 , T_3 and T_4 on basic diameters are specified in IS: 554—1955

Size Designation	Pitch P	BASIC DIAMETER Internal & External Threads		
		Major, d_2	Pitch, d	Minor, d_1
FP $\frac{1}{8}$	0.907	9.728	9.147	8.566
FP $\frac{1}{4}$	1.337	13.157	12.301	11.445
FP $\frac{3}{8}$	1.337	16.662	15.806	14.950
FP $\frac{1}{2}$	1.814	20.955	19.793	18.631
FP $\frac{3}{4}$	1.814	26.441	25.279	24.117
FP 1	2.309	33.249	31.770	30.291
FP $1\frac{1}{4}$	2.309	41.910	40.431	38.952
FP $1\frac{1}{2}$	2.309	47.803	46.324	44.845
FP 2	2.309	59.614	58.135	56.656
FP $2\frac{1}{4}$	2.309	65.710	64.231	62.752
FP $2\frac{1}{2}$	2.309	75.184	73.705	72.226
FP 3	2.309	87.884	86.405	84.926
FP $3\frac{1}{2}$	2.309	100.330	98.851	97.372
FP 4	2.309	113.030	111.551	110.072
FP 5	2.309	138.430	136.951	135.472
FP 6	2.309	163.830	162.351	160.872

Designation: An external pipe thread for fastening purposes of size 2 with class B tolerance shall be designated as Ext-FP 2B. An internal pipe thread for fastening purposes of size 2 shall be designated as Int-FP 2.

IS: 2643—1964

DIMENSIONS OF ENDS OF BOLTS AND SCREWS



Cut thread chamfered end

Cut thread radiused end

Rolled thread end

All dimensions in millimetres

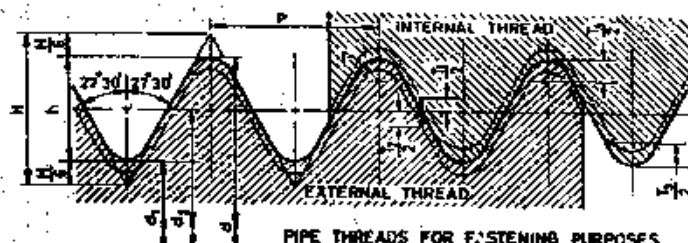
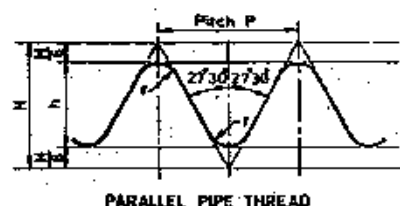
Thread diameter d	Z Max	r approx.	Thread diameter d	Z Max	r approx.
1.6	0.35	1.2	(39)	4.0	50
2	0.40	1.6	42	4.5	50
(2.2)	0.45	2.0	(45)	4.5	63
2.5	0.45	2.0	48	5.0	63
3	0.50	2.5	(52)	5.0	70
(3.5)	0.60	3.0	56	5.5	70
4	0.70	3.0	(60)	5.5	80
(4.5)	0.75	3.5	64	6.0	80
5	0.80	4.0	(68)	6.0	100
6	1.00	5	72	6.0	110
(7)	1.00	6	(76)	6.0	125
8	1.25	8	80	6.0	140
10	1.50	10	(85)	6.0	160
12	1.75	12	90	6.0	180
(14)	2.0	14	(95)	6.0	200
16	2.0	16	100	6.0	220
(18)	2.5	18	(105)	6.0	250
20	2.5	20	110	6.0	250
(22)	2.5	25	(115)	6.0	300
24	3.0	25	(120)	6.0	300
(27)	3.0	32	125	6.0	360
30	3.5	32	(130)	6.0	360
(33)	3.5	40	140	6.0	400
36	4.0	40	(150)	6.0	450

Note 1: For sizes of thread diameters not listed in this table, the values specified for the next higher size shall be applicable.

Note 2: Sizes in brackets are of second preference.

IS: 1368-1967

STANDARD PIPE THREADS



$$H = 0.961 P \quad h = 0.640 P \quad r = 0.137 P$$

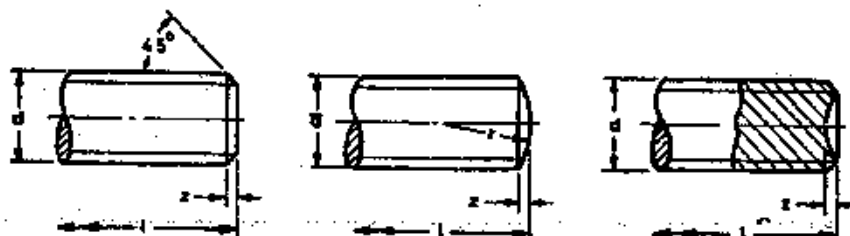
Tolerances T_1 , T_2 , T_3 and T_4 on basic diameters are specified in IS:554—1955

Size Designation	Pitch P	BASIC DIAMETER Internal & External Threads		
		Major, d_2	Pitch, d	Minor, d_1
FP $\frac{1}{8}$	0.907	9.728	9.147	8.566
FP $\frac{1}{4}$	1.337	13.157	12.301	11.445
FP $\frac{3}{8}$	1.337	16.662	15.806	14.950
FP $\frac{1}{2}$	1.814	20.955	19.793	18.631
FP $\frac{3}{4}$	1.814	26.441	25.279	24.117
FP 1	2.309	33.249	31.770	30.291
FP $1\frac{1}{4}$	2.309	41.910	40.431	38.952
FP $1\frac{1}{2}$	2.309	47.803	46.324	44.845
FP 2	2.309	59.614	58.135	56.656
FP $2\frac{1}{4}$	2.309	65.710	64.231	62.752
FP $2\frac{1}{2}$	2.309	75.184	73.705	72.226
FP 3	2.309	87.884	86.405	84.926
FP $3\frac{1}{2}$	2.309	100.330	98.851	97.372
FP 4	2.309	113.030	111.551	110.072
FP 5	2.309	138.430	136.951	135.472
FP 6	2.309	163.830	162.351	160.872

Designation: An external pipe thread for fastening purposes of size 2 with class B tolerance shall be designated as Ext-FP 2B. An internal pipe thread for fastening purposes of size 2 shall be designated as Int-FP 2.

IS: 2643—1964

DIMENSIONS OF ENDS OF BOLTS AND SCREWS



Cut thread chamfered end

Cut thread radiused end

Rolled thread end

All dimensions in millimetres

Thread diameter d	Z Max	r approx.	Thread diameter d	Z Max	r approx.
1.6	0.35	1.2	(39)	4.0	50
2	0.40	1.6	42	4.5	50
(2.2)	0.45	2.0	(45)	4.5	63
2.5	0.45	2.0	48	5.0	63
3	0.50	2.5	(52)	5.0	70
(3.5)	0.60	3.0	56	5.5	70
4	0.70	3.0	(60)	5.5	80
(4.5)	0.75	3.5	64	6.0	80
5	0.80	4.0	(68)	6.0	100
6	1.00	5	72	6.0	110
(7)	1.00	6	(76)	6.0	125
8	1.25	8	80	6.0	140
10	1.50	10	(85)	6.0	160
12	1.75	12	90	6.0	180
(14)	2.0	14	(95)	6.0	200
16	2.0	16	100	6.0	220
(18)	2.5	18	(105)	6.0	250
20	2.5	20	110	6.0	250
(22)	2.5	25	(115)	6.0	300
24	3.0	25	(120)	6.0	300
(27)	3.0	32	125	6.0	360
30	3.5	32	(130)	6.0	360
(33)	3.5	40	140	6.0	400
36	4.0	40	(150)	6.0	450

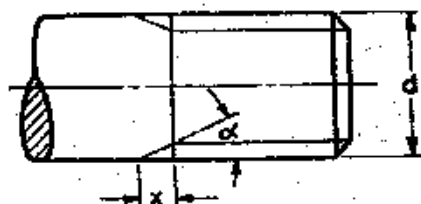
Note 1: For sizes of thread diameters not listed in this table, the values specified for the next higher size shall be applicable.

Note 2: Sizes in brackets are of second preference.

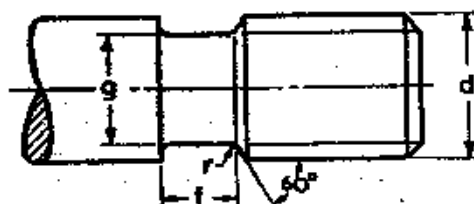
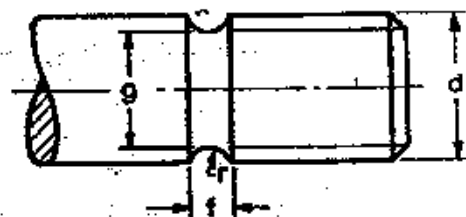
IS: 1368-1967

THREAD RUN OUTS AND THREAD UNDERCUTS FOR EXTERNAL THREADS

All dimensions in millimetres



Thread run out



Thread undercut

Thread diameter d		Thread run out x (Max) for throat angle α			Width of undercut f for throat angle α			Radius r	Nominal Undercut diameter (g)**
*Fine series with the following pitches	Coarse series	≥ 15° Large	≥ 22½° Normal	≥ 30° Small	≥ 22½° Normal	≥ 30° Normal	≥ 30° Small		
0.2	—	0.5	0.4	0.2	—	0.5	—	0.25	d-0.35
0.25	M1, M1.1, M1.2	0.6	0.4	0.3	—	0.6	—	0.3	d-0.40
0.3	M1.4	0.8	0.5	0.3	—	0.6	—	0.3	d-0.47
0.35	M1.6, M1.8	0.8	0.5	0.4	—	0.8	—	0.4	d-0.53
0.4	M2	1	0.6	0.4	—	1	—	0.5	d-0.61
0.45	M2.2, M2.5	1	0.8	0.5	—	1	—	0.5	d-0.67
0.5	M3	1.2	0.8	0.6	—	1.2	—	0.6	d-0.73
0.6	M3.5	1.6	1	0.6	—	1.2	—	0.6	d-0.90
0.7	M4	1.6	1	0.8	—	1.6	—	0.8	d-1.00
0.75	M4.5	2	1.2	0.8	—	1.6	—	0.8	d-1.10
0.8	M5	2	1.2	0.8	—	1.6	—	0.8	d-1.20
1	M6, M7	2.5	1.6	1	2	—	1.6	0.8	d-1.40
1.25	M8, M9	3	2	1.4	2.5	—	2	1	d-1.7
1.5	M10, M11	3.5	2.5	1.6	3	—	2	1	d-2.1
1.75	M12	4	2.5	2	4	—	2.5	1.2	d-2.4
2	M14, M16	5	3	2.5	4	—	2.5	1.2	d-2.7
2.5	M18, M20, M22	6	4	3	5	—	3	1.6	d-3.3
3	M24, M27	7	4.5	3.5	6	—	4	2	d-4.0
3.5	M30, M33	8	5	4	8	—	5	2	d-4.6
4	M36, M39	10	6	4.5	8	—	5	2	d-5.2
4.5	M42, M45	11	7	5	10	—	6	2.5	d-5.9
5	M48, M52	12	8	6	10	—	6	2.5	d-6.5
5.5	M56, M60	13	9	6	12	—	8	3	d-7.1
6	M64, M68	15	9	7	12	—	8	3	d-7.7

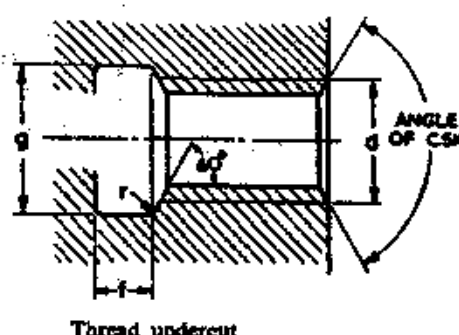
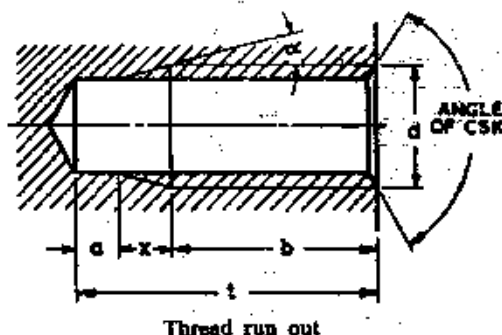
*For values of fine thread diameters, for the pitches given, refer IS: 1330—1958 General plan for metric screw threads with ISO profile.

**The tolerance on g shall be h13.

IS: 1369—1969

THREAD RUN OUTS AND THREAD UNDERCUTS FOR INTERNAL THREADS

All dimensions in millimetres



Thread Diameter d		Thread Run Out x (Max) for Lead Angle α		Clearance for Swarf a (Min) for Lead Angle α		Width of Undercut for Lead Angle α		Radius r	Nominal undercut diameter z
*Fine Series (Pitch in mm)	Coarse Series	$\geq 20^\circ$ Normal	$\geq 25^\circ$ Small	$\geq 20^\circ$ Normal	$\geq 25^\circ$ Small	$\geq 15^\circ$ Normal	$\geq 25^\circ$ Small		
0.2	—	0.4	—	0.6	—	—	—	—	—
0.25	M1, M1.1, M1.2	0.5	—	0.8	—	—	—	—	—
0.3	M1.4	0.6	—	1	—	—	—	—	—
0.35	M1.6, M1.8	0.7	—	1	—	—	—	—	—
0.4	M2	0.8	0.6	1	0.8	—	—	—	—
0.45	M2.2, M2.5	0.9	0.6	1.6	1	—	—	—	—
0.5	M3	1	0.8	1.8	1.2	—	—	—	—
0.6	M3.5	1.2	0.8	1.8	1.2	—	—	—	—
0.7	M4	1.4	1	2	1.4	—	—	—	—
0.75	M4.5	1.5	1	2	1.4	—	—	—	—
0.8	M5	1.6	1.2	2	1.4	—	—	—	—
1	M6, M7	2	1.5	2.5	1.6	—	—	—	—
1.25	M8, M9	2.5	1.8	2.5	1.6	—	—	—	—
1.5	M10, M11	3	2	2.5	1.6	5	3	1	$d+0.5$
1.75	M12	3.5	2.5	2.5	1.6	5	3.5	1	$d+0.5$
2	M14, M16	4	3	2.5	1.6	6	4	1.2	$d+0.5$
2.5	M18, M20, M22	5	3.5	2.5	1.6	8	5	1.6	$d+0.5$
3	M24, M27	6	4	2.5	1.6	10	6	2	$d+0.5$
3.5	M30, M33	7	5	3	2	10	6	2	$d+0.5$
4	M36, M39	8	6	3	2	12	8	2	$d+0.5$
4.5	M42, M45	9	6	3	2	14	8	2.5	$d+0.5$
5	M48, M52	10	7	3	2	14	8	2.5	$d+0.5$
5.5	M56, M60	11	8	4	3	16	10	3	$d+0.5$
6	M64, M68	12	9	4	3	16	10	3	$d+0.5$

*The value of fine thread diameters shall be chosen according to the pitches given (see IS: 1330-1958)

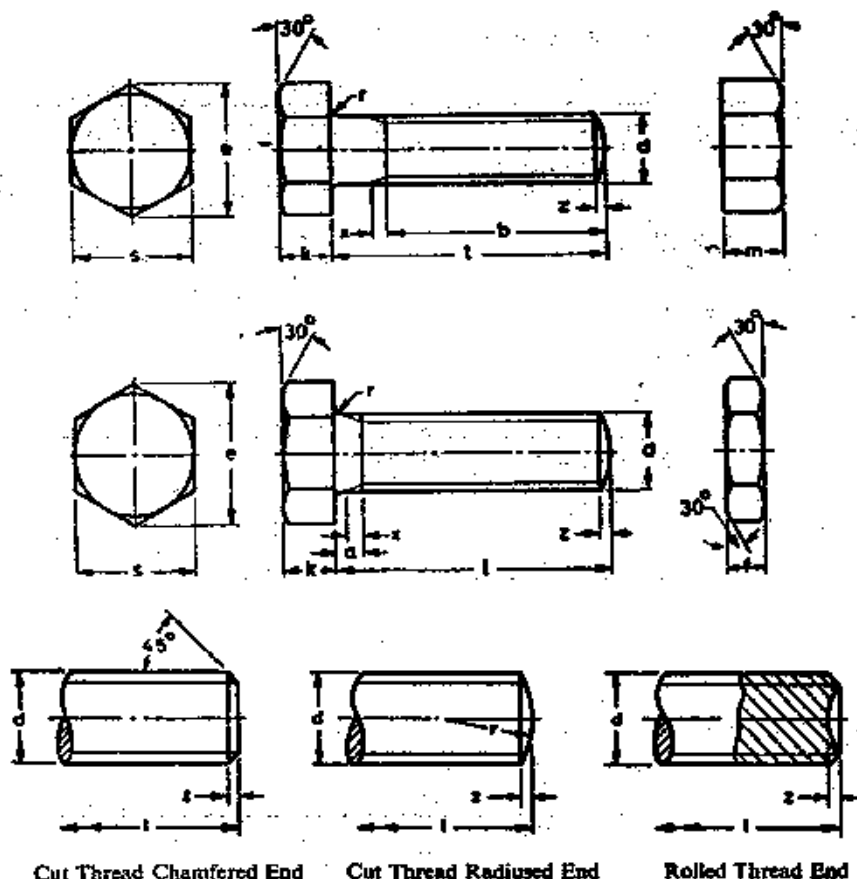
NOTE 1—Where a stud with a thread runout is used, the internal thread should be countersunk to 60° instead of 120° .

NOTE 2—The value of ' r ' should, in practice, be a little larger than the calculated value in order that the useful length may be larger than the securing length of bolt.

NOTE 3—In the special case, for screws up to M5 threaded up to neck, the small values of ' r ' and ' z ' may be taken as $1.5 \times \text{pitch}$ and $0.5 \times \text{pitch}$ respectively.

IS: 1369-1961

DIMENSIONS FOR BOLTS, SCREWS, NUTS AND LOCK NUTS



Cut Thread Chamfered End

Cut Thread Radiused End

Rolled Thread End

Designation

Bolts of size M4, having length equal to 12 mm, and made of steel having mechanical properties conforming to symbol 4D, shall be designated as:

Hexagonal Bolt M4×12-IS: 2389-P-4D

If made of a material other than steel, the symbol '4D' shall be replaced by the words 'brass', 'aluminium', etc., as applicable.

Lock Nuts of size M5 and made of brass shall be designated as:

Hexagonal Lock Nut M4-IS: 2389-P-Brass

If made of steel, the mechanical strengths of Bolts, Nuts and Screws are designated by symbol 4D or 5S of IS: 1367-1961:

Symbol-4D indicates the mechanical strength:

The digit indicates the minimum tensile strength and the letter yield point and elongation.

4D - Tensile strength, kgf/mm², min. 37

Yield point 21, kgf/mm², min.

Elongation, percent, δ , min - 25

P - refers to the grade—Precision

The other grades are T—Turned, B—Black

Precision grade (P)

All surfaces including threads

Screw ends

Turned grade (T): Thread and seating face

All other faces

Black grade (B): Threads

All other faces

Surface finish

▽▽

▽

▽▽

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▽▽

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IS: 2389-1963

DIMENSIONS FOR BOLTS, SCREWS, NUTS AND LOCK NUTS

d		M1.6 (M1.8)		M2	(M2.2)	M2.5	M3	(M3.5)	M4	(M4.5)	M5
b	Nom	8	9	9	9.5	10	11	12	13	14	15
s	Nom (h13)	3.2	3.5	4	4.5	5	5.5	6	7	8	8
s	Max	3.20	3.50	4.00	4.50	5.00	5.50	6.00	7.00	8.00	8.00
s	Min	3.02	3.32	3.82	4.32	4.82	5.32	5.82	6.78	7.78	7.78
e	Max	3.7	4	4.6	5.2	5.8	6.4	6.9	8.1	9.2	9.2
k	Nom (j13)	1.1	1.3	1.4	1.5	1.7	2	2.5	2.8	3	3.5
k	Max	1.17	1.37	1.47	1.57	1.77	2.07	2.57	2.87	3.07	3.59
k	Min	1.03	1.23	1.33	1.43	1.63	1.93	2.43	2.73	2.93	3.41
m	Nom (h13)	1.3	1.4	1.6	1.8	2.0	2.4	2.8	3.2	3.6	4
m	Max	1.30	1.40	1.60	1.80	2.00	2.40	2.80	3.20	3.60	4.00
m	Min	1.16	1.26	1.46	1.66	1.86	2.26	2.66	3.02	3.42	3.82
r	Max	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.25	0.25	0.25
f	Nom (h13)	0.8	0.9	1.0	1.1	1.3	1.5	1.8	2	2.3	2.5
f	Max	0.80	0.90	1.00	1.10	1.30	1.50	1.80	2.00	2.30	2.50
f	Min	0.66	0.76	0.86	0.96	1.16	1.36	1.66	1.86	2.16	2.36
a	Max	0.8	0.8	0.9	0.9	1.2	1.2	1.5	1.5	1.8	1.8

For z refer page 93

For x refer page 94

PREFERRED LENGTH DIAMETER COMBINATION

Length-l (j15)			M1.6 (M1.8)	M2 (M2.2)	M2.5	M3 (M3.5)	M4 (M4.5)	M5
Nom	Max	Min						
3	3.20	2.80	+	+	+	-	-	-
4	4.24	3.76	+	+	+	+	-	-
5	5.24	4.76	+	+	+	+	+	-
6	6.24	5.76	+	+	+	+	+	+
8	8.29	7.71	+	+	+	+	+	+
10	10.3	9.71	+	+	+	+	+	+
12	12.4	11.6	+	+	+	+	+	+
15	15.4	14.6	+	+	+	+	+	+
18	18.4	17.6	+	+	+	+	+	+
20	20.4	19.6	+	+	+	+	+	+
22	22.4	21.6	-	+	+	+	+	+
25	25.4	24.6	-	+	+	+	+	+
28	28.4	27.6	-	-	+	+	+	+
30	30.4	29.6	-	-	+	+	+	+
35	35.5	34.5	-	-	-	+	+	+
40	40.5	39.5	-	-	-	+	+	+
45	45.5	44.5	-	-	-	-	+	+
50	50.5	49.5	-	-	-	-	+	+
55	55.6	54.4	-	-	-	-	+	+
60	60.6	59.4	-	-	-	-	-	+
65	65.6	64.4	-	-	-	-	-	+
70	70.6	69.4	-	-	-	-	-	+
75	75.6	74.4	-	-	-	-	-	+

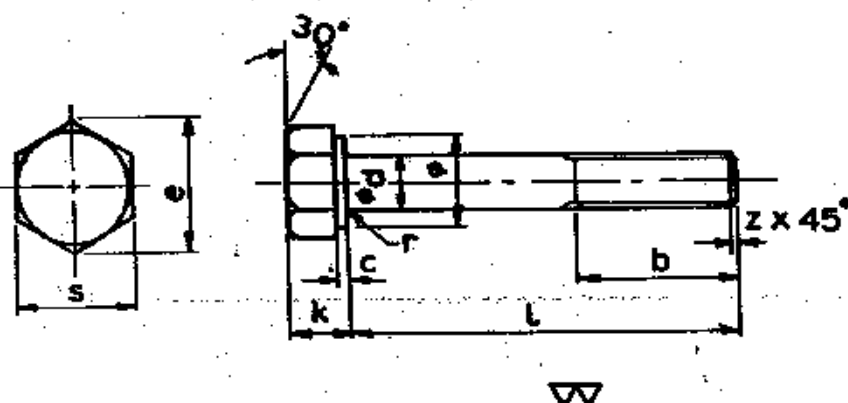
Where 'l' is less than 'b', it is to be understood that the screw is fully threaded.

Preferred combinations are indicated by +

HEXAGONAL BOLT (Contd)

Precision (P) Grade

M5—M30



All dimensions in mm

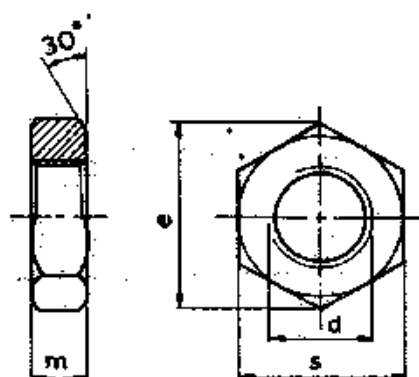
Size	M5	M6	M8	M10	M12	M16	M20	M24	M30
d max	5.00	6.00	8.00	10.00	12.00	16.00	20.00	24.00	30.00
min	4.82	5.82	7.78	9.78	11.73	15.73	19.67	23.67	29.67
s max	8.00	10.00	13.0	17.00	19.00	24.0	30.00	36.00	46.00
min	7.85	9.78	12.73	16.73	18.67	23.67	29.67	35.38	45.38
k max	3.65	4.15	5.65	7.18	8.18	10.18	13.22	15.22	19.26
min	3.35	3.85	5.35	6.82	7.82	9.82	12.78	14.78	18.74
b min for $l \leq 130$	16.00	18.00	22.00	26.00	30.00	38.00	46.00	54.00	66.00
for $130 < l < 300$		24.00	28.00	32.00	36.00	44.00	52.00	60.00	72.00
for $l > 300$						57.00	65.00	73.00	85.00
ϕ min	7.20	9.00	11.70	15.30	17.10	21.60	27.00	32.40	41.40
C min	0.20	0.30	0.40	0.40	0.40	0.40	0.40	0.50	0.50
e min	8.87	11.05	14.38	18.90	21.10	26.75	33.53	39.98	51.28
r min	0.20	0.25	0.40	0.40	0.60	0.60	0.80	0.80	1.0
z max	0.80	1.00	1.25	1.50	1.75	2.00	2.50	3.00	3.50
l	30—75	30—80	30—90	35—120	40—120	50—220	60—220	70—220	90—220

IS : 2389

IS : 1364

HEXAGONAL NUT AND LOCKNUT

Precision (P) Grade

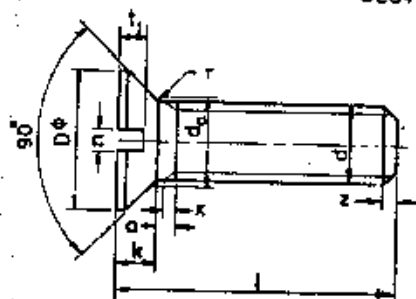


All dimensions in mm

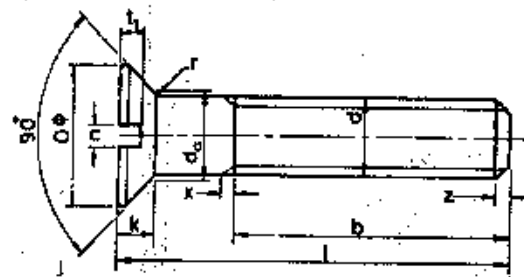
SIZE	S		e	m			
				Nut		Locknut	
	max	min		max	min	max	min
M3	5.5	5.38	6.08	2.4	2.15	1.6	1.35
M4	7.0	6.85	7.74	3.2	2.9	2.0	1.75
M5	8.0	7.85	8.87	4.0	3.7	2.5	2.25
M6	10.0	9.78	11.05	5.0	4.7	3.0	2.75
M8	13.0	12.73	14.38	6.5	6.14	4.0	3.70
M10	17.0	16.73	18.90	8.0	7.64	5.0	4.70
M12	19.0	18.67	21.10	10.0	9.64	7.0	6.64
M16	24.0	23.67	26.75	13.0	12.57	8.0	7.64
M20	30.0	29.67	33.53	16.0	15.57	9.0	8.64
M24	36	35.38	39.98	19.0	18.48	10.0	9.64

DIMENSIONS FOR SLOTTED COUNTERSUNK HEAD AND SLOTTED RAISED COUNTERSUNK HEAD SCREWS (DIAMETER RANGE 1.6 to 20 mm)

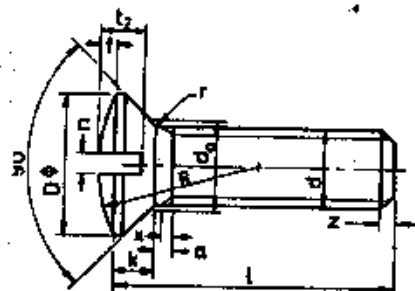
SLOTTED COUNTERSUNK HEAD SCREWS



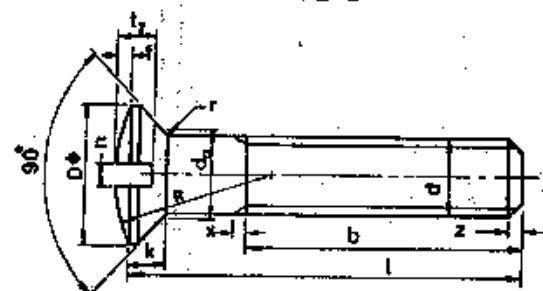
TYPE A



TYPE B



TYPE A



TYPE B

SLOTTED RAISED COUNTERSUNK HEAD SCREWS

All dimensions in millimetres

Size		M1.6	M2	(M2.2)	M2.5	M3	(M3.5)	M4	(M4.5)	M5	M6	M8	M10	M12	(M14)	M16	(M18)	M20
												M8×1	M10×1.25	M12×1.25	(M14×1.5)	M16×1.5	(M18×1.5)	M20×1.5
d	Nom	1.6	2	2.2	2.5	3	3.5	4	4.5	5	6	8	10	12	14	16	18	20
	Max	1.60	2.00	2.20	2.50	3.00	3.50	4.00	4.50	5.00	6.00	8.00	10.00	12.00	14.00	16.00	18.00	20.00
	Min	1.46	1.86	2.06	2.36	2.86	3.32	3.82	4.32	4.82	5.82	7.78	9.78	11.73	13.73	15.73	17.73	19.67

DIMENSIONS FOR SLOTTED COUNTERSUNK HEAD AND SLOTTED RAISED COUNTERSUNK HEAD SCREWS (DIAMETER RANGE 1.6 to 20 mm) (Contd.)

All dimensions in millimetres

Size	M1.6	M2	(M2.2)	M2.5	M3	(M3.5)	M4	(M4.5)	M5	M6	M8	M10	M12	(M14)	M16	(M18)	M20
											M8×1	M10×1.25	M12×1.25	(M14×1.5)	M16×1.5	(M18×1.5)	M20×1.5
D Max	3.20	4.00	4.40	5.00	6.00	7.00	8.00	9.00	10.00	12.00	16.00	20.00	24.00	28.00	32.00	36.00	40.00
Min	2.72	3.40	3.74	4.25	5.10	5.95	6.80	7.65	8.50	10.20	14.00	17.50	21.00	24.50	28.00	31.50	35.00
k Max	0.80	1.00	1.10	1.25	1.50	1.75	2.00	2.25	2.50	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
Min	0.72	0.90	0.99	1.12	1.35	1.57	1.80	2.03	2.25	2.70	3.60	4.50	5.40	6.30	7.20	8.10	9.00
f Approx	0.4	0.5	0.55	0.6	0.75	0.9	1	1.1	1.25	1.5	2	2.5	3	3.5	4	4.5	5
R Approx	3	4	4	5	6	6	8	8	10	12	16	20	25	25	32	32	40
n Nom	0.4	0.5	0.6	0.6	0.8	0.8	1	1	1.2	1.6	2	2.5	3	3	4	4	5
Max	0.60	0.70	0.80	0.80	1.00	1.00	1.20	1.20	1.51	1.91	2.31	2.81	3.31	3.31	4.37	4.37	5.37
Min	0.46	0.56	0.66	0.66	0.86	0.86	1.06	1.06	1.26	1.66	2.06	2.56	3.06	3.06	4.07	4.07	5.07
t ₁ Max	0.51	0.64	0.70	0.8	0.96	1.12	1.28	1.44	1.60	1.92	2.56	3.20	3.84	4.48	5.12	5.76	6.40
Min	0.32	0.40	0.44	0.50	0.60	0.70	0.80	0.90	1.00	1.20	1.60	2.00	2.40	2.80	3.20	3.60	4.00
t ₂ Max	0.83	1.04	1.14	1.30	1.56	1.82	2.08	2.34	2.60	3.12	4.16	5.20	6.24	7.28	8.32	9.36	10.40
Min	0.64	0.80	0.88	1.00	1.20	1.40	1.60	1.80	2.00	2.40	3.20	4.00	4.80	5.60	6.40	8.00	8.00
r Min	0.10	0.10	0.10	0.10	0.10	0.20	0.20	0.20	0.20	0.25	0.40	0.40	0.60	0.60	0.60	0.60	0.80
d _a Max	2.0	2.6	2.8	3.1	3.6	4.3	4.7	5.2	5.7	6.8	9.2	11.2	14.2	16.2	18.2	20.2	22.4
a Max	0.7	0.8	0.8	0.9	1	1.2	1.4	1.5	1.6	2	2.5	3	3.5	4	4	5	5
b Min	15	16	17	18	19	20	22	24	25	28	34	40	46	52	58	64	70

NOTE 1: Sizes shown in brackets are of second preference.

NOTE 2: Screws are permitted to have scant shank. In such cases the shank diameter may be made equal to the pitch diameter.

For z refer Page 5.44

For x refer Page 5.45

IS: 1365-1968.

PREFERRED LENGTH AND DIAMETER COMBINATION FOR SLOTTED COUNTERSUNK HEAD AND SLOTTED RAISED COUNTERSUNK HEAD SCREWS

(All dimensions in millimetres)

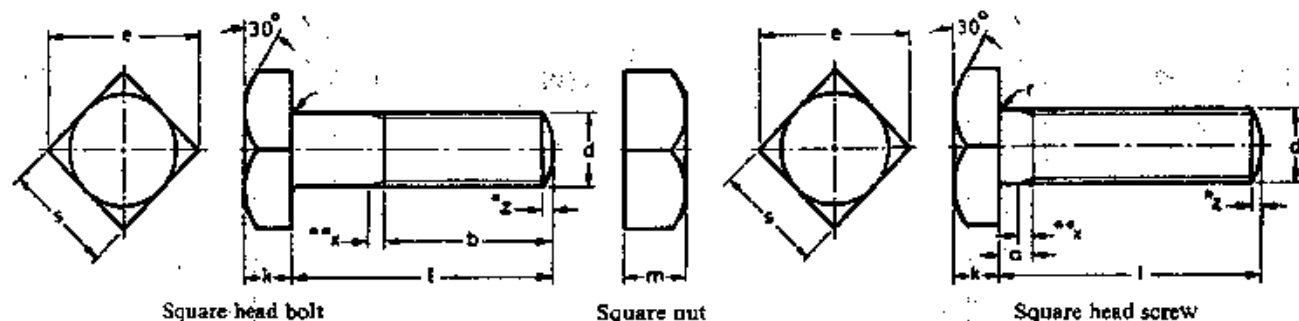
Size	M1.6	M2	(M2.2)	M2.5	M3	(M3.5)	M4	(M4.5)	M5	M6	M8	M8 × 1	M10	M10 × 1.25	M12	M12 × 1.25	(M14)	(M14 × 1.5)	M16	M16 × 1.5	(M18)	(M18 × 1.5)	M20	M20 × 1.5
3	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(7)	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(9)	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(11)	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	x	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-
14	x	x	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-	-
16	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-	-
(18)	-	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-	-
20	-	+	+	x	x	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-	-
(22)	-	-	+	+	+	x	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-	-
25	-	-	-	+	+	+	x	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-	-
(28)	-	-	-	-	+	+	+	+	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-	-
30	-	-	-	-	+	+	+	+	+	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-
(32)	-	-	-	-	-	+	+	+	+	x	x	x	x	x	x	x	x	x	x	x	-	-	-	-
35	-	-	-	-	-	+	+	+	+	+	x	x	x	x	x	x	x	x	x	x	-	-	-	-
(38)	-	-	-	-	-	-	+	+	+	+	+	x	x	x	x	x	x	x	x	x	-	-	-	-
40	-	-	-	-	-	-	+	+	+	+	+	x	x	x	x	x	x	x	x	x	x	-	-	-
45	-	-	-	-	-	-	-	+	+	+	+	+	x	x	x	x	x	x	x	x	x	x	-	-
50	-	-	-	-	-	-	-	-	+	+	+	+	+	x	x	x	x	x	x	x	x	x	x	-
55	-	-	-	-	-	-	-	-	-	+	+	+	+	+	x	x	x	x	x	x	x	x	x	-
60	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	x	x	x	x	x	x	x	x	-
65	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	x	x	x	x	x	x	-
70	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	x	x	x	x	x	-
75	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	x	x	x	x	-
80	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	x
85	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	x
90	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+
(95)	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
100	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+
(105)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+
110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+

NOTE 1 — Sizes shown in brackets are of second preference.

NOTE 2 — Preferred lengths are indicated by '+' and 'x'.

NOTE 3 — Lengths marked with 'x' are fully threaded.

DIMENSIONS FOR BLACK SQUARE HEAD BOLTS, SCREWS AND NUTS
(Diameter range M 6 to M 39)



Square head bolt

Square nut

Square head screw

All dimensions in millimetres

Size	M 6	M 8	M 10	M 12	(M 14)	M 16	(M 18)	M 20	(M 22)	M 24	(M 27)	M 30	(M 33)	M 36	(M 39)
d	Nom 6	8	10	12	14	16	18	20	22	24	27	30	33	36	39
	Max 6.48	8.90	10.90	13.10	15.10	17.10	19.10	21.50	23.30	25.30	28.30	31.30	34.60	37.60	40.60
	Min 5.70	7.64	9.64	11.57	13.57	15.57	17.57	19.48	21.48	23.48	26.48	29.48	32.38	35.38	38.38
	Nom 10	13	17	19	22	24	27	30	32	36	41	46	50	55	60
s { ≤ 19 - h 14															
> 19 - h 15	Max 10.00	13.00	17.00	19.00	22.00	24.00	27.00	30.00	32.00	36.00	41.00	46.00	50.00	55.00	60.00
	Min 9.64	12.57	16.57	18.48	21.16	23.16	26.16	29.16	31.00	35.00	40.00	45.00	49.00	53.80	58.80
e	Min 12.53	16.34	21.54	24.02	27.51	30.11	34.01	37.91	40.30	45.50	52.00	58.50	63.70	69.94	76.44
	Nom 4	5.5	7	8	9	10	12	13	14	15	17	19	21	23	25
k (js 16)	Max 4.38	5.88	7.45	8.45	9.45	10.45	12.55	13.55	14.55	15.55	17.55	19.65	21.65	23.65	25.65
	Min 3.62	5.12	6.55	7.55	8.55	9.55	11.45	12.45	13.45	14.45	16.45	18.35	20.35	22.35	24.35
d _a	Max 7.2	10.2	12.2	15.2	17.2	19.2	21.2	24.4	26.4	28.4	32.4	35.4	38.4	42.4	45.4
r	Min 0.25	0.4	0.4	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0
a	Max 4.0	4.5	5.0	6.0	7.5	7.5	9.0	9.0	9.0	11	—	—	—	—	—
d { b ₁	Min 18	22	26	30	34	38	42	46	50	54	60	66	72	78	84
b ₂	Min —	28	32	36	40	44	48	52	56	60	66	72	78	84	90
b ₃	Min —	—	—	49	53	57	61	65	69	73	79	85	91	97	100
	Nom 5	6.5	8	10	11	13	15	16	18	19	22	24	26	29	31
m (js 16)	Max 5.38	6.95	7.55	10.45	11.55	13.55	15.55	16.55	18.55	19.65	22.65	24.65	26.65	29.65	31.80
	Min 4.62	6.05	8.45	9.55	10.45	12.45	14.45	15.45	17.45	18.35	21.35	23.35	25.35	28.35	30.20

Note 1: Sizes shown in brackets are of second preference.

Note 2: Use b₁ for l ≤ 130, b₂ for 130 < l ≤ 200, b₃ for l > 200.

Note 3: d_a is the diameter of both including the shoulder fillet.

For x refer page 5.45

For x refer page 5.44

DESIGNATION SYSTEM FOR BLACK SQUARE HEAD BOLTS, SCREWS AND NUTS

Description			
Fastener	Thread Size	Length mm	Designation
Square bolt with a square nut	M 10	30	Square bolt M 10×30 N—IS:2585
Square bolt only	M 10	30	Square bolt M 10×30—IS:2585
Square screw	M 10	30	Square screw M 10×30—IS:2585
Square nut	M 10	—	Square nut M 10—IS:2585
Square bolt with a hexagon nut conforming to IS:1363—1967†	M 10	30	Square bolt M 10×30 HN—IS:2585

† Specification for black hexagon bolts, nuts and lock nuts (diameter 6 to 39 mm) and black hexagon screws (diameter 6 to 24 mm) (first revision).

IS: 2585—1968

PREFERRED LENGTHS AND DIAMETER COMBINATIONS FOR BLACK SQUARE HEAD SCREWS

All dimensions in millimetres

Size	M6	M8	M10	M12	(M14)	M16	(M18)	M20	(M22)	M24
16	×	×	×	×	—	—	—	—	—	—
20	×	×	×	×	—	—	—	—	—	—
25	×	×	×	×	×	×	—	—	—	—
30	×	×	×	×	×	×	—	—	—	—
35	×	×	×	×	×	×	—	—	—	—
40	×	×	×	×	×	×	×	—	—	—
45	—	×	×	×	×	×	×	×	—	—
50	—	×	×	×	×	×	×	×	×	—
55	—	—	×	×	×	×	×	×	×	×
60	—	—	×	×	×	×	×	×	×	×
65	—	—	—	×	×	×	×	×	×	×
70	—	—	—	×	×	×	×	×	×	×
75	—	—	—	×	×	×	×	×	×	×
80	—	—	—	×	×	×	×	×	×	×

NOTE 1—Preferred lengths are indicated by '×'

NOTE 2—Sizes shown in brackets are of second preference.

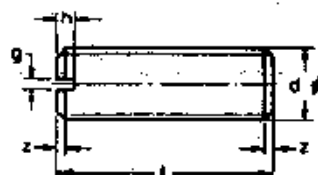
PREFERRED LENGTH AND DIAMETER COMBINATIONS FOR BLACK SQUARE HEAD BOLTS

All dimensions in millimetres

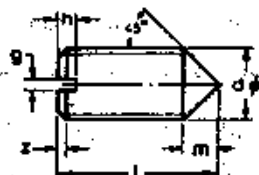
Size	M6	M8	M10	M12	(M14)	M16	(M18)	M20	(M22)	M24	(M27)	M30	(M33)	M36	(M39)
25	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
35	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
40	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
45	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
50	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
55	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-
60	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-
65	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-
70	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
75	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
80	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-
90	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-
100	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-
110	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
120	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
130	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+
140	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+
150	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+
160	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
170	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
180	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
190	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
200	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
220	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
240	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+
260	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
280	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
300	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
320	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+
340	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+
360	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+
380	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+
400	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+

NOTE 1 — Preferred lengths are indicated by '+'.
NOTE 2 — Sizes shown in brackets are of second preference.
NOTE 3 — Bolts with lengths less than the minimum preferred lengths indicated above are to be treated as screws, for which see table on page 5.55

DIMENSIONS FOR SLOTTED HEAD GRUB SCREWS



Type A Flat End



M1 TO M5

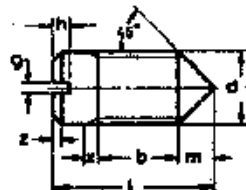
Type C Conical End



ABOVE M5

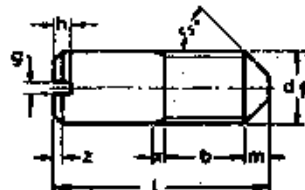


Type B Flat End with Body

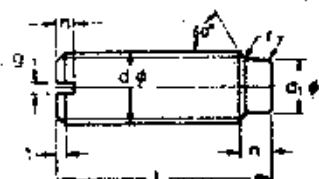


M1 TO M5

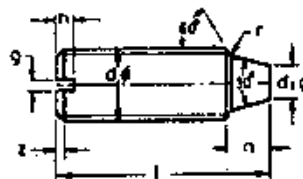
Type D Conical End with Body



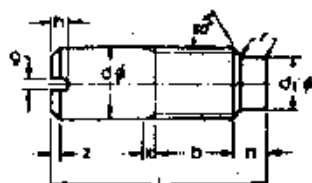
ABOVE M5



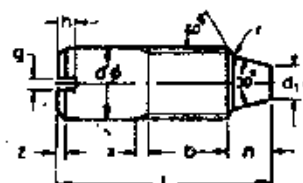
Type E Cylindrical Dog Point



Type G Tapered Dog Point



Type F Cylindrical Dog Point with Body



Type H Tapered Dog Point with Body

DIMENSIONS FOR SLOTTED HEAD GRUB SCREWS

All dimensions in millimetres

Type	d	M1	M1.2	M1.6	M2	M2.5	M3	M4	M5	M6	M8	M10	M12	(M14)	M16	(M18)	M20	(M22)	M24	
A, B, C, D, E, F, G and H	g (H14)	Nom	0.25	0.25	0.3	0.3	0.4	0.5	0.6	0.8	1	1.2	1.6	2	2	2.5	3	3	4	4
	g	Max	0.35	0.35	0.45	0.45	0.55	0.65	0.75	0.95	1.15	1.45	1.85	2.25	2.25	2.75	3.25	3.25	4.30	4.30
	g	Min	0.25	0.25	0.30	0.30	0.40	0.50	0.60	0.80	1.00	1.20	1.60	2.00	2.00	2.50	3.00	3.00	4.00	4.00
	h (j15)	Nom	0.6	0.6	0.8	0.8	1	1.2	1.4	1.8	2	2.5	3	4	4	4.5	5	5	6	6
	h	Max	0.70	0.70	0.90	0.90	1.10	1.40	1.60	2.00	2.20	2.70	3.20	4.24	4.24	4.74	5.24	5.24	6.24	6.24
	h	Min	0.50	0.50	0.70	0.70	0.90	1.00	1.20	1.60	1.80	2.30	2.80	3.76	3.76	4.26	4.76	4.76	5.76	5.76
B, D, F, and H	b	Nom	1.2	1.5	2.0	2.5	3.0	3.5	4.5	5.0	6.5	8	11	13	15	18	20	22	—	—
C and D	m	Nom	0.5	0.6	0.8	1.0	1.3	1.5	2.0	2.5	2.5	3.0	4.0	5.0	5.0	6.0	6.5	7	8	8
E and F	d ₁ (h13)	Nom	—	—	—	1.3	1.6	2.0	2.5	3.5	4	6	7	9	10	12	13	15	—	—
	d ₁	Max	—	—	—	1.30	1.60	2.00	2.50	3.50	4.00	6.00	7.00	9.00	10.00	12.00	13.00	15.00	—	—
	d ₁	Min	—	—	—	1.16	1.46	1.86	2.36	3.32	3.82	5.82	6.78	8.78	9.78	11.73	12.73	14.73	—	—
	n (+IT14)	Nom	—	—	—	1.5	2	2.5	3	3	3.5	5.0	5.5	7	7	9	9	9	—	—
	n	Max	—	—	—	1.75	2.25	2.75	3.25	3.25	3.80	5.30	5.80	7.36	7.36	9.36	9.36	9.36	—	—
	n	Min	—	—	—	1.50	2.00	2.50	3.00	3.00	3.50	5.00	5.50	7.00	7.00	9.00	9.00	9.00	—	—
	r	Nom	—	—	—	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.6	0.8	0.8	0.8	1.0	—	—
G and H	d ₂ (h13)	Nom	—	—	—	—	—	—	1.6	2.4	3.7	4.4	5.1	—	7.4	—	9.7	—	—	—
	d ₂	Max	—	—	—	—	—	—	1.60	2.40	3.70	4.40	5.10	—	7.40	—	9.70	—	—	—
	d ₂	Min	—	—	—	—	—	—	1.46	2.26	3.52	4.22	4.92	—	7.18	—	9.48	—	—	—
	n (+IT14)	Nom	—	—	—	—	—	—	4	4.5	5	6	8	—	10	—	12	—	—	—
	n	Max	—	—	—	—	—	—	4.30	4.80	5.30	6.30	8.36	—	10.36	—	12.43	—	—	—
	n	Min	—	—	—	—	—	—	4.00	4.50	5.00	6.00	8.00	—	10.00	—	12.00	—	—	—
	r	Nom	—	—	—	—	—	—	0.4	0.4	0.4	0.5	0.6	—	0.8	—	0.8	—	—	—

NOTE — Depending on their importance, the limits of the above dimensions have been arrived at by rounding off suitably the tolerances obtained from IS: 919-1959 Recommendations for Limits and Fits for Engineering.

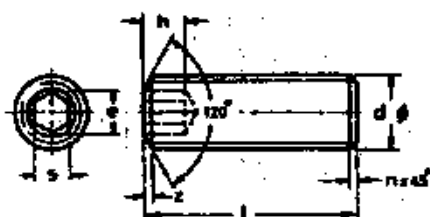
Designation: Slotted Head Grub Screw 'A' M12 x 50 — IS: 2388-P-4D.

For x refer page 5.45

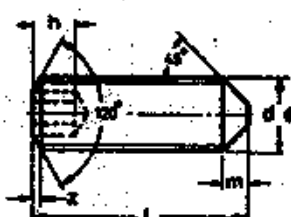
For z refer page 5.44

DIMENSIONS FOR HEXAGON SOCKET HEAD GRUB SCREWS

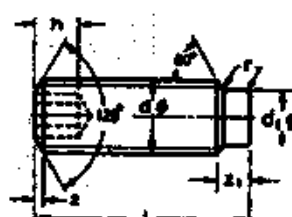
All dimensions in millimetres



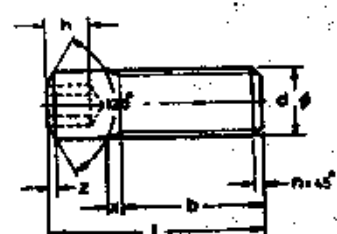
Type A Flat End



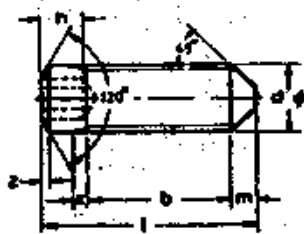
Type C Conical End



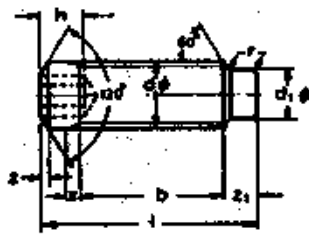
Type E Cylindrical Dog Point



Type B Flat End with Body



Type D Conical End with Body



Type F Cylindrical Dog Point with Body

Type	d		M6	M8	M10	M12	M16	M20	M24
A, B, C, D, E and F	s (D12)	Nom	3	4	5	6	8	10	12
		Max	3.11	4.15	5.15	6.15	8.19	10.19	12.23
		Min	3.02	4.03	5.03	6.03	8.04	10.04	12.05
	e (J15)	Nom	3.5	4.7	5.8	7.0	9.4	11.7	14
		Max	4	5	6	8	10	12	15
		Min	4.24	5.24	6.24	8.29	10.29	12.35	15.35
A and B	n	Nom	1	1.25	1.5	1.75	2	2.9	3
B, D and F	b	Nom	18	22	25	28	35	40	50
C and D	m	Nom	2.5	3	4	5	6	7	8
E and F	d1 (h13)	Nom	4	6	7	9	12	15	18
		Max	4.00	6.00	7.00	9.00	12.00	15.00	18.00
		Min	3.82	5.82	6.78	8.78	11.73	14.73	17.73
	z1 (+T14)	Nom	3.5	5	5.5	7	9	9	11
		Max	3.80	5.30	5.80	7.36	9.36	9.36	11.43
		Min	3.50	5.00	5.50	7.00	9.00	9.00	11.00
	r	Nom	0.4	0.4	0.5	0.6	0.8	1	1

NOTE—Depending on their importance, the limits of the above dimensions have been arrived at by rounding off suitably the tolerances obtained from IS: 919-1959. Recommendations for Limits and Fits for Engineering.

Designation: Hexagon Socket Head Grub Screw 'A' M12x50

For x refer page 5.43

For z refer page 5.44

IS: 2388-1963

LENGTH-DIAMETER COMBINATIONS FOR GRUB SCREWS

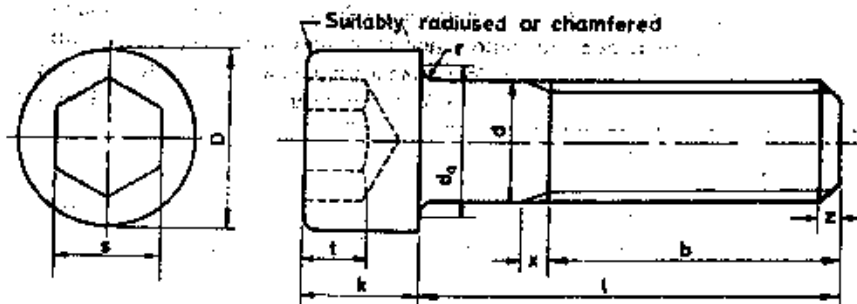
All dimensions in millimetres

LENGTH, <i>l</i> (j 15)			M1	M1.2	M1.6	M2	M2.5	M3	M4	M5	M6	M8	M10	M12	(M14)	M16	(M18)	M20	(M22)	M24
Norm	Max	Min																		
2	2.20	1.80		+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	3.20	2.80		+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	4.24	3.76		+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
5	5.24	4.76		-	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
6	6.24	5.76		-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
8	8.29	7.71		-	-	+	+	+	+	+	+o	+	-	-	-	-	-	-	-	-
10	10.3	9.71		-	-	-	+	+	+	+	+o	+o	+	-	-	-	-	-	-	-
12	12.4	11.6		-	-	-	-	+	+	+	+o	+o	+o	+	-	-	-	-	-	-
14	14.4	13.6		-	-	-	-	-	+	+	+o	+o	+o	+	+	-	-	-	-	-
16	16.4	15.6		-	-	-	-	-	+	+	+o	+o	+o	+o	+	+	-	-	-	-
20	20.4	19.6		-	-	-	-	-	-	-	+o	+o	+o	+o	+	+	+	+	-	-
25	25.4	24.6		-	-	-	-	-	-	-	o	+o	+o	+o	+o	+o	+	+	+	+
30	30.4	29.6		-	-	-	-	-	-	-	o	o	+o	+o	+o	+o	+o	+o	+	+
35	35.5	34.5		-	-	-	-	-	-	-	o	o	+o	+o	+o	+o	+o	+o	+	+
40	40.5	39.5		-	-	-	-	-	-	-	-	o	o	+o	+o	+o	+o	+o	+o	+o
45	45.5	44.5		-	-	-	-	-	-	-	-	-	o	+o	+o	+o	+o	+o	+o	+o
50	50.5	49.5		-	-	-	-	-	-	-	-	-	o	o	o	+o	+o	+o	+o	+o
55	55.6	54.4		-	-	-	-	-	-	-	-	-	-	o	o	o	+o	+o	+o	+o
60	60.6	59.4		-	-	-	-	-	-	-	-	-	-	o	o	o	+o	+o	+o	+o
65	65.6	64.4		-	-	-	-	-	-	-	-	-	-	-	-	o	o	+o	+o	+o
70	70.6	69.4		-	-	-	-	-	-	-	-	-	-	-	-	o	o	o	+o	+o
75	75.6	74.4		-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	o	o
80	80.6	79.4		-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	o	o
90	90.7	89.3		-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	o	o
100	101	99.3		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	o	o

NOTE 1—For slotted head grub screws preferred lengths are indicated by '+'.
 NOTE 2—For hexagon socket head grub screws preferred lengths are indicated by 'o'.
 NOTE 3—'+o' indicates that the corresponding 'l' is preferred length for both slotted head and hexagon socket head grub screws.
 NOTE 4—The Max and Min dimensions of 'l' have been rounded off suitably.

DIMENSIONS FOR HEXAGON SOCKET HEAD CAP SCREWS

(Diameter Range 3 to 24 mm)



All dimensions in millimetres

Size	M3	M4	M5	M6	M8 M8×1	M10 M10×1.25	M12 M12×1.25	(M14) M14×1.5	M16 M16×1.5	(M18) M18×1.5	M20 M20×1.5	(M22) M22×1.5	M24 M24×2
b	12	14	16	18	22	26	30	34	38	42	46	50	54
d (h 13)	3	4	5	6	8	10	12	14	16	18	20	22	24
D (h 13)	5.5	7	8.5	10	13	16	18	21	24	27	30	33	36
k (h 13)	3	4	5	6	8	10	12	14	16	18	20	22	24
S (D 12)	2.5	3	4	5	6	8	10	12	14	14	17	17	19
t	1.70	2.40	3.10	3.78	4.78	6.25	7.50	8.70	9.70	10.70	11.80	12.40	14.00
r	0.1	0.2	0.2	0.25	0.4	0.4	0.6	0.6	0.6	0.6	0.8	0.8	0.8
d _s	3.6	4.7	5.7	6.8	9.2	11.2	14.2	16.2	18.2	20.2	22.4	24.4	26.4

For z refer page

For x refer page

* For lengths upto 130 mm.

* For lengths over 130 mm and upto 200 mm.

PREFERRED LENGTH AND DIAMETER COMBINATIONS FOR HEXAGON SOCKET HEAD CAP SCREWS

(Diameter range 3 to 12 mm)

All dimensions in millimetres

Nom.	l (js 15)		M3	M4	M5	M6	M8 M8×1	M10 M10×1.25	M12 M12×1.25
	Max	Min							
4	4.24	3.76	+	-	-	-	-	-	-
5	5.24	4.76	+	-	-	-	-	-	-
6	6.24	5.76	+	+	-	-	-	-	-
(7)	7.29	6.71	+	+	-	-	-	-	-
8	8.29	7.71	+	+	-	-	-	-	-
(9)	9.29	8.71	+	+	-	-	-	-	-
10	10.29	9.71	+	+	+	-	-	-	-
(11)	11.35	10.65	+	+	+	-	-	-	-
12	12.35	11.65	+	+	+	+	-	-	-
14	14.35	13.65	+	+	+	+	+	+	-
16	16.35	15.65	+	+	+	+	+	+	-
(18)	18.35	17.65	+	+	+	+	+	+	-
20	20.42	19.58	+	+	+	+	+	+	+
(22)	22.42	21.58	+	+	+	+	+	+	+
25	25.42	24.58	+	+	+	+	+	+	+
(28)	28.42	27.58	+	+	+	+	+	+	+
30	30.42	29.58	+	+	+	+	+	+	+
35	35.50	34.50	+	+	+	+	+	+	+
40	40.50	39.50	+	+	+	+	+	+	+
45	45.50	44.50	-	+	+	+	+	+	+
50	50.50	49.50	-	+	+	+	+	+	+
55	55.60	54.40	-	-	+	+	+	+	+
60	60.60	59.40	-	-	+	+	+	+	+
65	65.60	64.40	-	-	-	-	+	+	+
70	70.60	69.40	-	-	-	-	+	+	+
75	75.60	74.40	-	-	-	-	+	+	+
80	80.60	79.40	-	-	-	-	+	+	+
85	85.70	84.30	-	-	-	-	+	+	+
90	90.70	89.30	-	-	-	-	+	+	+
100	100.70	99.30	-	-	-	-	+	+	+
110	110.70	109.30	-	-	-	-	-	+	+
120	120.70	119.30	-	-	-	-	-	+	+

Note 1: Preferred length diameter combinations are indicated by '+',

Note 2: Where 'l' is less than 'b' the screw shall be considered as fully threaded.

Note 3: Second preference lengths are given in brackets.

**PREFERRED LENGTH AND DIAMETER COMBINATIONS FOR
HEXAGON SOCKET HEAD CAP SCREWS (Contd.)**

(Diameter range 14 to 24 mm)

All dimensions in millimetres

Nom	<i>l</i> (js15) Max	Min	(M14) (M14 × 1.5)	M16 M16 × 1.5	(M18) (M18 × 1.5)	M20 M20 × 1.5	(M22) (M22 × 1.5)	M24 M24 × 2
30	30.42	29.58	+	+	-	-	-	-
35	35.50	34.50	+	+	-	-	-	-
40	40.50	39.50	+	+	+	+	-	-
45	45.50	44.50	+	+	+	+	-	-
50	50.50	49.50	+	+	+	+	+	-
55	55.60	54.40	+	+	+	+	+	-
60	60.60	59.40	+	+	+	+	+	+
65	65.60	64.40	+	+	+	+	+	+
70	70.60	69.40	+	+	+	+	+	+
75	75.60	74.40	+	+	+	+	+	+
80	80.60	79.40	+	+	+	+	+	+
85	85.70	84.30	+	+	+	+	+	+
90	90.70	89.30	+	+	+	+	+	+
100	100.70	99.30	+	+	+	+	+	+
110	110.70	109.30	+	+	+	+	+	+
120	120.70	119.30	+	+	+	+	+	+
130	130.80	129.20	-	+	+	+	+	+
140	140.80	139.20	-	+	+	+	+	+
150	150.80	149.20	-	+	+	+	+	+
160	160.80	159.20	-	-	-	+	+	+
170	170.80	169.20	-	-	-	+	+	+
180	180.80	179.20	-	-	-	+	+	+
190	190.92	189.08	-	-	-	-	+	+
200	200.92	199.08	-	-	-	-	+	+

Note 1: Preferred length diameter combinations are indicated by '+'.
Note 2: Where 'l' is less than 'b' the screws shall be considered as fully threaded.
Note 3: Second preference sizes are shown in brackets.

DIMENSIONS FOR STUDS (Diameter range 3 to 39 mm)



All dimensions in millimetres

Nominal Size, d		M3	(M3.5)	M4	(M4.5)	M5	M6	M8 M8 x 1	M10 M10 x 1.25	M12 M12 x 1.25	(M14) (M14 x 1.5)	M16 M16 x 1.5	(M18) (M18 x 1.5)	M20 M20 x 1.5	(M22) (M22 x 1.5)	M24 M24 x 2	(M27) (M27 x 2)	M30 M30 x 2	(M33) (M33 x 2)	M36 M36 x 3	(M39) (M39 x 3)		
b ₁ (+1T 17)	*	12	13	14	15	16	18	22	26	30	34	38	42	46	50	54	60	66	72	78	84		
	†	—	—	—	—	—	—	—	32	36	40	44	48	52	56	60	66	72	78	84	90		
	‡	—	—	—	—	—	—	—	—	—	—	57	61	65	69	73	79	85	91	97	103		
	Type A	Max	4.00	4.70	5.20	5.70	6.20	7.20	9.50	11.50	13.80	15.80	17.80	19.80	22.10	24.10	26.10	29.10	32.10	35.50	38.50	41.50	
		Min	3.00	3.50	4.00	4.50	5.00	6.00	8.00	10.00	12.00	14.00	16.00	18.00	20.00	22.00	24.00	27.00	30.00	33.00	36.00	39.00	
		Type B	Max	5.70	6.20	7.20	8.50	9.00	10.50	13.80	16.80	19.80	23.10	26.10	29.10	32.10	35.50	38.50	43.00	47.50	52.00	67.00	60.50
			Min	4.50	5.00	6.00	7.00	7.50	9.00	12.00	15.00	18.00	21.00	24.00	27.00	30.00	33.00	36.00	40.50	45.00	49.50	54.00	57.50

* For lengths upto 130 mm.

† For lengths above 130 mm and upto 200 mm.

‡ For lengths above 200 mm.

NOTE—Non-preferred diameters of studs are given within brackets.

For x refer page

IS: 1862—1967

PREFERRED LENGTH AND DIAMETER COMBINATIONS FOR STUDS

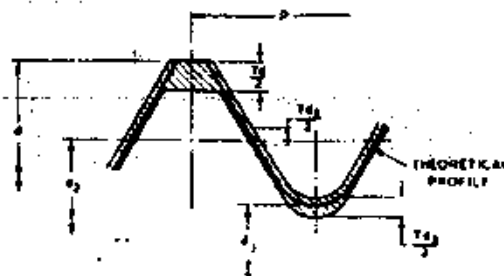
All dimensions in millimetres

Size l	M 3	(M3.5)	M 4	(M4.5)	M 5	M 6	M 8 M 8 x 1	M 10 M 10 x 1.25	M 12 M 12 x 1.5	(M 14) (M 14 x 1.5)	M 16 M 16 x 1.5	(M 18) (M 18 x 1.5)	M 20 M 20 x 1.5	(M 22) (M 22 x 1.5)	M 24 M 24 x 2	(M 27) (M 27 x 2)	M 30 M 30 x 2	(M 33) (M 33 x 2)	M 36 M 36 x 3	(M 39) (M 39 x 3)
14	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
30	-	-	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
35	-	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-
40	-	-	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-
45	-	-	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
50	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-
55	-	-	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	-
60	-	-	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-
65	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
70	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-
75	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-
80	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-
85	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-
90	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	-
100	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
110	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
120	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+
130	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+
140	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+
150	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+
160	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
170	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+
180	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+
190	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+
200	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+
225	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+
250	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+
275	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+
300	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+

Note 1: Non preferred diameters are given in brackets.

Note 2: Preferred length diameter combinations are indicated by '+'.
 Note 3: The length of the stud should be at least 1.5 times the diameter.

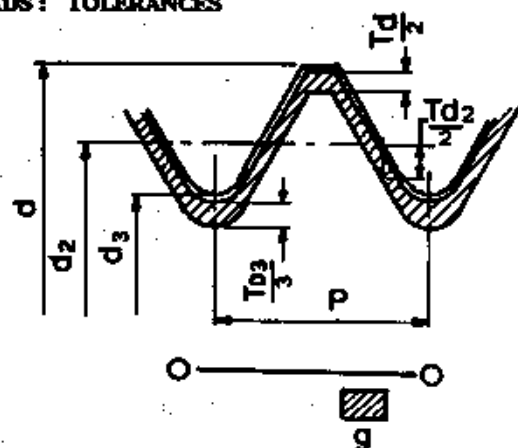
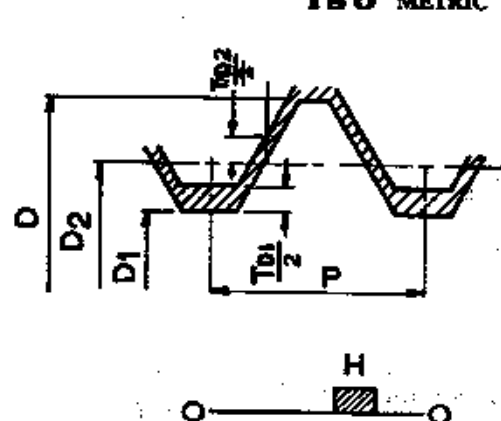
FUNDAMENTAL DEVIATIONS FOR EXTERNAL INTERFERENCE FIT THREADS



Thread Nominal Diameter mm	Pitch p mm	Deviations (microns)								
		Major diameter			Pitch diameter			Minor diameter		
		+	-	T_d	+	-	T_{d_2}	+	-	T_{d_3}
1, (1.1), 1.2	0.25		42	42						
(1.4)	0.3	0	48	48	28	8	36	11	45	56
1.6, (1.8)	0.35		53	53						
2	0.4		60	60						
(2.2), 2.5	0.45		63	63						
3	0.5		67	67						
(3.5)	0.6	0	80	80	40	10	50	17	63	80
4	0.7		90	90						
(4.5)	0.75		90	90						
5	0.8		95	95						
6, (7)	1		112	112						
8	1.25	0	132	132	56	15	71	22	90	112
10	1.5		150	150						
12	1.75		170	170						
(14), 16	2		180	180						
(18), 20, (22)	2.5	0	212	212	80	20	100	35	125	160
24, (27)	3		236	236						
30, (33)	3.5		265	265						
36, (39)	4		300	300						
42, (45)	4.5		315	315						
48, (52)	5	0	335	335	112	28	140	44	180	224
56, (60)	5.5		355	355						
64 to 80	6		375	375						
(85) to 150	6	0	375	375	160	40	200	65	250	315

Note : Diameters given in brackets are of second preference.

ISO METRIC SCREW THREADS: TOLERANCES



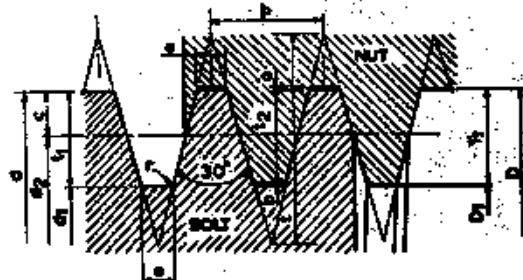
Tolerance Position for Nut threads

Tolerance position for Bolt threads.

Pitch	Basic Major Diameter		Deviations for nut thread tolerance class 6g (+) in μm				Deviations for bolt threads Tolerance class 6g (-) in μm			
	Above	upto and including	Pitch diameter TD2 upper	Minor diameter TD1 upper	Major diameter Td upper	lower	Pitch diameter Td2 upper	lower	Minor diameter Td3 upper	lower
0.35	2.8	5.6	90	100	19	104	19	86	19	111
0.5	2.8	5.6	100	140	20	126	20	95	20	131
0.7	2.8	5.6	118	180	22	162	22	112	22	162
0.75	5.6	11.2	132	190	22	162	22	117	22	171
0.8	2.8	5.6	125	200	24	174	24	119	24	177
1	5.6	11.2	150	236	26	206	26	138	26	210
	11.2	22.4	160	236	26	206	26	144	26	216
	22.4	45	170	238	26	206	26	151	26	223
1.25	5.6	11.2	160	265	28	240	28	146	28	236
1.5	5.6	11.2	180	300	32	268	32	164	32	272
	11.2	22.4	190	300	32	268	32	172	32	280
	22.4	45	200	300	32	268	32	182	32	290
	45	90	212	300	32	268	32	192	32	300
1.75	11.2	22.4	200	335	34	299	34	184	34	310
2	11.2	22.4	212	375	38	318	38	198	38	342
	22.4	45	224	375	38	318	38	208	38	352
	45	90	236	375	38	318	38	218	38	362
	90	180	250	375	38	318	38	228	38	372
	180	300	265	375	38	318	38	228	38	372
2.5	11.2	22.4	224	450	42	377	42	212	42	392
3	22.4	45	265	500	48	423	48	248	48	464
	45	90	280	500	48	423	48	260	48	478
	90	180	300	500	48	423	48	272	48	488
	180	300	335	500	48	423	48	298	48	514
	300	450	350	500	48	423	48	298	48	514
3.5	22.4	45	280	560	53	478	53	265	53	517
4	22.4	45	300	600	60	535	60	284	60	572

TRAPEZOIDAL THREAD

TRAPEZOIDAL THREAD
Single Thread



$$t = 1.866 p$$

$$t_2 = 0.5p + a$$

$$c_2 = 0.5p + a - b$$

$$T_1 = 0.5p + 2a - b$$

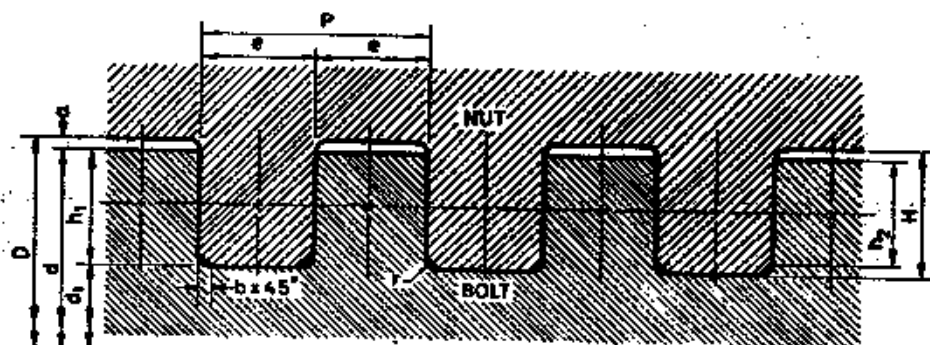
$$C = 0.25 p$$

All dimensions in mm

Nominal diameter	p	d ₁	D	D ₁	d ₂	r	c	t ₂	T ₁	a	b
10	3	6.5	10.5	7.5	8.5	0.25	0.96	1.75	1.5	0.25	.5
12		8.5	12.5	9.5	10.5						
14		9.5	14.5	10.5	12						
16	4	11.5	16.5	12.5	14	0.25	1.33	2.25	2	0.25	0.75
18		13.5	18.5	14.5	16						
20		15.5	20.5	16.5	18						
22	5	16.5	22.5	18	19.5	0.25	1.69	2.75	2.25	0.25	0.75
24		18.5	24.5	20	21.5						
26		20.5	26.5	22	23.5						
28		22.5	28.5	24	25.5						
30	6	23.5	30.5	25	27	0.25	2.06	3.25	2.75	0.25	0.75
32		25.5	32.5	27	29						
36		29.5	36.5	31	33						
40	7	32.5	40.5	34	36.5	0.25	2.42	3.75	3.25	0.25	0.75
44		36.5	44.5	38	40.5						
48	8	39.5	48.5	41	44	0.25	2.79	4.25	3.75	0.25	0.75
50		41.5	50.5	43	46						
52		43.5	52.5	45	48						
55	9	45.5	55.5	47	50.5	0.25	3.16	4.75	4.25	0.25	0.75
60		50.5	60.5	52	55.5						
65	10	54.5	65.5	56	60	0.25	3.52	5.25	4.75	0.25	0.75
70		59.5	70.5	61	65						
75		64.5	75.5	66	70						
80		69.5	80.5	71	75						

BASIC DIMENSIONS FOR SQUARE THREADS - FINE SERIES

All dimensions in millimetres



Nom Dia	Major Dia Bolt	Major Dia Nut	Minor Dia	Pitch								Area of Core, mm ²
	d	D	d ₁	P	e	r	h ₂	b	h ₁	a	H	
10	10	10.5	8									50.3
12	12	12.5	10									78.5
14	14	14.5	12	2	1	0.12	0.75	0.25	1	0.25	1.25	113
16	16	16.5	14									154
18	18	18.5	16									201
20	20	20.5	18									254
22	22	22.5	19									284
24	24	24.5	21									346
26	26	26.5	23									415
28	28	28.5	25									491
30	30	30.5	27									573
32	32	32.5	29									661
(34)	34	34.5	31									755
36	36	36.5	33									855
(38)	38	38.5	35									962
40	40	40.5	37									1075
42	42	42.5	39	3	1.5	0.12	1.25	0.25	1.5	0.25	1.75	1195
44	44	44.5	41									1320
(46)	46	46.5	43									1452
48	48	48.5	45									1590
50	50	50.5	47									1735
52	52	52.5	49									1886
55	55	55.5	52									2124
(58)	58	58.5	55									2376
60	60	60.5	57									2552
(62)	62	62.5	59									2734

BASIC DIMENSIONS FOR SQUARE THREADS - FINE SERIES (Contd.)

Nom Dia	Major Bolt Dia d	Minor Nut Dia D	Minor Dia d ₁	Pitch								Area of Cort. mm ²	
				P	e	r	h ₂	b	h ₁	a	H		
65	65	65.5	61									2922	
(68)	68	68.5	64									3217	
70	70	70.5	66									3421	
(72)	72	72.5	68									3632	
75	75	75.5	71									3959	
(78)	78	78.5	74									4301	
80	80	80.5	76									4536	
(82)	82	82.5	78									4778	
85	85	85.5	81	4	2	0.12	1.75	0.25	2	0.25	2.25	5153	
(88)	88	88.5	84									5542	
90	90	90.5	86									5809	
(92)	92	92.5	88									6082	
95	95	95.5	91									6504	
(98)	98	98.5	94									6940	
100	100	100.5	96									7238	
(105)	105	105.5	101									8012	
110	110	110.5	106									8825	
(115)	115	115.5	109									9331	
120	120	120.5	114									10207	
(125)	125	125.5	119									11122	
130	130	130.5	124	6	3	0.25	2.5	0.5	3	0.25	3.25	12076	
(135)	135	135.5	129									13070	
140	140	140.5	134									14103	
(145)	145	145.5	139									15175	
150	150	150.5	144									16286	

Note: Diameters indicated within brackets are of second preference.

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BASIC DIMENSIONS FOR SQUARE THREADS-NORMAL SERIES

All dimensions in millimetres

Nom Dia	Major Bolt d	Dia Nut D	Minor Dia d ₁	Pitch P	e	r	b ₂	b	b ₁	a	H	Area of Core, mm ²
22	22	22.5	17									227
24	24	24.5	19									284
26	26	26.5	21	5	2.5	0.25	2	0.5	2.5	0.25	2.75	346
28	28	28.5	23									415
30	30	30.5	24									452
32	32	32.5	26									531
(34)	34	34.5	28	6	3	0.25	2.5	0.5	3	0.25	3.25	616
36	36	36.5	30									707
(38)	38	38.5	31									755
40	40	40.5	33									855
(42)	42	42.5	35	7	3.5	0.25	3	0.5	3.5	0.25	3.75	962
44	44	44.5	37									1075
(46)	46	46.5	38									1134
48	48	48.5	40									1257
50	50	50.5	42	8	4	0.25	3.5	0.5	4	0.25	4.25	1385
52	52	52.5	44									1521
55	55	55.5	46									1662
(58)	58	58.5	49									1886
60	60	60.5	51	9	4.5	0.25	4	0.5	4.5	0.25	4.75	2043
(62)	62	62.5	53									2206
65	65	65.5	55									2376
(68)	68	68.5	58									2642
70	70	70.5	60									2827
(72)	72	72.5	62									3019
75	75	75.5	65	10	5	0.25	4.5	0.5	5	0.25	5.25	3318
(78)	78	78.5	68									3632
80	80	80.5	70									3848
(82)	82	82.5	72									4072

BASIC DIMENSIONS FOR SQUARE THREADS-NORMAL SERIES (Contd.)

Nom Dia	Major Bolt Dia d	Nut Dia D	Minor Dia d ₁	Pitch								Area of Core, mm ²	
				P	e	r	h ₂	b	h ₁	a	H		
	85	85.5	73									4185	
(88)	88	88.5	76									4536	
	90	90.5	78									4778	
(92)	92	92.5	80									5027	
(95)	95	95.5	83	12	6	0.25	5.5	0.5	6	0.25	6.25	5411	
(98)	98	98.5	86									5809	
	100	100.5	88									6082	
(105)	105	105.5	93									6793	
	110	110.5	98									7543	
(115)	115	116	101									8012	
	120	121	106									8825	
(125)	125	126	111									9677	
(130)	130	131	116	14	7	0.5	6	1	7	0.5	7.5	10568	
(135)	135	136	121									11499	
	140	141	126									12469	
(145)	145	146	131									13478	
(150)	150	151	134	16	8	0.5	7	1	8	0.5	8.5	14103	

Note : Diameters indicated within brackets are of second preference.

BASIC DIMENSIONS FOR SQUARE THREADS-COARSE SERIES

All dimensions in millimetres

Nom Dia	Major Dia		Minor Dia	Pitch								Area of core mm ²
	Bolt d	Nut D	d ₁	p	e	r	h ₂	b	h ₁	a	H	
22	22	22.5	14									164
24	24	24.5	16									201
26	26	25.5	18	8	4	0.25	3.5	0.5	4	0.25	4.25	254
28	28	28.5	20									314
30	30	30.5	20									314
32	32	32.5	22									380
(34)	34	34.5	24	10	5	0.25	4.5	0.5	5	0.25	5.25	452
36	36	36.5	26									531
(38)	38	38.5	28									616
40	40	40.5	28									616
(42)	42	42.5	30									707
44	44	44.5	32									804
(46)	46	46.5	34	12	6	0.25	5.5	0.5	6	0.25	6.25	908
48	48	48.5	36									1018
50	50	50.5	38									1134
52	52	52.5	40									1257
55	55	56	41									1320
(58)	58	59	44									1521
60	60	61	46	14	7	0.5	6	1	7	0.5	7.5	1662
(64)	64	65	48									1810
65	65	66	49	16	8	0.5	7	1	8	0.5	8.5	1886
(68)	68	69	52									2124
70	70	71	54									2290
(72)	72	73	56									2463
75	75	76	59	16	8	0.5	7	1	8	0.5	8.5	2734
(78)	78	79	62									3019
80	80	81	64									3217
(82)	82	83	66									3421

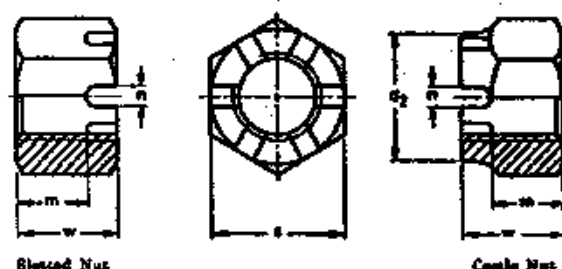
BASIC DIMENSIONS FOR SQUARE THREADS—COARSE (Contd.)

Nom Dia	Major Dia		Minor Dia	Pitch								Area of core mm ²
	Bolt d	Nut D	d ₁	p	e	r	h ₂	b	h ₁	a	H	
85	85	86	67									3526
(88)	88	89	70									3848
90	90	91	72									4072
(92)	92	93	74	18	9	0.5	8	1	9	0.5	9.5	4301
95	95	96	77									4657
(98)	98	99	80									5027
100	100	101	80									5027
(105)	105	106	85	20	10	0.5	9	1	10	0.5	10.5	5675
110	110	111	90									6362
(115)	115	116	93									6793
120	120	121	98	22	11	0.5	10	1	11	0.5	11.5	7543
(125)	125	126	103									8332
130	130	131	108									9161
(135)	135	136	111									9677
140	140	141	116	24	12	0.5	11	1	12	0.5	12.5	10568
(145)	145	146	121									11499
150	150	151	126									12469

Note: Diameters within brackets are of second preference.

DIMENSIONS FOR SLOTTED NUTS, PRECISION GRADE

(Diameter range 4 to 10 mm)



All dimensions in millimetres

Size, d		M4	M5	M6	(M7)	M8 M8×1	M10 M10×1.25
w (h 14)	Nom	5	6	7.5	8	9.5	12
	Max	5.00	6.00	7.50	8.00	9.50	12.00
	Min	4.70	5.70	7.14	7.64	9.14	11.57
m (h 15)	Nom	3.2	4	5	5.5	6.5	8
	Max	3.20	4.00	5.00	5.50	6.50	8.00
	Min	2.72	3.52	4.52	5.02	5.92	7.42
n (h 14)	Nom	1.2	1.4	2	2	2.5	2.8
	Max	1.45	1.65	2.25	2.25	2.75	3.05
	Min	1.20	1.40	2.00	2.00	2.50	2.80
s ≤ 8—(h 12) > 8—(h 13)	Nom	7	8	10	11	13	17
	Max	7.00	8.00	10.00	11.00	13.00	17.00
	Min	6.85	7.85	9.78	10.73	12.73	16.73

Note 1: The above dimensions have been obtained by rounding off the tolerances to the second place of decimal.

Note 2: Sizes shown in brackets are of second preference.

*See specification for split cotter pins (revised) IS : 549—1961.

IS : 2232—1967

DIMENSIONS FOR SLOTTED NUTS BLACK, GRADE

(Diameter range 12 to 33 mm)

All dimensions in millimetres

Size, d		M12	(M14)	M16	(M18)	M20	(M22)	M24	(M27)	M30	(M33)
w (js16)	Nom	15	16	19	21	22	26	27	30	33	35
	Max	15.55	16.55	19.65	21.65	22.65	26.65	27.65	30.65	33.80	35.80
	Min	14.45	15.45	18.35	20.35	21.35	25.35	26.35	29.35	32.20	34.20
m (h 16)	Nom	10	11	13	15	16	18	19	22	24	26
	Max	10.00	11.00	13.00	15.00	16.00	18.00	19.00	22.00	24.00	26.00
	Min	9.10	9.90	11.90	13.90	14.90	16.90	17.70	20.70	22.70	24.70
n (H 14)	Nom	3.5	3.5	4.5	4.5	4.5	5.5	5.5	5.5	7	7
	Max	3.80	3.80	4.80	4.80	4.80	5.80	5.80	5.80	7.36	7.36
	Min	3.50	3.50	4.50	4.50	4.50	5.50	5.50	5.50	7.00	7.00
S ≤ 19-(h14)	Nom	19	22	24	27	30	32	36	41	46	50
	Max	19.00	22.00	24.00	27.00	30.00	32.00	36.00	41.00	46.00	50.00
	Min	18.48	21.16	23.16	26.16	29.16	31.00	35.00	40.00	45.00	49.00
Size of split cotter pin*		3.2	3.2	4	4	4	5	5	5	6.3	6.3

Note 1: The above dimensions have been obtained by rounding off the tolerances to the second place of decimal.

Note 2: Sizes shown in brackets are of second preference.

*See specification for split cotter pins (Revised) IS : 549-1961

IS: 2232-1967

DIMENSIONS FOR CASTLE NUTS, PRECISION GRADE†

(Diameter range 12 to 39 mm)

All dimensions in millimetres

Size, d		M12 M12×1.25	(M14) (M14×1.5)	M16 M16×1.5	(M18) (M18×1.5)	M20 M20×1.5	(M22) (M22×1.5)	M24 M24×2	(M27) (M27×2)	M30 M30×2	(M33) (M33×2)	M36 M36×3	(M39) (M39×3)
d ₂ (h 14)	Nom	17	19	22	25	28	30	34	38	42	46	50	55
	Max	17.00	19.00	22.00	25.00	28.00	30.00	34.00	38.00	42.00	46.00	50.00	55.00
	Min	16.57	18.48	21.48	24.48	27.48	29.48	33.38	37.38	41.38	45.38	49.38	54.26
w (h 14)	Nom	15	16	19	21	22	26	27	30	33	35	38	40
	Max	15.00	16.00	19.00	21.00	22.00	26.00	27.00	30.00	33.00	35.00	38.00	40.00
	Min	14.57	15.57	18.48	20.48	21.48	25.48	26.48	29.48	32.38	34.38	37.38	39.38
m (h 15)	Nom	10	11	13	15	16	18	19	22	24	26	29	31
	Max	10.00	11.00	13.00	15.00	16.00	18.00	19.00	22.00	24.00	26.00	29.00	31.00
	Min	9.42	10.30	12.30	14.30	15.30	17.30	18.16	21.16	23.16	25.16	28.16	30.00
n (H 14)	Nom	3.5	3.5	4.5	4.5	4.5	5.5	5.5	5.5	7	7	7	7
	Max	3.80	3.80	4.80	4.80	4.80	5.80	5.80	5.80	7.36	7.36	7.36	7.36
	Min	3.50	3.50	4.50	4.50	4.50	5.50	5.50	5.5	7.00	7.00	7.00	7.00
S ≤ 22-(h13)													
> 22-(h14)	Nom	19	22	24	27	30	32	36	41	46	50	55	60
	Max	19.00	22.00	24.00	27.00	30.00	32.00	36.00	41.00	46.00	50.00	55.00	60.00
	Min	18.67	21.67	23.67	26.67	29.67	31.61	35.38	40.38	45.38	49.38	54.26	59.26
Size of split cotter pin*		3.2	3.2	4	4	4	5	5	5	6.3	6.3	6.3	6.3

Note 1: The above dimensions have been obtained by rounding off the tolerances to the second place of decimal.

Note 2: Sizes shown in brackets are of second preference.

*See specification for split cotter pins (revised) IS: 549-1961

† For figure see page 5.75

IS: 2232-1967

DIMENSIONS FOR CASTLE NUTS, PRECISION GRADE (Contd.)

(Diameter range 42 to 100 mm)

All dimensions in millimetres

Size, d		M42	(M45)	M48	(M52)	M56	(M60)	M64	(M68)	M72×6	(M76×6)	M80×6	(M85×6)	M90×6	(M95×6)	M100×6
d ₁ (h 14)	Nom	58	62	65	70	75	80	85	90	95	100	105	110	120	125	135
	Max	58.00	62.00	65.00	70.00	75.00	80.00	85.00	90.00	95.00	100.00	105.00	110.00	120.00	125.00	135.00
	Min	57.26	61.26	64.26	69.26	74.26	79.26	84.13	89.13	94.13	99.13	104.13	109.13	119.13	124.00	134.00
w (h 14)	Nom	46	48	50	54	57	63	66	69	73	76	79	88	92	96	100
	Max	46.00	48.00	50.00	54.00	57.00	63.00	66.00	69.00	73.00	76.00	79.00	88.00	92.00	96.00	100.00
	Min	45.38	47.38	49.38	53.26	56.26	62.26	65.26	68.26	72.26	75.26	78.26	87.13	91.13	95.13	99.13
m (h 15)	Nom	34	36	38	42	45	48	51	54	58	61	64	68	72	76	80
	Max	34.00	36.00	38.00	42.00	45.00	48.00	51.00	54.00	58.00	61.00	64.00	68.00	72.00	76.00	80.00
	Min	33.00	35.00	37.00	41.00	44.00	47.00	49.80	52.80	56.80	59.80	62.80	66.80	70.80	74.80	78.80
n (H 14)	Nom	9	9	9	9	9	11	11	11	11	11	11	14	14	14	14
	Max	9.36	9.36	9.36	9.36	9.36	11.43	11.43	11.43	11.43	11.43	11.43	14.43	14.43	14.43	14.43
	Min	9.00	9.00	9.00	9.00	9.00	11.00	11.00	11.00	11.00	11.00	11.00	14.00	14.00	14.00	14.00
S (h 14)	Nom	65	70	75	80	85	90	95	100	105	110	115	120	130	135	145
	Max	65.00	70.00	75.00	80.00	85.00	90.00	95.00	100.00	105.00	110.00	115.00	120.00	130.00	135.00	145.00
	Min	64.26	69.26	74.26	79.26	84.13	89.13	94.13	99.13	104.13	109.13	114.13	119.13	129.00	134.00	144.00
Size of split cotter pin*		8	8	8	8	8	10	10	10	10	10	10	13	13	13	13

Note 1: The above dimensions have been obtained by rounding off the tolerances to the second place of decimal.

Note 2: Sizes shown in brackets are of second preference.

* See specification for split cotter pins (revised) IS : 549-1961

IS : 2232-1967

DIMENSIONS FOR CASTLE NUTS, BLACK GRADE

(Diameter range 12 to 39 mm)

All dimensions in millimetres

Size, d		M12	(M14)	M16	(M18)	M20	(M22)	M24	(M27)	M30	(M33)	M36*	M39*
d ₂ (h 16)	Nom	17	19	22	25	28	30	34	38	42	46	50	55
	Max	17.00	19.00	22.00	25.00	28.00	30.00	34.00	38.00	42.00	46.00	50.00	55.00
	Min	15.90	17.70	20.70	23.70	26.70	28.70	32.40	36.40	40.40	44.40	48.40	53.10
w (js 16)	Nom	15	16	19	21	22	26	27	30	33	35	38	40
	Max	15.55	16.55	19.65	21.65	22.65	26.65	27.65	30.65	33.80	35.80	38.80	40.80
	Min	14.45	15.45	18.35	20.35	21.35	25.35	26.35	29.35	32.20	34.20	37.20	39.20
m (h 16)	Nom	10	11	13	15	16	18	19	22	24	26	29	31
	Max	10.00	11.00	13.0	15.00	16.00	18.00	19.00	22.00	24.00	26.00	29.00	31.00
	Min	9.10	9.90	11.90	13.90	14.90	16.90	17.70	20.70	22.70	24.70	27.70	30.40
n (H14)	Nom	3.5	3.5	4.5	4.5	4.5	5.5	5.5	5.5	7	7	7	7
	Max	3.80	3.80	4.80	4.80	4.80	5.80	5.80	5.80	7.36	7.36	7.36	7.36
	Min	3.50	3.50	4.50	4.50	4.50	5.50	5.50	5.50	7.00	7.00	7.00	7.00
S ≤ 19-(h14) > 19-(h15)	Nom	19	22	24	27	30	32	36	41	46	50	55	60
	Max	19.00	22.00	24.00	27.00	30.00	32.00	36.00	41.00	46.00	50.00	55.00	60.00
	Min	18.48	21.16	23.16	26.16	29.16	31.00	35.00	40.00	45.00	49.00	53.80	58.80
Size of split cotter pin**		3.2	3.2	4	4	4	5	5	5	6.3	6.3	6.3	6.3

Note 1: The above dimensions have been obtained by rounding off the tolerances to the second place of decimal.

Note 2: Sizes shown in brackets are of second preference.

* For castle nuts only

** See specification for split cotter pins (revised) IS : 549-1961

IS : 2232-1967

DIMENSIONS FOR CASTLE NUTS, BLACK GRADE (Contd.)

(Diameter range 42 to 100 mm)

All dimensions in millimetres

Size, d		M42	(M45)	M48	(M52)	M56	(M60)	M64	(M68)	M72×6	(M76×6)	M80	(M85×6)	M90×6	(M95×6)	M100×6
d_2 (h 16)	Nom	58	62	65	70	75	80	85	90	95	100	105	110	120	125	135
	Max	58.00	62.00	65.00	70.00	75.00	80.00	85.00	90.00	95.00	100.00	105.00	110.00	120.00	125.00	135.00
	Min	56.10	60.10	63.10	68.10	73.10	78.10	82.80	87.80	92.80	97.80	102.80	107.80	117.80	122.50	132.50
w (js 16)	Nom	46	48	50	54	57	63	66	69	73	76	79	88	92	96	100
	Max	46.80	48.80	50.80	54.95	57.95	63.95	69.95	69.95	73.95	76.95	79.95	89.10	93.10	97.10	101.10
	Min	45.20	47.20	49.20	53.05	56.05	62.05	65.05	68.05	72.05	75.05	78.05	86.90	90.90	94.90	98.90
m (h 16)	Nom	34	36	38	42	45	48	51	54	58	61	64	68	72	76	80
	Max	34.00	36.00	38.00	42.00	45.00	48.00	51.00	54.00	58.00	61.00	64.00	68.00	72.00	76.00	80.00
	Min	32.40	34.40	36.40	40.40	43.40	46.40	49.10	52.10	56.10	59.10	62.10	66.10	70.10	74.10	78.10
n (H14)	Nom	9	9	9	9	9	11	11	11	11	11	11	14	14	14	14
	Max	9.36	9.36	9.36	9.36	9.36	11.43	11.43	11.43	11.43	11.43	11.43	14.43	14.43	14.43	14.43
	Min	9.00	9.00	9.00	9.00	9.00	11.00	11.00	11.00	11.00	11.00	11.00	14.00	14.00	14.00	14.00
S (h 15)	Nom	65	70	75	80	85	90	95	100	105	110	115	120	130	135	145
	Max	65.00	70.00	75.00	80.00	85.00	90.00	95.00	100.00	105.00	110.00	115.00	120.00	130.00	135.00	145.00
	Min	63.80	68.80	73.80	78.80	83.60	88.60	93.60	98.60	103.60	108.60	113.60	118.60	128.40	133.40	143.40
Size of split cotter pin*		8	8	8	8	8	10	10	10	10	10	10	13	13	13	13

Note 1: The above dimensions have been obtained by rounding off the tolerances to the second place of decimal.

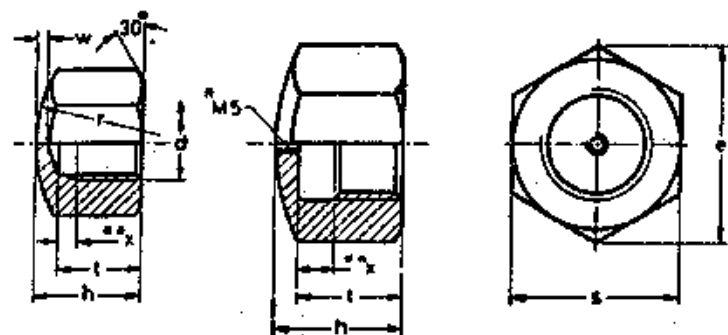
Note 2: Sizes shown in brackets are of second preference.

* See specification for split cotter pins (revised) IS : 549-1961

IS : 2232 - 1967

DIMENSIONS FOR CAP NUTS

All dimensions in millimetres



Upto and including M10 M12 and above

*For sizes above M24 only. Where this hole is required to be sealed, this may be done with a Slotted Head Grub Screw 'A' M5×6—IS: 2888-P-4D.

**For x, refer page 94.

d		M6	M8 M8×1	M10 M10×1.25	M12 M12×1.25	(M14) M14×1.5	M16 M16×1.5	(M18) M18×1.5	M20 M20×1.5	(M22) M22×1.5	M24 M24×2	(M27) M27×2	M30 M30×2	M36 M36×3
s (h13)	Nom	10	13	17	19	22	24	27	30	32	36	41	46	55
	Max	10.00	13.00	17.00	19.00	22.00	24.00	27.00	30.00	32.00	36.00	41.00	46.00	55.00
	Min	9.78	12.73	16.73	18.67	21.67	23.67	26.67	29.67	31.61	35.61	40.61	45.61	54.54
e	Max	11.5	15.0	19.6	21.9	25.4	27.7	31.2	34.6	36.9	41.6	47.3	53.1	63.5
h (h13)	Nom	9	12	14	16	18	20	22	25	28	30	32	34	44
	Max	9.00	12.00	14.00	16.00	18.00	20.00	22.00	25.00	28.00	30.00	32.00	34.00	44.00
	Min	8.78	11.73	13.73	15.73	17.73	19.67	21.67	24.67	27.67	29.67	31.61	33.61	43.61
r	Nom	12	15	20	25	28	30	32	35	35	40	50	60	70
w	Min	1.5	2	2	2	2	2	2	2.5	3	3	3	3	4
t (j15)	Nom	7	9.5	11	13.5	15	17	19	21	22	24	26	28	36
	Max	7.29	9.79	11.35	13.85	15.35	17.35	19.42	21.42	22.42	24.42	26.42	28.42	36.50
	Min	6.71	9.21	10.65	13.15	14.65	16.65	18.58	20.58	21.58	23.58	25.58	27.58	35.50

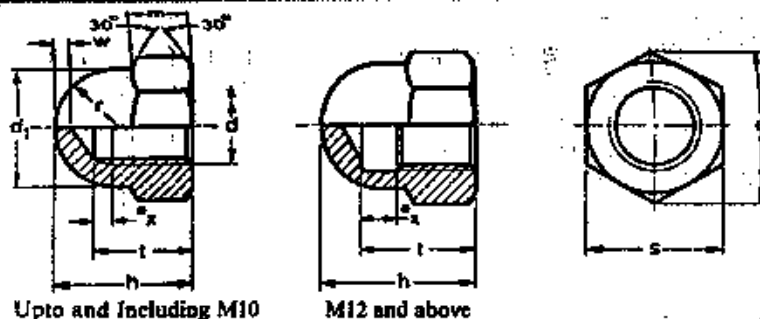
NOTE: 1—Depending on their importance, the limits of the above dimensions have been obtained by rounding off suitably the tolerances obtained from IS: 919-1963 Recommendations for Limits and Fits for Engineering (Revised).

NOTE: 2—Sizes given in brackets are of second preference.

Designation: Cap Nut M10—IS: 2687-P-5S.

DIMENSIONS FOR DOMED CAP NUTS

All dimensions in millimetres



d		M6	M8 M8×1	M10 M10×1.25	M12 M12×1.25	(M14) (M14×1.5)	M16 M16×1.5	(M18) (M18×1.5)	M20 M20×1.5	(M22) (M22×1.5)	M24 M24×2
Precision, s (h13)	Nom	10	13	17	19	22	24	27	30	32	36
	Max	10.00	13.00	17.00	19.00	22.00	24.00	27.00	30.00	32.00	36.00
	Min	9.78	12.73	16.73	18.67	21.67	23.67	26.67	29.67	31.61	35.61
Turned, s (h14 upto s=19) s (h15 over s=19) e	Max	10.00	13.00	17.00	19.00	22.00	24.00	27.00	30.00	32.00	36.00
	Min	9.64	12.57	16.57	18.48	21.16	23.16	26.16	29.16	31.00	35.00
	Max	11.5	15.0	19.6	21.9	25.4	27.7	31.2	34.6	36.9	41.6
Precision, h (h13)	Nom	12	15	18	22	25	28	32	34	39	42
	Max	12.0	15.0	18.0	22.0	25.0	28.0	32.0	34.0	39.0	42
	Min	11.7	14.7	17.7	21.7	24.7	27.7	31.6	33.6	39.6	41.6
Turned, h (h15)	Max	12.0	15.0	18.0	22.0	23.0	28.0	32.0	34.0	39.0	42.0
	min	11.3	14.3	17.3	21.2	22.2	27.2	31.0	33.0	38.0	41.0
	Nom	8	11	13	16	18	21	25	26	29	31
t (j15)	Max	8.3	11.4	13.4	16.4	18.4	21.4	25.4	26.4	29.4	31.5
	Min	7.7	10.6	12.6	15.6	17.6	20.6	24.6	25.6	28.6	30.6
	Nom	5	6.5	8	9.5	11	13	15	16	17	18
Precision, m (j13)	Max	5.1	6.6	8.1	9.6	11.1	13.1	15.1	16.1	17.1	18.1
	Min	4.9	6.4	7.9	9.4	10.9	12.9	14.9	15.9	16.9	17.9
	Max	5.2	6.8	8.3	9.8	11.4	13.4	15.4	16.4	17.4	18.4
Turned, m (j15)	Min	4.8	6.2	7.7	9.2	10.6	12.6	14.6	15.6	16.6	17.6
	Nom	9.5	13	16	18	21	23	26	28	31	34
	Nom	4.8	6.5	8	9	10.5	11.5	13	14	15.5	17
w	Min	2	2	2	3	3	3	3	3	3	3

NOTE: 1—Depending on their importance, the limits of the above dimensions have been obtained by rounding off suitably the tolerances obtained from IS: 919-1963.

Recommendations for Limits and Fits for Engineering (Revised).

NOTE: 2—Sizes given in brackets are of second preference.

*For x, refer page 5.45

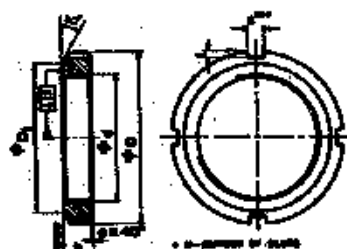
Designation: Domed Cap Nut M10—IS: 2687-P-55

PITCH DIAMETER COMBINATIONS FOR I S O METRIC SCREW THREADS

All dimensions in millimetres

Nominal Diameter		PITCHES													
		Series with Graded Pitches		Series with constant Pitches											
1st choice	2nd choice	Coarse	Fine	6	4	3	2	1.5	1.25	1	0.75	0.5	0.35	0.25	0.20
1	0.25			-	-	-	-	-	-	-	-	-	-	-	+
	1.1	0.25		-	-	-	-	-	-	-	-	-	-	-	+
1.2	0.25			-	-	-	-	-	-	-	-	-	-	-	+
	1.4	0.3		-	-	-	-	-	-	-	-	-	-	-	+
1.6	0.35			-	-	-	-	-	-	-	-	-	-	-	+
	1.8	0.35		-	-	-	-	-	-	-	-	-	-	-	+
2	0.4			-	-	-	-	-	-	-	-	-	-	+	-
	2.2	0.45		-	-	-	-	-	-	-	-	-	-	+	-
2.5	0.45			-	-	-	-	-	-	-	-	-	+	-	-
3	0.5			-	-	-	-	-	-	-	-	-	+	-	-
	3.5	0.6		-	-	-	-	-	-	-	-	-	+	-	-
4	0.7			-	-	-	-	-	-	-	-	+	-	-	-
	4.5	0.75		-	-	-	-	-	-	-	-	+	-	-	-
5	0.8			-	-	-	-	-	-	-	-	+	-	-	-
6	1			-	-	-	-	-	-	-	+	-	-	-	-
	7	1		-	-	-	-	-	-	-	+	-	-	-	-
8	1.25	1		-	-	-	-	-	-	+	+	-	-	-	-
10	1.5	1.25		-	-	-	-	-	+	+	+	-	-	-	-
12	1.75	1.25		-	-	-	-	+	+	+	-	-	-	-	-
	14	2	1.5	-	-	-	-	+	+	+	-	-	-	-	-
16	2	1.5		-	-	-	-	+	-	+	-	-	-	-	-
	18	2.5	1.5	-	-	-	+	+	-	+	-	-	-	-	-
20	2.5	1.5		-	-	-	+	+	-	+	-	-	-	-	-
	22	2.5	1.5	-	-	-	+	+	-	+	-	-	-	-	-
24	3	2		-	-	-	+	+	-	+	-	-	-	-	-
	25	3†		-	-	-	-	-	-	-	-	-	-	-	-
	27	3	2	-	-	-	+	+	-	+	-	-	-	-	-
30	3.5	2		-	-	×	+	+	-	+	-	-	-	-	-
	33	3.5	2	-	-	×	+	+	-	-	-	-	-	-	-
	35†			-	-	-	-	+	-	-	-	-	-	-	-
36	4	3		-	-	+	+	+	-	-	-	-	-	-	-
	39	4	3	-	-	+	+	+	-	-	-	-	-	-	-
42	4.5	3		-	+	+	+	+	-	-	-	-	-	-	-
	45	4.5	3	-	+	+	+	+	-	-	-	-	-	-	-
48	5	3		-	+	+	+	+	-	-	-	-	-	-	-
	52	5	3	-	+	+	+	+	-	-	-	-	-	-	-

DIMENSIONS OF RING NUTS



DIN 934

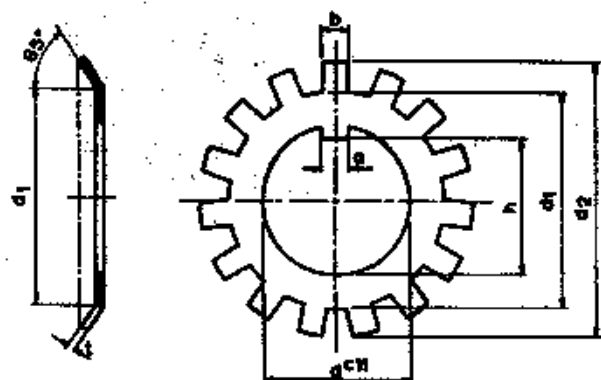
RING NUT

All dimensions in mm

d	D	D1	b	s	t	a	N
M10 × 0.75	18	13.5	4	3			
M12 × 1.0	22	17.0					
M15 × 1.0	25	21	5	4	2.0		
M17 × 1.0	28	24					
M20 × 1.0	32	26	6				4
M25 × 1.5	38	32	7				
M30 × 1.5	45	38					
M35 × 1.5	52	44	8				
M40 × 1.5	58	50	9				
M45 × 1.5	65	56	10	6	2.5		
M50 × 1.5	70	61	11				
M55 × 2	75	67					
M60 × 2	80	73		7	3.0		
M65 × 2	85	79					
M70 × 2	92	85	12				
M75 × 2	98	90	13				
M80 × 2	105	95	15				
M85 × 2	110	102	16				
M90 × 2	120	108					
M95 × 2	125	113	17	10	4		
M100 × 2	130	120	18				
M105 × 2	140	126					

X = IT 7 referred to d.

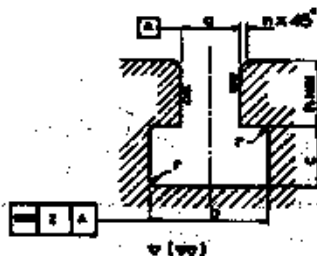
LOCKING WASHER
(for ring nuts)



All dimensions in mm

Nominal Size	h	d ₁	d ₂	a	size	b	Tol	t	N
10	8.5	13.5	21	3	3				
12	10.5	17	25	3	3				
15	13.5	21	28	4	4			1.0	11
17	15.5	24	32	4	4		-0.20 -0.45		
20	18.5	26	36	4	4				
25	23	32	42	5	5				13
30	27.5	38	49	5	5				
35	32.5	44	57	6	5				
40	37.5	50	62	6	6			1.25	15
45	42.5	56	69	6	6				
50	47.5	61	74	6	6		-0.25 -0.53		
55	52.5	67	81	8	7				17
60	57.5	73	86	8	7				
65	62.5	79	92	8	7				
70	66.5	85	98	8	8				
75	71.5	90	104	8	8		-0.28 -0.63	1.5	19
80	76.5	95	112	10	8				
85	81.5	102	119	10	8				
90	86.5	108	126	10	10			1.75	
95	91.5	113	133	10	10				
100	96.5	120	142	12	10				
							-0.35 -0.75		
105	100.5	126	145	12	12				

T-SLOTS

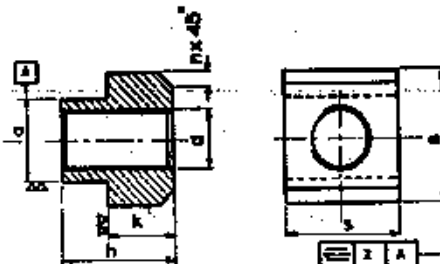


All dimensions in mm

Nominal size a*	b	Tolerance on b	c	Tolerance on c	h Min	n	r	Z
10	16	+1.5 -0	7	+1 -0	9	1.6	0.5	0.3
12	19		8		11			
14	23		9		13			
18	30	+2.5 -0	12	+2 -0	16	2	1	0.5
22	37		16		20			
28	46	+3 -0	20	+3 -0	26	3	1.6	0.5
36	56	+4 -0	25		32			
42	68	+5 -0	32		38			

IS : 2013 — 1962

*Tol for a : H8 for guiding Slots & H12 for fixing slots.



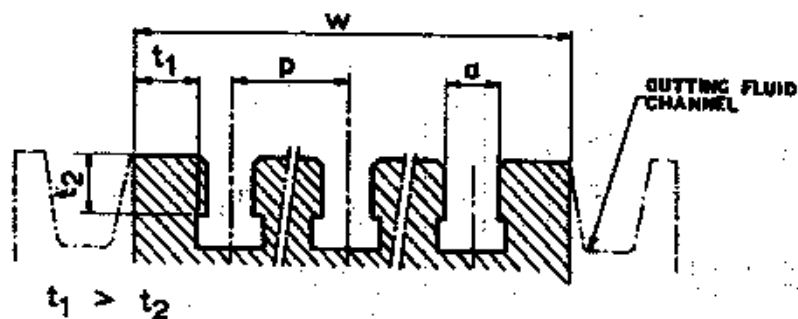
v (vw)

All dimensions in mm

T — NUTS

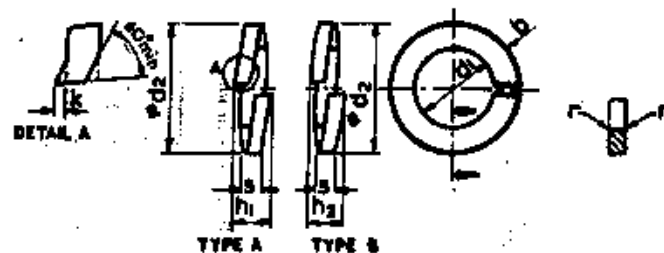
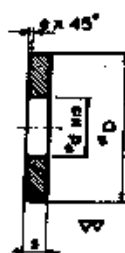
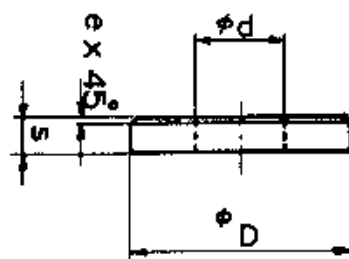
Nominal Size of T - Slot	Width of T - Nut		d	S	Tol on S	h	k	Tol on k	n Z		
	a	Tol									
10	10	-0.3 -0.5	M 8	15	+0 -0.5	12	6	+0 -0.5	1.6	0.2	
12	12		M 10	18		14	7		2.5	0.2	
14	14		M 12	22		16	8				
18	18	-0.3	M 16	28		20	10				
22	22	-0.6	M 20	34		28	14				
28	28		M 24	43	+0 -1	36	18	+0 -1	4	0.3	
36	36	-0.4	M 30	53		44	23		6		
42	42	-0.7	M 36	64		52	28				

SIZES OF MACHINE TOOL TABLES



All dimensions in mm

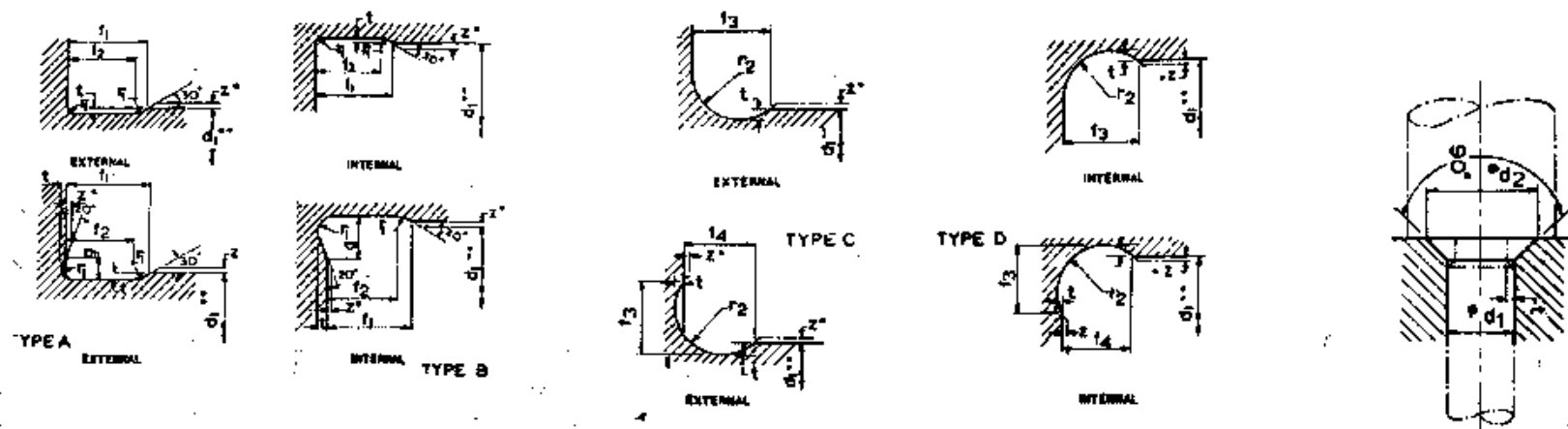
Pitch of T slots, p	40	45	50	56	63	70	80	90	100	112	125	140	160	180	200
Recommended Size of T slot	10		12		14		18		22		28		36		42
Table width over upto	80	90	100	112	125	140	160	180	200	212	224	250	280	315	355
	315	400	500	630	800	950	1120	1250	1400	1600	1800	2000	2240	2500	2800



WASHERS

All dimensions in mm

Nom Size	HARD WASHER				MACHINED WASHER						SPRING WASHER					
	d	D	S	e	d	D	tol on D	S	tol on S	e	d ₁	d ₂	b	s	r	k
M6					6.6	12	+0 -0.4	1.6	±0.2	0.5	+0.4 6.1	11.1	±0.15 2.5	±0.1 1.6	0.5	0.2
M8	8.4	18	4	0.5	9	16	"	2	"	"	+0.4 8.2	14.2	±0.15 3	±0.1 2	0.8	0.3
M10	10.5	22	"	"	11	22	0 -0.5	2.5	"	"	+0.6 10.2	17.2	±0.15 3.5	±0.15 2.2	"	"
M12	13	28	5	"	14	25	"	3	±0.3	"	+0.8 12.2	20.2	±0.2 4	±0.15 2.5	1.2	0.4
M16	17	34	"	"	18	30	"	"	"	"	+1.0 16.2	26.2	±0.2 5	±0.2 3.5	"	"
M20	21	40	6	1	22	37	0 -0.8	4	"	1	+1.0 20.2	32.2	±0.2 6	±0.2 4	"	"
M24	25	48	"	"	26	45	"	"	"	"	+1.0 24.5	38.5	±0.25 7	±0.2 5	2	0.5
M30	31	58	7	"	33	56	0 -1.0	5	±0.6	"	+1.3 30.5	46.5	±0.25 8	±0.2 6	"	0.8



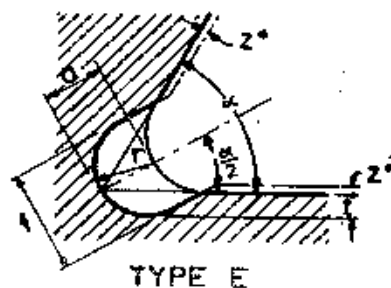
All dimensions in mm

Types A & B				Types C & D				Type E for dovetail guideways								Shafts					Countersinks							
f_1	t	f_2	g	r_1	r_2	t	f_3	f_4	ht. of guide-way	f	s	r	t (approx)			d_1	t	r_1	r_2	h (min)	t	d_2 (min)						
nom	+	approx				nom	+	approx	approx		approx	approx	$\alpha = 40^\circ$	50°	55°		Type A&B	Type C&D	Type B	Type D		Type A	C	D				
1	0.1	0.05	0.8	0.5	0.2	1	0.2	0.1	1.6	1.4	6-16	2.0	1.2	1.0	0.7	0.6	upto 3	0.1	—	0.2	—	1.6	—	0.1	$0.2+d_1$	—	—	
2	0.2	0.1	1.5	1.0	0.4	1.6	0.3	„	2.5	2.2	16-32	3.2	2.0	1.6	1.0	0.9	0.8	3-10	0.2	—	0.4	—	2.0	—	0.2	$0.5+d_1$	$2.0+d_1$	$0.5+d_1$
4	0.3	„	3.3	1.5	0.6	2.5	„	„	3.7	3.4	32-50	5.0	2.8	2.5	1.6	1.5	1.4	10-18	„	0.2	„	1.0	2.5	3.0	0.3	$1.0+d_1$	$*3.0+d_1$	$1.0+d_1$
6	0.4	„	5.0	2.3	1.0				Over 50	6.4	3.8	3.2	2.1	1.8	1.7		18-30	„	0.3	„	1.6	„	4.0			$+5.0+d_1$	$2.0+d_1$	
																	30-80	0.3	„	0.6	2.5	3.2	5.5	0.4	$1.5+d_1$	—	—	
																	above 80	0.4	„	1.0	„	4.5	7.0					

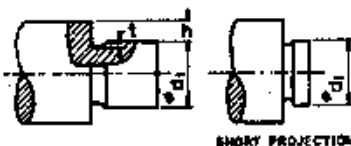
2°

* For $r_1=1.6$
† $r_1=2.5$

* For $r_2=1.6$
 $\dagger$ $t_1=2.5$



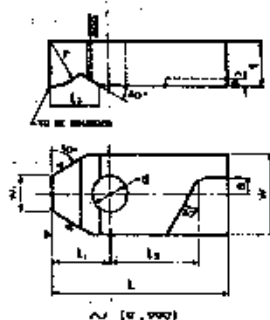
TYPE E



SHORT PROJECTION

SWING CLAMPS FOR FIXTURES : IS 5250 — 1969

(Toughened Steel, $\sigma_s = 750 \text{ N/mm}^2 \text{ min}$)



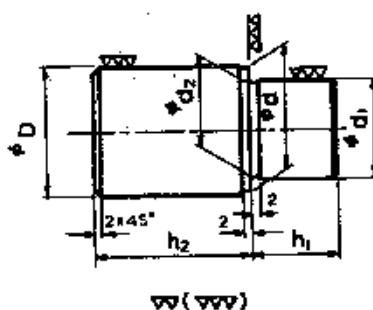
All dimensions in mm

d	W	W ₁	t	L	l ₁	l ₂	l ₃	a	r	Size of Screw
6.6	20	7	12	52	20	25	14	4	12	M 6
9	25	9	14	60	22	30	18	5	14	M 8
11	30	11	16	70	24	35	20	6	16	M 10
14	35	15	20	80	26	40	22	7	20	M 12
18	45	18	25	90	32	45	28	9	25	M 16
22	50	23	30	100	38	50	32	11	30	M 20

Designation : Swing Clamp, $d \times L$

END LOCATING PLUGS : IS : 5095

(Case hardening steel, hardness $> 59 \text{ R}_c$ Case depth 0.3 to 0.5 mm)

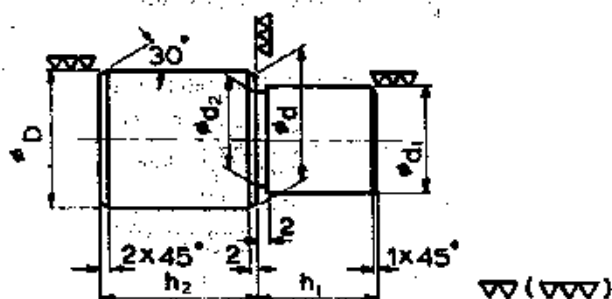


All dimensions in mm

D	h6	d	d ₁ p6	d ₂	h ₁	h ₂
16		15	12	11.5	12	16, 25, 40
20		19	16	15.5	15	20, 32, 45
25		24	20	19.5	18	25, 40, 60
32		31	25	24.5	22	40, 63
40		39	32	31.5	25	50, 80

ROUND LOCATING PINS : IS: 5093

(Case hardening steel; hardness > 59 R_c case depth 0.3 to 0.5 mm)...

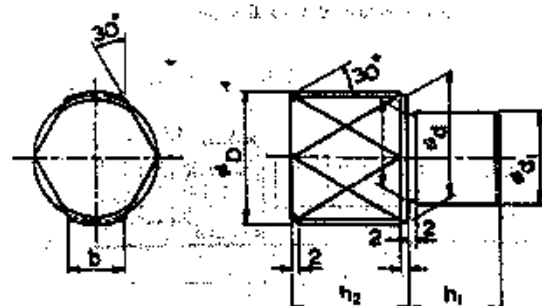


All dimensions in mm

D g6	d	d ₁ p6	d ₂	h ₁	h ₂
10	9.5	8	7.5	8	16
12	11.5	10	9.5	10	18
16	15	12	11.5	14	22
20	19	16	15.5	18	25
25	24	20	19.5	22	32
32	31	25	24.5	25	36

DIAMOND LOCATING PINS : IS : 5094

(Case hardening Steel; hardness > 59 R_c Case depth 0.3 to 0.5 mm)



All dimensions in mm

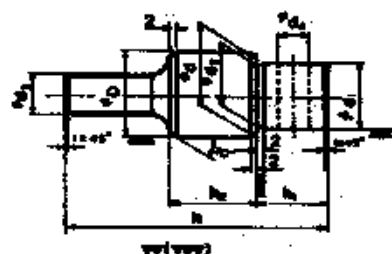
D e8	d	d ₁ p6	d ₂	b	h ₁	h ₂
12	11	8	7.5	4	8	12
14	13	10	9.5	5	10	14
18	17	12	11.5	6	14	18
22	21	16	15.5	8	8	21
28	27	20	19.5	10	22	28
36	35	25	24.5	12	25	32

ROUND LOCATING STUDS : IS 5096

(Case hardening steel; hardness > 59 Rc

case depth 0.3 to 0.5 mm)

ROUND LOCATING STUDS



vw(vvv)

All dimensions in mm

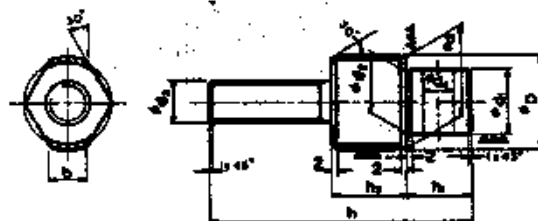
D g6	d	d ₁ p6	d ₂	d ₃	d ₄ s7	h	h ₁	h ₂
12	11.5	10	9.5	M 6	5	40	10	12
18	17	14	13.5	M 8	6	55	16	18
20	19	16	15.5	M 10	8	62	18	20
25	24	20	19.5	M 12	10	70	22	25
32	31	25	24.5	M 16	12	85	25	28

DIAMOND LOCATING STUDS : IS : 5097

(Case hardening Steel, hardness > 59 Rc

Case depth 0.3 to 0.5 mm)

DIAMOND LOCATING STUDS



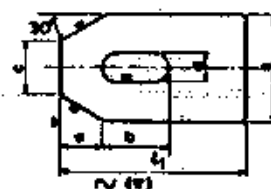
vw(vvv)

All dimensions in mm

D e8	d	d ₁ p6	d ₂	d ₃	d ₄ s7	b	h	h ₁	h ₂
14	13	10	9.5	M 6	5	5	40	10	12
20	19	14	13.5	M 8	6	8	55	16	18
22	21	16	15.5	M 10	8	8	62	18	20
28	27	20	19.5	M 12	10	10	70	22	25
36	35	25	24.5	M 16	12	12	85	25	28

STRAP CLAMPS : IS : 4292

Material : Steel having a minimum tensile strength of 600 N/mm²

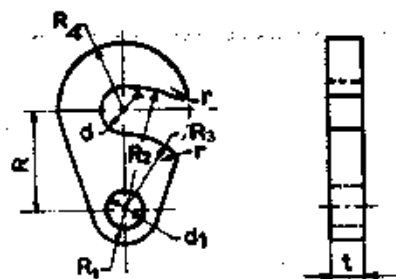


All dimensions in mm

d	l ₁	a	b	c	h	s	Screw size
7	50	10	20	8	10	20	M6
10	60	13	22	10	12	25	M8
12	80	15	30	12	15	30	M10
15	100 (125)	21	40 (50)	14	20	40	M12
19	125 (160)	26	45 (65)	18	25	50	M16
24	160 (200)	30	60 (80)	22	30	60	M20
28	200 (250)	35	80 (105)	26	30 (40)	70	M24
35	250 (315)	45	100 (130)	34	40 (50)	80	M30
42	315 (350)	48	125 (150)	40	45 (55)	90	M36
45	350 (400)	53	150 (180)	45	55 (60)	100	M39

SWING C WASHER : IS : 4298

(Rolled Steel)

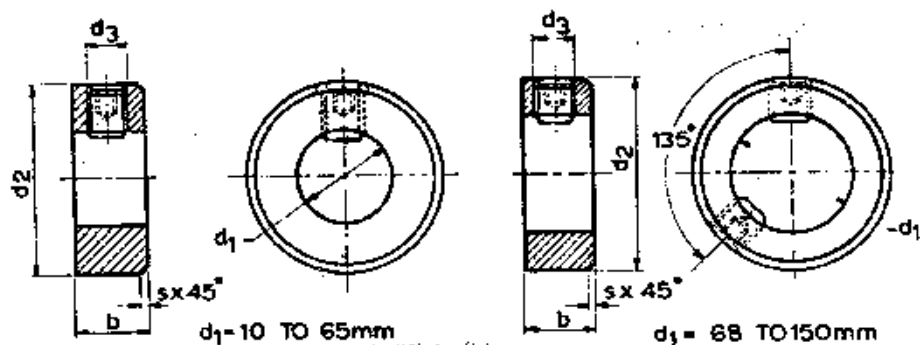


All dimensions in mm

d H13	d ₁	R	R ₁	R ₂	R ₃	R ₄	r	t nom	Bolt size
6.6	8.5	18	8	21.3	14.7	10.0	2.0	6	M6
9.0	"	21	"	25.5	16.5	13.0	2.5	"	M8
11.0	"	24	"	29.5	18.5	16.0	"	"	M10
14.0	10.5	27	10	34.0	20.0	20.0	3.0	8	M12
18.0	"	33	"	42.0	24.0	25.0	"	"	M16
22.0	"	38	"	49.0	27.0	30.0	"	"	M20
26.0	12.5	42	12	55.0	29.0	32.5	4.0	10	M24
30.0	"	45	"	60.0	30.0	35.0	"	"	M27

NOTE: The outer edge of both faces shall have a chamfer of 0.5 × 45°

SET COLLARS (HEAVY SERIES)

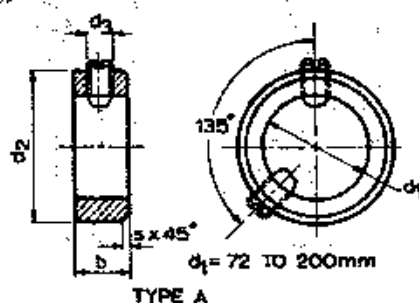
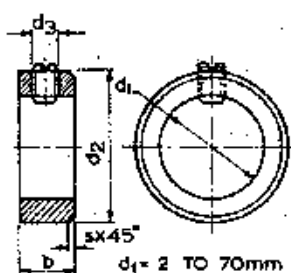


All dimensions in mm

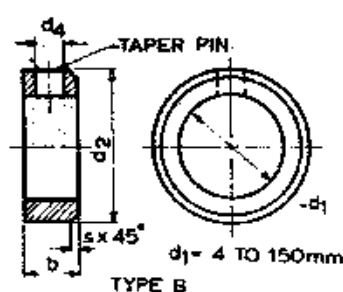
Nominal Bore dia d_1 H8	b j14	d_2 H13	d_3	s	Grub Screw
10	12	25	M 6	1.6	M8 × 8
11	"	"	"	"	"
12	14	30	M 8	"	M8 × 12
14	16	35	"	"	"
16	"	40	"	"	"
18	18	45	"	"	"
20	20	50	M 10	"	M10 × 16
25	22	56	"	"	"
28	"	63	"	"	"
32	"	63	"	"	"
36	"	70	"	"	"
40	28	80	M 12	"	M12 × 20
45	"	"	"	"	"
50	"	90	"	"	"
56	"	"	"	"	"
63	"	100	"	"	"
70	32	110	M 16	2.5	M16 × 20
80	"	125	"	"	"
90	"	"	"	"	"
100	"	140	"	"	"

SET COLLARS (LIGHT SERIES)

Material : Structural Steel St 37



TYPE A

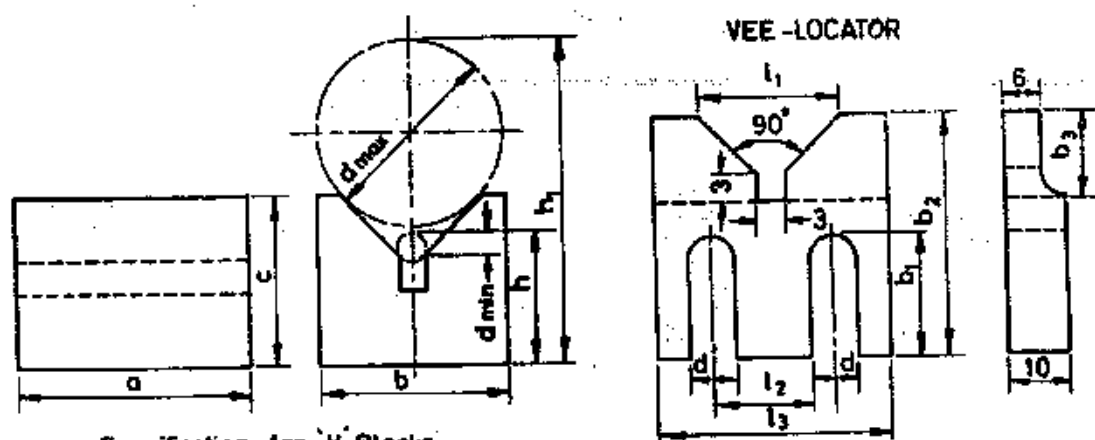


TYPE B

All dimensions in mm

Nominal bore d_1 H8	b j14	d_2 h13	d_3	d_4 H11	S	Grub screw	Taper pins
5	6	10	M3	1.6	0.4	M3×4	1.6×12
6	8	12	M4	"	"	M4×5	1.6×14
7	8	12	"	"	"	"	"
8	8	16	"	2	1.0	M4×6	2×20
10	10	20	M5	3	"	M5×8	3×25
11	10	20	"	"	"	"	"
14	12	25	M6	4	"	M6×8	4×30
16	12	28	"	4	1.6	"	4×35
18	14	32	"	5	"	"	5×35
20	14	32	"	"	"	"	5×35
25	16	40	M8	6	"	M6×10	"
28	16	45	"	"	"	M6×12	6×50
35	16	56	"	8	"	M8×12	8×60
40	18	63	M10	8	"	M10×16	8×70
45	18	70	"	8	"	"	8×80
50	18	80	"	10	"	"	10×90
56	18	"	"	"	"	M10×16	10×90
63	20	90	"	"	"	M10×20	10×100
80	22	110	M12	"	2.5	M12×20	10×120
90	22	125	"	12	"	"	12×140
100	25	140	"	"	"	M12×25	12×150
110	25	160	"	"	"	"	12×180
125	28	180	M16	16	4	M16×30	16×200

JIGS AND FIXTURES



Specification for V Blocks

V-Block

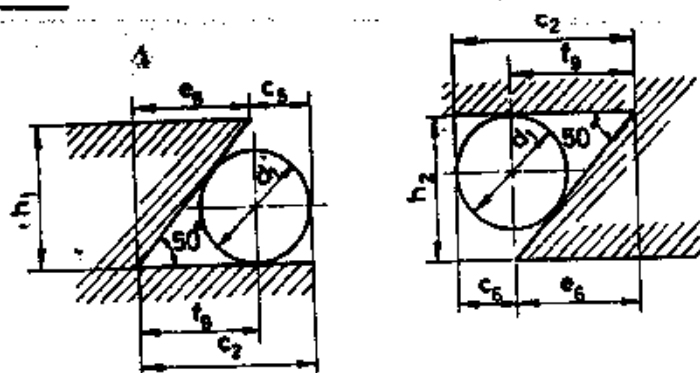
Material : CI (Gr. 20)

a	b	c	d_{max}	d_{min}
50	40	40	40	5
63	50	50	50	5
80	63	63	63	7
100	80	80	83	7
200	200	200	200	10
300	300	300	300	12

V-Locator

Material : C 45 Case hardened to 45-50 HRC

l_1	l_2	l_3	b_1	b_2	b_3	d
25	20	35	15	32	15	7
36	25	50	20	45	25	9
50	32	60	22	55	30	11

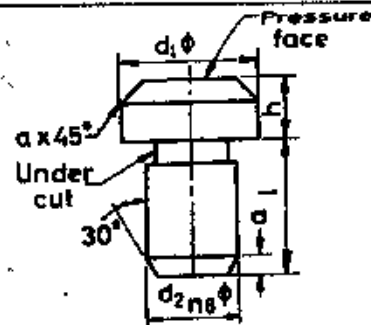


DOVETAIL DIMENSIONS

DOVETAIL CALCULATIONS

h_1	h_2	d_1	C_2	C_3	C_4	c_5	c_6	f_9
8	8.5	6	9.43	2.72	2.30	6.71	7.13	6.43
10	10.5	8	12.58	4.19	3.77	8.39	8.81	8.58
12	12.5	10	15.72	5.65	5.23	10.07	10.49	10.72
16	17.0	12	18.87	5.44	4.61	13.43	14.26	12.87
20	21.0	16	25.16	8.38	7.54	16.78	17.62	17.16
25	26.0	20	31.45	10.47	9.63	20.98	21.82	21.45
32	33.6	25	39.31	12.46	11.12	26.85	27.19	26.81
40	41.6	32	50.31	16.75	15.40	33.56	34.19	34.31
50	51.6	40	62.89	20.93	19.26	41.96	43.29	42.89
63	65.0	50	78.61	25.75	24.07	52.86	54.54	53.61
71	73.0	63	99.05	39.48	37.79	59.58	61.25	67.55
80	82.0	71	111.63	44.50	42.82	67.13	68.80	76.13

All dimensions in millimetres

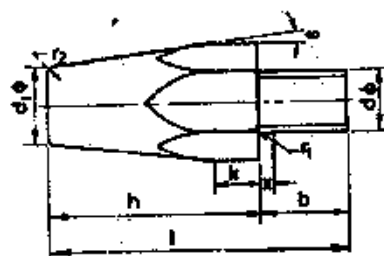


JIG BUTTON

Material: C45 Hardness: 45-50 R

d_1	d_2	h	a	l	Under cut
6	4	5	1.2	6	A2 × 0.2
10	6	8	1.6	8	B2 × 0.2
16	8	$\frac{10}{3}$	2.0	10	B2 × 0.2
25	12	$\frac{10}{3}$	2.5	14	B2 × 0.2
40	20	$\frac{12}{3}$	3.2	20	B2 × 0.2

IS: 4294

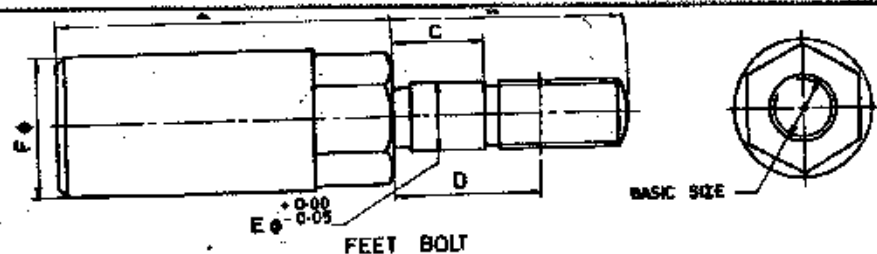


JIG FEET

Material: Free Cutting Steel - Hardness: $56 \pm 2 R_c$

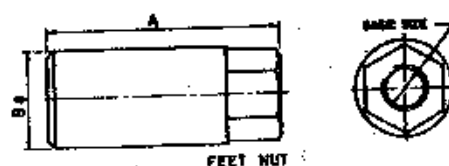
h	d	b	d_1	d_2	e_1	K	l	r_1	r_2	S	X	α
10	M 6	11	6	8	12.7	5	21	0.5	1	11	2.0	34°
20							31					13°
15	M 8	13	9	10	16.2	6	28	0.5	1	14	2.5	22°
30							43					9°
20	M10	16	12	12	19.6	8	36	0.5	1.5	17	2.5	18°
40							56					7°
25	M12	20	15	15	25.4	10	45	0.5	1.5	22	3.0	20°
50							70					8°
30	M16	24	20	19	31.2	12	54	1.0	2	27	3.0	18°
60							84					7°
40	M20	29	26	24	36.9	16	69	1.0	2	32	4.0	13°
80							109					5°

All dimensions in millimetres



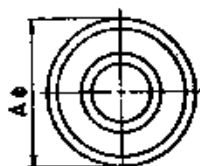
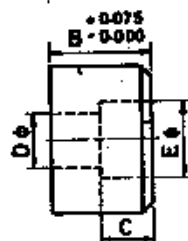
FEET BOLT

Basic Size	A	B	C	D	E ϕ	F ϕ
M 10	50	28	12	12-20	10	20
M 10	65	28	12	12-20	10	20
M 10	75	28	12	12-20	10	20
M 10	90	28	12	12-20	10	20
M 12	75	35	18	20-25	12	25
M 12	90	35	18	20-25	12	25
M 12	100	35	18	20-25	12	25
M 12	112	35	18	20-25	12	25
M 12	125	35	18	20-25	12	25
M 12	140	35	18	20-25	12	25
M 12	150	35	18	20-25	12	25

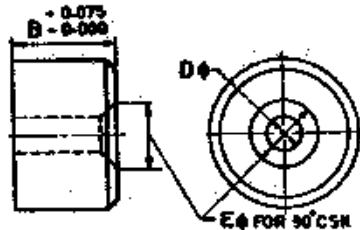


FEET NUTS

Basic Size	M10	M10	M10	M10	M12	M12	M12	M12	M12	M12	M12
A	20	25	36	50	20	25	36	50	62	75	87
B ϕ	20	20	20	20	25	25	25	25	25	25	25



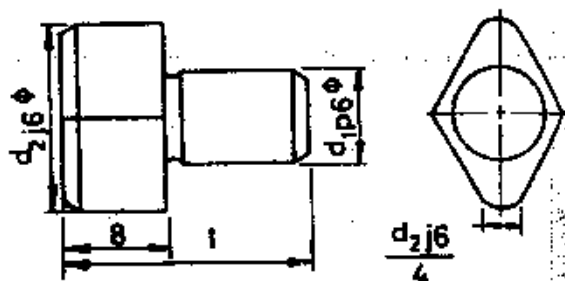
JIG FEET BUTTON



JIG FEET BUTTON

Basic size A ϕ	B ϕ	C	D ϕ	E ϕ
12	6	—	4	6
12	10	—	4	6
12	12	—	4	6
16	6	—	5	8
16	10	6	5.5	8.5
16	12	6	5.5	8.5
16	16	6	5.5	8.5
16	20	6	5.5	8.5
16	22	6	5.5	8.5
16	25	6	5.5	8.5
16	12	7	7	10
16	20	7	7	10
20	12	7	7	10
22	12	9	8.5	11.5
22	16	9	8.5	11.5
22	20	9	8.5	11.5
22	25	9	8.5	11.5
22	28	9	8.5	11.5
25	16	9	8.5	11.5
32	12	9	8.5	11.5
32	20	10	10	15
35	20	14	13	19.5
35	25	14	13	19.5

LOCATING PIN-NON SHOULDERED

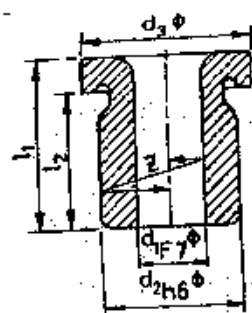


LOCATING PIN

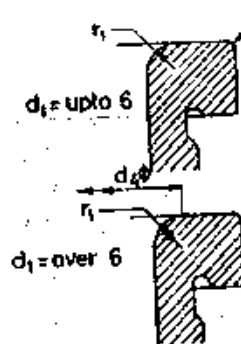
$d_{1/6} \phi$	$d_{2/6} \phi$	l
8	6.3	16
10	6.3	16
12	8.3	18
14	8.3	18
15	10.3	20
16	10.3	20
18	12.3	24
20	12.3	24
22	12.3	24
25	12.3	24

Note: Cylindrical locators have cylindrical head of diameter $d_2 j6$.

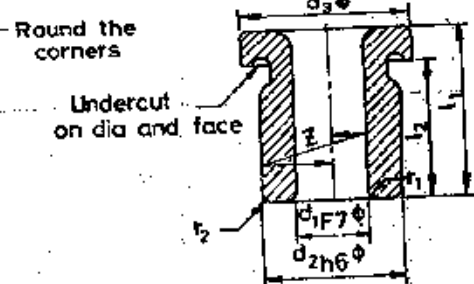
All dimensions in millimetres



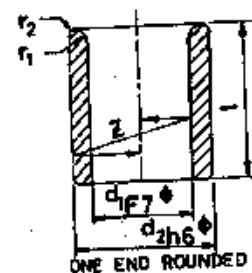
Bore rounded on top only



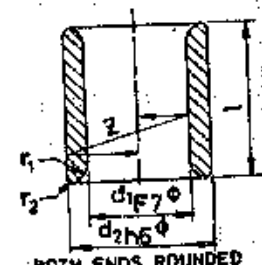
Detail of rounding



Bore rounded on both ends



ONE END ROUNDED



BOTH ENDS ROUNDED

FIXED BUSH

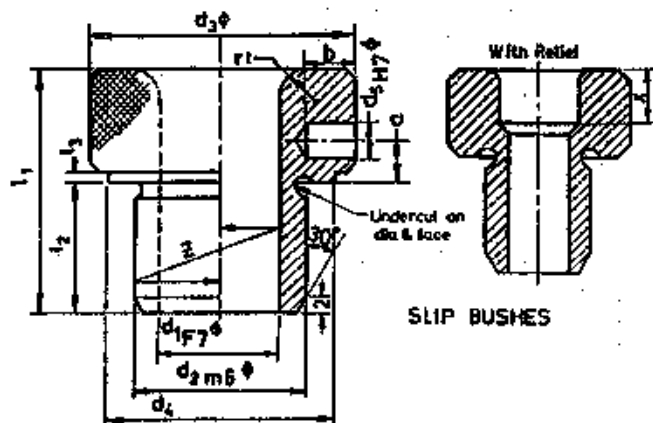
d ₁	Short		Long		d ₂	d ₃	d ₄	r ₁	r ₂	z
	l ₁	l ₂	l ₁	l ₂						
Upto 1	6	4	9	7	3	6	—	1.2	0.2	0.005
1.0—1.8	6	4	9	7	4	7	—	1.2	0.2	0.005
1.8—2.6	6	4	9	7	5	8	—	1.2	0.3	0.005
2.6—3.3	8	6	12	9	6	10	—	1.6	0.3	0.005
3.3—4.0	8	6	12	9	7	11	—	1.6	0.4	0.005
4.0—5.0	8	6	12	9	8	12	—	2.0	0.4	0.005
5.0—6.0	10	7	16	13	10	14	—	2.0	0.4	0.01
6.0—8.0	10	7	16	13	12	16	10	2.0	0.6	0.01
8.0—10	12	8	20	16	16	20	13	2.5	0.8	0.01
10—12	12	8	20	16	18	22	16	2.5	0.8	0.01
12—15	16	12	28	24	25	26	20	4.0	0.8	0.01
15—18	16	12	28	24	25	30	24	4.0	0.8	0.01
18—22	20	15	36	31	30	35	28	6.0	1.0	0.01
22—26	20	15	36	31	36	41	33	6.0	1.0	0.02
26—30	20	15	36	31	42	47	40	6.0	1.0	0.02
30—35	25	20	45	40	48	55	46	8.0	1.0	0.02
35—42	25	20	45	40	56	63	52	8.0	1.0	0.02
42—48	32	25	56	50	63	70	59	8.0	1.6	0.02
48—55	32	25	56	50	70	77	67	8.0	1.6	0.02
55—63	36	30	72	66	80	87	75	8.0	1.6	0.02

LINER BUSH

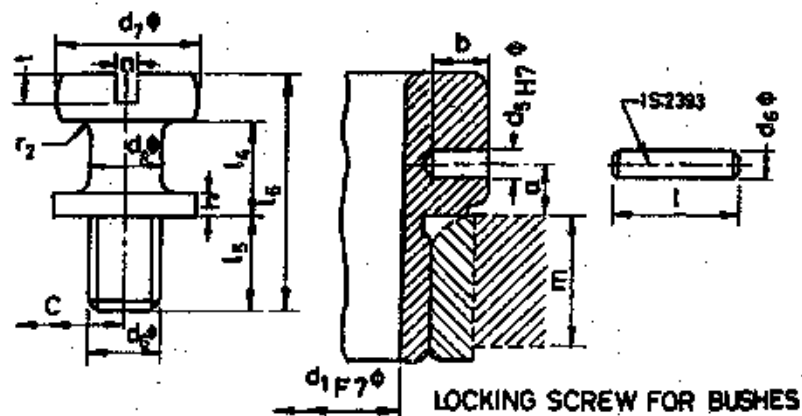
63 to 65 HRC

d ₁	Short	Long	d ₂	r ₁	r ₂	z
Upto 1	6	9	3	1.2	0.2	0.005
1.0—1.8	6	9	4	1.2	0.2	0.005
1.8—2.6	6	9	5	1.2	0.3	0.005
2.6—3.3	8	12	6	1.6	0.3	0.005
3.3—4.0	8	12	7	1.6	0.4	0.005
4.0—5.0	8	12	8	2.0	0.4	0.005
5.0—6.0	10	16	10	2.0	0.4	0.01
6.0—8.0	10	16	12	2.0	0.6	0.01
8.0—10	12	20	16	2.5	0.8	0.01
10—12	12	20	18	2.5	0.8	0.01
12—15	16	28	22	4.0	0.8	0.01
15—18	16	28	25	4.0	0.8	0.01
18—22	20	36	30	6.0	0.8	0.01
22—26	20	36	36	6.0	1.0	0.02
26—30	20	36	42	6.0	1.0	0.02
30—35	25	45	48	8.0	1.0	0.02
35—42	25	45	56	8.0	1.0	0.02
42—48	30	56	63	8.0	1.6	0.02
48—55	30	56	70	8.0	1.6	0.02
55—63	36	70	80	8.0	1.6	0.02

All dimensions in millimetres



SLIP BUSHES



LOCKING SCREW FOR BUSHES

SLIP BUSHES AND LOCKING SCREWS

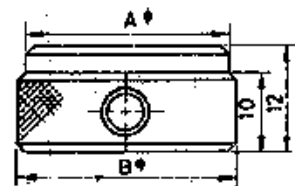
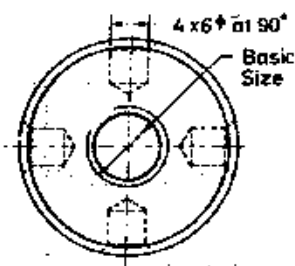
chamfer $1 \times 45^\circ$

Material C 45; Hardness HRC 50

All dimensions in millimetres.

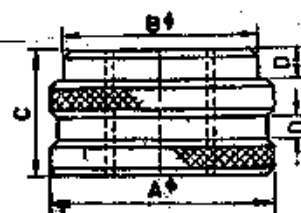
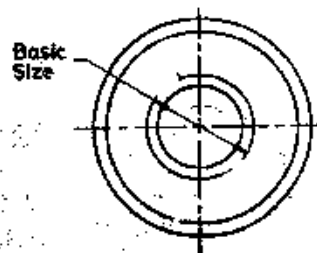
d_1	d_2	d_3	d_4	d_5	l_1	l_2	l_3	a	b	r_1	z	x
Upto 4	8	16	11	2.5	20	10	1	3	4	3	0.01	14
4—6	10	19	14	2.5	22	12	1	3	4	3	0.01	12
6—8	12	22	17	2.5	25	12	1	3	4	4	0.01	10
8—10	16	26	21	3.0	28	16	1	4	5	5	0.01	12
10—12	18	30	24	3.0	28	16	1	4	5	5	0.01	10
12—15	22	35	29	5.0	36	20	1	5	7	5	0.01	12
15—18	25	40	35	5.0	36	20	1	5	7	5	0.01	8
18—22	30	47	41	5.0	36	20	1	5	7	6	0.01	0
22—26	36	56	47	6.0	45	25	2	6	8	6	0.02	0
26—30	42	62	54	6.0	45	25	2	6	8	6	0.02	0
30—35	48	69	61	6.0	50	32	2	6	11	8	0.02	0
35—42	56	78	69	6.0	50	32	2	6	11	8	0.02	0
42—48	63	85	78	6.0	56	36	2	6	14	8	0.02	0

d_6	d_7	d_8	l_4	l_5	l_6	h	d_6	$m6^\circ \times l$	m	n	t	r_2	c
M 5								2.5 × 14	10				15
M 5								2.5 × 14	12				16
M 5	10	5	6	6	15	2		2.5 × 14	12	1.6	2.0	0.6	18
M 5								3.0 × 14	16				20
M 5								3.0 × 14	16				22
M 6								5 × 20	20				26
M 6	13	6	8	8	20	2		5 × 20	20	2.0	2.5	1.0	29
M 6								5 × 20	20				33
M 8								6 × 24	25				38
M 8								6 × 24	25				41
M 8	16	8	10	10	25	2.5		6 × 24	30	2.5	3.0	1.6	45
M 8								6 × 24	30				48
M 8								6 × 28	35				55



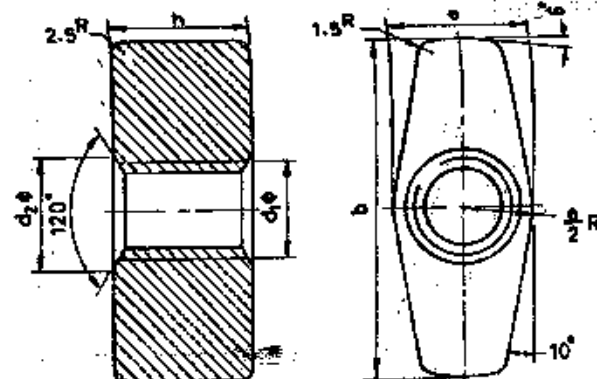
TOMMY NUT

KNURLED THUMB NUT



KNURLED THUMB NUT MATERIAL: C 45

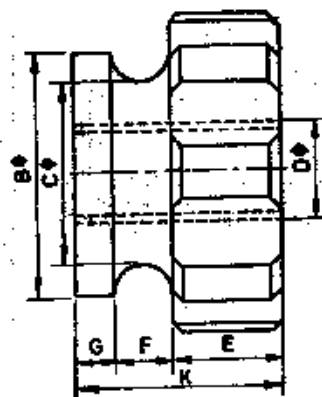
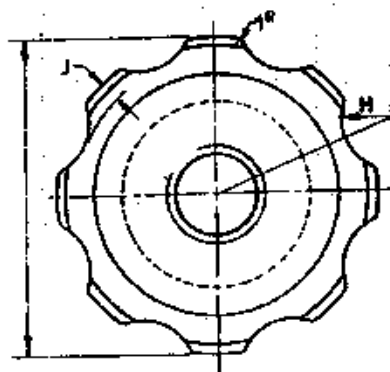
Basic Size	Aφ	Bφ	C	D
M 6	20	16	10	1.5
M 8	22	20	12	1.5
M 10	25	22	12	3
M 12	28	25	14	3
M 16	35	28	16	3



THUMB-NUT

THUMB NUT MATERIAL: C 45

	d ₁	d ₂	b	h	e
M 6	7	28	12	12	12
M 8	9	32	14	14	14
M 10	11	36	16	16	16
M 12	13	45	18	18	18
M 16	18	54	22	22	22



HAND NUT

MATERIAL: C 45

Aφ	Bφ	Cφ	Dφ	E	F	G	H	J	K
41	32	23	M 12	14	8	3	6	3	25
54	38	27	M 16	17	13	5	8	5	35
58	41	30	M 20	17	13	5	8	5	35
64	45	32	M 22	19	17	5	10	6	41
70	50	38	M 24	21	17	6	10	6	44
80	56	45	M 30	25	19	8	11	8	52

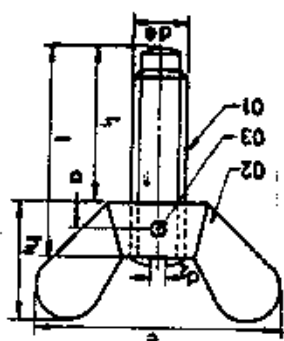
All dimensions in millimetres

HAND NUT

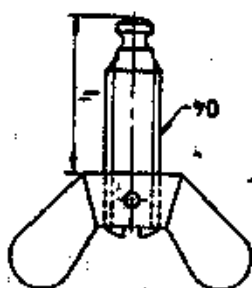
All dimensions in millimetres

	d	a	d _g	e	$\frac{b}{8}$	h	h ₁
M5	3	1.5	25	1.5	7	12	25
M6	4	1.5	32	2.0	8	16	28
M8	5	2.0	40	2.5	9.5	20	35
M10	6	3.0	50	3.5	12.0	25	50

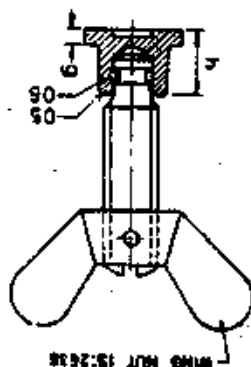
A. Cylindrical end



B. Grooved end



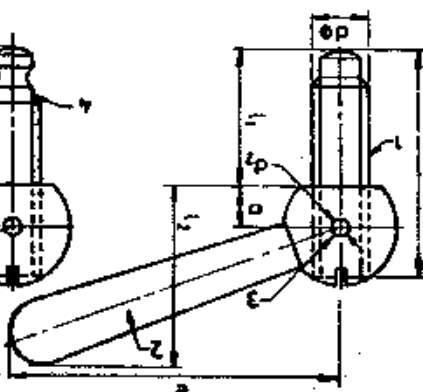
C. With floating pad



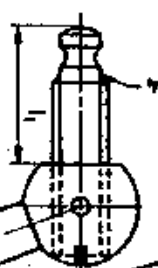
WING OR FLY SCREWS

	d	a	d _g	e	h	h ₁
M10	6	3	75	3.5	12	40
M12	7.5	4	90	4.0	15	50
M16	10.0	5	117	4.5	19	63
M20	12.5	6	150	6.5	24	80

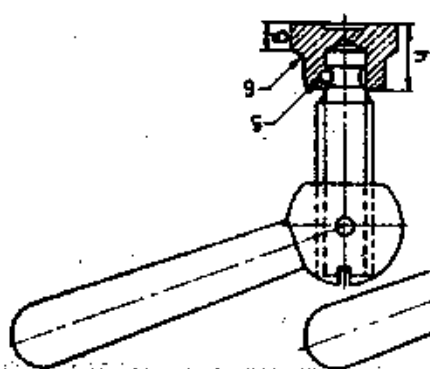
Cylindrical end



Grooved end



Floating end

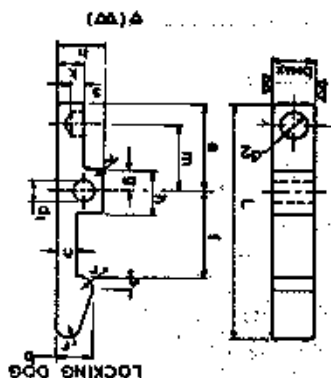


HANDLE GRIP SCREWS

Length	Locking deg										(to Effective Coils)						
	L	b	d ₁	E 9	d ₁	c	f	g	h	s	k	m	n	r	d ₂	d ₁	Free length
80	14	6	9.0	30	30	30	6	15.0	5	9.0	23	7	4.0	7.4	1.0	22	
60	10	5	7.0	20	20	20	5	12.0	3	7.0	15	5	2.5	5.8	0.8	18	
45	8	4	5.5	15	15	15	4	9.5	2	5.5	11	4	1.6	4.6	0.6	16	

Spring Steel (IS : 727 - 1964) for Springs

Material: C 14 for locking dogs

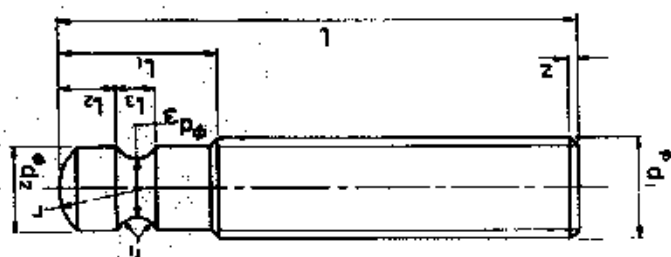


LOCKING DOGS : IS : \$69

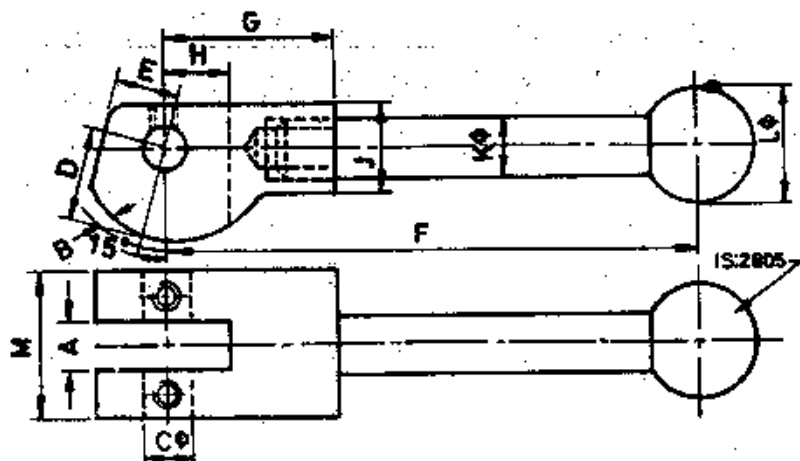
	d_1	d_2	r	r_1	l_1	l_2	l	z
M6	4.5	3	3	0.6	6.5	2.2	2.2	1.0
M8	6	4	5	0.8	8.5	2.8	3	1.25
M10	7	5	6	0.8	10.0	3.2	3	1.50
M12	9	6	6	1.0	13.0	4.3	4.5	1.75
M16	12	9	9	1.0	17.0	6.3	4.5	2.0
M20	15	10	13	1.5	21	7.4	6	2.5

ALL INFORMATION CONTAINED HEREIN IS UNCLASSIFIED

(Material) — Surface hardening steel—Hardness of the thrust surface is 60 Rc

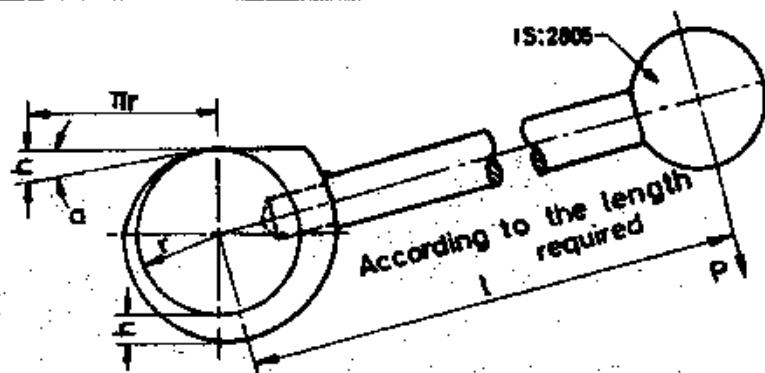


SCREWS FOR PRESSURE OR THRUST PADS IS : 6336



DOUBLE CAM LEVER
(Ball handle type)

A	B	Cφ	D	E	F	G	H	J	Kφ	Lφ	M
7	2	5	16	12	95	30	8	18	10	22	16
9	2	6	16	12	95	30	10	18	10	22	20
10	2	8	20	14	125	35	12	22	12	25	22
14	3	10	25	16	150	35	14	25	12	40	32
16.5	5	12	40	30	220	50	20	32	16	40	45
21	6	16	50	32	320	65	40	40	20	40	50



SPHERICAL CAM CLAMPING

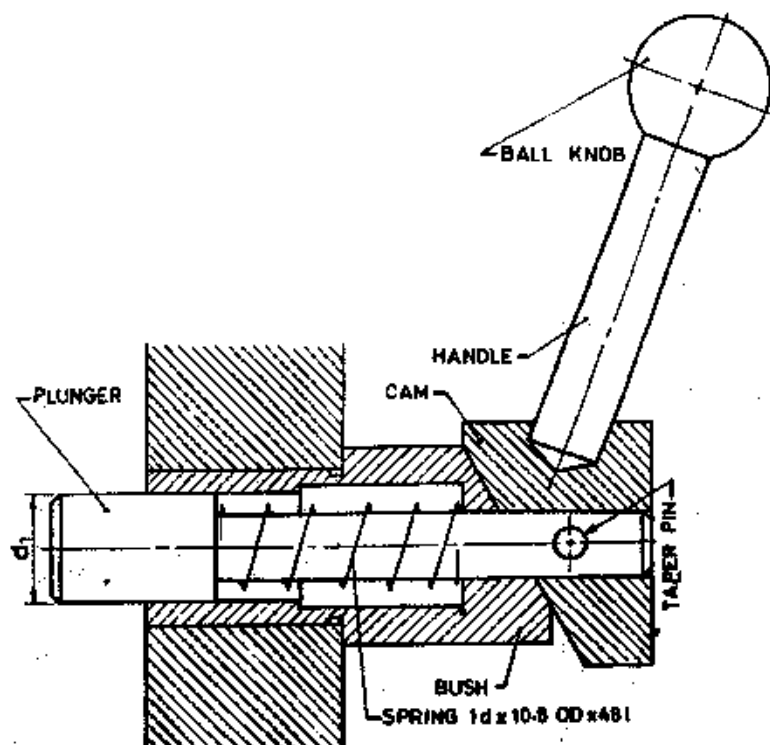
MATERIAL: C 45

HARDNESS OF SPHERE: 50 to 52 HRC

CLAMPING FORCE: 350 kgf when $\alpha = 5^\circ 45'$ for $P = 15$ kgf and $l = 10r$
550 kgf when $\alpha = 1^\circ 50'$ for $P = 15$ kgf and $l = 10r$

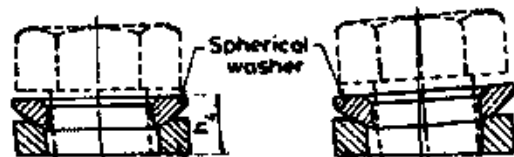
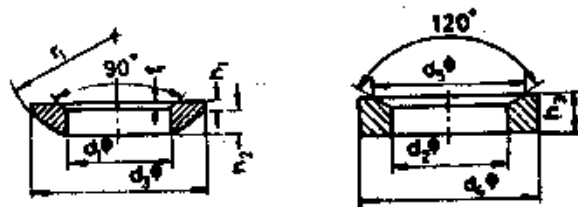
Type	r	h	α
1	10	3.2	$5^\circ 45'$
		1.0	$1^\circ 50'$
2	16	5.0	$5^\circ 45'$
		1.6	$1^\circ 50'$
3	25	8.0	$5^\circ 45'$
		2.5	$1^\circ 50'$
4	32	10.0	$5^\circ 45'$
		3.2	$1^\circ 50'$

All dimensions in millimetres



QUICK HAND INDEX

SPHERICAL WASHER AND CONICAL SEAT



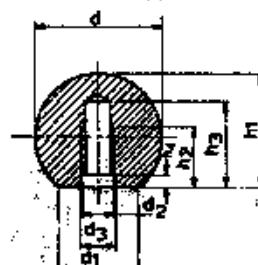
SPHERICAL WASHER AND CONICAL SEAT

Material: Rolled Steel

Size of Bolt or Screw	d	d ₁ H12	d ₂ H12	d ₃	d ₄	d ₅	f approx	h ₁	h ₂	h ₃	h ₄ approx	r ₁
M 6	6	6.4	7	12	12	11	0.3	0.6	2.3	2.8	4.0	9
M 8	8	8.4	10	17	17	14.5	0.5	0.6	3.2	3.5	5.0	12
M10	10	10.5	12	21	21	18.5	0.5	0.8	4.0	4.2	6.3	15
M12	12	13	15	24	24	20	0.5	1.1	4.6	5.0	8.0	17
M16	16	17	19	30	30	26	0.5	1.3	5.3	6.2	9.3	22
M20	20	21	24	36	36	31	0.5	2.0	6.3	7.5	11.5	27
M24	24	25	28	44	44	37	0.8	2.4	8.2	9.5	15.0	32
M30	30	31	35	56	56	49	0.8	3.6	11.1	12	19.7	41

All dimensions in millimetres

BALL GRIP

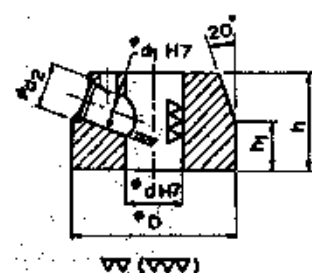


All dimensions in mm

d	d_1	h_1	d_2	h_2	h_3	d_3	h_4
11	6	10.1	M3	6	7.5	3.2	1
14	8	12.7	M4	8	10	4.3	1
18	10	16.5	M5	10	12	5.3	2
22	12	20.2	M6	11	15	6.4	2
28	14	26	M8	16	20	8.4	3
36	16	34.2	M10	18	26	10.5	4
45	18	43.2	M10	18	26	10.5	4
56	22	53.8	M12	25	36	13	4

CAP

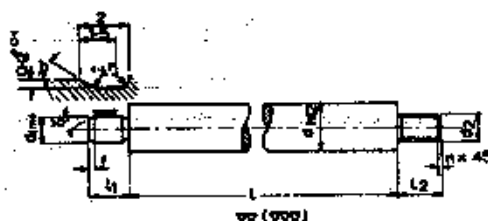
(for operating lever)



All dimensions in mm

D	h	h_1	d	d_1	d_2
40	20	10	15	8	10.5
52	30	15	18	12	14.5
70	36	18	25	14	18.5

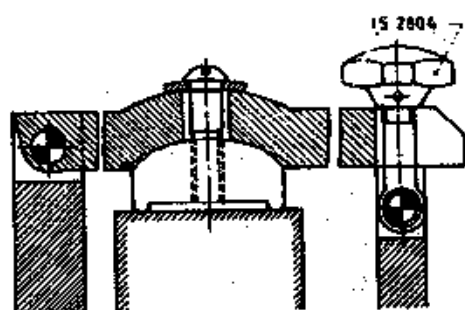
OPERATING LEVER ROD



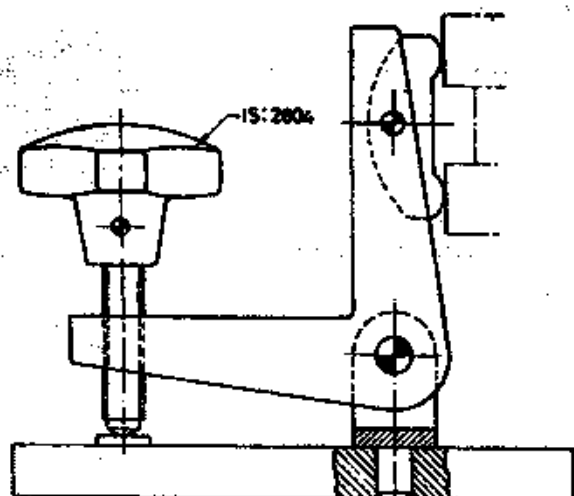
All dimensions in mm

d	d_1	d_2	h_1	h_2	n	f
10	8	M8	9	13	1.2	1
14	12	M10	12	15	1.5	1.25
18	14	M10	16	15	1.5	2

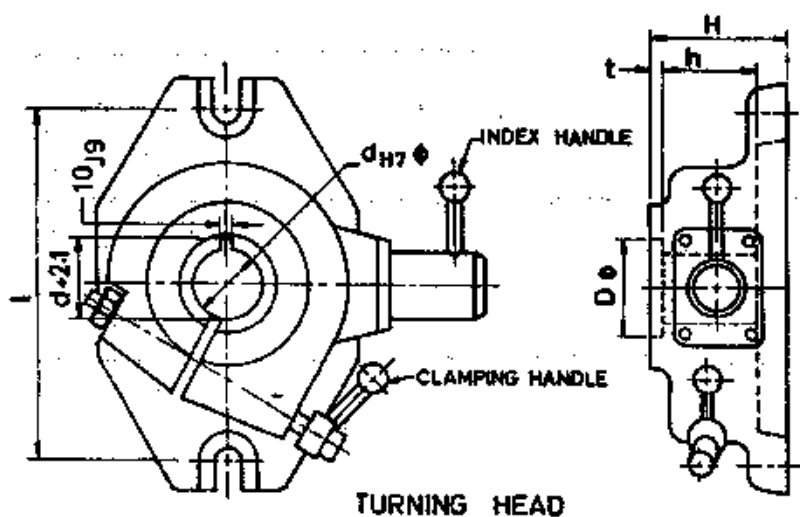
EXAMPLES OF EQUALISER CLAMPS



Equalizer with palm grip



AXIAL EQUALIZER

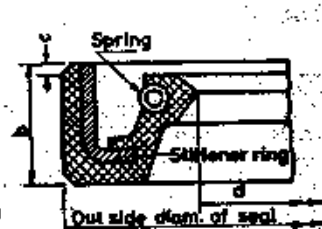


TURNING HEAD

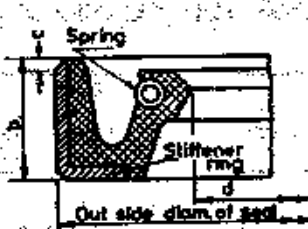
TURNING HEAD

Size	l	t	d_{H7}	$D \phi$	h	H
1	140	18	36	—	48	62
2	220	18	36	—	56	74

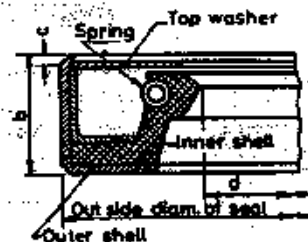
All dimensions in millimetres



TYPE A



TYPE B



TYPE C

DIMENSIONS FOR OIL SEALS

All dimensions in millimetres

Shaft Diameter d_1	Nominal* Bore Diameter of Housing	$b \approx 0.2$ Types A and B	t_c Min
6	16 22	7	0.3
7	16 22	7	0.3
8	16 22 24	7	0.3
9	22 24 26	7	0.3
10	19 22 24 26	7	0.3
11	22 26	7	0.3
12	22 24 28 30	7	0.3
14	24 28 30 35	7	0.3
15	24 26 30 32 35	7	0.3
16	28 30 32 35	7	0.3
17	28 30 32 35 40	7	0.3
18	30 32 35 40	7	0.3
20	30 32 35 40 47	7	0.3

Shaft Diameter d_1	Nominal* Bore Diameter of Housing	$b \approx 0.2$ Types A and B	Type C	t_c Min
22	32 35 40 47	7	9	0.3
24	35 37 40 47	7	9	0.3
25	35 40 42 47 52	7	9	0.4
26	37 42 47	7	9	0.4
28	40 47 52	7	9	0.4
30	40 42 47 52 62	7	9	0.4
32	45 47 52	7	9	0.4
35	47 50 52 62	7	9	0.4
36	47 50 52 62	7	9	0.4
38	52 55 62	7	9	0.4
40	52 55 62 72	7	9	0.4
42	55 62 72	8	10	0.4

* For limits of housing bore, see page 5.112

† The edges may be chamfered or rounded according to the manufacturer's discretion.

DIMENSIONS FOR OIL SEALS (Contd.)

Shaft Diameter d_1	Nominal* Bore Diameter of Housing	$b \pm 0.2$		$\frac{1}{2}c$ Min
		Types A and B	Type C	
45	60	8	10	0.4
	62			
	63			
	72			
48	62	8	10	0.4
	72			
50	65	8	10	0.4
	68			
	72			
	80			
52	68	8	10	0.4
	72			
55	70	8	10	0.4
	72			
	80			
	85			
56	70	8	10	0.4
	72			
	80			
	85			
58	72	8	10	0.4
	80			
60	75	8	10	0.4
	80			
	85			
	90			
62	85	10	12	0.5
	90			
63	85	10	12	0.5
	90			
65	85	10	12	0.5
	90			
	100			
68	90	10	12	0.5
	100			
70	90	10	12	0.5
	100			
72	95	10	12	0.5
	100			
75	95	10	12	0.5
	100			
78	100	10	12	0.6
	100			
80	100	10	12	0.5
	110			
85	110	12	15	0.8
	120			
90	110	12	15	0.8
	120			

Shaft Diameter d_1	Nominal* Bore Diameter of Housing	$b \pm 0.2$		$\frac{1}{2}c$ Min
		Types A and B	Type C	
95	120	12	15	0.8
	125			
100	120	12	15	0.8
	125			
	130			
105	130	12	15	0.8
	140			
110	130	12	15	0.8
	140			
115	140	12	15	0.8
	150			
120	150	12	15	0.8
	160			
125	150	12	15	0.8
	160			
130	160	12	15	0.8
	170			
135	170	12	15	0.8
140	170	15	15	1
145	175	15	15	1
150	180	15	15	1
160	190	15	15	1
170	200	15	15	1
180	210	15	15	1
190	220	15	15	1
200	230	15	15	1
210	240	15	15	1
220	250	15	15	1
230	260	15	15	1
240	270	15	15	1
250	280	15	15	1
260	300	20	20	1
280	320	20	20	1
300	340	20	20	1
320	360	20	20	1
340	380	20	20	1
360	400	20	20	1
380	420	20	20	1
400	440	20	20	1
420	460	20	20	1
440	480	20	20	1
460	500	20	20	1
480	520	20	20	1
500	540	20	20	1

* For limits of housing bore, see page

† The edges may be chamfered or rounded according to the manufacturer's discretion.

PRESS FIT ALLOWANCES AND TOLERANCES FOR TYPE A SEALS

All dimensions in millimetres

Nominal Bore Diameter of Housing	Housing Bore		Outside Diameter of Seal		Possible Press Fit Variation	
	High Limit	Low Limit	High Limit	Low Limit	Maximum Interference	Minimum Interference
Up to 25	+0.03	-0.03	+0.20	+0.10	0.23	0.07
25 to 55	+0.03	-0.03	+0.25	+0.15	0.28	0.12
55 to 125	+0.03	-0.03	+0.30	+0.20	0.33	0.17
125 to 200	+0.04	-0.04	+0.38	+0.22	0.42	0.18
200 and above	+0.05	-0.05	+0.48	+0.32	0.53	0.27

Note: All tolerances are relative to nominal bore diameter of housing.

PRESS FIT ALLOWANCES AND TOLERANCES FOR TYPES B AND C SEALS

All dimensions in millimetres

Nominal Bore Diameter of Housing	Housing Bore		Outside Diameter of Seal		Possible Press Fit Variation	
	High Limit	Low Limit	High Limit	Low Limit	Maximum Interference	Minimum Interference
Up to 50	Nominal	-0.03	+0.12	+0.04	0.15	0.04
50 to 90	Nominal	-0.03	+0.14	+0.06	0.17	0.06
90 to 115	+0.03	-0.03	+0.18	+0.08	0.21	0.05
115 to 170	+0.03	-0.03	+0.20	+0.10	0.23	0.07
170 to 215	+0.04	-0.04	+0.23	+0.13	0.27	0.09
215 to 230	+0.04	-0.04	+0.25	+0.15	0.29	0.11
230 and above	+0.04	-0.04	+0.30	+0.20	0.34	0.16

Note: All tolerances are relative to nominal bore diameter of housing.

DIMENSIONS FOR CHAMFER ON THE SHAFT FOR MOUNTING THE SEALS

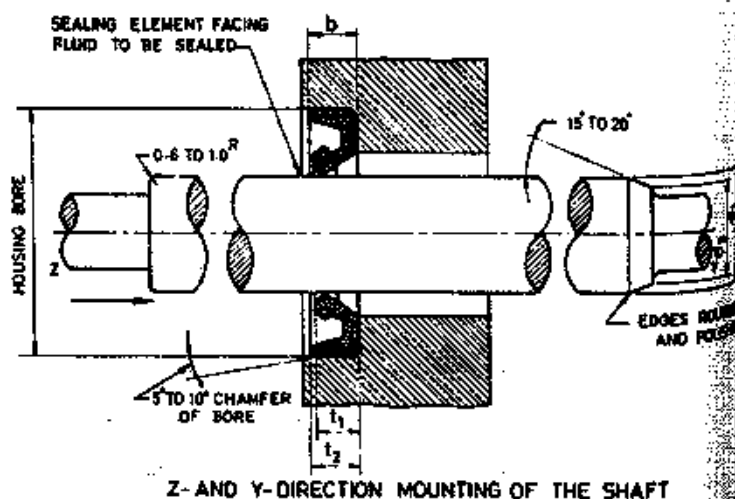
All dimensions in millimetres

d_1 h11	d_3	d_1 h11	d_3	d_1 h11	d_3	d_1 h11	d_3	d_1 h11	d_3	d_1 h11	d_3
6	4.8	24	21.5	52	48.3	85	80.4	160	153	340	329
7	5.7	25	22.5	55	51.3	90	85.3	170	163	360	349
8	6.6	26	23.4	56	52.3	95	90.1	180	173	380	369
9	7.5	28	25.3	58	54.2	100	95.0	190	183	400	389
10	8.4	30	27.3	60	56.1	105	99.9	200	193	420	409
11	9.3	32	29.2	62	58.1	110	104.7	210	203	440	429
12	10.2	35	32.0	63	59.1	115	109.6	220	213	460	449
14	12.1	36	33.0	65	61.0	120	114.5	230	223	480	469
15	13.1	38	34.9	68	63.9	125	119.4	240	233	500	489
16	14.0	40	36.8	70	65.8	130	124.3	250	243		
17	14.9	42	38.7	72	67.7	135	129.2	260	249		
18	15.8	45	41.6	75	70.7	140	133.0	280	269		
20	17.7	48	44.5	78	73.6	145	138.0	300	289		
22	19.6	50	46.4	80	75.5	150	143.0	320	309		

DEPTH OF THE HOUSING BORE

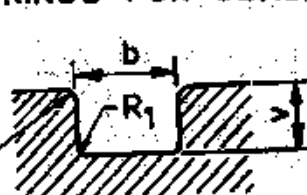
All dimensions in millimetres

b	t_1 (0.85 b) Min	t_2 ($b + 0.3$) Min
7	5.95	7.3
8	6.8	8.3
9	7.65	9.3
10	8.5	10.3
12	10.3	12.3
15	12.75	15.3
20	17	20.3



O-RINGS FOR SEALING NON-MOVING PARTS

R 0.2



For dimensions d and S refer figure on page

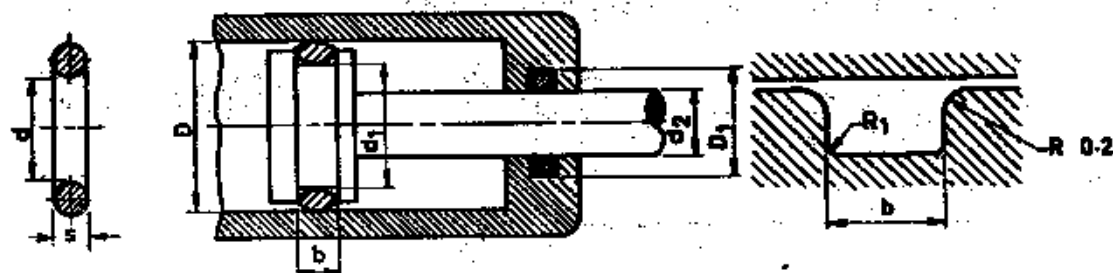
All dimensions in millimetres

S	Tol. on S	V ± 0.05	b ± 0.1	h ± 0.1	R ₁
2	+0.2 -0.1	1.5	2.7	2.8	0.2
3	+0.2 -0.1	2.3	4	4	0.3
5	± 0.2	3.9	6.7	7	0.5

Internal dia. d	Tol. on d	Internal dia. d	Tol. on d	Internal dia. d	Tol. on d
6		(52)		(210)	
8		55		220	
10		60		(240)	+1.2
12		(63)		250	-1.6
14		(65)		(260)	
16	+0.2	70	+0.4	280	
18	-0.3	(75)	-0.5	(300)	
20		80			
22		(85)		320	
25		90		(340)	
(26)		(95)		360	
28		100		(380)	+1.6
(30)				400	-2.0
				(420)	
32		(105)		450	
(34)		110		(480)	
36		(120)		500	
(38)	+0.3	125	+0.5		
40	-0.4	(130)	-0.8		
(42)		140			
		(150)			
45		160			
(48)		(170)	+0.8		
50		180	-1.2		
		(190)			
		200			

Designation: An O-ring of internal diameter d = 40 and thickness S = 2 shall be designated as O-ring 40 × 2.

Note: Sizes within brackets are of second preference.



O-RINGS For sealing moving parts

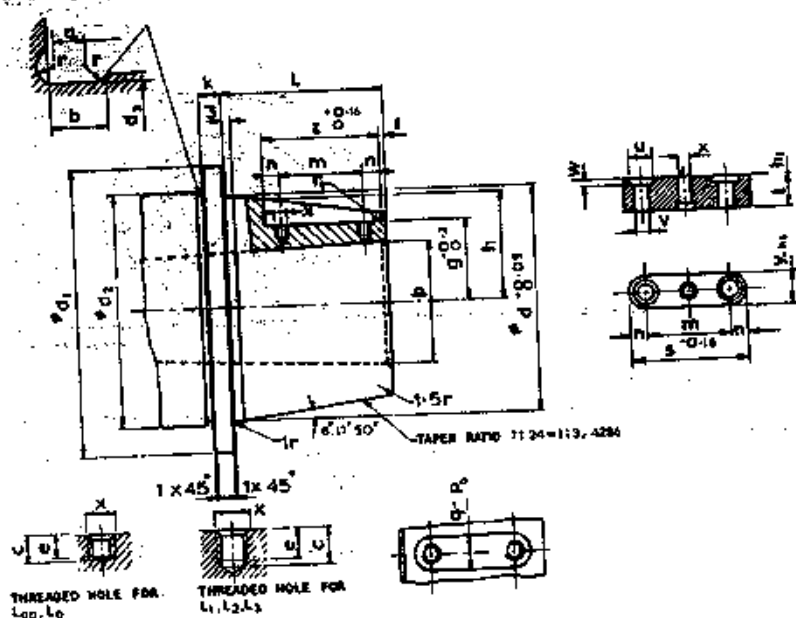
All dimensions in millimetres

Dimensions of O-Ring				Dimensions for sealing pistons		b		R ₁	s Max. per- missible error of coaxiality between holes D and d ₁
d		s		D	d ₁	Nominal Width	Permissible Deviation		
Nominal Diameter	Permissible Deviation	Nominal Diameter	Permissible Deviation	HS/f8					
				D ₁	d ₁ HS/f8				
3.6	± 0.10	2.3	± 0.10	8	4	3	± 0.10	0.50	0.007
4.6				9	5				
5.6				10	6				
6.6				11	7				
7.6				12	8				
9.6				14	10				
10.6	± 0.15	2.3	± 0.10	(15)	11	3	± 0.10	0.50	0.011
11.6				16	12				
13.6				18	14				
14.6				(19)	15				
15.6				20	16				
17.6				22	18				
19.6				(24)	20				
20.6				25	21				
19.3	± 0.20	4.6	± 0.10	28	20	6	± 0.10	0.80	0.014
21.3				(30)	22				
23.3				32	24				
24.3				(33)	25				
26.3				(35)	27				
27.3				36	28				
29.3				(38)	30				
31.3				40	32				
34.3				(43)	35				
35.3				(44)	36				
36.3				45	37				
37.3				(46)	38				
39.1	± 0.30	5.8	± 0.12	50	40	7.5	± 0.10	1.00	0.021
41.1				(52)	42				
44.1				55	45				
45.1				(56)	46				
49.1				(60)	50				
52.1				63	53				
54.1				(65)	55				
55.1				(66)	56				

Note: Sizes within brackets are of second preference.

Designation: An O-Ring for diameter D (D₁)=50mm and d₁ (d₂)=40mm shall be designated as O-Ring 50×40.

L TYPE SPINDLE NOSE FOR LATHES

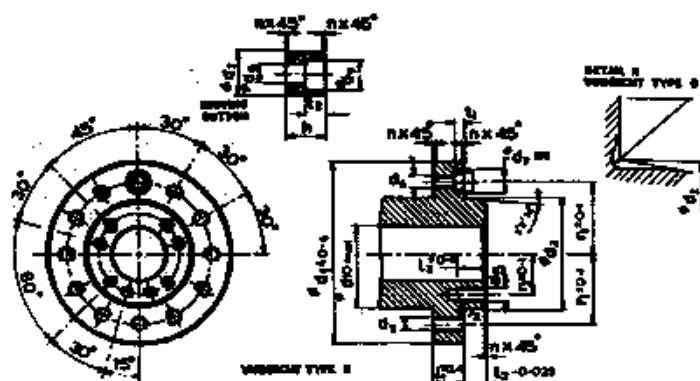


All dimensions in mm

All dimensions in mm														
TYPE	SPINDLE NOSE													
	d	l	d ₁	d ₂	c	e	f	g	h	k	p _{max}	q	r ₁	Z
L00	69.85	50	89	72	5	4	5	25.3	34.8	7	38.1	9.5	0.5	38
L0	82.55	60	105	88	5.5	4.5	6	31.6	41.1	8	50.8	"	"	44
L1	104.77	73	146	120	9	5	"	36.4	52.25	11	57.1	15.85	"	60
L2	133.35	85	187	161	13	9	"	47.5	66.5	16	76.2	19.0	1.0	78
L3	165.10	98	254	228	16	12	"	57	82.4	19	98.4	25.4	"	82

Type	Common dimensions			Key						Socket head screw	Undercut			
	m	n	x	s	t	v	u	w	y		a	b	d ₃	c
L00	26	6	M4	38	9.5	4.8	7.8	4.3	9.5		0.8	2	71.4	1
L0	28	8	M4	44	"	"	"	"	"	M4×10	"	"	87.4	"
L1	38	11	M6	60	15.8	7	11	6.3	15.85	M6×15	"	"	119.4	"
L2	45	14	M8	73	19	9.5	14.5	8.3	19	M8×20	1.0	2.5	160.4	1.5
L3	50	16	M8	82	25.4	"	"	"	25.4	M8×28	"	"	227.4	"

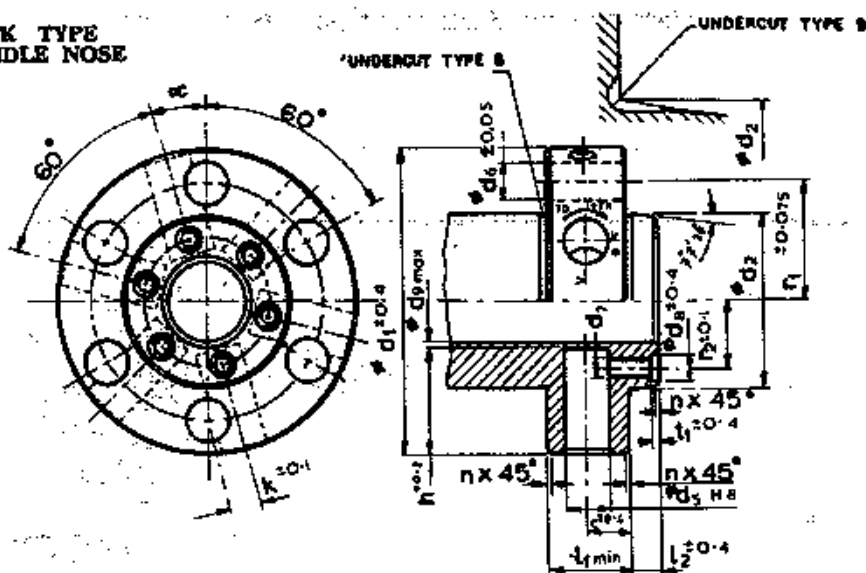
A1 TYPE SPINDLE NOSE FOR LATHES



All dimensions in mm

Nominal Size		5	6	8	11
SPINDLE NOSE	d_1	133	165	210	280
	d_2	82.563 ^{+0.01}	106.375 ^{+0.01}	139.719 ^{+0.012}	196.869 ^{+0.014}
	r_1	52.4	66.7	85.7	117.5
	r_2	30.95	41.3	55.55	82.55
	d_6	M10	M12	M16	M18
	d_8	M6	M8	M8	M10
	d_7	15.9	19.05	23.8	28.6
	l_1	22	25	28	35
	l_2	14.288	15.875	17.462	19.050
	l_3	19	22	25	32
	t_1	6	8	10	12
	n	1	1.6	1.6	1.6
	d_{10}	40	56	80	125
TAPER		MT5	MT6	Metric 80	¹ Metric 120
DRIVING BUTTON	d_4	7	9.5	9.5	11.5
	d_5	11	14.5	14.5	14.75
	h	11	13	16	20
	r_4	6.3	8.3	8.3	10.5
	Socket head Screw	M6×15	M8×20	M8×20	M10×25

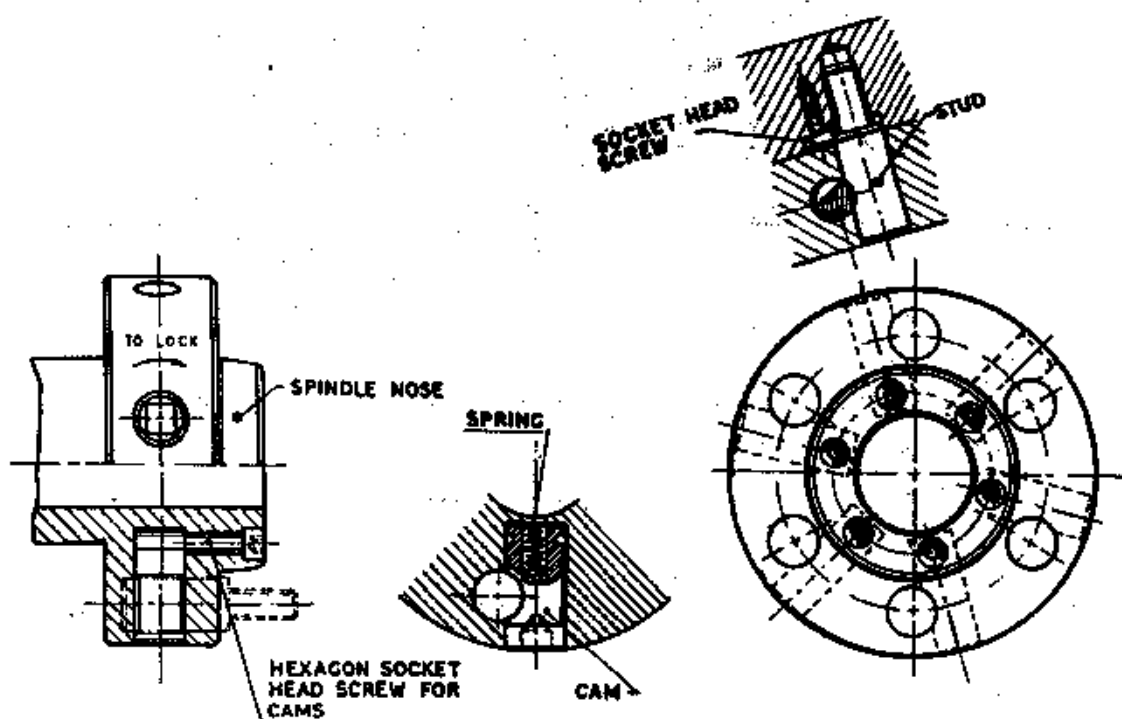
CAM LOCK TYPE LATHE SPINDLE NOSE



All dimensions in mm

Nominal size	5	6	8	11
d_1	146	181	225	298
d_2	82.563 ^{+0.01}	106.375 ^{+0.01}	139.719 ^{+0.012}	196.869 ^{+0.014}
r_1	52.4	66.7	85.7	117.5
r_2	32.3	41	57	86
d_3	22	26	29	32
d_4	19.8	23	26.2	31
d_5	M6	M8	M8	M8
d_6	10.5	13.5	13.5	13.5
l_1	38	45	50	60
l_2	13	14	16	18
c	20.6	23.8	27	31.8
h	46	57	64	75
k	13.5	15.9	18.25	21.45
α	14° 55'	13° 46'	12° 18'	10° 30'
f_1	7	9	9	9
n	1	1.6	1.6	1.6
d_7	40	56	80	120

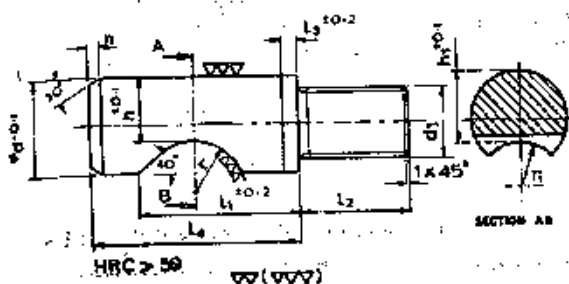
ASSEMBLY OF CAMLOCK TYPE SPINDLE NOSE



All dimensions in mm

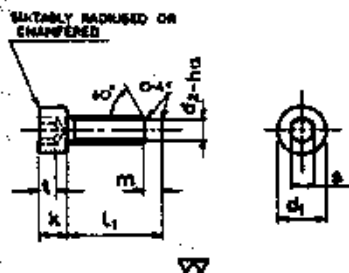
Spindle Nose	Cam	Spring	Size of Hex. socket Head screw for cam	Stud	Socket head Screw
5	22 × 45	0.9 × 6 × 21.3	M6 × 19	19 × 43	M6 × 12
6	26 × 56	1.4 × 9 × 23	M8 × 20	22.2 × 49	M8 × 16
8	29 × 63	"	M8 × 23	25.4 × 55.5	"
11	32 × 73	"	M8 × 28	30.2 × 67	"

STUD



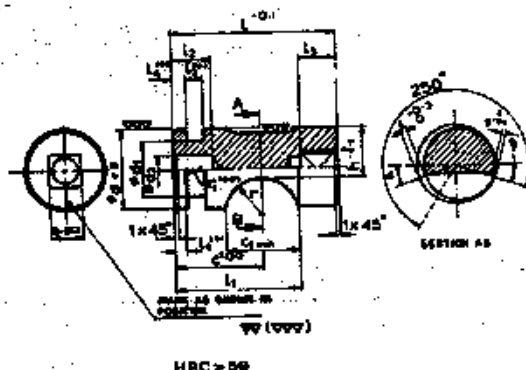
Size of Spindle nose	5	6	8	11
d	19.0	22.2	25.4	30.2
d ₁	M12×1	M16×1.5	M20×1.5	M22×1.5
l ₁	35.7	40.5	44.5	53.2
l ₂	22	27	30.5	35
l ₃	4.8	4.8	4.8	6.4
l ₄	43	49	55.5	67
h	11.9	14.3	16.7	20.6
h ₁	16.5	19.6	23.2	26.8
n	2.5	3	3	4
r	11.25	12.7	14.3	15.9
r ₁	11	14	14	14

SCREW

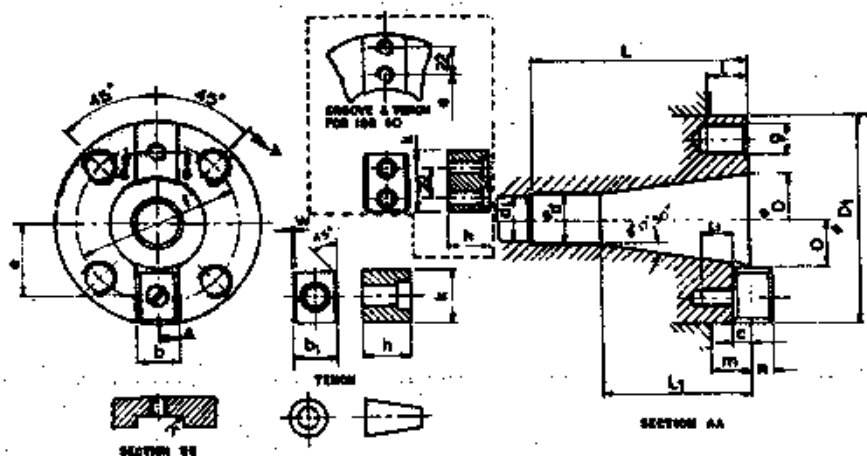


Size of spindle	5	6	8	11
d	M6	M8	M8	M8
l ₁	19	20	23	28
d ₁	10	13	13	13
d ₂	4.5	6	6	6
k	6	8	8	8
m	4	5	5	5
t max	3.78	4.78	4.78	4.78
t min	3.30	4.30	4.30	4.30
s max	5.15	6.15	6.15	6.15
s min	5.03	6.03	6.03	6.03

CAM



Size of Spindle nose	5	6	8	11
d	22	26	29	32
d ₁	14	17	21	24
d ₂	7	10	10	10
l	45	56	63	73
l ₁	35	43	49	59
l ₂	13	15	15	15
l ₃	5.0	6.5	6.5	6.5
l ₄	3.0	4.2	5.3	8.7
l ₅	11	12	14	16
l ₆	2.0	2.85	3.95	7.35
c	22.4	30.2	33.2	39.5
c ₁	22	25	28	32
h	14.2	16.7	18.9	21.2
r	11.1	12.7	14.2	16.7
r ₁	4.5	6	6	6
s	11	12	14	17
f	1.45	2.56	2.46	2.44
g	0	0.45	0.36	0.28
β	10°	10°	10°	15°
α	15°	20°	20°	20°
Slope on V	1.90	2.64	2.64	2.64

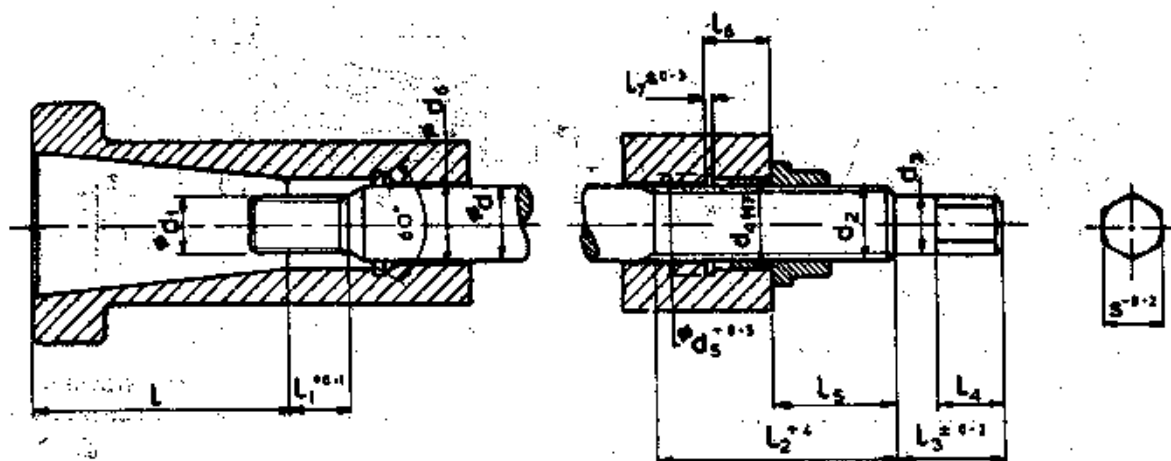


Taper:— ratio 7: 24=1: 3.4286

7/24 TAPERS FOR SPINDLE NOSES

7/24 TAPER No	30	40	50	60
D	31.750	44.450	69.850	107.950
D ₁	Tolerance h5	69.832	88.882	128.570
d	Tolerance H12	17.40	25.30	39.60
d ₁		17	21	30
b	Tolerance M6	15.9	15.9	25.4
	Eccentricity	± 0.03	± 0.03	± 0.04
b ₁	Tolerance h5	15.9	15.9	25.4
c	Minimum	8	8	12.5
e		25.0 ± 0.1	33.0 ± 0.125	49.5 ± 0.125
f	Tolerance j12	54.0	66.7	101.6
	Thread (Metric)	M10	M12	M16
g	Thread (Whitworth)	—	1"	1"
	Thread (Metric)	M6	M6	M12
h ₂	Thread (Whitw)	—	1"	1"
h	Maximum	16	16	25
k	Maximum	17	20	27
L	Minimum	73	100	140
L ₁		49.2	65.6	103.7
l		16	20	25
l ₁		9	9	18
m	Minimum	12.5	16	19
n	Maximum	8	8	12.5
o	Minimum	16.5	23	36
r	Maximum	1.5	1.5	2.5
w	Minimum	1.5	1.5	2.5

DRAW BOLT END
(For Spindle with 7/24 taper hole)

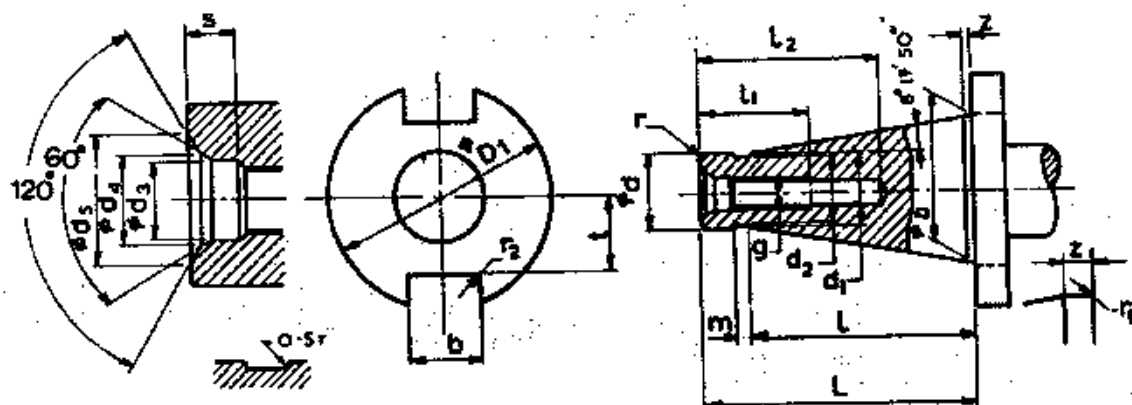


All dimensions in mm

7/24 TAPER NUMBER

30 40 50

	Normal	46	65	84
1	Maximum	46	72	103
	Minimum	16	36	60
d		16	20	28
d1		M12	M16	M24
l1		20	25	36
d2		M16	M20	M24
l2		50	80	90
d3		12.7	16.2	19.6
l3		22	24	28
l4		11	14	17
l5	Normal	48	48	45
	Maximum	48	57	64
	Minimum	18	21	21
d4		25	30	36
d5		25.5	30.5	36.5
l6		28	28	40
l7		3	4	4
d6		17	21	30



Taper Ratio 7 : 24 = 1 : 3.4286

All dimensions in mm

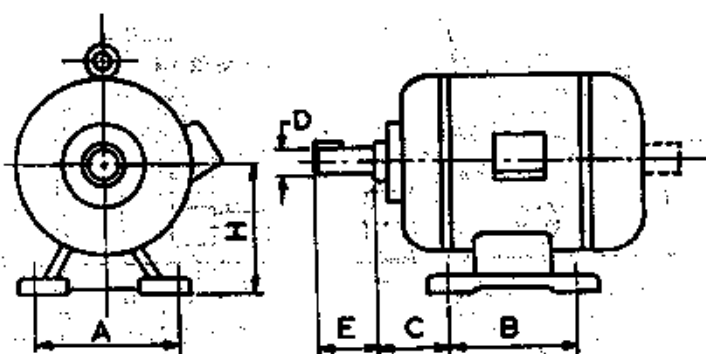
7/24 TAPERS FOR TOOL SHANKS

7/24 TAPER NUMBER	30	40	50	60
D	31.750	44.450	69.850	107.950
D ₁	50	65	100	155
d	Tolerance a 10	17.40	25.30	39.60
d ₁		16.5	24	38
d ₂	Thread Metric	10.25	14.0	21
	Whitworth	10.5	13.5	22
d ₃		13.2	17	26
d ₄	Maximum	15	19	30
d ₅	Maximum	16	22	35
b	Tolerance H12	16.1	16.1	25.7
	Eccentricity	±0.06	±0.06	±0.10
g	Metric	M12	M16	M24
	Whitworth	½"	¾"	1"
L	Maximum	70	95	130
i		50	67	105
l ₂		24	30	45
l ₁	Minimum	50	70	90
m		3	5	8
r		0.5	1	2
r ₁		0.8	0.8	1.5
r ₂		1.5	1.5	2.5
s		5.7	8	12
t	Maximum	16.2	22.5	35.3
z		1.6±0.4	1.6±0.4	3.2±0.4

FOOT MOUNTED MOTORS, 3 Phase

IS 1231 — 1974

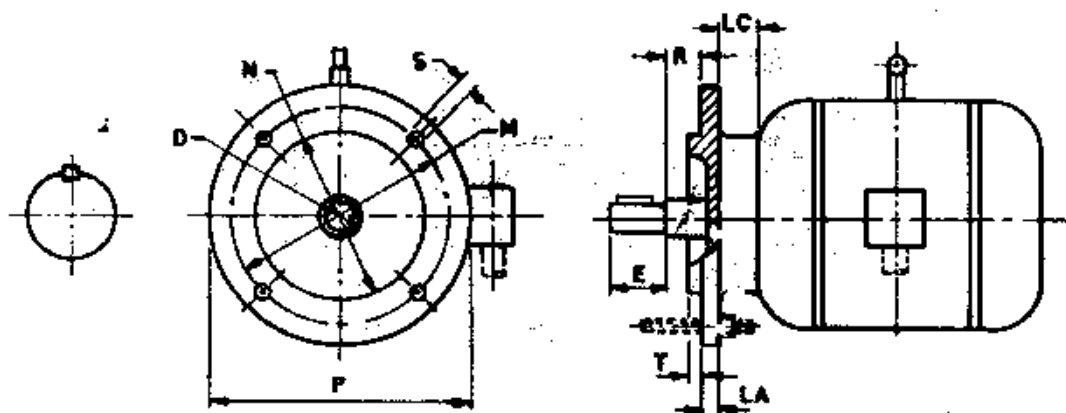
(Class E insulation)



All dimensions in mm

kW rating	motor rpm	Frame No.	H Tol—0.5	A	B	C	D	E	Bolt size
0.12 — 0.18	3000 1500	63 63	63 "	100 "	80 "	40 "	11j6 "	23 "	M6 "
0.25 — 0.37	3000 1500	71 71	71 "	112 "	90 "	45 "	14j6 "	30 "	M6 "
0.37 — 0.55 0.55 — 0.75	1000 3000 1500	80 80 80	80 " "	125 " "	100 " "	50 " "	19j6 " "	40 " "	M8 "
0.75 1.1 1.1	1000 3000 1500	90S 90S 90S	90 " "	140 " "	100 " "	56 "	24j6 "	50 "	" " "
1.1 1.5	1000 3000 1500	90L 90L 90L	" " "	" " "	125 " "	" " "	" " "	" " "	" " "
2.2	1000 3000 1500	100L 100L 100L	100 " "	160 " "	140 " "	63 "	28j6 "	60 "	M10 "
3.7	1000 3000 1500	112M " "	112 " "	190 " "	140 " "	70 "	" " "	" " "	M10 " "
5.5	3000 1500	132S 132S	132 "	216 "	140 "	89 "	38k6 "	80 "	" "
3.7 & 5.5 7.5	1000 3000 1500	132M 132M 132M	" " "	216 " "	178 " "	" " "	" " "	" " "	" " "
11	1000 3000 1500	160M 160M 160M	160 " "	254 " "	210 " "	108 "	42k6 "	110 "	M12 " "
11 15	1000 3000 1500	160L 160L 160L	160 " "	254 " "	254 " "	108 "	" " "	" " "	M12 " "
18.5 15 22	3000 1500 1000 3000 1500	180M 180M 180L 180L 180L	180 " " " "	279 " " " "	241 " " " "	121 " " " "	48k6 " " " "	110 " " " "	M12 " " " "

FLANGE MOUNTED MOTOR, 3 Phase
(Class E Insulation)



All dimensions in mm

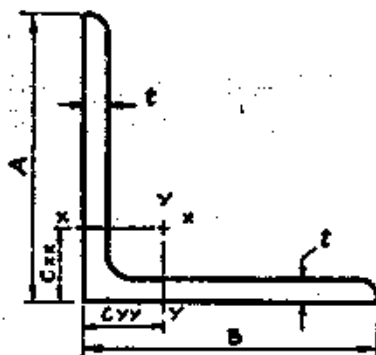
kW Rating	Motor rpm	Flange designation	Frame size	M	N j6	D	E	P Max	± S Hole Size	No	T Max	LA	LC Min
0.12—0.18	3000	F115B	63	115 ^{+0.3}	95	11j6	23	140	10	4	3	9	16
	1500	"	"	"	"	"	"	"	"	"	"	"	"
0.25—0.37	3000	F130B	71	130 ^{+0.3}	110	14j6	30	160	10	"	3.5	"	"
	1500	"	"	"	"	"	"	"	"	"	"	"	"
0.37—0.55	1000	F165B	80	165 ^{+0.3}	130	19j6	40	200	12	"	"	10	20
0.55—0.75	3000	"	"	"	"	"	"	"	"	"	"	"	"
	1500	"	"	"	"	"	"	"	"	"	"	"	"
0.75	1000	"	90S	"	"	24j6	50	"	"	"	"	"	"
1.1	3000	"	"	"	"	"	"	"	"	"	"	"	"
"	1500	"	"	"	"	"	"	"	"	"	"	"	"
"	1000	"	90L	"	"	"	"	"	"	"	"	"	"
1.5	3000	"	90L	"	"	"	"	"	"	"	"	"	"
2.2	1000	F215B	100L	215 ^{+0.3}	180	28j6	60	250	15	"	4	11	24
	3000	"	"	"	"	"	"	"	"	"	"	"	"
	1500	"	"	"	"	"	"	"	"	"	"	"	"
3.7	1000	F215B	112M	"	"	"	"	"	"	"	"	"	"
	3000	"	"	"	"	"	"	"	"	"	"	"	"
	1500	"	"	"	"	"	"	"	"	"	"	"	"

FLANGE MOUNTED MOTOR (Contd.)

kW Rating	Motor rpm	Flange designation	Frame size	M	N j6	D	E	P Max	φ S Hole Size	No	T Max	LA	LC Min
5.5	3000	F265B	132S	265 ^{+0.3}	230	38k6	80	300	15	4	4	12	24
	1500												
3.7 & 5.5	1000		132M										
7.5	3000												
	1500												
	1000	F300B	160M	300 ^{+0.3}	250	42k6	110	350	19	5	5	13	32
11	3000												
	1500												
	1000		160L										
15	3000		160L										
	1500												
18.5	3000	F300B	180M			48k6							
	1500												
22	1000		180L										
	3000												
	1500												

ROLLED STEEL EQUAL ANGLES

Dimensions and Properties



Designation	Size A × B mm × mm	Thickness t mm	Sectional Area a cm ²	Weight per Metre w kgf	Centre of Gravity $C_{xx} = C_{yy}$ cm	Moments of Inertia $I_{xx} = I_{yy}$ cm ⁴	Radii of Gyration $r_{xx} = r_{yy}$ cm
ISA 2020	20 × 20	3.0	1.12	0.9	0.59	0.4	0.58
		4.0	1.45	1.1	0.63	0.5	0.58
ISA 2525	25 × 25	3.0	1.41	1.1	0.71	0.8	0.73
		4.0	1.84	1.4	0.75	1.0	0.73
ISA 3030	30 × 30	5.0	2.25	1.8	0.79	1.2	0.72
		3.0	1.73	1.4	0.83	1.4	0.89
		4.0	2.26	1.8	0.87	1.8	0.89
ISA 3535	35 × 35	5.0	2.77	2.2	0.92	2.1	0.88
		3.0	2.03	1.6	0.95	2.3	1.05
		4.0	2.66	2.1	1.00	2.9	1.05
		5.0	3.27	2.6	1.04	3.5	1.04
ISA 4040	40 × 40	6.0	3.86	3.0	1.08	4.1	1.03
		3.0	2.34	1.8	1.08	3.4	1.21
		4.0	3.07	2.4	1.12	4.5	1.21
		5.0	3.78	3.0	1.16	5.4	1.20
ISA 4545	45 × 45	6.0	4.47	3.5	1.20	6.3	1.19
		3.0	2.64	2.1	1.20	5.0	1.38
		4.0	3.47	2.7	1.25	6.5	1.37
		5.0	4.28	3.4	1.29	7.9	1.36
ISA 5050	50 × 50	6.0	5.07	4.0	1.33	9.2	1.35
		3.0	2.95	2.3	1.32	6.9	1.53
		4.0	3.88	3.0	1.37	9.1	1.53
		5.0	4.79	3.8	1.41	11.0	1.52
ISA 5555	55 × 55	6.0	5.68	4.5	1.45	12.9	1.51
		5.0	5.27	4.1	1.53	14.7	1.67
		6.0	6.26	4.9	1.57	17.3	1.66
		8.0	8.18	6.4	1.65	22.0	1.64
ISA 6060	60 × 60	10.0	10.02	7.9	1.72	26.3	1.62
		5.0	5.75	4.5	1.65	19.2	1.82
		6.0	6.84	5.4	1.69	22.6	1.82
		8.0	8.96	7.0	1.77	29.0	1.80
		10.0	11.00	8.6	1.85	34.8	1.78

IS: 808-1967

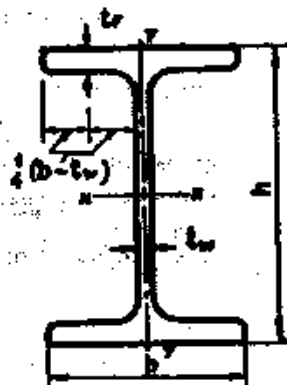
ROLLED STEEL EQUAL ANGLES (Contd.)

Designation	Size A × A mm × mm	Thickness t mm	Sectional Area a cm ²	Weight per Metre w kgf	Centre of Gravity C _{xx} = C _{yy} cm	Moments of Inertia I _{xx} = I _{yy} cm ⁴	Radii of Gyration r _{xx} = r _{yy} cm
ISA 6565	65 × 65	5.0	6.25	4.9	1.77	24.7	1.99
		6.0	7.44	5.8	1.81	29.1	1.98
		8.0	9.76	7.7	1.89	37.4	1.96
		10.0	12.00	9.4	1.97	45.0	1.94
ISA 7070	70 × 70	5.0	6.77	5.3	1.89	31.1	2.15
		6.0	8.06	6.3	1.94	36.8	2.14
		8.0	10.58	8.3	2.02	47.4	2.12
		10.0	13.02	10.2	2.10	57.2	2.10
ISA 7575	75 × 75	5.0	7.27	5.7	2.02	38.7	2.31
		6.0	8.66	6.8	2.06	45.7	2.30
		8.0	11.38	8.9	2.14	59.0	2.28
		10.0	14.02	11.0	2.22	71.4	2.26
ISA 8080	80 × 80	6.0	9.29	7.3	2.18	56.0	2.46
		8.0	12.21	9.6	2.27	72.5	2.44
		10.0	15.05	11.8	2.34	87.7	2.41
		12.0	17.81	14.0	2.42	101.9	2.39
ISA 9090	90 × 90	6.0	10.47	8.2	2.42	80.1	2.77
		8.0	13.79	10.8	2.51	104.2	2.75
		10.0	17.03	13.4	2.59	126.7	2.73
		12.0	20.19	15.8	2.66	147.9	2.71
ISA 100100	100 × 100	6.0	11.67	9.2	2.67	111.3	3.09
		8.0	15.39	12.1	2.76	145.1	3.07
		10.0	19.03	14.9	2.84	177.0	3.05
		12.0	22.59	17.7	2.92	207.0	3.03
ISA 110110	110 × 110	8.0	17.08	13.4	3.00	196.8	3.40
		10.0	21.12	16.5	3.09	240.2	3.37
		12.0	25.08	19.7	3.17	281.3	3.35
		16.0	32.76	25.7	3.32	357.3	3.30
ISA 130130	130 × 130	8.0	20.28	15.9	3.50	331.0	4.04
		10.0	25.12	19.7	3.59	405.3	4.02
		12.0	29.88	23.5	3.67	476.4	3.99
		16.0	39.16	30.7	3.82	609.1	3.94
ISA 150150	150 × 150	10.0	29.21	22.9	4.08	633.5	4.66
		12.0	34.77	27.3	4.16	746.3	4.63
		16.0	45.65	35.8	4.31	958.9	4.58
		20.0	56.21	44.1	4.46	1155.5	4.53
ISA 200200	200 × 200	12.0	46.94	36.9	5.39	1826.3	6.24
		16.0	61.82	48.5	5.56	2366.2	6.19
		20.0	76.38	60.0	5.71	2875.0	6.14
		25.0	94.13	73.9	5.90	3470.2	6.07

ISA—Indian standard angles

ROLLED STEEL BEAMS

Dimensions and properties



Designation	Weight per Metre w kgf	Sectional Area a cm ²	Depth of Section h mm	Width of Flange b mm	Thick- ness of Flange t _f mm	Thick- ness of Web t _w mm	Moments of Inertia		Radii of Gyration	
							I _{xx} cm ⁴	I _{yy} cm ⁴	r _{xx} cm	r _{yy} cm
ISJB 150	7.1	9.01	150	50	4.6	3.0	322.1	9.2	5.98	1.01
ISJB 175	8.1	10.28	175	50	4.8	3.2	479.3	9.7	6.83	0.97
ISJB 200	9.9	12.64	200	60	5.0	3.4	780.7	17.3	7.86	1.17
ISJB 225	12.8	16.28	225	80	5.0	3.7	1308.5	40.5	8.97	1.58
ISLB 75	6.1	7.71	75	50	5.0	3.7	72.7	10.0	3.07	1.14
ISLB 100	8.0	10.21	100	50	6.4	4.0	168.0	12.7	4.06	1.12
ISLB 125	11.9	15.12	125	75	6.5	4.4	406.8	43.4	5.19	1.69
ISLB 150	14.2	18.08	150	80	6.8	4.8	688.2	55.2	6.17	1.75
ISLB 175	16.7	21.30	175	90	6.9	5.1	1096.2	79.6	7.17	1.93
ISLB 200	19.8	25.27	200	100	7.3	5.4	1696.6	115.4	8.19	2.13
ISLB 225	23.5	29.92	225	100	8.6	5.8	2501.9	112.7	9.15	1.94
ISLB 250	27.9	35.53	250	125	8.2	6.1	3717.8	193.4	10.23	2.33
ISLB 275	33.0	42.02	275	140	8.8	6.4	5375.3	287.0	11.31	2.61
ISLB 300	37.7	48.08	300	150	9.4	6.7	7332.9	376.2	12.35	2.80
ISLB 325	43.1	54.90	325	165	9.8	7.0	9874.6	510.8	13.41	3.05
ISLB 350	49.5	63.01	350	165	11.4	7.4	13158.3	631.9	14.45	3.17
ISLB 400	56.9	72.43	400	165	12.5	8.0	19306.3	716.4	16.33	3.15
ISLB 450	65.3	83.14	450	170	13.4	8.6	27536.1	853.0	18.20	3.20
ISLB 500	75.0	95.50	500	180	14.1	9.2	38579.0	1063.9	20.10	3.34
ISLB 550	86.3	109.97	550	190	15.0	9.9	53161.6	1335.1	21.99	3.48
ISLB 600	99.5	126.69	600	210	15.5	10.5	72867.6	1821.9	23.98	3.79
ISMB 100	11.5	14.60	100	75	7.2	4.0	257.5	40.8	4.20	1.67
ISMB 125	13.0	16.60	125	75	7.6	4.4	449.0	43.7	5.20	1.62
ISMB 150	14.9	19.00	150	80	7.6	4.8	726.4	52.6	6.18	1.66
ISMB 175	19.3	24.62	175	90	8.6	5.5	1272.0	85.0	7.19	1.86

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ROLLED STEEL BEAMS (Contd.)

Designation	Weight per Metre w	Sectional Area a	Depth of Section h	Width of Flange b	Thick- ness of Flange t _f	Thick- ness of Web t _w	Moments of Inertia		Radii of Gyration	
	kgf	cm ²	mm	mm	mm	mm	I _{xx} cm ⁴	I _{yy} cm ⁴	r _{xx} cm	r _{yy} cm
ISWB 150	17.0	21.67	150	100	7.0	5.4	839.1	94.8	6.22	2.09
ISWB 175	22.1	28.11	175	125	7.4	5.8	1 509.4	188.6	7.33	2.59
ISWB 200	28.8	36.71	200	140	9.0	6.1	2 624.5	328.8	8.46	2.99
ISWB 225	33.9	43.24	225	150	9.9	6.4	3 920.5	448.6	9.52	3.22
ISWB 250	40.9	52.05	250	200	9.0	6.7	5 943.1	857.5	10.69	4.06
ISWB 300	48.1	61.33	300	200	10.0	7.4	9 821.6	990.1	12.66	4.02
ISWB 350	56.9	72.50	350	200	11.4	8.0	15 521.7	1 175.9	14.63	4.03
ISWB 400	66.7	85.01	400	200	13.0	8.6	23 426.7	1 388.0	16.60	4.04
ISWB 450	79.4	101.15	450	200	15.4	9.2	35 057.6	1 706.7	18.63	4.11
ISWB 500	95.2	121.22	500	250	14.7	9.9	52 290.9	2 987.8	20.77	4.96
ISWB 550	112.5	143.34	550	250	17.6	10.5	74 906.1	3 740.6	22.86	5.11
ISWB 600	133.7	170.38	600	250	21.3	11.2	106 198.5	4 702.5	24.97	5.25
ISWB 600	145.1	184.86	600	250	23.6	11.8	115 626.6	5 298.3	25.01	5.35
ISHB 150	27.1	34.48	150	150	9.0	5.4	1 455.6	431.7	6.50	3.54
ISHB 150	30.6	38.98	150	150	9.0	8.4	1 540.0	460.3	6.29	3.44
ISHB 150	34.6	44.08	150	150	9.0	11.8	1 635.6	494.9	6.09	3.35
ISHB 200	37.3	47.54	200	200	9.0	6.1	3 608.4	967.1	8.71	4.51
ISHB 200	40.0	50.94	200	200	9.0	7.8	3 721.8	994.6	8.55	4.42
ISHB 225	43.1	54.94	225	225	9.1	6.5	5 279.5	1 353.8	9.80	4.96
ISHB 225	46.8	59.66	225	225	9.1	8.6	5 478.8	1 396.6	9.58	4.84
ISHB 250	51.0	64.96	250	250	9.7	6.9	7 736.5	1 961.3	10.91	5.49
ISHB 250	54.7	69.71	250	250	9.7	8.8	7 983.9	2 011.7	10.70	5.37
ISHB 300	58.8	74.85	300	250	10.6	7.6	12 545.2	2 193.6	12.95	5.41
ISHB 300	63.0	80.25	300	250	10.6	9.4	12 930.2	2 246.7	12.70	5.29
ISHB 350	67.4	85.91	350	250	11.6	8.3	19 159.7	2 451.4	14.93	5.34
ISHB 350	72.4	92.21	350	250	11.6	10.1	19 802.8	2 510.5	14.65	5.22
ISHB 400	77.4	98.66	400	250	12.7	9.1	28 083.5	2 728.3	16.87	5.26
ISHB 400	82.2	104.66	400	250	12.7	10.6	28 823.5	2 783.0	16.61	5.16
ISHB 450	87.2	111.14	450	250	13.7	9.8	39 210.8	2 985.2	18.78	5.18
ISHB 450	92.5	117.89	450	250	13.7	11.3	40 349.9	3 045.0	18.50	5.08

ISJB—Indian standard junior beam
ISLB—Indian standard light beam
ISMB—Indian standard medium weight beam

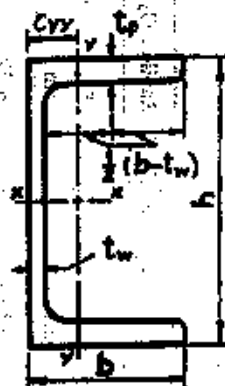
ISWB—Indian standard wide flange beam
ISHB—Indian standard column section—H beam

ROLLED STEEL CHANNELS—Dimensions and properties

Designation	Weight per Metre w kgf	Sectional Area a cm ²	Depth of Section h mm	Width of Flange b mm	Thickness of Flange t _f mm	Thickness of Web t _w mm	Centre of Gravity c _{yy} mm	Moments of Inertia		Radii of Gyration	
								I _{xx} cm ⁴	I _{yy} cm ⁴	r _{xx} cm	r _{yy} cm
ISJC 100	5.8	7.41	100	45	5.1	3.0	1.40	123.8	14.9	4.09	1.42
ISJC 125	7.9	10.07	125	50	6.6	3.0	1.64	270.0	25.7	5.18	1.60
ISJC 150	9.9	12.65	150	55	6.9	3.6	1.66	471.1	37.9	6.10	1.73
ISJC 175	11.2	14.24	175	60	6.9	3.6	1.75	719.9	50.5	7.11	1.88
ISJC 200	13.9	17.77	200	70	7.1	4.1	1.97	1161.2	84.2	8.08	2.18
ISLC 75	5.7	7.26	75	40	6.0	3.7	1.35	66.1	11.5	3.02	1.26
ISLC 100	7.9	10.02	100	50	6.4	4.0	1.62	164.7	24.8	4.06	1.57
ISLC 125	10.7	13.67	125	65	6.6	4.4	2.04	356.8	57.2	5.11	2.05
ISLC 150	14.4	18.36	150	75	7.8	4.8	2.38	697.2	103.2	6.16	2.37
ISLC 175	17.6	22.40	175	75	9.5	5.1	2.40	1148.4	126.5	7.16	2.38
ISLC 200	20.6	26.22	200	75	10.8	5.5	2.35	1725.5	146.9	8.11	2.37
ISLC 225	24.0	30.53	225	90	10.2	5.8	2.46	2547.9	209.5	9.14	2.62
ISLC 250	28.0	35.65	250	100	10.7	6.1	2.70	3687.9	298.4	10.17	2.89
ISLC 300	33.1	42.11	300	100	11.6	6.7	2.55	6047.9	346.0	11.98	2.87
ISLC 350	38.8	49.47	350	100	12.5	7.4	2.41	9312.6	394.6	13.72	2.82
ISLC 400	45.7	58.25	400	100	14.0	8.0	2.36	13989.5	460.4	15.50	2.81

ISJC—Indian standard junior channel. ISLC—Indian standard light channel.

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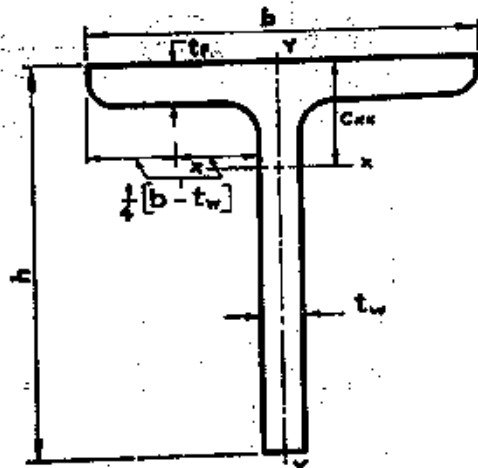


ROLLED STEEL BARS—Dimensions and properties

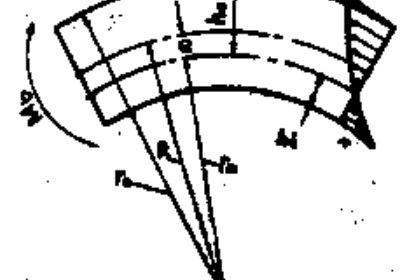
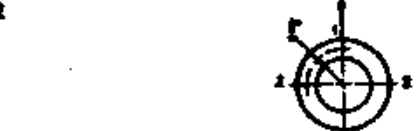
Designation	Weight per Metre w kgf	Sectional Area a cm ²	Depth of Section h mm	Width of Flange b mm	Thickness of Flange t _f mm	Thickness of Web t _w mm	Centre of Gravity c _{xx} cm	Moments of Inertia		Radii of Gyration	
								I _{xx} cm ⁴	I _{yy} cm ⁴	r _{xx} cm	r _{yy} cm
ISNT 20	1.1	1.45	20	20	4.0	4.0	0.60	0.5	0.2	0.58	0.41
ISNT 30	1.8	2.26	30	30	4.0	4.0	0.82	1.8	0.8	0.89	0.59
ISNT 40	3.5	4.45	40	40	6.0	6.0	1.14	6.1	2.9	1.18	0.81
ISNT 50	4.4	5.66	50	50	6.0	6.0	1.35	12.3	5.7	1.47	1.01
ISNT 60	5.4	6.85	60	60	6.0	6.0	1.56	21.4	9.7	1.77	1.19
ISNT 75	10.0	6.90	75	75	9.0	9.0	2.04	62.0	29.2	2.21	1.52
ISNT 100	14.9	18.97	100	100	10.0	10.0	2.62	163.9	76.8	2.94	2.01
ISNT 150	22.7	28.88	150	150	10.0	10.0	3.61	541.1	250.3	4.33	2.94
ISDT 100	8.1	10.37	100	50	10.0	5.8	3.03	99.0	9.6	3.09	0.96
ISDT 150	15.7	19.96	150	75	11.6	8.0	4.75	450.2	37.0	4.75	1.36
ISLT 200	28.4	36.22	200	165	12.5	8.0	4.78	1267.8	358.2	5.92	3.15
ISLT 250	37.5	47.75	250	180	14.1	9.2	6.40	2774.4	532.0	7.62	3.34
ISMT 50	5.7	7.30	50	75	7.2	4.0	0.96	9.7	20.4	1.15	1.67
ISMT 62.2	6.5	8.30	62.5	75	7.6	4.4	1.30	21.3	21.9	1.60	1.62
ISMT 75	7.5	9.50	75	80	7.6	4.8	1.67	40.1	26.3	2.05	1.66
ISMT 87.5	9.7	12.31	87.5	90	8.6	5.5	1.98	72.6	42.5	2.43	1.86
ISMT 100	12.7	16.16	100	100	10.8	5.7	2.13	115.8	75.0	2.68	2.15
ISHT 75	15.3	19.49	75	150	9.0	8.4	1.62	96.2	230.2	2.22	3.44
ISHT 100	20.0	25.47	100	200	9.0	7.8	1.91	193.8	497.3	2.76	4.42
ISHT 125	27.4	34.85	125	250	9.7	8.8	2.37	415.4	1005.8	3.45	5.37
ISHT 150	29.4	37.42	150	250	10.6	7.6	2.66	573.7	1096.8	3.92	5.41

Note: ISNT—Indian standard normal tee bars
 ISDT—Indian standard deep legged tee bars
 ISLT—Indian standard slit light weight tee bars
 ISMT—Indian standard slit medium weight tee bars
 ISHT—Indian standard slit bars from H-section

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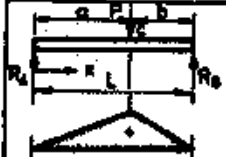
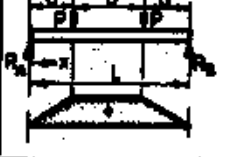
Radius of gyration	Modulus of section	Area moment of inertia
$r_1 = 0.1322 d$	$Z_1 = 0.0238 d^3$	$I_1 = 0.007 d^4$
$r_1 = \frac{2}{\pi}$ $r_2 = \frac{2}{\pi}$	$Z_1 = \frac{4}{\pi} a^2 b$ $Z_2 = \frac{4}{\pi} b^2 a$	$I_1 = \frac{4}{\pi} a^2 b$ $I_2 = \frac{4}{\pi} b^2 a$
$r_1 = r_2 = \sqrt{\frac{d^2 + d^2}{2}}$	$Z_1 = Z_2 = \frac{\pi (d^3 - d^3)}{32}$	$I_1 = I_2 = \frac{\pi (d^4 - d^4)}{64}$
$r_1 = r_2 = \frac{d}{2}$	$Z_1 = Z_2 = \frac{\pi d^3}{32}$	$I_1 = I_2 = \frac{\pi d^4}{64}$
$r_1 = \sqrt{\frac{bh^3 - b_1h_1^3}{12(bh - b_1h_1)}}$ $Z_1 = \frac{bh^2 - b_1h_1^2}{6h}$	$Z_2 = \frac{bh^2 - b_1h_1^2}{6h}$	$I_1 = \frac{bh^3 - b_1h_1^3}{12}$
$r_1 = 0.235h$ $Z_1 = \frac{bh^2}{84}$	$Z_2 = \frac{bh^2}{84}$	$I_1 = \frac{bh^3}{36}$
$r_1 = \frac{3(2b+b_1)}{b} \sqrt{\frac{6b^3 + 6bb_1 + b_1^3}{2}}$ $Z_1 = \frac{6b^2 + 6bb_1 + b_1^2}{12(3b+2b_1)} h^2$	$Z_2 = \frac{6b^2 + 6bb_1 + b_1^2}{12(3b+2b_1)} h^2$	$I_1 = \frac{6b^3 + 6bb_1 + b_1^3}{36(2b+b_1)} h^3$
$r_1 = 0.4568$ $Z_1 = 0.6258$ $Z_2 = 0.54135$	$Z_1 = 0.6258$ $Z_2 = 0.54135$	$I_1 = I_2 = 0.54135$
$r_1 = r_2 = 0.289 b$ $Z_1 = Z_2 = \frac{6}{b^2}$	$Z_1 = Z_2 = \frac{6}{b^2}$	$I_1 = I_2 = \frac{6}{b^4}$
$r_1 = \sqrt{\frac{h^3 - h_1^3}{12(h - h_1)}}$ $Z_1 = \frac{6}{b} \left[\frac{h^2 - h_1^2}{h - h_1} \right]$	$Z_1 = \frac{6}{b} \left[\frac{h^2 - h_1^2}{h - h_1} \right]$	$I_1 = \frac{6}{b} \left[\frac{h^3 - h_1^3}{h - h_1} \right]$
$r_1 = 0.289b$ $Z_1 = \frac{6}{bh^2}$ $Z_2 = \frac{6}{bh^2}$	$Z_1 = \frac{6}{bh^2}$ $Z_2 = \frac{6}{bh^2}$	$I_1 = \frac{6}{bh^3}$ $I_2 = \frac{6}{bh^3}$

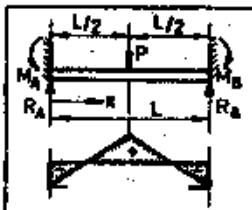
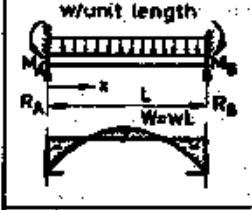
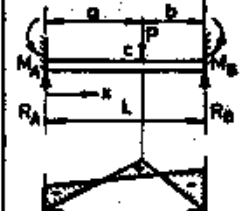
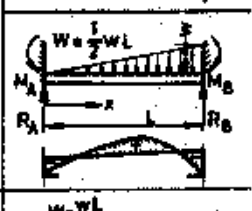
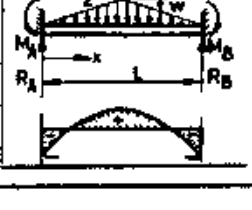
Straight Beam	$\sigma_b = \frac{M_b y}{I}$	M_b , bending moment, kgf cm a , area of cross section, cm ²	
Curved Beam	$\sigma_b = \frac{M_b y}{ae(r_n - y)}$	r , radius of curvature of neutral axis y , distance of fibre from NA, cm y is positive when measured towards centre of curvature	
Outer Fibre	$\sigma_{b \max} = \frac{M_b h_o}{ae r_o}$	y is negative when measured from NA away from centre of curvature	+ve, Tensile -ve, Compressive
Inside Fibre	$ \sigma_{b \max} = \frac{M_b h_i}{ae r_i}$	b , bending stress, kgf/cm ² r_o , outer radius of curvature of beam, cm	
Curved beam of elliptical cross section	$\sigma_{b \max} = \frac{4M_b'}{\pi a^3 b} \left[1 + \frac{0.6a}{r_i} \right]$	b_o , distance of outer fibre from NA, cm r_i , inner radius of curvature of beam, cm	
Inner Fibre		b_i , distance of inner most fibre from NA, cm r , mean radius, cm	
Ring	$M_1 = -0.318 Pr$ $M_2 = +0.182 Pr$	P , load, kgf M_1, M_2 , bending moment at 1 and 2, kgf cm	
Link of a Chain	$M_1 = \frac{Pr(2r+L)}{2(\pi r+L)}$ $M_2 = \frac{Pr(2r-\pi r)}{2(\pi r+L)}$		

	$r_n = \frac{4}{\pi} \left[\sqrt{r_0^2 + \sqrt{r_0^2}} \right]$ $R = r_1 + \frac{d}{2}$
	$r_n = \frac{b}{h} \ln \left(\frac{r_1}{r_0} \right)$ $R = r_1 + \frac{b}{2}$
	$r_n = \frac{(b_f - t_w) r_1 + (b_w - t_w) r_0 + t_w \ln \left(\frac{r_1}{r_0} \right) + b_w \ln \left(\frac{r_1}{r_0} \right)}{(b_f - t_w) r_1 + (b_w - t_w) r_0 + t_w \ln \left(\frac{r_1}{r_0} \right) + b_w \ln \left(\frac{r_1}{r_0} \right)}$ $R = r_1 + \frac{b_f h_w + \frac{1}{2} t_w (b_w - t_w) (b_f - t_w)}{(b_f - t_w) r_1 + (b_w - t_w) r_0 + t_w \ln \left(\frac{r_1}{r_0} \right) + b_w \ln \left(\frac{r_1}{r_0} \right)}$
	$r_n = \frac{(b_f - t_w) r_1 + t_w \ln \left(\frac{r_1}{r_0} \right) + t_w \ln \left(\frac{r_1}{r_0} \right)}{(b_f - t_w) r_1 + t_w \ln \left(\frac{r_1}{r_0} \right) + t_w \ln \left(\frac{r_1}{r_0} \right)}$ $R = r_1 + \frac{b_f h_w + \frac{1}{2} t_w (b_w - t_w) (b_f - t_w)}{(b_f - t_w) r_1 + t_w \ln \left(\frac{r_1}{r_0} \right) + t_w \ln \left(\frac{r_1}{r_0} \right)}$
	$r_n = \frac{\frac{h}{3} (b_1 + b_2) \ln \left(\frac{r_1}{r_0} \right) - (b_1 - b_2) \left(\frac{r_1}{r_0} \right)}{\frac{h}{3} (b_1 + b_2) \ln \left(\frac{r_1}{r_0} \right) - (b_1 - b_2) \left(\frac{r_1}{r_0} \right)}$ $R = r_1 + \frac{b (b_1 + b_2)}{3 (b_1 + b_2)}$
	$r_n = \frac{b \ln \left(\frac{r_1}{r_0} \right) + t \ln \left(\frac{r_1}{r_0} \right) + t \ln \left(\frac{r_1}{r_0} \right)}{(b - t) (r_1 + r_0) + t h}$ $R = r_1 + \frac{b h^2 r_1 + \frac{1}{2} t^2 (b - t) (r_1 + r_0)}{(b - t) (r_1 + r_0) + t h}$ r_0, distance from the centre of curvature to the centroidal axis r_n, distance from the centre of curvature to the neutral axis

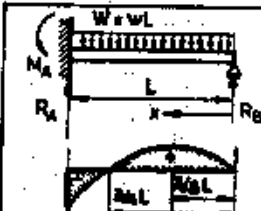
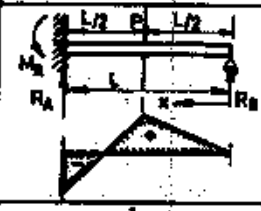
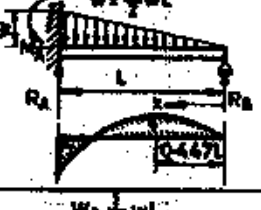
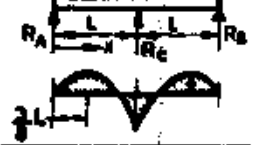
Bending Moment	Reaction	Deflection	Type of Loading
$M_x = -Px$ $M_{\max} = -PL$	$R_B = P$	$y = \frac{P}{6EI} [2L^3 - 3L^2x + x^3]$ $y_{\max} = \frac{PL^3}{3EI}$ at $x = 0$	
$M_x = -\frac{wx^2}{2}$ $M_{\max} = -\frac{wL^2}{2}$	$R_B = wL$	$y = \frac{w}{24EI} [3L^4 - 4L^3x + x^4]$ $y_{\max} = \frac{wL^4}{8EI}$ at $x = 0$	
$M_x = -P(x-a)$ for $x > a$ $M_{\max} = -P(L-a)$	$R_B = P$	$y = \frac{P}{EI} (L-a)^2 \left[\frac{(L-a)}{3} + \frac{(a-x)}{2} \right]$, $0 < x < a$ $y = \frac{P}{6EI} [(x-a)^3 + (L-a)^2 (2L-3x+a)]$, $a < x < L$ $y_{\max} = \frac{P(L-a)^3}{3EI} + a \frac{P(L-a)^2}{2EI}$ at $x = 0$	
$M_x = -\frac{wx^3}{6L}$ $M_{\max} = -\frac{wL^3}{6L}$	$R_B = \frac{wL}{2}$	$y = \frac{w}{120EI} [x^6 - 5L^4x + 4L^5]$ $y_{\max} = \frac{wL^4}{30EI}$ at $x = 0$	
$M_x = -\frac{wx^2}{6L} (3L-x)$ $M_{\max} = -\frac{wL^2}{3}$	$R_B = \frac{wL}{2}$	$y = \frac{w}{120EI} [-x^5 - 15L^4x + 5Lx^4 + 11L^5]$ $y_{\max} = \frac{11}{120EI} wL^4$ at $x = 0$	
$M_x = -m$ constant	$R_B = 0$	$y = \frac{m}{2EI} [L^2 - 2Lx + x^2]$ $y_{\max} = \frac{mL^2}{2EI}$ at $x = 0$	

SIMPLY SUPPORTED BEAM

Bending Moment	Reaction	Deflection	Type of Loading
$M_x = \frac{P}{2} x, 0 < x < \frac{L}{2}$ $M_{max} = \frac{PL}{4}$	$R_A = \frac{P}{2}$ $R_B = \frac{P}{2}$	$y = \frac{Px}{48EI} [3L^2x - 4x^3]$ $y_{max} = \frac{PL^3}{48EI}$ at $x = \frac{L}{2}$	
$M_x = \frac{Pb}{L} x, 0 < x < a$ $M_a = \frac{Pab}{L}$ $M_{max} = \frac{Pab}{L}$	$R_A = \frac{Pb}{L}$ $R_B = \frac{Pa}{L}$	$y_x = \frac{Pbx}{6EI} [L^2 - b^2 - x^2]$ $y_a = \frac{Pa^3b^3}{3EI}$ $y_{max} = \frac{Pb}{9\sqrt{3}EI} [a^3 + 2ab]^{\frac{2}{3}}$ at $x = \frac{a^3 + 2ab}{3}$	
$M_x = \frac{wLx}{2} - \frac{wx^2}{2}$ $M_{max} = \frac{wL^2}{8}$ at $x = \frac{L}{2}$	$R_A = \frac{wL}{2}$ $R_B = \frac{wL}{2}$	$y = \frac{wx}{24EI} [L^3 - 2Lx^2 + x^3]$ $y_{max} = \frac{5}{384} \frac{wL^4}{EI}$ at $x = \frac{L}{2}$	
$M_x = Px$ for $0 < x < a$ $M_x = Pa$ for $a < x < a + b$ $M_{max} = Pa$	$R_A = P$ $R_B = P$	$y = \frac{Px}{6EI} [3a(L-a) - x^2]$ for $0 < x < a$ $y = \frac{Pa}{6EI} [3x(L-x) - a^2]$ for $a < x < a + b$ $y_{max} = \frac{Pa}{24EI} [3L^2 - 4a^2]$ at $x = \frac{L}{2}$	
$M_x = Wx \left[\frac{1}{2} - \frac{2}{3} \frac{x^2}{L^2} \right]$ for $0 < x < \frac{L}{2}$	$R_A = \frac{W}{2}$ $R_B = \frac{W}{2}$	$y = \frac{Wx}{60EI} \left[L^3 \frac{x^2}{2} - \frac{x^4}{5} - 5 \frac{L^4}{16} \right]$ for $0 < x < \frac{L}{2}$ $y_{max} = \frac{WL^3}{60EI}$ at $x = \frac{L}{2}$	
$M_{max} = \frac{WL}{6}$ at $x = \frac{L}{2}$ $M_x = \frac{Wx}{3} \left[1 - \frac{x^2}{L^2} \right]$ $M_{max} = 0.128 WL$ at $x = 0.5774 L$	$R_A = \frac{W}{3}$ $R_B = \frac{2W}{3}$	$y = \frac{Wx}{180EI} [3x^4 - 10L^2x^2 + 7L^4]$ $y_{max} = 0.01304 \frac{WL^3}{EI}$ at $x = 0.519 L$	

Reaction	Bending Moment	Deflection	Type of Loading
$R_A = \frac{P}{2}$ $R_B = \frac{P}{2}$	$M_{max}(+) = \frac{PL}{8}; M_{max}(-) = \frac{PL}{8}$ $M_A = M_B = -\frac{PL}{8}$	$y_x = \frac{-Px^2}{EI} \left[\frac{x}{12} - \frac{L}{16} \right]$ for $0 < x < \frac{L}{2}$ $y_{max} = \frac{PL^3}{192EI}$ at $x = \frac{L}{2}$	
$R_A = \frac{W}{2}$ $R_B = \frac{W}{2}$	$M_{max}(-) = M_A = M_B = -\frac{WL}{12}$ $M_x = \frac{W}{2L} \left[\frac{L^3}{6} - Lx + x^3 \right]$ $M_{max} = \frac{WL}{24}$ at $x = \frac{L}{2}$	$y_x = \frac{Wx^3}{24EI} (1-x)^2$ $y_{max} = \frac{WL^3}{384EI}$ at $x = \frac{L}{2}$	
$R_A = \frac{Pb^2}{L^3} (3a+b)$ $R_B = \frac{Pa^2}{L^3} (3b+a)$	$M_A = -\frac{Pab^2}{L^2}; M_B = -\frac{Pa^2b}{L^2}$ $M_{max} = \frac{Pb^2}{L^3} (3a+b)a - \frac{Pab^2}{L^3}$ (+)	$y_x = \frac{Pb^3 x^3}{6EI L^3} [3aL - 3ax - bx]$ for $0 < x < a$ $y_{max} = \frac{2Pa^3 b^3}{3EI(3a+b)^3}$ at $x = \frac{2aL}{3a+b}$ $a > b$ $y_c = \frac{Pa^3 b^3}{3EI L^3}$	
$R_A = \frac{3W}{10}$ $R_B = \frac{7W}{10}$	$M_A = -\frac{WL}{15}; M_B = -\frac{WL}{10}$ $M_x = W \left[\frac{3x}{10} - \frac{L}{15} - \frac{x^3}{3L^2} \right]$ $M_{max} = 0.043 WL$ at $x = 0.548 L$	$y_x = \frac{-W}{60EI L^3} [3L^2 x^3 - 2L^2 x^2 - x^5]$ $y_{max} = \frac{WL^3}{384EI}$ at $x = 0.525L$	
$R_A = R_B = \frac{W}{2}$	$M_A = M_B = -\frac{5}{48} WL; M_x = W \left[\frac{x}{2} - \frac{5L}{48} - \frac{2x^3}{3L^2} \right]$ $M_{max} = \frac{WL}{16}$ at $x = \frac{L}{2}$	$y_x = \frac{-W}{480EI L^2} [40L^2 x^3 - 25L^2 x^2 - 16x^5]$ for $0 < x < \frac{L}{2}$ $y_{max} = \frac{7WL^3}{1920EI}$ at $x = \frac{L}{2}$	

PROPPED BEAM

Bending Moment	Reaction	Deflection	Type of Loading
$M_A = -\frac{WL}{8}$ $M_x = W \left[\frac{3}{8}x - \frac{x^2}{2L} \right]$ $M_{max}(+) = \frac{9}{128} WL$ at $x = \frac{3}{8} L$	$R_A = \frac{5}{8} W$ $R_B = \frac{3}{8} W$	$y_x = \frac{-W}{48EI} [3Lx^3 - 2x^4 - L^3x]$ $y_{max} = 0.0054 \frac{WL^3}{EI}$ at $x = 0.4215L$	
$M_A = -\frac{3}{16} PL$ $M_x = \frac{5}{16} Px - P \left(x - \frac{L}{2} \right); M_{max}(+) = \frac{5}{32} PL$	$R_A = \frac{11}{16} P$ $R_B = \frac{5}{16} P$	$y_x = \frac{Px}{96EI} [3L^3 - 5x^3]; y_{max} = 0.00932 \frac{PL^3}{EI}$ at $x = \frac{L}{\sqrt{5}}$	
$M_A = -\frac{2}{15} WL$ $M_x = Wx \left[\frac{1}{5} - \frac{x^3}{3L^3} \right]; M_{max}(+) = 0.0596 WL$ at $x = 0.447 L$	$R_A = \frac{4}{5} W$ $R_B = \frac{1}{5} W$	$y_x = \frac{-Wx}{EI} \left[\frac{x^3}{30} - \frac{x^4}{60L} - \frac{L^3}{60} \right]$ $y_{max} = 0.0047 \frac{WL^3}{EI}$ at $x = 0.447L$	
$M_A = -\frac{7}{60} WL$ $M_x = -\frac{WL}{60} \left[20 \frac{x^3}{L^3} - 27 \frac{x}{L} + 7 \right]$ $M_{max}(+) = 0.0846 WL$ at $x = 0.67 L$	$R_A = \frac{9}{20} W$ $R_B = \frac{11}{20} W$	$y_x = \frac{WL}{360EI} \left[6 \frac{x^5}{L^3} - 27 \frac{x^3}{L} + 21x^2 \right]$ $y_{max} = 0.0061 \frac{WL^3}{EI}$ at $x = 0.598L$	
$M_x = \frac{W}{8} [3Lx - 4x^2]$ $M_{max} = \frac{9}{128} WL^2$ at $x = \frac{3}{8} L$; $M_{max}(-) = \frac{WL^2}{8}$ at $x = L$	$R_A = \frac{3}{8} WL$ $R_B = \frac{3}{8} WL$ $R_C = \frac{10}{8} WL$	$y_x = \frac{W}{48EI} [L^3x - 3Lx^2 + 2x^3]$ $y_{max} = 0.00541 \frac{WL^4}{EI}$ at $x = 0.4215L$	

Euler's
Formula

$$P_c = \frac{n\pi^2 Ea}{(L/r)^2} = \frac{n\pi^2 EI}{L^2}$$

for $L/r > 120$ (steels)

Johnson's
Parabolic
Formula

$$P_c = a \sigma_y \left[1 - \frac{\sigma_y}{4n\pi^2 E} \left(\frac{L}{r} \right)^2 \right]$$

for $L/r < 120$ (steels)

Straight-
Line
Formula

$$P_c = a \left[\sigma_y - \frac{2\sigma_y}{3\pi} \left(\frac{L}{r} \right) \sqrt{\frac{\sigma_y}{3nE}} \right]$$

for $L/r < 120$ (steels)

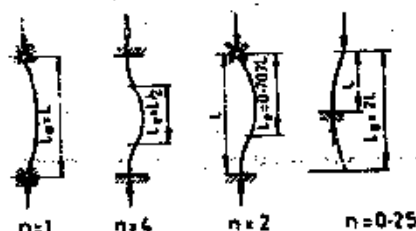
Ritter's
Formula

$$P_c = \frac{a \sigma_c}{1 + \frac{\sigma_y}{n\pi^2 E} \left(\frac{L}{r} \right)^2}$$

Rankine
Formula

$$P_c = \frac{a \sigma_c}{1 + C \left(\frac{L}{r} \right)^2}$$

for $60 < L/r < 120$ (steels)



n , coefficient of end condition

P_c , buckling load

E , Young's modulus

a , area of cross section

L , length of the column

I , area moment of inertia

r , least radius of gyration

L/r , slenderness ratio

σ_y , yield stress

σ_c , critical or buckling stress

e , eccentricity

y , distance of the outermost fibre from the neutral plane

Material W I C I Steel Timber

Rankine
Constant C 1/9000 1/1600 1/7500 1/750

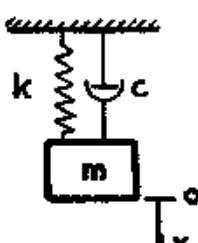
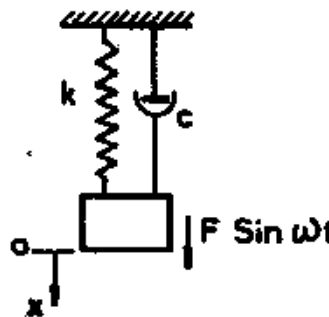
Values of C given above are for $n=1$.

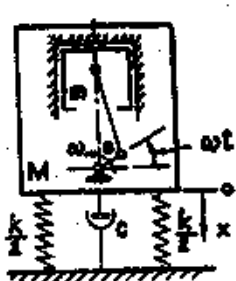
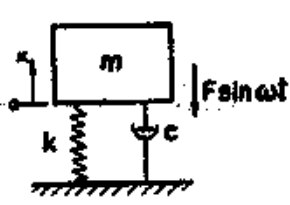
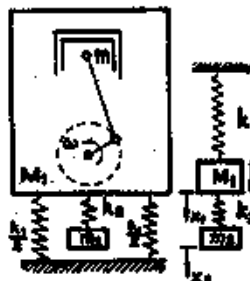
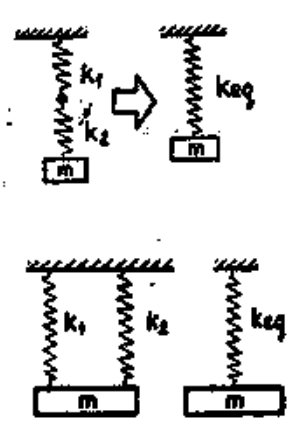
For other end conditions divide the above values by n .

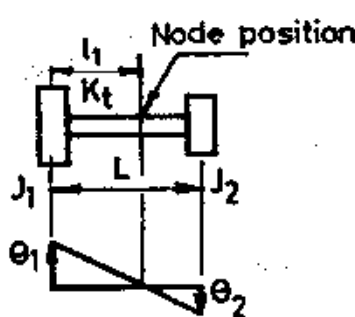
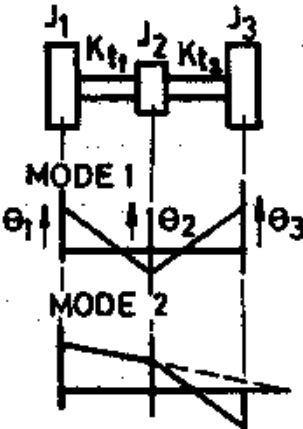
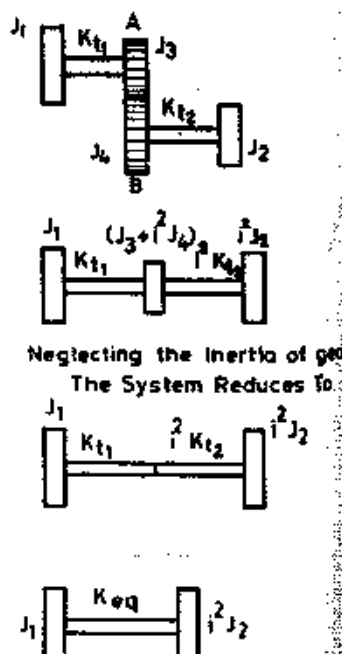
Secant
Formula
for
eccentrically
loaded
columns

$$P_c = \frac{a \sigma_y}{1 + \frac{ey}{r^2} \sec \left(\frac{L}{2r} \sqrt{\frac{P_c}{aE}} \right)}$$

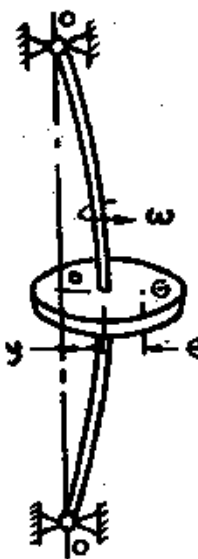
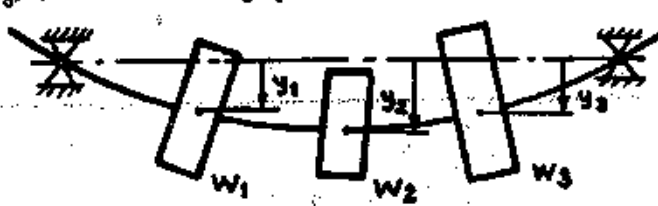
VIBRATION

Type	Equation and Solution	Figure and Notation
Free Vibration	$m\ddot{x} + kx = 0$ Linear $x = A \sin(\omega_n t - \phi)$ $\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{g}{\Delta}}$	
	Torsional $J\ddot{\theta} + k_t\theta = 0$ $\theta = A \sin(\omega_n t - \phi)$ $\omega_n = \sqrt{\frac{k_t}{J}}$	
Free Damped Vibration	$m\ddot{x} + c\dot{x} + kx = 0$ $x = Ae^{-\zeta\omega_n t} \sin(\omega_d t + \psi)$ $\omega_d = \omega_n \sqrt{1 - \zeta^2}$ $c_c = 2m\omega_n$ $\delta = \ln \frac{x_0}{x_1} = \ln \frac{x_1}{x_2} = \frac{2\pi\zeta}{\sqrt{1 - \zeta^2}}$	
	$m\ddot{x} + c\dot{x} + kx = F \sin \omega t$ $x = Ae^{-\zeta\omega_n t} \sin(\omega_d t + \psi) + X \sin(\omega t - \phi)$ Steady state amplitude $X = \frac{F/k}{\sqrt{(1 - r^2)^2 + (2\zeta r)^2}}$ $D = \frac{1}{\sqrt{(1 - r^2)^2 + (2\zeta r)^2}} = \frac{X}{X_0}$ $\tan \phi = \frac{2\zeta r}{1 - r^2}$ X is max. when $r = \sqrt{1 - 2\zeta^2}$ $\frac{X_{max}}{X_0} = \frac{1}{2\zeta\sqrt{1 - \zeta^2}}$ $\tan \phi = \frac{1}{\zeta} \sqrt{1 - 2\zeta^2}$ At resonance, $r = 1$ $X_{r.s.} = \frac{F}{c\omega_n} = \frac{X_0}{2\zeta}$	
Forced Vibration with Damping		

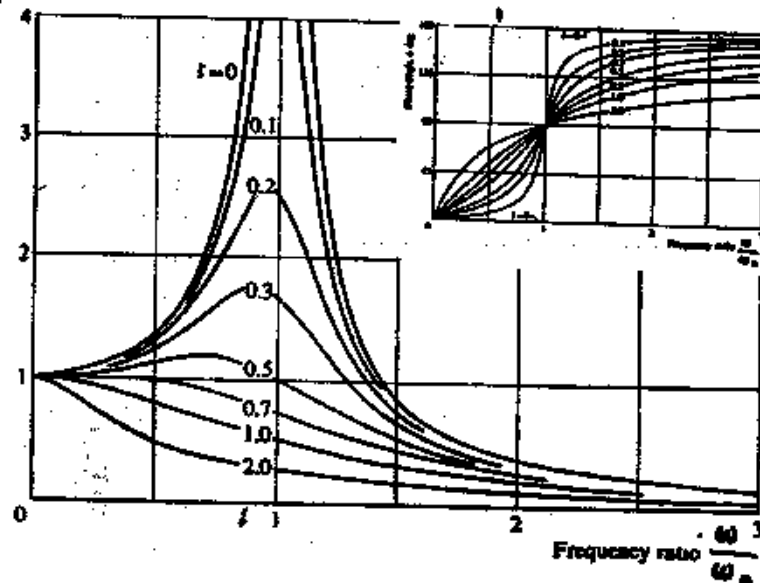
Type	Equation and Solution	Figure and Notation
Unbalance due to Reciprocating Mass	$M\ddot{x} + c\dot{x} + kx = me\omega^2 \sin \omega t$ Steady state amplitude, $X = \frac{(m/M) e r^2}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}}$	x, displacement m, mass M, M, total mass including m e, eccentricity ω, applied frequency 
Vibration Isolation	$T_R = \frac{F_{TR}}{F} = \frac{\sqrt{1+(2\zeta r)^2}}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}}$ When $\zeta=0$, $T_R = \frac{1}{1-r^2}$	$r = \frac{\omega}{\omega_n}$, frequency ratio $\omega_n = \sqrt{\frac{k}{m}}$ natural frequency c=damping coefficient 
Undamped Dynamic Absorber	$M_1\ddot{x}_1 + (k_1 + k_2)x_1 - k_2x_2 = F \sin \omega t$ $-k_2x_1 + m_2\ddot{x}_2 + k_2x_2 = 0$ $x_1 = X_1 \sin(\omega t + \phi_1)$ $x_2 = X_2 \sin(\omega t + \phi_2)$ When $k_2 - m_2 \omega^2 = 0$, $X_1 = 0; \text{ and } X_2 = -\frac{F}{k_2}$ Undamped dynamic absorber is tuned such that $\frac{k_1}{M_1} = \frac{k_2}{m_2}$	$\zeta = \frac{c}{c_0}$, damping factor c_0, critical damping factor T_R, transmissibility F_{TR}, Force transmitted to foundation F, Maximum periodic force 
Equivalent Springs	$k_{eq} = \frac{k_1 k_2}{k_1 + k_2}$ Springs in series $k_{eq} = k_1 + k_2$ Springs in parallel	k, spring constant k_{eq}, equivalent spring constant 

Type	Equation and Solution	Figure and notation
Torsional Vibration Two Rotor System	Semi definite system $\omega_n = \sqrt{\frac{k_t (J_1 + J_2)}{J_1 J_2}}$ $l_1 = \left(\frac{J_2}{J_1 + J_2} \right) L$	ω_n, natural frequency J, mass moment of inertia k_t, torsional stiffness θ, angular amplitude l_1, distance of node from J_1
	Semi definite system $J_1 \ddot{\theta}_1 + k_{t1} (\theta_1 - \theta_2) = 0$ $J_2 \ddot{\theta}_2 + k_{t1} (\theta_2 - \theta_1) + k_{t2} (\theta_2 - \theta_3) = 0$ $J_3 \ddot{\theta}_3 + k_{t2} (\theta_3 - \theta_2) = 0$ Frequency equation $\omega^2 \left[\omega^4 - \left\{ k_{t1} \left(\frac{1}{J_1} + \frac{1}{J_2} \right) + k_{t2} \left(\frac{1}{J_2} + \frac{1}{J_3} \right) \right\} \omega^2 + k_{t1} k_{t2} \left(\frac{J_1 + J_2 + J_3}{J_1 J_2 J_3} \right) \right] = 0$	
Torsional Vibration Three Rotor System	Roots of this equation are $\omega = 0, \omega_1 \text{ and } \omega_2$ Amplitude ratio $\frac{\theta_1}{\theta_2} = \frac{k_{t1}}{k_{t1} - J_1 \omega^2}, \quad \frac{\theta_2}{\theta_3} = \frac{k_{t2} - J_3 \omega^2}{k_{t2}}$ $\omega = \omega_1 \text{ or } \omega_2$	
Geared Systems	$k_{eq} = \frac{i^2 k_{t1} k_{t2}}{k_{t1} + i^2 k_{t2}}$ $\omega_n = 0, \sqrt{k_{eq} \left(\frac{1}{J_1} + \frac{1}{i^2 J_2} \right)}$ $i = \frac{\text{speed of gear B}}{\text{speed of gear A}}$ (Referred to shaft 1)	 Neglecting the inertia of gear The System Reduces to

CRITICAL SPEED

Type	Equation and Solution	Figure and Notation
Single Rotor	$ky = \frac{W}{g} (y \pm e) \omega^2$ $\frac{y}{e} = \pm \frac{r^2}{1-r^2}$ $\omega_c = \sqrt{\frac{k}{m}} = \sqrt{\frac{g}{\Delta}}$	$m = \frac{W}{g}$, mass W, weight of rotor $r = \frac{\omega}{\omega_n}$, frequency ratio k, transverse stiffness of shaft Δ, static deflection e, eccentricity of CG from shaft axis y, dynamic deflection ω_c, Critical or whirling speed 
Multi Rotor	Rayleigh—Ritz equation $\omega_c = \sqrt{\frac{g \sum_{n=1}^3 W_n y_n}{\sum_{n=1}^3 W_n y_n^2}}$	
	Dunkerley equation $\frac{1}{\omega_c^2} = \frac{1}{\omega_1^2} + \frac{1}{\omega_2^2} + \frac{1}{\omega_3^2} + \dots + \frac{1}{\omega_n^2}$	ω_c Rayleigh, Slightly more than the correct critical speed ω_c Dunkerley, Slightly less than the correct critical speed ω_1, Critical speed of shaft only $= \pi \sqrt{\frac{gEI}{wl^3}}$ where w is weight per unit length of shaft l, length of shaft ω_1, Critical speed of shaft due to weight W_1 only ω_n, Critical speed of shaft due to weight W_n only

$\frac{X}{X_0}$
Magnification factor

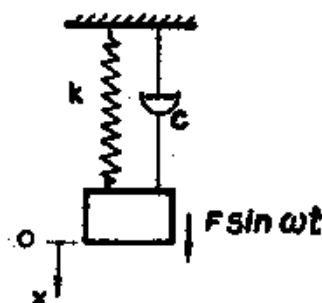


FORCED VIBRATION WITH DAMPING

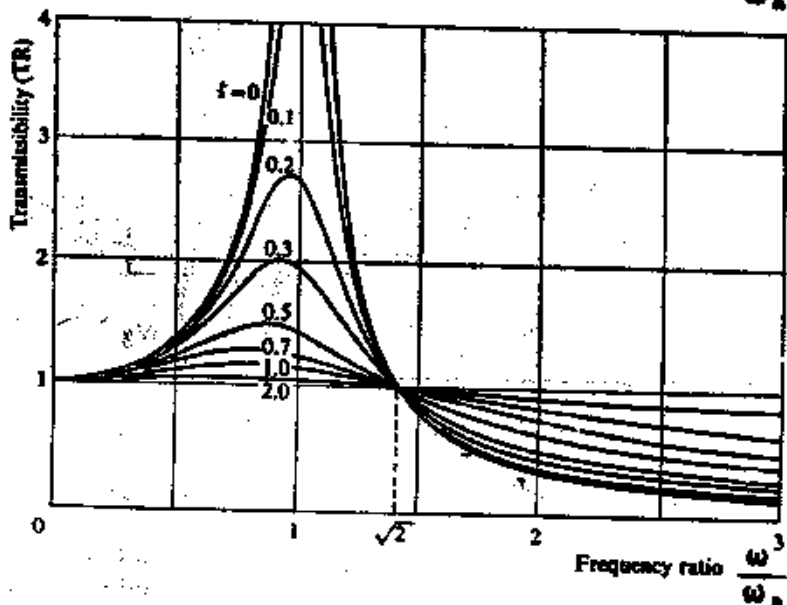
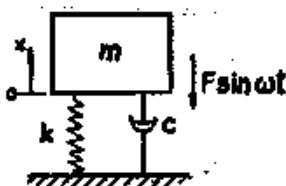
X = Maximum amplitude of steady-state forced vibration

X_0 = Equivalent static deflection

$$x = \frac{\frac{F}{k} \sin(\omega t - \phi)}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}}$$



$$TR = \frac{F_{TR}}{F} = \frac{\sqrt{1 + (2\zeta r)^2}}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}}$$



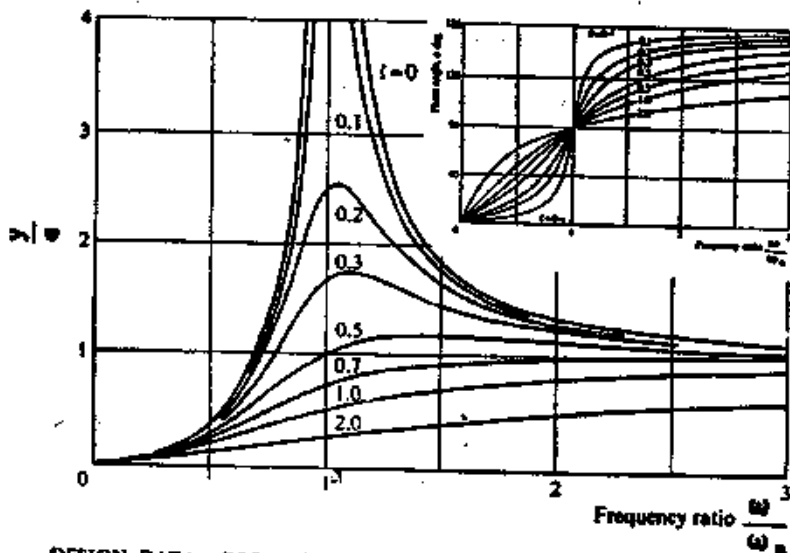
CRITICAL SPEED

y , deflection due to dynamic load

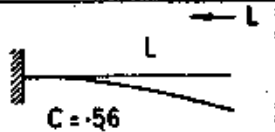
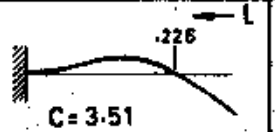
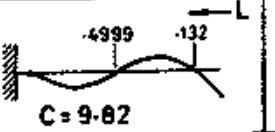
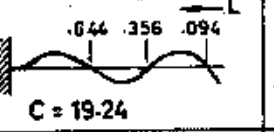
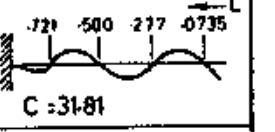
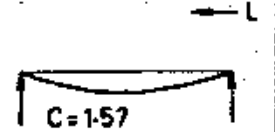
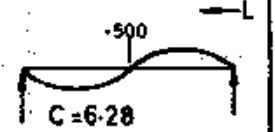
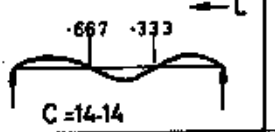
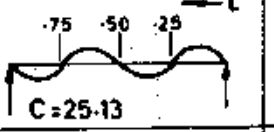
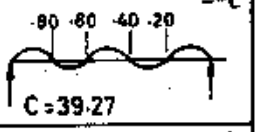
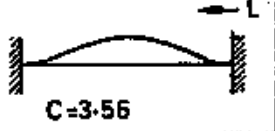
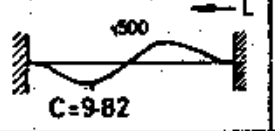
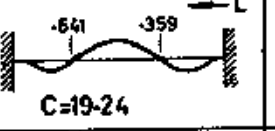
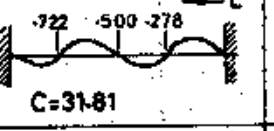
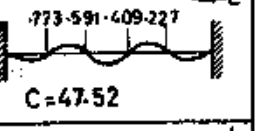
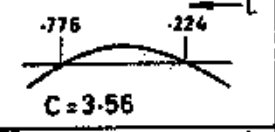
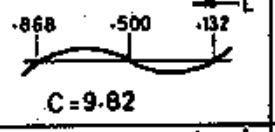
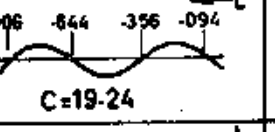
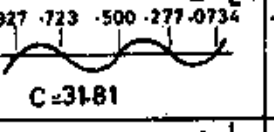
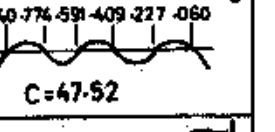
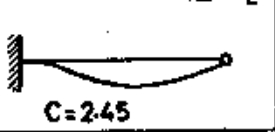
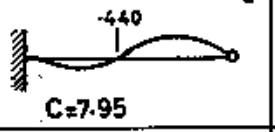
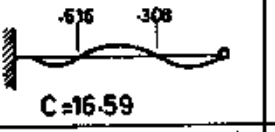
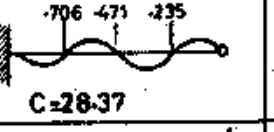
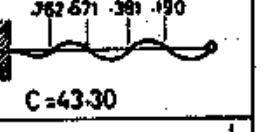
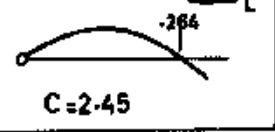
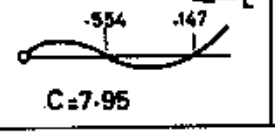
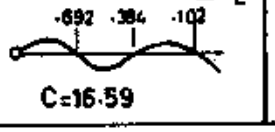
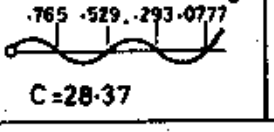
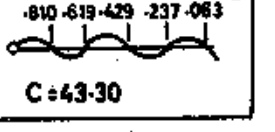
e , eccentricity of the CG from the shaft axis

$$\frac{y}{e} = \frac{r^2}{\sqrt{(1-r^2)^2 + (2\zeta r)^2}}$$

$$\tan \phi = \frac{2\zeta r}{1-r^2}$$



NATURAL FREQUENCY CONSTANTS OF BEAMS

Cantilever	 C = .56	 C = 3.51	 C = 9.82	 C = 19.24	 C = 31.81
Simply supported ends	 C = 1.57	 C = 6.28	 C = 14.14	 C = 25.13	 C = 39.27
Fixed ends	 C = 3.56	 C = 9.82	 C = 19.24	 C = 31.81	 C = 47.52
Free ends	 C = 3.56	 C = 9.82	 C = 19.24	 C = 31.81	 C = 47.52
Fixed - hinged	 C = 2.45	 C = 7.95	 C = 16.59	 C = 28.37	 C = 43.30
Hinged - free	 C = 2.45	 C = 7.95	 C = 16.59	 C = 28.37	 C = 43.30

$$f_n = C \sqrt{\frac{gEI}{wL^4}}$$

w = weight of unit length of beam

L = beam length

f_n = natural frequency in cycles/sec

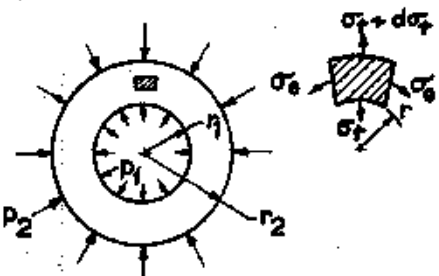
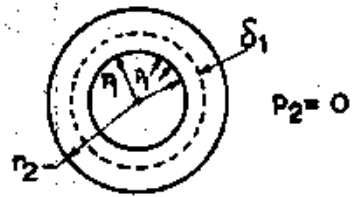
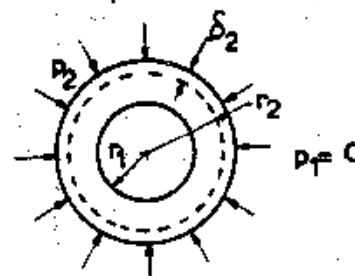
C = constant from above table

g = acceleration due to gravity

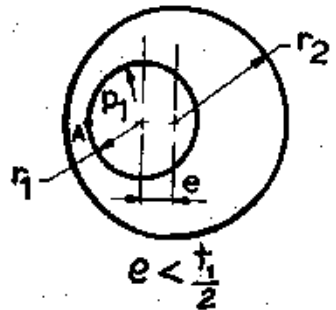
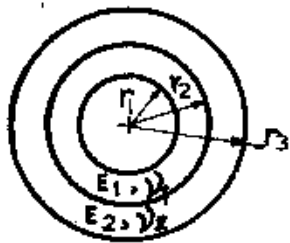
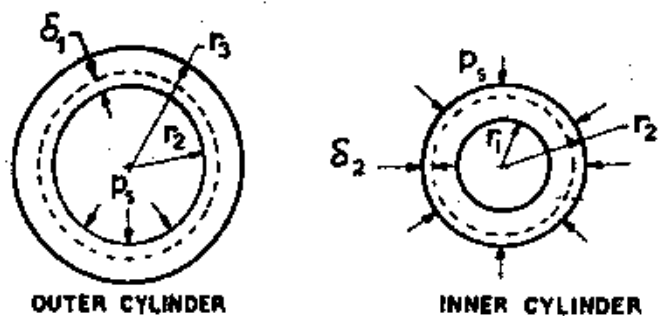
E = modulus of elasticity

I = sectional moment of inertia

THICK CYLINDERS

	Formula	Figure & notation
hollow cylinder subjected to int. & external pressure	Radial stress $\sigma_r = \frac{p_1 r_1^2 - p_2 r_2^2}{r_2^2 - r_1^2} + \frac{r_1^2 r_2^2}{r^2} \frac{(p_2 - p_1)}{r_1^2 - r_2^2}$ hoop stress $\sigma_\theta = \frac{p_1 r_1^2 - p_2 r_2^2}{r_2^2 - r_1^2} + \frac{r_1^2 r_2^2}{r^2} \frac{(p_1 + p_2)}{r_1^2 - r_2^2}$	
closed ends	long. stress $\sigma_z = \frac{p_1 r_1^2 - p_2 r_2^2}{r_2^2 - r_1^2}$	
radial displacement	$\delta_1 = \frac{p_1 r_1}{E} \left[\frac{(r_2^2 + r_1^2)}{r_2^2 - r_1^2} + \nu \right]$ $\delta_2 = \frac{p_1 r_2}{E} \left[\frac{r_2^2 + r_1^2}{r_2^2 - r_1^2} - \nu \right]$	
hollow cylinder subjected to internal pressure only	thickness = $r_2 - r_1 = t$ $\frac{t}{r_1} = \left\{ 1 + \frac{p_1}{[\sigma]} \left/ 1 - \frac{p_1}{[\sigma]} \right\}^{\frac{1}{2}} - 1 \right.$ (Max. Principal stress theory) $\frac{t}{r_1} = \frac{1}{\left\{ 1 - 2 \frac{p_1}{[\sigma]} \right\}^{\frac{1}{2}}} - 1$ (Max. shear stress theory)	

THICK CYLINDERS (Contd)

	Formula	Figure & notation
hollow cyl. p _i only	$\frac{t}{r_1} = \left\{ 1 + (1-2\nu) \frac{p_i}{[\sigma]} \left/ 1 - (1+\nu) \frac{p_i}{[\sigma]} \right. \right\}^{\frac{1}{2}} - 1 \quad \text{max strain theory}$ $\frac{t}{r_1} = \frac{1}{\left\{ 1 - \sqrt{3} \frac{p_i}{[\sigma]} \right\}^{\frac{1}{2}}} - 1 \quad \text{distortion energy theory}$ where $[\sigma]$ is working stress	
thick cyl. with eccentric bore and subjected to internal pressure	max. hoop stress at A $(\sigma_{\theta})_A = p_i \left[\frac{2r_1^2 (r_1^2 + r_2^2 - 2r_1e - e^2)}{(r_1^2 + r_2^2)(r_1^2 - r_2^2 - 2r_1e - e^2)} - 1 \right]$	
SHRINK FIT	shrinkage allowance, $\delta = \delta_1 + \delta_2$ $\delta = p_s r_2 \left[\frac{1}{E_1} \left(\frac{r_3^2 + r_1^2}{r_3^2 - r_1^2} - \nu_1 \right) + \frac{1}{E_2} \left(\frac{r_2^2 + r_2^2}{r_2^2 - r_2^2} + \nu_2 \right) \right]$ where p_s shrink fit pressure δ value of interference between the inner and outer cylinders E, young's modulus ν, Poisson ratio	 OUTER CYLINDER INNER CYLINDER

THICK CYLINDERS (Contd.)

Formula

Figure & notation

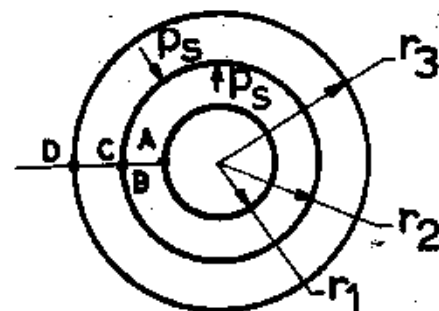
Shrunk fit
cylinders

$$(\sigma_{\theta})_A = -2 p_s \frac{r_3^2}{r_3^2 - r_1^2}$$

$$(\sigma_{\theta})_B = -p_s \frac{r_3^2 + r_1^2}{r_3^2 - r_1^2}$$

$$(\sigma_{\theta})_C = p_s \frac{r_3^2 + r_1^2}{r_3^2 - r_1^2}$$

$$(\sigma_{\theta})_D = 2 p_s \frac{r_3^2}{r_3^2 - r_1^2}$$

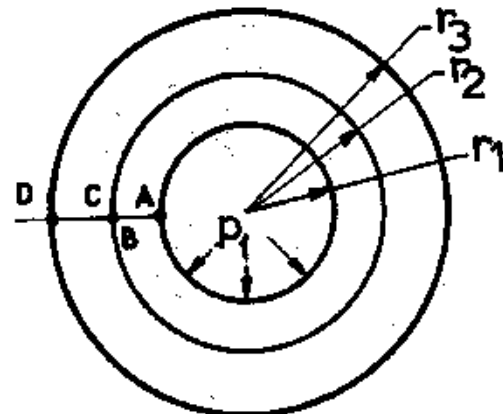
for estimation of p_s , see p. 6.19A, B ON INNER CYLINDER
C, D ON OUTER CYLINDERShrunk fit
cylinders subjected
to internal pressure

$$(\sigma_{\theta})_A = p_i \frac{r_3^2 + r_1^2}{r_3^2 - r_1^2} - 2 p_s \frac{r_1^2}{r_3^2 - r_1^2}$$

$$(\sigma_{\theta})_B = p_i \frac{r_3^2 + r_1^2}{r_3^2 - r_1^2} \left(\frac{r_1}{r_3} \right)^2 - p_s \frac{r_3^2 + r_1^2}{r_3^2 - r_1^2}$$

$$(\sigma_{\theta})_C = p_i \frac{r_3^2 + r_1^2}{r_3^2 - r_1^2} \left(\frac{r_1}{r_3} \right)^2 + p_s \frac{r_3^2 + r_1^2}{r_3^2 - r_1^2}$$

$$(\sigma_{\theta})_D = 2 p_i \frac{r_1^2}{r_3^2 - r_1^2} + 2 p_s \frac{r_3^2}{r_3^2 - r_1^2}$$

A, B ON INNER CYLINDER
C, D ON OUTER CYLINDER

Formula

Figure & notation

Shrink fit cylinders
subjected to internal
pressure

proportions of the cylinders for the optimum condition of

$$(\sigma_{\theta})_A = (\sigma_{\theta})_C = [\sigma]$$

$$t = r_3 - r_1 = r_1 (C^3 - 1)$$

$$\text{where } C^3 = \frac{1 + \frac{p_i}{[\sigma]} + 2 \left\{ 1 + \frac{p_i}{[\sigma]} \right\}^{\frac{1}{2}}}{3 - \frac{p_i}{[\sigma]}}$$

$$r_2 = C r_1 \quad \text{and} \quad r_3 = C^2 r_1 = C^3 r_1$$

A, B, on inner cyl.

C, D, on outer cylinder as before

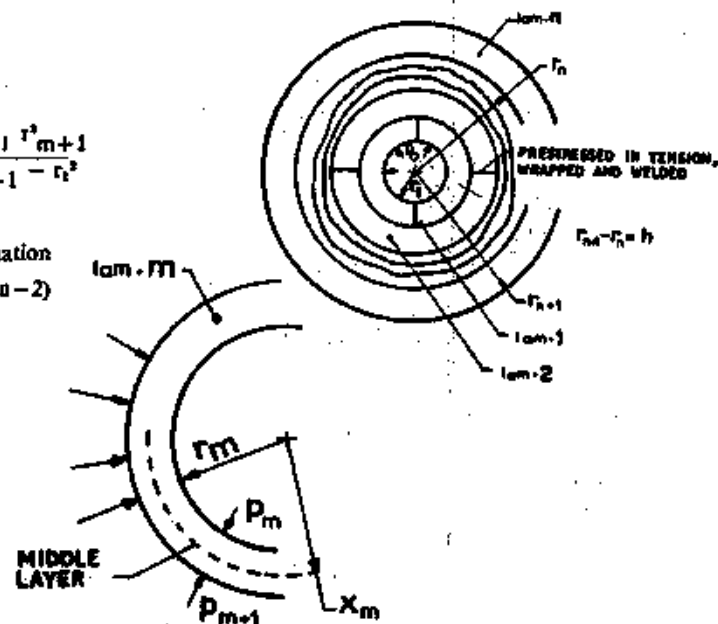
Hollow cylinder made
of thin walled lami-
nations of equal (6mm)
thickness and subjected to
internal pressure, p_0

$$[\sigma] = \frac{p_0 r_1}{nh}$$

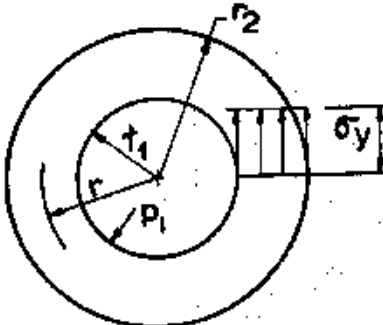
Hoop stress at the mid section of the m th lamination

$$(\sigma_{\theta})_m = p_0 \frac{r_1^3 (r_{n+1}^2 + x_m^2)}{x_m^3 (r_{n+1}^2 - r_1^2)} + \frac{p_m r_m}{h} - \left(1 + \frac{r_1^2}{x_m^2} \right) \sum_{m=m}^{n-1} \frac{p_{m+1} r_{m+1}^2}{r_{m+1}^2 - r_1^2}$$

In design practice $(\sigma_{\theta})_m$ is made $[\sigma]$. Application of the above equation is made first for the n th lamination and then successively for $(n-1)$, $(n-2)$ and 1st lamination. (on the n th lamination $p_{n+1} = 0$)



THICK CYLINDERS (Contd)

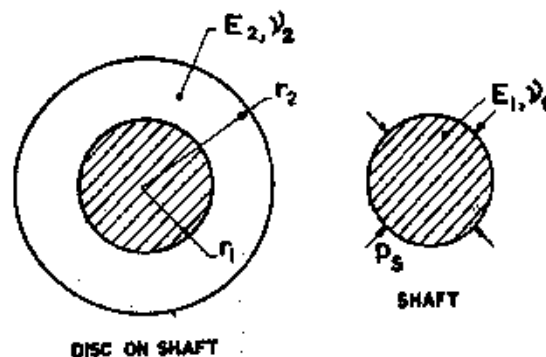
Formula	Figure and notation
hollow cylinder subjected to internal pressure (condition of plastic front reaching the outer radius—auto fretting)	
$p_i = p_f = \frac{2\sigma_y}{\sqrt{3}} \ln \frac{r_2}{r_1}$	
$\sigma_\theta = \frac{2}{\sqrt{3}} \sigma_y \left(1 + \ln \frac{r}{r_1} \right)$	

Shrink fit Disc on a Shaft

$$\sigma_\theta = \sigma_r = -p_s \text{ at the interface}$$

p_s is obtained from shrinkage allowance, δ

$$\delta = p_s r_1 \left[\frac{1}{E_1} (1 - \nu_1) + \frac{1}{E_2} \left(\frac{r_1^2 + r_2^2}{r_1^2 - r_2^2} + \nu_2 \right) \right]$$



ROTATING DISCS

Formula

Figure and notation

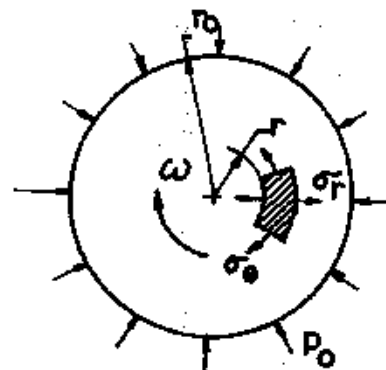
Solid Disc
subjected to
external pressure
and rotation

$$\sigma_r = -p_0 + \frac{3+\nu}{8} \rho \omega^2 (r_0^2 - r^2)$$

$$\sigma_\theta = -p_0 + \frac{3+\nu}{8} \rho \omega^2 \left[r_0^2 - \frac{1+3\nu}{3+\nu} r^2 \right]$$

radial displacement u , at radius r :

$$u = -p_0 r \frac{1-\nu}{E} + \frac{1-\nu}{8E} \rho \omega^2 r \left[(3+\nu)r_0^2 - (1+\nu)r^2 \right]$$



ρ , mass density
 ν , Poisson ratio

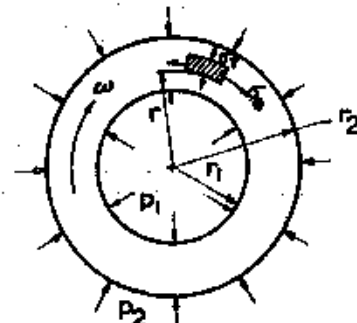
Rotating Disc
with a central
hole

$$\sigma_r = p_1 \frac{r_1^2}{r_2^2 - r_1^2} \left(1 - \frac{r_2^2}{r^2} \right) - p_2 \frac{r_2^2}{r_2^2 - r_1^2} \left(1 - \frac{r_1^2}{r^2} \right) + \rho \omega^2 \frac{3+\nu}{8} \left(r_2^2 + r_1^2 - \frac{r_1^2 r_2^2}{r^2} - r^2 \right)$$

$$\sigma_\theta = p_1 \frac{r_1^2}{r_2^2 - r_1^2} \left(1 + \frac{r_2^2}{r^2} \right) - p_2 \frac{r_2^2}{r_2^2 - r_1^2} \left(1 + \frac{r_1^2}{r^2} \right) + \rho \omega^2 \frac{3+\nu}{8} \left(r_2^2 + r_1^2 + \frac{r_1^2 r_2^2}{r^2} - \frac{1+3\nu}{3+\nu} r^2 \right)$$

radial displacement u , at radius r :

$$u = p_1 \frac{r}{E} \frac{r_1^2}{r_2^2 - r_1^2} \left[(1-\nu) + (1+\nu) \frac{r_2^2}{r^2} \right] - p_2 \frac{r}{E} \frac{r_2^2}{r_2^2 - r_1^2} \left[(1-\nu) + (1+\nu) \frac{r_1^2}{r^2} \right] + \rho \omega^2 \frac{r}{E} \frac{(3+\nu)(1-\nu)}{8} \left(r_2^2 + r_1^2 + \frac{1+\nu}{1-\nu} \frac{r_1^2 r_2^2}{r^2} - \frac{1+3\nu}{3+\nu} r^2 \right)$$



ROTATING
THIN RING

$$\sigma_\theta = \rho \omega^2 r^2$$

r , outer radius

ROTATING DISCS : (Contd.)

Limiting speed of rotating disc

For solid disc

$$\omega = \frac{1}{r} \sqrt{\frac{3\sigma_y}{\rho}}$$

For a disc with a central hole

 r_1 , inner radius; r_2 , outer radius

$$\omega = \left[\frac{3\sigma_y}{\rho} \left(\frac{r_2 + r_1}{r_2^2 - r_1^2} \right) \right]^{\frac{1}{2}}$$

Generally

$$\sigma_\theta \geq \sigma_r$$

when $\sigma_\theta = \sigma_y$ at the outer radius r , disc will collapse. ρ , mass density σ_y , yield stress

Rotating disc of uniform strength

$$t = t_0 e^{-\rho r^2 \omega^2 / [\sigma]}$$

$$\sigma_\theta = \sigma_r = [\sigma]$$

Rotating Disc of varying thickness

For, $t = C r^{-n}$ radial displacement u ,

$$u = C_1 r^\alpha + C_2 r^\beta - \rho \omega^2 \frac{1-\nu^2}{E} \frac{r^2}{(8-3n-n\nu)}$$

$$\text{where } \alpha, \beta = \frac{1}{2} [n \pm \sqrt{n^2 - 4(1+n\nu)}]$$

and C_1, C_2 are constants to be determined from the following Boundary conditions.

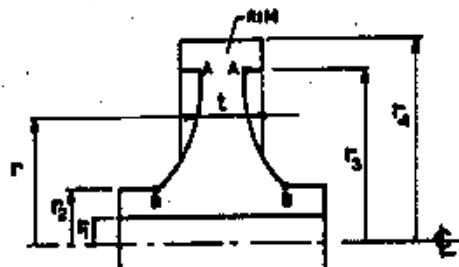
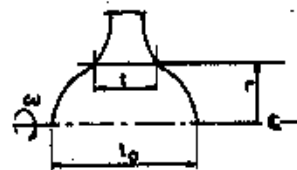
$$\text{At } r = r_1, \sigma_r = 0; \text{ At } r = r_2, (u_r)_{\text{disc}} = (u_r)_{\text{hub}}$$

$$\text{At } r = r_2, (u_A)_{\text{disc}} = (u_A)_{\text{rim}}$$

$$(\sigma_r)_{AA \text{ rim}} = (\sigma_r)_{AA \text{ Disc}} \text{ and } (\sigma_r)_{BB \text{ rim}} = (\sigma_r)_{BB \text{ Hub}}$$

$$\sigma_\theta = \frac{E}{1-\nu^2} \left[\frac{u}{r} + \nu \frac{du}{dr} \right]$$

$$\sigma_r = \frac{E}{1-\nu^2} \left[\nu \frac{u}{r} + \frac{du}{dr} \right]$$



ROTATING DISCS

Formula

Figure and notation

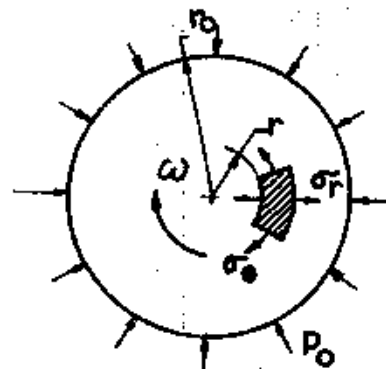
Solid Disc
subjected to
external pressure
and rotation

$$\sigma_r = -p_0 + \frac{3+\nu}{8} \rho \omega^2 (r_0^2 - r^2)$$

$$\sigma_\theta = -p_0 + \frac{3+\nu}{8} \rho \omega^2 \left[r_0^2 - \frac{1+3\nu}{3+\nu} r^2 \right]$$

radial displacement u , at radius r :

$$u = -p_0 r \frac{1-\nu}{E} + \frac{1-\nu}{8E} \rho \omega^2 r \left[(3+\nu)r_0^2 - (1+\nu)r^2 \right]$$



ρ , mass density
 ν , Poisson ratio

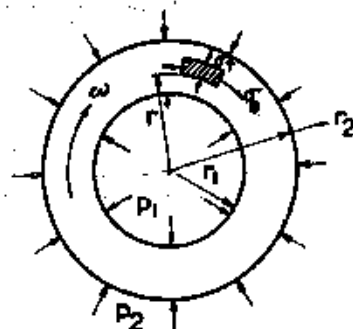
Rotating Disc
with a central
hole

$$\sigma_r = p_1 \frac{r_1^2}{r_2^2 - r_1^2} \left(1 - \frac{r_2^2}{r^2} \right) - p_2 \frac{r_2^2}{r_2^2 - r_1^2} \left(1 - \frac{r_1^2}{r^2} \right) + \rho \omega^2 \frac{3+\nu}{8} \left(r_2^2 + r_1^2 - \frac{r_1^2 r_2^2}{r^2} - r^2 \right)$$

$$\sigma_\theta = p_1 \frac{r_1^2}{r_2^2 - r_1^2} \left(1 + \frac{r_2^2}{r^2} \right) - p_2 \frac{r_2^2}{r_2^2 - r_1^2} \left(1 + \frac{r_1^2}{r^2} \right) + \rho \omega^2 \frac{3+\nu}{8} \left(r_2^2 + r_1^2 + \frac{r_1^2 r_2^2}{r^2} - \frac{1+3\nu}{3+\nu} r^2 \right)$$

radial displacement u , at radius r :

$$u = p_1 \frac{r}{E} \frac{r_1^2}{r_2^2 - r_1^2} \left[(1-\nu) + (1+\nu) \frac{r_2^2}{r^2} \right] - p_2 \frac{r}{E} \frac{r_2^2}{r_2^2 - r_1^2} \left[(1-\nu) + (1+\nu) \frac{r_1^2}{r^2} \right] + \rho \omega^2 \frac{r}{E} \frac{(3+\nu)(1-\nu)}{8} \left(r_2^2 + r_1^2 + \frac{1+\nu}{1-\nu} \frac{r_1^2 r_2^2}{r^2} - \frac{1+\nu}{3+\nu} r^2 \right)$$



r , outer radius

ROTATING
THIN RING

$$\sigma_\theta = \rho \omega^2 r^2$$

ROTATING DISCS : (Contd.)

Limiting speed of rotating disc

For solid disc

$$\omega = \frac{1}{r} \sqrt{\frac{3\sigma_y}{\rho}}$$

For a disc with a central hole

 r_1 , inner radius; r_2 , outer radius

$$\omega = \left[\frac{3\sigma_y}{\rho} \left(\frac{r_2 + r_1}{r_2^2 - r_1^2} \right) \right]^{\frac{1}{2}}$$

Generally

$$\sigma_\theta \geq \sigma_r$$

when $\sigma_\theta = \sigma_r$ at the outer radius r , disc will collapse. ρ , mass density σ_y , yield stress

Rotating disc of uniform strength

$$t = t_0 e^{-\rho r^2 \omega^2 / [\sigma]}$$

$$\sigma_\theta = \sigma_r = [\sigma]$$

Rotating Disc of varying thickness

For, $t = C r^{-n}$ radial displacement u ,

$$u = C_1 r^{\alpha_1} + C_2 r^{\alpha_2} - \rho \omega^2 \frac{1-\nu^2}{E} \frac{r^2}{(8-3n-n\nu)}$$

$$\text{where } \alpha_{1,2} = \frac{1}{2} \{ n \pm \sqrt{n^2 - 4(1+n\nu)} \}$$

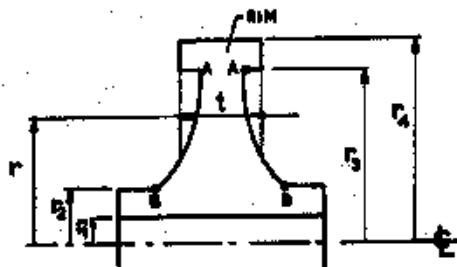
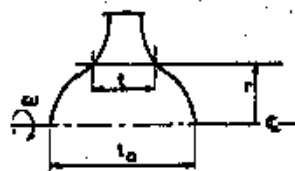
and C_1, C_2 are constants to be determined from the following Boundary conditions.

$$\text{At } r = r_1, \sigma_r = 0; \text{ At } r = r_2, (u_B)_{\text{boss}} = (u_B)_{\text{disc}} \\ = r_1 \quad \text{At } r = r_2, (u_A)_{\text{disc}} = (u_A)_{\text{rim}}$$

$$(\sigma_r)_{AA \text{ rim}} = (\sigma_r)_{AA \text{ Disc}} \text{ and } (\sigma_r)_{BB \text{ rim}} = (\sigma_r)_{BB \text{ Hub}}$$

$$\sigma_\theta = \frac{E}{1-\nu^2} \left[\frac{u}{r} + \nu \frac{du}{dr} \right]$$

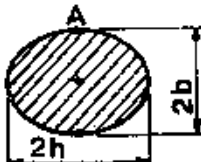
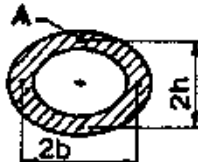
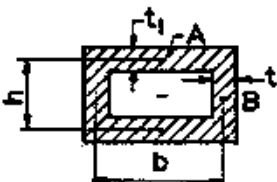
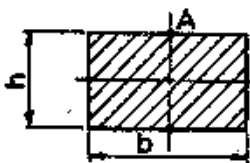
$$\sigma_r = \frac{E}{1-\nu^2} \left[\nu \frac{u}{r} + \frac{du}{dr} \right]$$



ROTATING DISCS (Contd.)

	Formula	Figure & Notation
Rotating Solid Cylinder	$\sigma_{\theta} = \frac{\rho \omega^2}{8} \left[\left(\frac{3-2\nu}{1-\nu} \right) R^2 - \left(\frac{1+2\nu}{1-\nu} \right) r^2 \right]$ $\sigma_r = \frac{\rho \omega^2}{8} \left[\left(\frac{3-2\nu}{1-\nu} \right) (R^2 - r^2) \right]$ $\sigma_z = \rho \omega^2 \nu \left[\frac{1}{4} \left(\frac{3-2\nu}{1-\nu} \right) R^2 - \frac{1}{2} \frac{r^2}{1-\nu} \right] \text{ for ends constrained}$ $\sigma_z = \frac{\rho \omega^2}{4} \left(\frac{\nu}{1-\nu} \right) (R^2 - 2r^2) \text{ for free ends.}$	R, radius of cylinder ρ, mass density ν, poisson ratio
Rotating Hollow Cylinder	$\sigma_{\theta} = \frac{\rho \omega^2}{8} \left(\frac{3-2\nu}{1-\nu} \right) \left[r_1^2 + r_2^2 + \frac{r_1^2 r_2^2}{r^2} - \left(\frac{1+2\nu}{3-2\nu} \right) r^2 \right]$ $\sigma_r = \frac{\rho \omega^2}{8} \left(\frac{3-2\nu}{1-\nu} \right) \left[r_1^2 + r_2^2 - \frac{r_1^2 r_2^2}{r^2} - r^2 \right]$ $\sigma_z = \frac{\rho \omega^2}{4} \left(\frac{\nu}{1-\nu} \right) \left[r_1^2 + r_2^2 - 2r^2 \right] \text{ ends free}$	r_2, outer radius r_1, inner radius $r_1 < r < r_2$

**ANGLE OF TWIST ϕ , AND SHEARING STRESS τ FOR SECTIONS
SUBJECTED TO TWISTING MOMENT, M_t**

Cross Section	Formula																														
	$\tau_A = \frac{2M_t}{\pi h b^3} ; \quad \phi = \left(\frac{h^2 + b^2}{\pi h b^3} \right) \frac{M_t}{G}$																														
	$\tau_A = \frac{20M_t}{b^3} ; \quad \phi = \frac{49.2}{b^2} \cdot \frac{M_t}{G}$																														
	$\tau = \frac{3M_t}{2\pi r t^3} ; \quad \phi = \frac{3}{2\pi r t^3} \cdot \frac{M_t}{G}$ $t \ll r$																														
	$\tau = \frac{M_t}{2\pi r^2 t} ; \quad \phi = \frac{1}{2\pi r^2 t} \cdot \frac{M_t}{G}$ $t \ll r$																														
	$\tau_A = \frac{M_t}{2\pi b h t} ; \quad \phi = \frac{(2(b^2 + h^2))^{1/2}}{4\pi b^3 h^3 t} \frac{M_t}{G}$																														
	$\tau_A = \frac{M_t}{2b h t_i} ; \quad \phi = \frac{b t_i + h t_i}{2 h t_i b^3 h^3} \frac{M_t}{G}$ $\tau_B = \frac{M_t}{2b h t} ;$																														
	$\tau_A = \frac{M_t}{\alpha b h^3} ; \quad \phi = \frac{1}{\beta b h^3} \frac{M_t}{G}$																														
	<table><tr><th>b/h</th><th>1.0</th><th>1.5</th><th>2</th><th>2.5</th><th>3</th><th>4</th><th>6</th><th>10</th><th>∞</th></tr><tr><td>α</td><td>0.208</td><td>0.231</td><td>0.246</td><td>0.256</td><td>0.267</td><td>0.282</td><td>0.299</td><td>0.312</td><td>0.333</td></tr><tr><td>β</td><td>0.141</td><td>0.196</td><td>0.229</td><td>0.249</td><td>0.263</td><td>0.281</td><td>0.299</td><td>0.312</td><td>0.333</td></tr></table>	b/h	1.0	1.5	2	2.5	3	4	6	10	∞	α	0.208	0.231	0.246	0.256	0.267	0.282	0.299	0.312	0.333	β	0.141	0.196	0.229	0.249	0.263	0.281	0.299	0.312	0.333
b/h	1.0	1.5	2	2.5	3	4	6	10	∞																						
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β	0.141	0.196	0.229	0.249	0.263	0.281	0.299	0.312	0.333																						

BENDING OF CIRCULAR PLATES

Conditions	Principal stress, $\sigma_{\max}$	Location of $\sigma_{\max}$	max deflection, $\delta_{\max}$	notation
edge simply supported. Udl of w	$\frac{3}{8} (3 + \nu) w \frac{a^2}{t^2}$	centre	$-\frac{3}{16} (1 - \nu) (3 + \nu) \frac{w a^4}{E t^3}$	a , radius of plate t , thickness of plate E , young's modulus w , load per unit area
edge fixed udl of w	$\frac{3}{4} w \frac{a^2}{t^2}$	edge	$\frac{3}{16} (1 - \nu^2) \frac{w a^4}{E t^3}$ for $\frac{t}{a} < 0.1$ $-\frac{3}{16} \left[1 + 5.72 \left(\frac{t}{a} \right)^4 \right] (1 - \nu^2) \frac{w a^4}{E t^3}$ for $\frac{t}{a} > 0.1$	
Simply supported edge, load P at centre (over a small area of radius b)	$\frac{3 (1 + \nu) P}{2 \pi t^2} \left[\frac{1}{1 + \nu} + \ln \frac{a}{b} - \left(\frac{1 - \nu}{1 + \nu} \right) \frac{b^2}{4 a^2} \right]$	centre	$\frac{3 (1 - \nu) (3 + \nu) P a^2}{4 \pi E t^3}$	
Fixed edge; load as above	$\frac{3 (1 + \nu) P}{2 \pi t^2} \left[\ln \frac{a}{b} + \frac{b^2}{4 a^2} \right]$ for $a > 1.7 b$	centre	$\frac{3 (1 - \nu^2) P}{\pi E t^3} \frac{a^2}{4}$	
Supported at the centre over a circular area of radius b and udl of w	$\frac{3 w a^2}{2 t} \left[(1 + \nu) \ln \frac{a}{b} + \frac{1}{4} (1 - \nu) \left(1 - \frac{b^2}{a^2} \right) \right]$	centre	$-\frac{3}{16} (1 - \nu) (7 + 3 \nu) \frac{w a^4}{E t^3}$	

BENDING OF NON CIRCULAR PLATES under udl of w

	Moment per unit width in span b		Moment per unit width in span a		Max deflection $= C(1-\nu^2) \frac{wb^4}{E^3}$ Values of C	notation
	at centre of edge (—)	at center of slab (+)	at center of edge (—)	along centreline of slab (+)		
Rectangular plate $a \times b$	all edges simply supported	0	$\frac{1}{8} \frac{wb^2}{1+2\alpha^4}$	0	$\frac{wb^4}{48} (1+\alpha^4)$	ν , Poisson ratio E , young's modulus a , long side b , short side
	span b fixed; span a , simply supported	$\frac{1}{12} \frac{wb^2}{1+0.2\alpha^4}$	$\frac{1}{24} \frac{wb^2}{1+0.4\alpha^4}$	0	$\frac{wb^4}{80} (1+0.3\alpha^4)$	$\alpha = \frac{b}{a}$ w , load per unit area
	span a , fixed span b , simply supported	0	$\frac{1}{8} \frac{wb^2}{1+0.8\alpha^4+6\alpha^4}$	$\frac{1}{8} \frac{wb^2}{1+0.8\alpha^4}$	$0.015wb^4 \frac{1+3\alpha^4}{1+\alpha^4}$	$\frac{0.16}{1+\alpha^4+5\alpha^4}$
	all edges fixed	$\frac{1}{12} \frac{wb^2}{1+\alpha^4}$	$\frac{1}{8} \frac{wb^2}{3+4\alpha^4}$	$\frac{1}{24} \frac{wb^2}{1+\alpha^4}$	$0.009wb^4 (1+2\alpha^4-\alpha^4)$	$\frac{0.032}{1+\alpha^4}$
	Elliptical slab with fixed edge; diameters a and b ; $a > b$	$\frac{1}{12} \frac{wb^2}{1+\frac{2}{3}\alpha^2+\alpha^4}$	$\frac{1}{24} \frac{wb^2}{1+\frac{2}{3}\alpha^2+\alpha^4}$	$\frac{1}{12} \frac{wb^2\alpha^2}{1+\frac{2}{3}\alpha^2+\alpha^4}$	$\frac{1}{24} \frac{wb^2\alpha^2}{1+\frac{2}{3}\alpha^2+\alpha^4}$	

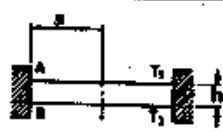
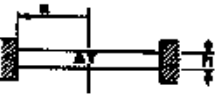
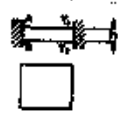
RECTANGULAR PLATE, IN BENDING, SUBJECTED TO A LOAD P OVER A CENTRAL
CIRCULAR AREA OF DIAMETER $d_c > 0.25 b$

Conditions	moment per unit width in span b		moment per unit width in span a		max. deflection = $C(1-\nu^2) \frac{P b^2}{E t^3}$
	at centre of edge (-)	*at centre of slab (+)	*at centre of slab (+)	at centre of edge (-)	Value of C
all edges simply supported	0	$\frac{0.213 P}{1+0.3 \alpha^4}$	$0.136 P (1+0.2 \alpha^4)$	0	$\frac{0.2}{1+0.45 \alpha^4}$
span b , fixed span a , simply supported	$\frac{1}{6} P$	0.148 P	$0.106 P (1+0.1 \alpha^4)$	0	0.087
span a , fixed span b , simply supported	0	$\frac{0.213 P}{1+0.9 \alpha^4}$	$\frac{P}{100} (14 - \cos \frac{1}{2} \pi \alpha)$	$\frac{P}{12} (1 - \cos \pi \alpha)$	$\frac{0.2}{1+0.1 \alpha^4 + 1.2 \alpha^4}$
all edges fixed	$\frac{P}{6+2 \alpha^4}$	$\frac{0.158 P}{1+0.1 (1-\alpha)^2}$	$\frac{0.158 P}{1+0.5 (1-\alpha)^2}$		$\frac{0.087}{1+0.3 \alpha^4}$

a , longer side; b , shorter side; $\frac{b}{a} = \alpha$;

* For $d_c < 0.25 b$ add the correction, $0.17 P \left[\frac{1 - \frac{4 d_c}{b}}{1 + \frac{2 d_c}{b}} \right]$ to the tabulated values above

THERMAL STRESSES IN PLATES

Conditions	Equation for stresses	Figure & notation
Circular plate clamped at edge $\Delta T = T_1 - T_2$ $\delta = 0$	$\sigma_A = -\frac{\alpha (\Delta T) E}{2(1-\nu)}$ $\sigma_B = -\sigma_A$	
Circular plate simply supported	$\sigma = 0$ $\delta = \frac{4 \alpha (\Delta T) R^2}{8 h}$	
Circular plate clamped at edge ΔT , increase in temp of the whole plate	$\sigma = -\frac{\alpha E (\Delta T)}{1-\nu}$ $\delta = 0$	
Triangular plate clamped at edge	$(\sigma_{max})_A = -\frac{3 \alpha (\Delta T) E}{4}$ at corners $(\sigma_{max})_B = -(\sigma_{max})_A$	
Square plate clamped at edges	$(\sigma_{max})_A = -\frac{\alpha E (\Delta T)}{2}$ $(\sigma_{max})_B = -(\sigma_{max})_A$	

α , coefft of linear expansion
 ν , Poisson Ratio
 E , young's modulus
 δ , deflection

BUCKLING :

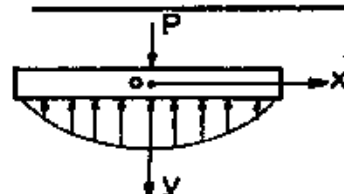
Condition	Equation	Notation
Cylinder subjected to internal pressure $P_{cr} = \frac{\pi E I}{(L r)^3}$	Critical pressure $P_{cr} = \frac{\pi E I}{(L r)^3}$	r , inner radius of cylinder E , young's modulus I , second moment of area of cross section of cylinder
Thin tube subjected to internal pressure $P_{cr} = \frac{\pi^3 E t r}{L^3}$	$P_{cr} = \frac{\pi^3 E t r}{L^3}$	L , length of the cylinder in which pressure is acting or ht of plate t , thickness of tube ν , Poisson ratio
Tubes subjected to external pressure $P_{cr} = \frac{E t^3}{4 R^3 (1-\nu^2)}$	$P_{cr} = \frac{E t^3}{4 R^3 (1-\nu^2)}$	R , mid-wall tube radius P_{cr} , N/cm
Thin tube subjected to axial force $F_{cr} = \frac{E t^3}{[3(1-\nu^2)]^{1/2}} \frac{1}{R}$	$F_{cr} = \frac{E t^3}{[3(1-\nu^2)]^{1/2}} \frac{1}{R}$	
Wide plate. Vertical edges free, axial load through pin joints $W_{cr} = \frac{\pi^2 E t^3}{12(1-\nu^2) L^3}$	Critical load, $W_{cr} = \frac{\pi^2 E t^3}{12(1-\nu^2) L^3}$	

BEAMS ON ELASTIC SUPPORTS

Loading condition

Formulae

Notation



Long beam on continuous support

$$\text{deflection: } y = \left(\frac{P\beta}{2k} \right) e^{-\beta x} (\cos \beta x + \sin \beta x)$$

$$\text{B. M.: } M = \left(\frac{P}{4\beta} \right) e^{-\beta x} (\cos \beta x - \sin \beta x)$$

$$L \geq \frac{2\pi}{\beta}; L, \text{ length of the beam}$$

$$\beta^4 = \frac{k}{4EI}$$

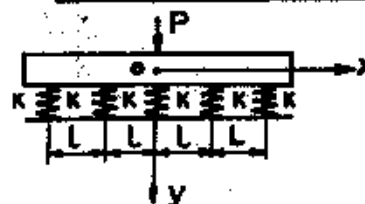
k , spring constant/unit length of elastic support
 $= w k_0$

w , width of bottom of beam

k_0 , spring const, N/cm

E , young's modulus of beam

I , second moment of area of beam

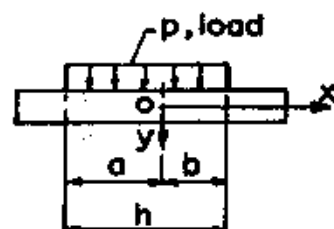


Beam on equally spaced elastic support

expressions for y and M can be obtained from the above, if

$$k = \frac{K}{L} \text{ and } \beta^4 = \frac{K}{4LEI}$$

$$\text{conditions, i) } L \leq \frac{\pi}{4\beta} \quad \text{ii) } L \geq \frac{3}{2} \frac{\pi}{\beta}$$



Long beam on elastic support over a portion of its length.

deflection at O:

$$y = \frac{p}{2k} \left[2 - e^{-\beta a} \cos \beta a - e^{-\beta b} \cos \beta b \right]$$

B. M. at O:

$$M = \frac{p}{4\beta^2} \left[e^{-\beta a} \sin \beta a + e^{-\beta b} \sin \beta b \right]$$

Max Moment occurs at O when $a=b$

$$\text{and } h < \frac{\pi}{2\beta}$$

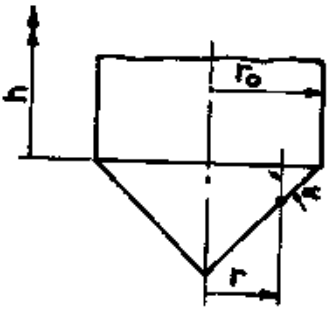
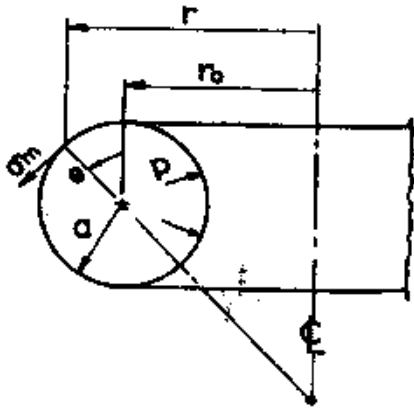
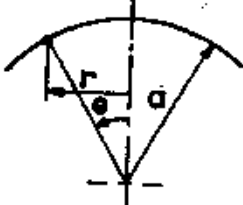
Max moment occurs at two locations,

$$\frac{\pi}{4\beta} \text{ from each end of the load}$$

$$\text{if } h > \frac{\pi}{2\beta}$$

 p , load per unit length $y_{\max}$ when $a=b$

MEMBRANE STRESSES :

Type of shell and loading	Meridional stress σ_m	tangential stress σ_t	figure & notation
Cylinder of radius r , under internal pressure, p	$\frac{pr}{2t}$	$\frac{pr}{t}$	t , thickness of shell
Spherical shell of radius r , under internal pressure p	$\frac{pr}{2t}$	$\frac{pr}{2t}$	t , thickness of shell
Cylindrical water tank with conical bottom	$\frac{\gamma r}{2t} \left[\frac{h}{\cos \alpha} + \frac{r_0 - \frac{1}{2}r}{\sin \alpha} \right]$	$\frac{pr}{t \cos \alpha}$	 h, height of water level γ, specific wt. of water t, thickness of tank
Toroidal shell, subjected to internal pressure, p . (thickness, t)	$\frac{pa}{t} \left(\frac{r + r_0}{2r} \right)$ $r = r_0 + a \sin \theta$	$\frac{pa}{2t}$	
Spherical dome, loaded by self weight only	$\frac{-\gamma a}{t(1 + \cos \theta)}$	$\frac{\gamma a}{t} \left(-\cos \theta + \frac{1}{1 + \cos \theta} \right)$	 γ, wt per unit area of dome t, thickness

MEMBRANE STRESSES (Contd.)

Type of shell & loading

σ_x

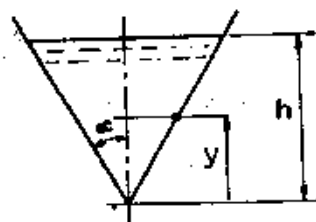
σ_t

Figure & notation

Conical tank filled with liquid; t , thickness

$$\gamma y \frac{(\tan \alpha) \left(h - \frac{2}{3} y \right)}{2t \cos \alpha}$$

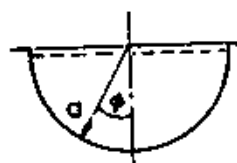
$$\frac{\gamma (h-y)}{t \cos \alpha} y \tan \alpha$$



Spherical tank filled with liquid; t , thickness

$$\frac{\gamma a^2}{3t} \frac{1 - \cos^2 \phi}{\sin^2 \phi}$$

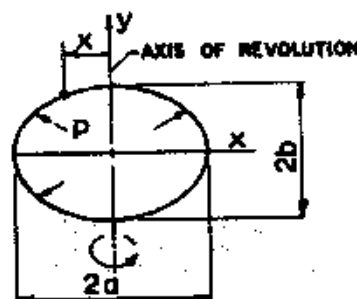
$$\frac{\gamma a^2}{3t} \left[3 \cos \phi - \frac{1 - \cos^2 \phi}{\sin^2 \phi} \right]$$



Ellipsoidal shell, generated by rotation about minor axis, subjected to int. pr. p , t , thickness of shell

$$\frac{pa}{2bt} \left[a^2 - x^2 + \frac{b^4}{a^4} x^2 \right]^{\frac{1}{2}}$$

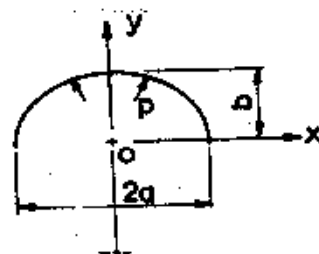
$$\frac{pa}{2bt} \left(a^2 - 2x^2 + \frac{2b^4}{a^4} x^2 \right)^{\frac{1}{2}}$$



Shell end cover in the form of half ellipsoid subjected to int. pr. p , t , thickness of shell

$$\frac{pa^2}{2t (x^2 + y^2)^{\frac{1}{2}}}$$

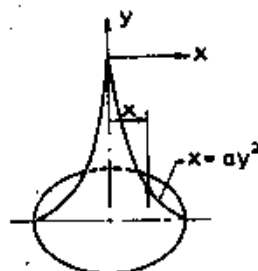
$$\frac{Pa^2}{2t b^2} \left(\frac{2b^2 - x^2 - y^2}{(x^2 + y^2)^{\frac{1}{2}}} \right)$$



Parabolic shell subjected to int. pr. p ; t , thickness

$$\frac{px}{2t} (1 + 4ax)^{\frac{1}{2}}$$

$$\frac{px}{t} \frac{1 + 3ax}{(1 + 4ax)^{\frac{1}{2}}}$$



MEMBRANE STRESSES (Contd.)

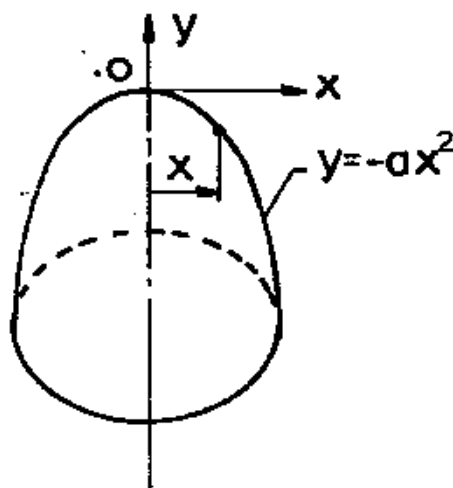
Type of shell & loading

σ_m

σ_1

—Do—

$$\frac{p}{4at} (1 + 4a^2 x^2)^{\frac{1}{2}} \quad \frac{p}{4at} \left[\frac{1 + 8a^2 x^2}{(1 + 4a^2 x^2)^{\frac{3}{2}}} \right]$$



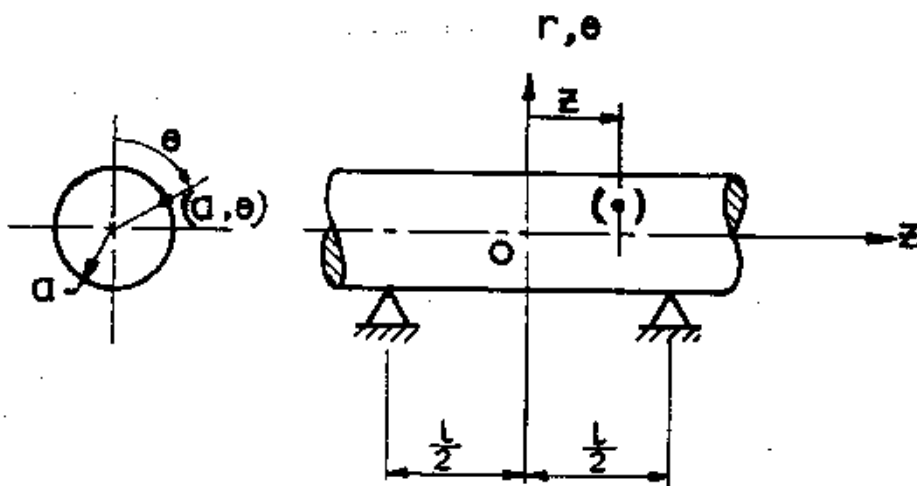
long horiz. pipe line
supported at intervals
of l , filled with liquid

$$\sigma_\theta = \frac{\gamma a^2}{t} (1 - \cos \theta)$$

$$\sigma_x = \frac{\gamma}{t} \left(\frac{x^2}{2} - \frac{l^2}{24} \right) \cos \theta + \nu \sigma_\theta$$

$$\tau = -\frac{\gamma a z}{t} \sin \theta$$

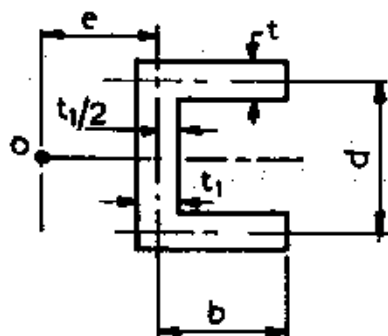
ν , Poisson ratio
 γ , specific wt of liquid



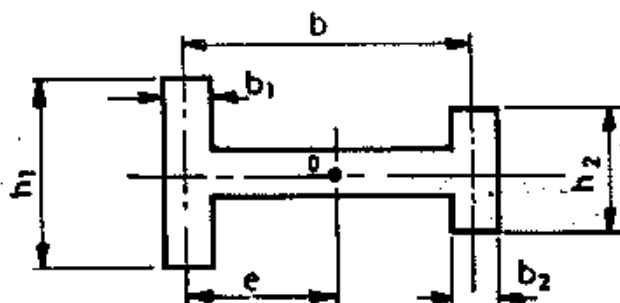
LOCATION OF SHEAR CENTRE

Section

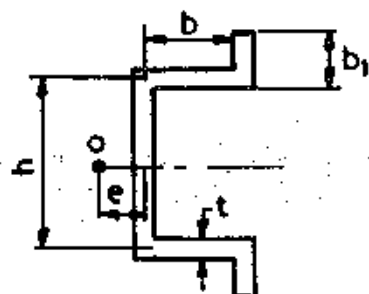
Location of shear centre, O



$$e = \frac{3bt^2}{6bt + t_1d}$$



$$e = b \left[\frac{b_1 b_2^3}{b_1 h_1^3 + b_2 b_1^3} \right]$$

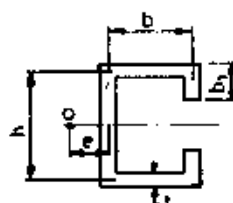


$$e = b \left[\frac{1 + \frac{1}{2} \frac{b}{b_1} - \frac{4}{3} \left(\frac{b_1}{h} \right)^2}{1 + \frac{1}{6} \frac{h}{b_1} + \frac{b}{b_1} + 2 \frac{b_2}{h} \left(1 + \frac{1}{3} \frac{b_1}{h} \right)} \right]$$

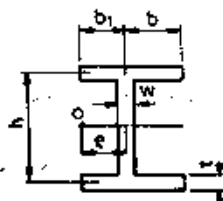
LOCATION OF SHEAR CENTRE (Contd.)

Section

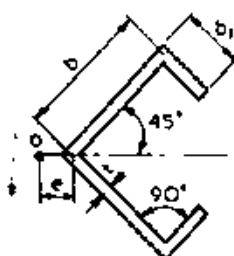
Location of shear centre, O



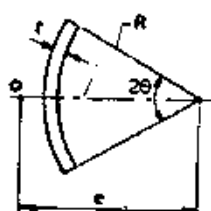
$$e = b \left[\frac{1 + \frac{1}{2} \frac{b}{b_1} - \frac{4}{3} \left(\frac{b_1}{b} \right)}{1 + \frac{1}{6} \frac{h}{b_1} + \frac{b}{b_1} - 2 \frac{b_1}{b} \left(1 - \frac{2}{3} \frac{b_1}{h} \right)} \right]$$



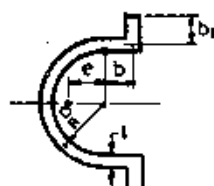
$$e = \frac{3(b^3 - b_1^3)}{\frac{w}{t}h + 6(b + b_1)} \quad ; \quad b_1 < b$$



$$e = b_1 \frac{\frac{b}{b_1} \left(3 \frac{b}{b_1} - 2 \right)}{\sqrt{2} \left[\left(\frac{b}{b_1} \right)^3 + 3 \left(\frac{b}{b_1} \right)^2 - 3 \frac{b}{b_1} + 1 \right]}$$



$$e = \frac{2R (\sin \theta - \theta \cos \theta)}{\theta - \sin \theta \cos \theta}$$



$$e = R \frac{12 + 6\pi \frac{b+b_1}{R} + 6 \left(\frac{b}{R} \right)^2 + 12 \frac{b}{R} \frac{b_1}{R} + 3\pi \left(\frac{b_1}{R} \right)^2 - 4 \left(\frac{b_1}{R} \right)^2 \frac{b}{R}}{3\pi + 12 \frac{b+b_1}{R} + 4 \left(\frac{b_1}{R} \right)^2 \left(3 + \frac{b_1}{R} \right)}$$

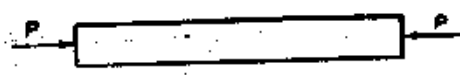
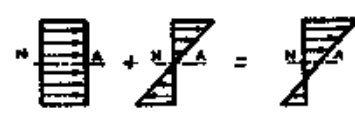
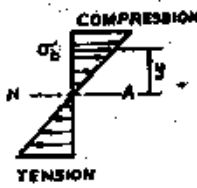
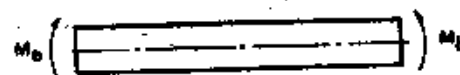
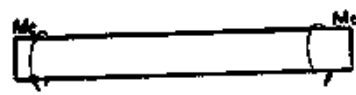
Special cases, either $b_1 = 0$

or $b = 0$

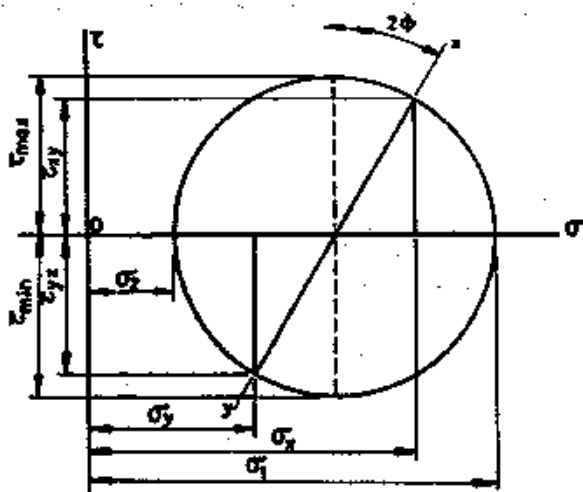
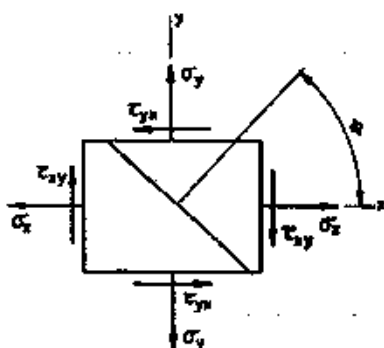
or $b = b_1 = 0$

MACHINE ELEMENTS - 7

STATIC STRESSES

	Formula	Figure and Notation
Direct Loading	$\sigma = \frac{P}{a}$ $e = \frac{P \cdot l}{aE}$ $\nu = \frac{E}{2G}$	 <i>P</i>, load, kgf <i>a</i>, area of cross section, cm² <i>l</i>, length, cm <i>E</i>, modulus of elasticity, kgf/cm² <i>G</i>, modulus of rigidity, kgf/cm² σ, tensile or compressive stress, kgf/cm² ν, Poisson's ratio <i>e</i>, elongation, cm
Eccentric Loading	$\sigma = \frac{P}{a} \pm \frac{P \cdot e}{x}$ 	 <i>e</i>, eccentricity, cm <i>x</i>, modulus of section, cm³ <i>P</i>, load, kgf <i>a</i>, area of cross section, cm² σ, combined stress, kgf/cm²
Bending	$\frac{M_b}{I} = \frac{\sigma_b}{y} = \frac{E}{R}$ $\sigma_b = \frac{M_b y}{I}$ 	 <i>M_b</i>, bending moment, kgf cm <i>y</i>, distance of fibre from Neutral Axis, cm <i>R</i>, radius of curvature, cm <i>I</i>, area moment of inertia, cm⁴ σ_b, bending stress, kgf/cm²
Torsion	$\frac{M_t}{J} = \frac{G\theta}{l} = \frac{\tau}{r}$ $\tau = \frac{M_t r}{J}$ $\theta = \frac{M_t l}{GJ}$ 	 <i>M_t</i>, torque or twisting moment, kgf cm <i>r</i>, distance from axis, cm <i>J</i>, polar moment of inertia, cm⁴ <i>l</i>, length, cm <i>G</i>, modulus of rigidity, kgf/cm² <i>n</i>, rpm τ, shear stress, kgf/cm² θ, angle of twist, radian
	Horse Power, hp = $\frac{2\pi n M_t}{450000}$	

PRINCIPAL STRESSES:



Two Dimensional stresses:

$$\sigma_{1,2} = \frac{1}{2} [(\sigma_x + \sigma_y) \pm \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2}]$$

$$\tau = \pm \frac{1}{2} \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2}$$

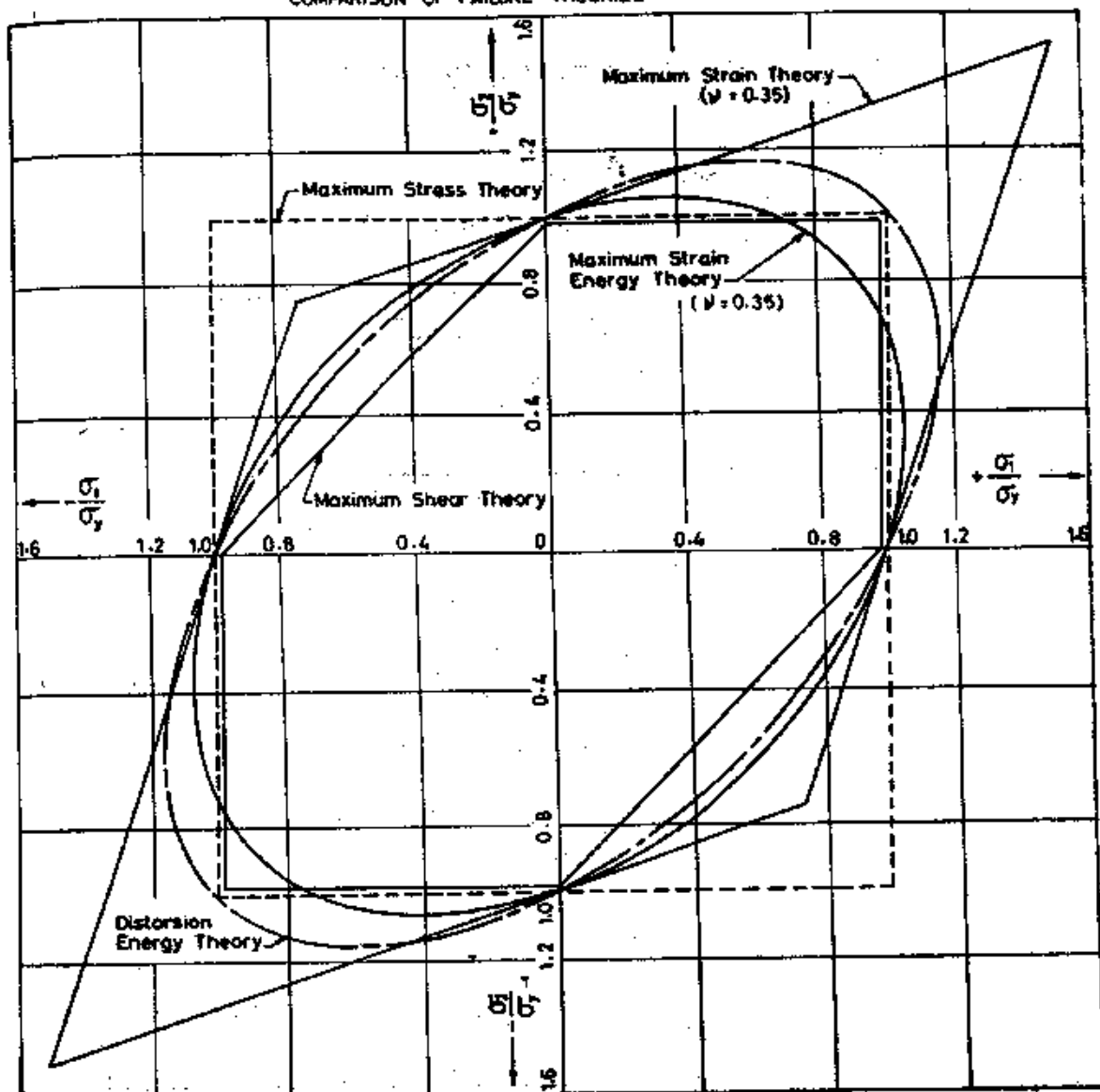
Three Dimensional stresses:

$$\begin{vmatrix} (\sigma_x - \sigma) & \tau_{xy} & \tau_{xz} \\ \tau_{yx} & (\sigma_y - \sigma) & \tau_{yz} \\ \tau_{zx} & \tau_{zy} & (\sigma_z - \sigma) \end{vmatrix} = 0$$

$\sigma_1, \sigma_2, \sigma_3$ —Principal stresses
 $\sigma_x, \sigma_y, \sigma_z$ —Stress components
 $\tau_{xy}, \tau_{yz}, \tau_{zx}$ —Shear stress components
 σ_y —Yield stress
 ν —Poisson's ratio

The roots of this cubic equation in σ are the principal stresses.

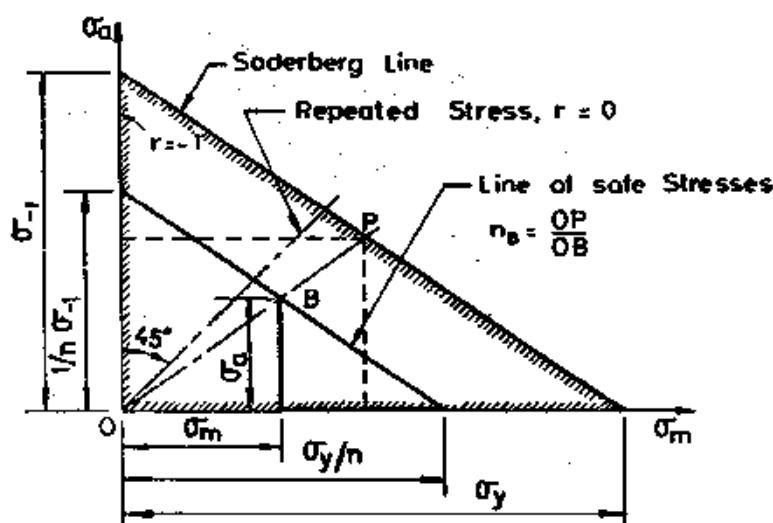
COMPARISON OF FAILURE THEORIES



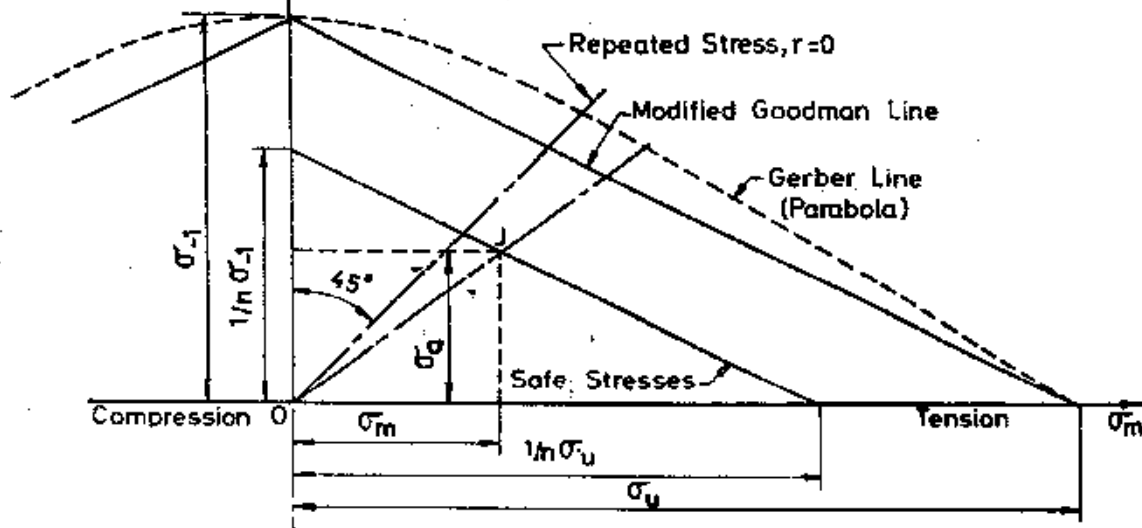
FAILURE THEORIES:

- Maximum stress theory (Rankine's)
 σ_1 or σ_2 or σ_3 (whichever is maximum) = σ_y
- Maximum shear theory (Guest's or Coulomb's)
 $(\sigma_1 - \sigma_2)$ or $(\sigma_2 - \sigma_3)$ or $(\sigma_3 - \sigma_1)$ (whichever is maximum) = σ_y
- Maximum strain theory (St. Venant's)
 $\sigma_1 - \nu (\sigma_2 + \sigma_3)$ or $\sigma_2 - \nu (\sigma_3 + \sigma_1)$ or $\sigma_3 - \nu (\sigma_1 + \sigma_2)$ whichever is maximum = σ_y
- Maximum strain energy theory
 $\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - 2\nu (\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1) = \sigma_y^2$
- Octahedral or Distortion energy theory (Von Mises-Hencky)
 $\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - \sigma_1\sigma_2 - \sigma_2\sigma_3 - \sigma_3\sigma_1 = \sigma_y^2$

SODERBERG LINE. (Recommended for ductile materials only)



MODIFIED GOODMAN LINE (For Brittle Materials)

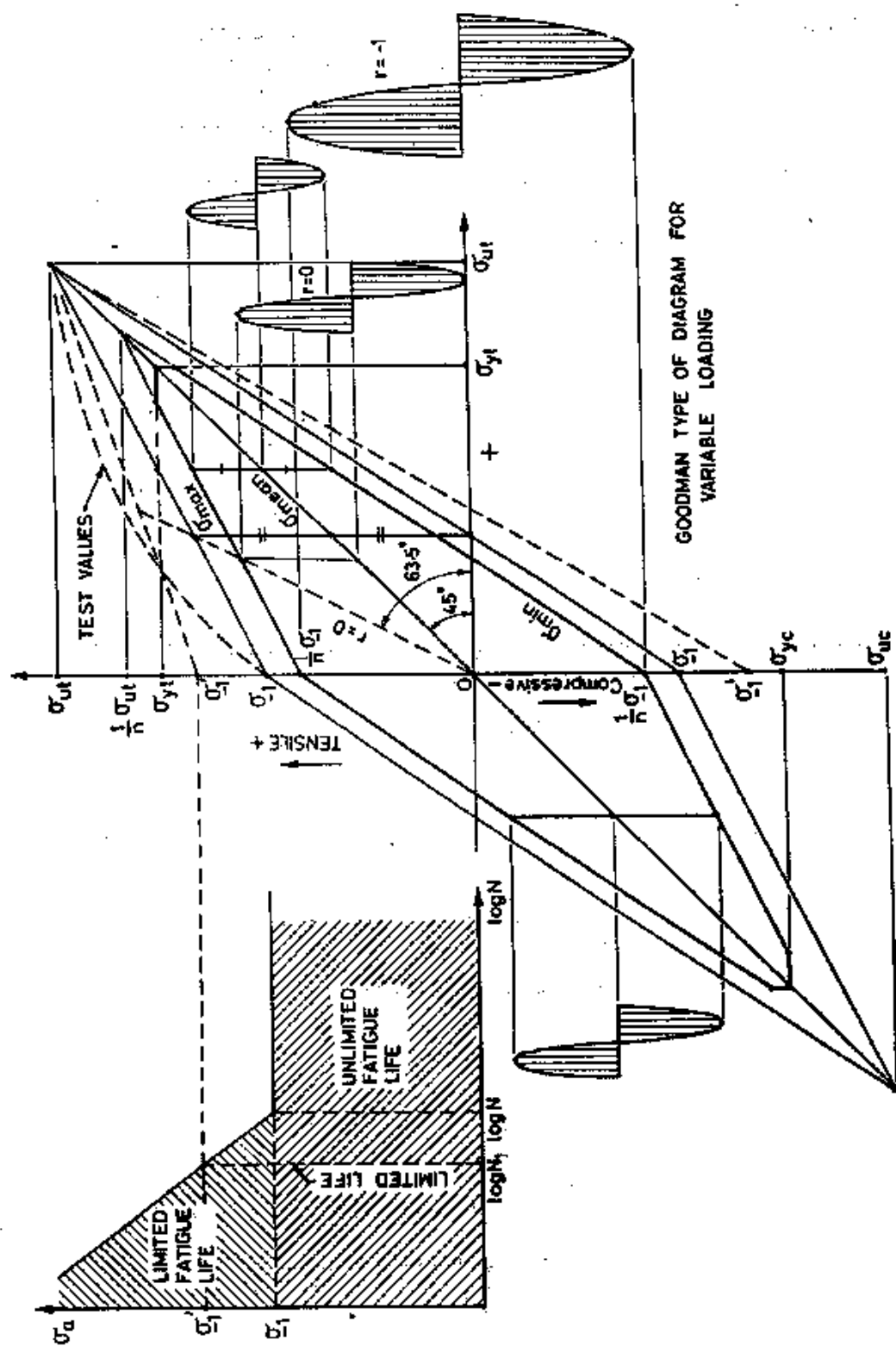


Soderberg Equations:

$$\frac{1}{n} = \frac{\sigma_m}{\sigma_y} + \frac{\sigma_a}{\sigma_{-1}}; \quad \frac{1}{n} = \frac{I_m}{I_y} + \frac{I_a}{I_{-1}}$$

Goodman Equations:

$$\frac{1}{n} = \frac{\sigma_m}{\sigma_u} + \frac{\sigma_a}{\sigma_{-1}}; \quad \frac{1}{n} = \frac{I_m}{I_u} + \frac{I_a}{I_{-1}}$$



VARYING STRESSES (Contd.)

σ_u — ultimate stress

σ_y — Yield stress

σ_{-1} — endurance limit stress

σ'_{-1} — endurance strength for specified life

σ_a — stress amplitude, $\frac{\sigma_{\max} - \sigma_{\min}}{2}$

σ_m — mean stress, $\frac{\sigma_{\max} + \sigma_{\min}}{2}$

$\sigma_{\max}$ — maximum stress

$\sigma_{\min}$ — minimum stress

τ_a — shear stress amplitude

τ_m — mean shear stress

q — notch sensitivity factor

r — stress ratio, $\sigma_{\min}/\sigma_{\max}$

n — factor of safety

σ_{eq} — equivalent static stress

τ_u — ultimate shear stress

τ_y — yield shear stress

τ_{-1} — endurance limit stress in shear

τ_{eq} — equivalent static shear stress

K'_t, K_t — theoretical stress concentration factors

K_f — fatigue stress concentration factor

$K_f = 1 + q (K_t - 1)$

Soderberg equation :

$$\frac{1}{n} = \frac{\sigma_m}{\sigma_y} + K_t \frac{\sigma_a}{\sigma_{-1}} ; \frac{1}{n} = \frac{\tau_m}{\tau_y} + K_t \frac{\tau_a}{\tau_{-1}}$$

for ductile materials.

Goodman (modified) equation :

$$\frac{1}{n} = K_t \left[\frac{\sigma_m}{\sigma_u} + \frac{\sigma_a}{\sigma_{-1}} \right] ; \frac{1}{n} = K_t \left[\frac{\tau_m}{\tau_u} + \frac{\tau_a}{\tau_{-1}} \right]$$

for brittle materials (notch sensitivity negligible).

Combined stresses :

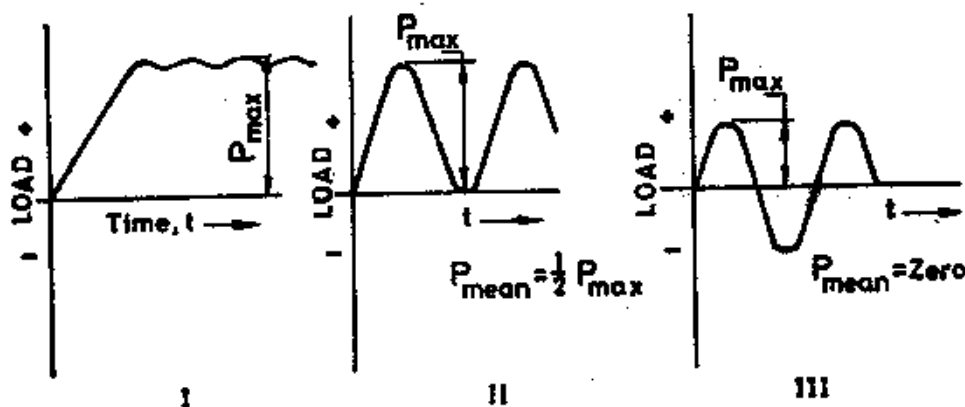
$$\sigma_{eq} = \frac{\sigma_x}{n} = \sigma_m + K_t \frac{\sigma_a}{\sigma_{-1}} ; \tau_{eq} = \frac{\tau_y}{n} = \tau_m + K_t \frac{\tau_a}{\tau_{-1}}$$

$$\frac{1}{n} = \left[\left(\frac{\sigma_{eq}}{\sigma_y} \right)^2 + \left(\frac{\tau_{eq}}{\tau_y} \right)^2 \right]^{\frac{1}{2}}$$

Max. shear theory : $\tau_y = \sigma_y/2$

Octahedral shear theory } $\tau_y = \sigma_y/\sqrt{3}$

APPROXIMATE VALUES OF ALLOWABLE STRESSES FOR STEELS: kgf/cm^2



Static

Repeated

Reversed

Material	Tensile Strength σ_u	Tensile, Compressive and Bending stresses $[\sigma]$			Shear stresses $[\tau]$		
		I	II	III	I	II	III
Carbon Steels	3000	1000	450	250	600	250	150
	4000	1350	600	350	800	350	200
	5000	1700	750	450	1000	450	250
	6000	2000	900	500	1200	550	300
	7000	2350	1050	600	1400	650	350
	8000	2700	1200	700	1600	700	400
Alloy Steels	9000	3000	1350	800	1800	800	500
	10000	3350	1500	900	2000	900	550
	12000	4000	1800	1050	2400	1100	650
	14000	4700	2100	1200	2800	1250	700
	16000	5350	2400	1400	3200	1450	850
	18000	6000	2700	1550	3600	1600	950
	20000	6650	3000	1750	4000	1800	1050
	22000	7350	3300	1900	4400	2000	1150
	24000	8000	3600	2100	4800	2150	1250
Cast Steels	4000	1000	500	300	600	300	200
	5000	1200	700	400	700	400	250
	6000	1500	800	500	900	500	300
	8000	2000	1000	650	1200	600	400
	10000	2500	1300	800	1500	800	500
	12000	3000	1600	1000	1800	950	600

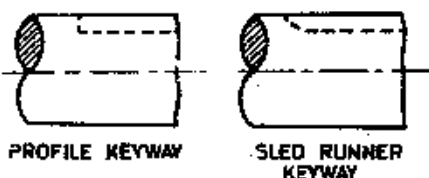
STRESS CONCENTRATION FACTORS

Stress concentration factor } $K_t = \frac{\text{maximum stress}}{\text{nominal stress at the net section}}$

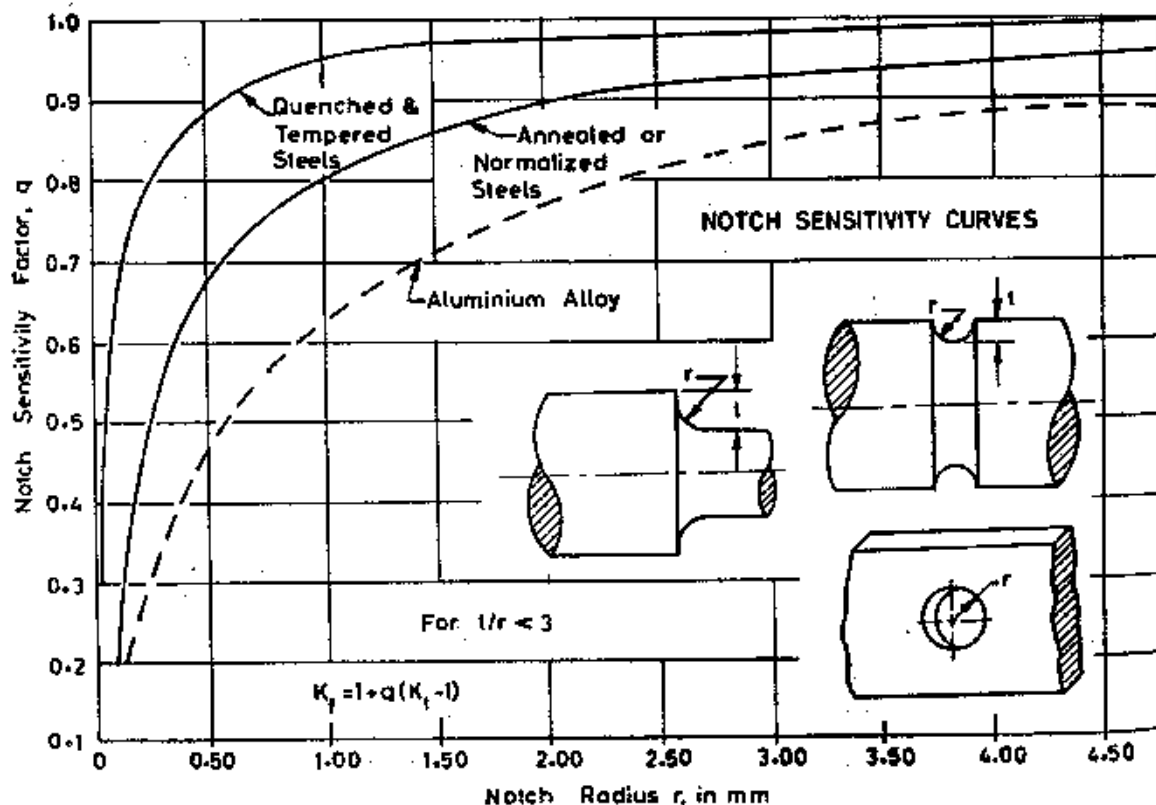
K_t' —combined stress concentration factor, taking into account biaxial or triaxial stresses and Von Mises-Hencky theory.

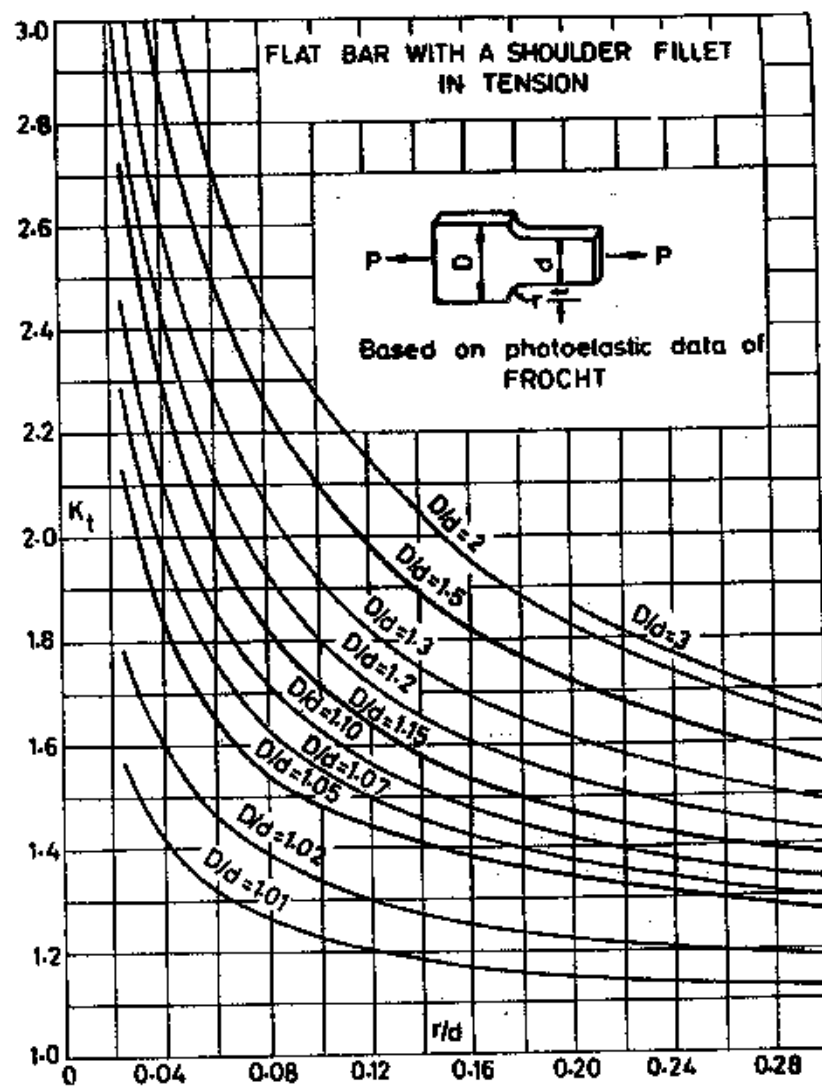
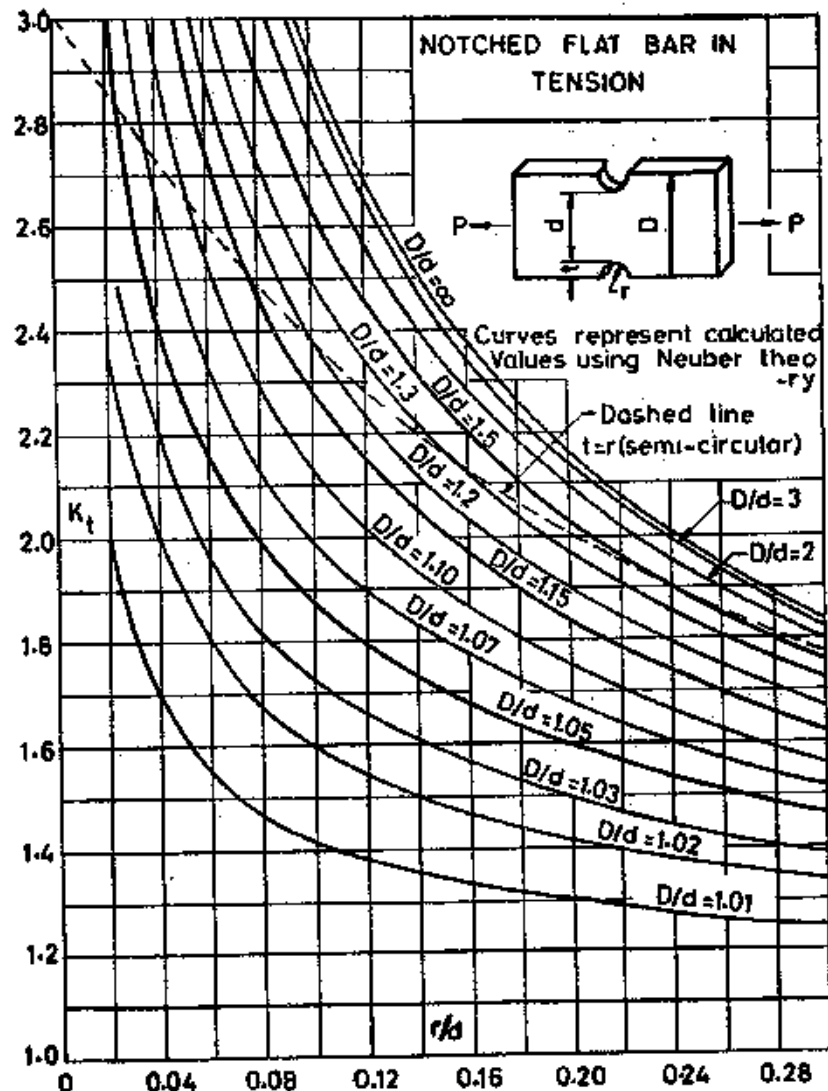
K_t is always greater than K_t' , therefore where information is lacking or doubtful, K_t should be used, to be on the safe side.

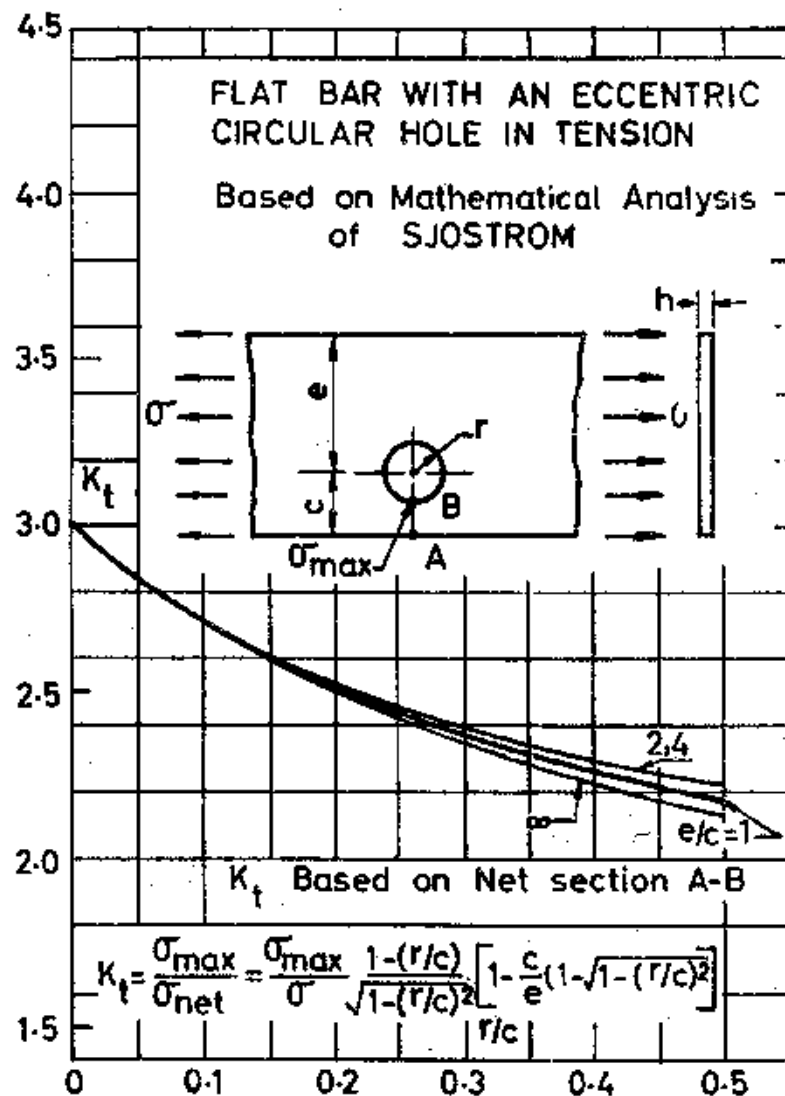
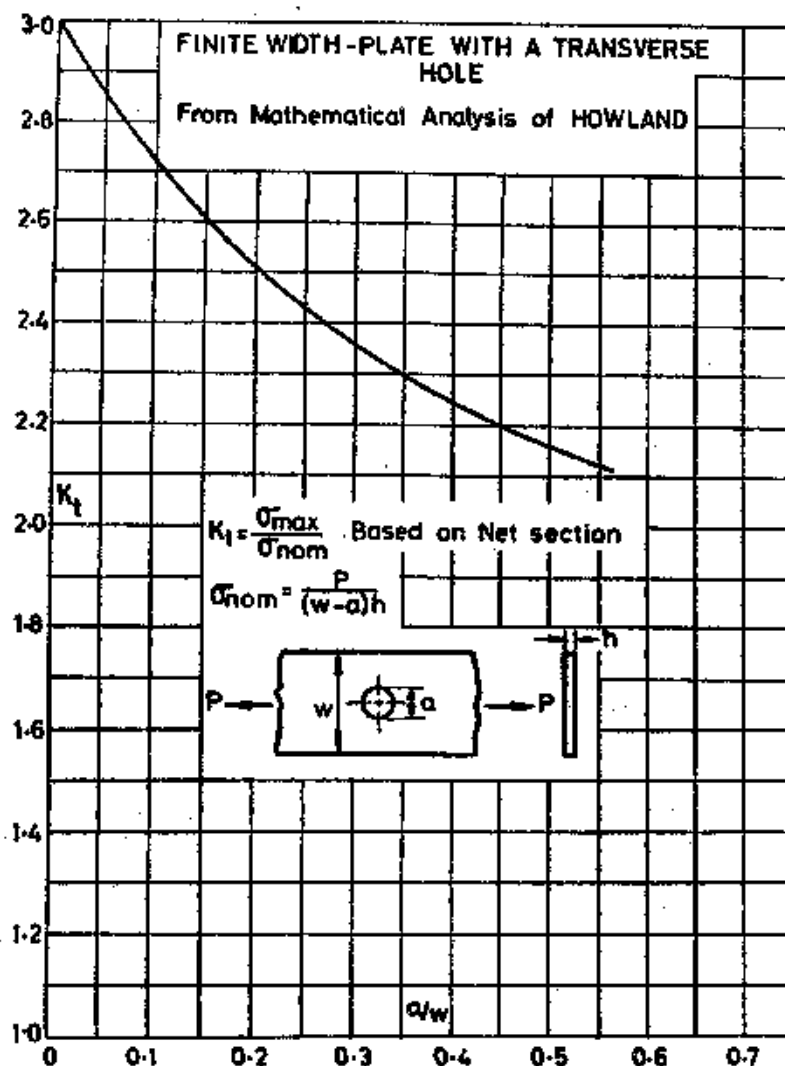
VALUES OF K_t FOR KEYWAYS

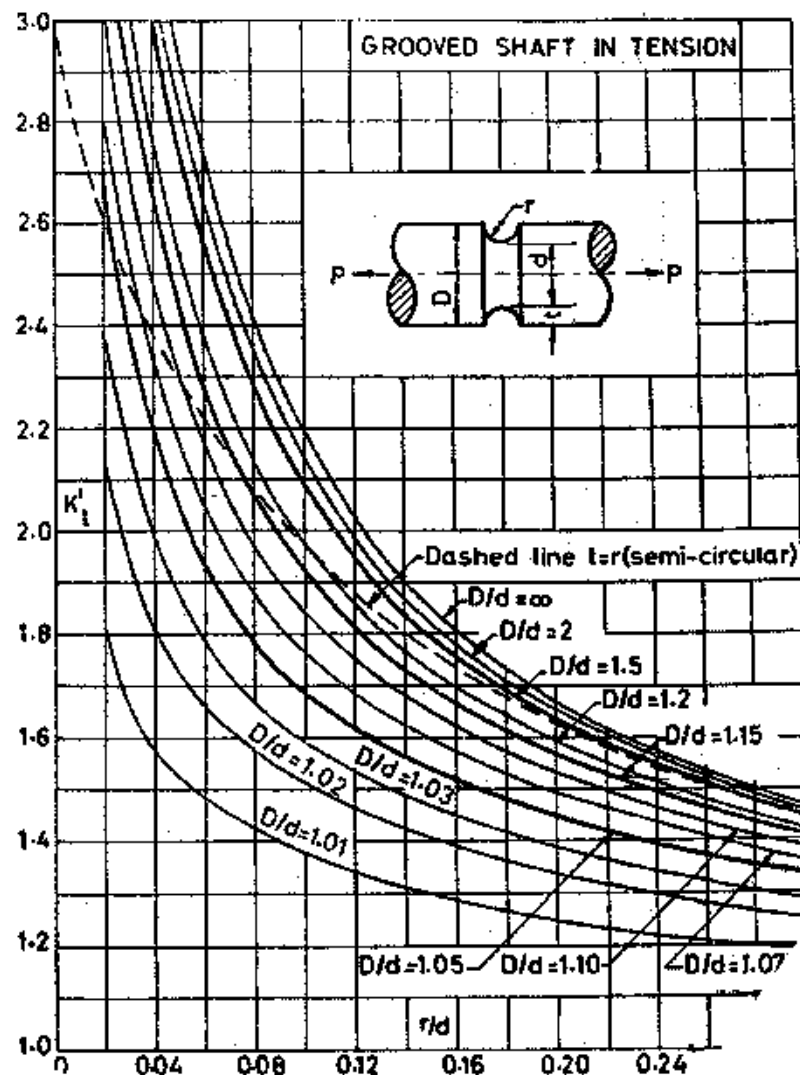
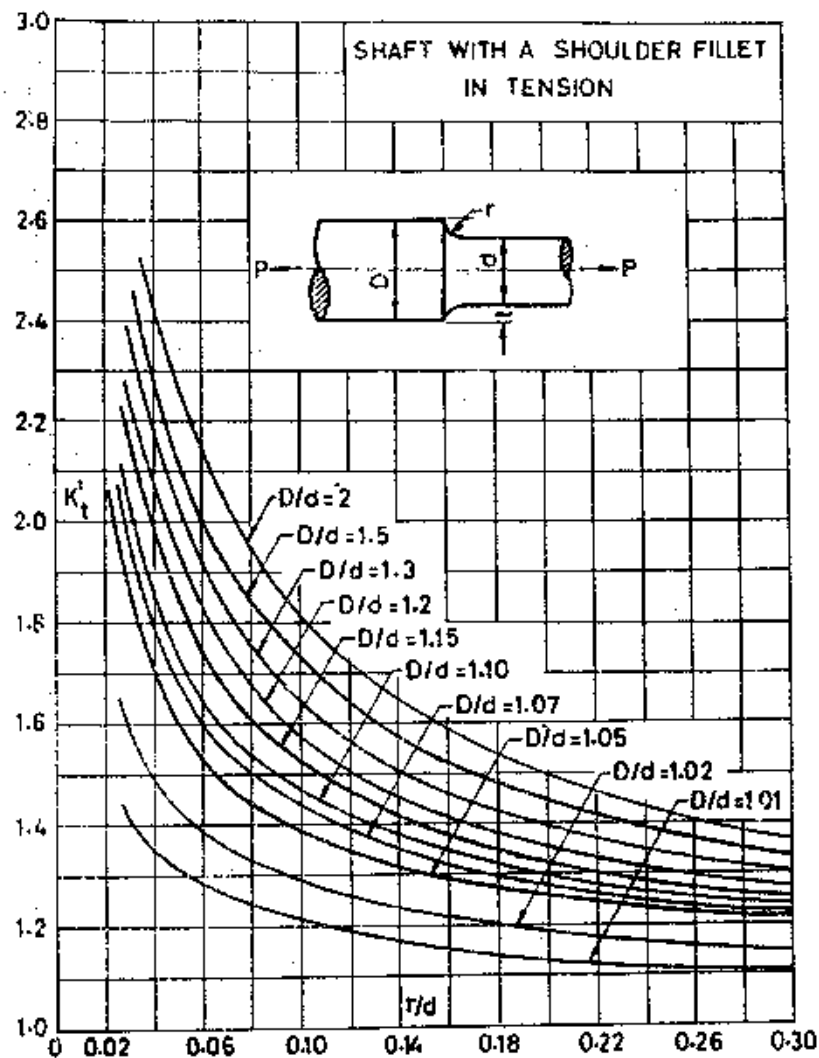


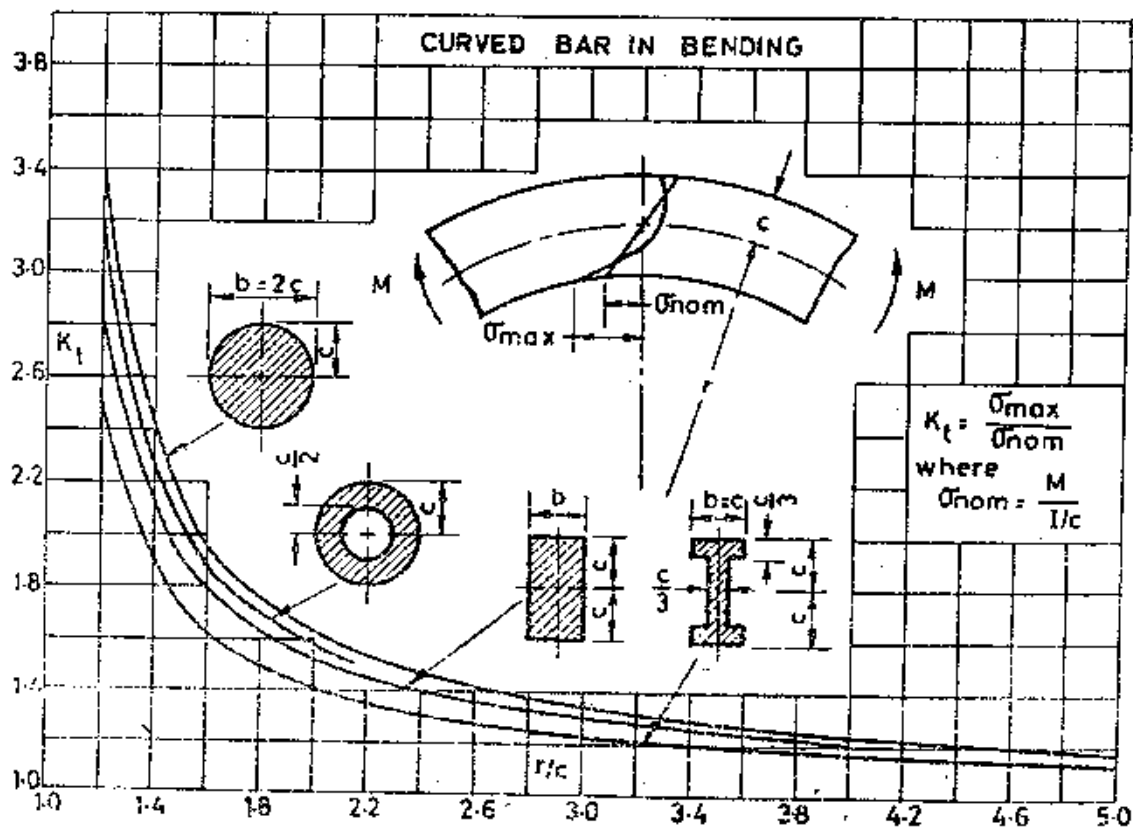
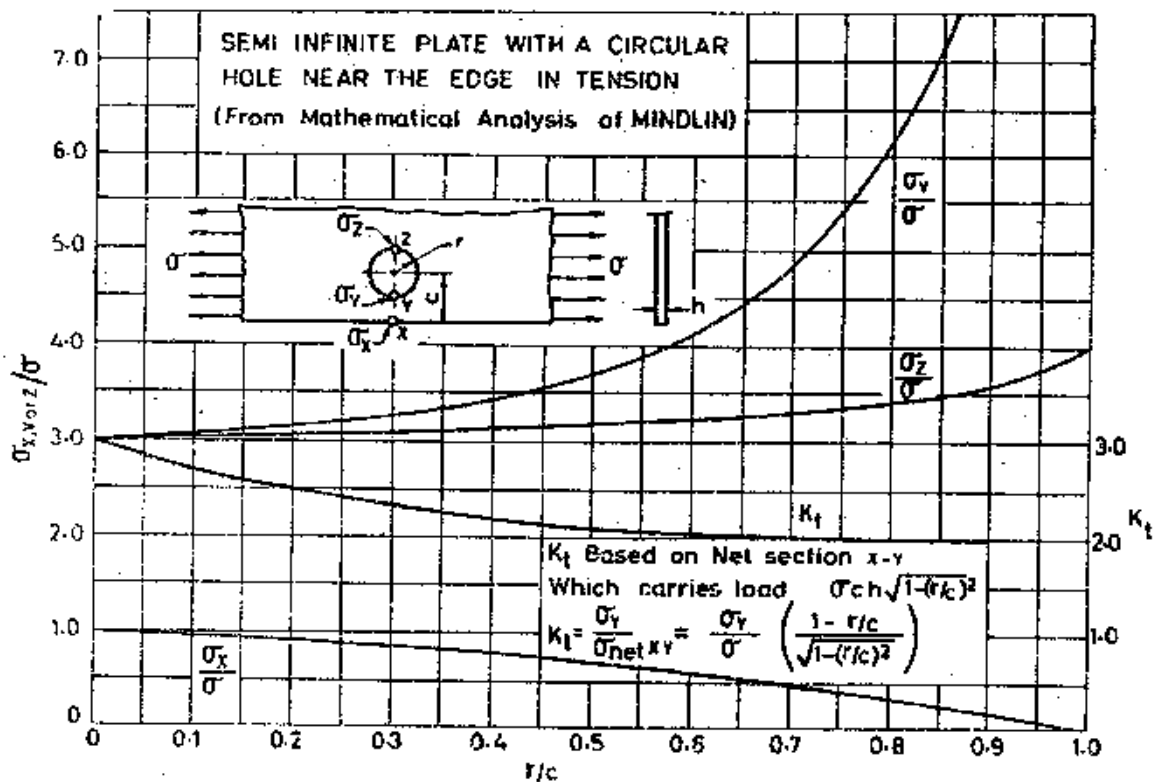
KIND OF KEYWAY	Annealed		Hardened	
	Bending	Torsion	Bending	Torsion
PROFILE	1.6	1.3	2.0	1.6
SLED RUNNER	1.3	1.3	1.5	1.6

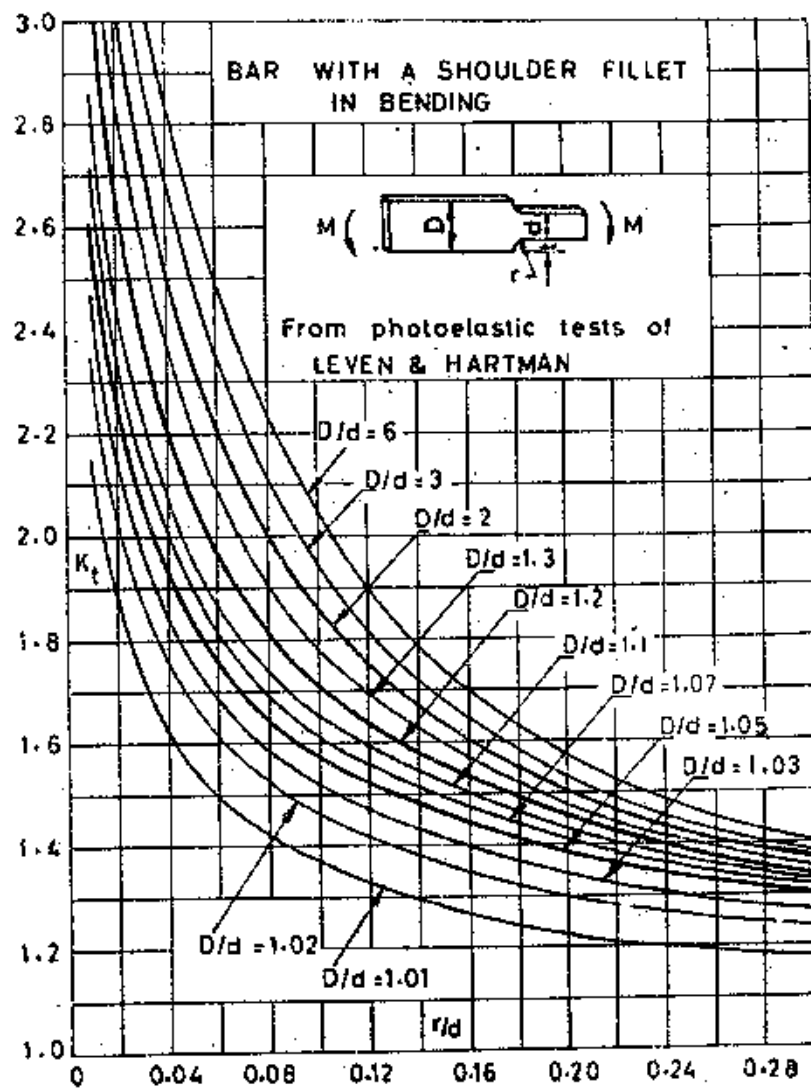
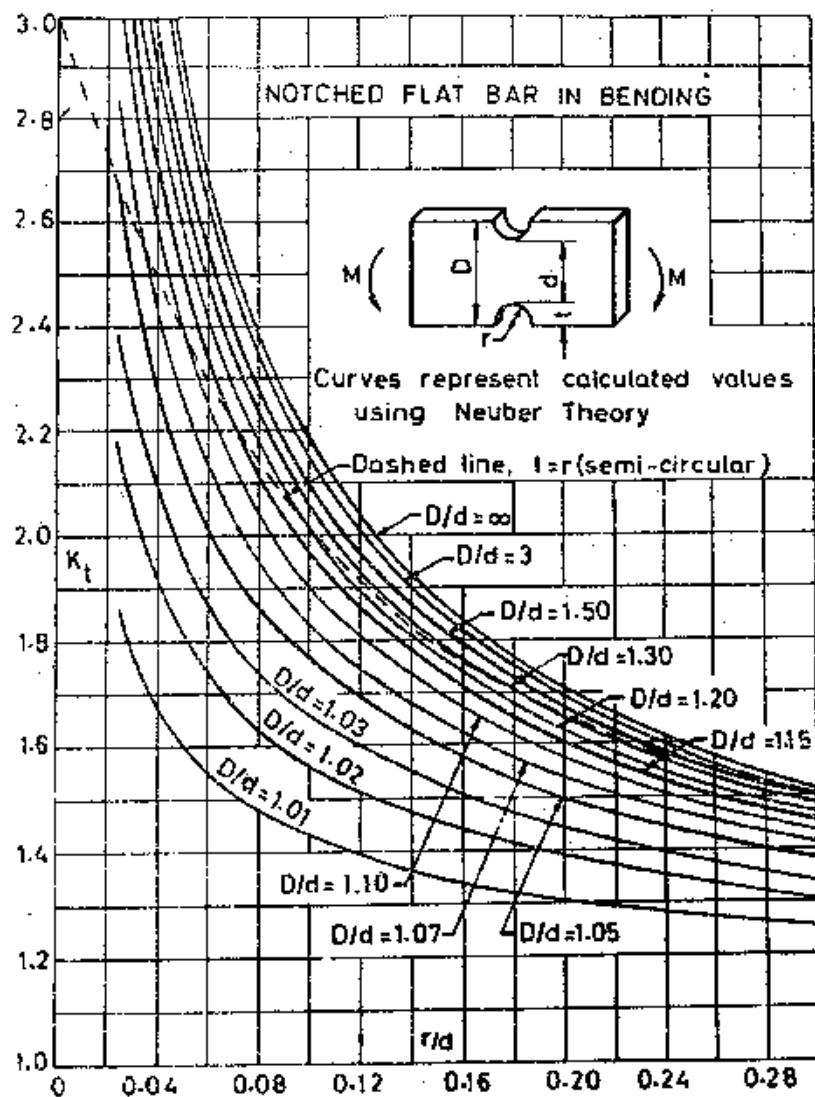


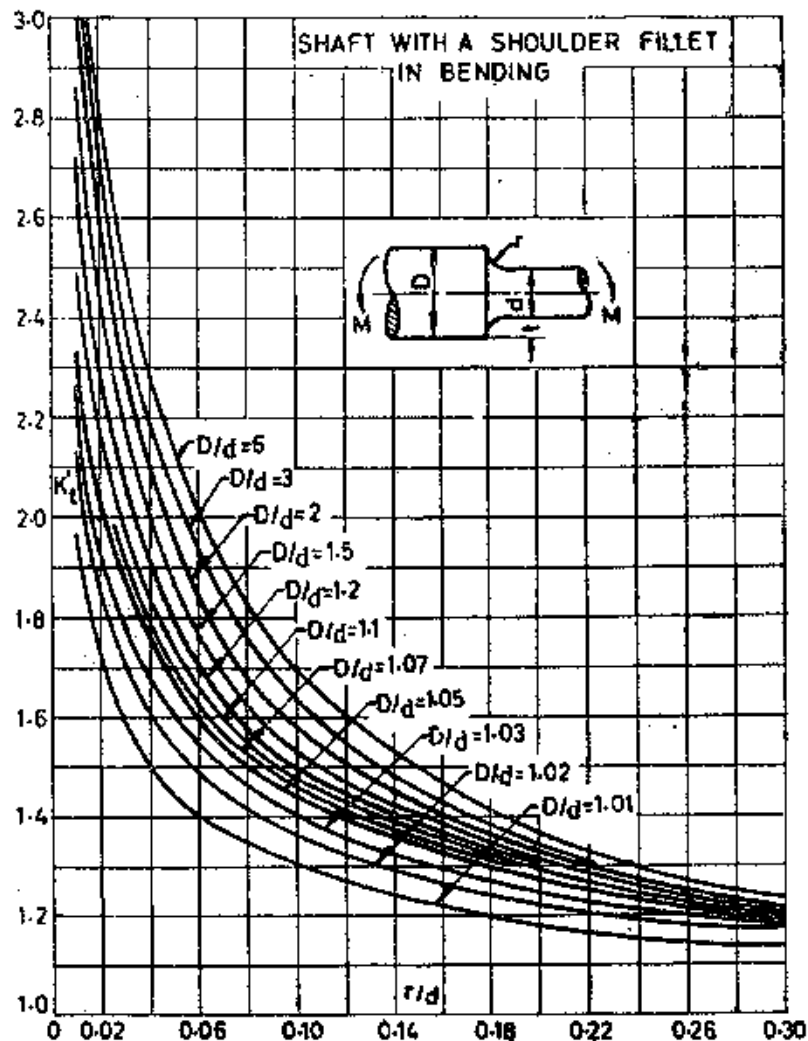
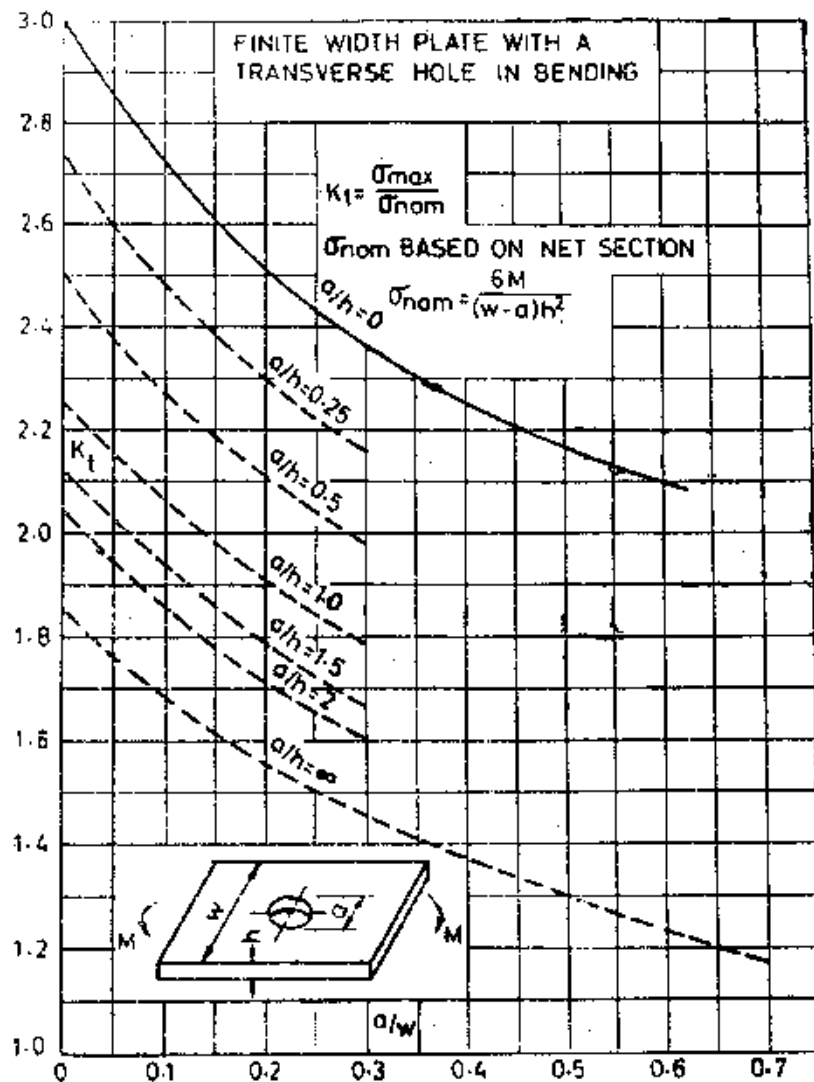


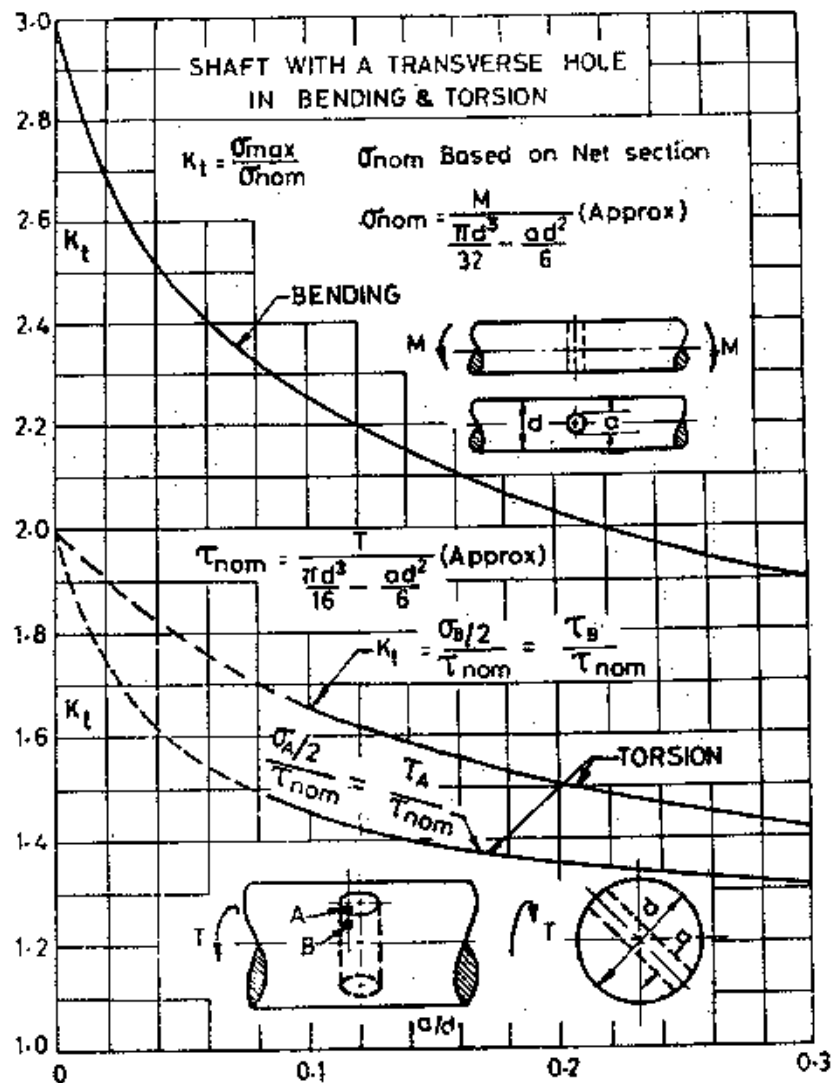
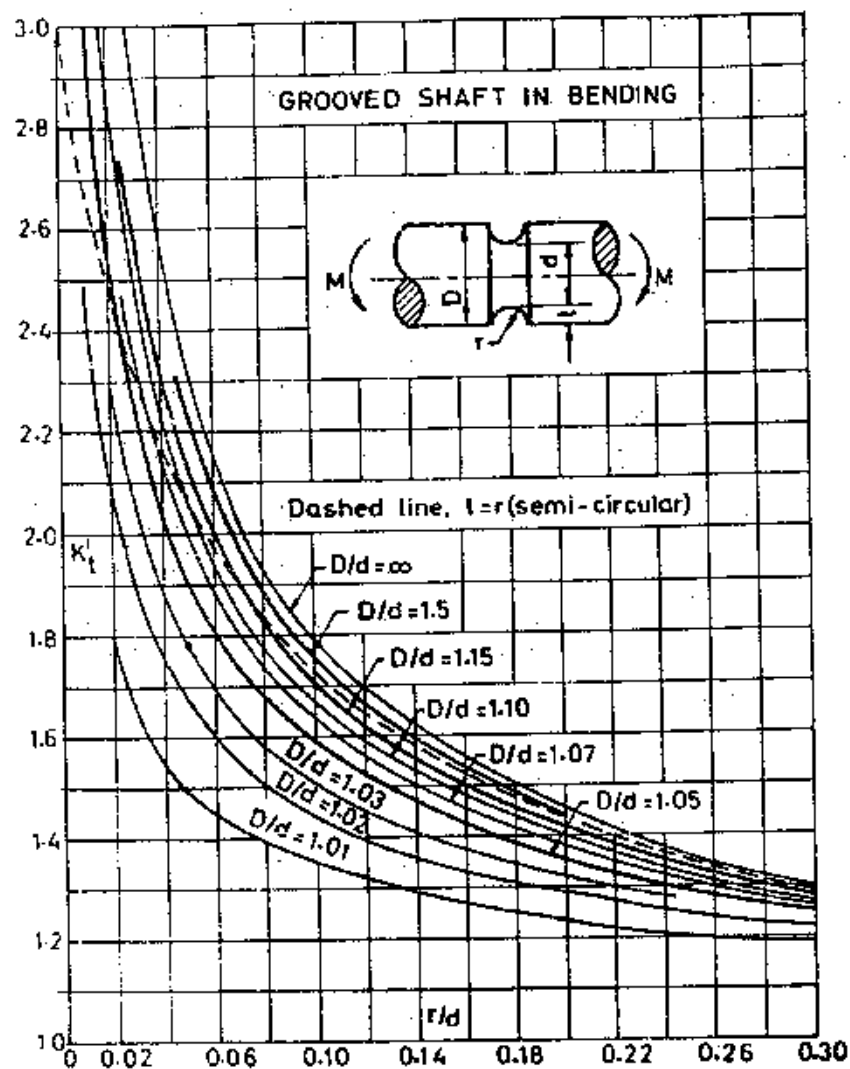


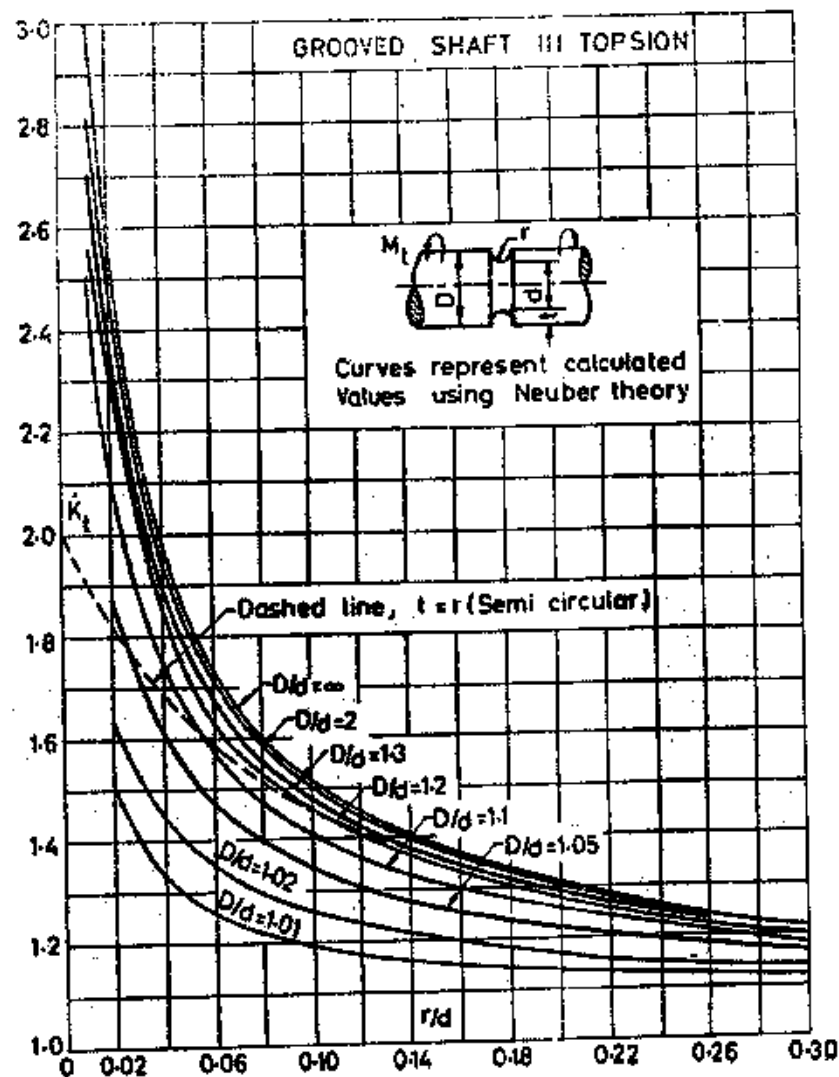
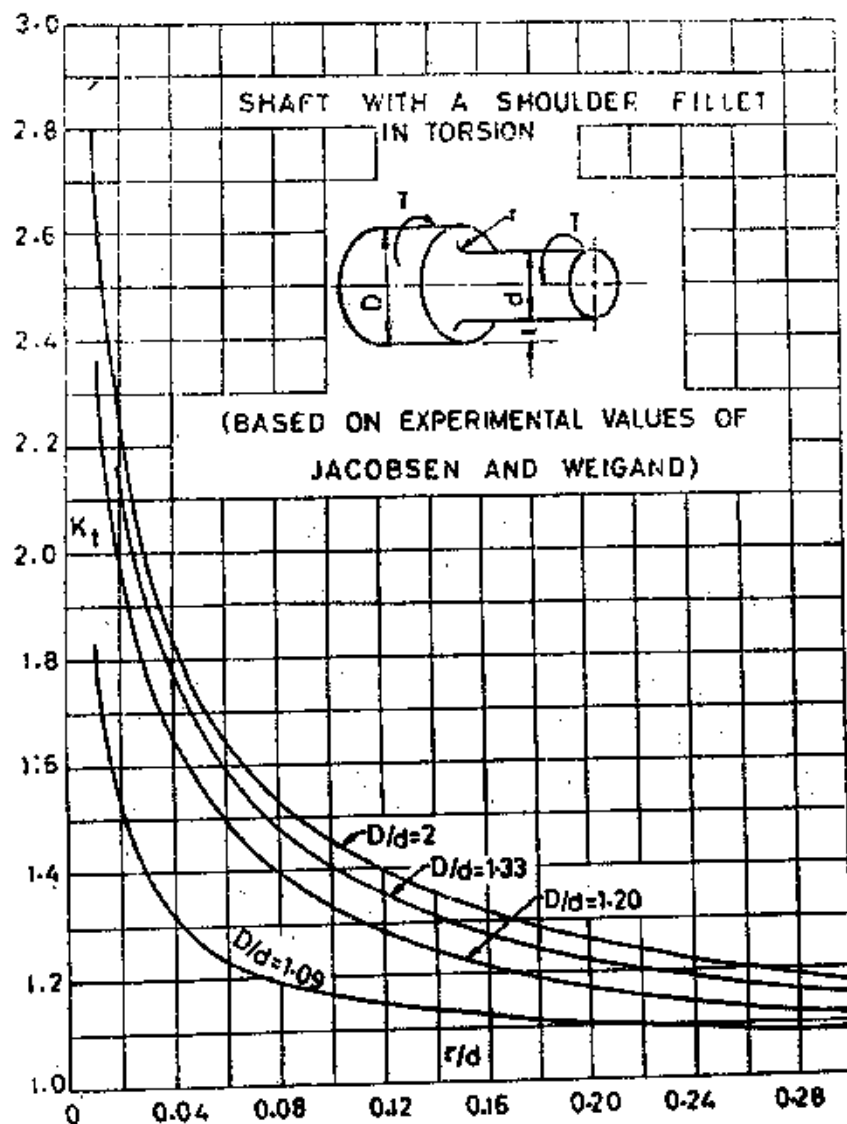


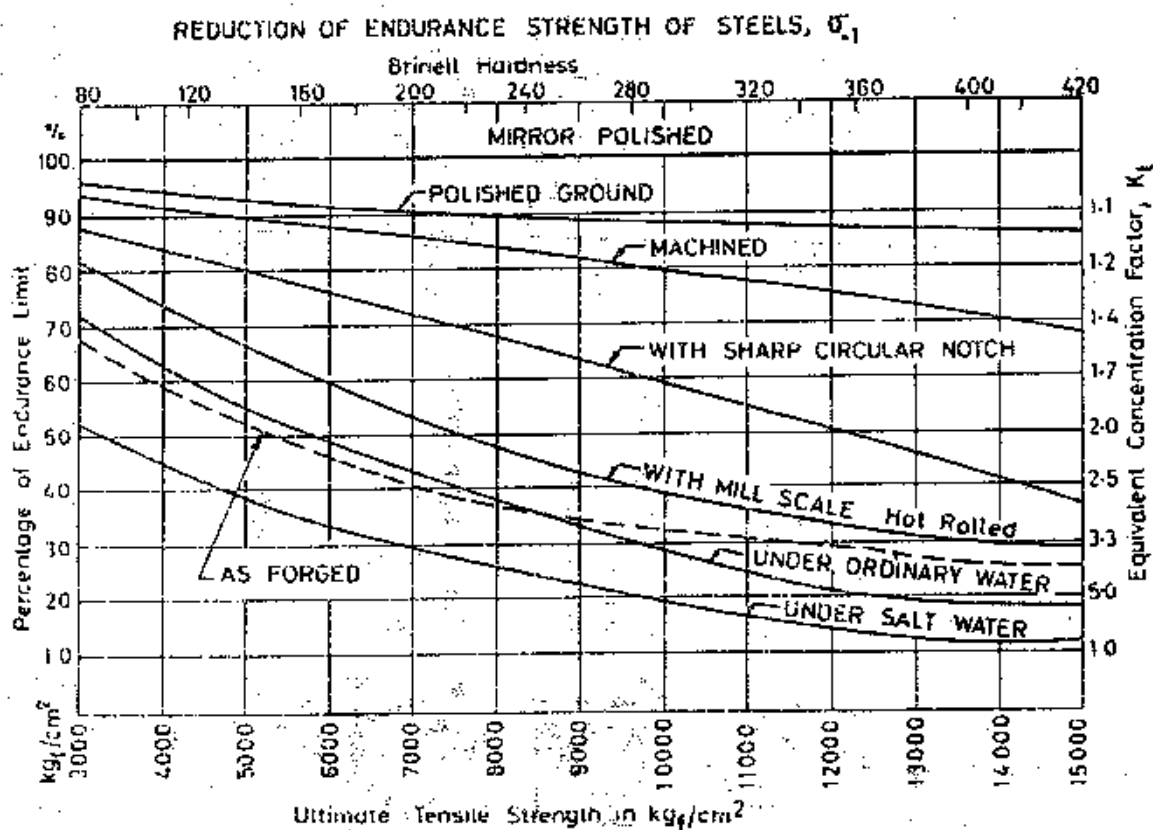
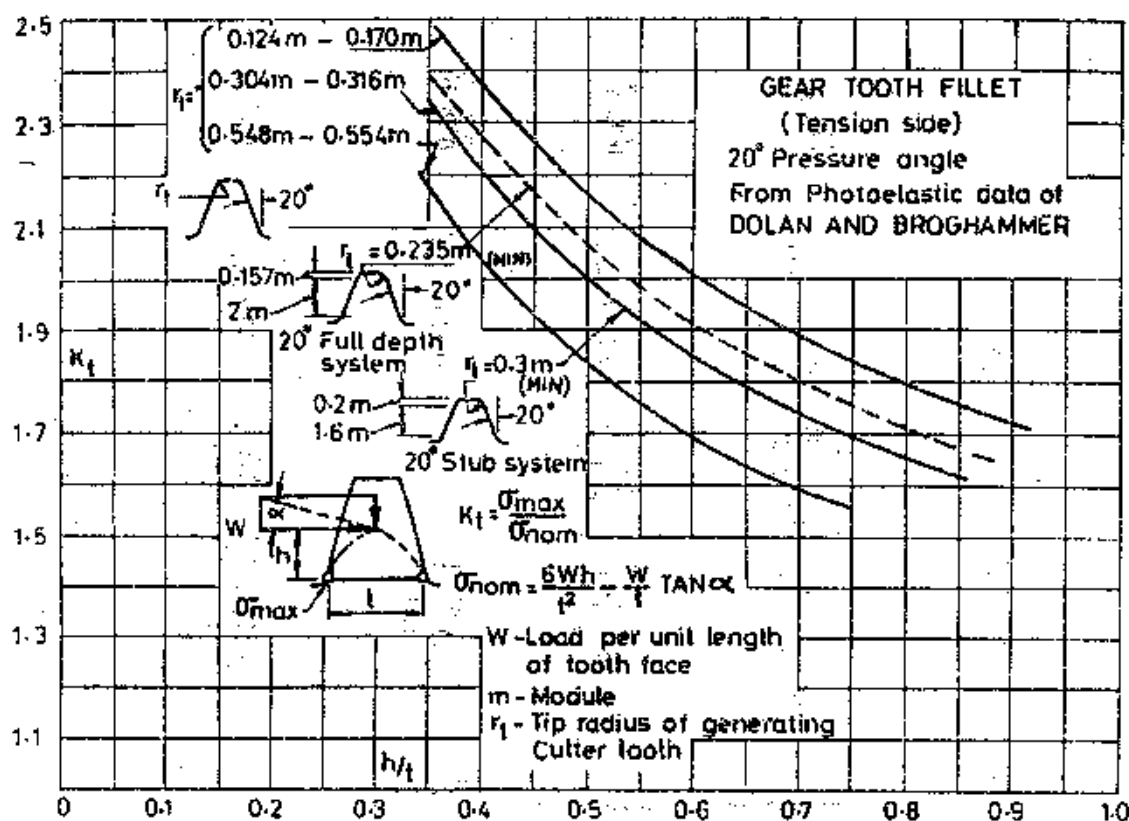






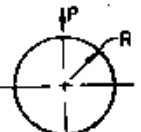
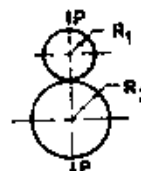
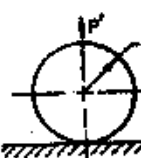
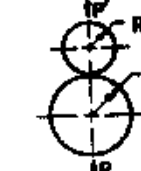






CONTACT STRESS: Formulae

7.18

Geometry	Dissimilar metals		Similar metals $\nu_1 = \nu_2 = 0.3, E_1 = E_2 = E$	
	$\sigma_c \text{ max}$	$\sigma_c \text{ max}$	t_{max}	Depth at t_{max}
 Sphere and flat plate P = Total load	$0.578 \left[\frac{P}{R^2 \left(\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2} \right)} \right]^{\frac{1}{3}}$	$0.388 \left[\frac{PE^2}{R^2} \right]^{\frac{1}{3}}$	$0.33 \sigma_c \text{ max}$	$0.25 a$
 Two Spheres P = Total load	$0.578 \left[\frac{P \left(\frac{1}{R_1} + \frac{1}{R_2} \right)^2}{\left(\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2} \right)} \right]^{\frac{1}{3}}$	$0.388 \left[PE^2 \left(\frac{1}{R_1} + \frac{1}{R_2} \right)^2 \right]^{\frac{1}{3}}$	$0.33 \sigma_c \text{ max}$	$0.25 a$
 Sphere and Spherical Socket P = Total load	$0.578 \left[\frac{P \left(\frac{1}{R_2} - \frac{1}{R_1} \right)^2}{\left(\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2} \right)} \right]^{\frac{1}{3}}$	$0.388 \left[PE^2 \left(\frac{1}{R_2} - \frac{1}{R_1} \right)^2 \right]^{\frac{1}{3}}$	$0.33 \sigma_c \text{ max}$	$0.25 a$
 Cylinder and flat plate $P' = \frac{P}{a}$	$0.564 \left[\frac{P'}{R \left(\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2} \right)} \right]^{\frac{1}{2}}$	$0.418 \left[\frac{P'E}{R} \right]^{\frac{1}{2}}$	$0.30 \sigma_c \text{ max}$	$0.79 b$
 Two Cylinders $P' = \frac{P}{a}$	$0.564 \left[\frac{P' \left(\frac{1}{R_1} + \frac{1}{R_2} \right)}{\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2}} \right]^{\frac{1}{2}}$	$0.418 \left[P'E \left(\frac{1}{R_1} + \frac{1}{R_2} \right) \right]^{\frac{1}{2}}$	$0.30 \sigma_c \text{ max}$	$0.79 b$
 Cylinder and cylindrical groove $P' = \frac{P}{a}$	$0.564 \left[\frac{P' \left(\frac{1}{R_2} - \frac{1}{R_1} \right)}{\frac{1-\nu_1^2}{E_1} + \frac{1-\nu_2^2}{E_2}} \right]^{\frac{1}{2}}$	$0.418 \left[P'E \left(\frac{1}{R_2} - \frac{1}{R_1} \right) \right]^{\frac{1}{2}}$	$0.30 \sigma_c \text{ max}$	$0.79 b$

PREFERRED NUMBERS

Preferred numbers are the conventionally rounded off values derived from geometric series, including the integral powers of 10 and having as common ratios the following factors:

$$^5\sqrt{10}, \quad ^{10}\sqrt{10}, \quad ^{20}\sqrt{10}, \quad ^{40}\sqrt{10}, \quad ^{80}\sqrt{10}$$

These ratios ϕ , known as step ratios, are approximately equal to 1.58 1.26 1.12 1.06 1.03 respectively.

This series of Preferred Numbers are designated R 5, R 10, R 20, R 40 and R 80 respectively, 'R' standing for Renard (in France) or for Reihe, i. e. a series or row (in Germany), and the number indicates the particular root of 10 on which the series is based.

$$^{10}\sqrt{10} \simeq {}^3\sqrt{2} \simeq 1.259$$

This means that the cube of this series ($\phi = 1.26$) is approximately equal to twice the preceding number.

$$(1.26^3 = 2)$$

10	12.5	16	20	25	31.5	40	50	63	80	100

Thus the terms of the R 10 series are doubled in every 3 terms, the terms of the R 20 series are doubled in every 6 terms, and those of the R 40 series are doubled in every 12 terms.

It will be found that the derived series R 10/3 covers all numbers which are powers of 2, namely

$$0.25 \quad 0.5 \quad 1 \quad 2 \quad 4 \quad 8 \quad 16 \quad 31.5 \quad 63 \quad 125 \quad 250$$

$$2^{-2} \quad 2^{-1} \quad 2^0 \quad 2^1 \quad 2^2 \quad 2^3 \quad 2^4 \quad (2^5) \quad (2^6) \quad (2^7) \quad (2^8)$$

In the same manner a derived series R 20/ is formed with a step ratio of $\sqrt{2} = 1.41$ which is one of the most frequently used ratios in Machine Tool Design as follows

$$10 \quad 14 \quad 20 \quad 28 \quad 40 \quad 56 \quad 80 \quad 112 \quad 160 \quad 224$$

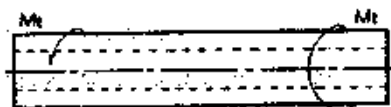
BASIC SERIES OF PREFERRED NUMBERS

R 5 $\phi = 1.6$	R 10 $\phi = 1.25$	R 20 $\phi = 1.12$	R 40 $\phi = 1.06$
1.00	1.00	1.00	1.00
			1.06
		1.12	1.12
			1.18
	1.25	1.25	1.25
			1.32
		1.40	1.40
			1.50
1.60	1.60	1.60	1.60
			1.70
		1.80	1.80
			1.90
	2.00	2.00	2.00
			2.12
		2.24	2.24
			2.36
2.50	2.50	2.50	2.50
			2.65
		2.80	2.80
			3.00
	3.15	3.15	3.15
			3.35
		3.55	3.55
			3.75
4.00	4.00	4.00	4.00
			4.25
		4.50	4.50
			4.75
	5.00	5.00	5.00
			5.30
		5.60	5.60
			6.00
6.30	6.30	6.30	6.30
			6.70
		7.10	7.10
			7.50
	8.00	8.00	8.00
			8.50
		9.00	9.00
			9.50
10.00	10.00	10.00	10.00

SHAFTS

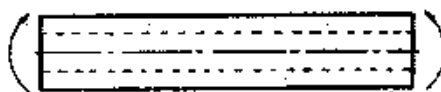
*Hollow Shaft subjected to Torsion only:

$$\tau_{\max} = \frac{16 M_t d_0}{\pi (d_0^4 - d_i^4)}$$

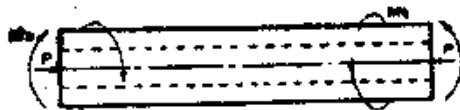


*Hollow Shaft subjected to Bending only

$$\sigma_{b \max} = \frac{32 M_b d_0}{\pi (d_0^4 - d_i^4)}$$



*Hollow Shaft subjected to Bending, torsion and axial load:



$$d_0^3 = \frac{16}{\pi [\tau]} \left\{ 1 - \left(\frac{d_i}{d_0} \right)^4 \right\} \sqrt{\left[K_b M_b + \alpha \frac{P d_0}{8} \left(1 + \frac{d_i^3}{d_0^3} \right) \right]^2 + (K_t M_t)^2}$$

* For solid shaft put $d_i = 0$.

Shaft sizes to be rounded off to R 20 series

Type	K_b	K_t
STATIONARY SHAFT		
Gradually applied load	1	1
Suddenly applied load	1.5-2	1.5-2
REVOLVING SHAFT		
Gradual loading	1.5	1
Minor shock loads	1.5-2	1-1.5
Heavy shock loads	2-3	1.5-3

P , axial load

M_t , twisting moment

M_b , bending moment

$[\tau]$, design shear stress

K_b , combined shock and fatigue factor applied to M_b

K_t , combined shock and fatigue factor applied to M_t

τ , shear stress

σ_b , bending stress

α , column action factor

= 1 for tensile load

$$= \frac{1}{1 - 0.0044 \left(\frac{l}{r} \right)^2} \quad \text{for } \frac{l}{r} < 115$$

$$= \frac{\sigma_y}{\pi^2 n E} \left(\frac{l}{r} \right)^2 \quad \text{for } \frac{l}{r} > 115$$

E , Young's modulus

σ_y , yield stress

r , radius of gyration

l , length of shaft under axial load

n - end condition coefficient, refer page 6.8

Equivalent bending moment at a cross-section

$$M = \sqrt{M_b^2 + (\alpha M_t)^2} \quad \text{kgf cm}$$

Diameter of shaft at the same cross-section

$$d = \sqrt[3]{\frac{M K_t}{\frac{\pi}{32} [\sigma_b]_{III}}} \quad \text{cm}$$

Factor of safety in bending

$$n_\sigma = \frac{\sigma_{-1}}{K_t \beta_{size} \sigma_b}$$

Factor of safety in torsion

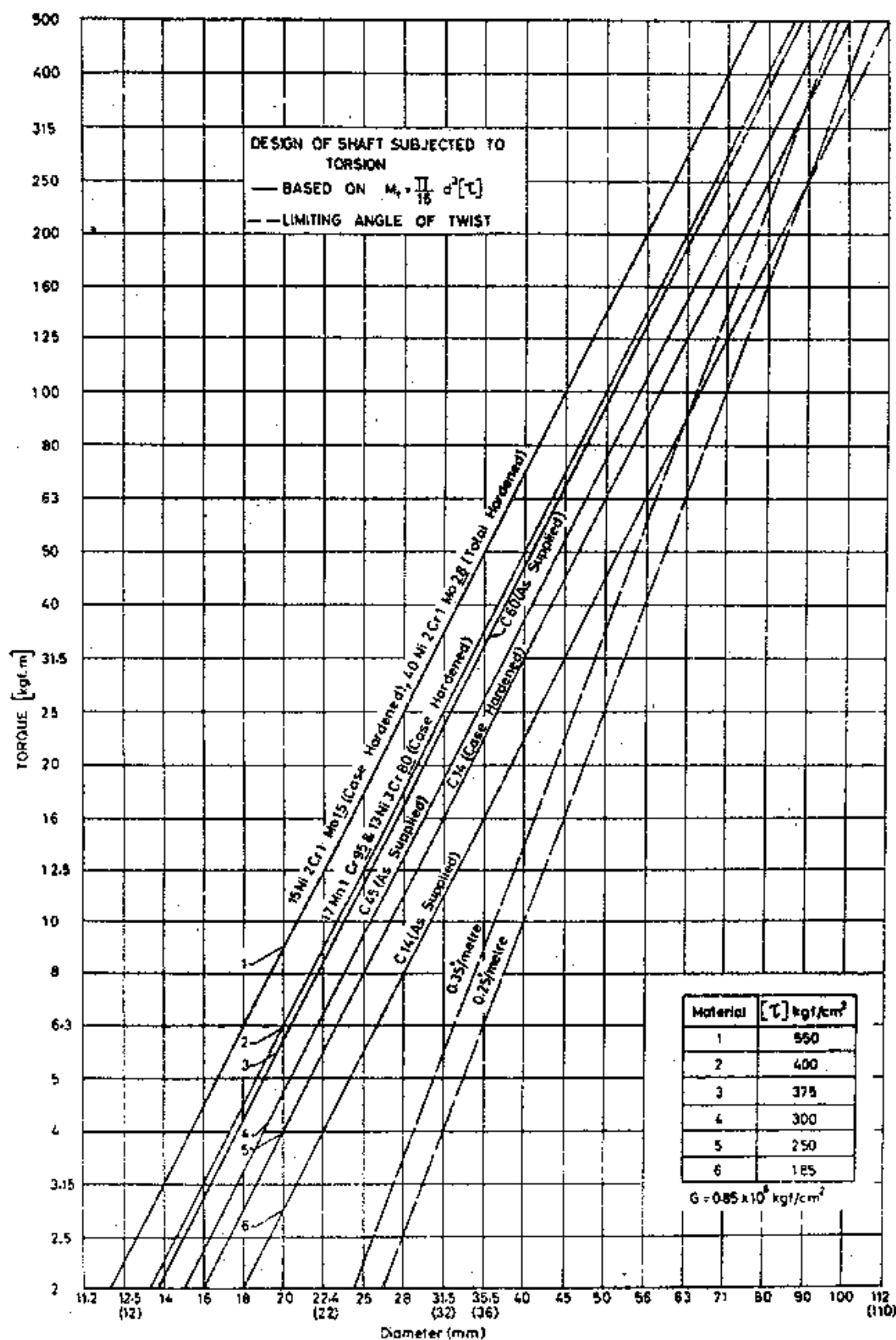
$$n_t = \frac{L_{-1}}{K_t \beta_{size} \tau}$$

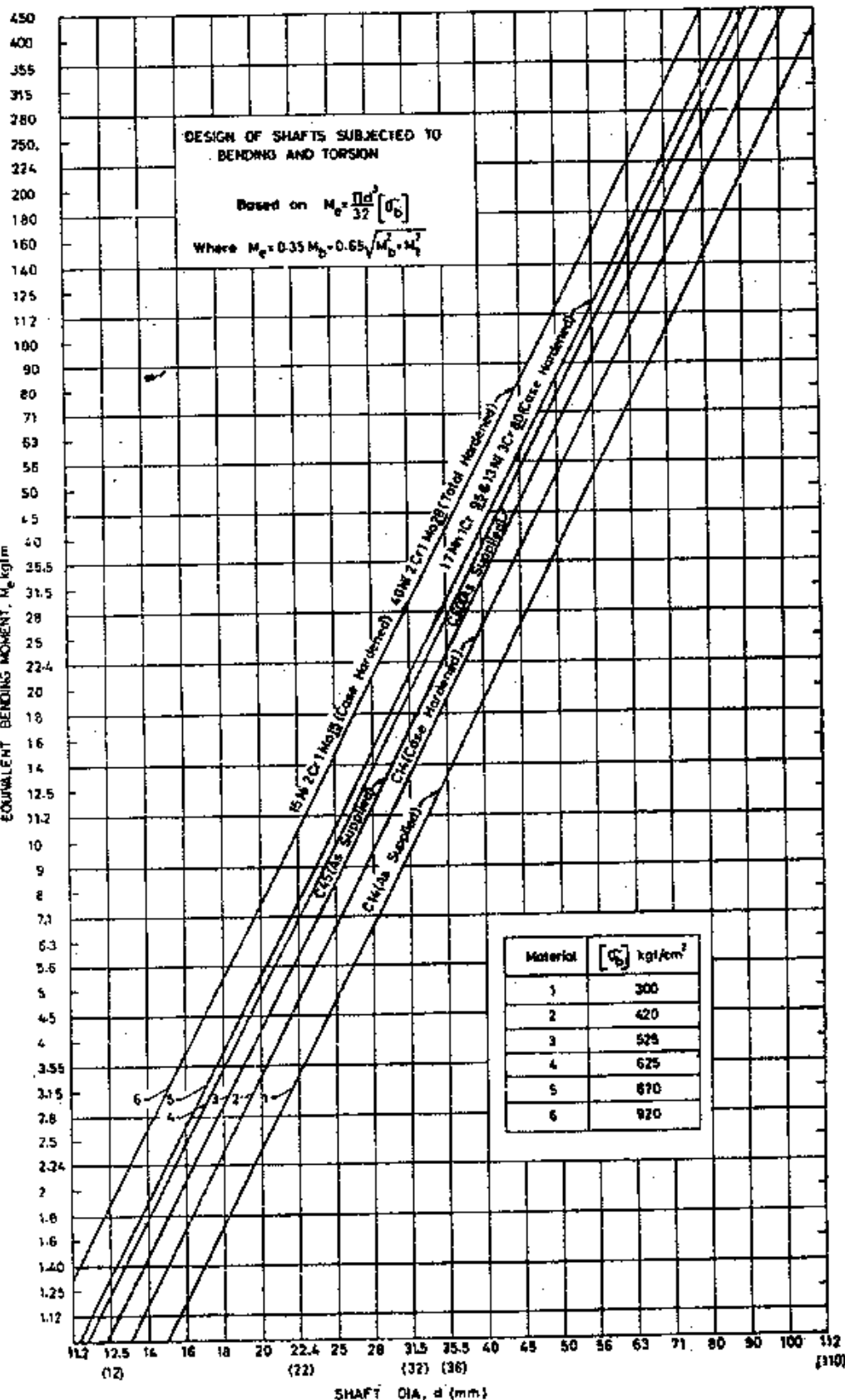
Actual factor of safety

$$n = \frac{n_\sigma n_t}{\sqrt{n_\sigma^2 + n_t^2}}$$

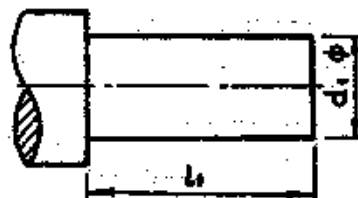
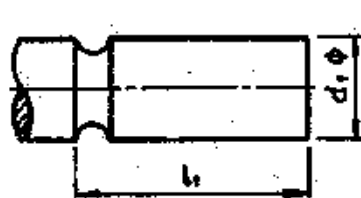
 M_t twisting moment, kgf cm M_b bending moment, kgf cm $\alpha = \frac{[\sigma_b]_{III}}{[\sigma_b]_{II}}$, refer page 7.7 $\alpha \approx 1$, When M_t is reversed K_t stress concentration factor σ_{-1} Endurance limit stress bending β_{size} Size factor, σ_b bending stress, kgf/cm² L_{-1} Endurance limit stress in torsion. n should normally be greater than 2.15 τ shearing stress, kgf/cm² β_{size} Size factor for shaft

	Range of diameter of shafts, mm												
	15-18	18-20	20-25	25-30	30-35	35-40	40-45	45-50	50-60	60-70	70-80	80-90	90-100
in bending	1.08	1.09	1.12	1.14	1.16	1.18	1.20	1.22	1.28	1.32	1.35	1.39	1.43
in shear	1.20	1.20	1.25	1.30	1.33	1.37	1.41	1.43	1.50	1.54	1.61	1.67	1.69



EQUIVALENT BENDING MOMENT, M_e kgfm

CYLINDRICAL SHAFT ENDS

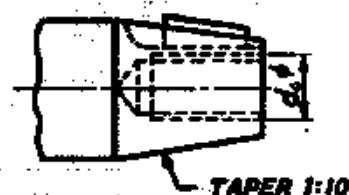
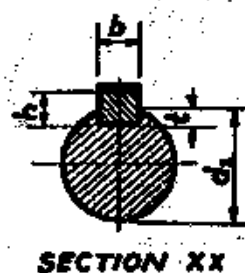
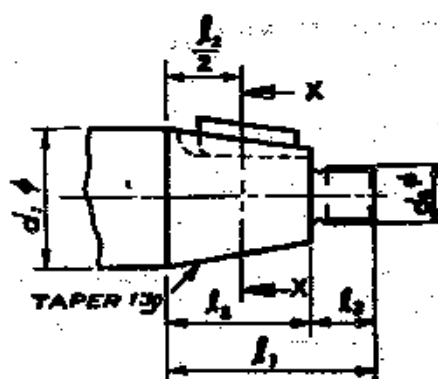


All dimensions in millimetres

Diameter. d_1		Length l_1	
nom.	tolerance	long series	short series
6	j6	16	—
7			
8		20	—
9			
10		23	20
11			
12		30	25
14			
16		40	28
18			
19			
20		50	36
22			
24			
25		60	42
28			
30	80	58	
32			
35			
38			
40	k6		
42			
45			
48			
50		110	82
55			
56		m6	
60			
63			
65			
70			
71	140	105	
75			

Diameter d_1		Length l_1	
nom.	tolerance	long series	short series
80		170	130
85			
90			
95		210	165
100			
110			
120		250	200
125			
130			
140		300	240
150			
160			
170		350	280
180			
190			
200	n6	410	330
220			
240			
250		470	380
260			
280			
300		550	450
320			
340			
360		650	540
380			
400			
420		800	680
440			
450			
460			
480			
500			
530			
560			
600			
630			

SHORT TAPERED SHAFT ENDS



All dimensions in millimetres

Diameter		Length			Key and Key way		t	Ext. Thread d ₂	Int. Thread d ₄
d ₁	Tol.	l ₁	l ₂	l ₃	d ₂	b × h			
16					15.2	3 × 3	1.8	M10 × 1.25	M 4
18	j6	28	16	12	17.2	4 × 4	2.5	M10 × 1.25	M 5
19					18.2	4 × 4	2.5	M10 × 1.25	M 5
20					18.9	4 × 4	2.5	M12 × 1.25	M 6
22	j6	36	22	14	20.9	4 × 4	2.5	M12 × 1.25	M 6
24					22.9	5 × 5	3	M12 × 1.25	M 6
25	j6	42	24	18	23.8	5 × 5	3	M16 × 1.25	M 8
28					26.8	5 × 5	3		
30	j6				28.2	5 × 5	3	M20 × 1.5	M10
32	k6	58	36	22	30.2	6 × 6	3.5		M10
35					33.2	6 × 6	3.5		M10
38					36.2	6 × 6	3.5	M24 × 2	M12
40	k6	82	54	28	37.3	10 × 8	5	M24 × 2	M12
42					39.3	10 × 8	5	M24 × 2	M12
45					42.3	12 × 8	5	M30 × 2	M16
48					45.3	12 × 8	5	M30 × 2	M16
50	m6				47.3	12 × 8	5	M36 × 3	M16
55					52.3	14 × 9	5.5		M20
56					53.3	14 × 9	5.5		M20
60	m6	105	70	35	56.5	16 × 10	6	M42 × 3	M20
63					59.5	16 × 10	6		M20
65					61.5	16 × 10	6		M20
70					66.5	18 × 11	7	M48 × 3	M24
71					67.5	18 × 11	7		M24
75					71.5	18 × 11	7		M24

SHORT TAPERED SHAFT ENDS (Contd.)

Diameter		Length			Key and Key way		t	Ext. Thread	Int. Thread
d ₁	Tol.	l ₁	l ₂	l ₃	d ₂	b × h		d ₃	d ₄
80	m6	130	90	40	75.5	20 × 12	7.5	M56 × 4	M30
85					80.5	20 × 12	7.5		M30
90					85.5	22 × 14	9.0	M64 × 4	M30
95					90.5	22 × 14	9.0		M36
100	m6	165	120	45	94	25 × 14	9	M72 × 4	M36
110					104	25 × 14	9	M80 × 4	M42
120					114	28 × 16	10	M90 × 4	M42
125					119	28 × 16	10		M48
130	m6	200	150	50	122.5	28 × 16	10	M100 × 4	
140					132.5	32 × 18	11	M100 × 4	
150					142.5	32 × 18	11	M110 × 4	
160	m6	240	180	60	141	36 × 20	12	M125 × 4	
170					161	36 × 20	12	M125 × 4	
180					171	40 × 22	13	M140 × 6	
190	m6	280	210	70	179.5	40 × 22	13	M140 × 6	
200					189.5	40 × 22	13	M160 × 6	
220					209.5	45 × 25	15	M160 × 6	

PROPERTIES OF LUBRICANTS

Purpose	SAE number	Pour Point °C max.	Flash point °C min.	Saybolt universal seconds at						Viscosity index
				37.8°C		54.3°C		99°C		
				min.	max.	min.	max.	min.	max.	
Automotive oils	10	—12	190			90	120			80
	20	—9.5	200			120	185			80
	30	—4	210			185	255			80
	40	—4	218			255	—	—	80	80
	50	—4	230			—	—	80	105	80
	60	—4	240			—	—	105	125	80
	70	—4	260			—	—	125	150	80
Aircraft Engine oils	30	—23.4	205					60	65	95
	40—50	—17.8	218					75	85	95
	50	—12.2	232					90	100	95
	60	—6.7	246					115	125	95
	70	—1	260					135	145	95
Transmission oils	90	—17.8	150	800	1500			—	—	
	140	2	205	—	—			120	200	
	250	2	260	—	—			200	—	
Diesel Engine oils	Light	20	—17.8	170		120	185	—		
	Medium	30	—12.2	177		185	255	—		
	Heavy	40	—6.7	188		255	310	—		
	Extra heavy	50	—6.7	194		—	—	75	90	
Turbine grade oils	Light	—	2	158	120	174				
	Medium	10	2	163	175	269				
	Heavy medium	20	2	177	270	339				
	Heavy	20—30	2	177	340	474				
	Extra heavy	30	2	177	475	525				
Refrigerating machine oils	Light	—	—30	158	140	170				
	Medium	10	—26	163	170	215				
	Heavy	20	—22	177	300	325				

PROPERTIES OF LUBRICANTS (Contd.)

Purpose	SAE number	Pour point °C max.	Flash point °C min.	Saybolt universal seconds at					
				37.8°C		54.3°C		99°C	
				min.	max.	min.	max.	min.	max.
Steam cylinder oils	compound mineral	Light	15	254				135	165
		Heavy	15	273				175	220
		Light	5	232				95	110
		Medium	15	245				120	150
		Heavy	15	270				175	220
Engine and machine oils		Spindle	—	—1	162	100	125		
		Light	10	—1	170	150	200		
		Medium	20	—1	182	250	300		
		Heavy medium	30	—1	188	350	400		
		Heavy	40	—1	193	700	800		
Marine engine oils		Mineral	40	2	182			65	75
		Compounded	40—50	2	182			65	80
Hydraulic oils			—23	150	100	120			
		Light turbine oil is a very satisfactory fluid medium for many oil operated hydraulic systems.							

SAE VISCOSITY NUMBERS FOR MOTOR, TRANSMISSION AND REAR AXLE LUBRICATION

Purpose	SAE number	Saybolt universal seconds at			
		54.3°C		99°C	
		min.	max.	min.	max.
Motor oils	10	90	120	—	—
	20	120	185	—	—
	30	185	255	—	—
	40	455	—	—	80
	50	—	—	80	105
	60	—	—	105	125
	70	—	—	120	150
Transmission and rear axle oils	80	1,00,000 seconds at —17.8°C max.			
	90	800 to 1500 sec. at 37.8°C			
	140	120 to 200 sec. at 99°C			
	250	200 sec. at 99°C min.			

MATERIALS AND APPLICATIONS—JOURNAL BEARING

Materials	Characteristics	Limitations	Applications
Wood (maple lignum vital)	Self lubricating, low cost, long life	Light loads at high speeds, under 65°C	Conveyors
Cast Iron	Low friction, low cost	Not over 35 kgf/cm ² and 40 m/min.	Cam shafts, light transmission
Steel	Low cost	Light loads 45 m/min.	Guides
Bronze bushing	Low cost, simple construction	Loads upto 210 kgf/cm ² , speeds upto 270 m/min.	All equipment
Heavy babbitt liner on steel or cast iron	Long life, low friction, must have good lubrication	Steady loads under 70 kgf/cm ²	Motor, turbine, shafting
Light liner on steel or bronze backing	Heavy duty, general purpose, good for dynamic loads	About 350 kgf/cm ² and 1200 m/min.	Gas and diesel engines, compressors
Rubber	Low friction, resists abrasion, shock absorbent, long life	About 5.5 kgf/cm ² , needs water lubrication	Marine propellers, pumps, turbines
Carbon graphite	No lubrication needed, light duty applications	Under 455°C, 40 kgf/cm ² , at low speeds	Electric motors, meters, conveyors
Moulded plastic laminate	Low friction, stronger than babbitt when water lubricated	About 120 m/min. and 175 kgf/cm ² , must be well cooled	Pumps, propellers
Moulded plastic	Low friction, clean	Low loads if used at high speeds	Dairy, textile and food machinery
Sintered bearings, steel, bronze	Self lubricating	Low loads, high speeds	All inaccessible places, typewriter, electric fans, instruments, piston rings

DESIGN PRACTICES—JOURNAL BEARING

Machinery	Bearing	L D	Bearing pressures allowable kg/cm ²	Lubricant	
				Z	Z _n P min
Stationary High Speed Steam Engines	Main	1.5—3.0	17.5	15	355.6
	Crank Pin	0.9—1.5	42.0	30	85.3
	Wrist Pin	1.3—1.7	126.0	25	71.1
Gas and Oil Engines (Four Stroke)	Main	0.6—2.0	49—84	20—65	284.5
	Crank Pin	0.6—1.5	108—126		142.2
	Wrist Pin	1.5—2.0	125—154		71.1
Gas and Oil Engines (Two Stroke)	Main	0.6—2.0	35—125	20—65	355.6
	Crank Pin	0.6—1.5	70—105		170.7
	Wrist Pin	1.5—2.2	84—125		142.2
Aircraft and Automobile Engine	Main	0.8—1.8	56—119	8	213.3
	Crank Pin	0.7—1.4	105—245		142.2
	Wrist Pin	1.5—2.2	161—350		113.8
Reciprocating Compressors and Pumps	Main	1.0—2.2	17.5	30—80	426.7
	Crank Pin	0.9—1.7	42		284.5
	Wrist Pin	1.5—2.0	70		142.2
Centrifugal Pump, Motors and Generators	Rotor	1.0—2.0	7—14	25	2844.5
Machine Tools	Main	1.0—4.0	21	40	14.2
Steam Turbines	Main	1.0—2.0	7—20	2—16	1422.3
Railway Cars	Axle	1.9	35	100	711.2
Marine Steam Engines	Main	0.7—1.5	35	30	284.5
	Crank Pin	0.7—1.2	42	40	213.3
	Wrist Pin	1.2—1.7	105	30	142.2
Transmissions	Light, Fixed +	2—3	1.8	25	1422.3
Gyroscopes	Rotor	—	60	30	782.3
Shafting	Self Aligning	2.5—4	11	60	426.7
	Heavy	2—3	11	60	426.7
Cotton Mills	Spindle	—	0.07	2	142231
Punching and Shearing Machines	Main	1—2	280	100	—
	Crank Pin	1—2	560	100	—
Rolling Mills	Main	1—1.5	210	50	142.2

Z, absolute viscosity, centipoises

n, speed, rpm

P, pressure, kg/cm²

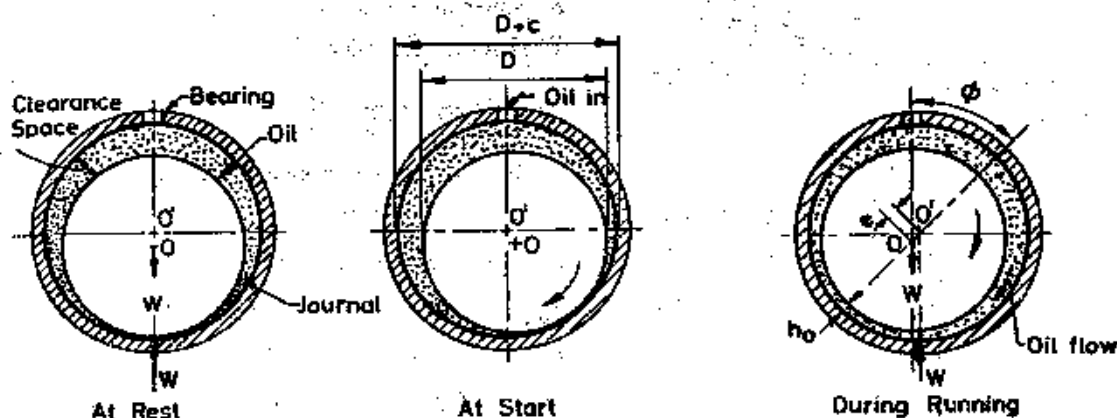
TYPICAL DIAMETRAL CLEARANCES, IN MICRONS

Upto shaft diameter, mm	12	25	50	90	140
Automotive Crank Shaft:					
Babbitt lined bearing			38	63	
Cadmium Silver Copper			50	75	
Copper lead			63	88	
Precision spindle, hardened, ground, lapped into bronze bushing; $v_m < 160\text{m/min}$ $p < 35\text{ kgf/cm}^2$; 0.2 to 0.4 microns rms	7 to 19	19 to 38	38 to 63	63 to 88	88 to 125
Precision spindle, hardened, ground, lapped into bronze bushing; $v_m > 160\text{m/min}$ $p > 35\text{ kgf/cm}^2$; 0.2 to 0.4 microns rms	13 to 25	25 to 50	50 to 75	75 to 113	113 to 163
Electric motor or generator, ground journal in broached bronze or babbitt bushing 0.4 to 0.8 microns rms	13 to 38	25 to 50	38 to 88	50 to 100	75 to 150
General machine practice, turned or cold-rolled journal in reamed bronze or babbitt bushing; 0.8 to 1.5 microns rms	50 to 100	63 to 113	75 to 125	100 to 175	125 to 200
Rough machine practice, turned or cold-rolled journal in poured babbitt bearings; 1.5 to 3.8 microns rms	75 to 150	125 to 225	200 to 300	275 to 400	350 to 500

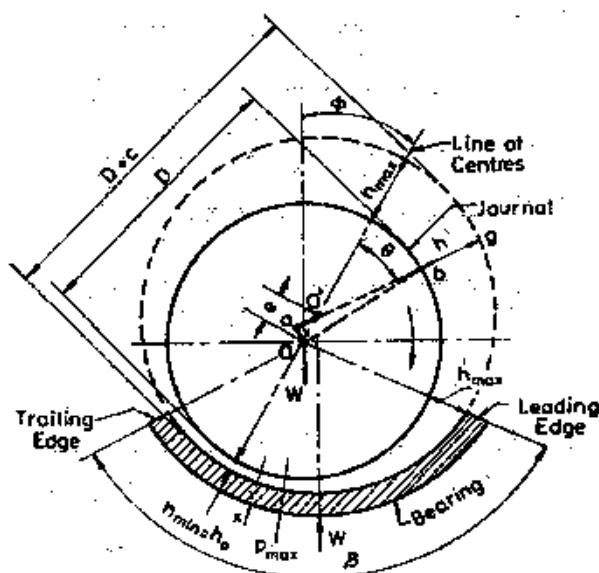
p , Unit load kgf/cm^2 1 micron = 10^{-6} metre

v_m , Surface speed of journal

HYDRODYNAMIC JOURNAL BEARINGS



MECHANISM OF LUBRICATION



GEOMETRIC RELATION FOR ANY JOURNAL BEARING

(Shown here partial clearance bearing)

GEOMETRIC RELATIONS FOR A CLEARANCE BEARING :

Clearance ratio C/D

Eccentricity, $e = \frac{C}{2} - h_0$

Eccentricity factor or

Attitude $\epsilon = \frac{2e}{C} = 1 - \frac{2h_0}{C}$

Film thickness at any

angle θ $h = \frac{C}{2} (\epsilon \cos \theta + 1)$

Minimum film thickness $h_0 = \frac{C}{2} (1 - \epsilon)$

D , journal diameter, cm

C , diametral clearance, cm

h_0 , minimum film thickness, cm

ϵ , attitude, dimensionless

ϕ , attitude, angle

L , Length of bearing, cm

W , Load, kgf

P , bearing pressure on projected area, kgf/cm^2

e , eccentricity, cm

n , speed of journal, rpm

n' , speed of journal, rps

Z , absolute viscosity of the oil, centipoises

$$\text{Sommerfeld number } S = \frac{Z' n'}{P} \left(\frac{D}{C} \right)^2$$

$$S = (2 + \epsilon^2) \sqrt{1 - \epsilon^2} / 12 \pi^2 \epsilon \text{ for } L/D = \infty$$

Coefficient of friction :

McKEES EQUATION

$$\mu = \frac{33.25}{10^{10}} \left(\frac{Z n}{P} \right) \left(\frac{D}{C} \right) + k \quad \left. \begin{array}{l} \text{for lightly} \\ \text{loaded bearings} \end{array} \right\} S > 0.15$$

PETROFF'S EQUATION

$$\mu = 2 \pi^2 \left(\frac{Z' n'}{P} \right) \left(\frac{D}{C} \right)$$

ν , Kinematic viscosity centistokes

Z' absolute viscosity,

$$\text{kgf sec/cm}^2 = \frac{Z}{9.81 \times 10^7}$$

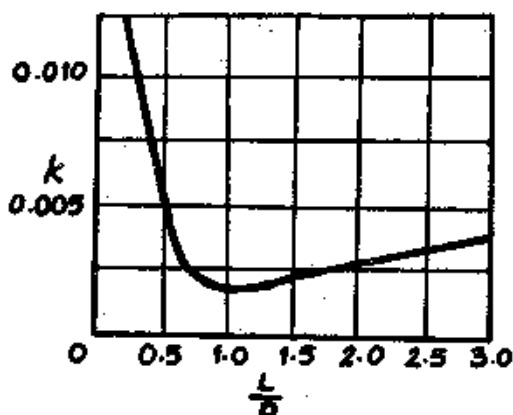
p , hydro dynamic pressure developed at any angles θ , kgf/cm²

p_i , inlet pressure, kgf/cm²

p_{max} , maximum pressure, kgf/cm²

ρ , density of the oil, kgf/cm³

p_0 - Pressure at $\theta = 0^\circ$



$$\mu = \frac{C}{D} \frac{(1 + 2 \epsilon^2)}{3 \epsilon} \quad \text{for medium or heavily loaded bearings}$$

$$S < 0.15$$

Reynolds' equation for pressure distribution at any angle θ .

$$p - p_0 = \frac{20 Z' \nu D}{C^2} \left[\frac{\epsilon (2 + \epsilon \cos \theta) \sin \theta}{(2 + \epsilon^2) (1 + \epsilon \cos \theta)^2} \right]$$

Load capacity :

$$W = \frac{20 Z' \nu L}{C} \left(\frac{D}{C} \right)^2 \frac{\pi \epsilon}{(2 + \epsilon^2) \sqrt{1 - \epsilon^2}}$$

$$\text{Heat generated } H_g = \mu W \nu \text{ Kgf m/min}$$

$$\text{Heat dissipated } H_d = \frac{(\Delta t + 18)^2 LD}{K} \text{ Kgf m/min}$$

S , Sommerfeld number, dimensionless

μ , coefficient of friction

q , oil flow through the bearing, cm³/sec

q_a , axial flow of oil, cm³/sec

q_{in} , axial flow of oil due to inlet pressure cm³/sec

C' , specific heat of oil 17100 kgf cm/kgf °C

Δt_o , temperature increase of the oil °C

DIMENSIONLESS PERFORMANCE PARAMETERS :

Coefficient of friction Variable $\mu \frac{D}{C}$

Flow variable $4q/DCn'L$

Flow ratio q_s/q

Pressure ratio P/p_{max}

Temperature rise variable $\frac{\rho C' \Delta t_o}{P}$

FLOW THROUGH THE BEARING :

Axial flow in a 360° bearing, pressure fed, through a cylindrical hole at the centre

$$q_{ax} = \frac{C^3 p_1}{24Z'} \left(\tan^{-1} \frac{\pi D}{L} \right) (1 + 1.5\epsilon^2)$$

Flow is 2 to 3 times greater when the feed hole is located in a longitudinal groove

With the feed hole in a central circumferential groove

$$q_{ax} = \frac{\pi DC^3 p_1}{24Z'L} (1 + 1.5\epsilon^2)$$

Energy increase of the oil $= q\rho C' \Delta t_o$

AVERAGE TEMPERATURE RISE :

Oil ring bearings (still air) $\Delta t_o = 2\Delta t$

Oil bath bearings (still air) $\Delta t_o = 1.3\Delta t$

Waste packed bearings (still air) $\Delta t_o = 2.5\Delta t$

Design oil film temperature 60–95 °C

FRICTIONAL LOSS IN THE CAP :

Average film thickness in the cap

$$h_{av} = \frac{C}{2} (1 + 0.74\epsilon^2)$$

$$F = \frac{Z' A v}{0.6 h_{av}}$$

$$U_f = F v$$

Δt_o , increase in bearing surface temp. from ambient temp, °C

k, constant for McKees eqn.

v , surface speed of Journal m/min.

K, constant for heat dissipation, 437 for heavy construction, well ventilated. 775 for light construction in still air

h_{av} , average film thickness, cm.

h , film thickness at any angle θ , cm

F, frictional force on the cap, kgf

U_f , frictional loss in the cap, kgf m/min

A, sliding area of the cap, cm²

Δt_o , difference in temperature of oil and ambient temperature, °C

TABLE I. DIMENSIONLESS PERFORMANCE PARAMETERS FOR FULL JOURNAL BEARINGS WITH SIDE FLOW

$\frac{L}{D}$	ϵ	$\frac{2h_o}{C}$	S	ϕ	$\mu \frac{D}{C}$	$\frac{4q}{DC\eta L}$	$\frac{q_s}{q}$	$\frac{\rho C' \Delta t_o}{P}$	$\frac{P}{P_{max}}$
∞	0	1.0	∞	(70.92)	∞	π	0	∞	—
	0.1	0.9	0.240	69.10	4.80	3.03	0	19.9	0.826
	0.2	0.8	0.123	67.26	2.57	2.83	0	11.4	0.814
	0.4	0.6	0.0626	61.94	1.52	2.26	0	8.47	0.764
	0.6	0.4	0.0389	54.31	1.20	1.56	0	9.73	0.667
	0.8	0.2	0.021	42.22	0.961	0.760	0	15.9	0.495
	0.9	0.1	0.0115	31.62	0.756	0.411	0	23.1	0.358
	0.97	0.03	—	—	—	—	0	—	—
	1.0	0	0	0	0	0	0	∞	0
1	0	1.0	∞	(85)	∞	π	0	∞	—
	0.1	0.9	1.33	79.5	26.4	3.37	0.150	106	0.540
	0.2	0.8	0.631	74.02	12.8	3.59	0.280	52.1	0.529
	0.4	0.6	0.264	63.10	5.79	3.99	0.497	24.3	0.484
	0.6	0.4	0.121	50.58	3.22	4.33	0.680	14.2	0.415
	0.8	0.2	0.0446	36.24	1.70	4.62	0.842	8.00	0.313
	0.9	0.1	0.0188	26.45	1.05	4.74	0.919	5.16	0.247
	0.97	0.03	0.00474	15.47	0.514	4.82	0.973	2.61	0.152
	1.0	0	0	0	0	—	1.0	0	0
0.5	0	1.0	∞	(88.5)	∞	π	0	∞	—
	0.1	0.9	4.31	81.62	85.6	3.43	0.173	343.0	0.523
	0.2	0.8	2.03	74.94	40.9	3.72	0.318	164.0	0.506
	0.4	0.6	0.779	61.45	17.0	4.29	0.552	68.6	0.441
	0.6	0.4	0.319	48.14	8.10	4.85	0.730	33.0	0.365
	0.8	0.2	0.0923	33.31	3.26	5.41	0.874	13.4	0.267
	0.9	0.1	0.0313	23.66	1.60	5.69	0.939	6.66	0.206
	0.97	0.03	0.00609	13.75	0.610	5.88	0.980	2.56	0.126
	1.0	0	0	0	0	—	1.0	0	0
0.25	0.0	1.0	∞	(89.5)	∞	π	0	∞	—
	0.1	0.9	16.2	82.31	322.0	3.45	0.180	1287.0	0.515
	0.2	0.8	7.57	75.18	153.0	3.76	0.330	611.0	0.489
	0.4	0.6	2.83	60.86	61.1	4.37	0.567	245.0	0.415
	0.6	0.4	1.07	46.72	26.7	4.99	0.746	107.0	0.334
	0.8	0.2	0.261	31.04	8.80	5.60	0.884	35.4	0.240
	0.9	0.1	0.0736	21.85	3.50	5.91	0.945	14.1	0.180
	0.97	0.03	0.0101	12.22	0.922	6.12	0.984	3.73	0.108
	1.0	0	0	0	0	—	1.0	0	0

q , cm³/sec ρ , density of the oil = 0.00083 kgf/cm³ C' , specific heat of the oil = 17100 kgf cm/kgf °C
 $\rho C' = 14.2$ kgf/cm³ °C

Values of $\frac{2h_o}{C}$

L/D ratio	∞	1	0.5	0.25
for min. friction	0.6	0.3	0.12	0.03
for max load	0.66	0.53	0.43	0.27

**TABLE II. DIMENSIONLESS PERFORMANCE PARAMETERS FOR 180°
BEARING, CENTRALLY LOADED, WITH SIDE FLOW**

$\frac{L}{D}$	ϵ	$\frac{2h_0}{C}$	S	ϕ	$\mu \frac{D}{C}$	$\frac{4q}{DC\eta' L}$	$\frac{q_1}{q}$	$\frac{\rho C \Delta t_0}{P}$	$\frac{P}{P_{max}}$
∞	0	1.0	∞	90.0	∞	π	∞	∞	—
	0.1	0.9	0.347	72.90	3.55	3.04	0	14.7	0.778
	0.2	0.8	0.179	61.32	2.01	2.80	0	8.99	0.759
	0.4	0.6	0.0898	49.99	1.29	2.20	0	7.34	0.700
	0.6	0.4	0.0523	43.15	1.06	1.52	0	8.71	0.607
	0.8	0.2	0.0253	33.35	0.859	0.767	0	14.1	0.459
	0.9	0.1	0.0128	25.57	0.681	0.380	0	22.5	0.337
	0.97	0.03	0.00384	15.43	0.416	0.119	0	44.0	0.190
	1.0	0	0	0	0	0	0	∞	0
1	0	1.0	∞	90.0	—	π	0	∞	—
	0.1	0.9	1.40	78.50	14.1	3.34	0.139	57.0	0.525
	0.2	0.8	0.670	68.93	7.15	3.46	0.252	29.7	0.513
	0.4	0.6	0.278	58.86	3.61	3.49	0.425	16.5	0.466
	0.6	0.4	0.128	44.67	2.28	3.25	0.572	12.4	0.403
	0.8	0.2	0.0463	32.33	1.39	2.63	0.721	10.4	0.313
	0.9	0.1	0.0193	24.14	0.921	2.14	0.813	9.13	0.244
	0.97	0.03	0.00483	14.57	0.483	1.50	0.915	6.96	0.157
	1.0	0	0	0	0	—	1.0	0	0
0.5	0	1.0	∞	90.0	∞	π	0	∞	—
	0.1	0.9	4.38	79.97	44.0	3.41	0.167	177.0	0.518
	0.2	0.8	2.06	72.14	21.6	3.64	0.302	87.8	0.499
	0.4	0.6	0.794	58.01	9.96	3.93	0.506	42.7	0.438
	0.6	0.4	0.321	45.01	5.41	3.93	0.665	25.9	0.365
	0.8	0.2	0.0921	31.29	2.54	3.56	0.806	15.0	0.273
	0.9	0.1	0.0314	22.80	1.38	3.17	0.886	9.80	0.208
	0.97	0.03	0.00625	13.63	0.581	2.62	0.951	5.30	0.132
	1.0	0	0	0	0	—	1.0	0	0
0.25	0	1.0	∞	90.0	∞	π	0	∞	—
	0.1	0.9	16.3	81.40	163.0	3.44	0.176	653.0	0.513
	0.2	0.8	7.60	73.70	79.4	3.71	0.320	320.0	0.489
	0.4	0.6	2.84	58.99	35.1	4.11	0.534	146.0	0.417
	0.6	0.4	1.08	44.96	17.6	4.25	0.698	79.8	0.336
	0.8	0.2	0.263	30.43	6.88	4.07	0.837	36.5	0.241
	0.9	0.1	0.0736	21.43	2.99	3.72	0.905	18.4	0.180
	0.97	0.03	0.0104	12.28	0.877	3.29	0.961	6.46	0.110
	1.0	0	0	0	0	—	1.0	0	0

	Values of $\frac{2h_0}{C}$			
L/D ratio	∞	1	0.5	0.25
for min. friction	0.6	0.44	0.23	0.03
for max. load	0.64	0.52	0.42	0.28

**TABLE III. DIMENSIONLESS PERFORMANCE PARAMETERS FOR 120°
BEARING, CENTRALLY LOADED, WITH SIDE FLOW.**

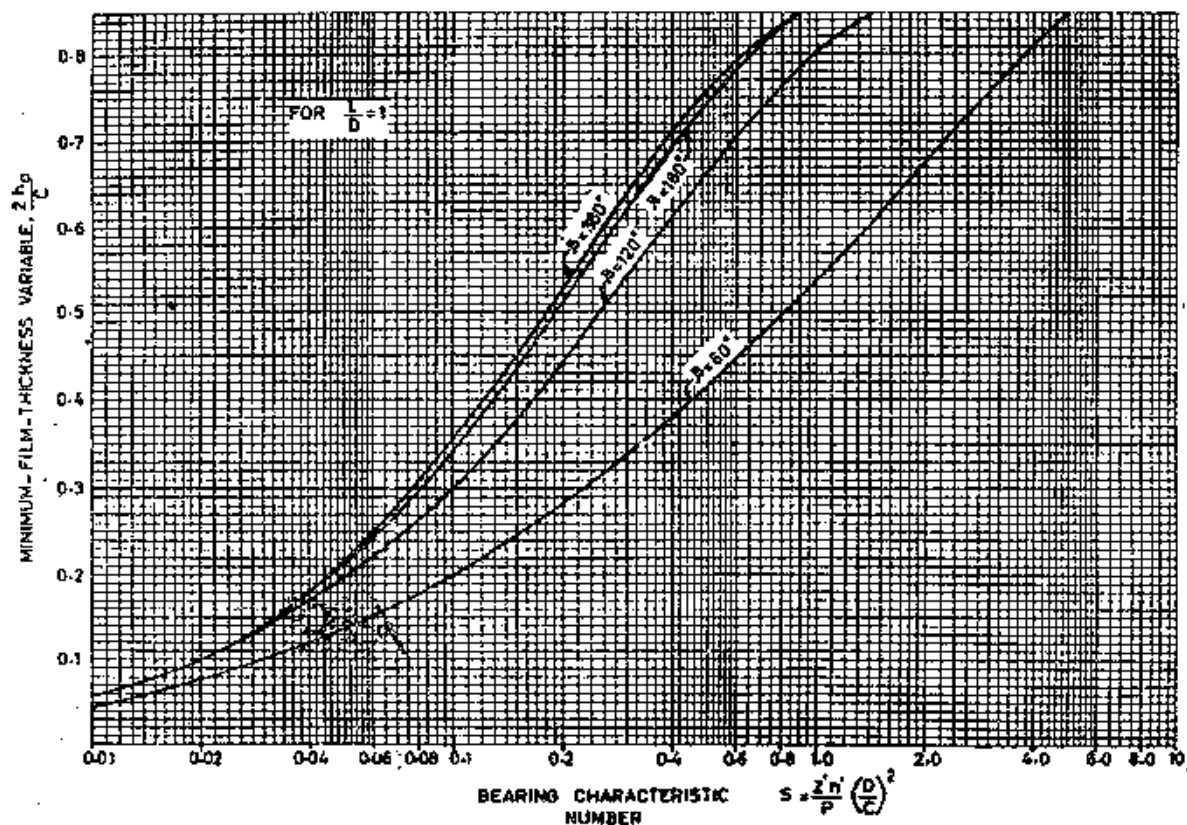
$\frac{L}{D}$	ϵ	$\frac{2h_o}{C}$	S	ϕ	$\mu \frac{D}{C}$	$\frac{4q}{DC\eta'L}$	$\frac{q_s}{q}$	$\frac{\rho C' \Delta t_o}{P}$	$\frac{P}{P_{max}}$
∞	0	1.0	∞	90.0	∞	π	0	∞	—
	0.1	0.9007	0.877	66.69	6.02	3.02	0	25.1	0.610
	0.2	0.8	0.431	52.60	3.26	2.75	0	14.9	0.599
	0.4	0.6	0.181	39.02	1.78	2.13	0	10.5	0.566
	0.6	0.4	0.0845	32.67	1.21	1.47	0	10.3	0.509
	0.8	0.2	0.0328	26.80	0.853	0.759	0	14.1	0.405
	0.9	0.1	0.0147	21.51	0.653	0.388	0	21.2	0.311
	0.97	0.03	0.00406	13.86	0.399	0.118	0	42.4	0.199
	1.0	0	0	0	0	0	0	∞	0
1	0	1.0	∞	90.0	∞	π	0	∞	—
	0.1	0.9024	2.14	72.43	14.5	3.20	0.0876	59.5	0.427
	0.2	0.8	1.01	58.25	7.44	3.11	0.157	32.6	0.420
	0.4	0.6	0.385	43.98	3.60	2.75	0.272	19.0	0.396
	0.6	0.4	0.162	35.65	2.16	2.24	0.384	15.0	0.356
	0.8	0.2	0.0531	27.42	1.27	1.57	0.535	13.9	0.290
	0.9	0.1	0.0208	21.29	0.855	1.11	0.657	14.4	0.233
	0.97	0.03	0.00498	13.49	0.461	0.694	0.812	14.0	0.162
	1.0	0	0	0	0	—	1.0	0	0
0.5	0	1.0	∞	90.0	∞	π	0	—	—
	0.1	0.9034	5.42	74.99	36.6	3.29	0.124	149.0	0.431
	0.2	0.8003	2.51	63.38	18.1	3.32	0.225	77.2	0.424
	0.4	0.6	0.914	48.07	8.20	3.15	0.386	40.5	0.389
	0.6	0.4	0.354	38.50	4.43	2.80	0.530	27.0	0.336
	0.8	0.2	0.0973	28.02	2.17	2.18	0.684	19.0	0.261
	0.9	0.1	0.0324	21.02	1.24	1.70	0.787	15.1	0.203
	0.97	0.03	0.00631	13.00	0.550	1.19	0.899	10.6	0.136
	1.0	0	0	0	0	—	1.0	0	0
0.25	0	1.0	∞	90.0	∞	π	0	∞	—
	0.1	0.9044	18.4	76.97	124.0	3.34	0.143	502.0	0.456
	0.2	0.8011	8.45	65.97	60.4	3.44	0.260	254.0	0.438
	0.4	0.6	3.04	51.23	26.6	3.42	0.442	125.0	0.389
	0.6	0.4	1.12	40.42	13.5	3.20	0.599	75.8	0.321
	0.8	0.2	0.268	28.38	5.65	2.67	0.753	42.7	0.237
	0.9	0.1	0.0743	20.55	2.63	2.21	0.846	25.9	0.178
	0.97	0.03	0.0105	12.11	0.832	1.69	0.931	11.6	0.112
	1.0	0	0	0	0	—	1.0	0	0

	Values of $\frac{2h_o}{C}$			
L/D ratio	∞	1	0.5	0.25
for min. friction	0.5	0.4	0.28	0.06
for max. load	0.53	0.46	0.38	0.26

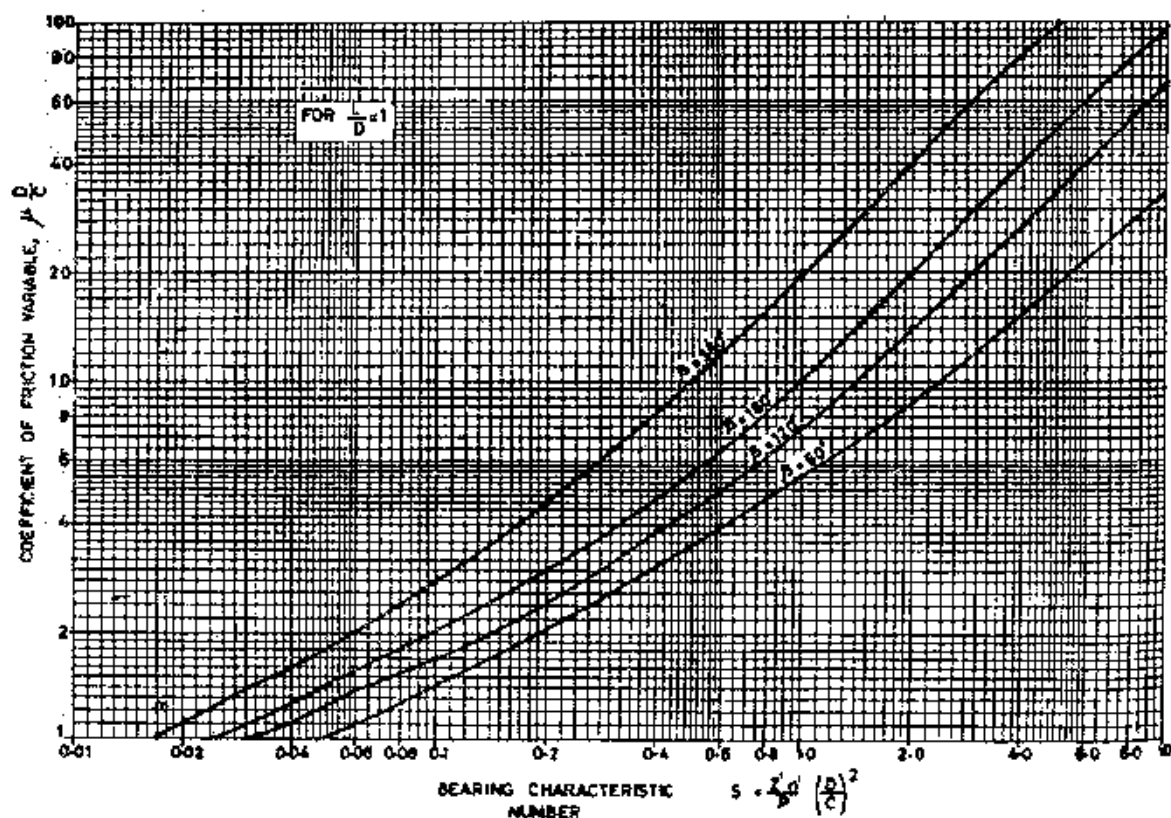
TABLE IV. DIMENSIONLESS PERFORMANCE PARAMETERS FOR 60° BEARING, CENTRALLY LOADED, WITH SIDE FLOW

$\frac{L}{D}$	ϵ	$\frac{2h_c}{C}$	S	ϕ	$\mu \frac{D}{C}$	$\frac{4q}{DC\eta' L}$	$\frac{q_s}{q}$	$\frac{\rho C' \Delta t_s}{P}$	$\frac{P}{P_{max}}$
∞	0	1.0	∞	90.0	∞	π	0	∞	—
	0.1	0.9191	5.75	65.91	19.7	3.01	0	82.3	0.337
	0.2	0.8109	2.66	48.91	10.1	2.73	0	46.5	0.336
	0.4	0.6002	0.931	31.96	4.67	2.07	0	28.4	0.329
	0.6	0.4	0.322	23.21	2.40	1.40	0	21.5	0.317
	0.8	0.2	0.0755	17.39	1.10	0.722	0	19.2	0.287
	0.9	0.1	0.0241	14.94	0.667	0.372	0	22.5	0.243
	0.97	0.03	0.00495	10.58	0.372	0.115	0	40.7	0.163
	1.0	0	0	0	0	0	0	0	0
1	0	1.0	∞	90.0	∞	π	0	∞	—
	0.1	0.9212	8.52	67.92	29.1	3.07	0.0267	121.0	0.252
	0.2	0.8133	3.92	50.96	14.8	2.82	0.0481	67.4	0.251
	0.4	0.6010	1.34	33.99	6.61	2.22	0.0849	39.1	0.247
	0.6	0.4	0.450	24.56	3.29	1.56	0.127	28.2	0.239
	0.8	0.2	0.101	18.33	1.42	0.883	0.200	22.5	0.220
	0.9	0.1	0.0309	15.33	0.822	0.519	0.787	23.2	0.192
	0.97	0.03	0.00584	10.88	0.422	0.226	0.465	30.5	0.139
	1.0	0	0	0	0	—	1.0	0	0
0.5	0	1.0	∞	90.0	∞	π	0.0	∞	—
	0.1	0.9223	14.2	69.00	48.6	3.11	0.0458	201.0	0.239
	0.2	0.8152	6.47	52.60	24.2	2.91	0.0883	109.0	0.239
	0.4	0.6039	2.14	37.00	10.3	2.38	0.160	59.4	0.233
	0.6	0.4	0.695	26.98	4.93	1.74	0.236	40.3	0.225
	0.8	0.2	0.149	19.57	2.02	1.05	0.350	29.4	0.201
	0.9	0.1	0.0422	15.91	1.08	0.664	0.464	26.5	0.172
	0.97	0.03	0.00704	10.85	0.490	0.329	0.650	27.8	0.122
	1.0	0	0	0	0	—	1.0	0	0
0.25	0	1.0	∞	90.0	∞	π	0	∞	—
	0.1	0.9251	35.8	71.55	121.0	3.16	0.0666	499.0	0.251
	0.2	0.8242	16.0	58.51	58.7	3.04	0.131	260.0	0.249
	0.4	0.6074	5.20	41.01	24.5	2.57	0.236	136.0	0.242
	0.6	0.4	1.65	30.14	11.2	1.98	0.346	86.1	0.228
	0.8	0.2	0.333	21.70	4.27	1.30	0.496	54.9	0.195
	0.9	0.1	0.0844	16.87	2.01	0.894	0.620	41.0	0.159
	0.97	0.03	0.0110	10.81	0.713	0.507	0.786	29.1	0.107
	1.0	0	0	0	0	—	1.0	0	0

	Values of $\frac{2 h_c}{C}$			
L/D ratio	∞	1	0.5	0.25
for min. friction	0.23	0.22	0.16	0.10
for max. load	0.25	0.23	0.20	0.15

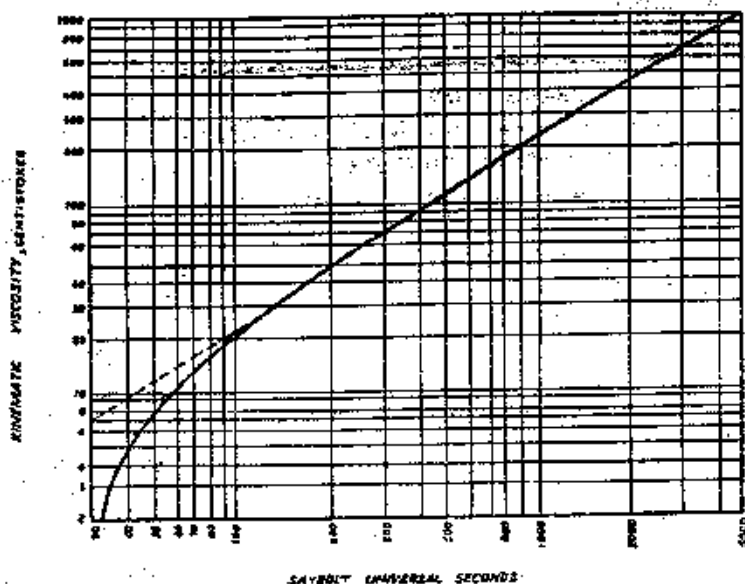


Minimum film thickness variable vs Sommerfeld number S

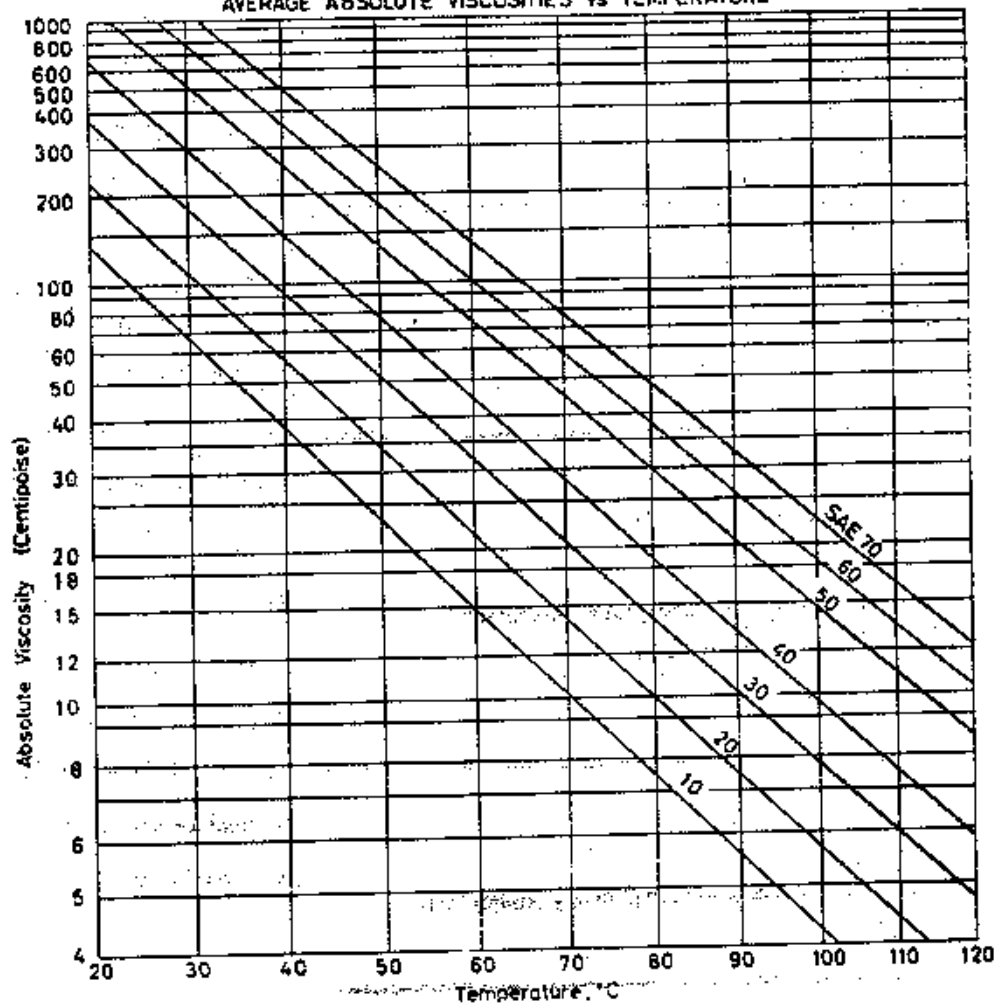


Coefficient of friction variable vs Sommerfeld number S

KINEMATIC VISCOSITY—SAYBOLT UNIVERSAL SECONDS

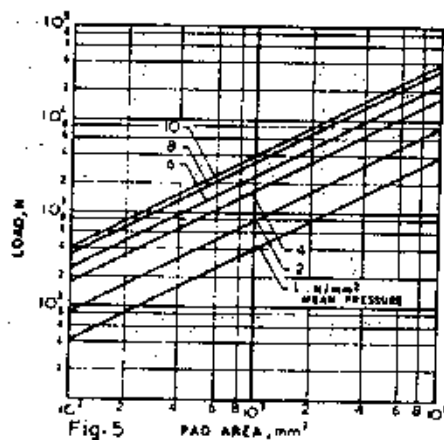
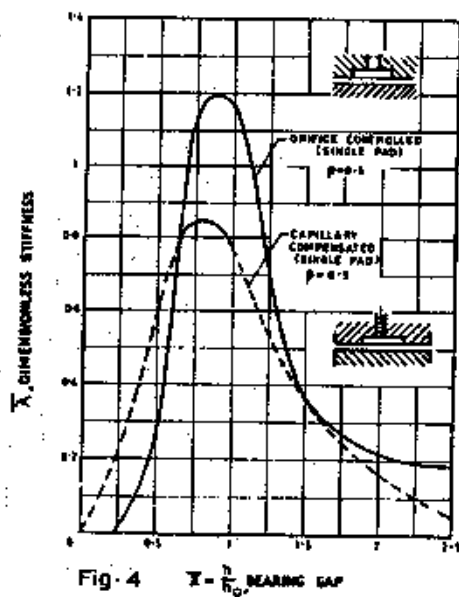
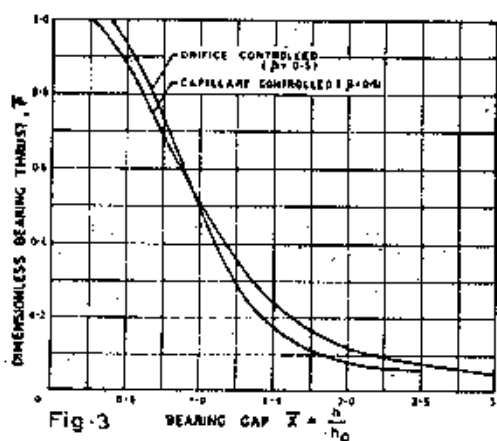
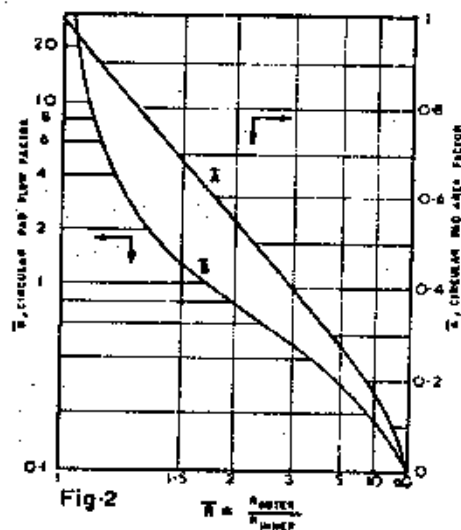
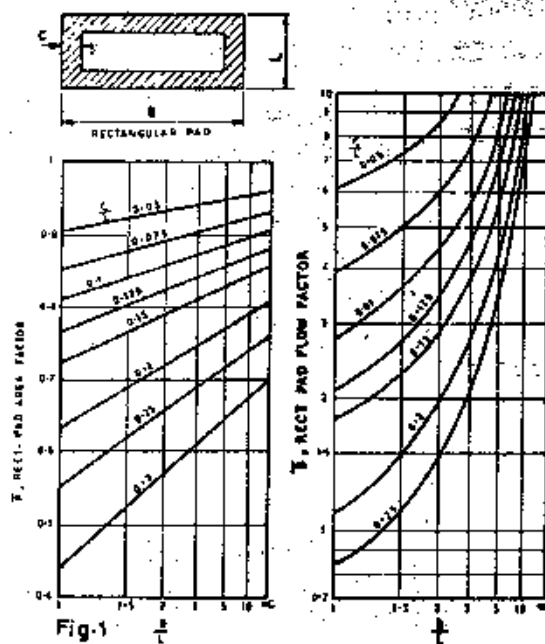


AVERAGE ABSOLUTE VISCOSITIES Vs TEMPERATURE



HYDROSTATIC BEARINGS

PLANE PAD	
RECTANGULAR & CIRCULAR	
Load	$W = P_f A \bar{A} \bar{P}$
	$\bar{A}$, factor for effective area
	Refer fig 1 for rect. pad
Flow	$Q = p_f h_o^3 \frac{\bar{P} \bar{B}}{\eta}$
	$\bar{B}$, factor for flow
	Refer fig 2 for circular pad
Bearing stiffness	$\lambda = p_f \frac{A \bar{A}}{h_o} \bar{\lambda}$
	η , absolute viscosity of oil used
	h_o , design film thickness
Design pressure ratio	$\beta = \frac{p_o}{p_f}$
	$\bar{\lambda}$, dimensionless stiffness parameter
	Refer fig 4 for capillary and orifice bearings.
optimum condition	$\beta = 0.5$ (recommended)
	v , linear velocity of bearing
	A_f , effective friction area
rough estimate of load	$\Delta T = 2 \frac{p_f}{J \rho C_v}$
	ΔT , temp. rise of oil
	J , mechanical equivalent of heat
rough estimate of load	ρ , mass density of oil
	C_v , specific heat of oil
	Use figure 5. Assume a mean pressure in the pad as $\frac{1}{2}$ (supply pr)



Rect & Circ. Pags

Capillary

Orifice

Restrictor design

$$Q_c = \frac{p_1 - p_2}{K_c \eta}$$

$$Q_c = \frac{p (p_1 - p_2)^{1/2}}{2 (C_f A)^{1/2}}$$

$$K_c = \frac{128 l}{\pi d^4}$$

choose

$$\frac{l}{d} > 100$$

 Q_c , flow from bearing recess at the design condition

 l , length of capillary

 d , diam. of capillary

 K_c , refer fig. 6

 A , cross sectional area of orifice

 C_f , flow coefficient (refer fig. 7)

so chosen that $Re < 1000$

For LAYOUT OF TYPICAL CIRCUIT

See fig. 8

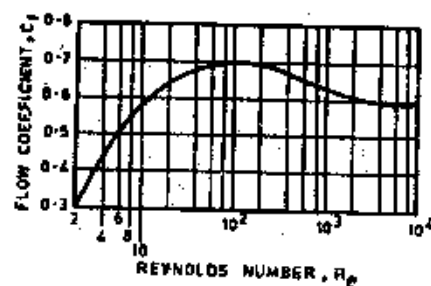


Fig-7

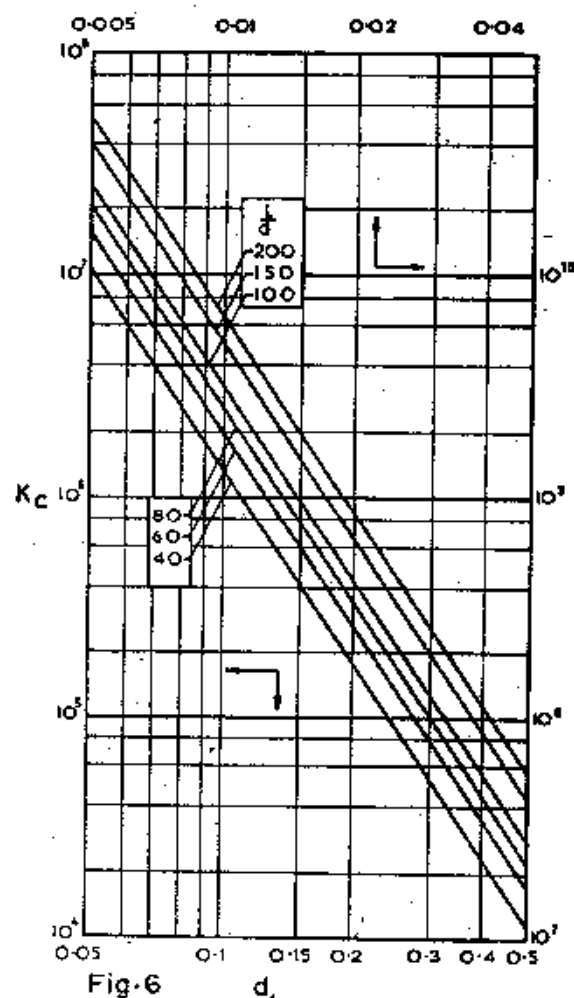
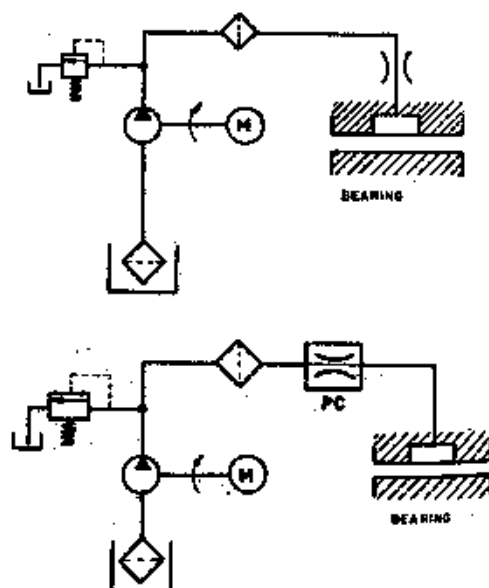


Fig-6

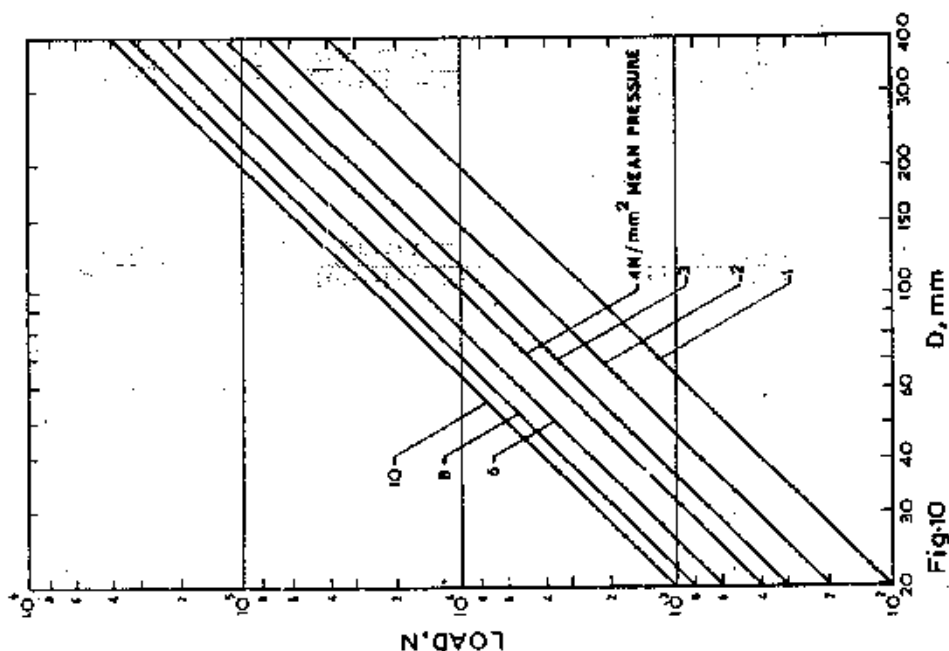


LAYOUT OF TYPICAL CONTROL CIRCUITS

Fig-8

HYDROSTATIC JOURNAL OIL BEARING

	Equations	Nomenclature
Load	$W = p_i D (L - a) \bar{W}$ $\bar{W} = \frac{\bar{\lambda}_1}{2}$ For capillaries with $\beta = 0.5$ $\bar{\lambda}_1 = \frac{1.91}{2 + \gamma} \quad \text{for 4 recesses}$ $= \frac{1.03}{1 + 0.35 \gamma} \quad \text{" 5 "}$ $= \frac{4.3}{4 + \gamma} \quad \text{" 6 "}$ where $\gamma = \frac{n a (L - a)}{\pi D b}$	W, load on bearing p_i, supply pressure L, length of bearing a, b, land widths (fig. 9)  Fig. 9 $a = \frac{L}{4}$; $b = \frac{\pi D}{4n}$ $\bar{W}$, load factor $\bar{\lambda}_1$, dimensionless stiffness factor γ, circumferential flow factor λ, stiffness n, number of recesses C = h_o, radial clearance $\bar{\lambda}_1$, refer table 1 η, abs. viscosity of oil β, design pressure ratio = 0.5 (recommended) D, diameter of bearing $\frac{L}{D} = 1$, (recommended value)
Stiffness	$\lambda = p_i \frac{D (L - a)}{C} \bar{\lambda}_1$	
Flow	$Q = \frac{p_i C^3}{\eta} \beta \frac{\pi D}{6 a}$	
Rough estimate of load, W	Use figure 10 Assume a mean pressure of one fourth supply pressure acting on the projected area.	



HYDROSTATIC BEARINGS (Cont.)

Optimum conditions

$$\frac{\eta N'}{p_l} \left(\frac{D}{2C} \right)^3 = \frac{1}{4\pi} \left(\frac{\pi \beta B}{\lambda_l} \right)^{\frac{1}{2}}$$

N' , rotational speed of journal, rps

C , radial clearance

$$\lambda_l = \left[\frac{\pi D L - \frac{1}{2} \text{ recess area}}{D^2} \right]$$

Recess depth = 20 C

temp rise

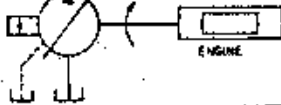
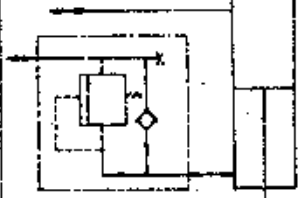
use eqn. for plane pad.

Note:- Dimensions of restrictors can be found from equations listed under plane pads.

TABLE-1: VALUES OF $\bar{\lambda}$

n	Capillary	Orifice	Constant flow
4	$\frac{3.82 \beta (1-\beta)}{1+\gamma (1-\beta)}$	$\frac{7.65 \beta (1-\beta)}{2-\beta+2\gamma (1-\beta)}$	$\frac{3.82 \beta}{1+\gamma}$
5	$\frac{4.12 \beta (1-\beta)}{1+0.69 \gamma (1-\beta)}$	$\frac{8.25 \beta (1-\beta)}{2-\beta+1.38 \gamma (1-\beta)}$	$\frac{4.25 \beta}{1+0.69 \gamma}$
6	$\frac{4.3 \beta (1-\beta)}{1+0.5 \gamma (1-\beta)}$	$\frac{8.68 \beta (1-\beta)}{2-\beta+\gamma (1-\beta)}$	$\frac{4.3 \beta}{1+0.5 \gamma}$

FLUID POWER SYMBOLS

1. LINES AND LINE FUNCTIONS		4. VALVES		Pressure compensated		Quick disconnecter, Connected	
Line, working (flow)		Check		Solenoid, single winding		" Disconnected	
Line, Pilot (pressure)		On-off (manual shut-off)		Reversing motor		Nozzle	
Line, Drain (leakage only)		Pressure relief, shown in Closed (normal) position		Pilot pressure, remote supply		Cylinder, cushioned, adjustable	
Connector		Pressure reducing, shown in open (normal) position		6 MISCELLANEOUS Rotating shaft		Cylinder, differential (large rod)	
Line, Flexible		Flow control, adjustable, non compensated		Enclosure		Hydraulic pump and motor	
Lines, Joining		Flow control, adjustable, (temperature and pressure compensated)		Reservoir, vented		Variable displacement pressure compensated Pump  ENGINE	
Lines, Passing		Two position, Two way		Reservoir, pressurised			
Direction of flow (hydraulic)		Two position, Three way		Pressure gauge		Unloading valve	
Direction of flow (Pneumatic)		Two position, Four way		Electric motor		Unloading valve (alternate)	
Line to reservoir above fluid level		Three position, Four way (closed centre)		Accumulator, spring loaded		Sequence valve	
Line to vented manifold		Two position in transition (open centre)		Accumulator, gas charged		Counter balance valve (to keep the piston in position) 	
Plug or plugged connection		Valves capable of infinite positioning (horizontal bars indicate infinite positioning ability)		Heater (on line)			
Restriction, fixed		5. METHODS OF OPERATION		Cooler (on line)			
Restriction, variable		Spring		Temperature controller			
2. PUMPS		Spring centered		Filter, strainer			
Single, fixed displacement		Manual		Lubricator			
Single, variable displacement		Push button		Pressure switch			
3. ACTUATORS		Push-pull lever		Thermal control			
Motor, fixed displacement, non reversible		Pedal or treadle		Muffler			
Motor, fixed displacement, reversible		Mechanical		Valve Controls (a) Pressure pilot, spring centered			
Motor, variable displacement, reversible		Detent		(b) Solenoid and pilot			
Cylinder, single acting							
Cylinder, double acting, non differential							
Cylinder, single acting, differential							

THRUST BEARING

Equations

load

$$W = C_L^3 \pi r_o^4 p_t$$

stiffness

$$k = 1.42 \frac{W}{h} \text{ for pocketed orifices.}$$

$$k = 0.95 \frac{W}{h} \text{ for annular bearing.}$$

orifice dimension

$$d = d^* \left(\frac{h}{h_o} \right)^3 \text{ for central recess bearing.}$$

$$d = d^* \left(\frac{h}{h_o} \right)^3 \frac{2}{\sqrt{N}} \text{ for annular bearings with } N \text{ pockets.}$$

$$d = (d^*)^2 \frac{h^2}{N h_o^2} \text{ for annular bearings (unpocketed)}$$

$$(d^* \text{ from graph for air at } 15^\circ\text{C \& } h_o = 0.025\text{mm})$$

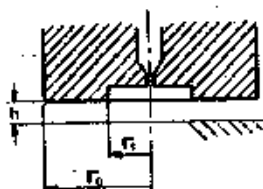
Flow

$$Q = Q^* \left(\frac{h}{h_o} \right)^3 \text{ for central recess}$$

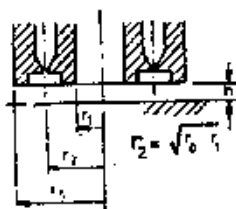
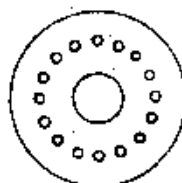
$$Q = 4 Q^* \left(\frac{h}{h_o} \right)^3 \text{ for annular bearing.}$$

$$(Q^* \text{ from graph for air at } 15^\circ\text{C \& } h_o = 0.025 \text{ mm})$$

NOMENCLATURE



CENTRAL RECESS BEARING



ANNULAR BEARING

Fig.11

p_t , supply pressure, gauge

C_L^3 , load coeff. refer Fig. 12

d , orifice diam

d^* , from fig. 13

h_o , design film thickness = 0.025 mm (usually)

N , number of orifices

Q , rate of flow

Q^* , refer fig. 14

JOURNAL BEARING

(Valid for 2 rows of 8 orifices. For other number of orifices, fig. 16)

load

$$W = W^* \frac{p_t}{p_t^*} \text{ for } e = 0.5 \text{ \& pocketed}$$

$$= \frac{1}{2} W^* \frac{p_t}{p_t^*} \text{ for } e = 0.5 \text{ \& unpocketed}$$

For $e = 0.9$, load is 28% higher than the above values

W , load on bearing

W^* , from fig. 15

p_t , Supply pressure, gauge

$p_t^* = 69 \text{ N/cm}^2$

e , eccentricity ratio = $\frac{c}{r}$

c , eccentricity

r , radial clearance

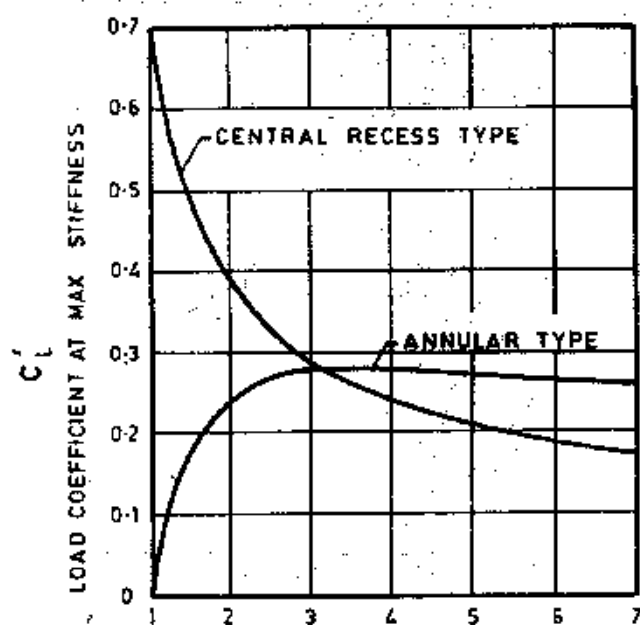


Fig.12 r_o/r_i

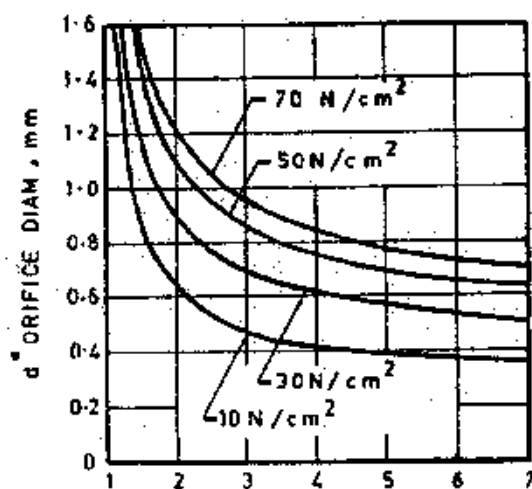


Fig.13 r_o/r_i

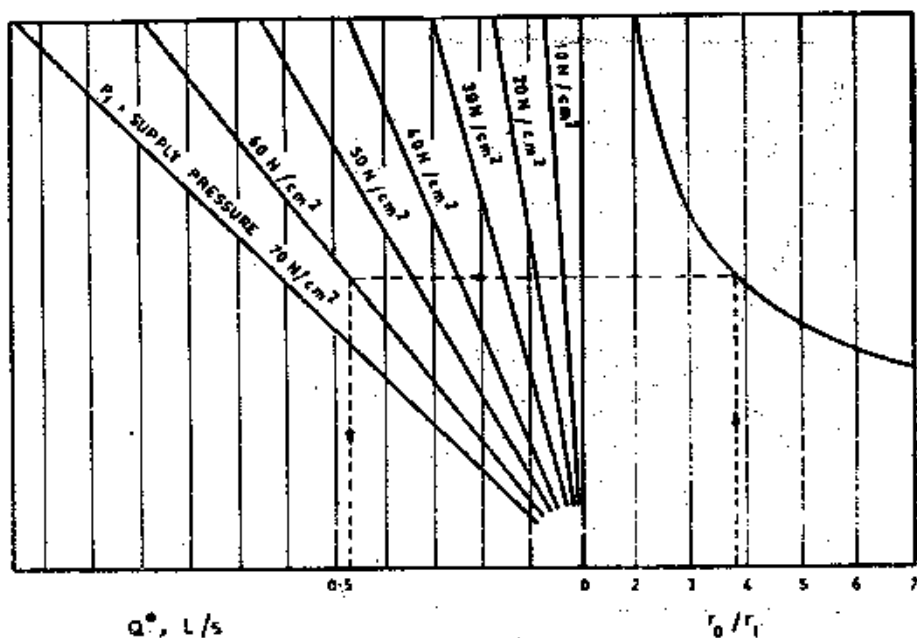


Fig 14

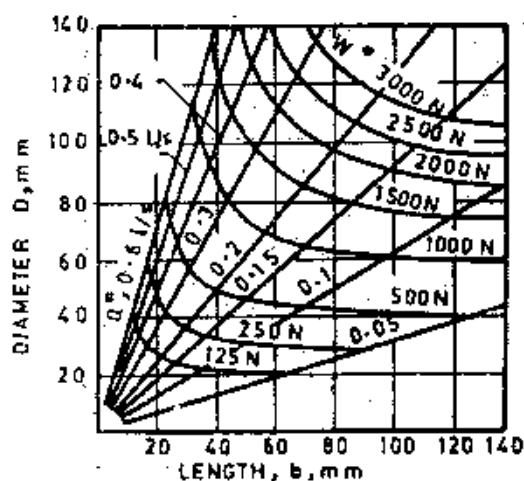


Fig 15

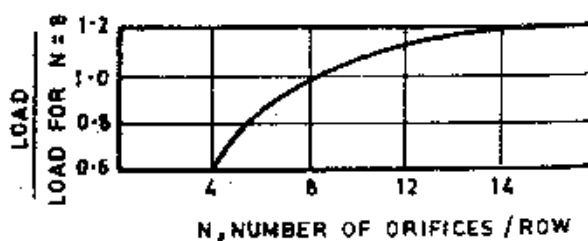


Fig 16

HYDROSTATIC AIR JOURNAL BEARINGS (CONTD)

Equations

Stiffness

$$k = \frac{\text{load at } e = 0.5}{0.5 C}$$

Flow

$$Q = Q^* \left(\frac{C_D}{C_D^*} \right)^3$$

Orifice dimension

For pocketed orifices

$$d = d^* \left(\frac{C_D}{C_D^*} \right)^{\frac{1}{2}} \left(\frac{8D}{N^2} \right)^{\frac{1}{2}}$$

For unpocketed orifices

$$d = d^* \left(\frac{C_D}{C_D^*} \right)^{\frac{1}{2}} \frac{8D}{Nb}$$

Location of orifices

$$l = \frac{b}{4} \text{ for 2 rows}$$

$$= \frac{b}{2} \text{ for 1 row}$$

Friction torque

$$M_{tf} = \frac{\pi^2 \eta D^3 b n}{2 C}$$

NOMENCLATURE

Q^* from fig 15

$C_D^* = 0.025$ mm (usually)

C , radial clearance

N , number of orifices

b , length of bearing

D , diameter of journal

d , diameter of orifice

d^* from fig 17

(for $\frac{b}{D} = 1$; 8 orifices/row, air at 15°C

and $h_0 = 0.025$ mm)

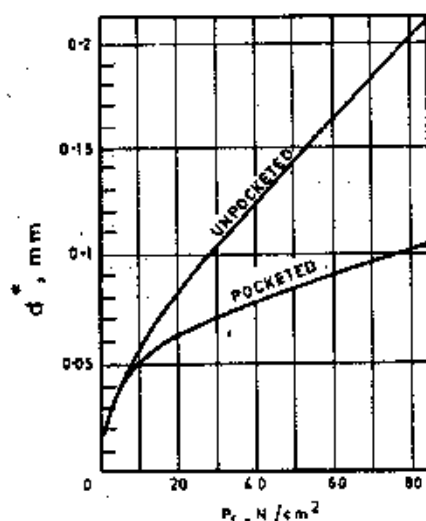


Fig.17

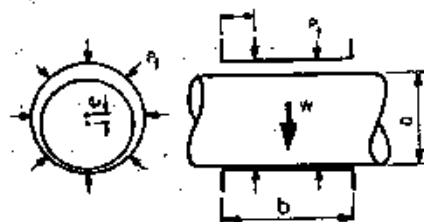


Fig.18

M_{tf} , friction torque

η , absolute viscosity of air

n , number of revolutions per second

FLAT BELTS

Type of flat belting

1. Dunlop "HI-SPEED" 878 g fabric belting, using in the construction soft fabric having nominal weight of 878g/m², generally recommended for light and medium duty and for high belt speeds.
2. Dunlop "FORT" 949 g fabric belting, using in the construction hard fabric having nominal weight of 949 g/m², recommended for heavy duty and for medium belt speeds.

Specification of transmission belting—Standard widths

3 PLY mm	4 PLY mm	5 PLY mm	6 PLY mm	8 PLY mm
*25	**25	*76	**100	***200
**32	**32	**90	*112	—
*40	*40	*100	*125	***250
44	*44	*112	—	*305
*50	*50	*125	*152	***355
*63	*63	—	*180	***400
*76	*76	*152	*200	
90	*90	*180	—	
100	*100	**200	*250	
	*112	**224		
	*125	***250		
	**140			
	*152			
	—			
	**200			

*These sizes are available in "HI-SPEED" and "FORT".

**These sizes are available in "HI-SPEED" only.

***These sizes are available in "FORT" only.

Minimum pulley diameter in mm for given speed and belting plies:

No. of plies	Maximum belt speed, m/s				
	10	15	20	25	30
3	90	100	112	140	180
4	140	160	180	200	250
5	200	224	250	315	355
6	250	315	355	400	450
8	450	500	560	630	710

Belt Length:

$$\begin{aligned} \text{Open drive} \quad L &= 2C + \frac{\pi}{2} (D+d) + \frac{(D-d)^2}{4C} \\ \text{Crossed drive} \quad L &= 2C + \frac{\pi}{2} (D+d) + \frac{(D+d)^2}{4C} \\ \text{Quarter turn drive} \quad L &= \frac{\pi}{2} (D+d) + \sqrt{C^2 + D^2} + \sqrt{C^2 + d^2} \end{aligned}$$

L—Length of the belt
 D—Dia. of large pulley
 d—Dia. of small pulley
 C—Centre distance

Belt speed

Most efficient power transmission is obtained from flat belts at speeds of 17.5 to 22.5 m/s.

Belt tension

Correct initial tension is obtained by cutting the belt shorter than the actual steel tape measurement around the pulleys on the following basis:

Belt of 3 plies	1.5% or 15 mm per metre length shorter
Belts of 4, 5 & 6 plies	1% or 10 mm per metre length shorter
Belt of 8 plies	0.5% or 5 mm per metre length shorter

Belt take-up

For accommodating the inevitable stretch in belt length which will accrue in service, provision approximately 1% of the centre distance should be allowed by means of a suitable take-up arrangement. For fixed centre distance, the belt will have to be cut frequently as it stretches and rejoined in order to prevent it from slipping.

Load correction factor

Load classification		Load correction factor
Normal load	(where peak load is known)	1.0
Steady load	Screens, centrifugal pumps and fans, evaporators, agitators, belt conveyors, light machine tools, laundry machinery, Printing and textile machinery.	1.2
Intermittent loads	Heavy duty fans and blowers, brick work machinery, reciprocating pumps and compressors, saw mill and paper mill machinery, heavy machine tools, stokers, elevators and line shafts.	1.3
Shock loads	Vacuum pumps, tube and ball mills, rolling mills, crushing machinery, disintegrators, stamp presses, grinders, hammers, mills, and calenders, automatic machinery.	1.5

Arc of contact factor

The load ratings have been developed for 180° of contact and have to be corrected for actual arc of contact. A decrease in arc of contact implies additional load.

$$\text{Arc of contact} = 180^\circ - \frac{D-d}{C} \times 60^\circ$$

D, diameter of larger pulley

d, diameter of smaller pulley

C, centre distance

Arc of contact	90°	120°	130°	140°	150°	160°	170°	180°	190°	200°	210°	220°	230°	240°	250°
Correction factor	1.68	1.33	1.26	1.19	1.13	1.08	1.04	1.00	0.97	0.94	0.91	0.88	0.86	0.84	0.82

Load rating per mm. width per ply at 180° arc of contact at 10 m/s belt speed

'HI-SPEED' 878 g duck belting $\left. \begin{array}{l} 0.023 \text{ kw} \\ 0.0314 \text{ hp} \end{array} \right\}$ per mm. per ply

'FORT' 949 g duck belting $\left. \begin{array}{l} 0.0289 \text{ kw} \\ 0.0392 \text{ hp} \end{array} \right\}$ per mm. per ply

Load rating at V m/s = load rating at 10 m/s $\times \frac{V}{10}$

millimetre plies of belt = $\frac{\text{Corrected load}}{\text{load rating per mm. per ply at belt speed}}$

The width and ply thickness are virtually dependent on each other and the aim is to select a wide thin belt.

Recommended series of pulley diameters and tolerances, mm.

Nominal Diameter	Tolerance on Nominal Diameter	Nominal Diameter	Tolerance on Nominal Diameter	Nominal Diameter	Tolerance on Nominal Diameter
40	± 0.5	160	± 2.0	560	± 5.0
45 } 50 }	± 0.6	180 } 200 }		630 } 710 }	
56 } 63 }		224 } 250 }		800 } 900 } 1000 }	
71 } 80 }	± 1.0	280 } 315 }	± 2.5	1120 } 1250 }	± 6.3
90 } 100 }		355 }		1400 }	
112 }	± 1.2	400 } 450 }	± 3.2	1600 } 1800 }	± 8.0
125 }		500 }		2000 }	
140 }		± 1.6			

Pulley width

Belt width	Pulleys to be wider than the belt width by
Upto and including 125 mm	13 mm
above 125 mm upto and including 250 mm	25 mm
above 250 mm upto and including 375 mm	38 mm
above 375 mm upto and including 500 mm	50 mm

Recommended series of width of flat pulleys, mm

Width	Tolerance	Width	Tolerance
20	± 1	160	± 2
25		180	
32		200	
40		224	
50		250	
63		280	
71	± 1.5	315	± 3
80		355	
90		400	
100		450	
112		500	
125		560	
140		630	

Crown of flat pulleys (40 to 355 mm diameter)

(Crown is unrelated to the width in this diameter range)



DIAMETER, D

CROWN, h

Crown of Pulley

Diameter D mm	Crown h mm
40 to 112	0.3
125 and 140	0.4
160 „ 180	0.5
200 „ 224	0.6
250 „ 280	0.8
315 „ 355	1

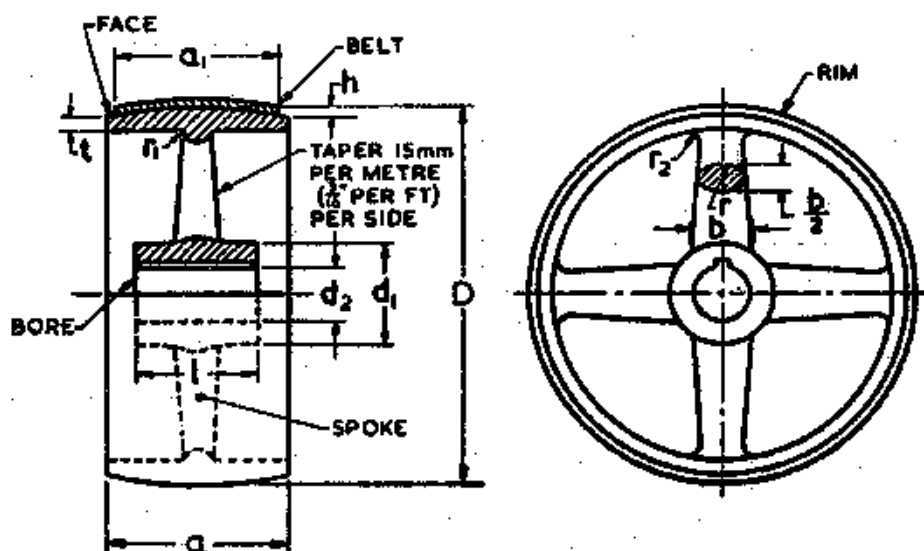
Crown of flat pulley (400 to 2000 mm diameter)

(Crown varies with the width in this diameter range)

Diameter D	CROWN h (IN mm) OF PULLEYS OF WIDTH (IN mm)						
	125 and Smaller	140 and 160	180 and 200	224 and 250	280 and 315	355	400 and Larger
400	1	1.2	1.2	1.2	1.2	1.2	1.2
450	1	1.2	1.2	1.2	1.2	1.2	1.2
500	1	1.5	1.5	1.5	1.5	1.5	1.5
560	1	1.5	1.5	1.5	1.5	1.5	1.5
630	1	1.5	2	2	2	2	2
710	1	1.5	2	2	2	2	2
800	1	1.5	2	2.5	2.5	2.5	2.5
900	1	1.5	2	2.5	2.5	2.5	2.5
1000	1	1.5	2	2.5	3	3	3
1120	1.2	1.5	2	2.5	3	3	3.5
1250	1.2	1.5	2	2.5	3	3.5	4
1400	1.5	2	2.5	3	3.5	4	4
1600	1.5	2	2.5	3	3.5	4	5
1800	2	2.5	3	3.5	4	5	5
2000	2	2.5	3	3.5	4	5	6

Type of pulley	Maximum rim speed m/min
a) Cast iron pulleys:	
Solid, with flat or crown face	1500
Split, with flat or crown face	1000
b) Mild steel pulleys, solid or split, with flat or crown face and mild steel spokes	1500

Proportions for cast iron pulleys



Cast Iron Pulley

- Number of arms
 - { 4 for diameters up to 450 mm
 - { 6 for diameters over 450mm
- Cross section of arms: elliptical
- (1) Thickness of arm,

$$b, \text{ near boss} = 2.94 \sqrt[3]{\frac{aD}{4n}} \text{ for single belt, and}$$

$$= 2.94 \sqrt[3]{\frac{13}{2n} \frac{aD}{2n}} \text{ for double belt}$$

where, a , width of pulley

D , diameter of pulley

n number of arms in the pulley

- Thickness of arm, b , near rim $= \frac{2}{3} \times \text{breadth of boss (or taper 4 mm per 100 mm)}$

- Radius of the cross section of arms, $r = \frac{3}{4} b$

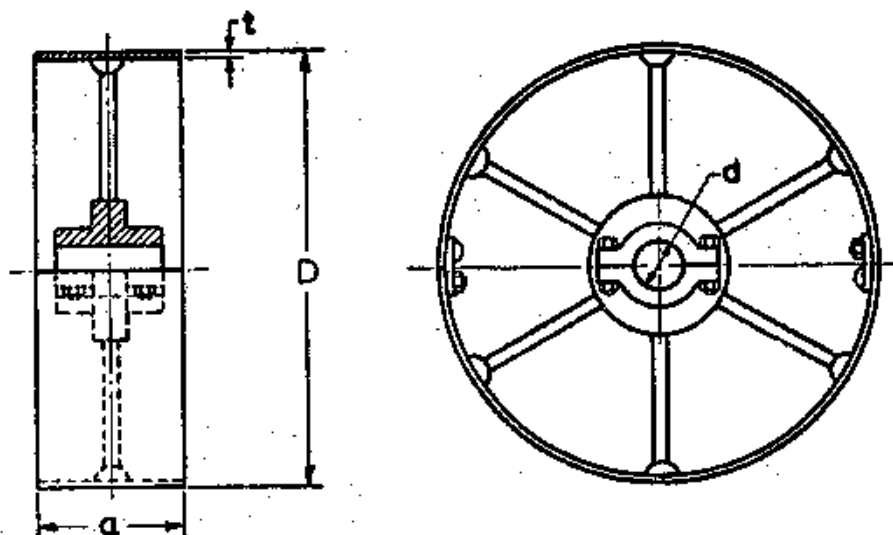
- Minimum length of bore, $l = \frac{2}{3} a$ (it may be more for loose pulley, but in no case it exceeds a).

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$$f) \quad \frac{d_1 - d_2}{2} = 0.412 \sqrt{aD} + 6 \text{ mm for single belt, and} \\ = 0.529 \sqrt{aD} + 6 \text{ mm for double belt.}$$

$$g) \quad \text{Radius } r_1 = \frac{b}{2} \text{ (near rim)} \\ \text{Radius } r_2 = \frac{b}{2} \text{ (near rim)}$$

Proportions for mild steel pulleys



Mild steel pulley

Number of spokes

Diameter	Details of Spokes
280 to 500 mm	6 spokes of 19 mm dia
560 to 710 mm	8 " of 19 mm dia
800 to 1000 mm	10 " of 22 mm dia
1120 mm	12 " of 22 mm dia
1250 mm	14 " of 22 mm dia
1400 mm	16 " of 22 mm dia
1600 mm	18 " of 22 mm dia
1800 mm	18 " of 22 mm dia
2000 mm	22 " of 22 mm dia

Minimum length of boss

The length of boss is equal to half the width of face, subject to minimum of 100 mm in the case of pulleys with 19 mm diameter spokes and minimum of 138 mm for pulleys with 22 mm diameter spokes.

Thickness of rim, t

The thickness of the rim of all mild steel pulleys of nominal diameter 40 to 2000 mm is usually 5 mm. For C. & I pulleys $t = \frac{D}{200} + 3$ mm for single belt

$$t = \frac{D}{200} + 6 \text{ mm for double belt}$$

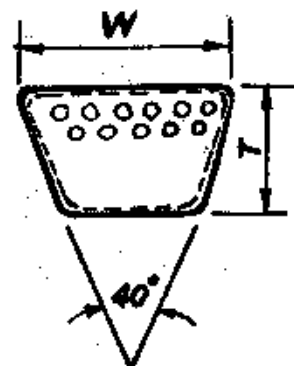
Arrangements of arms

Pulleys up to 300 mm width are normally supplied with single row of spokes. Wider pulleys require double row of spokes.

V-BELTS

Data on Standard V-Belt Sections

Cross-section symbol	Usual load of drive kW	Recommended minimum pulley pitch diameter d, mm	Nominal top width W, mm	Nominal thickness T, mm	Weight per metre kgf
A	0.75—5	75	13	8	0.106
B	2—15	125	17	11	0.189
C	7.5—75	200	22	14	0.343
D	22—150	355	32	19	0.596
E	30—190	500	38	23	—

STANDARD
SECTION OF
V BELTS

Nominal inside length, nominal pitch lengths, permissible length variations and correction factor for standard sizes of V-Belts

Nominal inside length mm	Nominal Pitch Length					Pitch Length Variation		Correction Factor, F_o				
	Cross-Section A	Cross-Section B	Cross-Section C	Cross-Section D	Cross-Section E	Pitch-length limits	Maximum variation in length within a matched set	Belt Cross-Section Symbols				
mm	mm	mm	mm	mm	mm	mm	mm	A	B	C	D	E
610	645	—	—	—	—	+11.4 — 6.4	2.5	0.80	—	—	—	—
660	696	—	—	—	—			0.81	—	—	—	—
711	747	—	—	—	—			0.82	—	—	—	—
787	823	—	—	—	—	+12.5 — 7.5	2.5	0.84	—	—	—	—
813	848	—	—	—	—			0.85	—	—	—	—
889	925	932	—	—	—			0.87	0.81	—	—	—
914	950	—	—	—	—			0.87	—	—	—	—

Nominal inside length	Nominal Pitch Length					Pitch Length Variation		Correction Factor, F_c				
	Cross- Section A	Cross- Section B	Cross- Section C	Cross- Section D	Cross- Section E	Pitch-length limits	Maximum variation in length within a matched set	Belt Cross-Section Symbols				
mm	mm	mm	mm	mm	mm	mm	mm	A	B	C	D	E
965	1 001	1 008	—	—	—	+14.0 — 8.9	2.5	0.88	0.83	—	—	—
991	1 026	—	—	—	—			0.88	—	—	—	—
1 016	1 051	1 059	—	—	—			0.89	0.84	—	—	—
1 067	1 102	1 110	—	—	—			0.90	0.85	—	—	—
1 092	1 128	—	—	—	—			0.90	—	—	—	—
1 168	1 204	1 212	—	—	—			0.92	0.87	—	—	—
1 219	1 255	1 262	—	—	—	+16.0 — 9.0	5.0	0.93	0.88	—	—	—
1 295	1 331	1 339	1 351	—	—			0.94	0.89	0.80	—	—
1 372	—	1 415	—	—	—			—	0.90	—	—	—
1 397	1 433	1 440	—	—	—			0.96	0.90	—	—	—
1 422	1 458	1 466	—	—	—			0.96	0.90	—	—	—
1 473	1 509	—	—	—	—			0.97	—	—	—	—
1 524	1 560	1 567	1 580	—	—	+17.8 —12.5	7.5	0.98	0.92	0.82	—	—
1 600	1 636	—	—	—	—			0.99	—	—	—	—
1 626	1 661	—	—	—	—			0.99	—	—	—	—
1 651	1 687	1 694	—	—	—			1.00	0.94	—	—	—
1 727	1 763	1 770	1 783	—	—			1.00	0.95	0.85	—	—
1 778	1 814	1 821	—	—	—			1.01	0.95	—	—	—
1 905	1 941	1 948	1 961	—	—	+17.8 —12.5	7.5	1.02	0.97	0.87	—	—
1 981	2 017	2 024	—	—	—			1.03	0.98	—	—	—
2 032	2 068	—	—	—	—			1.04	—	—	—	—
2 057	2 093	2 101	2 113	—	—			1.04	0.98	0.89	—	—
2 159	2 195	2 202	2 215	—	—			1.05	0.99	0.90	—	—
2 286	2 322	2 329	2 342	—	—			1.06	1.00	0.91	—	—
2 438	2 474	—	2 494	—	—			1.08	—	0.92	—	—

Nominal inside length	Nominal Pitch Length					Pitch Length Variation		Correction Factor, F_c				
	Cross- Section A	Cross- Section B	Cross- Section C	Cross- Section D	Cross- Section E	Pitch-length limits	Maximum variation in length within a matched set	Belt Cross-Section Symbols				
mm	mm	mm	mm	mm	mm	mm	mm	A	B	C	D	E
2 464	—	2 507	—	—	—	+34 -18	10	—	1.02	—	—	—
2 540	—	2 583	—	—	—			—	1.03	—	—	—
2 667	2 703	2 710	2 723	—	—			1.10	1.04	0.94	—	—
2 845	2 880	2 888	2 901	—	—			1.11	1.05	0.95	—	—
3 048	3 084	3 091	3 104	3 127	—			1.13	1.07	0.97	0.86	—
3 150	—	—	3 205	—	—	+38 -21		—	—	0.97	—	—
3 251	3 287	3 294	3 307	3 330	—			1.14	1.08	0.98	0.87	—
3 404	—	—	3 459	—	—			—	—	0.99	—	—
3 658	3 693	3 701	3 713	3 736	—			—	1.11	1.00	0.90	—
4 013	—	4 056	4 069	4 092	—			+43 -24	—	1.13	1.02	0.92
4 115	—	4 158	4 171	4 194	—	+43 -24	12.5	—	1.14	1.03	0.92	—
4 394	—	4 437	4 450	4 473	—			—	1.15	1.04	0.93	—
4 572	—	4 615	4 628	4 651	—			—	1.16	1.05	0.94	—
4 953	—	4 996	5 009	5 032	—			—	1.18	1.07	0.96	—
5 334	—	5 377	5 390	5 413	5 426			+49 -28	—	1.19	1.08	0.96
6 045	—	—	6 101	6 124	6 137	+56 -32		—	—	1.11	1.00	0.96
6 807	—	—	6 863	6 886	6 899			—	—	1.14	1.03	0.99
7 569	—	—	7 625	7 648	7 661	+56 -32 +65 -37	15	—	—	1.16	1.05	1.01
8 331	—	—	8 387	8 410	8 423			—	—	1.19	1.07	1.03
9 093	—	—	9 149	9 172	9 185			—	—	1.21	1.09	1.05
9 855	—	—	—	9 934	9 947	+65 -37 +76 -43 +89 -50 +105 -59	17.5	—	—	1.23	1.11	1.07
10 617	—	—	—	10 696	10 709			—	—	1.24	1.12	1.09
12 141	—	—	—	12 220	12 233			—	—	—	1.16	1.12
13 665	—	—	—	13 744	13 757			—	—	—	1.18	1.14
15 189	—	—	—	15 268	15 281			—	—	—	1.20	1.17
16 713	—	—	—	16 792	16 805			—	—	—	1.23	1.19

Designation:

A V-belt cross-section C and of nominal inside length of 3048 mm (120 inches) shall be designated as C 3048/120 IS:2494.

The belts should be stamped with Grading No. 50 if the measured pitch length is equal to the nominal pitch length. A deviation of 2.5 mm in length from nominal pitch length is to be represented by one unit and the grading number will increase or decrease, as the length is more or less.

Example:

A belt of designation C 3048/120 IS : 2494 having
an actual pitch length of 3104 should be marked C3048/120-50
If the actual pitch length is 3101.5, it should be marked C3048/120-49
If the actual pitch length is 3109, it should be marked C3048/120-52

Recommended standard pulley pitch diameters, mm. R-20 series (80 mm-2500 mm)

Diameter of larger pulley,

$$D = d \frac{n_1}{n_2} \eta$$

D, diameter of larger pulley, mm

d, diameter of smaller pulley, mm

n_1 , RPM of smaller pulley

n_2 , RPM of larger pulley

$\eta \approx 0.98$, efficiency (assumed)

Selection of centre distance, C

Speed ratio, $i = \frac{D}{d}$	1	2	3	4	5	6 to 9
Recommended $\frac{C}{D}$ ratio	1.5	1.2	1.0	0.95	0.9	0.85

$$C_{\min} = 0.55 (D + d) + T$$

$$C_{\max} = 2 (D + d)$$

T, nominal belt thickness, mm

L, nominal pitch length of belt, mm

(to be selected from table-pages 7.59 and 7.60)

$$L = 2C + \frac{\pi}{2} (D + d) + \frac{(D - d)^2}{4C}$$

C, Centre distance, mm

Centre distance for a given belt length and

diameters of pulleys $C = A + \sqrt{A^2 - B}$

$$\text{where } A = \frac{L}{4} - \pi \frac{D + d}{8}$$

$$B = \frac{(D - d)^2}{8}$$

Minimum allowances for the adjustment of the centres for two transmission pulleys:

Lower limiting value = Nominal centre distance minus 1.5% of L

Higher limiting value = Nominal centre distance plus 3% of L

Initial tension: In order to give the initial tension, the belts may be stretched to 0.5% to 1% of L

Formulae for transmitting capacities

The maximum power in kilowatt which the V-Belts of sections A, B, C, D and E can transmit shall be calculated from the following formula:

Belt cross-section symbol	Formula	Maximum value of d_p in the formula
		mm
A	$kW = \left(0.45S^{0.09} - \frac{19.62}{d_p} - 0.765 \times 10^{-4} S^2 \right) S$	125
B	$kW = \left(0.79S^{0.09} - \frac{50.8}{d_p} - 1.32 \times 10^{-4} S^2 \right) S$	175
C	$kW = \left(1.47S^{0.09} - \frac{142.7}{d_p} - 2.34 \times 10^{-4} S^2 \right) S$	300
D	$kW = \left(3.22S^{0.09} - \frac{506.7}{d_p} - 4.78 \times 10^{-4} S^2 \right) S$	425
E	$kW = \left(4.58S^{0.09} - \frac{952}{d_p} - 7.05 \times 10^{-4} S^2 \right) S$	700

where

kW , maximum power in kW at 180° arc of contact for a belt of average length

S , belt speed, m/s

d_p , equivalent pitch diameter = $d_p \times F_b$

d_p , pitch diameter of the smaller pulley, mm

F_b , the small diameter factor to account for variation of arc of contact, from table below

Speed ratio range, D/d	Small dia. factor, F_b
1.0 to 1.019	1.00
1.02 to 1.032	1.01
1.033 to 1.055	1.02
1.056 to 1.081	1.03
1.082 to 1.109	1.04
1.11 to 1.142	1.05
1.143 to 1.178	1.06
1.179 to 1.222	1.07

Speed ratio range, D/d	Small dia. factor, F_b
1.223 to 1.274	1.08
1.275 to 1.340	1.09
1.341 to 1.429	1.10
1.43 to 1.562	1.11
1.563 to 1.814	1.12
1.815 to 2.948	1.13
2.949 and over	1.14

Matched sets

Nominal belt length mm	Number of consecutive grading numbers any of which may be used to make a matched set
610—1168	2
1219—1778	3
1905—2464	4
2540—4013	5
4115—6807	6
7569—9093	7
9855 and over	8

RATINGS FOR V-BELTS IN KILOWATT

CROSS-SECTION A

Belt speed (m/s)	Equivalent pitch diameter d_e in mm					
	80	90	100	110	120	125 and over
0.5	0.13	0.13	0.14	0.14	0.15	0.15
1	0.22	0.24	0.25	0.27	0.28	0.29
2	0.37	0.40	0.43	0.46	0.49	0.51
3	0.51	0.58	0.64	0.68	0.72	0.74
4	0.58	0.74	0.81	0.88	0.93	0.96
5	0.74	0.85	0.95	1.04	1.13	1.18
6	0.81	0.94	1.05	1.15	1.25	1.32
7	0.88	1.08	1.25	1.39	1.50	1.54
8	0.96	1.17	1.35	1.50	1.62	1.69
9	1.03	1.32	1.54	1.69	1.77	1.84
10	1.10	1.40	1.62	1.77	1.91	1.99
11	1.18	1.47	1.69	1.91	2.06	2.13
12	1.25	1.54	1.84	2.06	2.21	2.28
13	1.32	1.62	1.91	2.13	2.35	2.43
14	1.32	1.69	1.99	2.28	2.50	2.50
15	1.32	1.77	2.06	2.35	2.57	2.65
16	1.40	1.84	2.13	2.43	2.65	2.79
17	1.40	1.84	2.21	2.50	2.79	2.87
18	1.40	1.84	2.28	2.57	2.87	2.94
19	1.40	1.84	2.28	2.65	2.94	3.02
20	1.32	1.91	2.35	2.72	3.02	3.09
21	1.32	1.91	2.35	2.72	3.02	3.16
22	1.25	1.91	2.35	2.72	3.09	3.24
23	1.25	1.84	2.35	2.79	3.09	3.24
24	1.18	1.84	2.35	2.79	3.16	3.31
25	1.10	1.77	2.28	2.79	3.16	3.31
26	1.03	1.69	2.28	2.72	3.16	3.31
27	0.88	1.62	2.20	2.72	3.09	3.31
28	0.81	1.54	2.13	2.65	3.09	3.24
29	0.66	1.47	2.06	2.57	3.02	3.24
30	0.51	1.32	1.99	2.50	2.94	3.16

RATINGS FOR V-BELTS IN KILOWATT

CROSS-SECTION B

Belt speed (m/s)	Equivalent pitch diameter d_p in mm					
	130	140	150	160	170	180 and over
0.5	0.22	0.22	0.22	0.22	0.29	0.29
1	0.37	0.44	0.44	0.44	0.51	0.51
2	0.66	0.74	0.81	0.81	0.88	0.88
3	0.96	1.03	1.10	1.17	1.25	1.39
4	1.18	1.32	1.40	1.47	1.50	1.62
5	1.47	1.54	1.69	1.84	1.91	1.99
6	1.62	1.84	1.99	2.06	2.21	2.28
7	1.91	2.13	2.21	2.35	2.50	2.65
8	2.06	2.28	2.43	2.65	2.79	2.94
9	2.21	2.43	2.65	2.87	3.02	3.16
10	2.35	2.65	2.87	3.09	3.31	3.46
11	2.50	2.79	3.09	3.31	3.53	3.75
12	2.65	3.02	3.31	3.53	3.75	3.97
13	2.79	3.16	3.46	3.75	3.97	4.19
14	2.87	3.16	3.60	3.90	4.19	4.56
15	2.94	3.38	3.75	4.05	4.34	4.63
16	3.02	3.46	3.90	4.19	4.49	4.78
17	3.09	3.60	3.97	4.34	4.71	4.92
18	3.16	3.60	4.04	4.49	4.78	5.07
19	3.16	3.68	4.19	4.56	4.92	5.22
20	3.16	3.75	4.19	4.63	5.00	5.44
21	3.16	3.75	4.27	4.71	5.07	5.44
22	3.16	3.75	4.27	4.78	5.15	5.52
23	3.09	3.75	4.27	4.78	5.22	5.59
24	3.02	3.68	4.27	4.78	5.22	5.66
25	2.94	3.60	4.19	4.78	5.22	5.66
26	2.79	3.53	4.19	4.71	5.22	5.66
27	2.65	3.46	4.12	4.63	5.15	5.66
28	2.50	3.31	3.97	4.56	5.15	5.59
29	2.43	3.16	3.82	4.49	5.00	5.52
30	2.13	2.94	3.68	4.34	4.92	5.44

RATINGS FOR V-BELTS IN KILOWATT

CROSS-SECTION C

Belt speed (m/s)	Equivalent pitch diameter d_p in mm						
	180	200	220	240	260	280	300 and over
0.5	0.37	0.44	0.44	0.51	0.51	0.51	0.51
1	0.64	0.73	0.81	0.88	0.88	0.96	0.96
2	1.15	1.32	1.47	1.50	1.69	1.77	1.84
3	1.62	1.84	2.06	2.21	2.35	2.50	2.57
4	2.06	2.35	2.57	2.79	3.02	3.16	3.31
5	2.35	2.79	3.09	3.38	3.60	3.75	3.97
6	2.72	3.16	3.60	3.90	4.19	4.41	4.63
7	3.02	3.60	4.05	4.41	4.71	5.00	5.22
8	3.31	3.97	4.49	4.85	5.22	5.59	5.81
9	3.60	4.27	4.85	5.37	5.81	5.10	6.40
10	3.82	4.56	5.22	5.81	6.25	6.62	6.99
11	4.04	4.92	5.59	6.18	6.69	6.13	7.58
12	4.19	5.15	5.96	6.62	7.13	7.72	8.00
13	4.34	5.44	6.25	6.91	7.58	8.16	8.46
14	4.49	5.59	6.55	7.28	7.94	8.53	8.97
15	4.63	5.81	6.77	7.58	8.31	8.90	9.41
16	4.71	5.96	7.06	7.87	8.61	9.27	9.78
17	4.78	6.10	7.21	8.09	8.90	9.56	10.15
18	4.78	6.25	7.35	8.38	9.19	9.93	10.51
19	4.78	6.33	7.58	8.53	9.41	9.15	10.81
20	4.78	6.33	7.65	8.68	9.63	10.44	11.11
21	4.71	6.33	7.72	8.83	9.86	10.66	11.33
22	4.56	6.33	7.80	8.90	10.00	10.81	11.62
23	4.34	6.25	7.80	8.97	10.08	10.03	11.77
24	4.19	6.18	7.72	9.05	10.15	11.11	11.91
25	4.05	6.03	7.72	9.05	10.15	11.18	11.99
26	3.82	5.88	7.58	8.97	10.15	11.18	12.06
27	3.60	5.66	7.43	8.90	10.15	11.18	12.13
28	3.24	5.44	7.35	8.75	10.08	11.18	12.13
29	2.79	5.15	7.06	8.60	9.93	11.03	12.06
30	2.43	4.78	6.77	8.38	9.71	10.80	11.99

RATINGS FOR V-BELTS IN KILOWATT

CROSS-SECTION D

Belt speed (m/s)	Equivalent pitch diameter d_e in mm							
	300	320	340	360	380	400	420	430 and over
0.5	0.81	0.88	0.96	0.96	1.03	1.03	1.10	1.10
1	1.47	1.54	1.69	1.77	1.84	1.91	1.91	1.99
2	2.50	2.79	2.94	3.09	3.24	3.38	3.53	3.53
3	3.46	3.75	4.04	4.34	4.56	4.71	4.92	5.00
4	4.34	4.78	5.15	5.44	5.74	6.03	6.25	6.40
5	5.07	5.66	6.10	6.55	6.91	7.21	7.58	7.65
6	5.81	6.55	7.06	7.51	7.94	8.38	8.75	8.90
7	6.47	7.28	7.94	8.46	8.97	9.41	9.86	10.08
8	7.13	7.94	8.68	9.34	10.00	10.52	10.96	11.25
9	7.65	8.68	9.49	10.22	10.96	11.47	12.06	12.28
10	8.23	9.34	10.22	11.03	11.84	12.43	13.02	13.31
11	8.68	9.86	10.88	11.84	12.58	13.39	14.05	14.34
12	9.12	10.37	11.47	12.50	13.39	14.19	14.93	15.30
13	9.49	10.88	12.06	13.16	14.05	15.00	15.74	16.11
14	9.79	11.25	12.58	13.75	14.56	15.74	16.55	16.99
15	10.00	11.62	13.09	14.34	15.44	16.40	17.28	17.72
16	10.30	11.91	13.46	14.78	15.96	16.99	18.02	18.46
17	10.44	12.21	13.83	15.22	16.55	17.58	18.61	19.05
18	10.51	12.43	14.12	15.59	16.99	18.09	19.20	19.71
19	10.51	12.50	14.27	15.89	17.36	18.53	19.86	20.23
20	10.51	12.58	14.49	16.11	17.65	18.98	20.15	20.74
21	10.37	13.31	14.56	16.40	17.87	19.27	20.52	21.11
22	10.22	12.58	14.56	16.47	18.02	19.49	20.81	21.48
23	9.93	12.43	14.56	16.40	18.17	19.71	21.11	21.70
24	9.63	12.21	14.34	16.40	18.24	19.78	21.26	21.99
25	9.19	11.91	14.27	16.25	18.17	19.78	21.33	22.06
26	8.68	11.47	13.97	16.11	17.87	19.78	21.33	21.99
27	8.16	11.03	13.53	15.81	17.80	19.56	21.26	21.99
28	7.51	10.51	13.09	15.44	17.43	19.34	21.11	21.84
29	6.77	9.86	12.58	15.00	17.14	19.12	20.89	21.62
30	5.96	9.12	11.91	14.42	16.70	18.68	20.52	21.33

RATINGS FOR BELTS IN KILOWATT

CROSS-SECTION E

Belt speed (m/s)	Equivalent pitch diameter d_e in mm					
	450	500	550	600	650	700 and over
0.5	1.40	1.47	1.54	1.62	1.69	1.77
1	2.43	2.65	2.87	2.94	3.09	3.24
2	4.34	4.78	5.15	5.44	5.66	5.88
3	6.03	6.69	7.21	7.65	8.02	8.38
4	7.58	8.46	9.19	9.78	10.22	10.74
5	9.05	10.15	11.03	11.77	12.36	13.02
6	10.44	11.69	12.80	13.68	14.49	15.07
7	11.77	13.32	14.49	15.51	16.40	17.14
8	13.02	14.78	16.11	17.28	18.31	19.05
9	14.12	16.11	17.72	18.98	20.15	21.11
10	15.22	17.43	19.12	20.59	21.85	22.95
11	16.25	18.61	20.59	22.20	23.61	24.71
12	17.21	19.78	21.92	23.68	25.15	26.40
13	18.02	20.81	23.17	25.08	26.69	28.02
14	18.84	21.85	24.35	26.40	28.10	29.57
15	19.56	22.80	25.45	27.65	29.49	31.04
16	20.15	23.61	26.40	28.83	30.82	32.44
17	20.74	24.42	27.36	29.86	31.99	33.76
18	21.18	25.08	28.24	30.89	33.10	35.01
19	21.55	25.60	28.97	31.77	34.13	36.19
20	21.77	26.11	29.71	32.58	35.08	37.22
21	21.99	26.48	30.23	33.17	35.97	38.17
22	22.06	26.77	30.74	33.90	36.70	38.98
23	21.99	27.07	31.04	34.42	37.29	39.72
24	21.92	27.07	31.33	34.79	37.88	40.38
25	21.71	26.99	31.48	35.08	38.25	40.89
26	21.25	26.92	31.48	35.30	38.54	41.26
27	20.74	26.62	31.41	35.38	38.69	41.56
28	20.15	25.89	31.18	35.30	38.83	41.78
29	19.49	25.74	30.89	35.08	38.76	41.78
30	18.61	25.08	30.45	34.79	38.54	41.70

NOTE 1—Belt speed is calculated using the pitch diameter and revolutions per second of one of the pulleys on the drive.

NOTE 2—If belt speeds are over 25 metres per second, the pulleys may require special construction or special material. They may also require dynamic balancing. Such applications should be referred to the manufacturer.

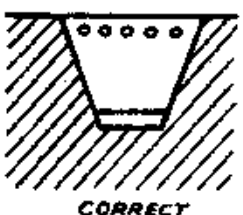
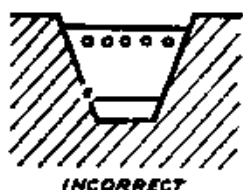
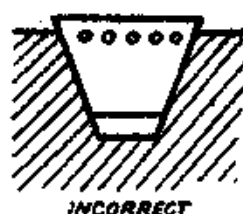
$$\text{Arc of contact angle} = 2 \cos^{-1} \frac{D-d}{2C}$$

$$= 180^\circ - 60^\circ \frac{D-d}{C}$$

D, pitch diameter of larger pulley
d, pitch diameter of smaller pulley
C, centre distance

Correction factor for arc of contact, F_a

Arc of contact on smaller pulley (in degrees)	Correction factor (Proportion of 180° rating)	
	V-V	V-Flat
180	1.00	0.75-
177	0.99	0.76
174	0.99	0.76
171	0.98	0.77
169	0.97	0.78
166	0.97	0.79
163	0.96	0.79
160	0.95	0.80
157	0.94	0.81
154	0.93	0.81
151	0.93	0.82
148	0.92	0.83
145	0.91	0.83
142	0.90	0.84
139	0.89	0.85
136	0.88	0.85
133	0.87	0.86
130	0.86	0.86
127	0.85	0.85
123	0.83	0.83
120	0.82	0.82
117	0.81	0.81
113	0.80	0.80
110	0.78	0.78
106	0.77	0.77
103	0.75	0.75
99	0.73	0.73
95	0.72	0.72
91	0.70	0.70
87	0.68	0.68
83	0.65	0.65



NOTE 1—Arcs of contact below 120° should not be used unless full drive details are first submitted to the V-drive manufacturer concerned for confirmation.

NOTE 2—It should be noted that the advantage of using V-Flat drives diminishes increasingly for arcs of contact greater than 133°, and the use of such drives is usually not found to be practical for arcs of contact greater than 151°.

Correction factors for industrial service, F_s

Severity of Service	Type of Driven Machines	Type of Driving Units					
		AC Motors; Normal Torque, Squirrel Cage, Synchronous and Split Phase			AC Motors; High Torque, High Slip Repulsion-Induction, Single Phase, Series Wound and Slip Ring		
		DC Motors; Shunt Wound, Multiple Cylinder Internal Combustion Engines Over 600 RPM			DC Motors; Series Wound and Compound Wound, Single Cylinder Internal Combustion Engines, Multiple Cylinder Internal Combustion Engines under 600 RPM, Line Shafts, Clutches, Brakes, Direct on-line starting		
		Upto 10 hr	Over 10 hr to 16 hr	Over 16 hr & continuous service	Upto 10 hr	Over 10 hr to 16 hr	Over 16 hr & continuous service
Light-duty	Agitators for liquids, blowers and exhausters, centrifugal pumps and compressors, fans upto 7.5 kW (10 hp), and light-duty conveyors.	1.0	1.1	1.2	1.1	1.2	1.3
Medium-duty	Belt conveyors for sand, grain etc; dough mixers; fans over 7.5 kW (10 hp); generators; line shafts; laundry machinery; machine tools; punches, presses and shears; printing machinery; positive displacement rotary pumps; and revolving and vibrating screens.	1.1	1.2	1.3	1.2	1.3	1.4
Heavy-duty	Brick machinery, bucket elevators, exciters, piston compressors, conveyors (drag-pan-screw), hammer mills, paper mill beaters, piston pumps, positive displacement blowers, pulverizers, saw mill and wood-working machinery and textile machinery.	1.2	1.3	1.4	1.4	1.5	1.6
Extra-heavy-duty	Crushers (gyratory-jaw-roll), mills (ball-rod-tube), hoists and rubber (calenders-extruders-mills).	1.3	1.4	1.5	1.5	1.6	1.8

NOTE 1—The table gives only a few examples of particularly representative machines.

NOTE 2—If an idler pulley is used, the following values must be added to the service factor:

Idler pulley on the slack side	inside : 0	Idler pulley on the tight side	inside : 0.1
	outside : 0.1		outside : 0.2

$$\text{Number of belts} = \frac{P \times F_s}{kW \times F_a \times F_d}$$

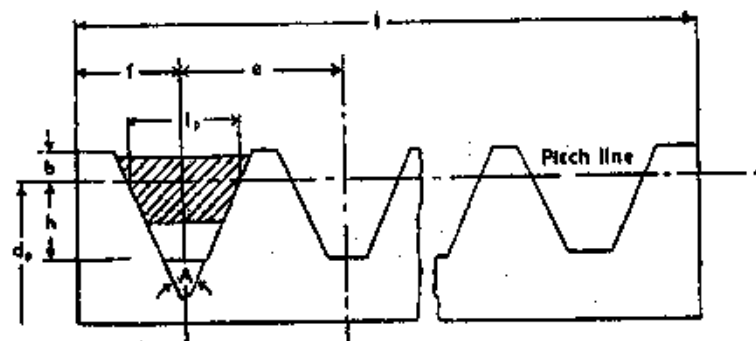
P, drive power, kW

F_s , correction factor according to service

kW, ratings of the V-belt

F_a , correction factor for length

F_d , correction factor for arc of contact



DIMENSIONS OF STANDARD V-GROOVED PULLEYS

Groove Cross Section	Pitch width l_p mm	Minimum distance down to pitch line b mm	Pulley pitch diameter d_p	Angle A Tolerance $\pm 1/2^\circ$	Minimum depth below pitch line h mm	Centre to centre distance of grooves e mm	Tolerance on e^* mm	Edge of pulley to first groove centre f mm	Tolerance on f mm
A	11	3.3	Under 75 mm to 67 mm	32°	8.7	15	± 0.3	10	+2 -1
			**Recommended min. 75 mm and under 125 mm	34°					
			125 mm and over	38°					
B	14	4.2	Under 125 mm to 117 mm	32°	10.8	19	± 0.4	12.5	+2 -1
			**Recommended min. 125 mm and under 200 mm	34°					
			200 mm and over	38°					
C	19	5.7	Under 200 mm to 175 mm	34°	14.3	25.5	± 0.5	17	+2 -1
			**Recommended min. 200 mm and under 300 mm	36°					
			300 mm and over	38°					
D	27	8.1	Under 355 mm to 300 mm	34°	19.9	37	± 0.6	24	+3 -1
			**Recommended min. 355 mm and under 500 mm	36°					
			500 mm and over	38°					
E	32	9.6			23.4	44.5	± 0.7	29	+4 -1

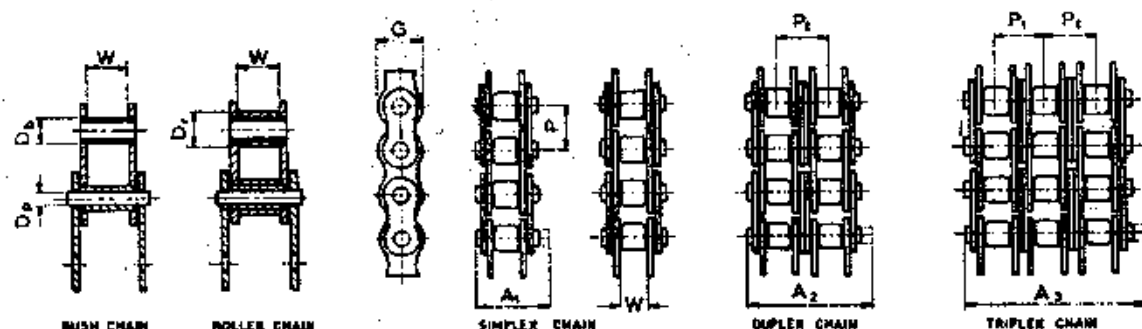
*The tolerances on dimension 'e' apply to the distance between the centres of any two grooves whether consecutive or not.

**The pitch diameter marked with two asterisks is the recommended minimum for standard use, but the largest possible pulleys should be used for long belt life, provided that the belt speed does not exceed 25 metres per second.

The values given above have been calculated subject to certain approximations, from the following formulae:—

$$b = 0.3 l_p \quad e = 1.35 l_p \quad f = 0.9 l_p \quad h = 0.7 l_p + 1 \text{ (expressed in millimetres)}$$

SPECIFICATION OF CHAINS



Chain Nos. with prefix R & B denote simplex, DR & DB denote duplex and TR & TB denote triplex chains.

A. Roller Chains

Chain No.		Pitch P	Roller dia max D _r	Width between inner Plates min W	Pin Body dia max D _p	Plate Depth max G	Trans- verse pitch P _t	Overall over joint max A ₁ , A ₂ A ₃	Bearing Area	Weight per Meter	Breaking Load min
ISO/ DIN	Rolon										
04-1	R628	6.0	4.00	2.80	1.85	5.45	—	8.00	0.07	0.12	300
05B-1	R830	8.0	5.00	3.10	2.31	7.05	—	11.10	0.11	0.18	460
05B-2	DR830	8.0	5.00	3.10	2.31	7.05	5.64	15.80	0.22	0.33	800
05B-3	TR830	8.0	5.00	3.10	2.31	7.05	5.64	21.50	0.33	0.52	1140
	R940	9.525	6.35	4.00	3.28	8.15	—	14.40	0.22	0.37	900
06B-1	R957	9.525	6.35	5.90	3.28	8.15	—	16.40	0.28	0.41	910
06B-2	DR957	9.525	6.35	5.90	3.28	8.15	10.24	26.60	0.56	0.77	1730
06B-3	TR957	9.525	6.35	5.90	3.28	8.15	10.24	36.70	0.84	1.09	2540
082-1	R1224	12.7	7.75	2.40	3.68	9.90	—	8.2	0.17	0.28	1000
081-1	R1230	12.7	7.75	3.48	3.68	9.90	—	11.00	0.21	0.30	820
	R1230H	12.7	7.75	3.48	3.68	9.90	—	12.10	0.22	0.35	1000
	R1248	12.7	7.75	4.90	3.68	9.90	—	12.80	0.26	0.34	820
084-1	R1248H	12.7	7.75	4.90	4.09	11.10	—	16.30	0.36	0.58	1600
083-1	R1249	12.7	7.75	4.90	4.09	10.25	—	14.40	0.32	0.49	1200
	R1253	12.7	7.75	5.25	3.68	10.35	—	13.80	0.29	0.38	1400
	R1264	12.7	7.77	6.40	3.97	11.70	—	15.90	0.39	0.47	1500
	R1252	12.7	8.51	5.30	4.45	11.70	—	18.10	0.39	0.58	1820
08A-1	R40	12.7	7.95	8.00	3.97	11.70	—	20.90	0.44	0.69	1410
08A-2	DR40	12.7	7.95	8.00	3.97	11.70	14.38	35.30	0.88	1.20	2820
08A-3	TR40	12.7	7.95	8.00	3.97	11.70	14.38	49.70	1.32	1.80	4230
08B-1	R1278	12.7	8.51	8.00	4.45	11.70	—	20.50	0.50	0.70	1820

Chain No. ISO/ DIN	Rolon	Pitch P mm	Roller dia max D _r mm	Width between inner Plates min W mm	Pin Body dia max D _p mm	Plate Depth max G mm	Trans- verse pitch P _t mm	Overall over joint max A ₁ A ₂ A ₃ mm	Bearing Area cm ²	Weight per Meter kgf	Breaking Load min kgf
08B-2	DR1278	12.7	8.51	8.00	4.45	11.70	13.92	34.40	1.00	1.32	3180
08B-3	TR1278	12.7	8.51	8.00	4.45	11.70	13.92	48.30	1.50	1.95	4540
	R1278H	12.7	8.51	8.00	4.45	11.70	—	22.50	0.54	0.75	2100
	R1548	15.875	7.75	4.90	3.68	9.90	—	12.80	0.26	0.29	820
	R1564	15.875	10.16	6.65	5.08	14.30	—	20.10	0.51	0.80	2270
10A-1	R50	15.875	10.16	9.55	5.08	15.05	—	25.90	0.70	1.01	2220
10A-2	DR50	15.875	10.16	9.55	5.08	15.05	18.11	44.00	1.40	1.78	4440
10A-3	TR50	15.875	10.16	9.55	5.08	15.05	18.11	62.00	2.10	3.02	6660
10B-1	R1595	15.875	10.16	9.85	5.08	14.30	—	23.50	0.67	0.91	2270
10B-2	DR1595	15.875	10.16	9.85	5.08	14.30	16.59	39.90	1.34	1.82	4540
10B-3	TR1595	15.875	10.16	9.85	5.08	14.30	16.59	56.40	2.01	2.73	6810
12A-1	R60	19.05	11.90	12.70	5.95	17.95	—	29.40	1.05	1.47	3200
12A-2	DR60	19.05	11.90	12.70	5.95	17.95	22.78	52.60	2.10	2.90	6360
12A-3	TR60	19.05	11.90	12.70	5.95	17.95	22.78	75.40	3.15	4.28	9540
12B-1	R1911	19.05	12.07	11.70	5.72	15.95	—	26.70	0.89	1.17	2950
12B-2	DR1911	19.05	12.07	11.70	5.72	15.95	19.46	46.30	1.78	2.36	5900
12B-3	TR1911	19.05	12.07	11.70	5.72	15.95	19.46	65.80	2.67	3.54	8850
16A-1	R80	25.40	15.88	15.90	7.92	24.10	—	37.50	1.79	2.57	5700
16A-2	DR80	25.40	15.88	15.90	7.92	24.10	29.29	66.80	3.58	5.01	11400
16A-3	TR80	25.40	15.88	15.90	7.92	24.10	29.29	96.10	5.37	7.47	17100
16B-1	R2517	25.40	15.88	15.90	8.27	21.00	—	40.40	2.10	2.70	6500
16B-2	DR2517	25.40	15.88	15.90	8.27	21.00	31.88	72.40	4.20	5.30	13000
16B-3	TR2517	25.40	15.88	15.90	8.27	21.00	31.88	104.40	6.30	7.85	19500
20A-1	R100	31.75	19.05	19.10	9.53	30.10	—	47.20	2.62	3.80	8850
20A-2	DR100	31.75	19.05	19.10	9.53	30.10	35.76	83.10	5.24	7.60	17700
20A-3	TR100	31.75	19.05	19.10	9.53	30.10	35.76	119.10	7.86	11.20	26550
	R100H	31.75	19.05	19.10	9.53	30.10	—	50.20	2.77	4.60	10000
	DR100H	31.75	19.05	19.10	9.53	30.10	39.10	89.20	5.54	9.20	20000
	TR100H	31.75	19.05	19.10	9.53	30.10	39.10	130.00	8.31	13.60	30000
20B-1	R3119	31.75	19.05	19.60	10.17	25.60	—	47.60	2.58	3.65	9500
20B-2	DR3119	31.75	19.05	19.60	10.17	25.60	36.45	84.10	5.16	7.20	19000
20B-3	TR3119	31.75	19.05	19.60	10.17	25.60	36.45	121.10	7.74	11.90	28500
24A-1	R120	38.10	22.23	25.50	11.10	36.20	—	57.40	3.93	5.40	12700
24A-2	DR120	38.10	22.23	25.50	11.10	36.20	45.44	102.90	7.86	10.80	25400
24A-3	TR120	38.10	22.23	25.50	11.10	36.20	45.44	148.30	11.79	16.10	38100
24B-1	R3825	38.10	25.40	25.50	14.63	33.40	—	59.60	5.54	6.85	9980

Chain No.		Pitch P	Roller dia max D _r	Width between Inner Plates min W	Pin Body dia max D _p	Plate Depth max G	Trans- verse pitch P _t	Overall over joint max A ₁ , A ₂ A ₃	Bearing Area	Weight per Meter	Breaking Load min
ISO/ DIN	Rolon										
		mm	mm	mm	mm	mm	mm	mm	cm²	kgf	kgf
24B-2	DR3825	38.10	25.40	25.50	14.63	33.40	48.36	108.40	11.09	14.50	19960
24B-3	TR3825	38.10	25.40	25.50	14.63	33.40	48.36	156.40	16.64	20.00	29940
28A-1	R140	44.45	25.40	25.50	12.70	42.10	—	62.30	4.70	7.30	17200
28A-2	DR140	44.45	25.40	25.50	12.70	42.10	—	111.00	9.40	14.30	34480
28A-3	TR140	44.45	25.40	25.50	12.70	42.10	—	159.80	14.10	21.40	51720
32A-1	R160	50.8	28.57	31.80	14.27	48.10	—	73.40	6.42	9.90	22680
32A-2	DR160	50.8	28.57	31.80	14.27	48.10	58.55	132.10	12.84	19.40	45360
32A-3	TR160	50.8	28.57	31.80	14.27	48.10	58.55	190.80	19.26	29.10	68040
208A	R2040	25.4	7.95	7.95	3.97	11.70	—	21.70	0.44	0.48	1410
208B	R2578	25.4	8.51	7.75	4.45	11.70	—	20.80	0.50	0.44	1820
210B	R3195	31.75	10.16	9.65	5.08	14.30	—	23.70	0.67	0.60	2270
212A	R2060	38.10	11.91	12.70	5.95	17.95	—	31.50	1.05	1.45	3200
212B	R3811	38.10	12.07	11.70	5.72	15.95	—	27.20	0.89	0.75	2950

B. Bush Chains

04C-1	B25	6.35	3.30	3.18	2.31	5.75	—	11.60	0.11	0.14	350
	B25H	6.35	3.30	3.18	2.31	5.75	—	12.60	0.12	0.16	450
	B748	7.77	4.57	4.80	3.15	7.35	—	14.00	0.24	0.22	1000
06C-1	B35	9.525	5.08	4.77	3.59	8.65	—	15.10	0.27	0.40	1030
06C-2	DB35	9.525	5.08	4.77	3.59	8.65	10.15	27.30	0.54	0.71	2050
06C-3	TB35	9.525	5.08	4.77	3.59	8.65	10.15	35.80	0.81	1.01	2370
	B975	9.525	5.00	7.50	3.54	9.20	—	17.50	0.39	0.53	1300
	B995	9.525	6.00	9.52	4.45	9.75	—	19.30	0.58	0.63	1200
	B995H	9.525	6.00	8.00	4.45	9.75	—	20.00	0.58	0.76	1550
	B980	9.525	6.00	8.00	4.45	9.75	—	21.50	0.58	0.80	1800
	DB957	9.525	6.35	5.75	4.45	9.55	—	26.60	0.76	0.66	1730
	B1511	15.875	10.07	11.40	7.00	16.75	—	34.00	1.49	2.08	4750
	B1278	12.70	6.25	7.75	4.45	11.70	—	20.50	0.50	0.60	1820
	B1595	15.875	7.08	9.85	5.08	14.30	—	23.50	0.67	0.72	2270
	B1911	19.05	8.41	11.70	5.72	15.95	—	26.70	0.89	1.87	2950
	B2517	25.40	11.63	17.02	8.27	21.00	—	40.40	2.10	2.18	6500

$$\text{Transmission ratio } i = \frac{Z_2}{Z_1} = \frac{n_1}{n_2}$$

Z_1 , number of teeth on sprocket pinion

Z_2 , number of teeth on sprocket wheel

n_1 , speed of rotation of pinion, rpm

n_2 , speed of rotation of wheel, rpm

Preferred transmission ratio, i

1 1.12 1.25 1.4 1.6 1.8 2 2.25 3.15 4 4.5 5 5.6 6.3 7.1

Recommended Z_1

Transmission ratio, i	1—2	2—3	3—4	4—5	5—7
Number of teeth on sprocket, Z_1	30—27	27—25	25—23	23—21	21—17

Where space is a problem, Z_1 minimum = 7

Number of teeth on sprocket wheel, Z_2

$$Z_2 = i \cdot Z_1$$

$$Z_{2 \max} = 100 \text{ to } 120$$

Note: When Z_2 is very large, chain slips off the sprocket for a small pull.

Maximum speed of rotation of the pinion, $n_{1 \max}$ rpm

Number of teeth on sprocket pinion Z_1	p, pitch, mm		
	9.525	12.7	15.875
7	2800	2600	2000
9	2800	2400	1800
15	2400	2400	1800
21	2400	2100	1500
27	2100	1800	1300
35	1800	1600	1200
45	1600	1400	1000

Centre distance, a , mm

Optimum centre distance $a = (30 \text{ to } 50) p$

a , centre distance, mm

p , pitch of chain, mm

Minimum centre distance, $a_{\min}$

Transmission ratio, i	Minimum centre distance, $a_{\min}$, mm
3	$a' + (30 \text{ to } 50), \text{ mm}$
3—4	$1.2 a'$
4—5	$1.3 a'$
5—6	$1.4 a'$
6—7	$1.5 a'$

where

$$a' = \frac{d_{a1} + d_{a2}}{2}$$

d_{a1} , tip diameter of sprocket pinion, mm

d_{a2} , tip diameter of sprocket wheel, mm

$$\text{tip diameter } d_a = \frac{p}{\tan \frac{180^\circ}{Z}} + 0.6p$$

Maximum centre distance, $a_{\max}$, mm

$$a_{\max} = 80p$$

p , pitch of chain, mm

Relationship between centre distance and length of chain

Nomenclature	Symbol	Formulae
Length of continuous chain in multiples of pitches (i. e. approximate number of links)	l_p	$l_p = 2a_p + \frac{Z_1 + Z_2}{2} + \frac{\left(\frac{Z_2 - Z_1}{2\pi}\right)^2}{a_p}$ to be corrected to an even number
Approximate centre distance in multiples of pitches	a_p	$a_p = \frac{a_0}{p}$ a_0, initially assumed centre distance, mm p, pitch, mm
Final centre distance corrected to even number of pitches	a	$a = \frac{c + \sqrt{c^2 - 8m}}{4} p$ $c = l_p - \frac{Z_1 + Z_2}{2}$ $m = \left(\frac{Z_2 - Z_1}{2\pi}\right)^2, \text{ constant}$ For value of m, see page 7.76
Length of chain	l	$l = l_p \cdot p$
Centre distance (decrement) allowance to accommodate initial chain sag	Δ	$\Delta = \frac{1}{2} \left[f - \left(\frac{Z_2 - Z_1}{2\pi a_p} \right)^2 \cdot p \right] \approx 0.5f$ f, chain sag of driven side, mm $f = 0.02 a$, mm

$$\text{Value of } m = \left(\frac{Z_2 - Z_1}{2\pi} \right)^2$$

$Z_2 - Z_1$	m	$Z_2 - Z_1$	m	$Z_2 - Z_1$	m	$Z_2 - Z_1$	m
1	0.025	26	17.12	51	66.0	76	146.3
2	0.101	27	18.47	52	68.5	77	150.2
3	0.228	28	19.86	53	71.2	78	154.1
4	0.405	29	21.3	54	73.9	79	158.1
5	0.633	30	22.8	55	76.6	80	162.1
6	0.912	31	24.3	56	79.4	81	166.2
7	1.24	32	25.9	57	82.3	82	170.3
8	1.62	33	27.6	58	85.2	83	174.5
9	2.05	34	29.3	59	88.2	84	178.7
10	2.53	35	31.0	60	91.2	85	183.0
11	3.07	36	32.8	61	94.3	86	187.3
12	3.65	37	34.7	62	97.4	87	191.7
13	4.28	38	36.6	63	100.5	88	196.2
14	4.97	39	38.5	64	103.8	89	200.6
15	5.70	40	40.5	65	107.0	90	205.2
16	6.49	41	42.6	66	110.3	91	209.8
17	7.32	42	44.7	67	113.7	92	214.4
18	8.21	43	46.8	68	117.1	93	219.1
19	9.14	44	49.0	69	120.6	94	223.8
20	10.13	45	51.3	70	124.1	95	228.6
21	11.17	46	53.6	71	127.7	96	233.4
22	12.26	47	56.0	72	131.3	97	238.3
23	13.40	48	58.4	73	135	98	243.3
24	14.59	49	60.8	74	138.7	99	248.3
25	15.83	50	63.3	75	142.9	100	253.3

Service factor, k_s

$$k_s = k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot k_5 \cdot k_6$$

Load factor, k_1

Constant load	k_1 1.0
Variable load or load with mild shocks	1.25
Variable load or load with heavy shocks	1.5

Factor for distance regulation, k_2

Adjustable supports	k_2 1.0
Drive using idler sprocket	1.1
Fixed centre distance	1.25

Factor for centre distance of sprockets, k_3

$\frac{l_p}{Z_1 + Z_2} > 1$ or $a_p < 25 p$	k_3 1.25
$\frac{l_p}{Z_1 + Z_2} \approx 1.5$ or $a_p = 30$ to $50 p$	1
$\frac{l_p}{Z_1 + Z_2} \geq 2.0$ or $a_p = 60$ to $80 p$	0.8

Factor for the position of the sprockets, k_1	k_1
Inclination of the line joining the centres of the sprockets to the horizontal	upto 60° more than 60°
	1 1.25
Lubrication factor, k_2	k_2
Continuous (oil-bath or forced lubrication)	0.8
Drop-Lubrication	1.0
Periodic	1.5
Rating factor, k_3	k_3
Single shift of 8 hours a day	1.0
Double shift of 16 hours a day	1.25
Continuous running	1.5

Power transmitted on the basis of breaking load

$$N = \frac{Q \cdot v}{75 \cdot n \cdot k_s} \text{ in hp}$$

Q , breaking load, kgf

v , chain velocity, m/s

$$N = \frac{Q \cdot v}{102 \cdot n \cdot k_s} \text{ in kW}$$

$k_s = k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot k_5 \cdot k_6$, service factor,

n , allowable factor of safety (minimum)

Minimum value of factor of safety, n (for $k_s = 1$ & $Z_1 = 15$ to 30)

Pitch p , mm	Speed of rotation of small sprocket, rpm										
	< 50	200	400	600	800	1000	1200	1600	2000	2400	2800
9.525	7.0	7.8	8.55	9.35	10.2	11.0	11.7	13.2	14.8	16.3	18.0
12.7											
15.875											

Power transmitted on the basis of allowable bearing stress

$$N = \frac{\sigma \cdot A \cdot v}{75 \cdot k_s} \text{ in hp}$$

σ , allowable bearing stress, kgf/cm²

A , projected bearing area, cm²

$$N = \frac{\sigma \cdot A \cdot v}{102 \cdot k_s} \text{ in kW}$$

v , chain velocity, m/s

k_s , service factor

Allowable bearing stress, σ , kgf/mm² (for $k_s = 1$ & $Z_1 = 15$ to 30)

pitch p, mm	Speed of rotation of small sprocket, rpm										
	< 50	200	400	600	800	1000	1200	1600	2000	2400	2800
9.525	3.5	3.15	2.87	2.62	2.42	2.24	2.10	1.85	1.65	1.50	1.37
12.7											
15.875											

Check for the actual factor of safety

$$[n] = \frac{Q}{\sum P}$$

$$\sum P = P_t + P_o + P_s$$

$$P_t = \frac{75 N}{v}, \text{ if } N \text{ in hp}$$

$$P_t = \frac{102 N}{v}, \text{ if } N \text{ in kW}$$

$$P_o = \frac{wv^2}{g}$$

$$P_s = k \cdot w \cdot a$$

[n], actual factor of safety, should be greater than allowable

Q, breaking load of chain, kgf

P_t, tangential force due to power transmission, kgf

P_o, centrifugal tension, kgf

P_s, tension due to sagging of chain, kgf

v, chain velocity, m/s

w, weight per metre of chain, kgf

g = 9.81 m/s², acceleration due to gravitational pull

a, centre distance, m

k, coefficient for sag

Coefficient for sag, k

Coefficient for sag	Position of chain drive			
	horizontal	upto 40°	more than 40°	vertical
k	6	4	2	1

Pitch diameter of sprockets

$$\text{Diameter of small sprocket, } d_1 = \frac{P}{\sin \frac{180^\circ}{Z_1}}, \text{ mm}$$

P, pitch of chain, mm

Z₁, Z₂, number of teeth on sprockets

$$\text{Diameter of large sprocket, } d_2 = \frac{P}{\sin \frac{180^\circ}{Z_2}}, \text{ mm}$$

Load on shafts

$$Q_o = k_s \cdot P_t$$

Q_o, load on shaft due to chain drive, kgf

$$P_t = \frac{75 N}{v} \text{ if } N \text{ in hp}$$

k_s, load factor

$$P_t = \frac{102 N}{v} \text{ if } N \text{ in kW}$$

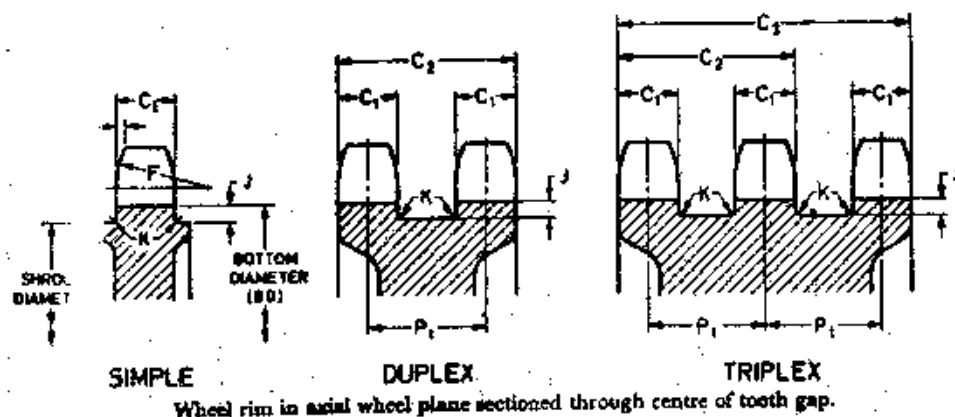
P_t, tangential force due to power transmission, kgf

Load factor, k_s

Load factor	Position of chain drive			
	Horizontal or upto 40°		Vertical or more than 40°	
	Constant load	Shock load	Constant load	Shock load
k _s	1.15	1.3	1.05	1.15

CHAIN WHEEL RIM PROFILE DIMENSIONS

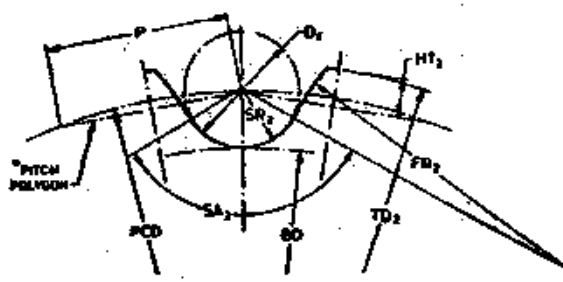
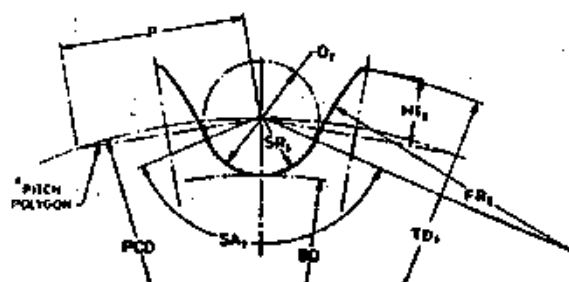
All dimensions in millimetres



Chain No.	*Pitch P	Roller diameter D_r max	Width between inner plates W min	Tooth width simple C_1		Width over tooth, Duplex C_2		Width over Tooth, Triplex C_3		Tooth side radius F	Side Relief G	Shroud Depth J Min	Shroud Radius K Max
				max	min	min	max	max	min				
6.0	9.525	6.35	3.94	3.58	3.40	—	—	—	—	9.53	0.97	3.30	0.76
6.1	9.525	6.35	5.72	5.33	5.11	1.57	15.34	25.81	25.58	9.53	0.97	3.30	0.76
8.0	12.70	7.75	3.30	2.97	2.79	—	—	—	—	12.70	0.89	2.16	0.76
8.1	12.70	7.75	4.88	4.47	4.27	—	—	—	—	12.70	0.89	2.16	0.76
8.2	12.70	8.51	5.21	4.80	4.60	—	—	—	—	12.70	1.27	2.79	0.76
8.3	12.70	8.51	7.75	7.24	6.99	2.16	20.90	35.08	34.82	12.70	1.27	2.79	0.76
10.0	15.875	10.16	6.48	6.02	5.79	—	—	—	—	15.88	1.60	3.43	0.76
10.1	15.875	10.16	9.65	9.04	8.76	2.63	25.35	42.21	41.94	15.88	1.60	3.43	0.76

*Nominal transverse pitch of teeth=nominal transverse pitch of chain, P_t .

CHAIN WHEEL TOOTH GAP FORM

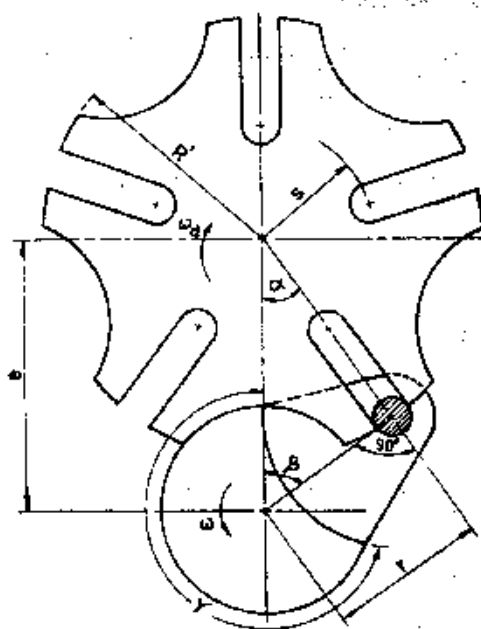


MINIMUM TOOTH GAP FORM							
Chain No.	Pitch P mm	Roller Diameter Max D _r mm	Roller seating Radius SR ₁ mm	Rolling seating Angle SA ₁ deg	Flank Radius FR ₁ mm	Top Diameter TD ₁ mm	Tooth Height above Pitch Polygon HT ₁ mm
6.0 and 6.1	9.525	6.35	3.20	$140 - \frac{90}{N}$	$0.76 (N+2)$	$PCD + 5.56$	$2.79 + \frac{7.62}{N}$
8.0 and 8.1	12.70	7.75	3.91	$140 - \frac{90}{N}$	$0.94 (N+2)$	$PCD + 8.13$	$4.06 + \frac{10.16}{N}$
8.2 and 8.3	12.70	8.51	4.29	$140 - \frac{90}{N}$	$1.02 (N+2)$	$PCD + 7.37$	$3.68 + \frac{10.16}{N}$
10.0 and 10.1	15.875	10.16	5.13	$140 - \frac{90}{N}$	$1.22 (N+2)$	$PCD + 9.68$	$4.85 + \frac{12.70}{N}$

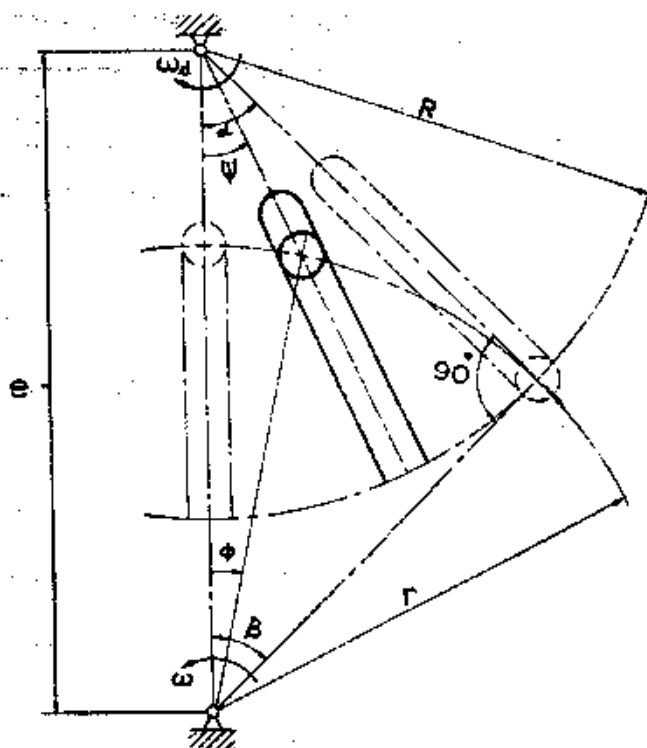
MAXIMUM TOOTH GAP FORM						
Chain No.	Roller Seating Radius SR ₁		Roller Seating Angle SA ₁ deg	Flank Radius FR ₁ mm	Top Diameter TD ₁ mm	Tooth Height above Pitch Polygon HT ₁ mm
	9 to 50 teeth mm	51 to 150 teeth mm				
6.0 and 6.1	3.33	3.45	120	$0.048 (N^2 + 34)$	$PCD + 3.18 - \frac{15.24}{N}$	1.57
8.0 and 8.1	4.04	4.17	120	$0.058 (N^2 + 34)$	$PCD + 4.95 - \frac{20.32}{N}$	2.46
8.2 and 8.3	4.45	4.57	120	$0.066 (N^2 + 34)$	$PCD + 4.19 - \frac{20.32}{N}$	2.08
10.0 and 10.1	5.28	5.41	120	$0.079 (N^2 + 34)$	$PCD + 5.72 - \frac{25.40}{N}$	2.84

NOTE:— N=Number of the teeth.

*The pitch polygon is the regular polygon, inscribed in the pitch circle having sides of length equal to chain pitch P and meeting at chain roller centres.



EXTERNAL GENEVA MECHANISM
(In the starting position)



For entry without shock,

$$\lambda = \frac{r}{e} = \sin \alpha = \sin \frac{\pi}{Z}$$

$$\beta = \frac{\pi}{2} - \alpha = \frac{\pi(Z-2)}{2Z}$$

$$\tan \psi = \frac{\lambda \sin \phi}{1 - \lambda \cos \phi}$$

$$\omega_d = \frac{d\psi}{dt} = \frac{\lambda (\cos \phi - \lambda)}{1 - 2\lambda \cos \phi + \lambda^2} \omega$$

$$\alpha_d = \frac{d^2\psi}{dt^2} = \pm \frac{\lambda (1 - \lambda^2) \sin \phi}{(1 - 2\lambda \cos \phi + \lambda^2)^2} \omega^2$$

$$\omega_{d \max} = \frac{\lambda}{1 - \lambda} \omega$$

At the start and finish of indexing,

$$\alpha_{do} = \pm \omega^2 \tan \frac{\pi}{Z}$$

$$t = \frac{60}{n} \text{ seconds}$$

$$\nu = \frac{t_i}{t} = \frac{\beta}{\pi} = \frac{Z-2}{2Z} < \frac{1}{2}$$

$$\frac{t_r}{t} = \frac{Z+2}{2Z}$$

$$\mu = \frac{R}{r} = \cot \alpha; S \leq e(1 - \sin \alpha)$$

$$\gamma = \frac{\pi}{Z} (Z+2)$$

r , radius of the driving crank

R , radius of the Geneva wheel

r_p , radius of driver pin

e , centre distance

ϵ , gear ratio

α , semi-indexing angle (driven)

β , semi-indexing angle (driver)

Z , number of slots on the driven disc

ω , angular velocity of driving crank, assumed to be constant

ϕ , angular position of crank at any time t

γ , angle of locking action

ψ , angular position of driven disc

ω_d , angular velocity of driven disc

α_d , angular acceleration of driven disc

t_i , time for indexing, seconds

t_r , resting time, seconds

t , time taken for one complete rotation of driving crank, seconds

ν , indexing time ratio

n , speed of rotation of crank, rpm

μ , radius ratio

R' , corrected outside radius of Geneva wheel = $R \sqrt{1 + (r_p^2/R^2)}$

d_w , diameter of wheel shaft

To avoid the wheel overhanging the bearing,
 $d_w/e < 2(1 - \sin \pi/Z)$

EXTERNAL GENEVA CHARACTERISTICS

Z	α	β	ϵ	$\frac{r}{c}$	$\frac{R}{c}$	μ	$\frac{S_{min}}{c}$	γ	ν
3	60°	30°	0.5	0.8660	0.5000	0.5774	0.13397	300°	0.1667
4	45°	45°	1	0.7071	0.7071	1.0000	0.2929	270°	0.2500
5	36°	54°	1.5	0.5878	0.8090	1.3764	0.4122	252°	0.3000
6	30°	60°	2	0.5000	0.8660	1.7320	0.5000	240°	0.3333
7	25°43'	64°17'	2.5	0.4339	0.9009	2.0765	0.5661	231°26'	0.3571
8	22°30'	67°30'	3	0.3827	0.9239	2.4142	0.6173	225°	0.3750
9	20°	70°	3.5	0.3420	0.9397	2.7475	0.6580	220°	0.3889
10	18°	72°	4	0.3090	0.9511	3.0777	0.6910	216°	0.4000
∞	0°	90°	∞	0	1	∞	1	180°	0.5000

Z	$\dagger \left(\frac{d\psi}{d\phi} \right)_{max}$	$\dagger\dagger \left(\frac{d^2\psi}{d\phi^2} \right)_{\phi = -\beta}^{initial}$	$^*\phi_{max}$	$^{**} \left(\frac{d^2\psi}{d\phi^2} \right)_{max}$	$\left(\frac{d^3\psi}{d\phi^3} \right)_{\phi=0}$
3	6.46	1.732	4°46'	31.44	±672
4	2.41	1.000	11°24'	5.409	±48.04
5	1.43	0.7265	17°34'	2.299	-13.32
6	1.00	0.5774	22°54'	1.350	-6.000
7	0.766	0.4816	27°33'	0.9284	-3.429
8	0.620	0.4142	31°38'	0.6998	-2.249
9	0.520	0.3640	35°16'	0.5591	-1.611
10	0.447	0.3249	38°30'	0.4648	-1.236
∞	0	0	90°	0	0

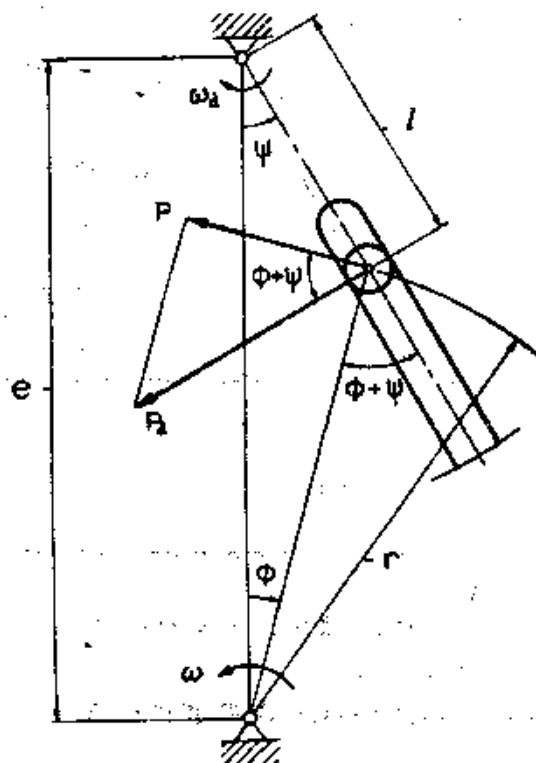
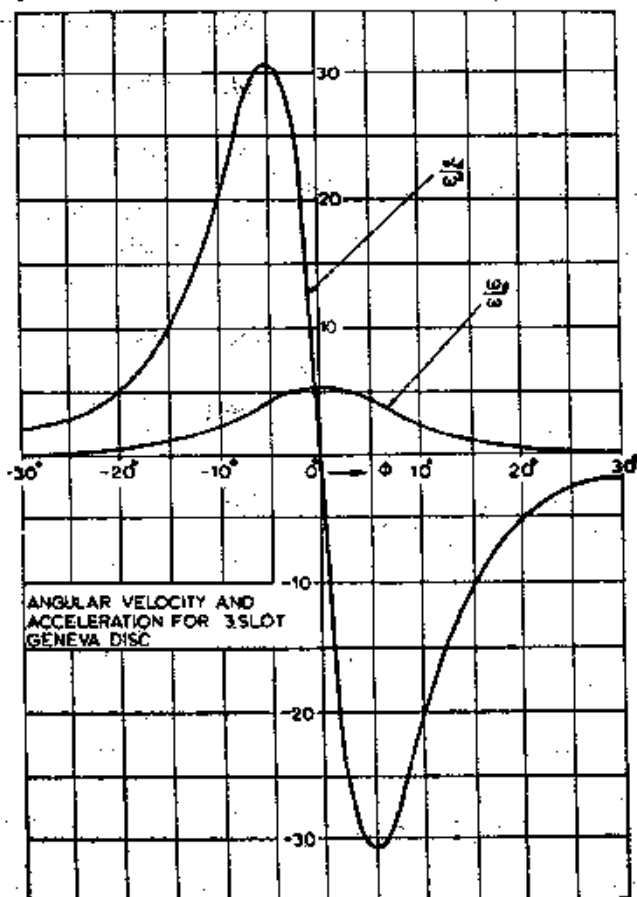
$$\dagger \left(\frac{d\psi}{d\phi} \right)_{max} = \frac{\omega_d}{\omega}$$

* angle at which maximum acceleration of driven wheel occurs

$$\dagger\dagger \left(\frac{d^2\psi}{d\phi^2} \right)_{initial} = \left(\frac{\alpha_d}{\omega^2} \right)_{initial}$$

$$^{**} \left(\frac{d^2\psi}{d\phi^2} \right)_{max} = \left(\frac{\alpha_d}{\omega^2} \right)_{max}$$

GENEVA MECHANISM (Contd.)



CONTACT FORCE

$$M_{td} = M_H + M_H$$

$$M_H = I \alpha_d$$

$$M_t = M_{td} \frac{\omega_d}{\omega} \frac{1}{\eta}$$

Instantaneous power required on the driving shaft

$$N = \frac{M_t \omega}{75} \text{ hp}$$

$$N = \frac{M_t \omega}{102} \text{ kW}$$

Average Power Calculation

$$M_H = 0 \text{ for one complete cycle}$$

For first half cycle

$$M_{t,av} = \frac{2}{Z-2} \left[M_H + \frac{ZI}{2\pi} \left(\frac{\lambda}{1-\lambda} \right)^2 \omega^2 \right] \frac{1}{\eta}$$

$$N_{av} = \frac{M_{t,av} \omega}{75} \text{ hp}$$

$$N_{av} = \frac{M_{t,av} \omega}{102} \text{ kW}$$

Maximum Power Calculation

$$M_{t,max} = M_H \frac{\omega_{d,max}}{\omega} \frac{1}{\eta} + \frac{I}{\omega} \left(\alpha_d \omega_d \right)_{max} \frac{1}{\eta}$$

$$M_{t,max} = M_H \frac{\lambda}{1-\lambda} \frac{1}{\eta} + \frac{\lambda^2 (1-\lambda^2) (\cos \phi_m - \lambda) \sin \phi_m}{(1-2\lambda \cos \phi_m + \lambda^2)^3} I \omega^2 \frac{1}{\eta}$$

$$N_{max} = \frac{M_{t,max} \omega}{75} \text{ hp}$$

$$N_{max} = \frac{M_{t,max} \omega}{102} \text{ kW}$$

Contact Force

$$P_{d,max} = P_{f,max} + P_{i,max}$$

$$P_{f,max} = \frac{M_H}{l_{min}} = \frac{M_H}{r} \frac{\lambda}{1-\lambda}$$

M_{td} , net torque on the driven shaft

M_H , frictional torque on the driven shaft

M_H , inertial torque on the driven shaft

I , mass moment of inertia of all the attached masses referred to the driven shaft

N , power required

α_d , angular acceleration of the driven shaft

M_t , net torque on the driving shaft, kgf m

η , efficiency of Geneva mechanism

$\eta = 0.80$ to 0.90 when the driven shaft is mounted on Journal bearings

$\eta = 0.95$ when the driven shaft is mounted on antifriction bearings

$\eta = 0.75$ for large driven mechanisms

ϕ_m , the angular position of crank at which the product $(\omega_d \alpha_d)$ is maximum

$P_{d,max}$, maximum contact force between the roller pin and slotted disc

$P_{f,max}$, maximum value of the component force due to the frictional torque on the driven shaft

$P_{i,max}$, maximum value of the component force due to the inertial torque on the driven shaft

Z	3	4	5	6	8
$P_{f,max}$ $\left(\frac{\text{In}^2}{r} \right)$	1.966	0.126	0.0318	0.0131	0.00424

Material for the roller

Steel 105 Cr 1 hardened to HRC 59 to 63 or Steel 15 Cr 65 case hardened to HRC 56 to 62

Material for the sides of slotted disc

Steel 40 Cr 1 hardened and tempered to HRC 45 to 50

RATCHET:

Number of teeth Σ

= 6 to 8 for rack and pinion jack, ratchets and brakes applied to the lifted loads (worm hoists)

= 12 to 20 for independent ratchet arresters

= 16 to 25 and more, for ratchet type brakes

Values of p , kgf/cm

Material	P
Steel pawl and CI Ratchet	50—100
Steel pawl and Steel Ratchet	150—300

Bending moment $M_b = Ph$

for $a = m$, $h = 0.75m$, $b = \psi m$

$D = \Sigma m$ and $P = 2M_b/D$

$$m = 2 \sqrt[3]{\frac{M_b}{\Sigma \psi [\sigma_b]}}$$

PAWL:

The pawl is checked for eccentric compression or tension

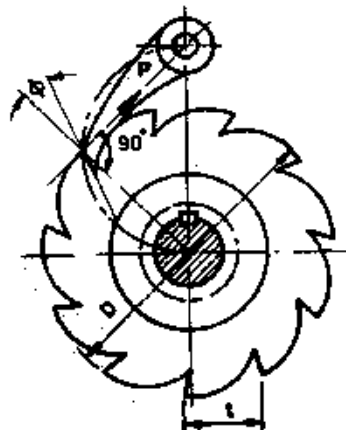
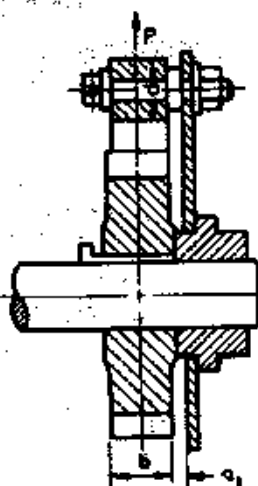
$$M_{bl} = P e_1$$

$$\sigma = \frac{6 M_{bl}}{b x^2} + \frac{P}{x b} \leq [\sigma]$$

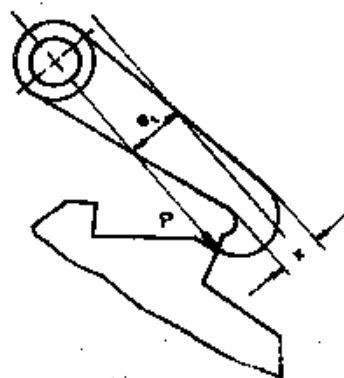
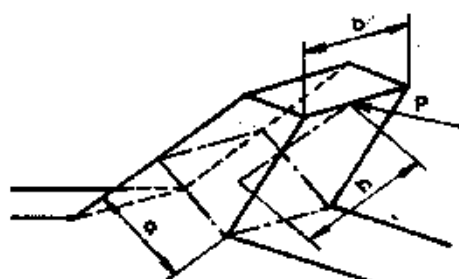
diameter of the pawl pin

$$d = 2.71 \sqrt[3]{\frac{P}{2[\sigma_b]} \left(\frac{b}{2} + a_1 \right)}$$

For best conditions of sliding, the ratchet tooth angle $\phi > \rho$



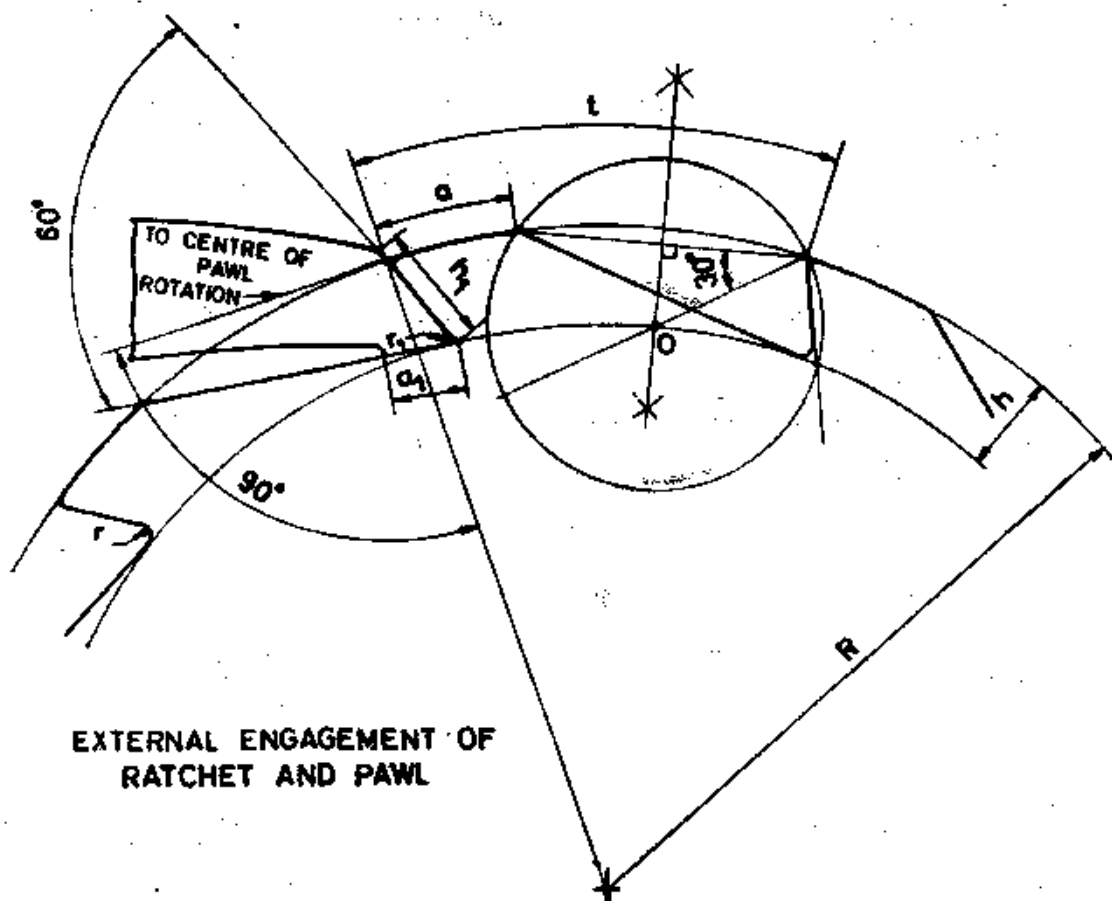
- M bending moment on tooth
- M_t transmitted torque
- D tip circle diameter of ratchet
- d diameter of pawl pin
- Σ number of teeth on ratchet
- m module, D/Σ
- b face width of ratchet
- P peripheral force, $2M_b/\Sigma m$
- p linear unit pressure, P/b
- ψ b/m ratio, 1.5 to 3.0
- $[\sigma_b]$ design bending stress, for C 45, 300—500 kgf/cm²
- h normal distance of the force P from critical section
- $a \times b$ area of critical section of the tooth
- μ coefficient of friction
- ρ friction angle, $\tan^{-1} \mu$
- ϕ ratchet tooth angle
- M_{bl} bending moment on pawl
- a_1 thickness of collar on pawl pin



* Somewhat reduced safe bending stress is taken to allow for the impact loads

DIMENSIONS OF RATCHET TOOTH PROFILE AND PAWL

All dimensions in millimetres



EXTERNAL ENGAGEMENT OF RATCHET AND PAWL

m		6	8	10	12	14	16	18	20	22	24	26	30
z		from 6 to 30 inclusive											
Ratchet wheel	t	18.85	25.13	31.42	37.70	43.98	50.27	56.55	62.83	69.12	75.4	81.68	94.25
	h	4.5	6	7.5	9	10.5	12	13.5	15	16.5	18	19.5	22.5
	a	6.0	8	10	12	14	16	18	20	22	24	26	30
	r	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Pawl	h ₁	6	8	10	12	14	14	16	18	20	20	22	25
	a ₁	4	4	6	6	8	8	12	12	14	14	14	16
	r ₁	2	2	2	2	2	2	2	2	2	2	2	2

CALCULATION FOR WEAR:

$$\text{Unit pressure } p = \frac{P S}{\pi \psi d_p^2 t_2 \bar{z}} \leq [p]$$

$$d_p \geq \sqrt{\frac{P S}{\pi \psi t_2 \bar{z} [p]}}$$

$$d_p \geq \sqrt{\frac{2P}{\pi \psi [p]}} \text{ for } t_2 = 0.5 \frac{S}{\bar{z}}$$

S and $\bar{z}$ are usually found from kinematic calculations.

Values of unit pressure, p

Material combination	p, kgf/cm ²
Steel screw—Bronze nut	120
Steel screw—Cast iron nut	80
Steel screw—Bronze nut for machine tool lead screws }	30

The nearest standard d_p is to be selected.

CHECK FOR STRENGTH: (done only for heavily loaded screws)

$$M_t = P \frac{d}{2} \tan(\beta + \rho) + M_i$$

$$M_i = P \frac{d_{red}}{2} \mu$$

$$\tau = \frac{16M_t}{\pi d_1^3}; \quad \sigma = \frac{4P}{\pi d_1^2}$$

$$\sigma_{com} = \sqrt{\sigma^2 + 4\tau^2} \leq \frac{\sigma_T}{n}$$

CHECK FOR SHEARING OF THE NUT: (for bronze and cast iron)

The shearing stress

$$\tau = \frac{P S}{\pi d_o H \bar{z} h} \leq [\tau]$$

P axial force on the screw, kgf

p unit pressure on the thread, kgf/cm²

d_o major diameter, cm

d_{red} reduced diameter of friction forces on the pivot, cm

d_p thread pitch diameter, cm

S thread pitch (lead), cm

t_2 depth of thread engagement, cm

d_1 core diameter, cm

H nut thickness, cm

h thickness at the thread base, cm

$\bar{z}$ number of starts of the thread

ψ ratio H/d_p
= 1.2 to 2.5 for solid nuts
= 2.5 to 3.5 for split nuts

M_t friction moment on the end or support, kgf cm

μ , Coefficient of friction, $\tan \rho$

M_i torque transmitted by the screw, kgf cm

σ normal stress in the screw, kgf/cm²

σ_{com} combined stress, kgf/cm²

β helix angle of the screw, $\tan^{-1} \frac{S}{\pi d_p}$

ρ friction angle 6° to 8°

for self locking $\beta < \rho$

n factor of safety, 3 to 3.5

σ_T yield point stress, kgf/cm²

CHECK FOR STABILITY:

For $\frac{l_{sup}}{d_{sup}} \approx 1.5$ to 2 pivoted support is assumed
and $l_e = l$

for slenderness ratio $\frac{l}{d_1} > 7.5$ to 10

$$P_c = \frac{\pi^2 EI_{min}}{l_e^2}$$

Considering sag due to self weight of the screw

$$P_c = \frac{\pi^2 EI_{min}}{l_e^2} - 0.5 ql$$

$$n_{st} = \frac{P_c}{P} \geq 2.5 \text{ to } 4$$

CHECK FOR RIGIDITY:

$$\Delta_{sp} = \frac{4PS}{\pi E d_1^2}$$

$$\Delta_{st} = \frac{16M_t S^3}{\pi^2 G d_1^4}$$

The permissible increase or decrease in the thread pitch should be assigned on the basis of the pitch tolerance for a lead screw of the corresponding accuracy class.

(t) design shear stress 250-300 kgf/cm² for phosphor bronze and CI

l length of screw between supports, cm

l_e equivalent length, cm

l_{sup} length over support, cm

d_{sup} diameter at support, cm

P_c critical or buckling load, kgf

n_{st} stability factor of safety

I_{min} least moment of inertia of the section, cm⁴

E modulus of elasticity, kgf/cm²

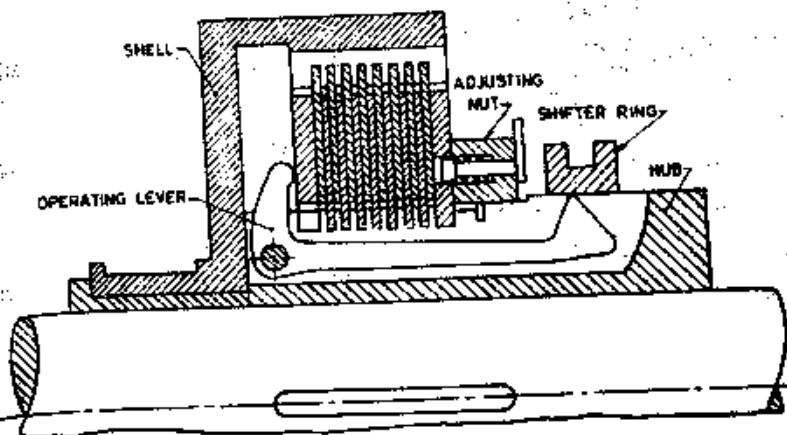
q intensity of self weight, kgf/cm

Δ_{sp} change in thread pitch due to axial load

Δ_{st} change in thread pitch due to twisting moment

G modulus of rigidity, kgf/cm²

MULTIPLE PLATE CLUTCHES



LEVER OPERATED MULTIPLE FRICTION CLUTCH

Transmitted torque:

$$M_t = \frac{97400 \text{ kW}}{n} = \frac{71620 \text{ HP}}{n}$$

Design torque $[M_t] = k_w M_t$

$$k_w = k_1 + k_2 + k_3 + k_4$$

Number of friction surfaces:

$$i = m_1 + m_2 - 1$$

$$i_{\min} = \frac{[M_t]}{2\pi p_a b \mu r_m^2}$$

Allowable pressure:

$$p_a = k p_b$$

Values of p_b :

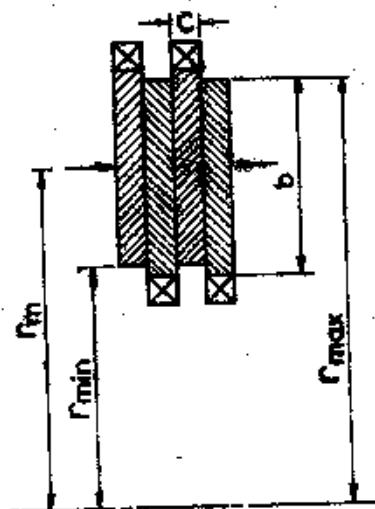
Steel plates (wet running) 6 to 8 kgf/cm²

Steel plates (dry running) 2.5 to 3 kgf/cm²

Compressed asbestos on steel, operating dry 2 to 2.5 kgf/cm²

Diameter of clutch shaft:

$$d = \sqrt[3]{\frac{495000 \times kW \times k_w}{n [t]}}$$



DIMENSIONS OF PLATES

kW , HP rated power

n , rpm of the drive

M_t , transmitted torque, kgf cm

k_w , factor based on working conditions

k_1 , driver dynamic characteristic factor

k_2 , driven shaft dynamic characteristic factor

k_3 , wear factor

k_4 , frequency of operation factor

m_1 , number of driving plates

m_2 , number of driven plates

p_a , allowable pressure between plates, kgf/cm²

p_b , basic pressure, kgf/cm²

k , speed factor (from graph)

r_m , mean radius, $\frac{r_{\max} + r_{\min}}{2}$, cm

μ , coeff. of friction between plates

$[t]$, allowable shear stress, kgf/cm²

b , width of friction surface, cm

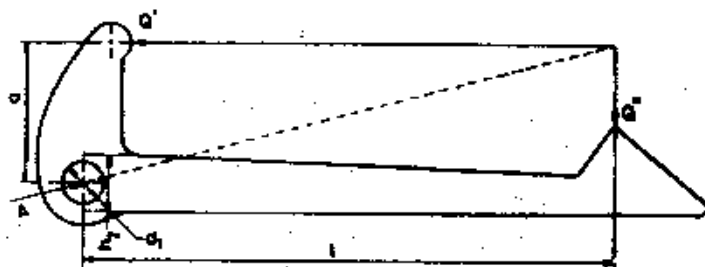
d , diameter of shaft, cm

c , plate thickness, cm

Q , axial force between plates, kgf

σ , pressure between the plates, kgf/cm²

MULTIPLE PLATE CLUTCHES (Contd.)



DIMENSIONS OF OPERATING LEVER

Basic proportions:

$$r_{\min} \approx 2d; \quad r_{\max} \approx 1.25 \text{ to } 1.8 r_{\min}$$

$$c \approx 1 \text{ to } 3 \text{ mm}$$

$$m_1 = \frac{i}{2}; \quad m_2 = \frac{i}{2} + 1$$

Actual pressure between plates

$$\sigma = \frac{[M]}{2\pi i b \mu r_m^2}$$

Operating levers:

$$\text{Axial force } Q = \pi \sigma (r_{\max}^2 - r_{\min}^2)$$

$$Q' = \frac{Q}{i_{o1}}; \quad Q'' = Q' \frac{a}{l}$$

$$h_2 = \sqrt[3]{\frac{6Qa}{[\sigma_b] \psi i_{o1}}}$$

$$A = \sqrt{Q'^2 + Q''^2}$$

$$d_1 = \sqrt{\frac{2A}{\pi [t]}}$$

For medium carbon steel with

$$[t] = 300 \text{ kgf/cm}^2,$$

$$d_1 = 0.046 \sqrt{A}$$

CHOICE OF COEFFICIENTS:

Factor k_1

Type of driving system	Factor k_1	
	For direct coupling or when gear box is used	for belt transmissions
Electric motor directly connected to mains	0.5	0.33
Machines with low starting torque characteristics, turbines and line transmissions	0.33	

i_{o1} , number of operating levers, 3 or 4

Q', Q'' , force on the levers, kgf

$\bar{a}, l$ length of levers, cm

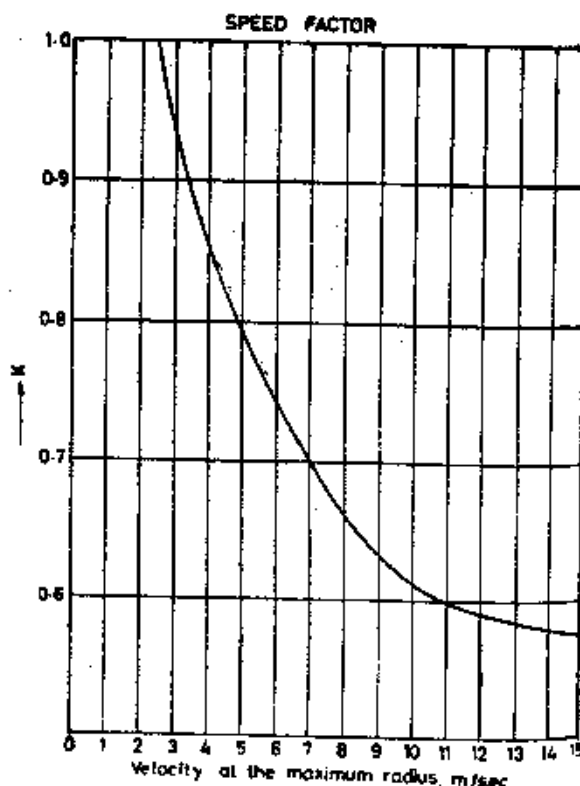
$[\sigma_b]$, allowable bending stress for lever material, kgf/cm²

b_2, h_2 , lever dimensions, cm

ψ , b_2/h_2 ratio ≈ 0.8 to 1

A , reaction on the lever pin, kgf

d_1 , diameter of the pin, cm



MULTIPLE PLATE CLUTCHES (Contd.)

Factor k_2

Type of driven system	k_2	Usage
Driven machines where often a starting torque greater than the nominal value occurs	1.25	Metal cutting machine tools, wood working machine tools, piston type compressors, centrifugal pumps.
	1.6	Metal cutting machine tools with reverse motion (planing), turbo compressors, cranes, heavy machinery, heavy drills, piston pumps etc.
	2.5	Forging machines, presses, wire drawing machines, piston pumps, paper machinery etc.

Factor k_3

rpm	100	160	240	400	620	1000	1400	1800
k_3	0.1	0.13	0.16	0.20	0.25	0.32	0.38	0.43

Factor k_4

Number of engagements in an 8 hour shift	1	8	16	32	48	96	240	480
factor k_4	0	0.20	0.55	0.75	0.90	1.20	1.80	2.00

Check Calculations:

Stress in the arm:

$$\sigma_b = \frac{6Q'l}{b_2 h_2^2} \leq [\sigma_b]$$

$$\sigma_o = \frac{2[M_1]}{m_1 i_1 c e D_1}$$

$$\sigma_c \leq \sigma_{oa}$$

σ_c , surface stress between the lugs of the plate and hub slots, kgf/cm^2

σ_{oa} , allowable surface stress, 200 to 250 kgf/cm^2

i_1 , number of lugs

D_1, c, e , lug dimensions, cm

y , deflections at the long end of the lever, cm

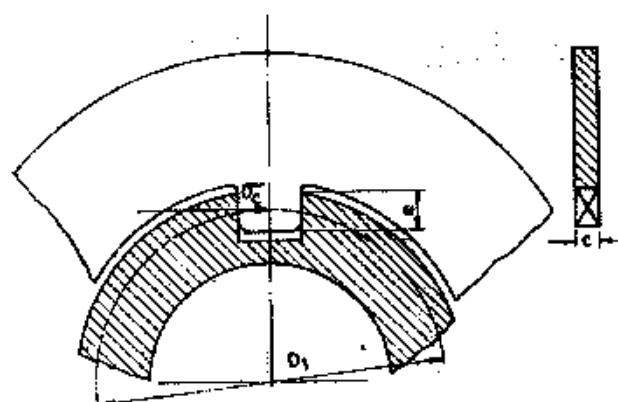
E , Young's modulus, kgf/cm^2

t , shear stress in the pin, kgf/cm^2

σ_{o1}, σ_{c2} bearing pressure on lever pin, kgf/cm^2

σ_{oa1} , allowable bearing pressure, 800 to 1000 kgf/cm^2

b_2' , width of bearing in hub, cm



CHECKING OF PLATES FOR BEARING PRESSURE

MULTIPLE PLATE CLUTCHES (Contd.)

Deflection of the lever:

$$\delta = \frac{6 Q a l^3}{E b_2 h_2^3 i_{cl}} = 0.05 \text{ to } 0.15 \text{ mm}$$

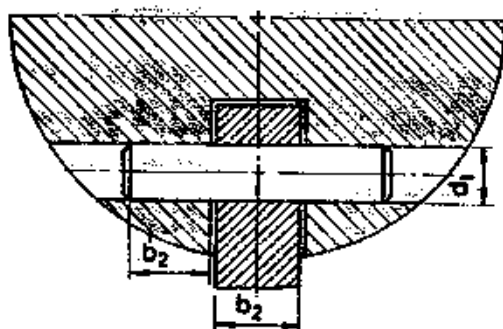
Shear stress in the lever pin:

$$\tau = \frac{2A}{\pi d_1^2} \leq 450 \text{ to } 500 \text{ kgf/cm}^2$$

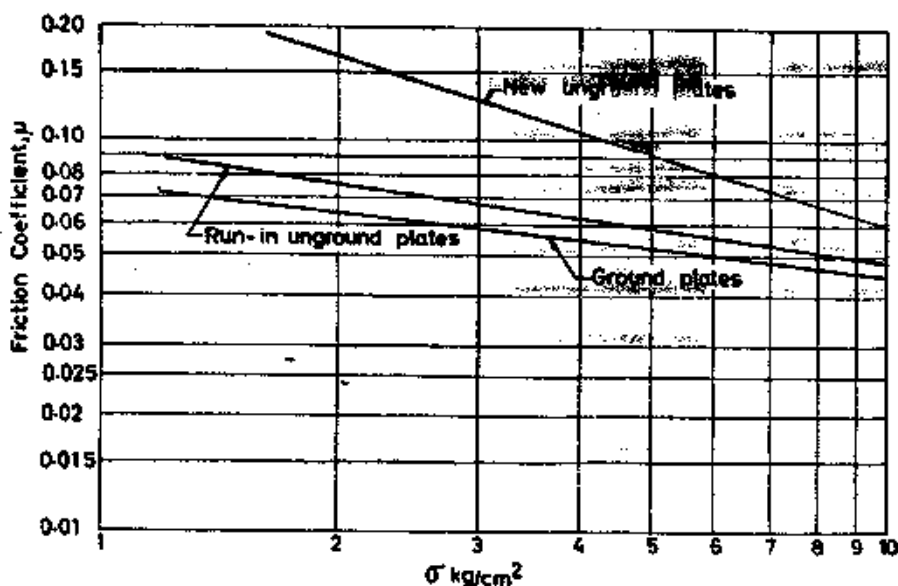
Bearing pressure at lever pin,

$$\sigma_{cl} = \frac{A}{b_2 d_1} \leq \sigma_{cal}$$

$$\sigma_{ca} = \frac{A}{2b_2' d_1} \leq \sigma_{cal}$$



CHECKING OF LEVER PIN FOR BEARING PRESSURE



RELATIONSHIP BETWEEN FRICTION COEFFICIENT, μ AND PRESSURE BETWEEN PLATES, σ'

ROLLER TYPE UNIDIRECTIONAL CLUTCHES

ROLLER SIZE :

$$M_t = F_t Z R$$

$$F_t = F \sin \beta$$

$$F_n = F_t / \tan \beta$$

$$a = \left(R - \frac{d}{2} \right)$$

$$\cos \alpha = \frac{d}{2R}$$

$$F = \frac{1}{Z \sin \frac{\alpha}{2}} \frac{M_t}{R}$$

$$= p_o / d$$

width of the ring b should be equal to the length of the roller l .

RING THICKNESS :

$$M_{b1} = C_1 F R_m$$

$$\sigma_b = \frac{M_{b1}}{Z_1}$$

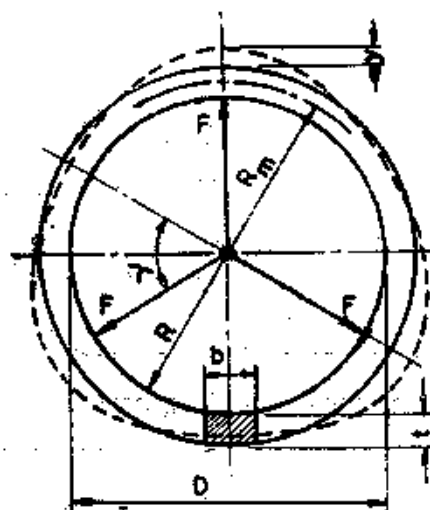
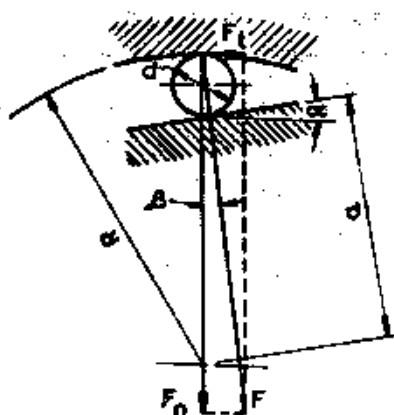
$$t \geq \frac{C_2}{2} + \sqrt{C_2 D}$$

$$C_2 = \frac{3 C_1 F}{\sigma_b b} = C_3 \frac{F}{b}$$

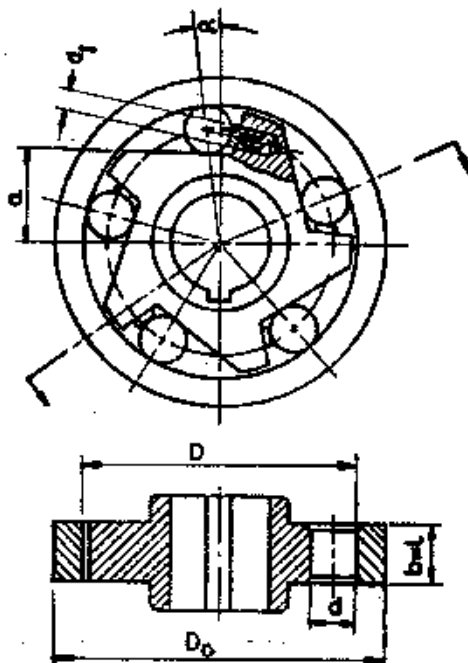
CHECK FOR DEFORMATION

$$y = \frac{F R_m}{b t} \left[k_1 \left(\frac{R_m}{t} \right)^2 + k_2 \right]$$

Z	C ₁	C ₃ for $\sigma_b = 2000$ kgf/cm ²	k ₁	k ₂
3	0.189	2.85×10^{-4}	9.1×10^{-8}	4.84×10^{-7}
4	0.137	2.05×10^{-4}	3.45×10^{-8}	4.91×10^{-7}
5	0.1076	1.61×10^{-4}	1.7×10^{-8}	5.18×10^{-7}
6	0.089	1.34×10^{-4}	0.96×10^{-8}	5.62×10^{-7}
8	0.066	0.99×10^{-4}	0.4×10^{-8}	6.87×10^{-7}
10	0.0527	0.79×10^{-4}	0.25×10^{-8}	8.20×10^{-7}
12	0.044	0.66×10^{-4}	0.11×10^{-8}	9.55×10^{-7}



- M_t transmitted torque, kgf cm
- Z number of rollers
- R inner radius of outer ring, cm
- F_t tangential force, kgf
- F_n normal force, kgf
- α angle between the runner surface and the tangent to the roller
- β friction angle $\approx \alpha/2$
- d diameter of the roller, $(\frac{1}{3}$ to $\frac{1}{2}) R$, to be selected from standard sizes
- p_o pressure on the projected area of the roller, kgf/mm² (5 kgf/mm² for hardened steel)
- M_{b1} bending moment on the ring, kgf cm
- R_m mean radius of the ring, cm $= \frac{1}{2} (D+t)$
- D inside diameter of the ring, cm
- t thickness of the ring, cm
- σ_b bending stress, kgf/cm²
- b width of ring, cm
- Z_1 modulus of section of the ring, cm³
- y deformation of the ring at the point of action of the force F , cm
- k_1, k_2 constants depending on the number of rollers



LENGTH DIAMETER COMBINATIONS OF STEEL ROLLERS

d = nominal diameter, mm

l = length, mm

d	l	d	l	d	l	d	l	d	l	d	l	d	l
3	5	6.5	6.5	12	12	19	28	28	28	42	70	68	68
3.5	5	6.5	9	12	18	20	20	28	44	45	45	68	110
4	4	7	7	13	13	20	30	30	30	45	75	75	75
4	6	7	10	13	20	21	21	30	48	48	48	80	80
4	8	7	4	14	14	21	30	32	32	48	80		
4.5	4.5	7.5	7.5	14	20	22	22	32	52	50	50		
4.5	6	7.5	11	15	15	22	34	34	34	50	85		
5	5	8	8	15	22	23	23	34	55	52	52		
5	8	8	12	16	16	23	34	36	36	52	90		
5	10	9	9	16	24	24	24	36	58	56	56		
5.5	5.5	9	14	17	17	24	36	38	38	56	90		
5.5	8	10	10	17	24	25	25	38	62	60	60		
6	6	10	14	18	18	25	36	40	40	60	95		
6	8	11	11	18	26	26	26	40	65	64	64		
6	12	11	15	19	19	26	40	42	42	64	100		

RECOMMENDED DIMENSIONS OF UNIDIRECTIONAL CLUTCHES

Maximum Torque M_t , kgf cm	Inside diameter D, mm	Outside diameter D_o , mm	Rollers			Diameter of Roller Pin d_1 , mm	a, mm
			Diameter d, mm	Length l, mm	Number Z		
0.63	40	55	5	8	3	3	14.85
1.25	40	55	6.5	8	3	3	13.34
2.50	50	65	8	12	3	4	16.80
4.0	50	65	8	12	5	4	16.80
6.3	56	70	9	14	5	4	18.77
10	70	85	11	15	5	5	22.70
16	70	85	12	18	6	6	23.70
25	90	110	14	20	6	6	30.60
40	100	120	16	24	6	8	33.60
63	120	140	16	24	8	8	43.50
100	140	165	19	28	8	8	50.40
160	160	190	22	34	8	8	57.30

BALL AND SPRING SAFETY CLUTCH

equation

nomenclature

Calculation of spring force

$$F_t = \frac{2 M_t}{D}$$

$$F_s = F_t \left[\frac{\cos \alpha - \mu \sin \alpha}{\sin \alpha + \mu \cos \alpha} - \mu \right]$$

Force on each spring,

$$F = \frac{F_s}{Z_b}$$

Stiffness of spring

$$K_s = \frac{K_t}{n}$$

Compression of spring to exert a force F ,

$$\delta_1 = \frac{F}{K_s}$$

Movement of ball while the clutch is slipping,

$$\delta_2 = \frac{d}{2} (1 - \cos \alpha)$$

The number of turns of the spring and its pitch p should be chosen to give such a free length, l of the spring which satisfies the following expression :

$$\delta_1 + \delta_2 \leq 0.7 \delta_{\max}$$

where $\delta_{\max}$ = max. possible deflection of spring

Stiffness and permissible static and dynamic loads for helical springs

Wire dia mm	Outer dia mm	Stiffness of spring per turn, K_t N/mm	Permissible loads	
			static, N	Dynamic, N
0.5	4.0	15.49	12.4	5.3
"	5.0	7.29	9.8	4.3
"	6.0	3.99	8.2	3.6
0.6	4.0	35.03	21.8	9.1
"	5.0	16.17	17.1	7.4
"	6.0	8.74	14.2	6.2
"	7.0	5.25	12.0	5.4
0.8	5.0	58.74	41.5	17.1
"	6.0	30.95	34.4	14.4
"	7.0	18.26	29.0	12.5
"	8.0	11.66	25.1	11.0
1.0	6.0	85.0	67.8	27.6
"	7.0	49.19	57.5	24.0
"	8.0	30.98	49.6	21.3
"	10.0	14.57	39.3	17.5
"	12.0	7.98	32.4	14.5
1.3	8.0	100.90	94.0	42.7
"	10.0	46.08	73.9	34.9
"	12.0	24.77	60.8	29.4
"	14.0	14.81	51.7	25.5
1.6	10.0	117.50	140.0	63.7
"	12.0	61.90	115.0	54.0
"	14.0	36.52	96.52	46.9
"	16.0	23.32	80.32	41.3
"	18.0	15.79	67.79	37.0

d , diameter of ball, mm

D , pitch circle diameter of grooves, mm

F_t , total tangential force on balls, N

F , total spring force, N

K_s , spring stiffness, N/mm

l , free length of spring, mm

M_t , Torque transmitted, N mm

n , no. of turns of each spring

p , pitch of the spring, mm

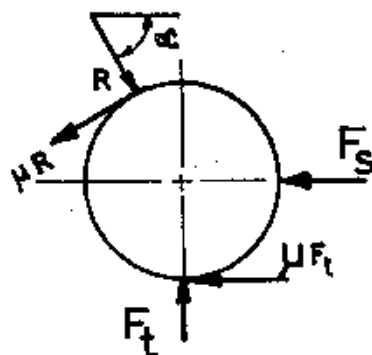
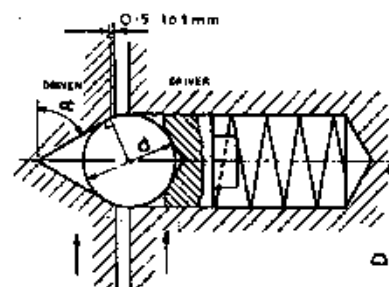
Z_b , no. of balls in the clutch

α , angle of inclination of the groove

μ , Coefficient of friction between ball and body. ≈ 0.08

K_t , stiffness per turn, see table below

δ_1, δ_2 in mm



CLAW CLUTCH

Proportions:

$$p = 1.3 \text{ to } 1.7 d$$

$$q = 2 \text{ to } 2.5 d$$

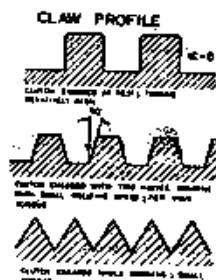
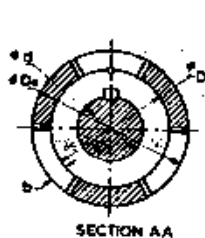
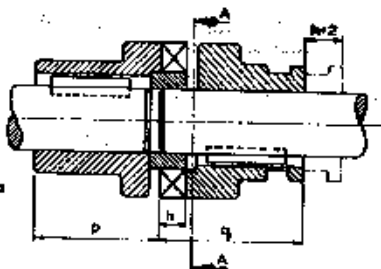
$$D_o = 1.8 \text{ to } 2.5 d$$

$$b = 0.125 \text{ to } 0.2 D_o$$

$$h = 0.6 \text{ to } 1 b$$

$$D_t = D_o - 2b$$

$$D_m = \frac{1}{2} (D_o + D_t)$$



Equation

Nomenclature

$$M_t = \frac{9.73 \times 10^6 \text{ kW}}{n}$$

$$[M_t] = K M_t$$

$$d = 120 \left[\frac{(\text{kW}) K}{n} \right]^{1/3}$$

$$F_a = 2 [M_t] \left[\frac{\mu_1}{d} + \frac{\tan(\alpha + \lambda_2)}{D_m} \right]$$

$$F_d = 2 [M_t] \left[\frac{\mu_1}{d} - \frac{\tan(\alpha - \lambda_2)}{D_m} \right]$$

$$Z_{min} = \frac{60}{t \Delta n}$$

Self locking condition:

$$\tan \alpha \leq \frac{\mu_2 \left(1 + \frac{\mu_1 D_m}{\mu_2 d} \right)}{1 - \mu_1 \mu_2 \left(\frac{D_m}{d} \right)}$$

$$F = \frac{[M_t]}{D_m}$$

Stress:

$$\sigma_c = \frac{F}{bh} \leq [\sigma_{ca}]$$

Bending stress in square tooth:

$$\sigma_b = \frac{9.6 [M_t] h}{b D_m^3} \leq [\sigma_{ba}]$$

Bending stress in trapezoidal tooth:

$$\sigma_b = \frac{9.6 [M_t] h}{b D_m (D_m + 1.276 h \tan \alpha)}$$

$$\leq [\sigma_{ba}]$$

M_t , torque transmitted, N mm

kW, power transmitted

n , shaft speed, rpm

$[M_t]$, Design torque, N mm

K , load factor, = 1.25 for steady load
= 1.5 for shock load

d , shaft diam, mm (C45)

F_a , axial force required to engage the clutch, N

μ_1 , coefft of friction between the sliding half and shaft
= 0.05 to 0.1 when lubricated
= $\mu_2 = 0.1$ to 0.15 when not lubricated

$\mu_2 = \tan \lambda_2$, coefft. of friction between claws.

D_m , mean diam of claws, mm

F_d , axial force required to disengage the clutch, N

α , tooth angle

Z_{min} , minimum number of claws

t , time for engagement, ≤ 0.05 -sec

Δn , relative speed at the time of engagement, 100 to 150 rpm.

F , load on one pair of claws, N (under the condition that only two pairs are transmitting the entire torque)

σ_c , Compressive stress, N/mm²

$[\sigma_{ca}]$ allowable stress, N/mm²

= 80 to 120 for clutches engaged at rest.

= 20 to 30 for clutches engaged when shafts are running.

σ_b , induced bending stress, N/mm²

$[\sigma_{ba}]$ allowable bending stress, N/mm²

= 80 to 100 for clutches engaged at rest

= 20 to 25 for clutches engaged when in motion.

BRAKES

Block brakes

Case 1. Line of action of F passing through fulcrum

$$F = \mu (a/b) P$$

$$M_t = \frac{\mu a D P}{2b}$$

μ , Coefficient of friction

a, b , Brake lever dimensions, cm

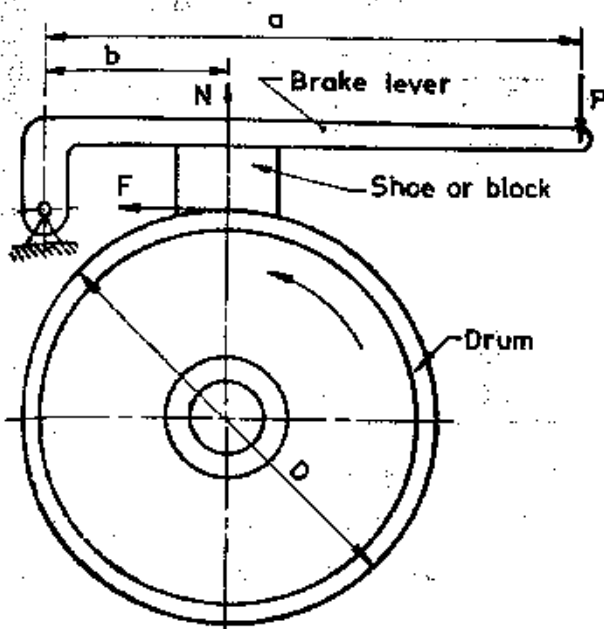
F , Friction force, kgf

M_t , Braking torque, kgf cm

P , Force applied on the lever, kgf

D , Diameter of the brake drum, cm

N , Normal reaction between the drum and the shoe, kgf



Maximum Permissible Pressures

Materials of rubbing surfaces	Pressure, kgf/cm ²	
	Holding brake	Lowering brake
Cast iron on cast iron	20	15
Steel on cast iron	20	15
Steel on steel	4	2
Asbestos brake band on metal	6	3
Rolled band on metal	6	4

Case 2. Line of action of F passing at a distance e' below the fulcrum

$$F = \frac{P a}{\frac{b}{\mu} - e'}$$

$$M_t = \frac{P a}{\frac{b}{\mu} - e'} \cdot \frac{D}{2}$$

For clockwise drum rotation,

$$F = \frac{P a}{\frac{b}{\mu} + e'}$$

Case 3. Line of action of F passing at a distance e' above fulcrum

$$F = \frac{P a}{\frac{b}{\mu} + e'}$$

anticlockwise rotation of drum

$$F = \frac{P a}{\frac{b}{\mu} - e'}$$

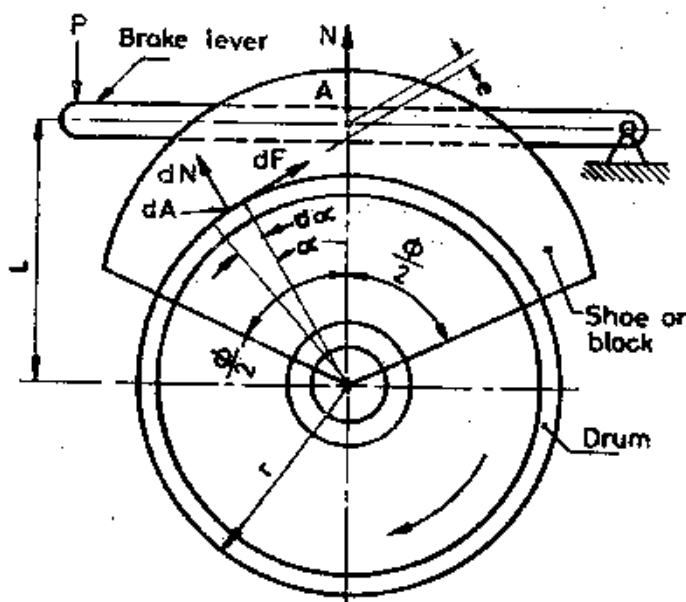
clockwise rotation of drum

Characteristics of Friction Materials

Name	μ on dry surface	Permissible temp. °C	Safe pressure kgf/cm ²	Specific Gravity	Remarks
Asbestos brake lining with interwoven brass wires	0.45-0.35	350	2-6	1.55	Normal brake lining
Asbestos brake lining without brass wires	0.45-0.35	200	1-4	1.55	For less intensive duty
Fibre brake lining of wood pulp without brass wires	0.55-0.4	150 to 200	10	1.25	Normal brake lining
Hydraulically Compressed Asbestos with brass wires	0.5-0.35	300	2-6	1.5	brake lining
Linings of braking fibre	0.55	110	8-10	1.25	For rope drive pulleys; lining by application on a washer

Case 4. For a normal pressure distribution,

$$p = p_{\max} \cos \alpha$$



$$L = \frac{4r \sin \frac{\phi}{2}}{\phi + \sin \phi}$$

$$N = p_{\max} \frac{W r}{2} (\phi + \sin \phi)$$

$$M_1 = \mu p_{\max} W r^2 \int_{-\phi/2}^{\phi/2} \cos \alpha d\alpha = \mu N L$$

Band Brake:

$$F_t = F_1 - F_2$$

$$\frac{F_1}{F_2} = e^{\mu \theta}$$

$$F_1 = \frac{F_2 e^{\mu \theta}}{e^{\mu \theta} - 1}$$

$$P = \frac{F_t (b_2 - e^{\mu \theta} b_1)}{a (e^{\mu \theta} - 1)}$$

Safe pressures in band brakes, kgf/cm²

Type of brake	Material of the rubbing surfaces			
	Steel band on cast iron or steel drum	Asbestos brake band on steel or cast iron drum	Rolled, press formed and shaped friction material on metal drum	Wood on cast iron drum
Holding	15	6	8	6
Lowering	10	3	4	4

- p Normal pressure on the shoe at any angle α , kgf/cm²
 $p_{\max}$ Maximum normal pressure on the shoe, kgf/cm²
 W Face width of the brake drum, cm
 L Distance from the drum centre to the line of action of F , cm
 r Radius of the brake drum, cm

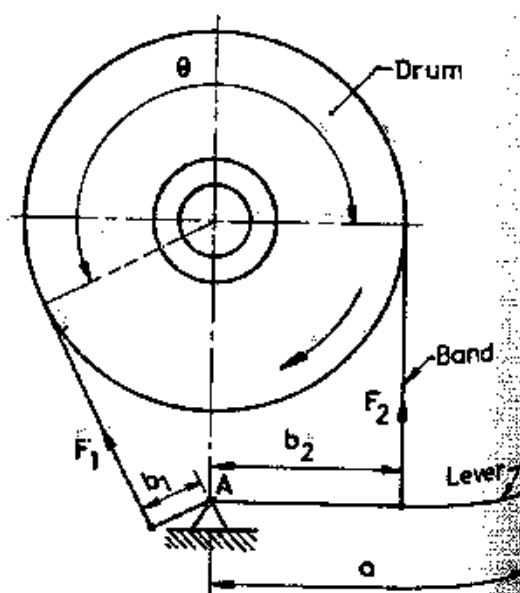
Dimensions of brake wheel

Power of hoisting motor	Brake wheel dia, mm	Brake wheel width, mm
10	160	50
15	200	65
21	250	80
35	320	100
59	400	125
96	500	160
156	630	200
260	800	250

F Braking force, kgf

F_1, F_2 Tensions at the ends of the band, kgf

θ Angle of contact, radians



Braking torque

$$M_f = \mu b r^2 \left(\frac{\cos \theta_1 - \cos \theta_2}{\sin \theta_m} \right) (p_m + p'_m)$$

$$p'_m = \frac{c P p_m}{M_n + M_f}$$

$$p = \frac{p_m \sin \theta}{\sin \theta_m}$$

$$\theta_m = \theta_2 \text{ for } \theta_2 < 90^\circ$$

$$= 90^\circ \text{ for } \theta_2 > 90^\circ$$

$$M_f = \frac{\mu p_m b r}{\sin \theta_m} \int_{\theta_1}^{\theta_2} \sin \theta (r - a \cos \theta) d\theta$$

$$M_n = \frac{p_m b r a}{\sin \theta_m} \int_{\theta_1}^{\theta_2} \sin^2 \theta d\theta$$

For the right shoe

$$P = \frac{M_n - M_f}{c}$$

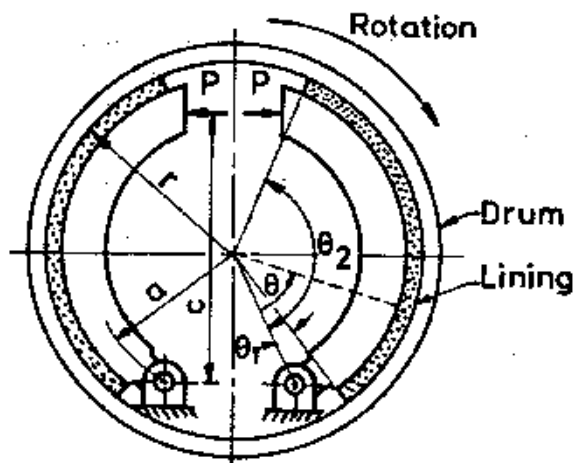
For the left shoe

$$P = \frac{M'_n + M'_f}{c}$$

$$M'_n = \frac{M_n p'_m}{p_m}; \quad M'_f = \frac{M_f p'_m}{p_m}$$

$$\left. \begin{array}{l} \text{Heat generated} \\ \text{per operation} \end{array} \right\} H_g = \frac{\pi^2 n^2 J}{1800 \times 427} \text{ k cal}$$

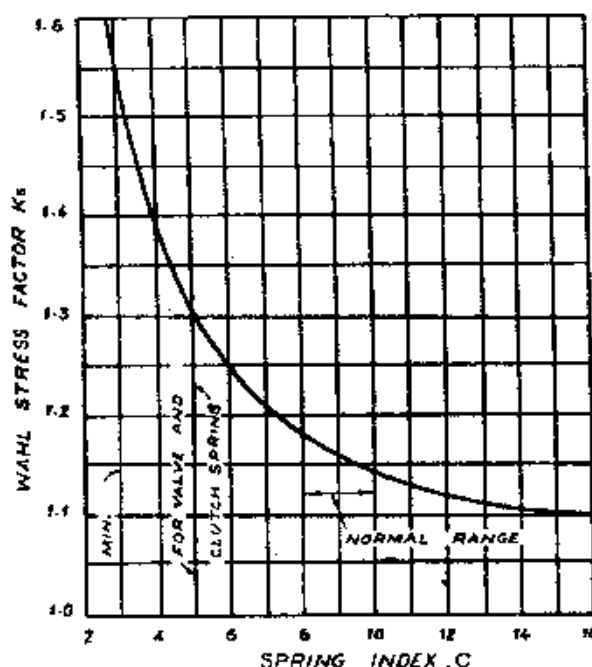
$$t_r = \frac{H_g}{w c_p}$$



- r , internal radius of the brake drum
- b , face width of the shoe
- a , distance from the centre of the drum to the shoe pivot
- c , moment arm of the actuating force
- P , actuating force
- p , pressure at any angle θ
- p_m, p'_m , maximum pressure on the right and left shoes
- M_n, M'_n , moment of normal force on the right and left shoes
- M_f, M'_f , moment of the frictional force on the right and left shoes
- θ_1, θ_2 , centre angle of heel and toe of lining from pivot
- θ_m , centre angle of the point of maximum pressure from pivot
- μ , coefficient of friction
- J , polar moment inertia of the brake drum assembly, kgf m sec^2
- t_r , temperature rise of brake drum
- c_p , specific heat of drum material
 $= 0.13$ for CI
 $= 0.116$ for steel
- w , weight of the brake drum, kgf
- n , speed of the drum, rpm

Helical Springs :

Circular section	Rectangular section
$k = K_s \frac{8PD}{\pi d^3} = K_s \frac{8PC}{\pi d^3}$	$k = \frac{Q_2 PD}{2tb^3}$
$y = \frac{8PD^3n}{Gd^4} = \frac{8PC^3n}{Gd}$	$y = \frac{Q_1 \pi PD^3n}{4Gt^3b}$
$q = \frac{Gd^4}{8D^3n} = \frac{Gd}{8C^3n}$	$q = \frac{4Gt^3b}{Q_1 \pi D^3n}$



$$U = \frac{Py}{2}$$

Wahl stress factor :

$$K_s = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

(may be obtained from the graph also)

Factors for rectangular wire section:

b/t	1	1.5	2	3	4	6	8	10	∞
Q_1	7.09	5.1	4.36	3.80	3.56	3.36	3.26	3.21	3
Q_2	4.79	4.35	4.05	3.71	3.52	3.35	3.25	3.20	3

P, axial load, kgf

D, mean diameter of spring, cm

d, diameter of wire, cm

C, spring index, D/d

b, breadth of wire, cm

t, thickness of wire, cm

n, number of active coils

L, shear stress, kgf/cm²

G, modulus of rigidity, kgf/cm²

y, deflection of spring, cm

q, spring rate or stiffness, kgf/cm

K_s , Wahl stress factor

Q_1, Q_2 factors for springs of rectangular section

U, resilience, kgf cm

f, lowest natural frequency for circular coil helical springs, cycles per second

γ , specific weight of spring material, kgf/cm³

g, gravitational constant, 981 cm/s²

L_f , free length of spring, cm

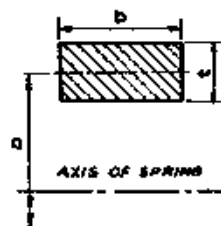
L_s , solid length, cm

p, pitch of coils, cm

α , helix angle, < 12°

λ , solid deflection, cm

Δ , clearance between concentric springs



lowest natural frequency

$$f = \frac{(q/m)^{1/2}}{2} = \frac{d}{\pi D^2 n} \sqrt{\frac{Gg}{8\gamma}}$$

Check for surging:

$$f \geq 12 f_s$$

Check for solid stress:

$$\tau_s < 0.5 \sigma_u \text{ for hard drawn carbon steels}$$

$$< 0.6 \sigma_u \text{ for alloy steels}$$

To avoid Buckling:

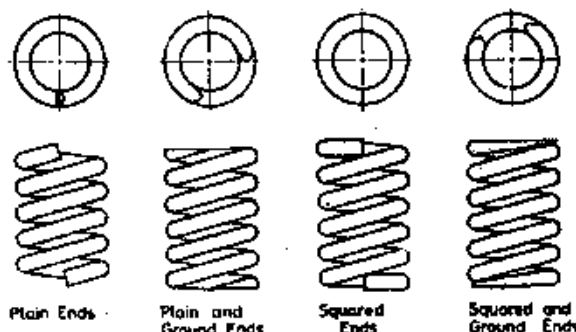
$$\frac{L_t}{D} < 3,$$

for $\frac{L_t}{D} > 3$ the spring must be suitably guided

m, mass of the active coils in the spring

f_s , frequency of the applied load

τ_s , shear stress in spring when compressed solid



Coaxial springs:

(suffixes 1, 2 refer to outer and inner springs respectively)

$$\tau_1 = \tau_2 < [\tau]$$

$$\frac{D_1}{d_1} = \frac{D_2}{d_2} = C$$

$$\frac{P_1}{P_2} = \left(\frac{C}{C-2} \right)^2$$

$$\Delta = \frac{(D_1 - D_2) - (d_1 + d_2)}{2} \approx \frac{d_1 - d_2}{2}$$

$$d_1 \leq \frac{D_1 - D_2}{2}$$

End conditions and length of springs:

Type of end	Total coils	Free length L_f	Solid height L_s
Plain	n	pn + d	dn + d
Plain and Ground	n	pn	dn
Squared	n + 2	pn + 3d	dn + 3d
Squared and Ground	n + 2	pn + 2d	dn + 2d

The winding of the springs should be of opposite hands

SPRINGS UNDER VARYING LOADS:

Repeated Loading:

$$l_s = \frac{8 k_s P_s D}{\pi d^3} = \frac{8 k_s P_s C}{\pi d^3}$$

$$l_m = \frac{8 k_{sh} P_m D}{\pi d^3} = \frac{8 k_{sh} P_m C}{\pi d^3}$$

$$\frac{1}{n} = \frac{l_m - l_s}{l_y} + \frac{2l_s}{l_o}$$

Curvature factor k_s

C 3 4 6 7 8 9 10

k_s 1.35 1.25 1.15 1.13 1.11 1.1 1.09

Static Approach to Varying Loads:

No. of cycles Classification *Recommended Design stress [τ]

$> 10^6$ Severe service $\approx 0.263\sigma_u$

$> 10^4$ but $< 10^6$ Average service $\approx 0.324\sigma_u$

$< 10^4$ Light service $\approx 0.405\sigma_u$

*For extension springs 0.8 times the values recommended for compression springs may be used.

EXTENSION SPRINGS:

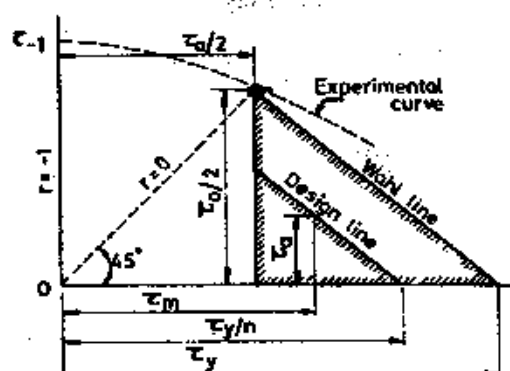
$$P_i = \frac{\pi \tau_i d^3}{8D} = \frac{\pi \tau_i d^3}{8C}$$

$$P = P_i + yq$$

The calculations for extension springs are done as per the compression springs based on the total load P.

Approximate maximum stresses at initial tension:

C	3	4	5	6	7	8	9	10	11	12	15
τ_i	1700	1600	1430	1300	1160	1000	930	830	780	690	500
kgf/cm ²											



VARIABLE STRESSES IN SPRINGS

P_a , amplitude load, kgf

P_m , mean load, kgf

τ_m , mean shear stress, kgf/cm²

τ_a , amplitude shear stress, kgf/cm²

τ_o , endurance shear stress for repeated loading

k_s , Wahl stress factor, k_{sh} , k_c

k_{sh} , direct shear factor

k_c , curvature factor

n , factor of safety

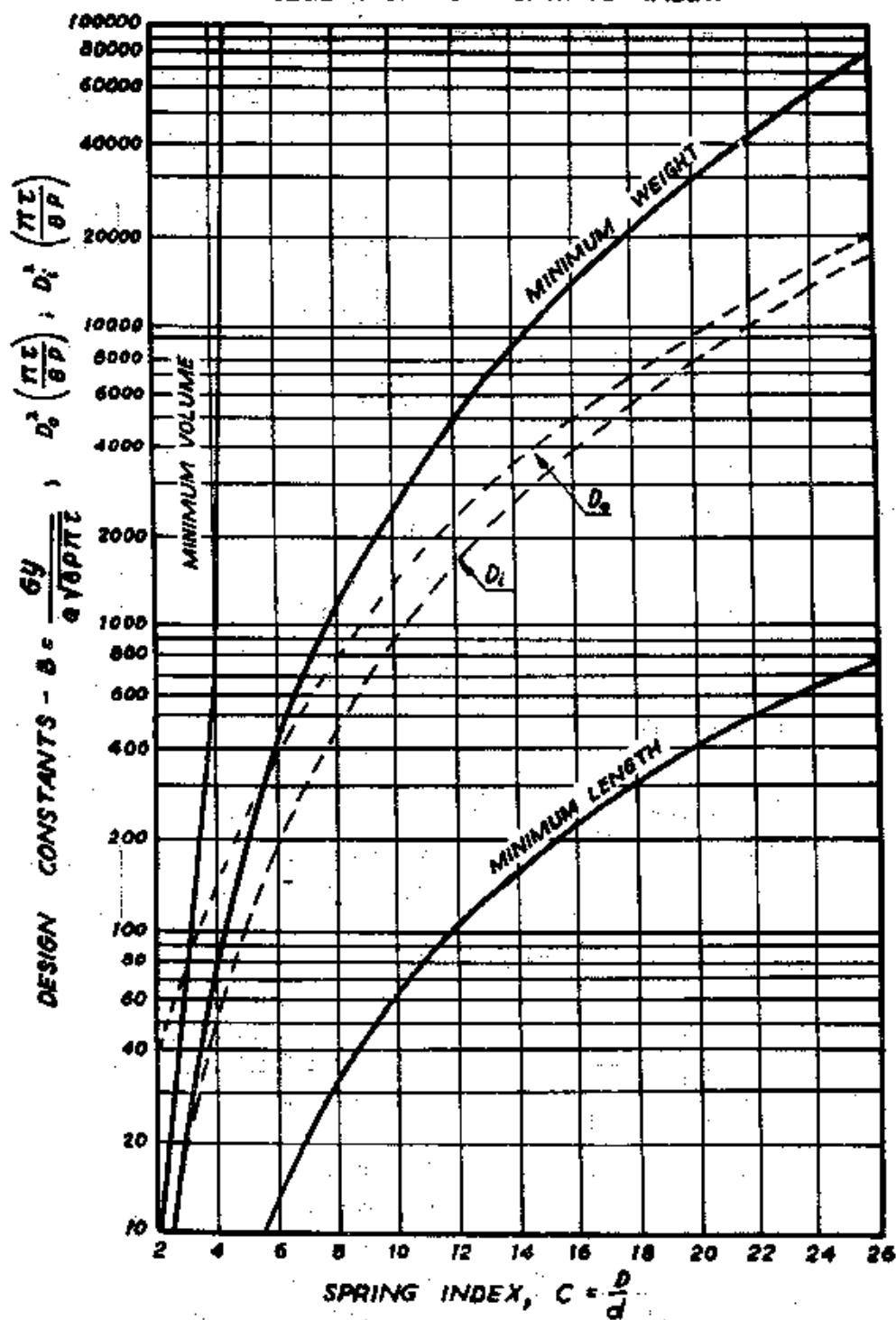
P , total load on the spring, kgf

P_i , initial load to separate the coils, kgf

τ_i , maximum value of initial stress, kgf/cm²



COIL SPRINGS SELECTION OF SPRING INDEX



- P axial load, kgf
y deflection, cm
t allowable shear stress, kgf/cm²
G modulus of rigidity, kgf/cm²

- Q number of inactive coils
D_o outside coil diameter, cm
D_i inside coil diameter, cm

LEAF SPRINGS:

Treating the spring as a cantilever beam of uniform strength,

$$\sigma_b = \frac{6PL}{nb^3t^2}$$

$$y = \frac{6PL^3}{E_n b t^3}$$

spring with extra full length leaves:

$$\sigma_{bo} = \frac{12PL}{bt^3(3n_o + 2n_g)}$$

$$\sigma_{bo} = \frac{18PL}{bt^3(3n_o + 2n_g)}$$

$$y = \frac{12PL^3}{bt^3(3n_o + 2n_g)}$$

BELLEVILLE SPRINGS:

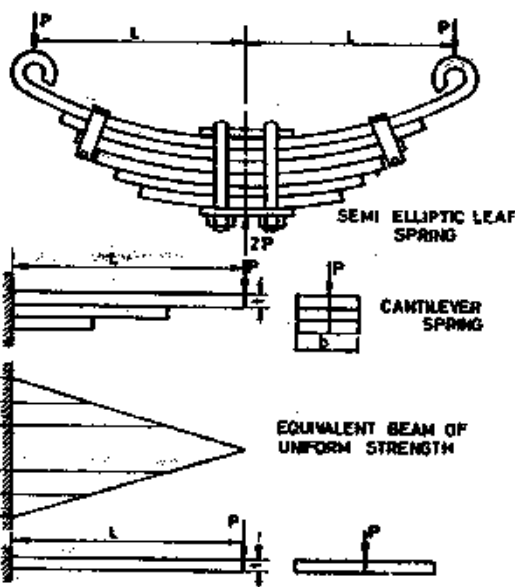
$$P = \frac{Ey}{(1-\nu^2)M\left(\frac{d_o}{d_i}\right)^2} \left[\left(h - \frac{y}{2} \right) (h-y)t + t^3 \right]$$

$$\sigma = \frac{Ey}{(1-\nu^2)M\left(\frac{d_o}{d_i}\right)^2} \left[C_1 \left(h - \frac{y}{2} \right) + C_2 t \right]$$

$$M = \frac{6}{\pi \log_e \left(\frac{d_o}{d_i} \right)} \left[\frac{\left(\frac{d_o}{d_i} - 1 \right)}{\frac{d_o}{d_i}} \right]^2$$

$$C_1 = \frac{6}{\pi \log_e \left(\frac{d_o}{d_i} \right)} \left[\frac{\frac{d_o}{d_i} - 1}{\log_e \left(\frac{d_o}{d_i} \right)} - 1 \right]$$

$$C_2 = \frac{6}{\pi \log_e \left(\frac{d_o}{d_i} \right)}$$



- $2P$ load on the spring, kgf
- y deflection of the spring, cm
- L Length of the cantilever beam (spring), cm
- b width of the leaf, cm
- t thickness of the leaf, cm
- n number of leaves in the spring
- n_g number of graduated leaves
- n_o number of extra full length leaves
- σ_b bending stress, kgf/cm²
- σ_{bo} bending stress in graduated leaves, kgf/cm²
- σ_{bo} bending stress in extra full length leaves, kgf/cm²
- E modulus of elasticity, kgf/cm²



- P axial load on the spring, kgf
- d_i internal diameter, cm
- d_o outside diameter, cm
- y deflection, cm
- t thickness of the disc, cm
- h free height minus thickness, cm
- E modulus of elasticity, kgf/cm²
- ν Poisson's ratio
- σ stress at the inside circumference, kgf/cm²
- M, C_1, C_2 constants

PROPERTIES OF SPRING STEELS

Diameter of wire mm	Average values of Tensile strength, kgf/mm ² , σ_b									
	Steel wire unalloyed cold drawn				Spring steel oil hardened and tempered		Spring steels for moderately elevated temperatures			
	Gr 1	Gr 2	Gr 3	Gr 4	†SW	⊕ VW	**1 S	*1 D	**2 S	*2 D
0.1	—	—	258	—	—	—	—	—	—	—
0.5	170	205	244	263	—	—	—	—	—	—
1.0	160	194	228	245	190	180	—	—	210	210
1.5	152	184	214	231	180	165	190	180	200	200
2.0	145	175	203	220	172	160	190	180	200	200
2.5	140	167	193	209	166	155	180	170	195	195
3.0	135	160	187	202	162	151	180	170	195	195
3.6	130	154	178	193	158	148	170	160	190	190
4.0	128	151	173	188	158	148	170	160	190	190
4.5	125	147	169	184	154	145	162	155	185	185
5.0	121	142	163	178	154	145	162	155	185	185
5.6	117	138	158	172	150	142	155	150	180	180
6.0	115	135	156	170	150	142	155	150	180	180
6.5	113	132	151	165	146	138	150	145	175	175
7.0	111	129	149	164	146	138	150	145	175	175
7.5	109	127	146	160	146	138	—	—	170	170
8.0	107	124	143	157	140	—	—	—	170	170
8.5	104	122	140	153	140	—	—	—	—	—
9.0	102	120	138	151	140	—	—	—	—	—
9.5	101	117	134	—	140	—	—	—	—	—
10.0	100	115	132	—	135	—	—	—	—	—
10.5	—	112	—	—	135	—	—	—	—	—
11.0	—	110	—	—	135	—	—	—	—	—
12.0	—	106	—	—	135	—	—	—	—	—
12.5	—	105	—	—	135	—	—	—	—	—
13.0	—	104	—	—	135	—	—	—	—	—

† SW intended for general purposes.

⊕ VW intended for valve springs subjected to high dynamic stresses.

* 1D and 2D intended for springs subjected to dynamic loads.

** 1S and 2S intended for springs subjected to static loads.

IS: 4454-1967

COUPLINGS

equation

nomenclature

RIGID COUPLING:

$$F_t = \frac{2M_t}{D_s} = n \frac{\pi}{4} d_s^2 [\tau_s]$$

$$F_t \leq n d_s b [\sigma_b]$$

FLEXIBLE COUPLING

$$p = \frac{F_t}{d_b (G - \frac{2}{3} F) n}$$

$$M_b = F_t \left[1 + \frac{1}{2} (G - \frac{2}{3} F) \right] \frac{1}{n}$$

$$M_t \leq \left(\frac{\pi C^2 E}{2} \right) [\tau_s]$$

$$\sigma_b \leq [\sigma_b]$$

$$M_t \leq \frac{WLA}{2} [\tau_s]$$

$$\leq \frac{TLA}{4} [\sigma_b]$$

F_t , tangential force, N

M_t , torque transmitted, N mm

$[\tau_s]$, allowable shear stress, N/mm²

n , number of bolts

$[\sigma_b]$, allowable bearing stress, N/mm²

p , bearing pressure on pin, N/mm²

M_b , bending moment on pin, N mm

For proportions of couplings, see tables 1 & 2, p. 7.107, 108.

For service factors see table p. 7.109

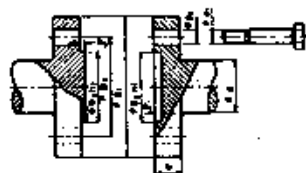
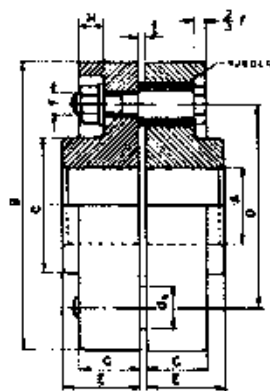
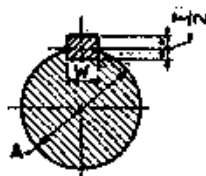


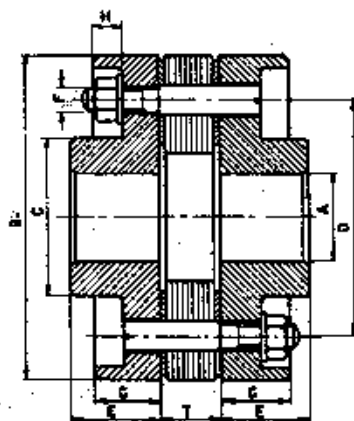
FIGURE 7.107 RIGID TYPE COUPLING



$$F = 2M_t/A$$



HUSH TYPE FLEXIBLE COUPLING



DISC TYPE FLEXIBLE COUPLING

PROPORTIONS OF FORGED END. RIGID COUPLING IS : 3653 — 1966

All dimensions in mm

Table 1

Coupling No.	Shaft diam, d		D ₁	b	D ₂	b ₁	D ₃	d ₁	d ₁ H8	n	b ₂
	max	min									
1	35	—	100	17	50	6	70	M 10	11	4	4
2	45	36	120	22	60	6	85	12	13	„	„
3	55	46	140	22	75	7	100	14	15	„	5
4	70	56	175	27	95	„	125	16	17	6	„
5	80	71	195	32	95	„	140	18	19	„	„
6	90	81	225	32	125	„	160	20	21	„	„
7	110	91	265	36	150	9	190	24	25	„	7
8	130	111	300	46	150	„	215	30	32	„	„
9	150	131	335	50	195	„	240	M 33	34	„	„
10	170	151	375	55	„	10	265	36	38	8	8
11	190	171	400	55	240	„	290	36	38	„	„
12	210	191	445	65	„	„	315	42	44	„	„
13	230	211	475	70	280	„	340	M 45	46	„	„
14	250	231	500	„	„	„	370	45	46	10	„
15	270	251	560	80	330	„	400	52	55	„	„
16	300	271	600	85	„	„	440	56	60	„	„

PROPORTIONS OF FLEXIBLE COUPLINGS — BUSH & DISC TYPES : IS 2693 — 1964

All dimensions in mm

Table 22

Coupling No.	BUSH TYPE										DISC TYPE														
	A		B min	C min	E min	G	kw* per 100 rpm	H min	D	n bolt holes	F	d _b	t	A		B min	C min	E min	G	T	kw* per 100 rpm	FH min	ID min	bolt holes in	FF
	min	max												min	max										
1	12	16	80	25	28	18	0.4	10	53	3	8	20	2	12	16	82	25	28	18	15	0.4	110	53	66	88
2	16	22	100	30	30	20	0.6	12	63	"	10	22	2	16	22	100	30	30	20	16	0.6	112	63	"	110
3	22	30	112	38	32	22	0.8	"	73	"	"	"	"	22	30	110	38	32	22	18	0.8	"	73	"	"
4	30	45	132	55	40	30	2.5	15	90	4	12	25	4	30	45	132	55	40	30	25	2.5	115	90	88	112
5	45	56	170	80	45	35	4.0	"	120	"	"	"	"	45	56	165	80	45	35	30	4	"	1120	"	"
6	56	75	200	100	56	40	6	"	150	"	"	30	"	56	75	200	100	56	40	35	6	"	1150	"	"
7	75	85	250	140	63	45	16	22	190	6	16	40	5	75	85	250	140	63	45	40	16	22	190	112	116
8	85	110	315	180	80	50	25	"	250	"	"	"	"	85	110	315	180	80	50	45	25	"	250	"	"
9	110	130	400	212	90	56	52	28	315	8	18	45	6	110	130	400	212	90	55	50	52	28	315	116	118
10	130	150	500	280	100	60	74	"	400	"	"	"	"	130	150	500	280	100	60	55	74	"	400	"	"

*kW of power application $\times$ service factor $\times 100$ / rpm of application = max. rating at 100 rpm, listed in the above table

SERVICE FACTORS FOR COUPLINGS

Type of driven machine	Service factor for Prime movers					
	Motor steam & water turbines	Gas engine (high speed)	Petrol engine		Oil engine	
			≥ 4 cyl	< 4 cyl	≥ 6 cyl	≤ 4 cyl
Alternators, i.d. fan, printing m/c, Rotary pumps, compressors, exhausters, conveyors.	1.5	2	2.5	3	3.5	5
Wood working m/c, m/c tools, Calenders, mixers, elevators.	2	2.5	3	3.5	4	5.5
f.d. fans, high speed recip. compressors, high speed crushers and pulverisers, metal forming m/c tools	2.5	3	3.5	4	4.5	6
rotary screens, rod mills; tube, cable and wire machinery; vacuum pumps	3	3.5	4	4.5	5	6.5
Low speed recip. compressors, haulage gears, metal planing m/c, brick & tile m/c, rubber machinery tube mills, welding generators	3.5	4	4.5	5	5.5	7

- NOTE :
- i) Parallel alignment error ≤ 0.25 mm/100 mm outside diam of coupling.
 - ii) Rubber bushes — hardness 80° IRH
 - iii) Disc — hardness 80° IRH

characteristic equations of basic curves

Curves	Displacement, y	Velocity, v	Acceleration, a
St. line	$h\theta/\beta$	$\omega h/\beta$	$\infty, 0, -\infty$
Circular arc	$H - [H^2 - R_p^2 \theta^2]^{\frac{1}{2}}$	$\omega R_p^2 \theta / [H^2 - (R_p^2 \theta^2)]^{\frac{1}{2}}$	$(\omega R_p H)^2 / [H^2 - (R_p^2 \theta^2)]^{\frac{3}{2}}$
SHM	$\frac{h}{2} \left(1 - \cos \frac{\pi\theta}{\beta}\right)$	$\frac{h\pi\omega}{2\beta} \left(\sin \frac{\pi\theta}{\beta}\right)$	$\frac{h}{2} \left(\frac{\pi\omega}{\beta}\right)^2 \cos \frac{\pi\theta}{\beta}$
Double Harmonic	$\frac{h}{2} \left[\left(1 - \cos \frac{\pi\theta}{\beta}\right) - \frac{1}{4} \left(1 - \cos \frac{2\pi\theta}{\beta}\right) \right]$	$\frac{h\pi\omega}{2\beta} \left(\sin \frac{\pi\theta}{\beta} - \frac{1}{2} \sin \frac{2\pi\theta}{\beta} \right)$	$\frac{h}{2} \left(\frac{\pi\omega}{\beta}\right)^2 \left(\cos \frac{\pi\theta}{\beta} - \cos \frac{2\pi\theta}{\beta} \right)$
Cycloidal	$\frac{h}{\pi} \left(\frac{\pi\theta}{\beta} - \frac{1}{2} \sin \frac{2\pi\theta}{\beta} \right)$	$\frac{h\omega}{\beta} \left(1 - \cos \frac{2\pi\theta}{\beta} \right)$	$\frac{2h\pi\omega^2}{\beta^2} \sin \frac{2\pi\theta}{\beta}$
Parabolic or Const. Accn.	$\frac{\theta}{\beta} \leq 0.5 \quad 2h \left(\frac{\theta}{\beta} \right)^2$	$4h\omega\theta/\beta^2$	$4h\omega^2/\beta^2$
	$\frac{\theta}{\beta} \geq 0.5 \quad h \left[1 - 2 \left(1 - \frac{\theta}{\beta} \right)^2 \right]$	$\frac{4h\omega}{\beta} \left(1 - \theta/\beta \right)$	$-4h\omega^2/\beta^2$
Cubic no. 1 or Const. pulse no. 1	$\frac{\theta}{\beta} \leq 0.5 \quad 4h \left(\frac{\theta}{\beta} \right)^3$	$\frac{12h\omega}{\beta} \left(\frac{\theta}{\beta} \right)^2$	$\frac{24h\omega^2}{\beta^2} \left(\frac{\theta}{\beta} \right)$
	$\frac{\theta}{\beta} \geq 0.5 \quad h \left[1 - 4 \left(1 - \frac{\theta}{\beta} \right)^3 \right]$	$\frac{12h\omega}{\beta} \left(1 - \frac{\theta}{\beta} \right)^2$	$-\frac{24h\omega^2}{\beta^2} \left(1 - \frac{\theta}{\beta} \right)$
Cubic or Const. pulse no. 2	$h \left(\frac{\theta}{\beta} \right)^2 \left(3 - 2 \frac{\theta}{\beta} \right)$	$\frac{6h\omega\theta}{\beta^2} \left(1 - \frac{\theta}{\beta} \right)$	$\frac{6h\omega^2}{\beta^2} \left(1 - 2 \frac{\theta}{\beta} \right)$
2-3 Polynomial	$h \left[3 \left(\frac{\theta}{\beta} \right)^2 - 2 \left(\frac{\theta}{\beta} \right)^3 \right]$	$\omega h \left[6 \frac{\theta}{\beta} - 6 \left(\frac{\theta}{\beta} \right)^2 \right]$	$\omega^2 h \left[6 - 12 \frac{\theta}{\beta} \right]$
3-4-5 Polynomial	$h \left[10 \left(\frac{\theta}{\beta} \right)^3 - 15 \left(\frac{\theta}{\beta} \right)^4 + 6 \left(\frac{\theta}{\beta} \right)^5 \right]$	$\frac{\omega h}{\beta} \left[30 \left(\frac{\theta}{\beta} \right)^2 - 60 \left(\frac{\theta}{\beta} \right)^3 + 30 \left(\frac{\theta}{\beta} \right)^4 \right]$	$\frac{h\omega^2}{\beta^2} \left[60 \frac{\theta}{\beta} - 180 \left(\frac{\theta}{\beta} \right)^2 + 120 \left(\frac{\theta}{\beta} \right)^3 \right]$

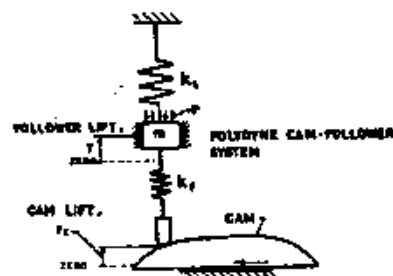
 h —maximum rise of follower β —cam angle for rise h ω —angular velocity of cam θ —cam angle for displacement y H — Radius of circular arc R_p — Radius of pitch circle

POLYDYNE CAMS

Cams to give polynomial displacement for the follower-end, with the dynamics of the latter accounted for.

Design steps:

1. Select a polynomial $y = f(\theta)$; (usually 5-6-7-8-9)
2. Plot y_c , y_0'' , y and y'' vs θ .
3. Check the values of y_c and y_0'' to avoid jerk or pulse.



Equation

Nomenclature

$$y_c = r_a + k_r y + cy''$$

y_c , cam lift

$$r_a = r_s + r_k$$

y , displacement of follower end

$$r_s = \frac{P + S_1}{k_f}$$

r_a , ramp height

$$k_r = \frac{k_t + k_s}{k_f}$$

r_s , initial static deflection of the follower linkage

k_r , backlash in the linkage

$$C = 36 \frac{N^2 m}{k_f}, \text{deg.}^2$$

k_r , equivalent stiffness of the follower

k_f , stiffness of the follower linkage (40000 to 120000 N/cm)

Natural frequency

k_s , stiffness of compression spring (200 to 1200 N/cm)

$$\omega_n = \left[\frac{k_s + k_f}{m} \right]^{\frac{1}{2}}$$

P , external load on the follower (gas, weight, inertia & friction)

S_1 , initial compression of the spring k_s

C , dynamic constant

N , cam speed, rpm

m , equivalent mass at the follower end

$$y'' = \frac{d^2 y}{d\theta^2} ; \theta = \omega t$$

Characteristic equations of 4-5-6-7 polynomial cam:

$$\text{displacement, } y = h \left[35 \left(\frac{\theta}{\beta} \right)^4 - 84 \left(\frac{\theta}{\beta} \right)^5 + 70 \left(\frac{\theta}{\beta} \right)^6 - 20 \left(\frac{\theta}{\beta} \right)^7 \right]$$

$$\text{velocity, } \dot{y} = h \frac{\omega}{\beta} \left[140 \left(\frac{\theta}{\beta} \right)^3 - 420 \left(\frac{\theta}{\beta} \right)^4 + 420 \left(\frac{\theta}{\beta} \right)^5 - 140 \left(\frac{\theta}{\beta} \right)^6 \right]$$

$$\text{Accn., } \ddot{y} = h \frac{\omega^2}{\beta^2} \left[420 \left(\frac{\theta}{\beta} \right)^2 - 1680 \left(\frac{\theta}{\beta} \right)^3 + 2100 \left(\frac{\theta}{\beta} \right)^4 - 840 \left(\frac{\theta}{\beta} \right)^5 \right]$$

5-6-7-8-9 Polynomial Cam:

$$y = h \left[126 \left(\frac{\theta}{\beta} \right)^4 - 420 \left(\frac{\theta}{\beta} \right)^5 + 540 \left(\frac{\theta}{\beta} \right)^6 - 315 \left(\frac{\theta}{\beta} \right)^7 + 70 \left(\frac{\theta}{\beta} \right)^8 \right]$$

COMPARISON OF VARIOUS TYPES OF CAM CURVES

Type of curve	*Velocity factor	*Accn. factor	*Jerk factor	Cam speed application	Performance at high speed	Comments
Constant velocity motion	1	∞		Low speed and Low masses	Poor	Automatic generation possible
S H M	1.57	4.93	$2 \times \infty \dagger$	Medium speed	Good	Automatic generation possible
Double Harmonic	2	5.5/9.9	—	Medium speed	—	Very accurate machining required
Cycloidal	2	6.28	40	High speed	Excellent	Automatic generation possible
Parabolic	2	4	$3 \times \infty$	Medium speed	Good	Automatic generation possible but not worth while
Cubic No. 1	3	12	$1 \times \infty$	Low speed	Poor	
Cubic No. 2	1.5	6	$2 \times \infty$	Low speed	Poor	
Polynomial 3—4	2	6	48	High speed	Excellent	
Polynomial 3—4—5	1.88	5.77	60	High speed	Excellent	
Circular cam profile				High speed	Best of all	Can be made on a lathe with highest accuracy
Circular arc & st. line profile				Medium speed	Good	Small cams can be made accurately

* Velocity, acceleration and jerk factors refer to maximum values of the respective quantities for a cam having $h=1$ and $\beta/\omega=1$.

† Jerk factor is ∞ at two places

MATERIAL COMBINATIONS FOR CAM AND FOLLOWERS

Good	Poor
CI and Phosphor Bronze	Hardened steel and Hardened bronze
Hardened steel and Phosphor Bronze	Hardened nickel steel and Hardened nickel steel
CI and soft steel	Soft steel and Bronze
Babbitt and soft steel	Soft steel and soft steel
Soft brasses and soft steel	Soft steel and laminated thermoset resins
Hardened steel and soft bronze	Soft steel and Nylon
Hardened steel and Brass	

COMPARISON OF VARIOUS TYPES OF CAM CURVES

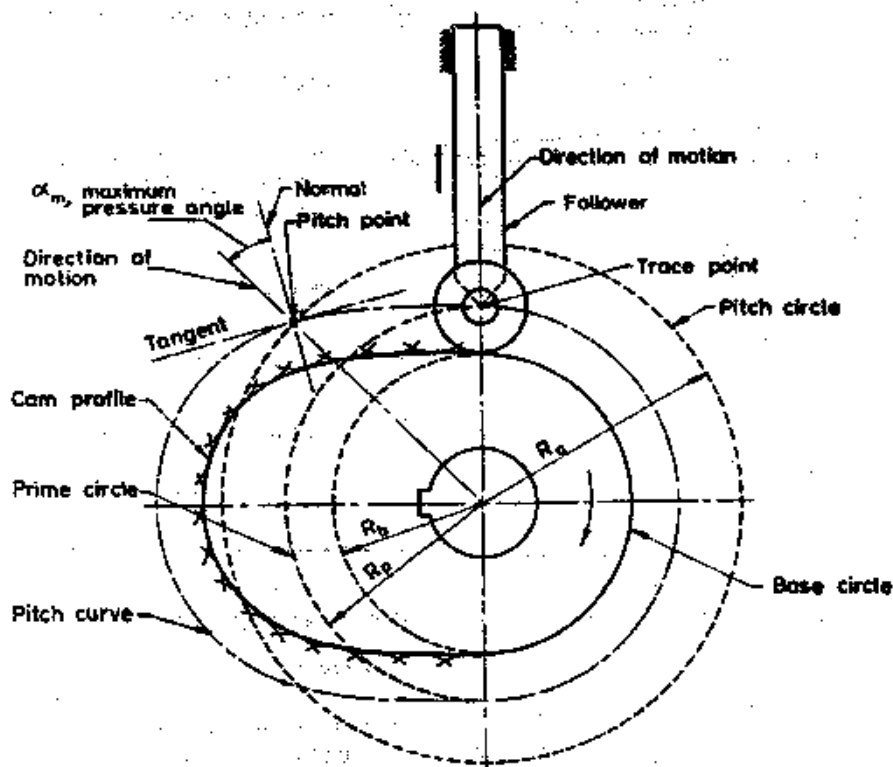
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* Velocity, acceleration and jerk factors refer to maximum values of the respective quantities for a cam having $h=1$ and $\beta/\omega=1$.

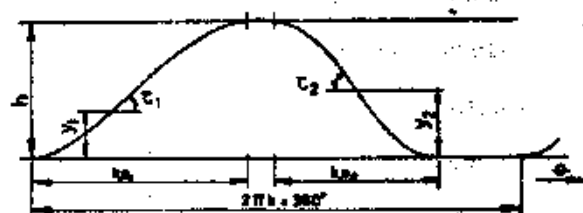
† Jerk factor is ∞ at two places

MATERIAL COMBINATIONS FOR CAM AND FOLLOWERS

Good	Poor
C I and Phosphor Bronze Hardened steel and Phosphor Bronze C I and soft steel Babbitt and soft steel Soft brasses and soft steel Hardened steel and soft bronze Hardened steel and brass	Hardened steel and Hardened bronze Hardened nickel steel and Hardened nickel steel Soft steel and Bronze Soft steel and soft steel Soft steel and laminated thermoset resins Soft steel and Nylon



CAM NOMENCLATURE



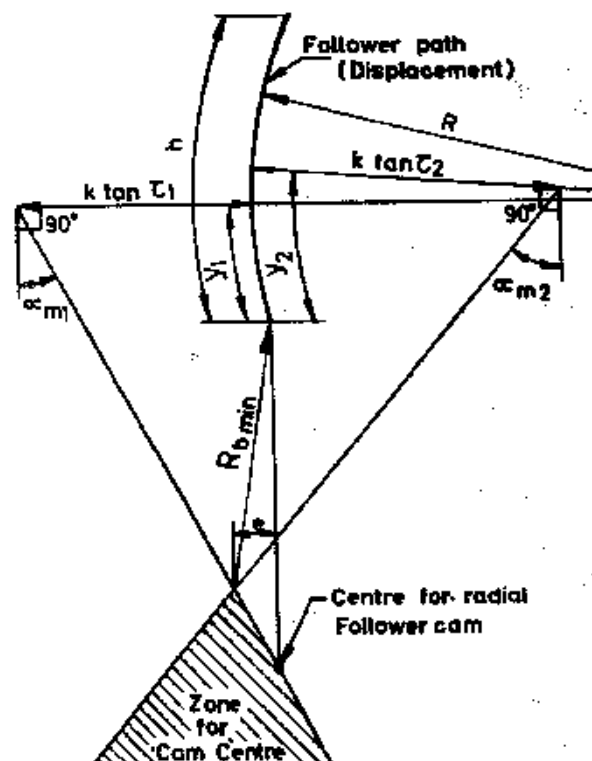
DISPLACEMENT-TIME DIAGRAM

$$\tan t = \frac{dy}{d\theta}$$

$$\tan \alpha = \left\{ \frac{\left(\frac{dy}{d\theta} \right)}{R_p + y_\theta} \right.$$

- y follower displacement
- h total displacement
- y_1, y_2 follower displacements at maximum slope
- k scale factor
- R_r radius of the roller
- R_b base circle radius
- R_p prime circle radius
- R length of the oscillating follower
- R_o pitch circle radius
- e follower offset

Construction for the determination of minimum base circle radius for knife edged followers (prime circle radius for roller followers)



- b face width of the cam
- θ cam angle for any position
- β cam angle for rise or fall
- t slope of the $y-\theta$ curve
- α_m maximum allowable pressure angle
30° for translating roller followers,
45° for oscillating roller followers
- f cam factor
- ρ_k radius of curvature of the pitch curve
- ρ_c radius of curvature of the cam profile

CAM FACTOR, f.

Basic curve	f
Straight line	$\cot \alpha_m$
Straight line-circular arc (circular arc radius = total rise)	$2 \tan \frac{\alpha_m}{2} + \cot \alpha_m$
Circular arc	$\cot \frac{\alpha_m}{2}$
Simple harmonic	$\frac{\pi}{2} \cot \alpha_m$
Double harmonic	$2 \cot \alpha_m$
Cycloidal	$2 \cot \alpha_m$
Parabolic	$2 \cot \alpha_m$
Cubic No. 1	$3 \cot \alpha_m$
Cubic No. 2	$3/2 \cot \alpha_m$

NOTE: 1) $k \tan \tau_1$ is measured to the left for C C W rotation of the cam and vice versa

2) Follower path is a straight line for translating followers

$$\text{Cam factor } f = \frac{R_b \beta}{h}$$

CAM CURVATURE

Flat follower :

$$*p_{\text{min}} = R_b + \left(y + \frac{1}{\omega^2} \frac{d^2 y}{dt^2} \right) > 0 \text{ to avoid under cutting}$$

Roller follower : (Convex profile)

$$*p_{\text{min}} = \frac{\left[(R_p + y)^2 + \left(\frac{1}{\omega} \frac{dy}{dt} \right)^2 \right]^{3/2}}{(R_p + y)^2 + 2 \left(\frac{1}{\omega} \frac{dy}{dt} \right)^2 - (R_p + y) \left(\frac{1}{\omega^2} \frac{d^2 y}{dt^2} \right)} > R_p \text{ to avoid under cutting}$$

* for y at point of maximum negative acceleration.

R_g radius of the grinding wheel or cutter

σ_c contact stress

E_1, E_2 modulus of elasticity for cam and follower

P_n normal force at the point of contact

Roller follower (concave profile)

$$\rho_{k \min} = - \frac{R_p^2}{R_p - \frac{1}{\omega^2} \left(\frac{d^2 y}{dt^2} \right)_{\theta=0}}$$

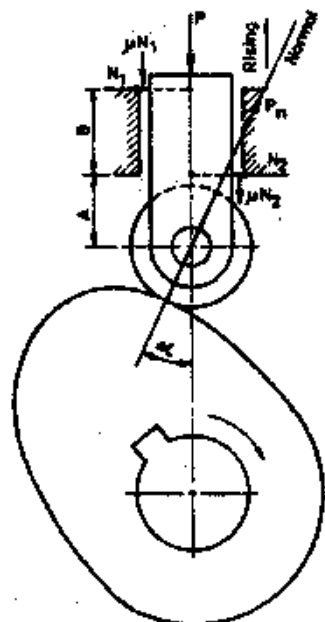
> 0 to avoid under cutting

To permit cutting of the cam with a grinding wheel or cutter

$$\rho_{k \min} + R_r > R_g$$

CONTACT STRESS

$$\sigma_c = 0.591 \sqrt{\frac{P_n E_1 E_2}{b (E_1 + E_2) \left(\frac{1}{\rho_{a \min}} \pm \frac{1}{R_r} \right)}} \leq [\sigma_c]$$

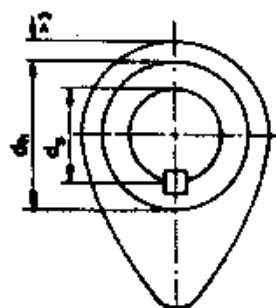


RADIAL CAM TRANSLATING ROLLER FOLLOWER—FORCE DISTRIBUTION

Allowable contact stress values for cam materials :

Cam material for use with hardened steel roller	$[\sigma_c]$ kgf/cm ² no sliding	$[\sigma_c]$ kgf/cm ² 8.3% sliding
Grey iron casting		
140 – 160 HB (phosphate coated)	4000	3600
200 – 220 HB	5000	4500
225 – 255 HB	6000	5400
255 – 300 (Heat treated)	6700	5300
C 20, 130 – 150 HB	6300	5000
40 C, 1 M _n 28 Heat treated to 270 – 300 HB	14700	11000
C 20, Carburised 50 – 58 HRC	17700	11300
40 M _n 2 S 12 Induction Hardened 45 – 55 HRC	15300	12250

HUB SIZE



$d_2 = \text{Dia. of shaft in mm}$

$d_1 = 1.75 d_2 + 6$

FORCES ON RADIAL CAM WITH RECIPROCATING ROLLER FOLLOWER

$$P_n = \frac{P}{\cos \alpha - \mu \left(\frac{2A+B}{B} \right) \sin \alpha}$$

Referring to fig. on
p. 7.115

μ , coefficient of friction

$$N_1 = \frac{A}{B} P_n \sin \alpha$$

$$N_2 = \frac{A+B}{B} P_n \sin \alpha$$

α_m , Max. press. angle for locking the follower in its guide

$$\alpha_m = \tan^{-1} \frac{B}{\mu (2A+B)}$$

PRESSURE ANGLE IN OFFSET FOLLOWER :

$$\alpha = \tan^{-1} \frac{\frac{r^2}{\omega} \dot{y} - e r^2}{\pi \left(\frac{v}{\omega} \dot{y} + r^2 \right)}$$

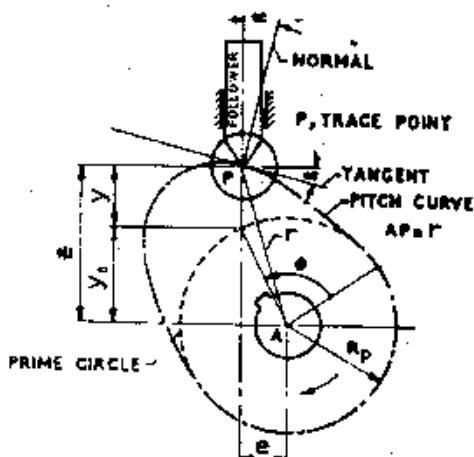
M_t TORQUE REQUIRED TO DRIVE THE CAM :

$$M_t = \frac{Pv}{\omega}$$

v , follower velocity

P , Resistive force on the follower
along the line of stroke.

ω , angular vel of cam



DISPLACEMENT RATIO y/h^*

Cam Angle Divisions	Parabolic	Simple Harmonic motion (SHM)	Cycloidal
0	0.000000	0.000000	0.000000
1	0.003472	0.004278	0.000474
2	0.013889	0.017037	0.003756
3	0.031250	0.038060	0.012461
4	0.055556	0.066987	0.028835
5	0.086806	0.103323	0.054602
6	0.125000	0.146447	0.090845
7	0.170139	0.195629	0.137935
8	0.222222	0.250000	0.195501
9	0.281250	0.308658	0.262461
10	0.347222	0.370590	0.337089
11	0.420139	0.434737	0.417141
12	0.500000	0.500000	0.500000
13	0.579861	0.565263	0.582859
14	0.652778	0.629410	0.662911
15	0.718750	0.691341	0.737539
16	0.777778	0.750000	0.804499
17	0.829861	0.804371	0.862065
18	0.875000	0.853553	0.909155
19	0.913194	0.896677	0.945398
20	0.944444	0.933013	0.971165
21	0.968750	0.961940	0.987539
22	0.986111	0.982963	0.996244
23	0.996528	0.995722	0.999526
24	1.000000	1.000000	1.000000

* y = rise of cam for the respective angle division.

h = total rise of cam for 24 divisions.

CIRCULAR ARC CAM WITH RECIPROCATING FLAT FACED FOLLOWER

$0 \leq \theta \leq \theta_1$ A to B	follower motion	$\theta_1 \leq \theta \leq \theta_2$ B to D
$(r_2 - r_1) (1 - \cos \theta)$	y, displacement	$(r_2 - r_1) + (r_2 - r_1) \cos (\theta_2 - \theta)$
$\omega^2 (r_2 - r_1) \cos \theta$	$\ddot{y}$, acceleration	$-\omega^2 (r_2 - r_1) \cos (\theta_2 - \theta)$

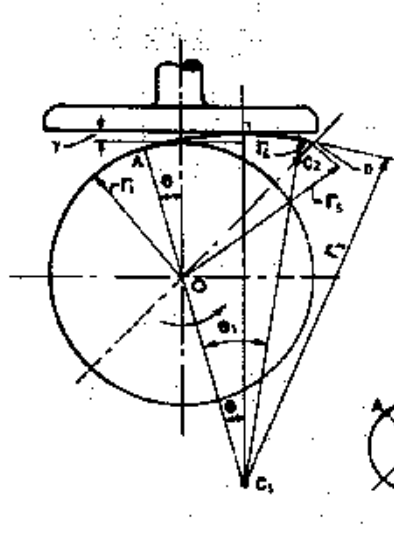
TANGENT CAM WITH ROLLER FOLLOWER

$0 \leq \theta \leq \theta_1$ A to B	follower motion	$\theta_1 \leq \theta \leq \theta_2$ B to D
$(r_1 + r_2) \left[\frac{1 - \cos \theta}{\cos \theta} \right]$	y, displacement	$(r_2 - r_1) \cos (\theta_2 - \theta) +$ $\left[(r_1 + r_2)^2 - (r_2 - r_1)^2 \sin^2 (\theta_2 - \theta) \right]^{\frac{1}{2}} - (r_1 + r_2)$
$\omega^2 (r_1 + r_2) \left[\frac{1 + 2 \tan^2 \theta}{\cos \theta} \right]$	$\ddot{y}$, acceleration	$-\omega^2 \left[(r_2 - r_1) \cos (\theta_2 - \theta) \right.$ $\left. + (r_2 - r_1)^2 \{ (r_1 + r_2)^2 \cos 2 (\theta_2 - \theta) + (r_2 - r_1)^2 \sin^2 (\theta_2 - \theta) \} \right.$ $\left. \{ (r_1 + r_2)^2 - (r_2 - r_1)^2 \sin^2 (\theta_2 - \theta) \}^{-\frac{3}{2}} \right]$

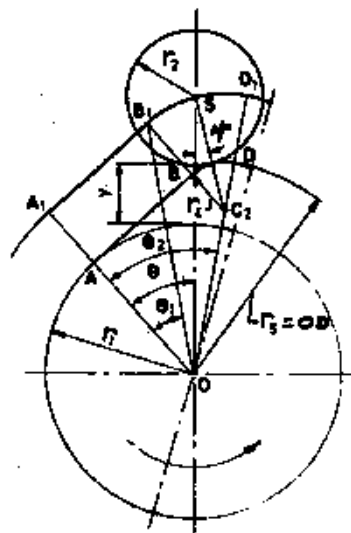
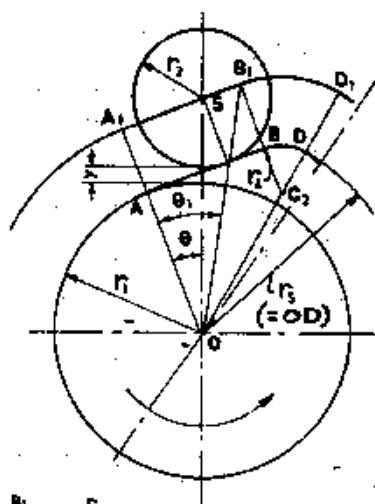
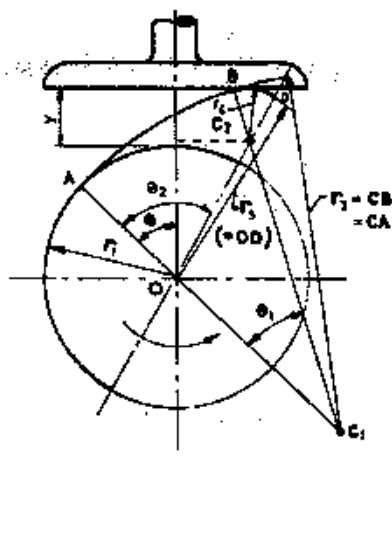
CIRCULAR ARC CAM WITH ROLLER FOLLOWER

$0 \leq \theta \leq \theta_1$ A to B	Follower motion	$\theta_1 \leq \theta \leq \theta_2$ B to D
$-a \cos \theta + [b^2 - a^2 \sin^2 \theta]^{\frac{1}{2}} - (r_1 + r_2)$ $\omega^2 \left[a \cos \theta - \frac{a^2 (b^2 \cos 2\theta + a^2 \sin^4 \theta)}{(b^2 - a^2 \sin^2 \theta)^{\frac{3}{2}}} \right]$ where $a = r_2 - r_1$ $b = r_2 + r_1$	y, displacement y, acceleration	The expressions are identical with those obtained for the tangent cam with roller follower in the region B to D.

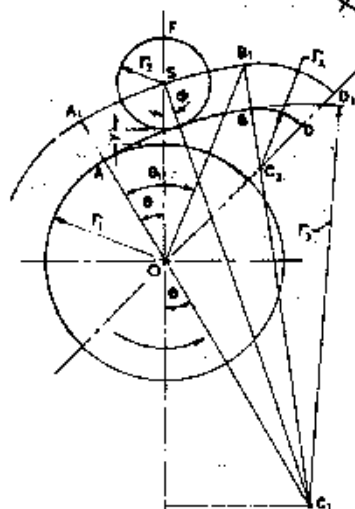
for figures see p. 7.119



CIRCULAR ARC CAM WITH FLAT FACED FOLLOWER



TANGENT CAM WITH ROLLER FOLLOWER



CIRCULAR ARC CAM WITH ROLLER FOLLOWER

$$\Delta E = I k_s \omega^2$$

$$k^2 = \frac{D_o^2 + (D_o - 2h)^2}{8} \text{ for rim flywheel}$$

$$\approx D^2/4 \text{ when } h \text{ is small}$$

$$k^2 = D_o^2/8 \text{ for disc flywheel}$$

$$v = \pi D N$$

For C I flywheel

$$v < 1500 \text{ m/min for H. P.} < 100$$

$$< 2000 \text{ m/min for H. P.} > 100$$

For cast steel flywheel

$$v = 3000 - 4000 \text{ m/min}$$

$$w = \pi D b h \gamma$$

$$b/h = 0.65 - 2$$

For belt pulley flywheel b should be 3 to 5 cm wider than the belt

Stresses in the rim:

$$\text{Tensile stress due to centrifugal force } \sigma_t = \frac{\gamma v^2}{g}$$

$$\text{Bending stress } \sigma_b = \frac{\pi^2 v^2 D \gamma}{n^2 g h}$$

$$\sigma_{\text{total}} = \frac{3}{4} \sigma_t + \frac{1}{4} \sigma_b$$

$$< 350 \text{ kgf/cm}^2 \text{ for C. I.}$$

$$\sigma_t < 65 \text{ kgf/cm}^2 \text{ for C. I.}$$

$$< 280 \text{ kgf/cm}^2 \text{ for cast steel.}$$

Stresses in the arm (at the hub End):

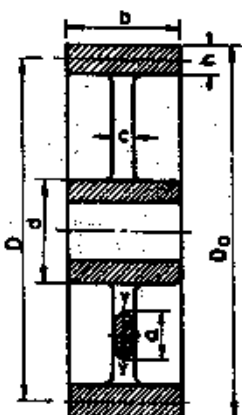
$$\text{Bending stress } \sigma_{bl} = \frac{M_t (D-d)}{n Z_{rr} D}$$

$$\text{For C. I. } \sigma_{bl} < 130 \text{ kgf/cm}^2$$

$$< 65 \text{ kgf/cm}^2, \text{ for severe load}$$

Section of arm:

$$a = \sqrt[3]{\frac{64 Z_{rr}}{\pi}} \text{ with } C = a/2$$



ΔE , Excess energy

I , Mass moment of inertia of the flywheel

k_s , coefficient of fluctuation of speed (refer table)

$$= \frac{\omega_1 - \omega_2}{\omega}$$

ω_1, ω_2 and ω are maximum, minimum and mean angular velocities respectively

k , radius of gyration of flywheel

D_o , D , outside and mean diameters of the rim

h , thickness of the rim

v , mean rim speed

w , weight of the rim of the flywheel

b , width of the flywheel

γ , Specific weight

n , number of arms 6, 8 or 10

M_t , transmitted torque

T_1, T_2 , belt tensions

Taper of arm - 1 in 50

For belt pulley flywheel

$$\sigma_{b1} = \frac{(T_1 - T_2)(D - d)}{2 n Z_{yy}}$$

$$\sigma_t = \frac{8bh \gamma v^2}{n c a g}$$

$$\sigma_{total} = \sigma_{b1} + \sigma_{b2} + \sigma_t$$

$$< 200 \text{ kgf/cm}^2 \text{ for C.I.}$$

Values of K_s

Driven machinery	Type of drive	K_s
Hammers, Crushers, Punch Presses	Belt	0.2
Compressors, Concrete mixers, Excavators	Belt	0.1 - 0.14
Pumps, Shears	Belt or flexible coupling	0.04 - 0.05
Metal working and Wood working machines	Belt	0.033
Flour, Paper and Textile mills	Belt	0.02 - 0.025
Compressors, Pumps and Similar machines	Gears	0.02
Spinning machines, Coarse to fine	Belt	0.016 - 0.02
D. C. generators single or parallel	Belt	0.03
D. C. generators single or parallel	Direct coupled	0.014
A. C. generators single or parallel	Belt	0.016
A. C. generators single or parallel	Direct coupled	0.01

CONNECTING ROD

AXIAL LOAD ON THE CONNECTING ROD:

Load due to gas or steam pressure

$$F_G = \frac{\pi}{4} d^2 p$$

Inertia force due to reciprocating parts

$$F_i = \frac{R}{g} \omega^2 r \left[\cos \theta + \frac{\cos 2\theta}{(l/r)} \right]$$

Effective force on the piston

$$F = F_G \pm F$$

Axial load on the connecting rod

$$F_s = \frac{F}{\sqrt{1 - \left(\frac{\sin \theta}{l/r}\right)^2}}$$

By Johnson's formula

$$\frac{F_s}{a} = \frac{\sigma_T}{n} \left[1 - \frac{\sigma_T}{4\pi^2 E} \left(\frac{L_s}{k} \right)^2 \right]$$

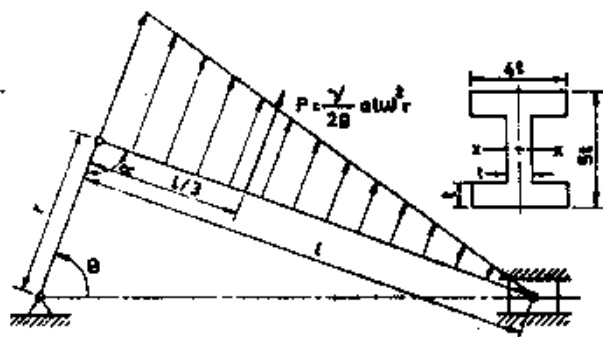
INERTIA FORCE:

Inertia force on the connecting rod at $\frac{1}{3}l$ from the crank pin

$$P = \frac{\gamma}{2g} a \omega^2 r \quad (\text{for } \alpha = 90^\circ)$$

Bending stress due to inertia force

$$\sigma_{b \max} = \frac{\gamma a l^3 \omega^2 r}{9 \sqrt{3} g Z_{xx}}$$



p. gas or steam pressure, kgf/cm²

d. diameter of piston, cm

R, wt. of reciprocating parts, kgf

ω , angular velocity, rad/sec

l, length of connecting rod, cm

r, radius of the crank, cm

γ , specific weight, kgf/cm³

a. area of cross section at mid section of con. rod, cm²

Z_{xx} , modulus of section, cm³

n. factor of safety, 3 to 6

L_s , equivalent length, cm

k, radius of gyration, cm

E, modulus of elasticity, kgf/cm²

P, inertia force, kgf

α , angle between crank and connecting rod, degrees

At mid section

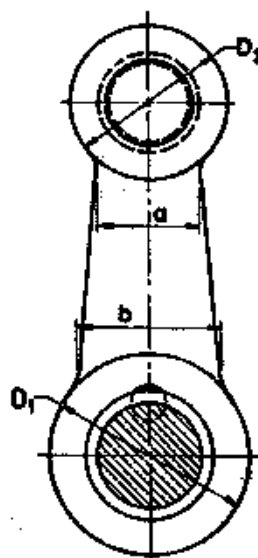
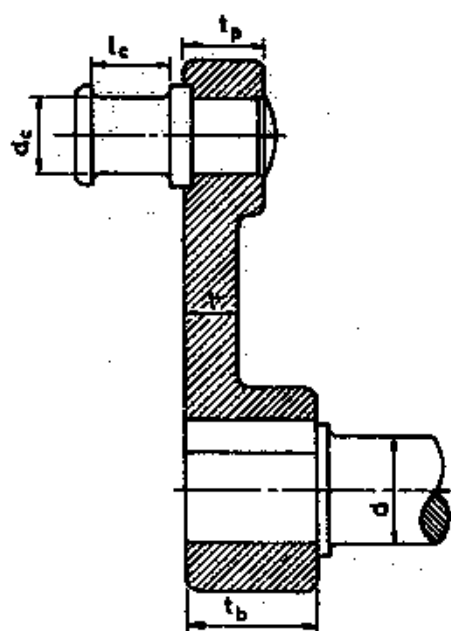
$$a = 11 t^2$$

$$I_{xx} = \frac{419}{12} t^4$$

$$k_{xx}^2 = 3.18 t^2$$

Depth at big end 1.1 to 1.2 times the depth at the mid section.

CRANK SHAFTS Proportions:



$$a = 1.5 d_o$$

$$b = 1.35 d_o$$

$$l_o = 1.25 d_o$$

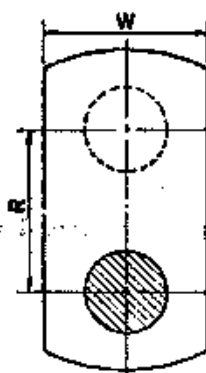
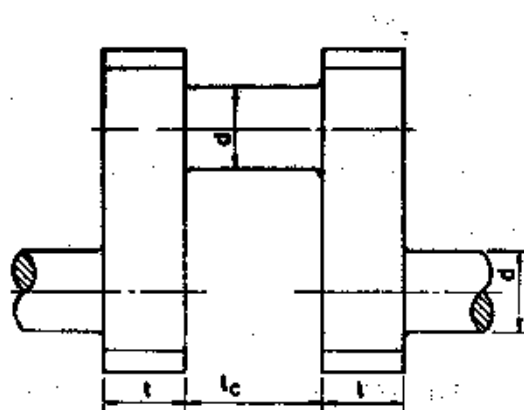
$$D_1 = 1.75 d_o$$

$$D_2 = 2 d_o$$

$$t_b = 1 \text{ to } 1.25 d_o$$

$$t_p = 1.4 d_o$$

OVERHUNG CRANK



$$t = 0.7 d_o$$

$$l_o = 1.1 d_o$$

$$W = 1.14 d_o$$

CENTRE CRANK

RIVETED JOINTS

Length of the rivet:

$$l = \sum t + (1.5 \text{ to } 1.7) d$$

$$D \approx 1.6 d$$

$$h \approx 0.7 d$$

$$\sigma_1 = \alpha E \Delta t$$

Strength of riveted joints:

Shearing of the rivet,

$$\frac{F}{i} \leq n \frac{\pi d^2}{4} [\tau]_{riv}$$

Tearing of the plate between rivets

$$\frac{F}{i} \leq (P-d) t [\sigma_t]_p$$

Tearing of the Plate edge along the length
[$e-d/2$]

$$\frac{F}{i} \leq 2 \left(e - \frac{d}{2} \right) t [\tau]_p$$

Crushing of the surface of joint between rivet and plate,

$$\frac{F}{i} \leq d t [\sigma_c]$$

$$\eta = \frac{(P-d)}{K_1 P}$$

For variable load,

Design stresses

$$= (\text{Design stresses under static load}) \times r$$

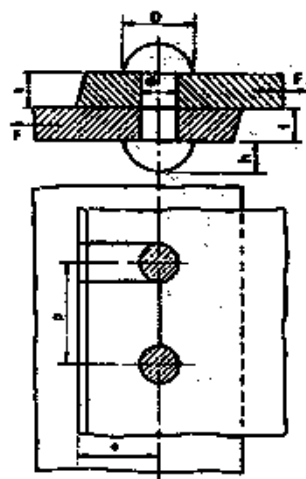
$$r = \frac{1}{1 - 0.3 \frac{F_{min}}{F_{max}}}$$

Strong riveted joints

[For machine units, columns trusses etc.]

$$i \geq \frac{4}{\pi} \times \frac{F}{nd^2 [\tau]_{riv}}$$

$$\geq \frac{F}{td [\sigma_c]}$$



- d , diameter of rivet
- D , diameter of rivet head
- D_i , internal diameter of pressure vessel
- e , margin of plate
- E , Young's modulus
- F , force acting on the joint
- F_1 , force per pitch length of the joint
- h , height of rivet head
- i , number of rivets
- k , number of rivets per pitch
- k_t , theoretical stress concentration factor for plate with hole
- l , length of shank of undriven rivet
- n , number of cross sections under shear
- p , pressure of fluid inside the pressure vessel
- P , Pitch
- t , Thickness of the plate
- Δt , temperature drop
- $[\sigma_c]$, allowable compressive stress 2100–2400 kgf/cm² for steel
- $[\sigma]_p$, allowable tensile stress of plate $\approx [\tau]_{riv}$
- $[\tau]_{riv}$, allowable shear stress of rivet 1000–1400 kgf/cm² for steel
- $[\tau]_p$, allowable shear stress of plate $\approx 0.8 [\tau]_{riv}$

RIVETED JOINTS (Contd.)

Tight strong riveted joints:

[For pressure vessels]

tensile stress induced in the hot driven rivet when it is cooled through Δt

$$\frac{4F'}{n k \pi d^2} < [\xi]$$

α , coefficient of linear expansion

$$F' = \frac{D_1 p P}{2} \text{ for longitudinal joint}$$

η , efficiency of joint allowable

$$= \frac{D_1 p P}{4} \text{ for circumferential joint}$$

$[\xi]$, coefficient of sliding

$$t = \frac{D_1 p}{2\eta [\sigma]_{ps}} + \delta$$

δ , corrosion allowance for thickness of plate

$$\delta = 0.1 \text{ to } 0.3 \text{ cm}$$

r , correction factor for variable load

Characteristics of strong joints made of carbon steels:

Type of joint	Diameter of rivet, d	Margin of plate, e	Pitch, P	Efficiency, η %, for $k_1=1$
Single riveted lap joint	2t	1.5d	3d	67
Double riveted lap joint	2t	1.5d	4d	75
Single riveted, Single strap butt joint	2t	1.5d	3d	67
Double riveted, Single strap butt joint	2t	1.5d	4d	75
Single riveted, Double strap butt joint	1.5t	1.5d	3.5d	71
Double riveted, Double strap butt joint	1.5t	1.5d	6d	83

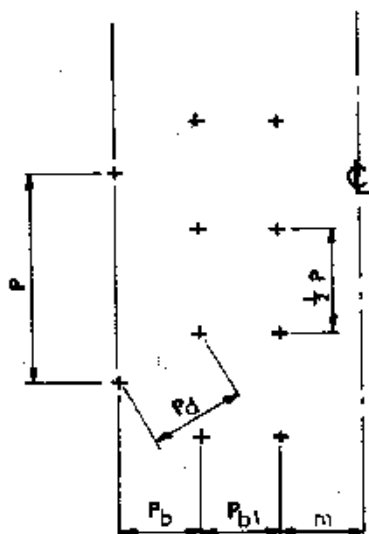
Characteristics of tight strong joints:

Type of joint	$c = \frac{D_1 p}{2}$ kgf/cm	Diameter of rivet d, mm	Pitch p, mm	Efficiency, η %, for $k_1=1$	$[\xi]$ kgf/cm ²
Single riveted lap joint	upto 500	t+8	2d+8	56-60	600-700
Double riveted lap joint	350-950	t+8	2.6d+15	70	600-650
Triple riveted lap joint	450-1350	t+(6-8)	3d+22	75	550-600
Double riveted, double strap butt joint	450-1350	t+(5-6)	3.5d+15	75	2(475-575)
Triple riveted, double strap butt joint	450-2300	t+5	6d+20	85	2(450-550)

RIVETED JOINTS FOR PRESSURE VESSELS

Equation	Nomenclature
Longitudinal (butt) joint:	p , pressure, N/mm ²
$t = \frac{p \cdot D}{2 \eta_1 [\sigma_t]}$	D , diam of vessel, mm
	η_1 , efficiency of long. joint
	= 0.6 to 0.8 single riveted
	= 0.75 to 0.85 double riveted
	= 0.8 to 0.9 triple riveted
$d = 6\sqrt{t}$ for $t > 8$ mm	$[\sigma_t]$, design stress in tension, for plate, N/mm ²
	t , plate thickness, mm
$P_{max} = Ct + 41$	d , diam of rivet, mm
	(for $t < 8$ mm, obtain d by equating the shear strength to crushing strength)
	P_{max} , maximum permissible pitch, mm
	C , factor from Boiler code,

Condition	chain riveted	zig zag riveted	No. of rivets/pitch	Value of C	
				LAP joint	BUTT JOINT
equal no. of rivets in all rows	$P_b \geq 2d$	$P_b \geq 0.33P + 0.67d$			single cover double cover
no. of rivets in outer row is half the no. in the inner row	$P_b \geq 0.33P + 0.67d$ & $P_{b1} \geq 2d$	$P_b \geq 0.2P + 1.15d$ & $P_{b1} \geq 0.165P + 0.67d$	1	1.31	1.53
			2	2.62	3.06
			3	3.47	4.05
			4	4.17	—
			5	—	—



Equation	Nomenclature										
$t_1 = 1.125 t$ (for single cover)	t_1 , cover or strap thickness										
$= 0.625 t$ (for double cover of equal widths)	t , thickness of main plate										
$= 1.125 \frac{P - d}{p - 2d}$ (single cover, with the outer most row having alternate rivets)	m , margin of rivet centre from edge of plate.										
$= 0.625 \frac{P - d}{p - 2d}$ (for double cover with the outer most row having alternate rivets)	i , total number of rivets										
	$[\tau]$, design shear stress for rivet										
	η_c , efficiency of circumferential joint										
	r_n , no. of rows of rivets.										
For unequal widths of cover plates:											
$t_1 = 0.75 t$ (Wider one)											
$= 0.625 t$ (narrower cover)											
$m = 1.5 d$											
CIRCUMFERENTIAL JOINT (LAP)											
$i = \left(\frac{D}{d} \right) \times \frac{p}{[\tau]}$											
$\eta_c = \frac{P - d}{P}$											
$r_n = \frac{i P}{\pi (D + t)}$											
d, m, P_b &c. are the same as for long. joint.											
	<table border="1"> <thead> <tr> <th>Condition</th> <th>Type of joint</th> <th>η_c</th> </tr> </thead> <tbody> <tr> <td>Single riveted</td> <td rowspan="3"> </td> <td>0.45 to 0.63</td> </tr> <tr> <td>double</td> <td>0.63 to 0.77</td> </tr> <tr> <td>triple</td> <td>0.75 to 0.85</td> </tr> </tbody> </table>	Condition	Type of joint	η_c	Single riveted		0.45 to 0.63	double	0.63 to 0.77	triple	0.75 to 0.85
Condition	Type of joint	η_c									
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	<table border="1"> <thead> <tr> <th>diameter of rivet, d, mm</th> <th>recommended diam of rivet holes, mm d_1</th> </tr> </thead> <tbody> <tr> <td>Over 12 upto 24</td> <td>$d + 1$</td> </tr> <tr> <td>27 to 36</td> <td>$d + 1.5$</td> </tr> <tr> <td>39 to 48</td> <td>$d + 2$</td> </tr> </tbody> </table>	diameter of rivet, d , mm	recommended diam of rivet holes, mm d_1	Over 12 upto 24	$d + 1$	27 to 36	$d + 1.5$	39 to 48	$d + 2$		
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	Factor of safety recommended based on ult. tensile strength.										
	<table border="1"> <thead> <tr> <th>type</th> <th>Lap</th> <th>Butt unequal straps</th> <th>Butt equal straps</th> <th>Butt single strap</th> </tr> </thead> <tbody> <tr> <td>F.O.S.</td> <td>4.75</td> <td>4.25</td> <td>4</td> <td>4.75</td> </tr> </tbody> </table>	type	Lap	Butt unequal straps	Butt equal straps	Butt single strap	F.O.S.	4.75	4.25	4	4.75
type	Lap	Butt unequal straps	Butt equal straps	Butt single strap							
F.O.S.	4.75	4.25	4	4.75							

BOLTED JOINTS

$$F_e = \frac{\sigma_y S^{3/2}}{15.3} \text{ (to be used when } F_t \text{ is not known)}$$

$$M_t = C d F_t$$

$C = 0.2$, for average unlubricated bolts

$= 0.15$, for lubricated bolts

$$F_t = F_i + \Delta F_b$$

$$\text{where } \Delta F_b = \left(\frac{k_b}{k_b + k_c} \right) F_e$$

$$F_c = F_t - \left(\frac{k_c}{k_b + k_c} \right) F_e > 0,$$

for the joint to remain closed,

$$k_b = \frac{S E_b}{L_b}, \quad k_c = \frac{A_c E_c}{L_c}$$

$$A_c = \frac{\pi}{4} (d_s^2 - d^2)$$

$$d_s = (\text{nut or head width across flats}) + \frac{h}{2}$$

$$\frac{1}{k_c} = \frac{1}{k_1} + \frac{1}{k_2} + \dots \text{ where}$$

k_1, k_2 etc. are the spring constants of the individual connected parts.

$$k_1 = \frac{A_c E_1}{L_1}, \quad k_2 = \frac{A_c E_2}{L_2} \text{ etc.}$$

For varying loads:

$$\frac{1}{N} = \frac{\sigma_m}{\sigma_y} + k_1 \frac{\sigma_a}{\sigma_{-1}}$$

F_e load taken by connected parts, kgf

F_s safe external load, kgf

F_t initial tension in bolt, kgf

F_i total load on bolt, kgf

S stress area of the bolt, cm^2

C torque coefficient

d nominal diameter of bolt, cm

h grip of the bolt (total thickness of parts being clamped), cm

k_b, k_c spring constant of bolt and connected parts

L_b length of the bolt

L_c thickness of connected parts, cm

A_c equivalent area of the connected parts, cm^2

d_s equivalent diameter of the plate in compression

E young's modulus

σ_y yield stress of bolt material, kgf/cm^2

σ_{-1} endurance stress, kgf/cm^2

M_t applied torque, kgf cm

N factor of safety

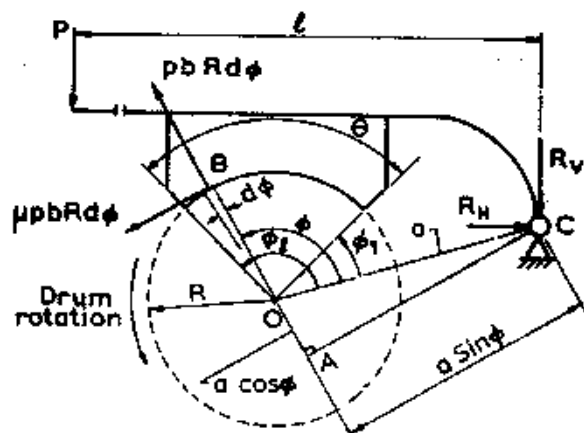
k_1 fatigue stress concentration factor for the threads

4.4 to 5 for medium carbon steels

5.6 to 6.4 for heat treated alloy steels

σ_m, σ_a mean and amplitude stresses

SHOE BRAKE ($\theta > 60^\circ$)



p , normal pressure

p_{max} , max. pressure, see table below

M_p , moment due to force P

P , brake actuating force

M_n , sum of moments due to normal pressure p

M_μ , sum of moments due to frictional force

M_T , Braking torque on drum

b , width of shoe

R , radius of brake drum

μ , coefft of friction, see table below.

m , lever arm length

$\theta = \phi_1 - \phi_2$ refer figure

If $\phi_2 > 90^\circ > \phi_1$

$(\sin \phi)_{max} = 1$

$$P = p_{max} \frac{\sin \phi}{(\sin \phi)_{max}}$$

$$= p_{max} \sin \phi, \text{ normally}$$

$$M_p + M_n + M_\mu = 0$$

$$M_p = P l$$

$$M_n = \frac{-p_{max} b R a}{4 (\sin \phi)_{max}} [2 \theta - \sin 2 \phi_2 + \sin 2 \phi_1]$$

$$M_\mu = \frac{\mu p_{max} b R}{4 (\sin \phi)_{max}} [4 R (\cos \phi_1 - \cos \phi_2) + a (\cos 2 \phi_2 - \cos 2 \phi_1)]$$

$$M_T = \frac{\mu p_{max} b R^2}{(\sin \phi)_{max}} (\cos \phi_2 - \cos \phi_1)$$

Properties of some typical friction materials:

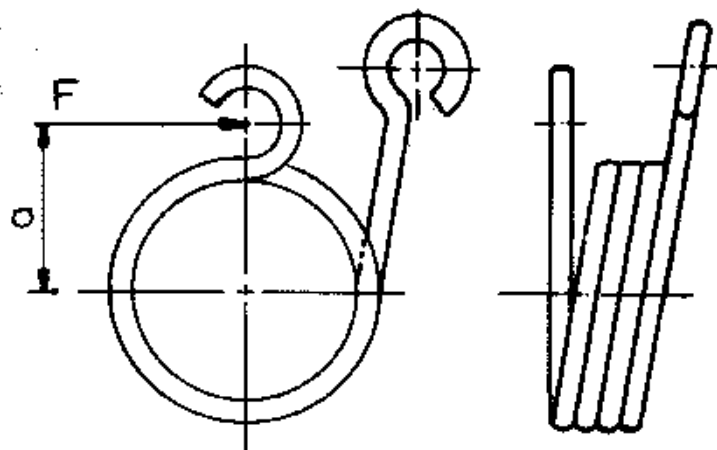
Materials	Max temp. $^\circ\text{C}$	μ , Coeff. of friction		p_{max} Max. pressure N/cm ^{2}
		Dry	In oil	
1. Leather on metal	70	0.40	—	25
2. Wood on metal	70	0.45	—	60
3. Woven asbestos on metal	260	0.40	0.20	70
4. Moulded asbestos on metal	400	0.40	0.20	100
5. Sintered metal on CI	—	0.30	0.07	280

Approximate rates of energy absorption for brakes :

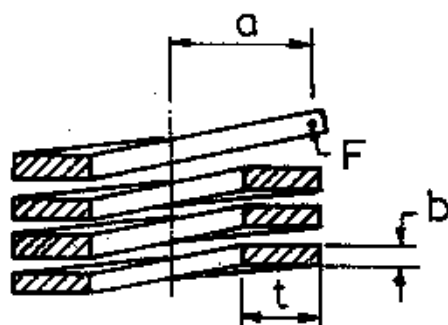
Condition	$\mu p v$, (proportional to energy absorbed)
1. Continuous application of load and poor dissipation of heat	2,000
2. Intermittent application of load, Comparatively long periods of rest, and poor dissipation of heat	4,000
3. Continuous application of load and good dissipation of heat as in an oil bath	6,250
4. Vehicle brakes	12,500

v in metres/min , p in N/cm^2

TORSION SPRING



ROUND WIRE



RECTANGULAR WIRE

$$\sigma = \frac{32 K_b M}{\pi d^3} \text{ (for round wire)} \leq [\sigma]$$

$$\sigma = \frac{6 K_b M}{b t^2} \text{ (for rect. wire)} \leq [\sigma]$$

$$\theta = \frac{\pi M D n_a}{E I}$$

$$\frac{[\sigma]}{\sigma_u} = 0.8 \text{ for oil tempered wire}$$

$$= 0.65 \text{ ,, music wire and hard drawn}$$

$$= 0.9 \text{ ,, alloy steel wire}$$

$$= 0.55 \text{ ,, stainless steel wire}$$

$$= 0.42 \text{ ,, brass wire}$$

$$= 0.67 \text{ ,, phosphor bronze, monel, beryllium Copper wires, wires.}$$

σ , induced bending stress

$M = Fa$, bending moment

$I = \frac{\pi d^4}{64}$ for round wire

$= \frac{1}{12} b t^3$ for rect wire

K_b , = Wahl factor refer p. 7.100

d , wire diameter

θ , angular deformation, radian

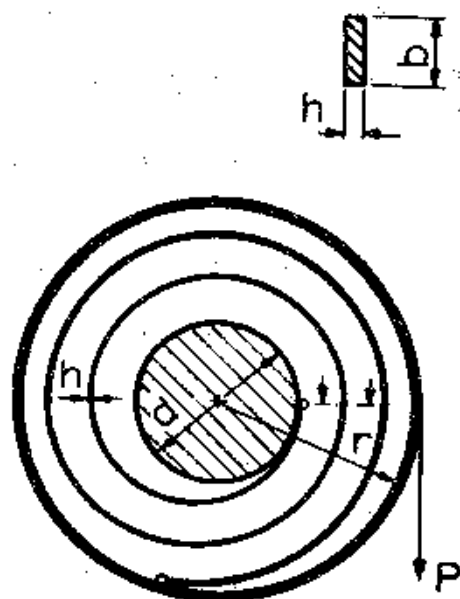
D , mean coil diam of spring

n_a , number of active turns

$[\sigma]$, design stress (see below)

b, t , dimensions of rect. spring

SPIRAL SPRING



SPIRAL SPRING

$$P = \frac{b h^3 [\sigma]}{6 r k}$$

$$k = \frac{3 C - 1}{3 C - 3}$$

$$C = \frac{d}{h}$$

$$\text{deflection, } \delta = r \theta$$

$$= \frac{P l r^2}{E I}$$

$$\text{also } = \frac{2 r l [\sigma]}{h E k}$$

$$\text{Energy stored, } U = P \frac{\delta}{2}$$

$$= \frac{\sigma^2 V}{6 E k^2}$$

P, safe load

b, width of spring leaf

h, thickness of " "
= (0.03 to 0.04) d

d, arbor diameter

[\sigma], design bending stress

r, radius of outer drum

k, spring factor

\theta, angular deformation of drum

l, length of spring

E, young's modulus

$$I, = \frac{b h^3}{12}$$

$$V, \text{ volume of spring} \\ = b h l$$

GEARS - 8

SPUR, HELICAL AND BEVEL GEARS

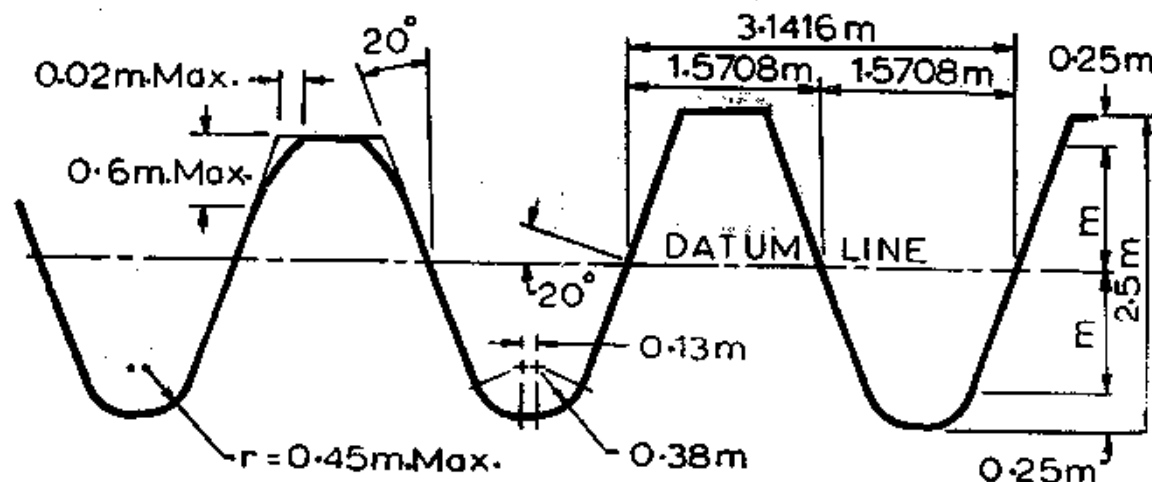
Symbol	Unit	Nomenclature
a	cm	Centre distance, to be rounded off to R 10 series in mm*
R	cm	Cone distance
i	—	Gear ratio, $\frac{Z_2}{Z_1} > 1$. Standard Gear ratio, Table-4
Z	—	Number of teeth, Z_1 on pinion & Z_2 on wheel
m	mm	Standard module, Table-1*
m_n	mm	Standard normal module, Table-1*
b	cm	Face width
α	degrees	Pressure angle, standard $\alpha = 20^\circ$. Other pressure angles in vogue $14^\circ 30'$ & 15°
β	degrees	Helix angle, 8° to 25° for Helical gears 25° to 40° for Herringbone gears Spiral angle, 8° to 35° & Zero degree for zerol bevel gears
f_o	—	Height factor, $f_o = 1$ for Standard gear tooth $f_o = 0.8$ for Stub gear tooth
c	—	Radial clearance, $c = 0.25 m$ for standard gears. Other clearances in vogue $c = 0.157 m$; $c = 0.167 m$; $c = 0.2 m$ & $c = 0.3 m$
X	—	Correction factor or Addendum modification coefficient for S_o and S corrected gears
ψ	—	$\psi = \frac{b}{a}$, Table-10. Recommended values, Table-11
ψ_m	—	$\psi_m = \frac{b}{m}$, Table-12
ψ_r	—	$\psi_r = \frac{R}{b}$, Table-13
y	—	Form factor, Table-18
y_v	—	Form factor based on equivalent number of teeth on the virtual cylinder, Z_v $Z_v = \frac{Z}{\cos^3 \beta} \text{ for Helical and Herringbone gears}$ $Z_v = \frac{Z}{\cos \delta} \text{ for Straight bevel gears}$ $Z_v = \frac{Z}{\cos \delta \cdot \cos^3 \beta_{av}} \text{ for Spiral bevel gears}$
M_t	kgf. cm	Torque transmitted by PINION
E	kgf/cm ²	Equivalent Young's Modulus, Table-9

*NOTE:— The standardized modules and centre distances are in mm. These values, when used in the formulae for computation shall be only in cm.

SPUR, HELICAL AND BEVEL GEARS (Contd.)

Symbol	Units	Nomenclature
k	—	Load concentration factor, Table-14
k_d	—	Dynamic load factor, Table-15
$k_{cd}; k_{bt}$	—	Life factors, k_{cd} for contact (surface) stress, Table-17 k_{bt} for bending, Table-22
k_σ	—	Stress concentration factor for the fillet, Table-21
n	—	Factor of safety in bending, Table-20
$[\sigma_c]$	kgf/cm ²	Design Surface stress or contact (crushing strength) compressive stress for the weaker material, to be modified for the required life
$[\sigma_b]$	kgf/cm ²	Design bending stress (tensile) for the weaker material, to be modified for the required life

BASIC RACK



Recommended Series of Modules* mm IS: 2535 - 1963 Table 1

Preferred (1)	Choice 2 (2)	Choice 3 (3)
1		
1.25	1.125	
1.5	1.375	
2	1.75	
2.5	2.25	
3	2.75	
4	3.5	(3.25)
5	4.5	(3.75)
6	5.5	
8	7	(6.5)
10	9	
12	11	
16	14	
20	18	

* Note: Preference is to be given to the use of the modules stated in column 1. Modules given in brackets in column 3 should be avoided as far as possible.

Peripheral Speed of Gears

Table 2

IS Quality	Preferred Quality	Speed of gears in metres per second			
		Cylindrical Gears	Straight Bevel	Spiral Bevel	
High Precision	3 & 4	4	Above 15	upto 9	upto 18
Precision	5 & 6	6	Above 8 & upto 15	.. 6	.. 12
Medium	7, 8 & 9	8	Above 1 & upto 8	.. 3	.. 7
Coarse	10 & 12	10, 12	upto 1	.. 2	.. 4

Backlash for Gears, mm

Table 3

Upto 8 m/s pitch line velocity			Above 8 m/s pitch line velocity	
Module	Backlash		Module	Backlash
	Min.	Max.		
20	0.75	1.25	8	0.40
16	0.50	0.85	7	0.38
12	0.35	0.60	6	0.36
10	0.30	0.51	5	0.28
8	0.22	0.40	4	0.23
6	0.20	0.33	3.5	0.22
5	0.15	0.25	3	0.21
4	0.13	0.20	2.75	0.20
3	0.10	0.15	2.5	0.19
2.5	0.08	0.13	2	0.18
2	0.08	0.13		
1.5 & Finer	0.00	0.10		

Standard Gear Ratio, i

Table 4

Single	Double stage reduction	Triple	Single	Double stage reduction	Triple
1.25	8	40	3.55	20	112
1.4	9	45	4	22.4	125
1.6	10	50	4.5	25	140
1.8	11	56	5	28	160
2	12	63	5.6	31.5	180
2.24	12.5	71	6.3	35.5	200
2.5	14	80	7.1	40	250
2.8	16	90	8	45	280
3.15	18	100	9	50	315
					355
			10		400

SELECTION OF GEAR MATERIALS

Some Recommended Combinations of Materials for Pinion and Wheel

Table 5

Gear Ratio, i	Surface hardness HB	Mating gears	Steel Classification					
$i < 8$	$HB \leq 350$	Pinion	C 45	C 50	C 55 Mn75 C 50 Mn 1	40 Cr 1	35 Ni 1 Cr60	16 Ni 1 Cr80
		Wheel	St 50, C 35 Mn75 Cast steel grade	C 35 Mn75 Cast steel grade	St 63 C 45 Cast steel grade	C 50 C 55 Mn75 Cast steel grade	40 Cr 1 Cast steel grade	35 Ni 1 Cr60
$i < 4$	$HB > 350$	Pinion	C 45 C 50	C 55 Mn75 C 55 Mn 1	40 Cr 1	35 Ni 1 Cr60	16 Ni 1 Cr80	40 Ni 2 Cr 1 Mo28
		Wheel	C 35 Mn75	St 63; C 45	C 50 C 55 Mn75	40 Cr 1	35 Ni 1 Cr60	15 Ni 2 Cr 1 Mo15
$i \geq 4$	$HB_1 > 350$	Pinion	C 45	C 50	40 Cr 1	15 Ni 2 Cr 1 Mo15	40 Ni 2 Cr 1 Mo28	
	$HB_2 \leq 350$	Wheel	Cast steel grade	35 Ni 1 Cr60	Cast steel grade 35 Ni 1 Cr60	C 45	C 55 Mn75 55 Cr70	
		Pinion	C 45				17 Mn 1 Cr 95	17 Mn 1 Cr 95
		Rack	St 58			St 58/C45		17 Mn 1 Cr 95

In general, when the surface hardness of materials HB is less than 350, the difference in surface hardnesses of pinion and wheel must be greater than 30 for $i > 1$. i. e. $HB_1 - HB_2 \geq 30$

Ratio of endurance limit stress of materials of pinion & wheel for various gear ratios

Table 6

Gear Ratio, i	1	2	4	6	8	10
$\frac{\sigma_{-1} \text{ Pinion}}{\sigma_{-1} \text{ Wheel}} >$	1.0	1.1	1.25	1.35	1.40	1.60

Table 7

Design Stress for Gear Materials

I. S. Classification		Heat Treatment	σ_u kgf/mm ²	σ_{-1} Min. kgf/mm ²	Endurance limit Number of cycles	Surface Hardness HB	Design stress		
							$[\sigma_b]$, kgf/cm ²		$[\sigma_s]$ kgf/cm ²
							Module, m, in mm		
						m upto 6	m=7 to 10		
Cast Iron	Grade 20	—	≥ 20	10	10^7	179–223	500	460	5000
	Grade 25	—	≥ 25	12	10^7	197–241	600	550	6000
	Grade 35	—	≥ 35	13	10^7	207–241	600	550	6000
	Grade 35	Heat Treated	≥ 35	16	10^7	300 Min.	800	750	7500
Steel	C 45	—	≥ 63	27	10^7	175–215	1400	1350	5000
	15Ni 2 Cr 1 Mo13	Carburized	≥ 90	55	25×10^7	case (500) core (250)	3200	3000	9500
	40Ni 2 Cr 1 Mo28	Case hardened	≥ 155	60	25×10^7	case (600) core (250)	4000	3800	11000

 σ_u , ultimate tensile strength, kgf/mm² σ_{-1} Min., minimum endurance limit stress for complete reversal of stresses, kgf/mm² $[\sigma_s]$, design surface stress, kgf/cm² $[\sigma_b]$, design bending stress, kgf/cm²

NUMBER OF TEETH IN A DRIVE FOR STANDARD RATIOS

Z , Total number of teeth = $Z_1 + Z_2$

Z_1 , Number of teeth in driving gear

Z_2 , Number of teeth in driven gear

i , Standard ratio, $\frac{Z_1}{Z_2}$

S , % deviation = $\left[\frac{\text{Actual ratio} - \text{Standard ratio}}{\text{Standard ratio}} \right] \times 100$

Values tabulated are :

$$Z_1 : Z_2^{\pm S}$$

Z i	30	31	32	33	34	35	36	37	38	39
1	15:15		16:16		17:17		18:18		19:19	
1.06		-0.7 15:16		-0.3 16:17		17:18		0.4 18:19		0.6 19:20
1.12			-1.0 15:17		-0.3 16:18		0.4 17:19		1.0 18:20	
1.26					-0.6 15:19		0.7 16:20			
1.41					-1.1 14:20		0.9 15:21			
1.58							0.9 14:22			0.9 15:24
1.78							0.5 13:23			0.4 14:25
2							-0.2 12:24			-0.2 13:26
2.24										-0.5 12:27

$\begin{matrix} Z \\ i \end{matrix}$	40	41	42	43	44	45	46	47	48	49
1	20:20		21:21		22:22		23:23		24:24	
1.06		0.9 20:21		1.1 21:22		1.3 22:23		1.5 23:24		-0.7 23:26
1.12	1.5 19:21							-1.3 22:25		
1.26		-1.5 18:23		-0.5 19:24		0.7 20:25				
1.41		0.1 17:24					-0.5 19:27			
1.58		1.4 16:25			-0.2 17:27					0.4 19:30
1.78			-0.2 15:27					0.8 17:30		
2.0			-0.2 14:28			-0.2 15:30			-0.2 16:32	
2.24			0.4 13:29			1.1 14:31				0.5 15:234
2.5			-0.5 12:30				-1.0 13:33			0.5 14:35
2.82							0.5 12:34			

i \ Z	50	51	52	53	54	55	56	57	58	59
1	25:25		26:26		27:27		28:28		29:29	
1.06							0.4 27:29		-1.1 28:30	
1.12		-0.3 24:27		0.2 25:28		0.5 26:29		1.0 27:30		1.3 28:31
1.26	-1.1 22:28		-0.2 23:29		0.7 24:30		1.5 25:31			0.5 26:33
1.41		-1.1 21:30		0.2 22:31		1.5 23:32			-0.3 24:34	
1.58		-0.3 19:32	-0.5 20:32		0.9 21:33			-0.4 22:35		1.3 23:36
1.78	18:32			-0.5 19:34			-1.2 20:36		0.9 21:37	
2		-0.2 17:34			-0.2 18:36			-0.2 19:38		
2.24			-0.5 16:36			0.2 17:38			0.7 18:40	
2.51				-0.8 15:38			0.5 16:40			
2.82	-1.0 13:37			1.2 14:39	-1.4 14:40			0.7 15:42		
3.16	-0.1 12:38				0.2 13:41				0.5 14:44	
3.55					1.4 12:42	-1.1 12:43				0.3 13:46
3.98										1.5 12:47

i \ Z	60	61	62	63	64	65	66	67	68	69
1	30:30		31:31		32:32		33:33		34:34	
1.06	-0.9 29:31		-0.7 30:32		-0.5 31:33		-0.3 32:34		-0.1 33:35	
1.12			-1.4 29:33		-1.0 30:34		-0.6 31:35		-0.3 32:36	
1.18		-0.8 28:33		1.4 29:34	-1.5 29:35		-1.0 30:36		-0.4 31:37	
1.26		27:34		0.7 28:35		1.4 29:36	-1.3 29:37		-0.6 30:38	
1.41	0.9 25:35			-0.7 26:37		0.4 27:38		1.4 28:39	-1.1 28:40	
1.58	-1.5 23:37			0.1 24:38		-0.9 25:40		0.5 26:41		
1.78		-1.0 22:39			-0.2 23:41			-0.7 24:43		1.0 25:44
2.0	-0.2 20:40				-0.2 21:42		-0.2 22:44			-0.2 23:46
2.24		1.3 19:42	-1.1 19:43			-0.5 20:45				21:47
2.51	-0.7 17:43			0.5 18:45			1.5 19:47	-1.6 19:48		
2.82		0.2 16:45				-0.2 17:48			1.5 18:50	-0.5 18:51
3.16			0.9 15:47	-1.2 15:48			1.2 16:50	-0.8 16:51		
3.55				1.4 14:49	-0.7 14:50				0.4 15:53	-1.4 15:54
3.98	-0.5 12:48				1.5 11:51	-0.5 13:52				-1.3 14:55
5.01								-1.6 11:56		

Z										
	70	71	72	73	74	75	76	77	78	79
1	35:35		36:36		37:37		38:38		39:39	
1.06	34:36		-0.2 35:37		0.4 36:38		0.5 37:39		0.6 38:40	
1.12	0.1 33:37		0.4 34:38		0.7 35:39		1.0 36:40	1.5 36:41	1.3 37:41	-1.2 37:42
1.26	0.1 31:39		0.7 32:40		1.3 33:41	-1.1 33:42		-0.5 34:43		0.1 35:44
1.41	-0.1 29:41		-0.9 30:42	-1.5 30:43		-0.5 31:44		0.4 32:45		1.3 33:46
1.58	-0.5 27:43		0.9 28:44	-1.4 28:45		-0.1 29:46		-1.2 30:42	-0.9 30:48	
1.78	-1.2 25:45		0.5 26:46			27:48			-0.4 28:50	
2.0			-0.2 24:48			-0.2 25:50			-0.2 26:52	
2.24		0.5 22:49	-1.5 22:50		1.0 23:51	-1.0 23:52		1.4 24:53	-0.5 24:54	
2.51	0.5 20:50	-1.5 20:51		1.4 21:52	-0.5 21:53			0.5 22:55	-1.3 22:56	
2.82			1.1 19:53	-0.8 19:54			0.7 20:56	-1.1 20:57		
3.16	1.4 17:53	-0.4 17:54				-0.1 18:57				0.1 19:50
3.55			1.4 16:56	0.4 16:57			0.5 17:59	1.1 17:51		
3.98	-0.5 14:56				1.2 15:59	0.5 15:50				-1.1 16:53
5.01		1.9 12:59	0.2 12:50	-1.4 12:51				1.8 13:54	0.2 13:55	-1.5 13:56

i \ Z	80	81	82	83	84	85	86	87	88	89
1	40:40		41:41		42:42		43:43		44:44	
1.06	0.8 39:41		0.9 40:42	-1.5 40:43	1.0 41:43	-1.3 41:44	1.1 42:44	-1.1 42:45	1.2 43:45	-1.0 43:46
1.12	1.5 38:42	-0.8 38:43		-0.5 39:44		-0.3 40:45			41:46	0.3 42:47
1.26		0.7 36:45	-1.5 36:46	1.3 37:46	-0.9 37:47		-0.3 38:48		0.2 39:49	
1.41	-0.8 33:47		0.1 34:48		-0.9 35:49	0.1 35:50		-0.3 36:51		-0.5 37:52
1.58	0.3 31:49		1.4 32:50	-0.6 32:51		0.5 33:52	-1.3 33:53		-0.2 34:54	
1.78	1.1 29:51	-0.8 29:52		0.7 30:53	-1.2 30:54		0.2 31:55			-0.2 32:57
2.0		-0.2 27:54			-0.2 28:56		1.5 29:57	-0.2 29:58		1.5 30:59
2.24		-0.1 25:56			0.4 26:58	-1.3 26:59		0.7 27:60	-0.9 27:61	
2.51	1.4 23:57	-0.4 23:58			-0.5 24:60	-1.2 24:61		1.3 25:62	-0.3 25:63	
2.82	0.3 21:59	-1.4 21:60				22:62		1.3 23:64	-0.3 23:65	
3.16	-1.5 19:61			0.4 20:63	-1.2 20:64			0.6 21:66	-0.9 21:67	
3.55		1.4 18:63	-0.2 18:64	-1.7 18:65			0.5 19:67	-0.9 19:68		
3.98	-0.5 16:64	2.0 16:65			1.0 17:67	-0.5 17:68	-1.9 17:69			0.9 18:71
5.01				1.7 14:69	0.2 14:70	-1.2 14:71				-1.5 15:74

$\begin{matrix} Z \\ i \end{matrix}$	90	91	92	93	94	95	96	97	98	99
1	45:45		46:46		47:47		48:48	49:48 ^{2.0}	49:49	50:49 ^{2.0}
1.06	-1.3 44:46	-0.8 44:47	1.4 45:47	-0.7 45:48	1.5 46:48	-0.5 46:49	1.6 47:49	-0.4 47:50		-0.3 48:51
1.12		0.5 43:48	-1.5 43:49	-0.8 44:49	-1.3 44:50	1.0 45:50	-1.0 45:51	1.12 46:51	-0.7 46:52	1.4 47:52
1.26	0.7 40:50	-1.3 40:51	1.2 41:51	-0.7 41:52		-0.2 42:53		-0.2 43:54		0.7 44:55
1.41	-1.4 37:53	1.3 38:53	-0.6 38:54		0.2 39:55		0.9 40:56	-0.9 40:57		-0.1 41:58
1.58	0.9 35:55	-0.9 35:56		0.1 36:57		1.1 37:58	-0.6 37:59		1.4 38:50	-1.3 38:61
1.78		1.2 33:58	-0.5 33:59		0.8 34:60	-0.3 34:61		0.4 35:62	-1.2 35:63	
2.0	-0.2 30:60		1.4 31:61	-0.2 31:62		1.3 32:63	-0.2 32:64		1.3 33:65	-0.2 33:66
2.24	1.1 28:62	-0.5 28:63		1.4 29:64	-0.1 29:65			0.2 30:67	-1.2 30:68	
2.51		0.5 26:65	-1.0 26:66		1.2 27:67	-0.3 27:68			0.5 28:70	-0.9 28:71
3.16		0.8 22:69	-0.6 22:70			1.0 23:72	-0.4 23:73			-1.2 24:75
3.55	1.4 20:70	-0.1 20:71	-1.4 20:72			0.7 21:74	-0.7 21:75			1.4 22:77
3.98	-0.5 18:72	-1.8 18:73			0.9 19:75	-0.5 19:76	-1.8 19:77			0.8 20:79
5.01	0.2 15:75	-1.1 15:76				1.5 16:79	0.2 16:80	-1.0 16:81		

Table 8

Formulae Based on Surface (contact compressive) Strength

Cylindrical Gears	Bevel Gears
FOR DESIGNING	
Spur $a \geq (i \pm 1) \sqrt[3]{\left(\frac{0.74}{[\sigma_c]}\right)^2 \frac{E[M_t]}{i \psi}} \quad \dots(1.1)$	Straight and Spiral $R \geq \psi_r \sqrt{i^2 + 1} \sqrt[3]{\left(\frac{0.72}{(\psi_r - 0.5)[\sigma_c]}\right)^2 \frac{E[M_t]}{i}} \quad \dots(1.3)$
Helical and Herringbone $a \geq (i \pm 1) \sqrt[3]{\left(\frac{0.7}{[\sigma_c]}\right)^2 \frac{E[M_t]}{i \psi}} \quad \dots(1.2)$	
FOR CHECKING	
Spur $\sigma_c = 0.74 \frac{i \pm 1}{a} \sqrt{\frac{i \pm 1}{i b}} E[M_t] \leq [\sigma_c] \quad \dots(1.4)$	Straight and Spiral $\sigma_c = \frac{0.72}{(R - 0.5b)} \sqrt{\frac{\sqrt{(i^2 + 1)^3}}{i b}} E[M_t] \quad \dots(1.6)$
Helical and Herringbone $\sigma_c = 0.7 \frac{i \pm 1}{a} \sqrt{\frac{i \pm 1}{i b}} E[M_t] \leq [\sigma_c] \quad \dots(1.5)$	

Formulae Based on Beam (bending) Strength of Pinion Tooth

Cylindrical Gears	Bevel Gears
FOR DESIGNING	
Spur $m \geq 1.26 \sqrt[3]{\frac{[M_t]}{y_s [\sigma_b] \psi_m Z_1}} \quad \dots(2.1)$	Straight $m_{av} \geq 1.26 \sqrt[3]{\frac{[M_t]}{y_s [\sigma_b] \psi_m Z_1}}$ $m_t = m_{av} + \frac{b}{Z} \sin \delta \dots(2.3)$
Helical and Herringbone $m_n \geq 1.15 \cos \beta \sqrt[3]{\frac{[M_t]}{y_s [\sigma_b] \psi_m Z_1}} \quad \dots(2.2)$	Spiral $m_{av} \geq 1.15 \cos \beta_{av} \sqrt[3]{\frac{[M_t]}{y_s [\sigma_b] \psi_m Z_1}} \quad \dots(2.4)$
FOR CHECKING	
Spur $\sigma_b = \frac{i \pm 1}{a m b y} [M_t] \leq [\sigma_b] \quad \dots(2.5)$	Straight $\sigma_b = \frac{R \sqrt{i^2 + 1} [M_t]}{(R - 0.5b)^2 b m y_s} \frac{1}{\cos \alpha} \leq [\sigma_b] \dots(2.8)$
Helical $\sigma_b = 0.7 \frac{i \pm 1}{a b m_n y_s} [M_t] \leq [\sigma_b] \quad \dots(2.6)$	Spiral $\sigma_b = \frac{0.7 R \sqrt{i^2 + 1} [M_t]}{(R - 0.5b)^2 b m_n y_s} \leq [\sigma_b] \quad \dots(2.9)$
for $8^\circ < \beta < 45^\circ$ and $\alpha = 20^\circ$ Herringbone, $i \pm 1$ $\sigma_b = 0.85 \frac{i \pm 1}{a b m_n y_s} [M_t] \leq [\sigma_b] \quad \dots(2.7)$	

Plus for external and Minus for internal

Table 9

$$\text{Equivalent Young's Modulus, } E_{eq} = \frac{2E_1 E_2}{E_1 + E_2} \dots (3.0)$$

Pinion, 1		Wheel, 2		Equivalent Young's Modulus E_{eq}
Material	Young's Modulus E_1 , kgf/cm ²	Material	Tensile strength σ_u , kgf/mm ²	Modulus E_2 , kgf/cm ²
Steel	2.15×10^6	Steel		2.15×10^6
		C I	≤ 28	1.1×10^6
			> 28	1.4×10^6
		Bronze		1.2×10^6
		Nylon		7×10^4
				1.36×10^6

For other combination of materials, use Formula, (3.0)

Table 10

Type of gear transmission	$\psi = \frac{b}{a}$
Open type gearing	0.1 to 0.3
Speed reducers (Closed type)	
a. High speed 8 to 25 m/s	upto 0.3
b. Medium speed 3 to 8 m/s	upto 0.6
c. Low speed 1 to 3 m/s	upto 1.0
Gear boxes with sliding gears	0.12 to 0.15

Note: For light and medium duty $b \leq d_1$
 For heavy duty $b \leq 1.5 d_1$

Where b , face width
 and d_1 , pinion diameter

Table 11

Recommended ψ values

$\psi =$	0.20	0.25	0.30	0.40	0.50	0.60	0.80	1.0	1.2

Table 12

Type of gear Transmission	$\psi_m = \frac{b}{m}$
Non-ground gears	6
Ground gears	
a. Sliding gears	10 to 20
b. Gears in rigid housing	upto 45
c. Planetary gears	8 to 20

In general: $\psi_m = 10$ or $b = 10 m$

For Nylon gears $\psi_m = 10$ to 20

Table 13

Type of gear Transmission	$\psi_T = \frac{R}{b}$	
a. Housed in roller bearings		
Speed Reducers	$i = 1$ to 4	3
	$i = 4$ to 6	4
b. Housed in Journal & Thrust bearings		
	$i = 6$	5

Design Twisting Moment, $[M_t]$

$[M_t] = M_t k_d k$... (4.0)	M_t , nominal twisting moment transmitted by the pinion, kgf. cm
Initially assume for symmetric scheme	
$k_d k = 1.3$... (4.1)	hp , nominal horsepower transmitted
For unsymmetric and over-hanging scheme	n , speed of rotation of pinion, rpm
$k_d k = 1.5$... (4.2)	k_d , dynamic load factor, table 15
$M_t = 71620 \frac{hp}{n} = 97420 \frac{kW}{n}$... (4.3)	kW , nominal power transmitted in kW

Load Concentration Factor, k for steel gears of Quality 1-8 having HB > 350

Table 14

Cylindrical Gears					Bevel Gears			
$\psi_D = \frac{b}{d_1}$	Bearings close to Gears and Symmetrical	Asymmetrical		Over hung pinion	Surface hardness of Gears HB	b/d _{av} ratio		
		*Very rigid Shaft	**Less rigid Shaft			≤ 1	1 to 1.6	1.6 to 1.8
0.2	1	1	1.05	1.15	> 350 for both the Gears	1.6	—	—
0.4	1	1.04	1.1	1.22				
0.6	1.03	1.08	1.16	1.32				
0.8	1.06	1.13	1.22	1.45	≤ 350 for both the gears or at-least for wheel	1.1	1.2	1.3
1.0	1.1	1.18	1.29	—				
1.2	1.14	1.23	1.36	—				
1.4	1.19	1.29	1.45	—				
1.6	1.25	1.35	1.55	—				

d_{av} — Average pitch diameter of bevel pinion = $m, z_1 \left(\frac{R + 0.5b}{n} \right)$ mm

* $1/d_1 < 3$ l — length of the shaft.** $1/d_1 > 3$ d_1 — diameter of shaft d_{1av} — Average pitch diameter of bevelpinion $= m_t z_1 \left(\frac{R + 0.5b}{R} \right)$ mm

pitch line velocity,

 $V = \frac{\pi d_{1av} n_1}{60 \times 1000}$, m/sec

$$\psi_D = \frac{\psi}{2} (\pm 1)$$

IS quality		Pinion Surface Hardness HB	Spur & Straight bevel				Helical & Spiral Bevel			
Cylindrical gear	Conical gear		Pitch line velocity, m/s, upto							
			1.0	3.0	8.0	12.0	3.0	8.0	12.0	18.0
5	—	≤ 350	—	—	1.2	1.4	—	1	1.1	1.2
		> 350	—	—	1.2	1.3	—	1	1.0	1.1
6	5	≤ 350	—	1.25	1.45	—	1	1	1.2	1.3
		> 350	—	1.2	1.3	—	1	1	1.1	1.2
8	6	≤ 350	1	1.35	1.55	—	1.1	1.3	1.4	—
		> 350	—	1.3	1.4	—	1.1	1.2	1.3	—
10	8	≤ 350	1.1	1.45	—	—	1.2	1.4	—	—
		> 350	—	1.4	—	—	1.2	1.3	—	—
	10	≤ 350	1.2	—	—	—				

Design Surface (contact compressive) Stress $[\sigma_c]$

$[\sigma_c] = C_B \text{ HB } k_{dt}, \text{ kgf/cm}^2$	...(5.1)	C_B or C_R , coefficient depending on the surface hardness, from table 16
$[\sigma_c] = C_R \text{ HRC } k_{dt}, \text{ kgf/cm}^2$	...(5.2)	HB or HRC, Brinell or Rockwell 'C' hardness number
		k_{dt} , life factor from table 17

Coefficients, C_B & C_R

Table 16

Wheel Material	Heat Treatment	Surface Hardness	Coefficient C_B or C_R
Carbon Steels and Alloy Steels of any type	Normalised or Hardened and Tempered	HB ≤ 350	$C_B = 25$
High strength Alloy Nickel Chromium Steels	Case Hardened	HRC = 55 to 63	$C_R = 310$
Alloy Steels	"	"	$C_R = 280$
Carbon & Manganese Steels C15; C20; C15 Mn 85; C20 Mn 85	"	"	$C_R = 220$
Alloy Steels, Carbon Steels C40; C45	Hardened & Tempered	HRC = 40 to 55	$C_R = 265$
"	Surface Hardened	"	$C_R = 230$
Cast Iron, Grade 20, 25	—	HB = 170 to 200	$C_B = 20$
Cast Iron, Grade 30, 35	—	HB = 200 to 260	$C_B = 23$

Equivalent mean life

Condition	Formula	Notation
Constant Loading	$N = 60nT$... (6.1)	N, Life in number of cycles n, rpm T, Life in hours
Variable Loading	$N = \frac{60}{M_{u1}^3} \sum M_{ui}^3 T_i n_i$... (6.2)	

When the load comprises of a maximum sustained wheel or pinion torque M_{u1} acting for T_1 hours at a mean speed of n_1 and small sustained torques $M_{u2}, M_{u3}, \dots$ acting for $T_2, T_3, \dots$ hours, at mean speeds of $n_2, n_3, \dots$ the equivalent number of cycles at the maximum sustained load is N_{eq} .

$$N_{eq} = 60 \left[T_1 n_1 \left(\frac{M_{u1}}{M_{u1}} \right)^3 + T_2 n_2 \left(\frac{M_{u2}}{M_{u1}} \right)^3 + T_3 n_3 \left(\frac{M_{u3}}{M_{u1}} \right)^3 + \dots \right] \quad \dots (6.3)$$

Life Factor for Surface (Contact Compressive) Strength $k_{cs} = \sqrt[6]{\frac{10^7}{N}}$

Table 17

Material	Surface Hardness, HB	Life in number of cycles	Life Factor, k_{cs}
Steel	≤ 350	$\geq 10^7$	1
		$< 10^7$	$\sqrt[6]{\frac{10^7}{N}}$
	> 350	$\geq 25 \times 10^7$	0.585
		$< 25 \times 10^7$	$\sqrt[6]{\frac{10^7}{N}}$
Cast Iron			$\sqrt[6]{\frac{10^7}{N}}$

Table 18

Form Factor, y for $\alpha = 20^\circ$ and $f_0^* = 1$
 y includes $\cos \alpha$ term)

Z or Z _e	External Pinion, Wheel & Internal Pinion								Annulus
	Addendum Modification Coefficient, X								
	-0.6	-0.4	-0.2	0	+0.2	+0.4	+0.6	+1.0	
12	—	—	0.239	0.308	0.378	—	—	—	—
14	—	—	0.266	0.330	0.392	0.458	—	—	—
16	—	—	0.302	0.355	0.408	0.461	—	—	—
18	—	—	0.330	0.377	0.424	0.470	—	—	—
20	—	—	0.348	0.389	0.431	0.471	0.513	—	—
22	—	—	0.367	0.402	0.437	0.473	0.509	—	—
24	—	0.355	0.384	0.414	0.445	0.475	0.504	—	—
26	—	0.373	0.400	0.427	0.455	0.481	0.509	—	—
28	0.358	0.383	0.408	0.434	0.458	0.484	0.509	—	0.942
30	0.369	0.392	0.416	0.440	0.464	0.486	0.511	—	0.916
35	0.390	0.411	0.431	0.452	0.473	0.494	0.514	0.556	0.863
40	0.406	0.426	0.445	0.465	0.485	0.503	0.523	0.562	0.825
45	0.415	0.434	0.452	0.471	0.490	0.509	0.528	0.565	0.795
50	0.423	0.441	0.459	0.477	0.495	0.513	0.531	0.568	0.769
60	0.440	0.456	0.474	0.490	0.507	0.523	0.540	0.574	0.731
80	0.457	0.471	0.485	0.499	0.512	0.526	0.541	0.569	0.688
100	0.464	0.481	0.490	0.505	0.517	0.530	0.542	0.566	0.660
150	0.492	0.499	0.508	0.515	0.521	0.531	0.540	0.556	0.620
300	0.517	0.519	0.521	0.521	0.523	0.523	0.524	0.526	0.585
RACK				0.550					

* for height factor, $f_0 = 0.8$ (Stub Teeth), the above values should be divided by 0.8

Design Bending Stress (Tension) [σ_b]

Rotation in one direction only,

$$[\sigma_b] = \frac{k_{bl}}{n \cdot k_\sigma} \sigma_o = \frac{1.4 k_{bl}}{n \cdot k_\sigma} \sigma_{-1} \quad \dots(7.1)$$

Rotation in both directions,

$$[\sigma_b] = \frac{k_{bl}}{n \cdot k_\sigma} \sigma_{-1} \quad \dots(7.2)$$

k_{bl} , life factor for bending, table 22

k_σ , fillet stress concentration factor, table 21

$\sigma_o = 1.4 \sigma_{-1}$

σ_o , Endurance limit stress in bending for repeated stress, kgf/cm²

σ_{-1} , Endurance limit stress in bending for complete reversal of stresses, kgf/cm², table 19

n , factor of safety, table 20

Material of mating gear	σ_{-1} , Endurance limit stress in bending for complete reversal of stresses, kgf/cm ²
Forged Steels	$\sigma_{-1} = 0.25 (\sigma_u + \sigma_y) + 500$
Cast Steels	$\sigma_{-1} = 0.22 (\sigma_u + \sigma_y) + 500$
Alloy steels	$\sigma_{-1} = 0.35 \sigma_u + 1200$
Cast Iron	$\sigma_{-1} = 0.45 \sigma_u$

σ_u , ultimate tensile stress, kgf/cm²
 σ_y , yield stress, kgf/cm²

Factor of Safety, n

Table 20

Material	Mode of Manufacture	Heat Treatment	Factor of Safety, n
Steel, Cast Iron	Cast	No heat treatment	2.5
		Tempered or Normalised	2.0
Steel	Cast or Forged	Case Hardened	2.0
	Forged	Surface Hardened	2.5
		Normalised	2.0

Stress Concentration Factor for the Fillet, k_f

Table 21

Material and Heat Treatment	Addendum Modification Coefficient, X		
	$X < 0$	$0 \leq X \leq 0.1$	$X > 0.2$
Steel, Normalised, Surface Hardened	1.4	1.5	1.6
Steel Case Hardened	1.1	1.2	1.3
Cast Iron	1.2	1.2	1.3

Material	Surface Hardness HB	Life in Number of Cycles, N	k_{bf}
Steel	≤ 350	$\geq 10^7$	1
		$< 10^7$	$\sqrt[9]{\frac{10^7}{N}}$
	> 350	$\geq 25 \times 10^7$	0.7
		$< 25 \times 10^7$	$\sqrt[9]{\frac{10^7}{N}}$
Cast Iron			$\sqrt[9]{\frac{10^7}{N}}$

NOTE:- If the case hardness $HB > 350$ and the core hardness $HB < 350$, then the coefficient k_{bf} is obtained for $HB < 350$.

For non-metallic materials [Nylon, Textolite, Plastic],

$$[\sigma_b] = \frac{\sigma_u}{n} \dots (7.3)$$

σ_u , ultimate tensile strength, kgf/cm²

$n = 2.5$ to 3 , factor of safety.

Table 23

Design Bending Stress for non-metallic materials

Material	$[\sigma_b]$, kgf/cm ²
Textolite	500
Vulcanised Fibre Gears	360
Plastic	600
Bakelite	560

Formulae to check the design for Plastic Deformation or Brittle Crushing

Under Surface Contact Stress

$$\sigma_{c \max} = \sigma_c \sqrt{\frac{(M_t)_{\max}}{M_t}} \leq [\sigma_c]_{\max} \quad \dots(8.1)$$

Table 24

Material	Surface Hardness	$[\sigma_c]_{\max}$, kgf/cm ²
Steel	HB ≤ 350	3.1 σ_y
	HB > 350	420 HRC
Cast Iron	HB ≤ 350	1.8 σ_u

σ_y , yield stress in tension, kgf/cm²

σ_u , ultimate tensile strength, kgf/cm²

HRC, Rockwell 'c' hardness

Under Bending

$$\sigma_{b \max} = \sigma_b \frac{(M_t)_{\max}}{M_t} \leq [\sigma_b]_{\max} \quad \dots(8.2)$$

Table 25

Material	Core Hardness	$[\sigma_b]_{\max}$, kgf/cm ²
Steel	No Heat Treatment HB ≤ 350	0.8 σ_y
	Heat Treated HB ≥ 350	0.36 $\frac{\sigma_u}{k_\sigma}$
Cast Iron	—	0.6 σ_u

M_t , nominal twisting moment on pinion, kgf. cm. Ref. (4.3)

$(M_t)_{\max}$, instantaneous maximum twisting moment, kgf. cm. (starting, braking, sudden stopping etc.)

$(M_t)_{\max} = 2M_t$ can be assumed where $(M_t)_{\max}$ is not known specifically

$\sigma_{c \max}$, max. surface stress due to $(M_t)_{\max}$, kgf/cm²

σ_c , calculated surface stress, kgf/cm², Ref. (1.4) to (1.6)

$[\sigma_c]_{\max}$, max. allowable surface contact, stress to avoid plastic deformation or brittle crushing, table 24

$\sigma_{b \max}$, bending stress due to $(M_t)_{\max}$, kgf/cm²

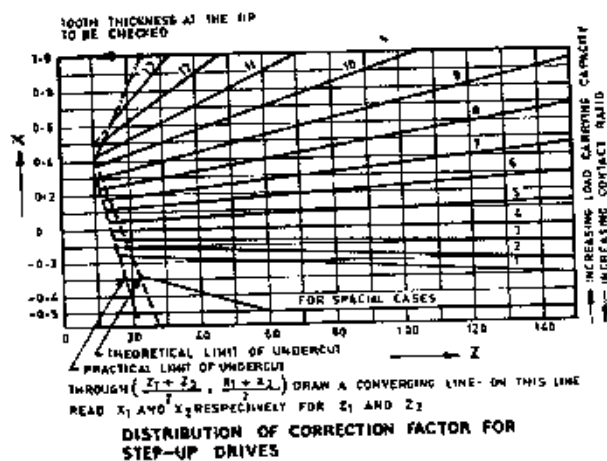
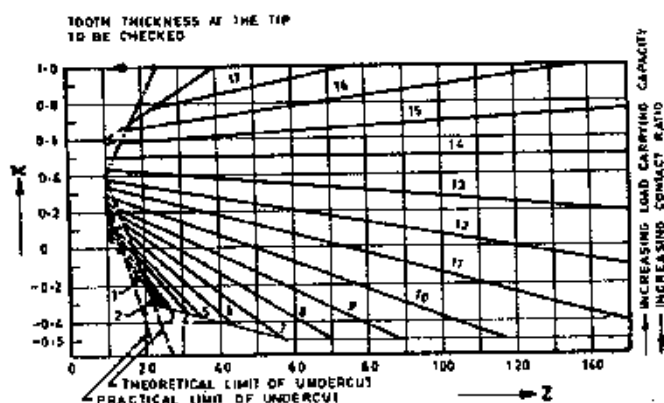
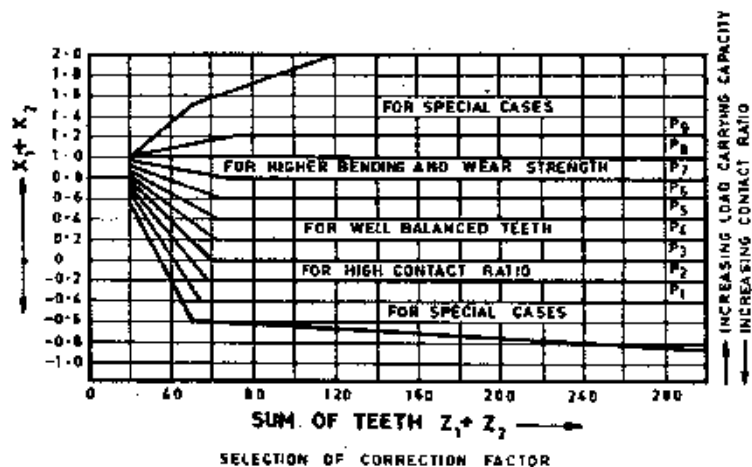
σ_b , calculated bending stress Ref. (2.5) to (2.9) kgf/cm²

$[\sigma_b]_{\max}$, maximum allowable stress to avoid plastic deformation or brittle crushing in bending, table 25

k_σ , stress concentration factor for the fillet, table 21

Basic Dimensions of Externally Meshing Standard Cylindrical Gears
Suffix 1 for Pinion and 2 for Wheel

Nomenclature	Notation	Units	Spur Gears	Helical and Herringbone Gears
Module	m	mm	$m = \frac{2a}{Z_1 + Z_2}$	
Normal module	m_n	mm		$m_n = \frac{2a \cos \beta}{Z_1 + Z_2}$
Transverse module	m_t	mm		$m_t = \frac{m_n}{\cos \beta}; m_t = \frac{2a}{Z_1 + Z_2}$
Centre distance	a	mm	$a = m \frac{Z_1 + Z_2}{2}$	$a = \frac{m_n}{\cos \beta} \frac{Z_1 + Z_2}{2}$
Height factor	f_o	—	$f_o = 1$ (In special cases $f_o = 0.8$, stub teeth)	
Bottom clearance	c	mm	$c = 0.25 m$ (For stub teeth $c = 0.3 m$)	$c = 0.25 m_n$ (For stub teeth $c = 0.3 m_n$)
Tooth depth	h	mm	$h = 2.25 m$ (For stub teeth, $h = 1.9 m$)	$h = 2.25 m_n$ (For stub teeth, $h = 1.9 m_n$)
Pitch diameter or reference diameter	d	mm	$d_1 = m Z_1; d_2 = m Z_2$	$d_1 = \frac{m_n}{\cos \beta} Z_1; d_2 = \frac{m_n}{\cos \beta} Z_2$
Tip diameter	d_a	mm	$d_{a1} = (Z_1 + 2f_o) m$ $d_{a2} = (Z_2 + 2f_o) m$	$d_{a1} = \left(\frac{Z_1}{\cos \beta} + 2f_o \right) m_n$ $d_{a2} = \left(\frac{Z_2}{\cos \beta} + 2f_o \right) m_n$
Root diameter	d_f	mm	$d_{f1} = (Z_1 - 2f_o) m - 2c$ $d_{f2} = (Z_2 - 2f_o) m - 2c$	$d_{f1} = \left(\frac{Z_1}{\cos \beta} - 2f_o \right) m_n - 2c$ $d_{f2} = \left(\frac{Z_2}{\cos \beta} - 2f_o \right) m_n - 2c$
Helix angle	β	deg.		For helical, $\beta = 8^\circ$ to 25° For herringbone, $\beta = 25^\circ$ to 40° $\cos \beta = \frac{m_n (Z_1 + Z_2)}{2a}$
Number of teeth	Z	—	$Z_1 = \frac{2a}{m(i+1)}; Z_2 = i Z_1$	$Z_1 = \frac{2a \cos \beta}{m_n(i+1)}; Z_2 = i Z_1$
Virtual number of teeth	Z_v			$Z_{v1} = \frac{Z_1}{\cos^3 \beta}; Z_{v2} = \frac{Z_2}{\cos^3 \beta}$



Basic Dimensions of Corrected Cylindrical Gears

"S₀ Correction": $X_1 > 0$; $X_2 = -X_1$; $X_1 + X_2 = 0$

Nomenclature Symbol Unit			Cylindrical Gears	
			Spur	Helical and Herringbone
Pinion	Tip diameter	d_{a1} mm	$d_{a1} = m(Z_1 + 2f_o + 2X_1)$	$d_{a1} = m_n \left[\left(\frac{Z_1}{\cos \beta} \right) + 2X_1 + 2f_o \right]$
	Root diameter	d_{f1} mm	$d_{f1} = m(Z_1 - 2f_o + 2X_1) - 2c$	$d_{f1} = m_n \left[\left(\frac{Z_1}{\cos \beta} \right) + 2X_1 - 2f_o \right] - 2C$
Wheel	Tip diameter	d_{a2} mm	$d_{a2} = m(Z_2 + 2f_o + 2X_2)$	$d_{a2} = m_n \left[\left(\frac{Z_2}{\cos \beta} \right) + 2X_2 + 2f_o \right]$
	Root diameter	d_{f2} mm	$d_{f2} = m(Z_2 - 2f_o + 2X_2) - 2c$	$d_{f2} = m_n \left[\left(\frac{Z_2}{\cos \beta} \right) + 2X_2 - 2f_o \right] - 2C$

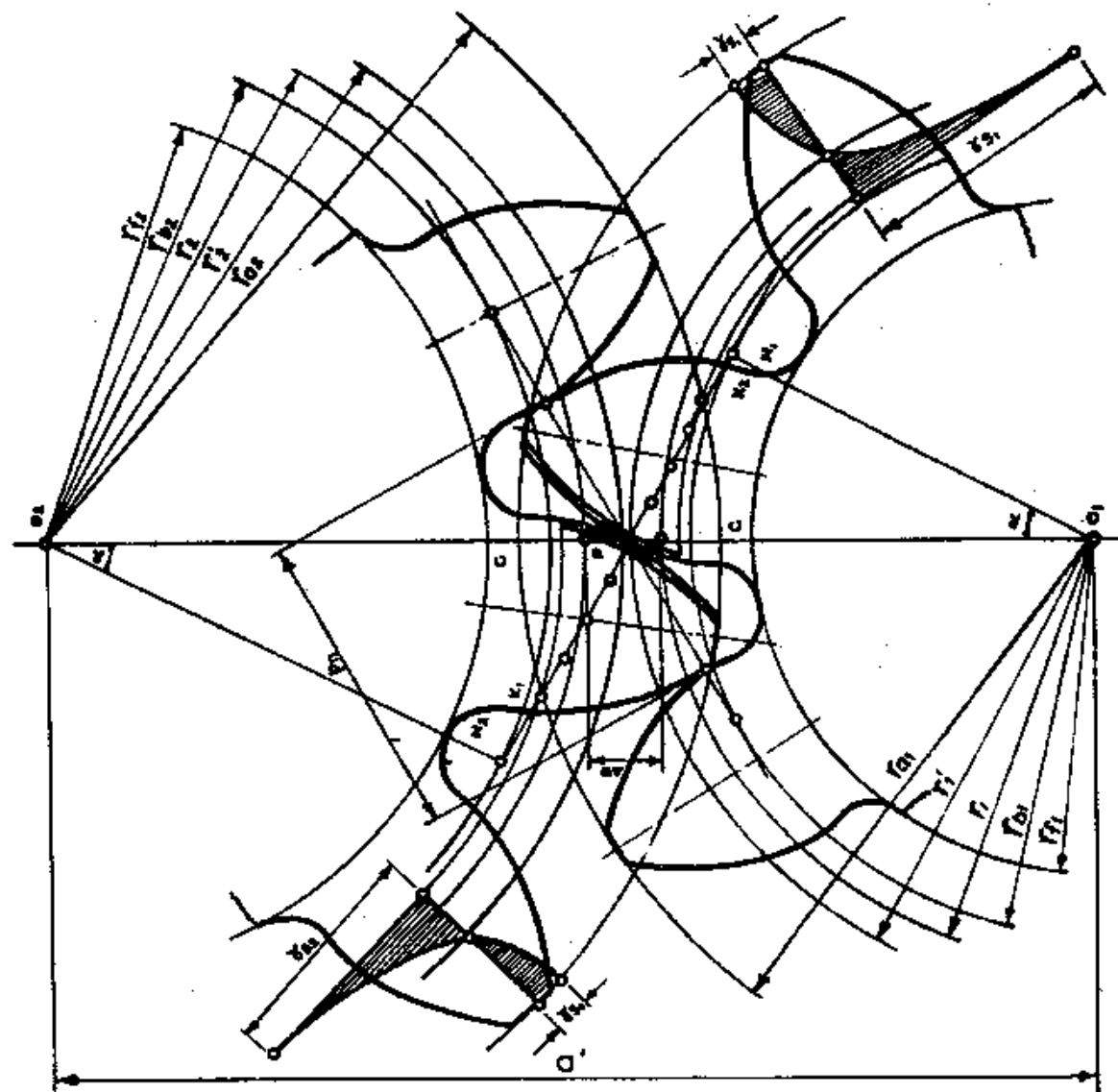
NOTE: All the remaining dimensions as for Cylindrical Gears, Table 26

Table 28

"S Correction": $\sum X = |X_1| + |X_2| \neq 0$ and $f_o = 1$

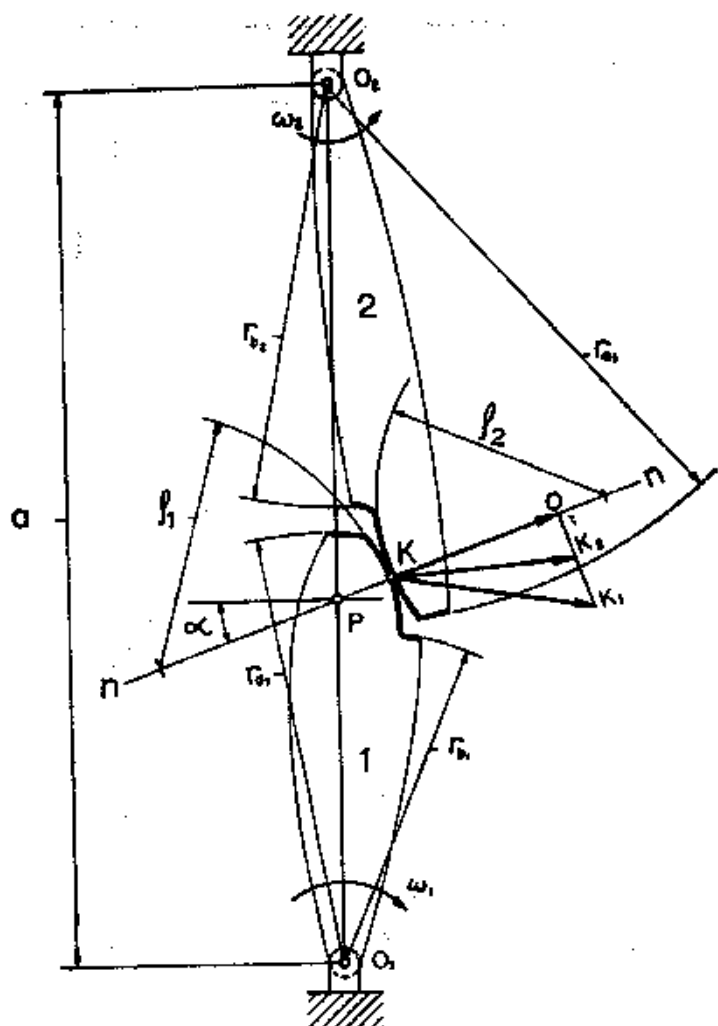
Nomenclature	Symbol	Unit	Formulae
Module	m	mm	IS: 2535—1963, Table 1
Pressure angle of S gear pair	α'	deg.	$\text{Inv. } \alpha' = \theta + 2 \frac{X_1 + X_2}{Z_1 + Z_2} \tan \alpha$, table 29 $\text{Inv } \alpha = \theta = \tan \alpha - \alpha = 0.01490$ radian for $\alpha = 20^\circ$, table 30
Reference cylinder diameter	d	mm	$d_1 = mZ_1$; $d_2 = mZ_2$
Pitch diameter	d'	mm	$d_1' = d_1 \frac{\cos \alpha}{\cos \alpha'}$; $d_2' = d_2 \frac{\cos \alpha}{\cos \alpha'}$
Centre distance of S zero pair	a	mm	$a = \frac{d_1 + d_2}{2}$ $a \cos \alpha = a' \cos \alpha'$
Centre distance of S gear pair	a'	mm	$a' = \frac{d_1' + d_2'}{2}$
Increase of centre distance	Δa	mm	$\Delta a = a' - a$. Check with table 29
Tooth depth	h	mm	$h = h_{f1} + h_{f2} + \Delta a - 0.25 m$
Change of tooth depth	Δh	mm	$\Delta h = 2.25 m - h$. Check with table 29
Dedendum	h_f	mm	$h_{f1} = (1.25 - X_1)m$; $h_{f2} = (1.25 - X_2)m$
Addendum	h_a	mm	$h_{a1} = h - h_{f1}$; $h_{a2} = h - h_{f2}$
Tip diameter	d_a	mm	$d_{a1} = d_1 + 2h_{a1}$; $d_{a2} = d_2 + 2h_{a2}$
Root diameter	d_f	mm	$d_{f1} = d_1 - 2h_{f1}$; $d_{f2} = d_2 - 2h_{f2}$

MESHING OF CORRECTED SPUR GEARS



γ_s , specific sliding

GEAR CHARACTERISTICS



$$OK_1 = v_{11}$$

$$OK_2 = v_{12}$$

$$a \cos \alpha = a' \cos \alpha'$$

Specific sliding, γ ,

$$\gamma_{s1} = \frac{v_{11} - v_{12}}{v_{11}} = 1 - \frac{1}{i'} \frac{\rho_2}{\rho_1} \quad \dots(9.1)$$

$$\gamma_{s2} = \frac{v_{11} - v_{12}}{v_{12}} = 1 - i' \frac{\rho_1}{\rho_2} \quad \dots(9.2)$$

At the beginning of contact,

$$\rho_1 = a \sin \alpha - \rho_2 \quad \dots(9.3)$$

$$\rho_2 = \sqrt{r_{a2}^2 - r_{b2}^2} \quad \dots(9.4)$$

At the end of contact,

$$\rho_1 = \sqrt{r_{a1}^2 - r_{b1}^2} \quad \dots(9.5)$$

$$\rho_2 = a \sin \alpha - \rho_1 \quad \dots(9.6)$$

Contact ratio ϵ

$$\epsilon = \frac{\sqrt{r_{a1}^2 - r_{b1}^2} + \sqrt{r_{a2}^2 - r_{b2}^2} - a \sin \alpha}{\pi m \cos \alpha} \quad \dots(10.1)$$

v_{11} , the velocity component of a point on gear 1, at the point of contact of two mating profiles along a direction perpendicular to the common normal

ρ , radius of curvature of tooth profile at the point of contact

i' , transmission ratio, $\frac{\omega_1}{\omega_2} > 1$

r_a , tip circle radius

r_b , base circle radius

a , centre distance

a' , mounted centre distance

α , pressure angle at reference radius, standard $\alpha = 20^\circ$

α' , pressure angle at pitch radius

m , module

$Z_1 + Z_2$	$X_1 + X_2$	α'	$\frac{\Delta a}{m}$	$\frac{\Delta b}{m}$
16	0.880	30° 12'	0.698	0.181
17	0.836	29° 28'	0.674	0.162
18	0.792	28° 46'	0.648	0.144
19	0.748	28° 07'	0.621	0.127
20	0.704	27° 29'	0.592	0.112
21	0.660	26° 53'	0.563	0.097
22	0.616	26° 19'	0.532	0.084
23	0.572	25° 46'	0.500	0.072
24	0.528	25° 15'	0.467	0.061
25	0.484	24° 44'	0.433	0.051
26	0.440	24° 15'	0.398	0.040
27	0.396	23° 46'	0.362	0.030
28	0.352	23° 19'	0.325	0.026
29	0.308	22° 50'	0.288	0.020
30	0.264	22° 26'	0.249	0.015
31	0.220	22° 00'	0.210	0.010
32	0.176	21° 35'	0.170	0.006
33	0.132	21° 11'	0.128	0.004
34	0.088	20° 47'	0.087	0.001
35	0.044	20° 23'	0.043	0.000
36	0.000	20° 00'	0.000	0.000

*Recommended parameters of S-corrected mating gears, whose total number of teeth is small, but having the following qualities (1) undercutting is completely eliminated & (2) minimum overlap or contact ratio is assured.

Table 30

Involute Functions $\theta = (\tan \alpha) - \alpha$, radian

Minutes	$\alpha = 10^\circ$	$\alpha = 11^\circ$	$\alpha = 12^\circ$	$\alpha = 13^\circ$	$\alpha = 14^\circ$	Minutes
0	0.0017941	0.0023941	0.0031171	0.0039754	0.0049819	0
1	0.0018031	0.0024051	302	909	0.0050000	1
2	122	161	434	0.0040065	182	2
3	213	272	567	221	364	3
4	305	383	699	377	546	4
5	397	495	832	534	729	5
6	489	607	966	692	912	6
7	581	719	0.0032100	849	0.0051096	7
8	674	831	234	0.0041008	280	8
9	767	944	369	166	465	9
10	860	0.0025057	504	325	650	10
11	0.0018954	0.0025171	0.0032639	0.0041485	0.0051835	11
12	0.0019048	285	775	644	0.0052022	12
13	142	399	911	805	208	13
14	237	513	0.0033048	965	395	14
15	332	628	185	0.0042126	582	15
16	427	744	322	288	770	16
17	523	859	460	450	958	17
18	619	975	598	612	0.0053147	18
19	715	0.0026091	736	775	334	19
20	812	208	875	938	526	20
21	0.0019909	0.0026325	0.0034014	0.0043102	0.0053716	21
22	0.0020006	443	154	266	907	22
23	103	560	294	430	0.0054098	23
24	201	678	434	595	290	24
25	299	797	575	760	482	25
26	398	916	716	926	674	26
27	497	0.0027035	858	0.0044092	867	27
28	596	154	0.0035000	259	0.0055060	28
29	695	274	142	426	254	29
30	795	394	285	593	448	30
31	0.0020895	0.0027515	0.0035428	0.0044761	0.0055643	31
32	995	636	572	929	838	32
33	0.0021096	757	716	0.0045098	0.0056034	33
34	197	879	860	267	230	34
35	299	0.0028001	0.0036005	437	427	35
36	400	123	150	607	624	36
37	502	246	296	777	822	37
38	605	369	441	948	0.0057020	38
39	707	493	588	0.0046120	218	39
40	810	616	735	291	417	40
41	0.0021914	0.0028741	0.0036882	0.0046464	0.0057617	41
42	0.0022017	865	0.0037029	636	817	42
43	121	990	177	809	0.0058017	43
44	226	0.0029115	326	983	218	44
45	330	241	474	0.0047157	420	45
46	435	367	623	331	622	46
47	541	494	773	506	824	47
48	647	620	923	681	0.0059028	48
49	753	747	0.0038073	857	230	49
50	859	875	224	0.0048033	434	50
51	0.0022966	0.0030003	0.0038375	0.0048210	0.0059638	51
52	0.0023073	131	527	387	843	52
53	180	260	678	564	0.0060048	53
54	288	389	831	742	254	54
55	396	518	984	921	460	55
56	504	648	0.0039137	0.0049099	667	56
57	613	778	291	279	874	57
58	722	908	445	458	0.0061081	58
59	831	0.0031039	599	639	289	59
60	0.0023941	0.0031171	0.0039754	0.0049819	0.0061498	60

Involute functions $\theta = (\tan \alpha) - \alpha$, radian (Contd.)

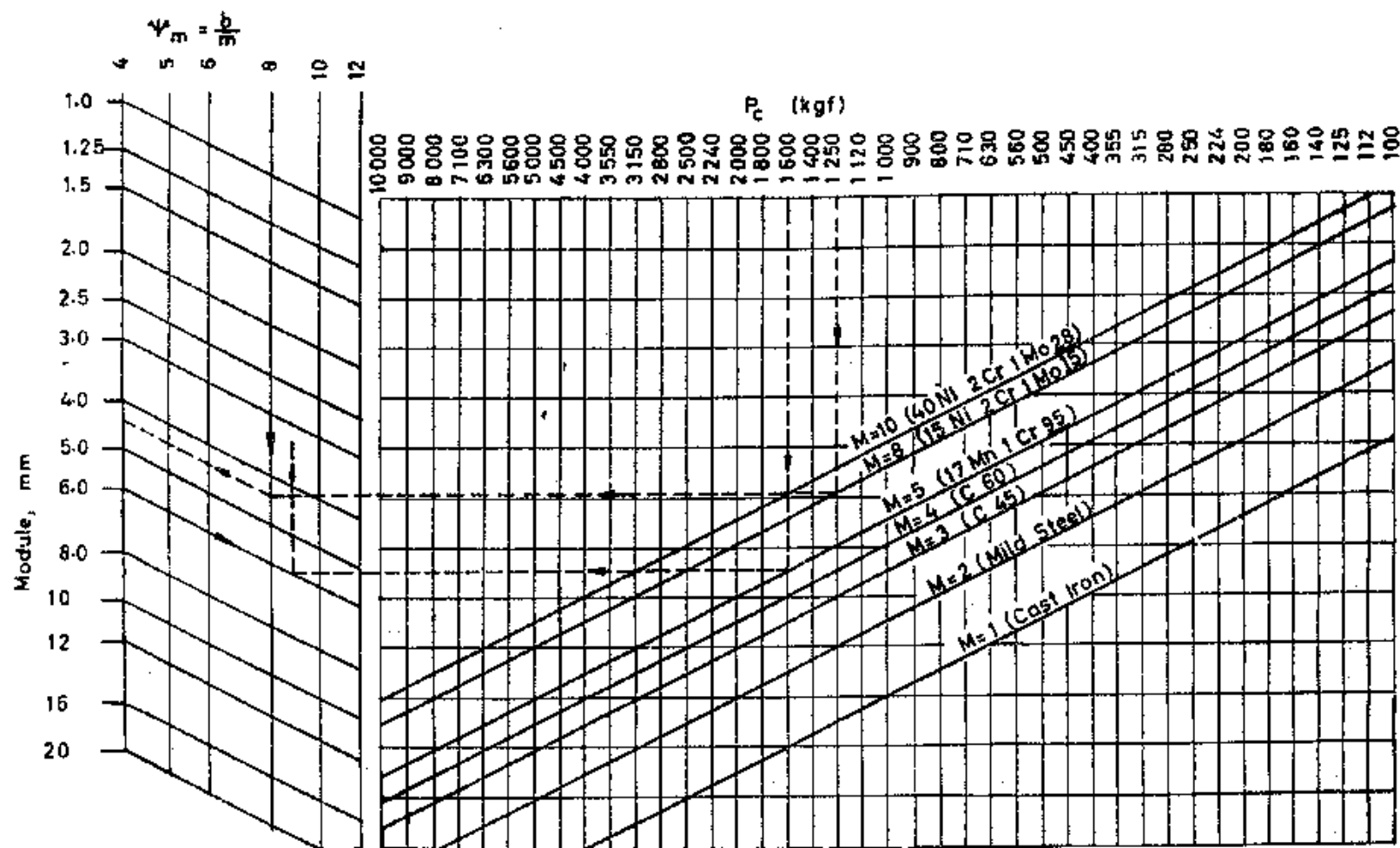
Minutes	$\alpha = 15^\circ$	$\alpha = 16^\circ$	$\alpha = 17^\circ$	$\alpha = 18^\circ$	Minutes
0	0.0061498	0.007493	0.009025	0.010760	0
1	707	517	052	791	1
2	917	541	079	822	2
3	0.0062127	565	107	853	3
4	337	589	134	884	4
5	548	613	161	915	5
6	760	637	189	946	6
7	972	661	216	977	7
8	0.0063184	686	244	0.011008	8
9	397	710	272	039	9
10	611	735	299	071	10
11	0.0063825	0.007759	0.009327	0.011102	11
12	0.0064039	784	355	133	12
13	254	808	383	165	13
14	470	833	411	196	14
15	686	857	439	228	15
16	902	882	467	260	16
17	0.0065119	907	495	291	17
18	337	932	523	323	18
19	555	957	552	355	19
20	773	982	580	387	20
21	0.0065992	0.008007	0.009608	0.011419	21
22	0.0066211	032	637	451	22
23	431	057	665	483	23
24	652	082	694	515	24
25	873	107	722	547	25
26	0.0067094	133	751	580	26
27	316	158	780	612	27
28	539	183	808	644	28
29	762	209	837	677	29
30	985	234	866	709	30
31	0.0068209	0.008260	0.009895	0.011742	31
32	434	285	924	775	32
33	659	311	953	807	33
34	884	337	982	840	34
35	0.0069110	362	0.010012	873	35
36	337	388	041	906	36
37	564	414	070	939	37
38	791	440	099	972	38
39	0.0070019	466	129	0.012005	39
40	248	492	158	038	40
41	0.0070477	0.008518	0.010188	0.012071	41
42	706	544	217	105	42
43	936	571	247	138	43
44	0.0071167	597	277	172	44
45	398	623	307	205	45
46	630	650	336	239	46
47	862	676	366	272	47
48	0.0072095	702	396	306	48
49	328	729	426	340	49
50	561	756	456	373	50
51	0.0072796	0.008782	0.010486	0.012407	51
52	0.0073030	809	517	441	52
53	266	836	547	475	53
54	501	863	577	509	54
55	738	889	608	543	55
56	975	916	638	578	56
57	0.0074212	943	669	612	57
58	450	970	699	646	58
59	688	998	730	681	59
60	0.0074927	0.009025	0.010760	0.012715	60

Involute functions $\theta = (\tan \alpha) - \alpha$, radian (Contd.)

Minutes	$\alpha = 19^\circ$	$\alpha = 20^\circ$	$\alpha = 21^\circ$	$\alpha = 22^\circ$	$\alpha = 23^\circ$	Minutes
0	0.012715	0.014904	0.017345	0.020054	0.023049	0
1	750	943	388	101	102	1
2	784	982	431	149	154	2
3	819	0.015020	474	197	207	3
4	854	059	517	244	259	4
5	888	098	560	292	312	5
6	923	137	603	340	365	6
7	958	176	647	388	418	7
8	993	215	690	436	471	8
9	0.013028	254	734	484	524	9
10	063	293	777	533	577	10
11	0.013098	0.015333	0.017821	0.020581	0.023631	11
12	134	372	865	629	684	12
13	169	411	908	678	738	13
14	204	451	952	726	791	14
15	240	490	996	775	845	15
16	275	530	0.018040	824	899	16
17	311	570	084	873	952	17
18	346	609	129	921	0.024006	18
19	382	649	173	970	060	19
20	418	689	217	0.021019	114	20
21	0.013454	0.015729	0.018262	0.021069	0.024169	21
22	490	769	306	118	223	22
23	526	809	351	167	277	23
24	562	850	395	217	332	24
25	598	890	440	266	386	25
26	634	930	485	316	441	26
27	670	971	530	365	495	27
28	707	0.016011	575	415	550	28
29	743	052	620	465	605	29
30	779	092	665	514	660	30
31	0.013816	0.016133	0.018710	0.021564	0.024715	31
32	852	174	755	614	770	32
33	889	215	800	665	825	33
34	926	255	846	715	881	34
35	963	296	891	765	936	35
36	999	337	937	815	992	36
37	0.014036	379	983	866	0.025047	37
38	073	420	0.019028	916	103	38
39	110	461	074	967	159	39
40	148	502	120	0.022018	214	40
41	0.014185	0.016544	0.019166	0.022068	0.025270	41
42	222	585	212	119	326	42
43	259	627	258	170	382	43
44	297	669	304	221	439	44
45	334	710	350	272	495	45
46	372	752	397	324	551	46
47	409	794	443	375	608	47
48	447	836	490	426	664	48
49	485	878	536	478	721	49
50	523	920	583	529	777	50
51	0.014560	0.016962	0.019630	0.022581	0.025834	51
52	598	0.017004	676	633	891	52
53	636	047	723	684	948	53
54	674	089	770	736	0.026005	54
55	713	132	817	788	062	55
56	751	174	864	840	120	56
57	789	217	912	892	177	57
58	827	259	959	944	235	58
59	866	302	0.020007	997	292	59
60	0.014904	0.017345	0.020054	0.023049	0.026350	60

Involute functions $\theta = (\tan \alpha) - \alpha$, radian (Contd.)

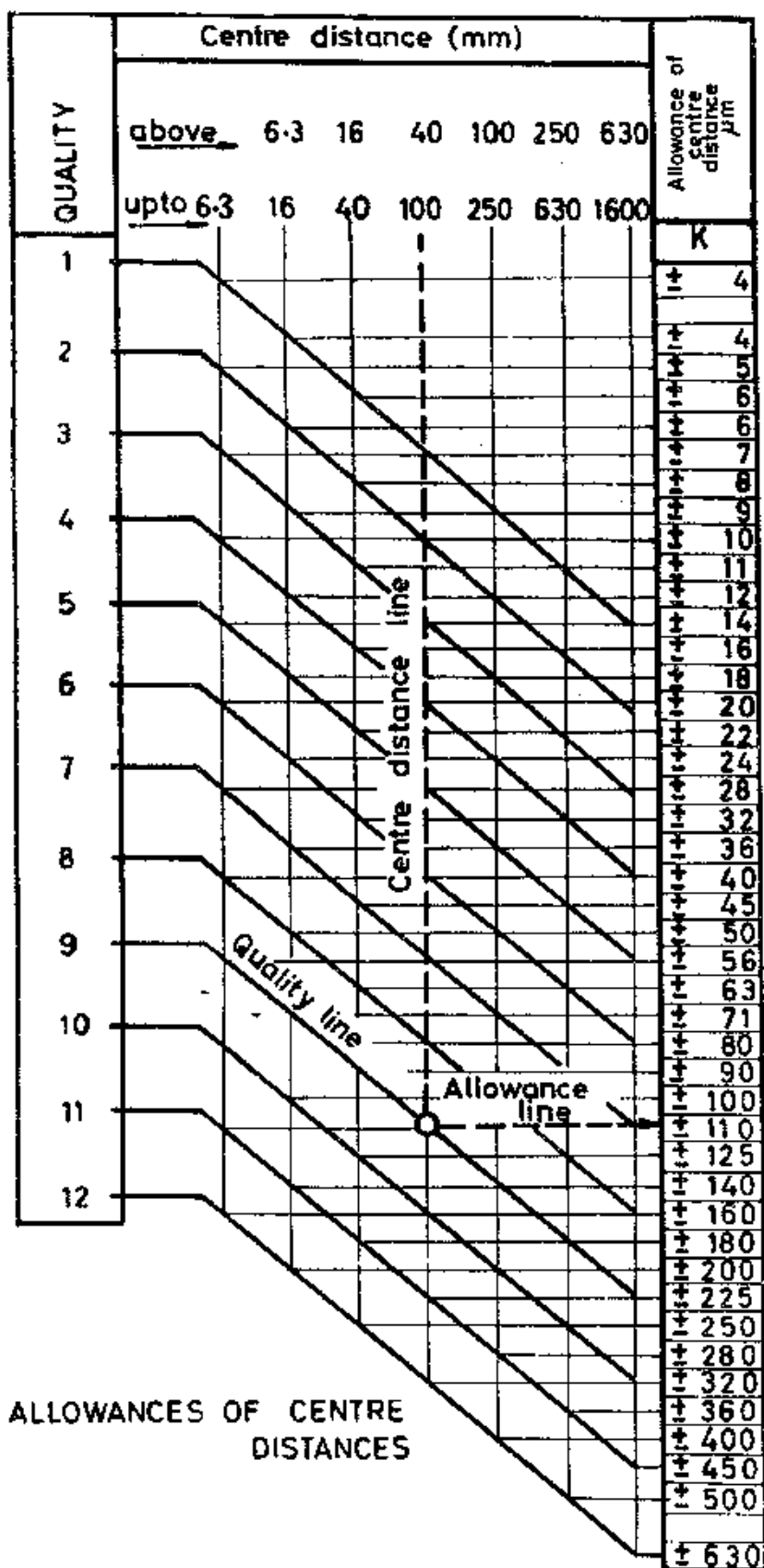
Minutes	$\alpha = 24^\circ$	$\alpha = 25^\circ$	$\alpha = 26^\circ$	$\alpha = 27^\circ$	Minutes
0	0.026350	0.029975	0.033947	0.038287	0
1	407	0.030039	0.034016	362	1
2	465	102	086	438	2
3	523	166	155	514	3
4	581	229	225	590	4
5	639	293	294	666	5
6	697	357	364	742	6
7	756	420	434	818	7
8	814	484	504	894	8
9	872	549	574	971	9
10	931	613	644	0.039047	10
11	0.026989	0.030677	0.034714	0.039124	11
12	0.027048	741	785	201	12
13	107	806	855	278	13
14	166	870	926	355	14
15	225	935	997	432	15
16	284	0.031000	0.035067	509	16
17	343	065	138	586	17
18	402	130	209	664	18
19	462	195	280	741	19
20	521	260	352	819	20
21	0.027581	0.031325	0.035423	0.039897	21
22	640	390	494	974	22
23	700	456	566	0.040052	23
24	760	521	637	131	24
25	820	587	709	209	25
26	880	653	781	287	26
27	940	718	853	366	27
28	0.028000	784	925	444	28
29	060	850	997	523	29
30	121	917	0.036069	602	30
31	0.028181	0.031983	0.036142	0.040680	31
32	242	0.032049	214	759	32
33	302	116	287	839	33
34	363	182	359	918	34
35	424	249	432	997	35
36	485	315	505	0.041076	36
37	546	382	578	156	37
38	607	449	651	236	38
39	668	516	724	316	39
40	729	583	798	395	40
41	0.028791	0.032651	0.036871	0.041475	41
42	852	718	945	556	42
43	914	785	0.037018	636	43
44	976	853	092	716	44
45	0.029037	920	166	797	45
46	099	988	240	877	46
47	161	0.033056	314	958	47
48	223	124	388	0.042039	48
49	285	192	462	120	49
50	348	260	537	201	50
51	0.029410	0.033328	0.037611	0.042282	51
52	472	397	686	363	52
53	535	465	761	444	53
54	598	534	835	526	54
55	660	602	910	607	55
56	723	671	985	689	56
57	786	740	0.038060	771	57
58	849	809	136	853	58
59	912	878	211	935	59
60	0.029975	0.033947	0.038287	0.043017	60



m = module, mm P_c = Circumferential force (kgf) M = Material constant, b = Face width, mm

$$m = \sqrt{\frac{P_c}{\psi_m M}} ; \quad \psi_m = \frac{b}{m}$$

SELECTION OF MODULE & FACE WIDTH OF SPUR GEARS



ALLOWABLE ERRORS FOR SPUR AND HELICAL GEARS (in microns)

NEEDLE BEARINGS FOR SPINDLE AND TURRET GEARS (in fractions)																			
Pitch diameter, mm																			
Above Upto		12 25		25 50		50 100		100 200		200 400		400 800							
Module, mm																			
Above Upto		0.5 1.6	1.6 4.0	0.6 1.6	1.6 4.0	4.0 10	0.6 1.6	1.6 4.0	4.0 10	0.6 1.6	1.6 4.0	4.0 10	0.6 1.6	1.6 4.0	4.0 10	0.6 1.6	1.6 4.0	4.0 10	
Quality	Error																		
5	f_t, f_a, f_r	4	4.5	4.5	5	6	5	5.5	7	5.5	6	8	7	7	9	8	9	10	
	F_t	14	16	16	18	22	18	20	25	20	22	25	25	25	32	28	32	36	
	f_r	12	14	14	16	18	16	18	20	18	20	22	20	22	25	22	25	28	
6	f_t, f_a, f_r	6	6	6	7	9	7	8	10	8	9	11	9	10	12	11	12	14	
	F_t	20	22	22	25	28	25	28	32	28	32	36	36	36	40	40	45	50	
	f_r	18	20	20	22	25	22	25	28	25	28	32	28	32	36	32	36	40	
7	f_t, f_a, f_r	8	9	9	10	12	10	11	14	11	12	16	12	14	18	16	18	20	
	F_t	28	32	32	36	40	36	40	45	40	45	50	50	50	63	63	63	71	
	f_r	25	28	28	32	36	32	36	40	36	40	45	40	45	50	45	50	56	
8	f_t, f_a, f_r	11	12	12	14	18	14	16	20	16	18	22	18	20	25	22	25	28	
	F_t	40	45	45	50	63	50	56	63	56	63	71	71	71	80	80	90	100	
	f_r	36	40	40	45	50	45	50	56	50	56	63	56	63	71	63	71	80	
9	f_t, f_a, f_r	16	18	18	20	25	20	22	28	22	25	32	25	28	36	32	36	40	
	F_t	56	63	63	71	80	71	80	90	80	90	100	100	100	125	125	126	140	
	f_r	50	56	56	63	71	63	71	80	71	80	90	80	90	100	90	100	110	
10	f_t, f_a, f_r	25	28	28	32	40	32	36	45	36	40	50	40	45	56	50	56	63	
	F_t	90	100	100	110	140	110	125	140	125	140	160	160	160	180	180	200	220	
	f_r	71	80	80	90	100	90	100	110	100	110	125	110	125	140	125	140	160	

f_t = involute profile error f_a = error in adjacent pitches f_r = radial run out
 f_b = base pitch error F_t = cumulative pitch error

Note :-

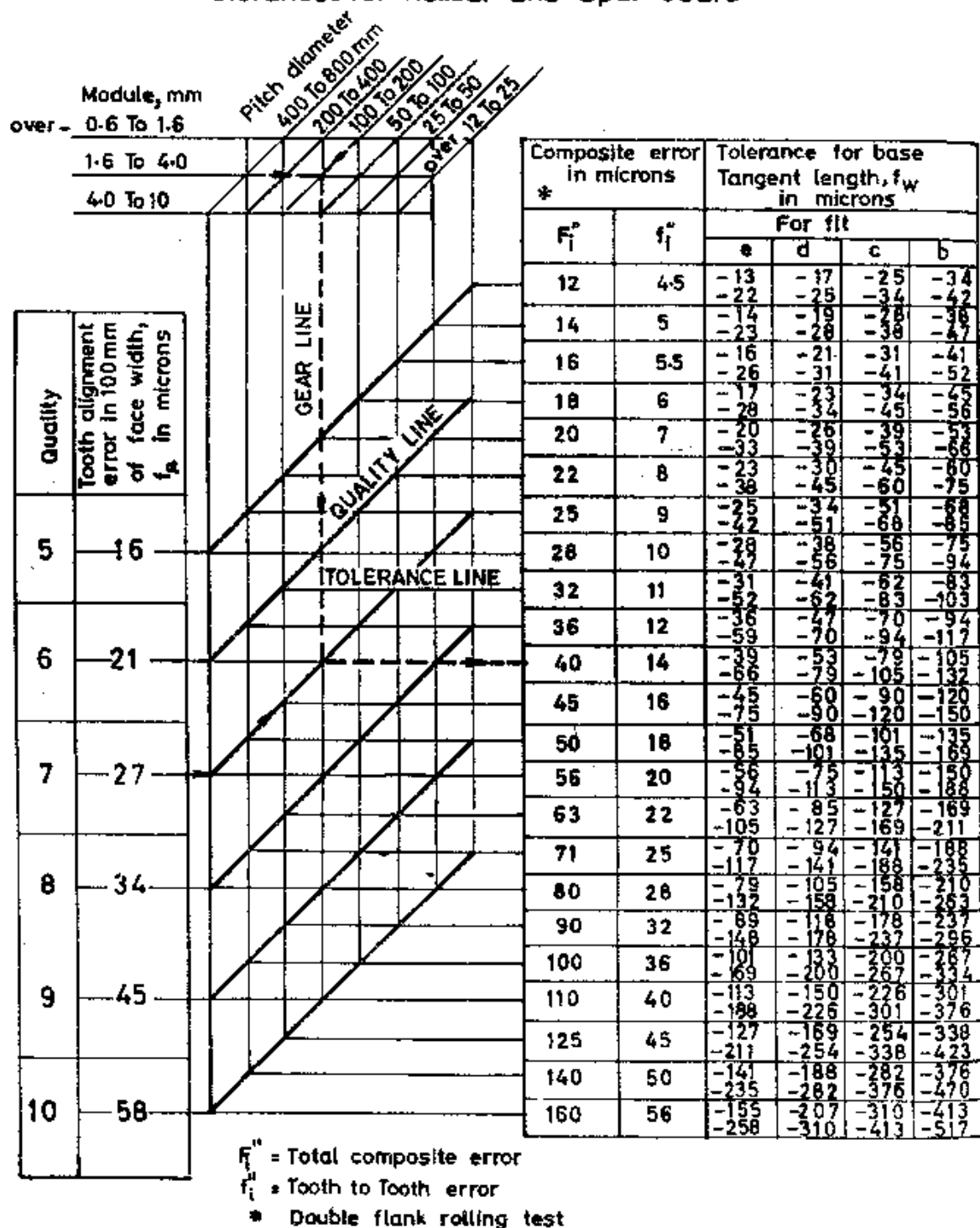
For helical gears, specify tooth alignment error, f_b , instead of involute profile error, f_t . Also, multiply the value of the radial run out f_r , by the factor

$$L = \frac{\tan 20^\circ}{\tan \alpha_t}, \text{ where } \alpha_t = \text{the transverse pressure angle} = \arcsin(\tan \alpha_n \times \sec \beta)$$

α_n = Normal pressure angle

β = Helix angle

Tolerances for Helical and Spur Gears



Note: For base tangent length of machine tool gears, the top value of fit b as upper limit and the bottom value of fit c as lower limit may be specified. For helical gears F_t' should be multiplied by the factor $L = \frac{\tan 20^\circ}{\tan \alpha_1}$, where $\tan \alpha_1 = \tan \alpha_n \sec \beta$

BASE TANGENT LENGTH : W_k in mm

for SPUR GEAR :

$$W_k = (f_1 + f_2 \pm f_3) m$$

where $f_1 = \pi (k - 0.5) \cos \alpha$

$$f_2 = Z \operatorname{Inv} \alpha \cos \alpha$$

$$\pm f_3 = \pm 2X \sin \alpha$$

m , module in mm

k , number of teeth to be spanned from Chart below

X , $\pm$ correction factor for corrected gears

For $\alpha = 20^\circ$,

$$f_1 = 2.9521 (k - 0.5)$$

$$f_2 = 0.014 Z$$

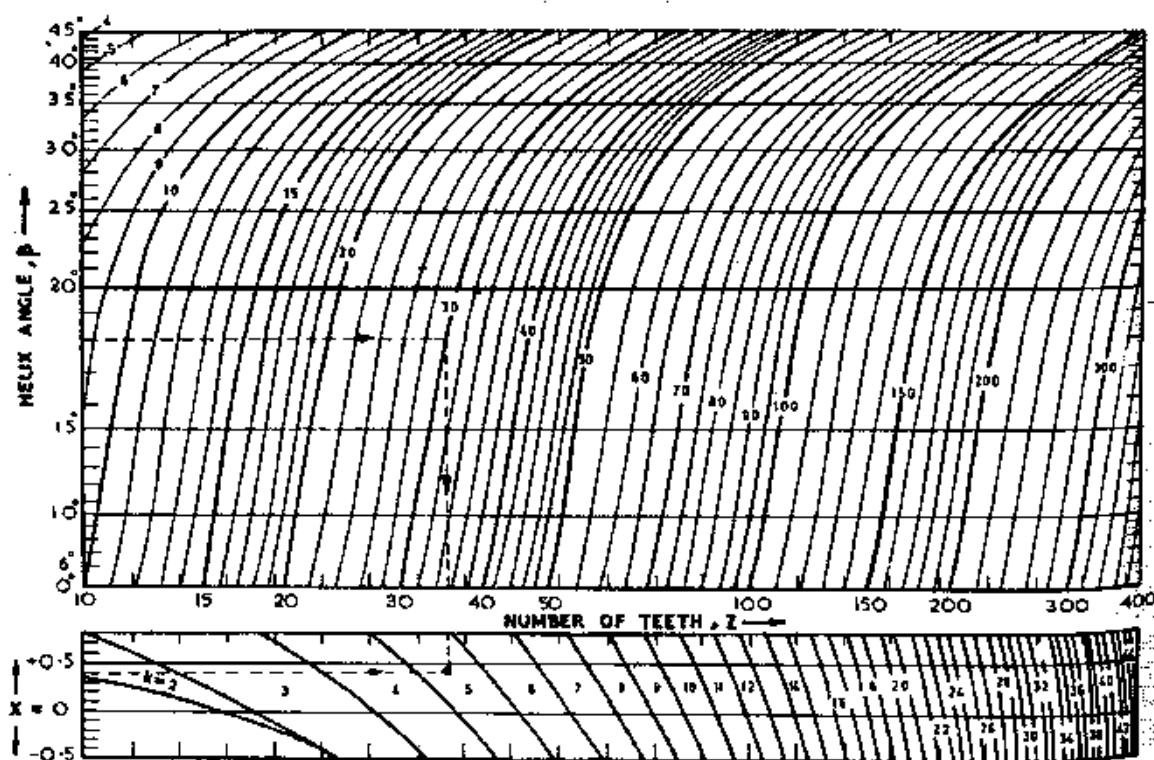
$$f_3 = 0.684 X$$

for HELICAL GEAR :

$$W_k = (f_1 + f_2' \pm f_3) m \quad \alpha_t = \tan^{-1} \left[\frac{\tan \alpha}{\cos \beta} \right]$$

where $f_2' = Z \operatorname{Inv} \alpha_t \cos \alpha$ β = helix angle

NUMBER OF TEETH k TO BE SPANNED FOR
BASE TANGENT LENGTH MEASUREMENT FOR
SPUR & HELICAL GEARS, $\alpha = 20^\circ$



EXAMPLE : $Z=30, \beta=18^\circ, X=+0.4, k=5$

NOMENCLATURE OF STANDARD BEVEL GEARS

$$\Sigma = 90^\circ$$

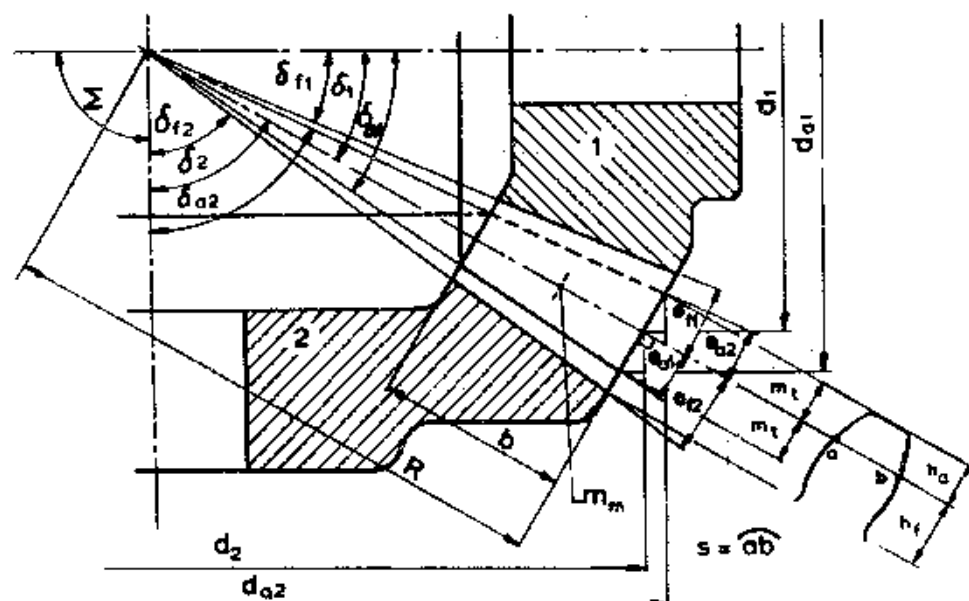


TABLE 31

Nomenclature	Symbol	Formulae for straight and spiral bevel gears
transverse module	m_t	$m_t = m_m \frac{\psi_y}{\psi_y - 0.5} = m_m + \frac{b \sin \delta}{Z}$
mean module	m_m	
normal module	m_n	$m_n = m_t \cos \beta_m$
Cone distance	R	$R = 0.5 m_t Z_1 \sqrt{i^2 + 1} = 0.5 m_t \sqrt{Z_1^2 + Z_2^2}$ $= \frac{m_t Z_1}{2 \sin \delta_1} = \frac{m_t Z_2}{2 \sin \delta_2}$
Reference diam	d	$d_1 = m_t Z_1$; $d_2 = m_t Z_2$ For spiral bevel see chart, p 8.40
tip diameter	d_a	$d_{a1} = m_t (Z_1 + 2 \cos \delta_1)$; $d_{a2} = m_t (Z_2 + 2 \cos \delta_2)$
face width	b	$b \approx 0.3 R$ or $10 m_t$ whichever is smaller For spiral bevel, see chart, p 8.40
number of teeth	Z	Z_1, Z_2 ; $Z_2 = i Z_1$ For spiral bevel, see chart, p 8.40
number of teeth on crown wheel	Z_{cw}	$Z_{cw} = \frac{2 R}{m_t}$
minimum number of teeth on pinion to avoid undercutting	Z_u	$Z_u = \frac{2 X \cos \delta}{\sin^2 \alpha}$; ($X = 1$, for uncorrected gears)
pressure angle	α	$\alpha = 20^\circ$ usually

Nomenclature

Symbol

Formulae for straight and spiral bevel gears.

mean spiral angle β_m β_m usually 30 to 35°; 35° preferred.
= 0 for ZEROL BEVEL

$$\Psi_T \quad \Psi_T = \frac{R}{b}; \text{ also refer table 13}$$

Reference angle δ $\tan \delta = i$; $\delta_1 = 90^\circ - \delta_2$

addendum angle θ_a $\tan \theta_{a1} = \tan \theta_{a2} = \frac{m_t f_o}{R}$

dedendum angle θ_d $\tan \theta_{d1} = \tan \theta_{d2} = \frac{m_t (f_o + c)}{R}$

height factor f_o $c = 0.2$; $f_o = 1$; standards

clearance c

tip angle δ_a $\delta_a = \delta + \theta_a$

root angle δ_f $\delta_f = \delta - \theta_f$

STRAIGHT BEVEL

SPIRAL BEVEL

tooth height h $h = h_a + h_f$

$$h = 1.88 m_t \text{ (for } \alpha = 20^\circ)$$

working depth h_w $h_w = 2 m_t$

$$h_w = 1.7 m_t \text{ (for } \alpha = 20^\circ)$$

addendum h_a $h_a = m_t$

$$h_{a1} = h_w - h_{a2}$$

$$h_{a2} = m_t C_a$$

Select C_a from Table 31a.

dedendum h_f $h_f = 1.1236 m_t$ (Reinecker)

$$= 1.67 m_t \text{ (AEG)}$$

$$= 1.88 m_t \text{ (Gleason)}$$

$$h_{f1} = h - h_{a1}$$

$$h_{f2} = h - h_{a2}$$

Circular tooth thickness S $S_1 = \pi m_t - S_2$

$$S_1 = \pi m_t - S_2$$

$$S_2 = \frac{\pi m_t}{2} - (h_{a1} - h_{a2}) \tan \alpha + K m_t$$

$$S_2 = \frac{\pi m_t}{2} - 1.22 (h_{a1} - h_{a2}) \tan \alpha - K_a m_t$$

Select K from table 31b

Select K_a from chart, p. 8.42

Virtual number of teeth Z_v $Z_v = \frac{Z}{\cos \delta}$

$$Z_v = \frac{Z}{\cos \delta \cos^2 \beta_m}$$

$$Z_{v \min} = 18 \text{ for } \alpha = 20^\circ \text{ and } f_o = 1$$

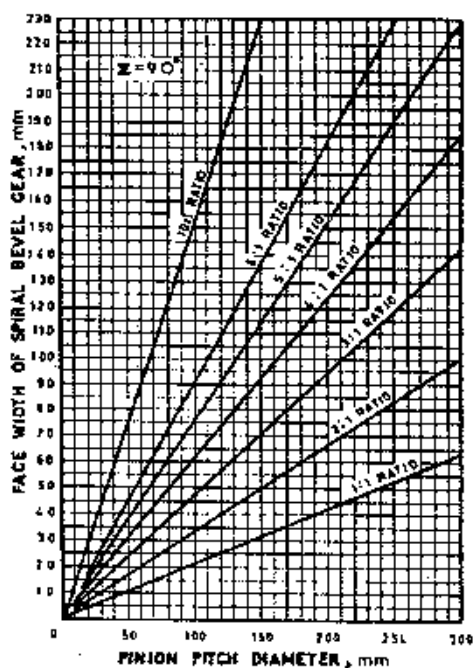
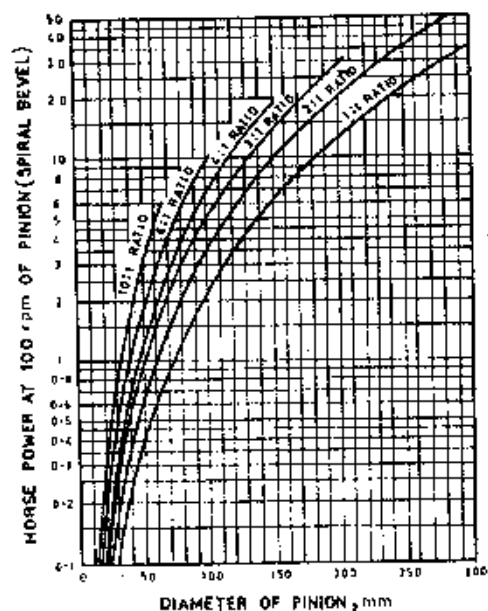
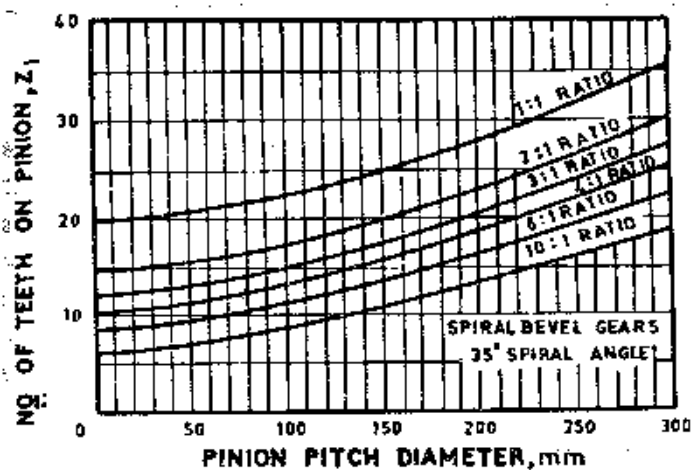
face contact ratio ϵ_f

$$\epsilon_f = \frac{b R \tan \beta_m}{\pi m_t (R - 0.5 b)}$$

corrected gear

usually S_o correction is applied.
To avoid undercutting the
correction factor

$$X_{ou} = 1 - \frac{2 f_o \cos \delta_1}{Z_1 \sin^2 \alpha}$$

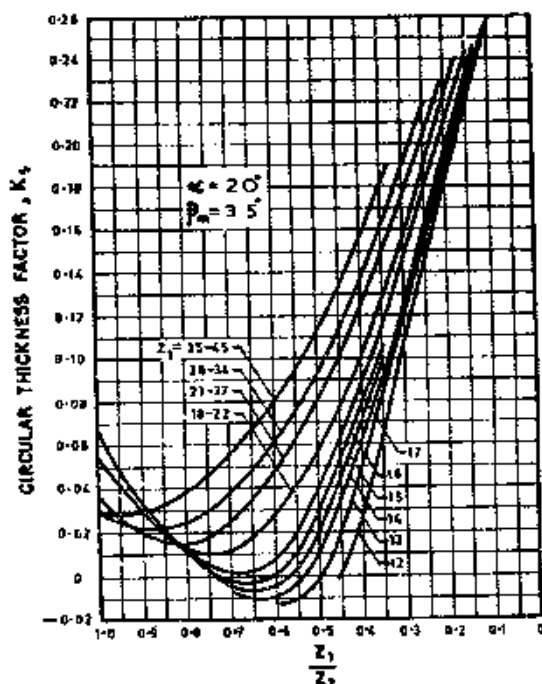


VALUES OF C_a FOR SPIRAL BEVEL GEARS: Table 31 a.For $i = 1$, $C_a = 0.85$ Values of C_a , for other ranges of gear ratio i , decrease in steps of 0.01 for the following ranges, from 0.85

1 — 1.02;	1.02 — 1.03;	1.03 — 1.05;	1.05 — 1.06;	1.06 — 1.08
1.08 — 1.09;	1.09 — 1.11;	1.11 — 1.13;	1.13 — 1.15;	1.15 — 1.17
1.17 — 1.19;	1.19 — 1.21;	1.21 — 1.23;	1.23 — 1.26;	1.26 — 1.28
1.28 — 1.31;	1.31 — 1.34;	1.34 — 1.37;	1.37 — 1.41;	1.41 — 1.44
1.44 — 1.48;	1.48 — 1.52;	1.52 — 1.57;	1.57 — 1.63;	1.63 — 1.68
1.68 — 1.75;	1.75 — 1.82;	1.82 — 1.90;	1.90 — 1.99;	1.99 — 2.10
2.10 — 2.23;	2.23 — 2.38;	2.38 — 2.58;	2.58 — 2.82;	2.82 — 3.17
3.17 — 3.67;	3.67 — 4.56;	4.56 — 7.0;	7.0 to ∞	

VALUES OF K FOR STRAIGHT BEVEL GEARS: Table 31 b

Gear ratios, i	Number of teeth on pinion, Z_1					
	13—14	15—16	17—21	22—26	27—35	36—45
1—1.02		0.0	0.0	0.0	0.0	0.0
1.02—1.075		+0.02	+0.03	+0.015	+0.015	+0.01
1.075—1.14		+0.035	+0.035	+0.03	+0.025	+0.02
1.14—1.26		+0.055	+0.05	+0.045	+0.04	+0.03
1.26—1.855	+0.075	+0.07	+0.07	+0.06	+0.05	+0.04
1.855—2.25	+0.06	+0.06	+0.06	+0.05	+0.04	+0.03
2.25—2.645	+0.04	+0.045	+0.045	+0.035	+0.03	
2.645—3.105	+0.02	+0.025	+0.025	+0.02	+0.015	
3.105—3.65	+0.005	+0.01	+0.01	+0.005	+0.00	
3.65—4.35	—0.015	—0.01	—0.005	—0.005	—0.01	
4.35—5.21	—0.035	—0.03	—0.025	—0.025	—0.03	
5.21—6.25	—0.05	—0.045	—0.04	—0.04	—0.045	
6.25—7.58	—0.07	—0.065	—0.06	—0.06	—0.06	
7.58—9.35	—0.09	—0.08	—0.075	—0.075	—0.075	
9.35—11.5	—0.11	—0.1	—0.095	—0.095	—0.095	



VALUES OF FACE CONTACT RATIO ϵ_f FOR SPIRAL BEVEL GEARS

$$\left(\beta_m = 35^\circ; \frac{b}{R} = 0.3 \right)$$

Table 31c

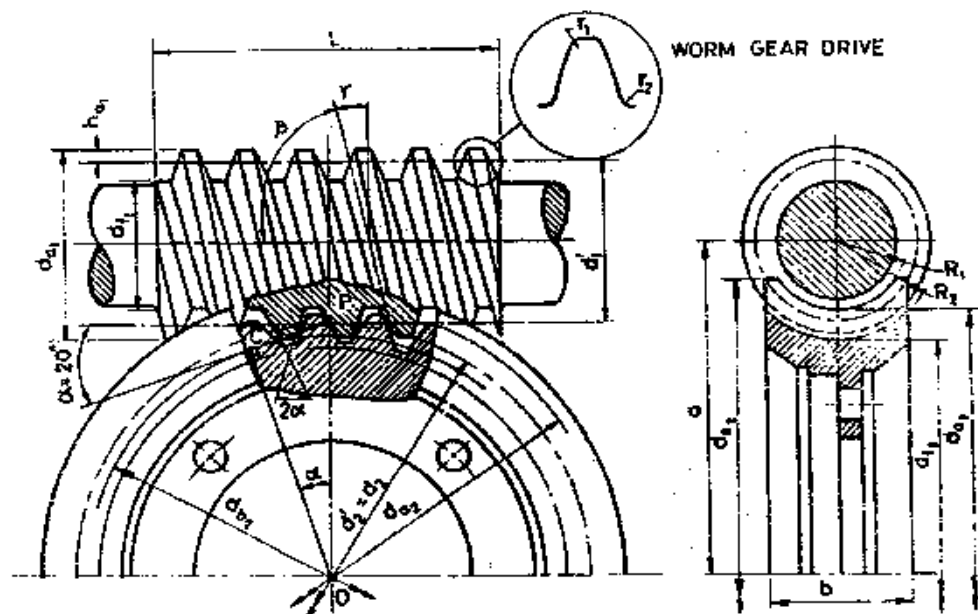
b m_t	4	5	6	7	8	9	10	11
ϵ_f	1.05	1.31	1.57	1.84	2.09	2.36	2.62	2.89

* ϵ_f should be greater than 1.25 and is usually kept equal to a value around 2.

RECOMMENDED BACKLASH FOR STRAIGHT BEVEL GEARS

Table 31d

module m_t	over to	1.25 2.5	2.5 3.5	3.5 4.5	4.5 5	5 6.5	6.5 7	7 8	8 10	10 12	12 14	14
backlash mm	0.025 to 0.075	0.05 to 0.1	0.075 to 0.125	0.1 to 0.15	0.15 to 0.175	0.15 to 0.2	0.175 to 0.225	0.2 to 0.275	0.25 to 0.325	0.3 to 0.4	0.35 to 0.45	0.4 to 0.55



BASIC DIMENSIONS OF WORM GEAR PAIR

Tab. 35

Nomenclature	Symbol	Formulae	Nomenclature	Symbol	Formulae
Centre distance	a	$a = 0.5m_x (q + z + 2x)$	WORM		
Face width of wheel	b	From table 38	Reference diameter	d_1	$d_1 = qm_x$
Length of worm	L	From table 39	Tip diameter	d_{a1}	$d_{a1} = d_1 + 2f_o m_x$
Axial module	m_x	$m_x = \frac{2a}{q + z + 2x}$	Root diameter	d_{f1}	$d_{f1} = d_1 - 2f_o m_x - 2c$
Number of starts	Z	Determined by calculation	Pitch diameter	d_1'	$d_1' = m_x (q + 2x)$
Number of teeth on wheel	z	$z = iZ$	WORM WHEEL		
Gear ratio	i	$i = \frac{z}{Z}$	(In axial section)		
Diameter factor	q	$q = \frac{d_1}{m_x}$	Reference diameter	d_2	$d_2 = \pi m_x$
Height factor	f_o	Normally $f_o = 1$	Tip diameter	d_{a2}	$d_{a2} = (z + 2f_o + 2x) m_x$
Axial pitch	p_x	$p_x = \pi m_x$	Root diameter	d_{f2}	$d_{f2} = (z - 2f_o) m_x - 2c$
Pitch of the helix, lead	p_z	$p_z = Z p_x$	Pitch diameter	d_2'	$d_2' = d_2$
Pressure Angle in axial section	α	$\alpha = 20^\circ$	WORM WHEEL THROAT		
(Archimedean worm)			Throat tip radius	R_1	$R_1 = \frac{d_1}{2} - f_o m_x$
Lead angle on the reference cylinder	γ	$\tan \gamma = \frac{Z}{q}$	Throat root radius	R_2	$R_2 = \frac{d_1}{2} + f_o m_x + c$
Lead angle on the pitch cylinder	γ	$\tan \gamma' = \frac{Z}{(q + 2x)}$	WORM		
Bottom clearance	c	$c = 0.2 \text{ to } 0.3 m_x$	Tip relief radius	r_1	$r_1 = 0.1 m_x$
Addendum modification coefficient	x	$x = \frac{a}{m_x} - 0.5 (q + z)$	Root relief radius	r_2	$r_2 = 0.2 m_x$
			Nominal tooth thickness on reference diameter in axial section	S	$S = \frac{\pi m_x}{2}$
			Nominal tooth thickness on reference diameter in normal section	S_n	$S_n = \frac{\pi}{2} m_x \cos \gamma$

Formula based on surface stress

$$a = \left(\frac{z}{q} + 1 \right) \sqrt[3]{\left[\frac{540}{q} [\sigma_c] \right]^3 [M_t]} \quad \dots(11.1)$$

$$\sigma_c = \left(\frac{540}{q} \right) \sqrt[3]{\left[\frac{z}{q} + 1 \right]^3 [M_t]} \leq [\sigma_c] \quad \dots(11.2)$$

$$m_x = 1.24 \sqrt[3]{\frac{[M_t]}{z q y_v [\sigma_b]}}, \text{ cm} \quad \dots(11.3)$$

$$\sigma_b = \frac{1.9 [M_t]}{m_x^3 q z y_v} \leq [\sigma_b] \quad \dots(11.4)$$

$$M_t = 71620 \frac{\text{hp}}{n} i \eta \quad \dots(11.5)$$

$$[M_t] = M_t k k_d \quad \dots(11.6)$$

$$v_s = \frac{v_1}{\cos \gamma} = \frac{m_x n}{1910} \sqrt{Z^2 + q^2} \quad \dots(11.7)$$

$$v_s \approx v_1 \text{ for } Z=1 \text{ or } 2 \quad \dots(11.8)$$

a , centre distance, cm

Z , number of starts on the worm, to be selected from 1 to 4

$q = \frac{d}{m_x}$, diameter factor, table 36
initially choose $q=11$

d , pitch diameter of worm, mm

m_x , axial module, mm

$[M_t]$, design twisting moment transmitted by worm wheel, kgf. cm

z , no. of teeth on the worm wheel, normally from 30 to 70. For compact reduction unit choose z towards the lower limit, for higher transmission efficiency choose z towards the higher limit. For $\text{hp} > 20$, $z = 60$ to 70 , for small hp , $z = 30$ to 50

$[\sigma_c]$, design surface stress, kgf/cm² table 32

y_v , form factor, modified, table 18

$[\sigma_b]$, design bending stress, kgf/cm² table 32

M_t , nominal twisting moment transmitted by worm wheel, kgf. cm

n , speed of worm, rpm

hp , horse power transmitted

$i = \frac{z}{Z}$, gear ratio

η , efficiency of worm gear, table 37

k , load concentration factor, $k=1$, when load is almost constant

k_d , dynamic load factor $k_d=1$, for $v_2 < 3 \text{ m/s}$

v_2 , pitch line velocity of the wheel

v_s , sliding velocity, m/sec

v_1 , pitch line velocity of worm, m/s

γ , lead angle, $= \tan^{-1} \left(\frac{Z}{q} \right)$, table 34

Design Surface Stress*, $[\sigma_s]$, kgf/cm²

Table 32

Worm	Material Wheel	Sliding Velocity, v_s , m/s					
		0.25	0.5	1	2	3	4
Steel	Cast Iron	1700—1400	1200	1000	700	—	—
	Bronze	1900	1350	1760	1680	1590	1490

* NOTE:- The above values are for accurately cut and well lubricated worm gear pair. If these two conditions are not satisfied, reduce the above values by 30%. The above values need not be modified for fatigue life, as the main failure in worm gearing is due to seizure.

Design Bending Stress, $[\sigma_b]$, kgf/cm²

Table 33

Material of wheel	Method of casting of wheel	σ_u , kgf/mm ²	Rotation in one direction only	Rotation in both directions
Bronze	Sand	$\sigma_u > 39$	780	640
	Chill		1100	900
	Sand	$\sigma_u < 39$	500	350
	Chill		550	400
	Centrifugally cast		600	470
Cast Iron	Grade 25	25	300	200
	Grade 35	35	400	275

Lead Angle, γ

Table 34

No. of starts Z	Diameter Factor, q					
	13	12	11	10	9	8
1	4° 23' 55"	4° 45' 49"	5° 11' 40"	5° 42' 38"	6° 20' 25"	7° 07' 30"
2	8° 44' 46"	9° 27' 44"	10° 18' 17"	11° 18' 36"	12° 31' 44"	14° 02' 10"
3	12° 59' 41"	14° 02' 10"	15° 15' 18"	16° 41' 57"	18° 26' 06"	20° 33' 22"
4	17° 06' 10"	18° 26' 06"	19° 58' 59"	21° 48' 05"	23° 57' 45"	26° 33' 54"

Selection of number of teeth, z , on the worm wheel**

Table 36

m_x , mm	4	5	5	6	6	8	8	10	10	12	12	16	20
$\frac{q}{a}$, mm $\rightarrow$ $\downarrow$	11	10	12	9	11	8	11	8	11	8	11	9	8
100	39	30	28	—	—	—	—	—	—	—	—	—	—
120	49	38	36	31	29	—	—	—	—	—	—	—	—
150	64	50	48	41	39	29*	—	—	—	—	—	—	—
180	79	62	60	51	49	37	34	28	—	—	—	—	—
210	—	74	72	61	59	44*	41*	34	31	—	—	—	—
240	—	—	—	71	69	52	49	40	37	32	29	—	—
270	—	—	—	81	79	59*	56*	46	43	37	34	—	—
300	—	—	—	—	—	67	64	52	49	42	39	28*	—
360	—	—	—	—	—	82	79	64	61	52	49	36	28
420	—	—	—	—	—	—	—	76	73	62	59	43*	34
480	—	—	—	—	—	—	—	—	—	72	69	51	40
540	—	—	—	—	—	—	—	—	—	82	79	58*	46
600	—	—	—	—	—	—	—	—	—	—	—	66	52

** z could be ± 2 teeth from values found from the table above except numbers marked with* where the deviation permissible is -1 or $+2$ teeth.

Example : Determine the number of teeth on the worm wheel for the following specifications.

Gear ratio, $i = 23 \pm 3\%$

$a = 240$ mm

$m_x = 8$ mm

Number of

starts, $Z = 2$

From table above, for $a = 240$ and $m_x = 8$ & $q = 11$ (assumed)

$z = 49$

Choosing, $z = 47$ (permissible), $i = \frac{z}{Z} = \frac{47}{2} = 23.5$.

% Deviation of $i \approx 2\%$ which is within the allowed 3% .

Approximate Efficiencies in worm Gear Drive

Table 37

For $Z = 1$, $\eta = 0.70$ to 0.75

$= 2$, $\eta = 0.70$ to 0.82

$= 3$ and 4 , $\eta = 0.80$ to 0.92

RECOMMENDED VALUES OF TRANSMISSION RATIOS, CENTRE DISTANCES, * $Z/z/q/m_x$

All dimensions in millimetres

Trans- mission ratio Centre distance	5	7.5	10	12.5	15	20	25	30	40	50	60
25	2/10/(11)/2.5	1/7/(18)/2	—	—	1/15/(18)/1.5	1/21/(18)/1.25	—	1/33/16/1	—	—	—
31.5*	4/21/(11)/2	2/15/(11)/2.5	2/21/(11)/2	1/13/(18)/2	1/15/(11)/2.5	1/20/(11)/2	1/26/16/1.5	1/32/(18)/1.25	—	1/48/16/1	—
40	4/21/(11)/2.5	—	2/21/(11)/2.5	—	1/16/16/2.5	1/21/(11)/2.5	—	1/29/(11)/2	—	—	1/62/16/1
50	6/29/(11)/2.5	4/29/(11)/2.5	4/38/(11)/2	—	2/29/(11)/2.5	2/38/(11)/2	—	1/29/(11)/2.5	1/38/(11)/2	—	1/62/(18)/1.25
63	6/31/(11)/3	4/31/(11)/3	4/39/(11)/2.5	4/51/(11)/2	2/31/(11)/3	2/39/(11)/2.5	2/51/(11)/2	1/31/(11)/3	1/39/(11)/2.5	1/51/(11)/2	—
80	6/29/(11)/4	4/30/(10)/4	4/42/(11)/3	4/53/(11)/2.5	2/30/10/4	2/42/(11)/3	2/53/(11)/2.5	1/30/10/4	1/42/(11)/3	1/53/(11)/2.5	1/62/(18)/2
100	6/29/(11)/5	4/30/10/5	4/40/10/4	4/49/(18)/3	2/30/10/5	2/40/10/4	2/54/(11)/3	1/30/10/5	1/40/10/4	1/55/(11)/3	1/64/16/2.5
125	6/32/10/6	4/31/10/6	4/40/10/5	4/52/10/4	2/31/10/6	2/40/10/5	2/52/10/4	1/31/10/6	1/40/10/5	1/52/10/4	—
160	6/31/(9)/8	4/30/10/8	4/43/10/6	4/54/10/5	2/30/10/8	—	2/54/10/5	1/30/10/8	—	1/54/10/5	1/62/(18)/4
200	8/39/(11)/8	4/30/10/10	4/40/10/8	—	2/30/10/10	2/40/10/8	—	1/30/10/10	1/40/10/8	—	—
250	8/39/(11)/10	—	4/40/10/10	4/52/8/8	—	2/40/10/10	2/52/10/8	—	1/40/10/10	1/52/10/8	—
315	8/41/(11)/12	4/30/(9)/16	4/43/(9)/12	4/53/10/10	2/30/(9)/16	—	2/53/10/10	1/30/(9)/16	—	1/53/10/10	1/60/(18)/8
400	8/39/(11)/16	4/31/(9)/20	4/41/(9)/16	—	2/31/(9)/20	2/41/(9)/16	—	1/31/(9)/20	1/41/(9)/16	1/49/(18)/12	1/58/(9)/12
500	8/39/(11)/20	—	4/41/(9)/20	4/53/(9)/16	—	2/41/(9)/20	2/53/(9)/16	—	1/41/(9)/20	1/53/(9)/16	—

NOTE: The values within brackets are non-preferred.

* 6/32/10/6 denotes, 6 starts on the worm, 32 teeth on the wheel, $q=10$ and $m_x=6$.

Face width of the wheel, b Table 38

Z	b	$d_{a2} \geq$
1	$0.75 d_1$	$d_{a2} + 2 m_x$
2 or 3	$0.75 d_1$	$d_{a2} + 1.5 m_x$
4	$0.67 d_1$	$d_{a2} + m_x$

Length of the worm, L

Table 39

Correction factor x	Z , no. of starts	
	1 or 2	3 or 4
0	$L \geq (11 + 0.06x) m_x$	$L \geq (12.5 + 0.09x) m_x$
-0.5	$L \geq (8 + 0.06x) m_x$	$L \geq (9.5 + 0.09x) m_x$
-1	$L \geq (10.5 + Z) m_x$	$L \geq (10.5 + Z) m_x$
+0.5	$L \geq (11 + 0.1x) m_x$	$L \geq (12.5 + 0.1x) m_x$
1	$L \geq (12 + 0.1x) m_x$	$L \geq (13 + 0.1x) m_x$

For correction factor other than that given in the table take the higher value of L , after calculating for the two adjacent values of x .

For ground worm, increase L to get L_1

For $m_x < 10$ mm by 25 mm

$m_x = 10$ to 16 by 35 to 40 mm

$m_x > 16$ mm by 50 mm

To avoid dynamic unbalance, length of the cut portion of worm must be multiples of axial pitch.

$$\lambda = \frac{L_1}{\pi m_x} \text{ should be rounded off}$$

so that the final length of cut portion of worm $L_2 = \lambda \pi m_x$

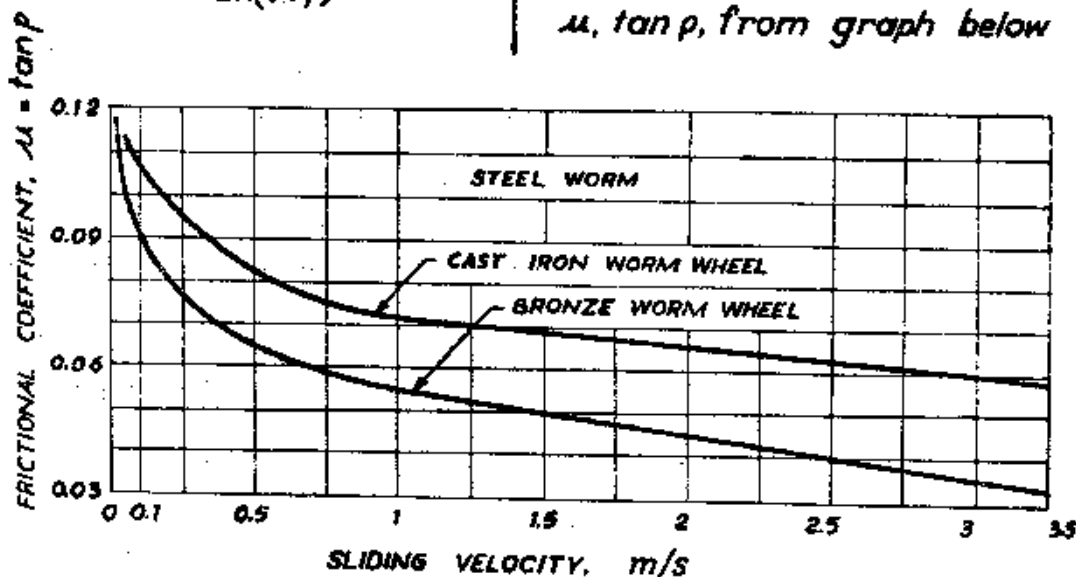
WORM GEAR EFFICIENCY OF WORM GEAR DRIVE (When worm is driving)

$$\eta = \frac{\tan \gamma}{\tan(\gamma + \rho)}$$

γ , lead angle, deg.

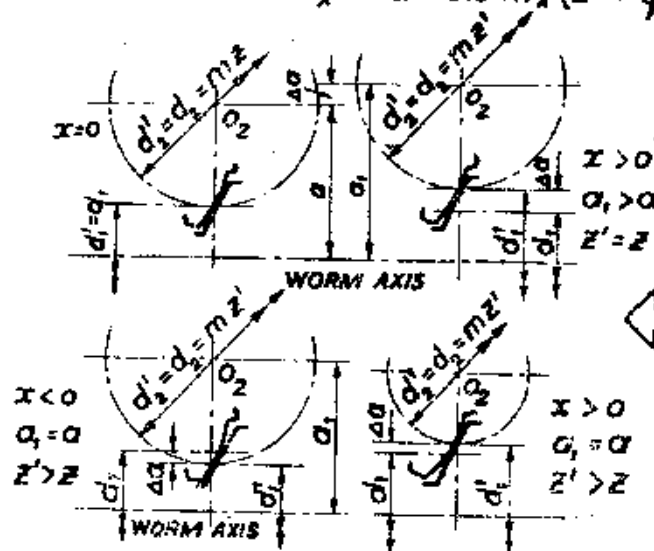
ρ , friction angle deg.

μ , $\tan \rho$, from graph below



ADDENDUM MODIFICATION COEFFICIENT, x
TO OBTAIN STANDARDISED CENTRE DISTANCE.

$$aa = x m_x = a - 0.5 m_x (z' + z)$$



a , centre distance, standard, cm
 m_x , axial module, cm

In worm gear pair, only the wheel is corrected.

DUE TO CORRECTION OR ADDENDUM MODIFICATION THE DIAMETER OF WORM PITCH CYLINDER ONLY IS CHANGED, WHILE THE DIAMETER OF WHEEL PITCH CYLINDER REMAINS UNCHANGED.

CORRECTED GEAR

GEAR DESIGN BASED ON LEWIS AND BUCKINGHAM EQUATIONS

Z_1 , Number of teeth on pinion	d, Pitch diameter, reference diameter (bevel gears), cm
Z_2 , Number of teeth on gear	b, Face width, cm
Z_v , Virtual number of teeth	R, Cone distance, cm
i, Speed ratio Z_2/Z_1	y, Lewis form factor based on P_d
P_d , Diametral pitch, $\frac{Z}{d} = \frac{\pi}{P_d}$, cm^{-1}	Y, Lewis form factor based on P_d ($Y = \pi y$)
P_o , Circular pitch, $\frac{\pi d}{Z}$, cm	C_v , Velocity factor
P_a , Axial pitch, cm	k, Load stress factor, kgf/cm^2
P_{dn} , Normal diametral pitch, cm^{-1}	Q, Ratio factor
P_{on} , Normal circular pitch, cm	v_m , Mean Velocity, m/s
m, Module, $\left(\frac{1}{P_d}\right)$, cm	V_m , Pitch line Velocity, m/min
m_n , Normal module	F_a , Axial force, kgf
m_t , Transverse module	F_d , Dynamic load, kgf
α , Pressure angle, degrees	F_s , Strength of gear tooth, kgf
α_n , Normal pressure angle	F_t , Transmitted load, kgf
β , Helix angle 8°–25° for helical gears 25°–40° for Herringbone gears	F_w , Wear load, kgf
δ , Reference cone angle, degrees	$[\sigma_b]$, design bending stress, kgf/cm^2
	$[\sigma_c]$, design contact stress, kgf/cm^2
	E, Modulus of Elasticity, kgf/cm^2

SPUR GEARS

Lewis Equation:

$$F_s = [\sigma_b] b y P_d = [\sigma_b] b \frac{Y}{P_d}$$

$$F_t = HP \times \frac{75}{v_m}$$

$$F_d = F_t \times C_v$$

Lewis form factor based on P_d

$$y = 0.124 - \frac{0.684}{Z} \text{ for } 14\frac{1}{2}^\circ \text{ involute}$$

$$= 0.154 - \frac{0.912}{Z} \text{ for } 20^\circ \text{ involute}$$

$$= 0.175 - \frac{0.95}{Z} \text{ for } 20^\circ \text{ involute stub teeth}$$

Y and y can also be taken from table 40

$$C_v = \frac{(3 + v_m)}{3}; \quad v_m < 10 \text{ m/s for commercially cut wheels}$$

$$= \frac{(6 + v_m)}{6}; \quad v_m, 5-20 \text{ m/s for carefully cut wheels}$$

$$= \frac{(5.5 + v_m)}{5.5}; \quad v_m > 20 \text{ m/s for precision wheels}$$

$$= \frac{(1 + v_m)}{(1 + 0.25 v_m)} \text{ for non-metallic gears}$$

$$b = 3 \text{ to } 4 \text{ times } P_d \text{ or } \frac{8}{P_d} \text{ to } \frac{12.5}{P_d}$$

$$F_w = d_1 Q k b$$

$$F_s \geq F_d$$

$$F_w \geq F_d, \text{ for severe service}$$

Buckingham's Dynamic load

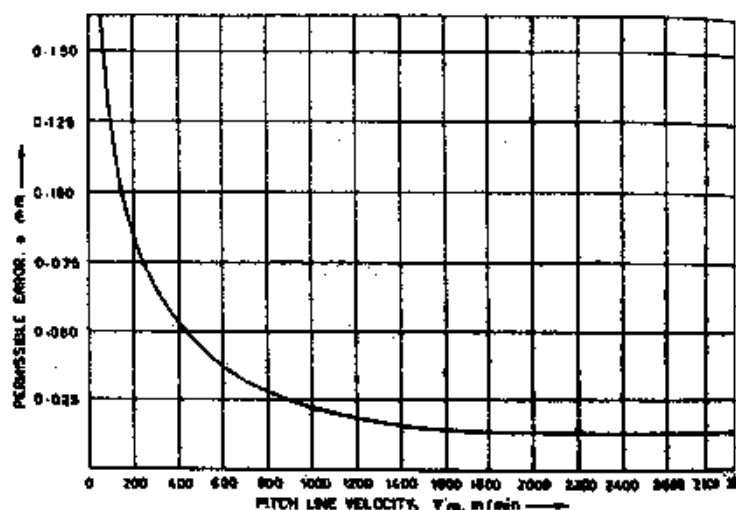
$$F_d = F_t + \left[\frac{0.164 V_m (cb + F_t)}{0.164 V_m + 1.485 \sqrt{cb + F_t}} \right]$$

for c refer table 41

$$k = \frac{[\sigma_c] \sin \alpha \left[\frac{1}{E_1} + \frac{1}{E_2} \right]}{1.4}$$

$$Q = \frac{2i}{i \pm 1} \quad \begin{array}{l} + \text{ for external} \\ - \text{ for internal} \end{array}$$

Design steel gears for wear and check for strength.



HELICAL GEARS

Modified Lewis equation:

$$F_s = \frac{[\sigma_b] b Y_y}{P_{da}} = [\sigma_b] b y_v P_{da}$$

Use Z_v instead of Z in the equation for y to get y_v .

[C_v values are the same as for spur gears]

Buckingham's dynamic load

$$F_d = F_t + \left[\frac{0.164 V_m (cb \cos^2 \beta + F_t) \cos \beta}{0.164 V_m + 1.485 \sqrt{cb \cos^2 \beta + F_t}} \right]$$

for c refer table 41

$$F_w = \frac{b d_1 Q k}{\cos^2 \beta}$$

$$P_d = P_{da} \cos \beta; \quad P_s = \frac{P_c}{\tan \beta}$$

$$P_c = \frac{P_{an}}{\cos \beta}; \quad m_t = \frac{m_n}{\cos \beta} = \frac{1}{P_d}$$

$$\tan \alpha_n = \tan \alpha \cos \beta$$

$$b \geq \frac{2\pi}{P_d \tan \beta}$$

$$Z_v = \frac{Z}{\cos^3 \beta}; \quad F_s = F_t \tan \beta$$

$$F_t = \frac{(HP \times 75)}{v_m}$$

$$k = [\sigma_c] \frac{\sin \alpha}{1.4} \left[\frac{1}{E_1} + \frac{1}{E_2} \right]$$

$$F_s \geq F_d$$

$$F_w \geq F_d, \text{ for severe service}$$

BEVEL GEARS

(Right angled: $\delta_1 + \delta_2 = 90^\circ$)

$$F_t = \frac{[\sigma_b] b Y_v \left(1 - \frac{b}{R}\right)}{P_d}$$

$$F_d = C_v N_{st} k_m F_t$$

Straight bevel gears, $C_v = \frac{3.5 + v_m^{1/4}}{3.5}$ $v_m \leq 5 \text{ m/s}$

Spiral bevel gears, $C_v = \left[\frac{5.5 + v_m^{1/4}}{5.5} \right]^4$ $v_m > 5 \text{ m/s}$ or $\text{rpm} > 1000$

d_1, d_2 and m refer to the large end

$$b \approx 0.3 R \text{ or } \frac{10}{P_d}$$

N_{st} Service factor 1 to 2

β , Spiral angle

Straight bevel gears, $Z_v = \frac{Z_1}{\cos \delta_1}$ or $\frac{Z_2}{\cos \delta_2}$

Spiral bevel gears, $Z_v = \frac{Z_1}{\cos \delta_1 \cos^3 \beta_{av}}$
or $\frac{Z_2}{\cos \delta_2 \cos^3 \beta_{av}}$

Load distribution factor

k_m

Both gears straddle mounted 1 to 1.1

One gear straddle mounted 1.1 to 1.25

Both gears overhanging 1.25 to 1.4

For Buckingham's dynamic load use the equation for spur gear taking V_m for the largest pitch circle.

WORM GEARS

Tooth strength:

$$F_s = \frac{[\sigma_b] Y b P_{an}}{\pi} = \frac{[\sigma_b] Y b}{P_{da}}$$

Lead angle of worm $\lambda_w = \tan^{-1} \frac{L}{\pi D_w}$

Helix angle of worm $\beta_w = 90^\circ - \lambda_w$

Helix angle of gear (worm wheel) $\beta_g = 90^\circ - \lambda_g$

$\beta_w = \lambda_g$ and $\lambda_w = \beta_g$

Dynamic load $F_d = \left(\frac{6 + V_{mg}}{6} \right) F_t$

Check $-F_s \geq F_d$

Wear load $F_w = D_g b k_w$

Heat generated, H_g :

$H_g = (1 - \eta) \times \text{Input hp} \times 4500 \text{ kgf m/min}$

Heat dissipated, H_d :

$H_d = h_{ca} A \Delta t \text{ kgf m/min}$

$A \approx 57.2 a^{1.7} \text{ cm}^2$

Form factor Y for $z + Z > 40$

α_n	$14\frac{1}{2}^\circ$	20°	25°	30°
Y	0.314	0.392	0.47	0.55

Z , Number of starts on worm

z , Number of teeth on wheel

D_w , Pitch diameter of worm

D_g , Pitch diameter of gear

V_{mg} , Pitch line speed of gear

F_t , Transmitted load based on output power, kgf

k_w , Wear factor (table 43)

h_{ca} , Heat transfer coefficient

Δt , Temperature rise of the lubricant, $^\circ\text{C}$

A , Minimum area of the housing, cm^2

a , Centre distance, cm

L , Lead of worm, cm

λ_w , Lead angle of worm

λ_g , Lead angle of gear

α_n , Normal pressure angle

η , Efficiency

Table 40

FORM FACTOR Y IN LEWIS' EQUATION: FD = Full depth; $y = \frac{Y}{\pi}$

No. of teeth	14½° F D	20° F D	20° Stub	No. of teeth	14½° F D	20° F D	20° Stub
10	0.176	0.201	0.261	32	0.322	0.364	0.443
11	0.192	0.226	0.289	33	0.324	0.367	0.445
12	0.210	0.245	0.311	35	0.327	0.373	0.449
13	0.223	0.264	0.324	37	0.330	0.380	0.454
14	0.236	0.276	0.339	39	0.335	0.386	0.457
15	0.245	0.289	0.349	40	0.336	0.389	0.459
16	0.255	0.295	0.360	45	0.340	0.399	0.468
17	0.264	0.302	0.368	50	0.346	0.408	0.474
18	0.270	0.308	0.377	55	0.352	0.415	0.480
19	0.277	0.314	0.386	60	0.355	0.421	0.484
20	0.283	0.320	0.393	65	0.358	0.425	0.488
21	0.289	0.326	0.399	70	0.360	0.429	0.493
22	0.292	0.330	0.404	75	0.361	0.433	0.496
23	0.296	0.333	0.408	80	0.363	0.436	0.499
24	0.302	0.337	0.411	90	0.366	0.442	0.503
25	0.305	0.340	0.416	100	0.368	0.446	0.506
26	0.308	0.344	0.421	150	0.375	0.458	0.516
27	0.311	0.348	0.426	200	0.378	0.463	0.524
28	0.314	0.352	0.430	300	0.382	0.471	0.534
29	0.316	0.355	0.434	Rack	0.390	0.484	0.550
30	0.318	0.358	0.437				

Table 41

Values of c

Tooth form	Material of Pinion and gear	c
14.5°	Cast iron and Cast iron	5720 c
	Steel and Cast Iron	7850 c
	Steel and Steel	11440 c
20° Full depth	Cast iron and Cast iron	5930 c
	Steel and Cast iron	8150 c
	Steel and Steel	11860 c
20° Stub tooth	Cast iron and Cast iron	6150 c
	Steel and Cast Iron	8450 c
	Steel and Steel	12300 c

c — Error in action, mm

Table 42

Expected errors in tooth profiles, in mm

Quality Module	First class commercial gears	Carefully cut gears	Precision gears
up to 4	0.05	0.025	0.0125
5	0.056	0.025	0.0125
6	0.064	0.030	0.015
7	0.072	0.035	0.017
8	0.080	0.038	0.019
9	0.085	0.041	0.0205
10	0.090	0.044	0.022

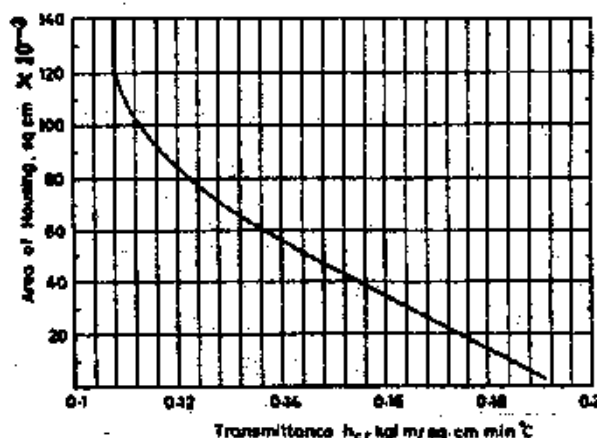
WEAR FACTOR k_w FOR WORM GEARS, kgf/cm^2

Table 43

Materials		Pressure Angle, α_p			
Worm	Gear (worm wheel)	14½°	20°	25°	30°
*Hardened steel	Chilled Bronze	6.3	8.8	10.5	12.6
*Hardened steel	Bronze	4.2	5.6	7.0	8.4
Steel, 250HB (min)	Bronze	2.52	3.5	4.2	5.05
**Grey iron	Aluminium	0.7	0.84	1.05	1.26
High test CI	Bronze	5.60	8.05	9.8	11.5
High test CI	Grey iron	6.3	8.80	10.5	12.6
High test CI	Cast steel	1.54	2.10	2.59	3.15
High test CI	High test CI	9.45	12.90	15.7	18.9
Steel, 250HB (min)	Laminated phenolic	3.8	4.48	5.6	6.65
Grey Iron	Laminated phenolic	4.9	6.72	8.4	9.80

* Over 500 HB surface

** For steel worms, multiply given values by 0.6

Values of h_{gr} 

SCREW OR SKEW GEARS



$$P_{dn} \cdot P_{cn} = \pi$$

$$P_{o1} = \frac{P_{cn}}{\cos \beta_1}; \quad P_{o2} = \frac{P_{cn}}{\cos \beta_2}$$

$$P_{d1} = P_{dn} \cos \beta_1; \quad P_{d2} = P_{dn} \cos \beta_2$$

$$D_1 = \frac{Z_1 P_{cn}}{\pi \cos \beta_1}; \quad D_2 = \frac{Z_2 P_{cn}}{\pi \cos \beta_2}$$

$$i = \frac{D_2 \cos \beta_2}{D_1 \cos \beta_1} = \frac{Z_2}{Z_1}$$

$$\gamma = \beta_1 \pm \beta_2; \quad + \text{ when both helices are of the same hand, } - \text{ when of opposite hands.}$$

$$Z_v = \frac{Z}{\cos^3 \beta}$$

$$F_t = \frac{[\sigma_b] b Y}{P_{dn} c_w}; \quad F_d = F_t \cdot c_v$$

$$F_w = K Q D_1^2; \quad Q = \left(\frac{2D_2}{D_1 + D_2} \right)^2$$

$$l_1 = \pi D_1 \tan \beta_2 = P_{o2} Z_1$$

$$l_2 = \pi D_2 \tan \beta_1 = P_{o1} Z_2$$

$$a = \frac{Z_1}{2P_{dn} \cos \beta_1} + \frac{Z_2}{2P_{dn} \cos \beta_2}$$

$$D_1 = \frac{2a}{\frac{Z_2 \cos \beta_1}{Z_1 \cos \beta_2} + 1}$$

Wear and lubrication factor c_w Table 44

Nature of lubrication	c_w
Enclosed gears continuous lubrication	1.15
Scant lubrication	1.25
Indifferent lubrication	1.35

P_c . Circular pitch

P_d . Diametral pitch
suffix n refers to normal plane
Suffixes 1, 2 refer to driving and driven wheels respectively.

D. Pitch diameter of the gear

i. Velocity ratio

γ . Angle between the shafts

Z_v . Virtual number of teeth

β . Helix angle

F_t . Transmitted load

F_d . Dynamic load

$$c_v = \frac{4.5 + v_m}{4.5}$$

F_w . Wear load

Y. Form factor based on Z_v

c_w . Wear and lubrication factor (Table 44)

K. Load stress factor (Table 45)

a. Centre distance

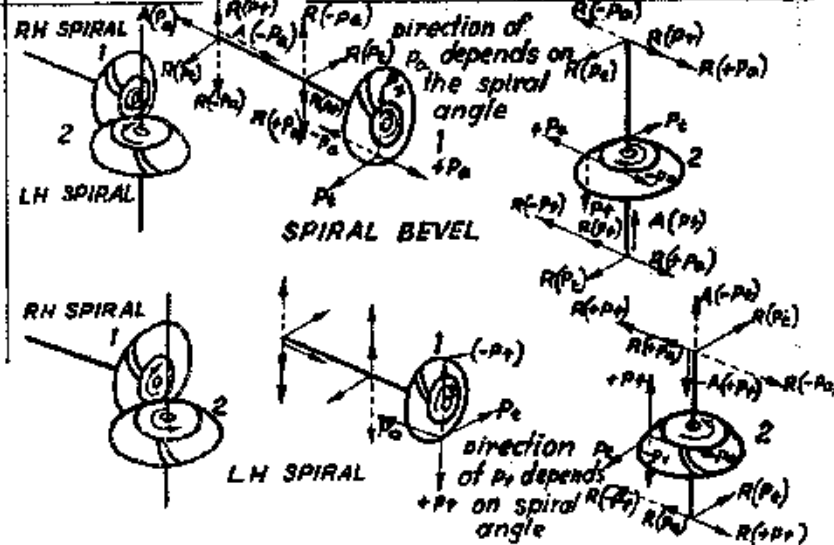
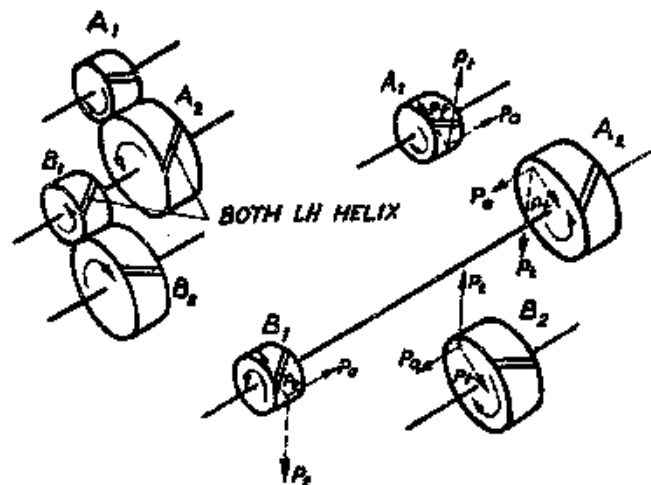
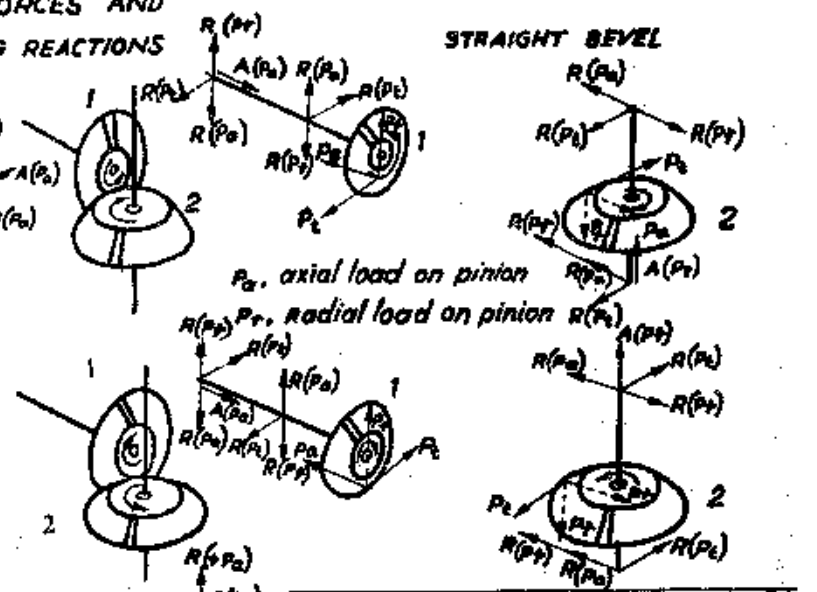
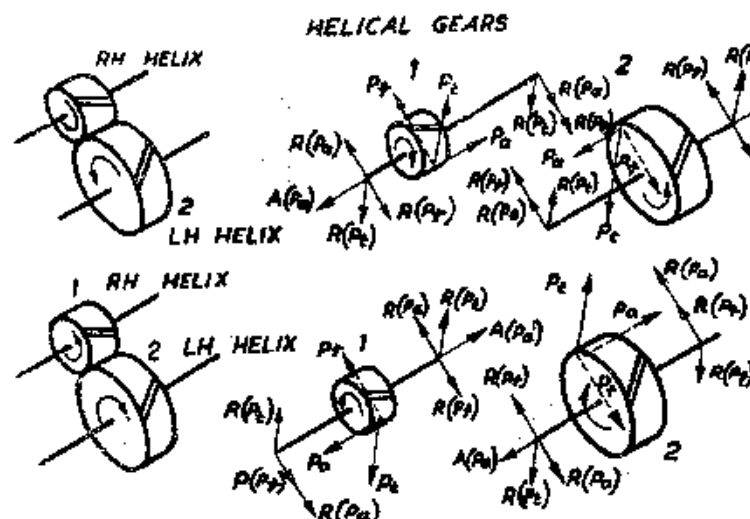
l. Lead

Values of K for skew gears Table 45

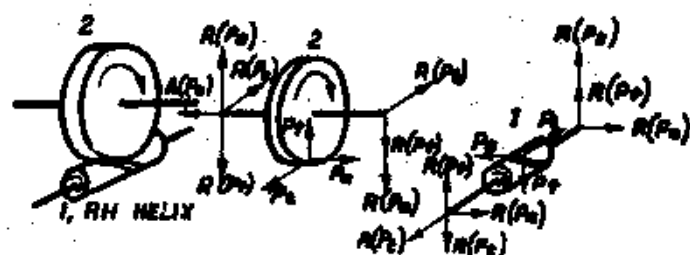
Materials	K after polishing run	
	Short	Careful
Steel (250 HB)–Steel (250 HB)	0.14	0.35
Steel (250 HB)–Bronze (100 HB)	0.28	0.84
Steel (500 HB)–Bronze (120 HB)	0.35	1.4
Steel (500 HB)–CI (180 HB)	0.42	1.4
Steel (500 HB)–Steel (500 HB)	0.49	1.05
CI (180 HB)–CI (180 HB)	0.56	1.4
Non metallic–Steel or CI	0.7	1.75

GEAR FORCES AND BEARING REACTIONS

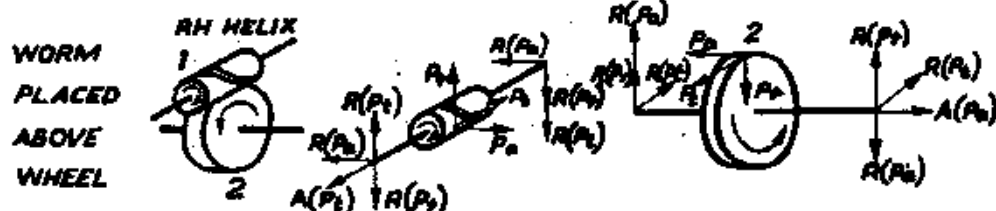
STRAIGHT BEVEL



GEAR FORCES & BEARING REACTIONS (CONTD)



WORM PLACED
BELOW WHEEL



WORM
PLACED
ABOVE
WHEEL

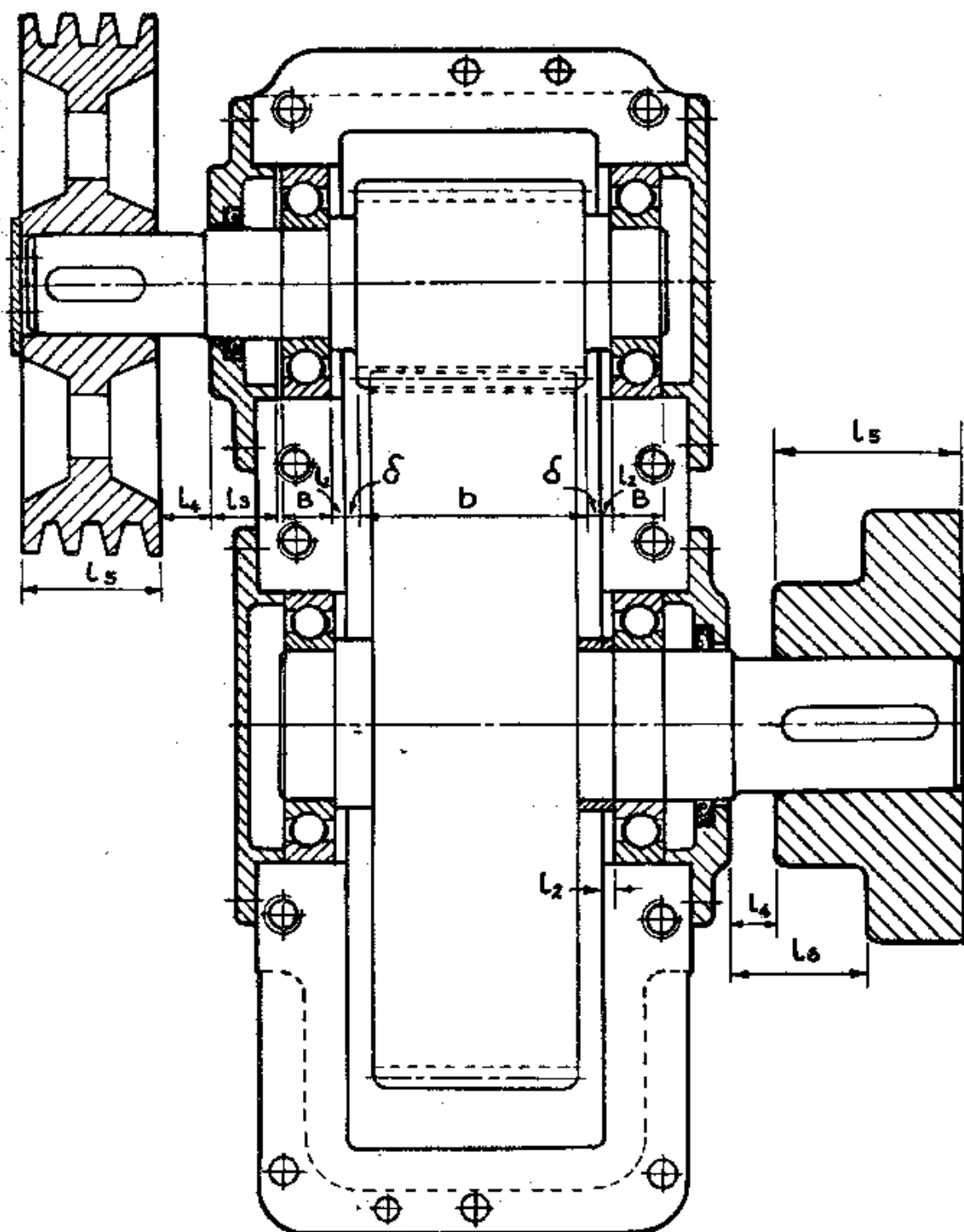
FORMULAE FOR GEAR FORCES

(All forces referred to pinion or worm wheel)

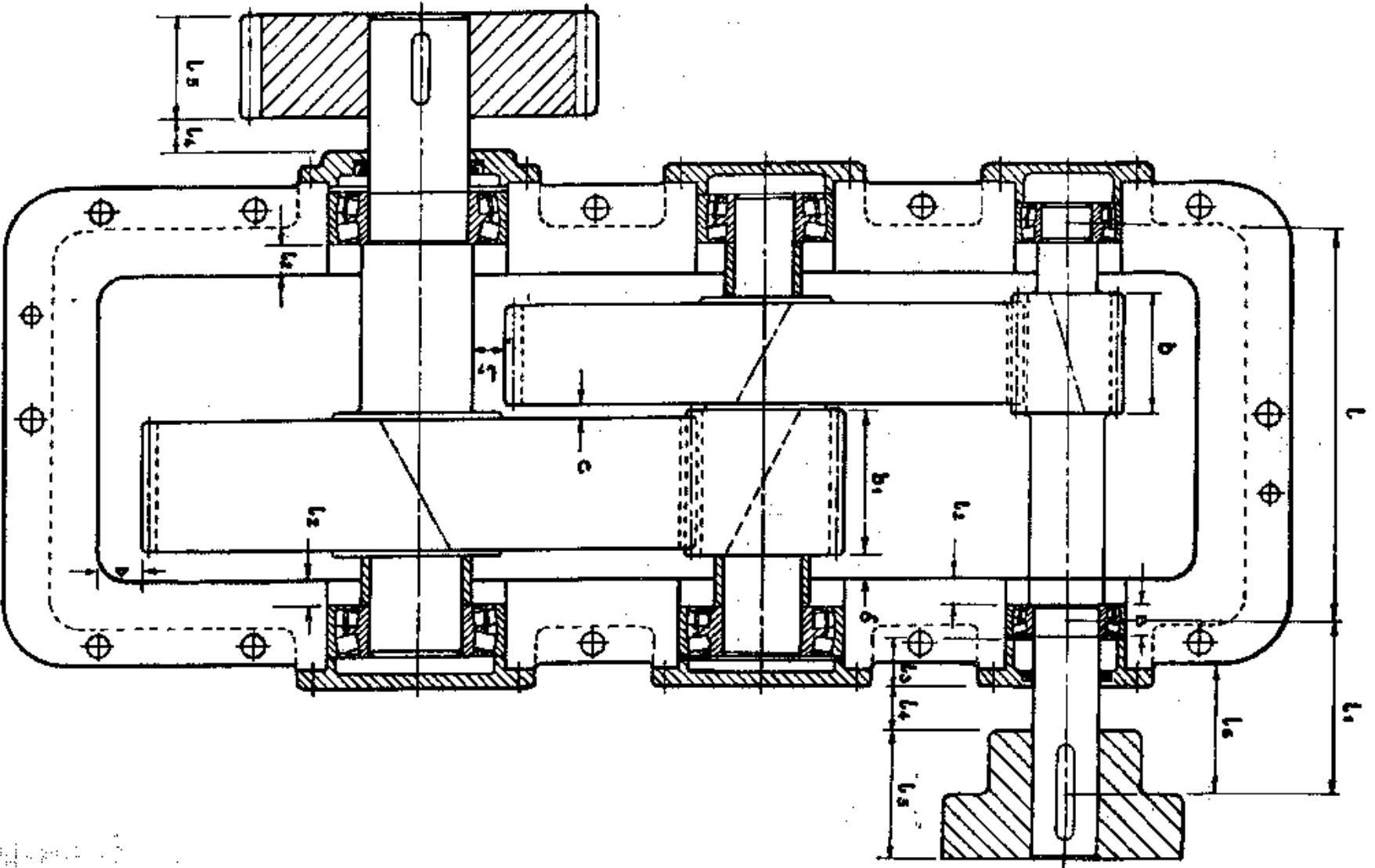
Table 46

		Tangential force, P_t	Radial force, P_r	Axial force, P_a
Cylindrical Gears	Spur	$\frac{2M_t}{d_1}$	$P_t \tan \alpha$	
	Helical	$\frac{2M_t}{d_1}$	$P_t \frac{\tan \alpha}{\cos \beta}$	$P_t \tan \beta$
	Herring- bone	$\frac{2M_t}{d_1}$	$P_t \frac{\tan \alpha}{\cos \beta}$	
Bevel Gears	Straight	$(P_t)_{av} = \frac{2M_t}{d_{av}} = \frac{2M_t}{d_1(1-0.5b/R)}$	$(P_t)_{av} \tan \alpha \cos \delta$	$(P_t)_{av} \tan \alpha \sin \delta$
	Spiral	$(P_t)_{av} = \frac{2M_t}{d_{av}} = \frac{2M_t}{d_1(1-0.5b/R)}$	$(P_t)_{av} \left[\tan \alpha \cos \delta \mp \sin \beta_{av} \sin \delta \right] \frac{(P_t)_{av}}{\cos \beta_{av}}$	$\frac{(P_t)_{av}}{\cos \beta_{av}} \left[\tan \alpha \sin \delta \mp \sin \beta_{av} \cos \delta \right]$
Worm Gear	Wheel	$\frac{2M_t}{d_2}$	$P_t \tan \alpha$	$P_t \tan(\gamma + \rho)$
	Worm	$P_t \tan(\gamma + \rho)$	$P_t \tan \alpha$	$\frac{2M_t}{d_2}$

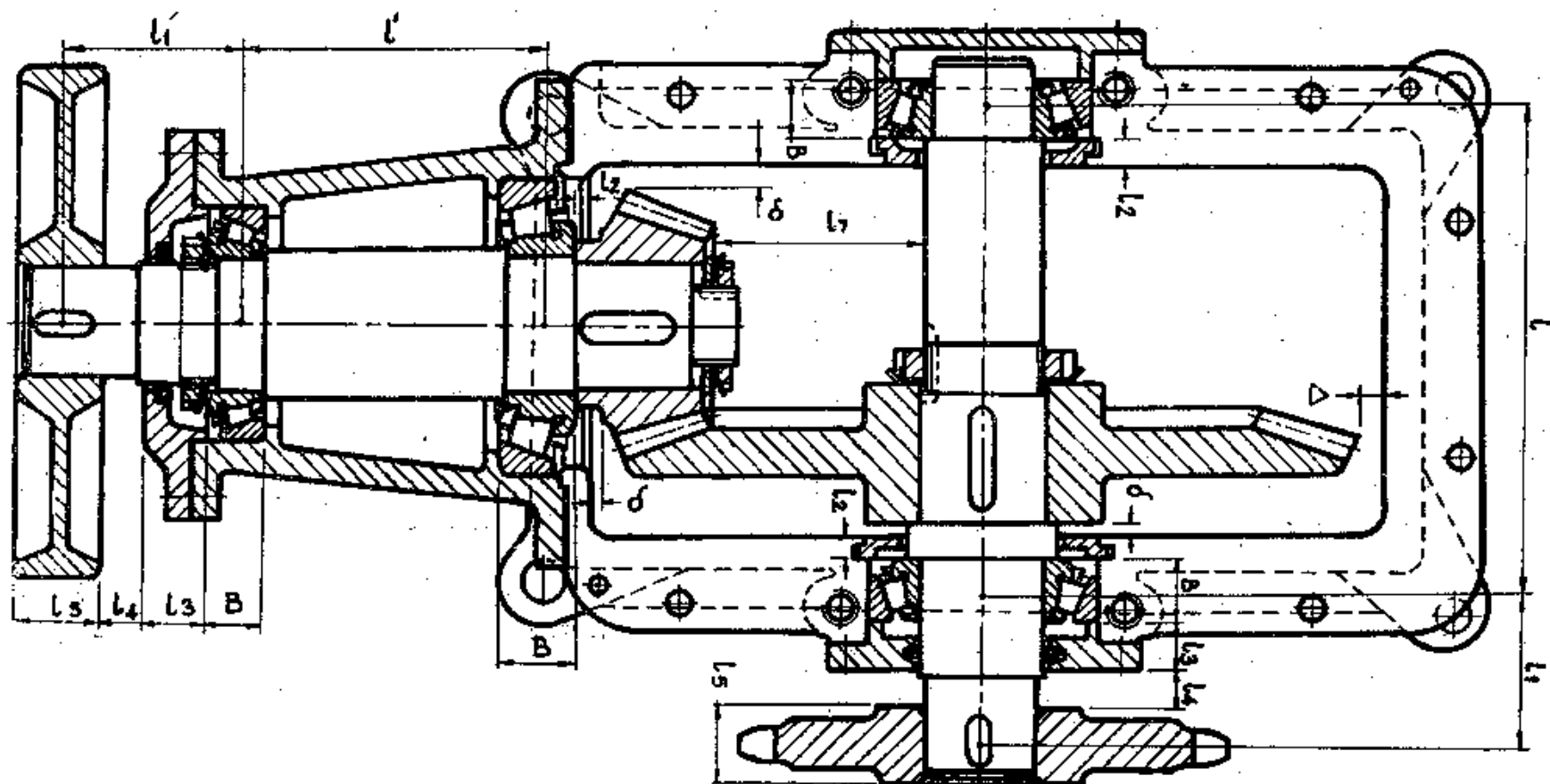
SINGLE STAGE CYLINDRICAL GEAR SPEED REDUCER



TWO STAGE CYLINDRICAL GEAR SPEED REDUCER



SINGLE STAGE BEVEL GEAR SPEED REDUCER



m – module

a – centre distance

d_o – tip diameter

d – diameter of the gear shaft

$$d \approx 0.3 a$$

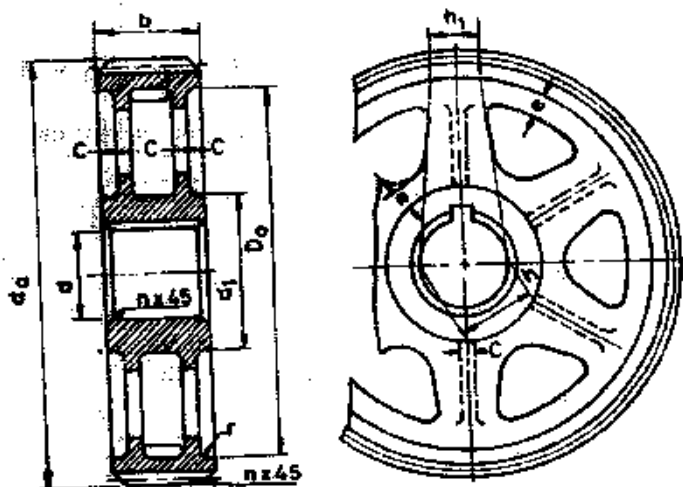
d_1 – diameter of hub $\approx 1.6 d$

$$D_o \approx d_o - 10 m$$

$$\left. \begin{array}{l} c \approx 0.2 h \\ < 10 \text{ mm} \end{array} \right\} ; n \approx 0.5 m$$

$$h \approx 0.8 d \quad h_1 \approx 0.8 b$$

$$e \approx 0.2 d \quad r \approx 10 \text{ mm}$$



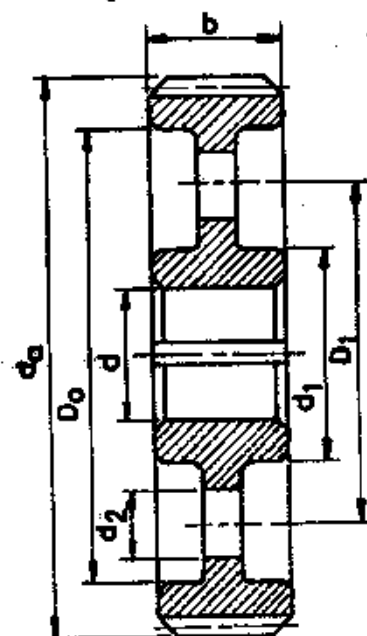
Cast Cylindrical Gear

$$d \approx 0.3 a ; d_1 \approx 1.6 d$$

$$d_2 \approx \frac{D_o - d_1}{5} ; D_1 = \frac{D_o + d_1}{2}$$

$$D_o \approx d_o - 10 m$$

$$\text{rib thickness} \approx 0.3 b$$

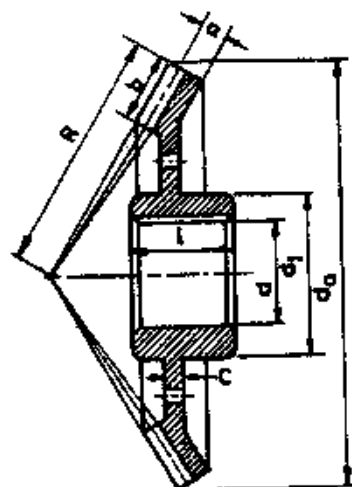


Forged Cylindrical Gear

$$d \approx 0.5 R ; d_1 \approx 1.6 d$$

$$l \approx 1.1 d ; c \approx 0.3 d$$

$$a \approx 0.2 R$$



Forged Bevel Gear

SPEED REDUCER

Commonly adopted values for speed reducer schemes

Table 47

Nomenclature	Symbol	Values
Distance of rotating parts from the inner wall of housing	δ	$\delta = 10$ to 15 mm; may be more for high power & heavy duty
Distance between adjacent rotating parts	c	$c = 10$ to 15 mm
Minimum clearance between gears & inner wall of housing	Δ	$\Delta \geq 1.2 t$ t , thickness of housing
Distance between bearings of over-hanging shaft	l'	$l' = 2.5$ to $3 d$ d , diameter of shaft
Distance of bearing from the wall	l_2	$l_2 = 5$ to 10 mm
Cap height from bolt end	l_3	Depends on empirical design of cap
Distance of rotating parts from the bearing cap	l_4	$l_4 = 15$ to 20 mm
Width of boss of rotating parts	l_5	$l_5 = 1.2$ to $1.5d$ d , diameter of shaft
Distance of coupling to cap	l_6	Depends on the type of coupling
Distance between gear and shaft	l_7	$l_7 \geq 20$ mm
Distance between bearings	l	from the drawing
Distance of rotating part from the bearing	l_1	$\frac{B}{2} + l_3 + l_4 + \frac{l_5}{2}$ B , width of bearing

GENERAL DESIGN EQUATIONS

Case 1 Polar equation of one curve and centre distance are known; to find the polar equation of the curve of the mating gear

$$R_1 = f(\theta_1)$$

$$R_2 = C - f(\theta_1)$$

$$\theta_2 = -\theta_1 + C \int \frac{d\theta_1}{C - f(\theta_1)}$$

Case 2 Relationship between angular rotation of two members and centre distance are known; to find the polar equations of curves of both members.

$$\theta_2 = F(\theta_1)$$

$$R_1 = \frac{CF'(\theta_1)}{1 + F'(\theta_1)}$$

$$R_2 = C - R_1 = \frac{C}{1 + F'(\theta_1)}$$

Case 3 Relationship between angular velocities of two members and centre distance are known, to find polar equations of curves of both members.

$$\omega_2 = \omega_1 G(\theta_1)$$

$$R_1 = \frac{CG(\theta_1)}{1 + G(\theta_1)}$$

$$R_2 = C - R_1; \theta_2 = \int G(\theta_1) d\theta_1$$

CONDITIONS FOR CLOSED PITCH CURVES

Case 1 If $R = f(\theta) = f(\theta + 2\pi Z)$, the pitch curve is closed.

Case 2 If $\theta_2 = F(\theta_1)$ and $F(\theta_0) = 0$, the curve is closed, when the equation $F\left(\theta_0 + \frac{2\pi}{Z_1}\right) = \frac{2\pi}{Z_2}$ can be satisfied by substituting integers for Z_1 and Z_2 .

Case 3 If $\theta_2 = \int G(\theta_1) d\theta_1$, let $G(\theta_1) d\theta_1 = F(\theta_1)$, and use the same method as for case 2 with the subscripts reversed.

CORRECT CENTRE DISTANCE

To find the correct centre distance C in order to get a closed pitch curve, use the following

$$\text{equation } \int_0^{2\pi} \frac{d\theta_1}{C - f(\theta_1)} = 4\pi$$

ANGLE OF OBLIQUITY

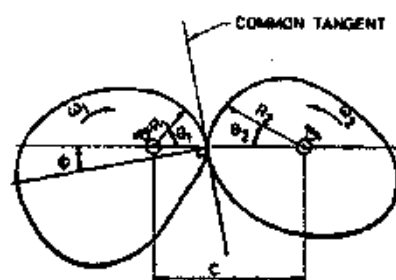
$$\alpha = \tan^{-1} \left(\frac{f'(\theta)}{f(\theta)} \right)$$

CHECK FOR TOOTH UNDERCUT

For any point on the pitch curve, $r_c > \frac{Z_{\min} m}{2}$ where $r_c = \frac{[R^2 + (R')^2]^{3/2}}{R^2 - R(R'') + 2(R')^2}$

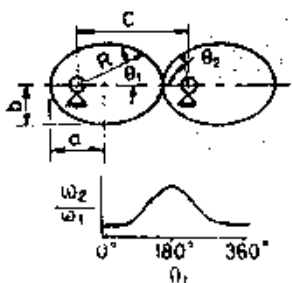
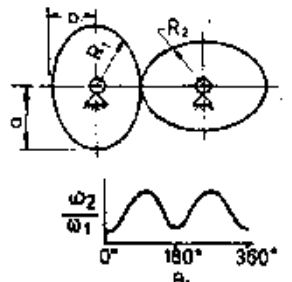
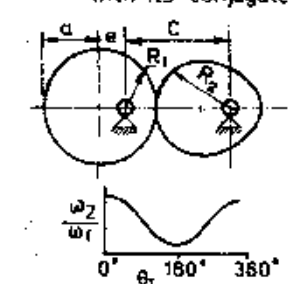
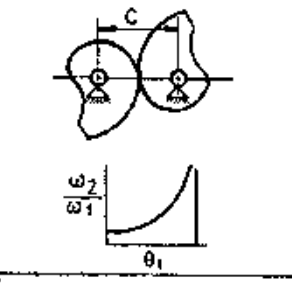
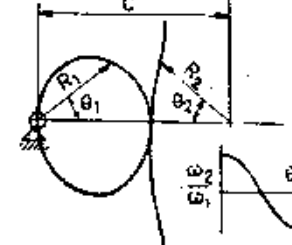
For closed pitch curves, $Z = \frac{S}{\pi m} > 18$ for $\alpha = 20^\circ$

$$\text{where } S = \int_0^{2\pi} [(dR)^2 + (Rd\theta)^2]^{1/2}$$



- C — Centre distance
- θ — Polar angle to R
- R — Pitch radius
- α — angle of obliquity or pressure angle
- ω — angular velocity
- Z — numbers of teeth
- m — module
- r_c — radius of curvature
- S — length of periphery of pitch curve
- $f(\theta), F(\theta), G(\theta)$ — Various functions of θ
- $f'(\theta), F'(\theta), G'(\theta)$ — first derivatives of function θ
- R', R'' — first and second derivatives of R

CHARACTERISTICS OF A FEW NON - CIRCULAR GEARS

Type	Basic Equation	Velocity Equation	Comments
Two ellipses pivoted at foci 	$R = \frac{b^2}{a(1 + e \cos \theta)}$ e = eccentricity $= \sqrt{1 - \left(\frac{b}{a}\right)^2}$	$\omega_2 = \omega_1 \left[\frac{r^2 + 1 + (r^2 - 1) \cos \theta_2}{2r} \right]$ $r = \frac{R_{\max}}{R_{\min}}$	Gears are identical. Used for quick-return mechanisms, printing presses, automatic machinery.
Second order ellipses rotated about their geometric centers 	$R = \frac{2ab}{(a+b) - (a-b) \cos 2\theta}$	$\omega_2 = \omega_1 \left[\frac{r + 1 + (r^2 - 1) \cos 2\theta_2}{2r} \right]$ $r = \frac{a}{b}$	Gears are identical. Better balance than true elliptical. Two complete speed cycles in one revolution.
Eccentric circular gear meshing with its conjugate 	$R_1 = e \cos \theta_1 + \sqrt{a^2 - e^2 \sin^2 \theta_1}$	$\omega_2 = \frac{\omega_1 R_1}{C - R_1}$	Standard circular spur gear. Can be employed as the eccentric. Mating gear has special shape.
Logarithmic Spirals 	$R_1 = A e^{K\theta_1}$ $R_2 = A e^{K\theta_2}$ $\theta_2 = \frac{1}{K} [\log (C - A e^{K\theta_1}) - \log A]$	$\omega_2 = \frac{\omega_1 R_1}{C - R_1}$	Gears can be identical or in combinations to give variety of functions. Must be open gears.
Sine function gears 	$\theta_2 = K \sin \theta_1$ $R_2 = \frac{C}{1 + K \cos \theta_1}$ $R_1 = C - R_2$	$\omega_2 = \omega_1 (K \cos \theta_1)$	For producing angular displacement proportional to sine of input angle. Must be open gears.

MATERIALS HANDLING - 9

WIRE ROPES

Considering the bending and tensile stresses in the rope:

$$A = \frac{F}{\frac{\sigma_u}{n} - \frac{d}{D_{min}} \frac{d_w}{d} E'}$$

$$P = \frac{F \sigma_u}{\frac{\sigma_u}{n} - \frac{d}{D_{min}} \frac{d_w}{d} E'}$$

For 6×19 group of ropes

$$P = \frac{F \sigma_u}{\frac{\sigma_u}{n} - \frac{d}{D_{min}} 50000}$$

For 6×37 group of ropes

$$P = \frac{F \sigma_u}{\frac{\sigma_u}{n} - \frac{d}{D_{min}} 36000}$$

d diameter of wire rope, cm

d_w diameter of wire, cm

D diameter of pulley or sheave, cm

F load or tension per fall of rope, kgf

P breaking strength of rope, kgf

A area of useful cross section of

the rope, cm² $\approx 0.4 \frac{\pi}{4} d^2$

E' corrected modulus of elasticity of steel ropes; 0.8×10^8 kgf/cm²

n stress factor or design factor = n' × Duty factor

σ_u tensile strength of the wire, kgf/cm²

D_{min}/d as a function of the number of bends in the system :

No. of bends	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
D _{min} /d	16	20	23	25	26.5	28	30	31	32	33	34	35	36	37	37.5	38

Ratio of Drum diameter to rope diameter :

Factors of safety : n'

Purpose	Rope	*Minimum D/d		
		Class 1	2 & 3	4
Mining installations	All ropes	100	100	100
Cranes & Hoists	6 × 37	15	17	22
	6 × 19	19	23	27
	6 × 19 F	18	20	23

*Ratio for 50 m/min of rope speeds — to be increased by 8% for each additional 50 m/min. Larger ratios to be used for non rotating ropes.

Rope application	Class 1	Classes 2 & 3	Class 4
Fixed guys, jib cranes or ancilliary applications	3.5	4.0	4.5
Hoisting systems in flexible cranes (example: mobile crawler tower) where jibs are supported by ropes	4.0	4.5	5.5
Cranes and hoists in general hoist blocks	4.5	5.0	6.0
Mining installations 10 or as laid in codes.			

Fatigue loading of ropes :

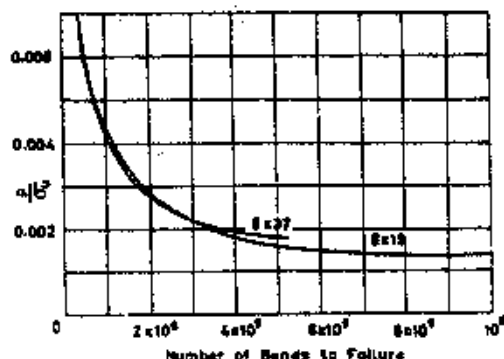
$$p = \frac{2 F}{d D_{min}}$$

$$d D_{min} \geq \frac{2 n F}{(p/\sigma_u) \sigma_u}$$

D_{min}/d ratio must be selected from the above value for survival through N cycles

N : life in number of cycles

p : bearing pressure on projected area of the rope on the sheave, kgf/cm^2



(p/σ_u) : Pressure ratio obtained from graph for N bends to failure

Duty factor and life of Mechanism :

Mechanism Class	Duty factor		Average life		
	Strength	Wear	Running Hours per day	Total life Hours	Days per year on 20 years life
1	1.0	0.4	0.5	over 2500	250
2	1.2	0.5	1.5	over 9000	300
3	1.4	0.6	3	over 26000	333
4	1.6	0.7	over 6	over 40000	333

The design factor is obtained by multiplying the factor of safety for the appropriate class by the duty factor.

ROPE DRUMS:

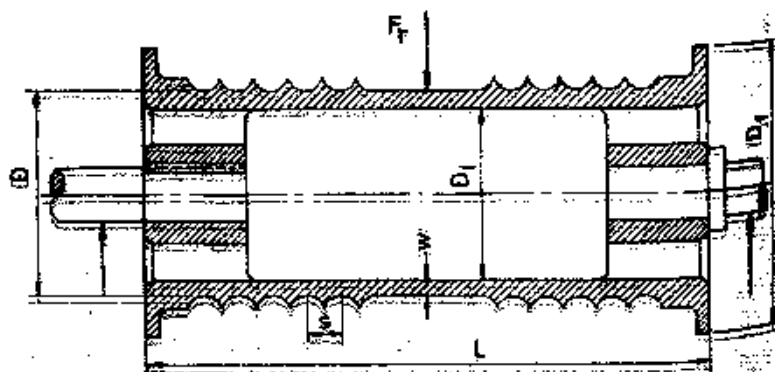
No. of turns on the drum
1. F one rope,

$$Z = \frac{H_i}{\pi D} + 2$$

Length of the drum,

$$L = \left(\frac{2H_i}{\pi D} + 7 \right) S \text{ for one rope}$$

$$= \left(\frac{2H_i}{\pi D} + 12 \right) S + \frac{1}{2} \text{ for two ropes}$$



Diameter of groove of sheaves and drums :

Rope dia. d, mm	Minimum groove diameter, mm
6—8	$d + 0.8$
9—19	$d + 1.6$
21—29	$d + 2.4$
over 29	$d + 3.2$

Depth of grooves to be less than 0.1 d.

Wall thickness of CI drums;

$$w = 0.02 D + (0.6 \text{ to } 1.0) \text{ cm}$$

$$D_f \approx (D + 6d)$$

Max. bending stress

$$\sigma_b = \frac{8F_t L D}{(D^4 - D_1^4) \pi}$$

Max. shear stress

$$\tau = \frac{16 M_t D}{\pi (D^4 - D_1^4)}$$

$$\text{Crushing stress } \sigma_c = \frac{F_t}{wS}$$

$$\text{Total normal stress } \sigma_n = \sqrt{\sigma_b^2 + \sigma_c^2}$$

$$\text{combined equivalent stress } \sigma_e = \sqrt{\sigma_n^2 + 4\tau^2} \leq [\sigma]$$

ROPE SHEAVES:

Minimum depth of groove

$$t_{sg} = 1.5 d$$

outside diameter of sheave

$$d_{so} = d_s + 2 t_{sg}$$

Z number of turns on the drum for one rope member

i ratio of the pulley system

D drum diameter, cm

D_1 flange diameter of rope drum, cm

H height to which the load is raised, cm

S pitch of the grooves on the drum, cm

l_1 distance between the grooves of two rope pulleys, cm

L length of drum, cm

w wall thickness, cm

Minimum clearance between ropes :

Dia. of rope, mm		Minimum clearance between the ropes, mm
over	including	
—	12	1.5
12	29	2.5
29	—	3.0

1. The pitch must be selected allowing for the minimum clearance.

2. The lead angle must be less than the allowable fleet angle of 5°

$$M_t \text{ torque on drum, kgf cm} \\ = F_t (D_{min} + d) / 2$$

F_t load on the drum, kgf

σ_b bending stress, kgf/cm²

σ_c compressive stress, kgf/cm²

τ shear stress, kgf/cm²

σ_n total normal stress, kgf/cm²

σ_e combined equivalent stress, kgf/cm²

$[\sigma]$ design stress, kgf/cm²

d_s minimum diameter of sheave, cm

t_{sg} depth of sheave groove, cm

WIRE ROPES FOR GENERAL ENGINEERING PURPOSES

Group 6×37

6×14/7 and 7/7/1 6×14/7+7F/7/1

6×16/8+8F/6/1 6×15/15/6/1

6×18/12/6/1 6×16/8 and 8/8/1

Diameter of Rope mm	Approx weight kgf/m	Nominal Breaking strength of Rope, Tonnes	
		Tensile strength of wire 160 to 175 kgf/mm ²	Tensile strength of wire 175 to 190 kgf/mm ²
10	0.45	6.2	6.8
12	0.60	8.1	8.9
14	0.74	10.3	11.3
16	0.92	12.7	13.9
18	1.32	18.3	20.0
20	1.58	21.4	23.5
22	1.81	24.6	26.9
24	2.10	28.4	31.0
25	2.37	32.5	35.6
29	2.99	40.6	44.7
32	3.69	50.3	55.4
35	4.48	61.0	67.1
38	5.32	72.6	79.8
41	6.25	85.3	93.5
44	7.24	99.1	108.7
48	8.32	113.8	125.0
51	9.46	129.1	142.2
54	10.68	146.3	160.5
57	11.98	163.6	179.8
64	14.79	202.2	221.5
70	17.88	244.9	268.2

NOTE 1: To find the aggregate breaking strength, add 21% to the figures in columns 3 and 4.

NOTE 2: To find the nominal breaking strength with a hard drawn wire main core add 7.5% to the figures given in columns 3 and 4.

NOTE 3: To find the weight with wire main core, add 11% to the figures in column 2.

IS : 2266-1963

WIRE ROPES FOR GENERAL ENGINEERING PURPOSES (Contd.)

Group 6×19

6×12/6/1 6×12/6+6F/1

6×9/9/1 6×10/5+5F/1

Diameter of Rope mm	Approx. weight kgf/m	Nominal Breaking strength of Rope, Tonnes	
		Tensile strength of wire 160 to 175 kgf/mm ²	Tensile strength of wire 175 to 190 kgf/mm ²
8	0.24	3.4	3.7
10	0.44	6.6	7.2
12	0.54	8.6	9.4
14	0.76	10.9	11.9
16	0.94	13.4	14.7
18	1.25	19.3	21.1
20	1.47	22.6	24.6
22	1.84	25.9	28.4
24	2.13	30.0	33.0
25	2.41	34.0	37.6
29	3.05	43.2	47.2
32	3.76	53.3	58.4
35	4.55	64.5	70.6
38	5.43	76.7	84.3
41	6.37	90.4	99.1
44	7.38	104.7	114.8
48	8.48	119.9	132.1
51	9.64	137.2	150.4
54	10.89	154.4	169.7

NOTE 1: To find the aggregate breaking strength, add 14.25% to figures given in columns 3 and 4.

NOTE 2: To find the nominal breaking strength with a hard drawn wire main core add 7.5% to the figures given in columns 3 and 4.

NOTE 3: To find the weight with a wire main core add 11% to the figures given in column 2.

IS : 2266—1963.

WIRE ROPES FOR GENERAL ENGINEERING PURPOSES (Contd.)

6×19 group (contd.) (For lifts and hoists)

6×12/6/1 6×12/6+6F/1 6×9/9/1

Diameter mm	Approximate weight kgf/m	Nominal Breaking strength, Tonnes	
		Tensile strength of wire 110 to 125 kgf/mm ²	Tensile strength of wire 125 to 140 kgf/mm ²
6	0.15	1.5	1.7
8	0.25	2.3	2.7
10	0.40	4.0	4.5
12	0.55	5.5	6.0
14	0.75	7.7	8.8
16	0.95	9.6	11.0
18	1.25	12.7	14.2
20	1.45	15.0	17.0
22	1.85	18.8	21.2
25	2.25	23.0	26.0

NOTE 1: To find the aggregate breaking strength, add 14.25 percent to the figures given in columns 3 and 4.

NOTE 2: The nominal breaking strengths of dual-tensile ropes of 6×19 (9/9/1) scale construction, having outer wires of 110 to 125 kgf/mm² tensile strength and inner wires of 125 to 140 kgf/mm² tensile strength, are the same as given in column 4.

IS: 2365-1963

DESIGN OF HOISTING GEAR

Equation	Nomenclature															
Effort : (in hand operation)	P, effort to be applied by operator to the crank handle, kgf															
$\frac{Pv}{C\eta}$	Recommended values of P, kgf.															
	<table> <tr> <th>Nature of operation</th> <th>on drive handle</th> <th>on pull chain</th> <th>on control pedal</th> <th>on control lever</th> </tr> <tr> <td>Continuous</td> <td>12</td> <td>20</td> <td>25</td> <td>18</td> </tr> <tr> <td>not exceeding 5 min</td> <td>25</td> <td>40</td> <td>35</td> <td>20</td> </tr> </table>	Nature of operation	on drive handle	on pull chain	on control pedal	on control lever	Continuous	12	20	25	18	not exceeding 5 min	25	40	35	20
Nature of operation	on drive handle	on pull chain	on control pedal	on control lever												
Continuous	12	20	25	18												
not exceeding 5 min	25	40	35	20												
Efficiency:																
$\eta = \eta_p \eta_d (\eta_g)^p$	Q, weight of load lifted, kgf															
	v, velocity of hoisting, m/min															
	C, Speed of point of application of effort, (30 to 45 m/min)															
	η , efficiency of the mechanism															
Power:	η_p , efficiency of pulley															
$hp = \frac{Qv}{\eta 4500}$	η_d , efficiency of drum															
	η_g , efficiency of one gear pair															
	p, no. of pairs of gears															

DESIGN FOR LIFE OF HOIST ROPES

Equation	Nomenclature
$N = \frac{0.4Z}{a\beta Z_1}$	N, rope life in months of 25 days
	Z, Number of repeated bends corresponding to m, refer table 1.
$\frac{D}{d} = m \sigma C_1 C_2 C + 8$	a, Z_1 , β , refer table 2.
	D, drum or pulley diameter, mm
	d, rope diameter, mm
	σ , tensile stress in rope
	$= \frac{10F}{\pi d^2}$
	F, tension per fall of rope, kgf
	C_1 , refer table 3
	C_2 , 0.63 to 1.15 depending on the rope material and its treatment
	C, refer table 4.

VALUES OF FACTOR m Z in thousands
m in hundredths

Table 1.

Z	30	50	70	90	110	130	150	170	190	210	230	255	280
m	26	41	56	70	83	95	107	118	129	140	150	162	174
Z	310	340	370	410	450	500	550	600	650	700			
m	187	200	212	227	242	260	277	294	310	317			

VALUES OF a , Z_1 and β

Table 2

	Condition of hoisting	a working cycles/month	Z_1 No. of repeated bends/cycle	β endurance factor
POWER DRIVEN	hand driven	400	2	0.7
	light duty 8 hrs/day	1000	4	0.5
	medium duty 16 hrs/day	3400	3	0.4
	heavy duty 24 hrs/day	9600	5 (2 × 2)	0.3
			7 (2 × 4)	0.25
			9 (2 × 5)	0.2

VALUES OF FACTOR C_1

Table 3.

Rope diam. mm	Over	5.5	8.5	11	15	18	19.5	25	30	37
	upto 5	8	10	14	17.5	19	24	28	34.5	43.5
C_1	0.83	0.85	0.89	0.93	0.97	1.0	1.04	1.09	1.16	1.24

VALUES OF FACTOR C

Table 4.

ulti. strength of rope kgf/mm ²	rope construction									
	6 × 7 and one core		6 × 19 and one core						6 × 37 and one core	
			ORDINARY		WARRINGTON		SEALE			
	Cross laid	parallel laid	cross	parallel	cross	parallel	cross	parallel	cross	parallel
130	1.31	1.13	1.08	0.91	0.69	0.61	0.81	0.69	1.12	0.99
160	1.22	1.04	1.0	0.83	0.63	0.54	0.75	0.62	1.06	0.93
180	1.16	0.98	0.95	0.78	0.59	0.5	0.7	0.57	1.02	0.89

DIMENSIONS OF DRUM GROOVES FOR WIRE ROPES

All dimensions in mm

Rope diam, d	STANDARD GROOVE			DEEP GROOVE		
	r ₁	S ₁	C ₁	r ₂	S ₂	C ₂
4.8	3.5	7	2	5.5	9	4.5
6.2	4	8	"	7.0	11	5.5
8.7	5	11	3	8.0	13	6.5
11	7	13	"	10.0	17	8.5
13	8	15	4	11.0	19	9.5
15	9	17	5	13.0	22	11.0
19.5	11.5	22	"	15.5	27	13.5
24	13.5	27	6	18.5	31	16.0
28	15.5	31	8	20.5	36	18.0
34.5	19	38	10	25.0	41	22.0
39	21	42	12	28.0	50	24.5

SPROCKET FOR WELDED CHAINS

$$D = \left[\left(\frac{l}{\sin \left(\frac{90}{T} \right)} \right)^2 + \left(\frac{d}{\cos \left(\frac{90}{T} \right)} \right)^2 \right]^{\frac{1}{2}}$$

D, diam of sprocket or sheave, cm

l, inside length of link, cm

d, diam of chain bar, cm

T, no. of sprocket teeth > 4

t, pitch of chain, cm

SPROCKET FOR ROLLER CHAIN

Lifting capacity ≥ 10 tonnes

$$D = \frac{l}{\sin \left(\frac{180}{T} \right)}$$

SHEAVES

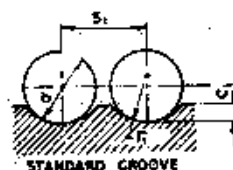
for welded chain,

D ≥ 20 d

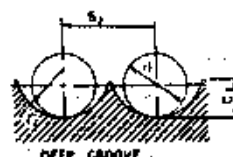
for hand drive

D ≥ 30 d

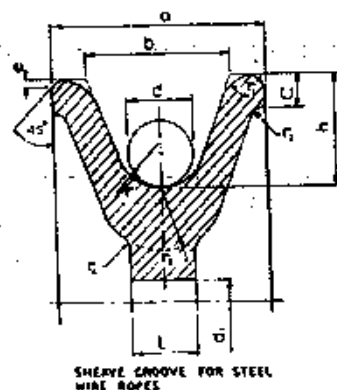
for power drive



STANDARD GROOVE



DEEP GROOVE



SHEAVE GROOVE FOR STEEL WIRE ROPES

PROPORTIONS OF SHEAVE GROOVES : Dimensions in mm

Wire Rope diam	a	b	c	e	h	i	j	r ₁	r ₂	r ₃	r ₄
4.8	22	15	5	0.5	12.5	8	4	2.5	2	8	6
6.2	22	"	"	"	"	"	"	"	"	"	"
8.7	28	20	6	1.0	15	"	5	3	2.5	9	"
11.0	40	30	7	"	25	10	8.5	4	3	12	8
13.0	"	"	"	"	"	"	"	"	"	"	"
15.0	"	"	"	"	"	"	"	"	"	"	"
19.5	55	40	10	1.5	30	15	12	5	5	17	10
24.0	65	50	"	"	37.5	18	14.5	"	"	20	15
28.0	80	60	12	2.0	45	20	17	6	7	25	"
34.5	90	70	15	"	55	22	20	7	8	28	20
39.0	110	85	18	2.9	65	"	25	9	10	40	30

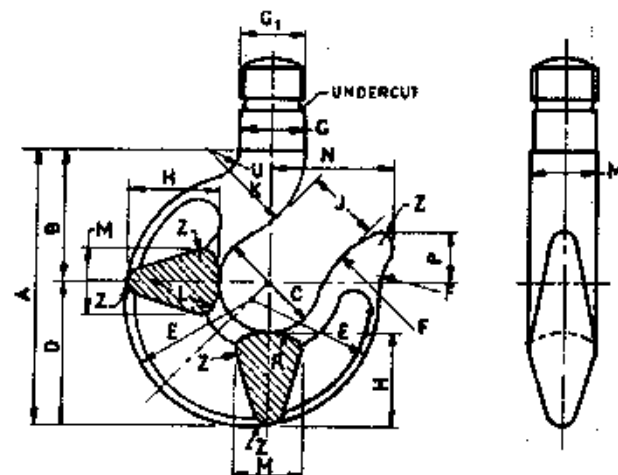
PERMISSIBLE BEARING STRESS IN SHEAVE BUSHES

(Recommended $\frac{l}{d_1} = 1.5$ to 1.8)

Rubbing velocity in bush, m/s	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5
bearing stress on projected area kgf/mm ²	0.75	0.7	0.66	0.62	0.6	0.57	0.55	0.54	0.53	0.52	0.51	0.5	0.49	0.48	0.47

DIMENSIONS FOR STANDARD TRAPEZOIDAL SECTION POINT HOOKS WITH SHANKS IS : 3815 — 1969

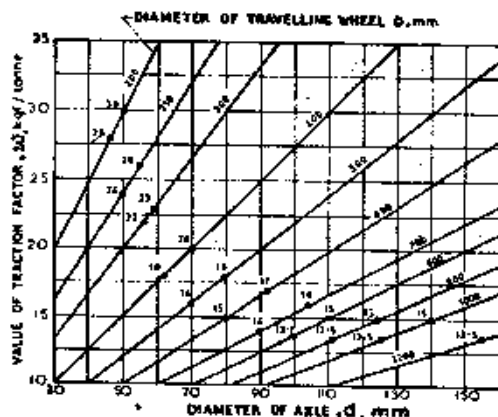
Safe load tonnes	Proof Load tonnes	C	G min	THREAD		Thrust bearings on G Series
				G ₁	pitch	
0.5	1	27 23	A = 2.75C B = 1.31C D = 1.44C	15 12	M14 M12	COURSE SERIES
1	2	38 33	E = 1.25C F = C H = 0.93C	20 20	M20 M18	
2	4	53 46	J = 0.75C K = 0.92C L = 0.7 C	30 25	M27 M24	
3.2	6.4	68 59	M = 0.6 C N = 1.2 C P = 0.5 C	35 30	M33 M30	
5	10	85 73	R = 0.5 C U = 0.3 C Z = 0.12C	45 40	M42 M30	
8	16	107 93		55 50	M52 M48	
10	20	119 104		60 55	M60 M52	
12	25	134 116		70 60	M68 M60	
16	32	151 131		80 70	M76 M68	
20	40	169 147		85 80	M80 M72	
25	50	189 164		100 85	M90 M80	513
32	60	207 175		110 100	M100 M90	



Dimensions in the top row for Mild Steel ; bottom row for high tensile steel

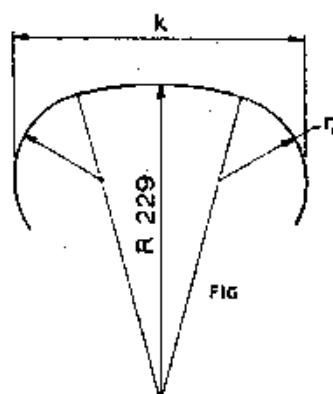
DESIGN OF TRAVELLING MECHANISM FOR TROLLEY & EOT CRANE

Equation	Nomenclature
$w = \left[\frac{d\mu + 0.1}{D} \right] 1000$	w , coefft of resistance to motion, kgf/tonne, see fig. below d , wheel axle diam, cm μ , frictional coefft of brg. for sliding $\mu = 0.1$ Antifriction brg = 0.01
$W = \beta [Q + G_o] w$	D , diam of trolley or crane wheel, cm W , resistance to motion, kgf β , factor to account for flange friction = 1.25 to 1.4 for wheels run on sliding bearings = 2.5 to 5.2 for wheels run on antifriction bearings
	Q , wt of load lifted, tonnes G_o , trolley weight, tonnes [for EOT cranes, G_o will include the self weight of bridge in this case $\beta = 1.4$ to 1.6]
Power required to drive	v , travelling speed of trolley or crane, m/s
$N = \frac{W v}{\eta \cdot 75}$ (power driven)	η , transmission efficiency η_{tw} , = 0.97 for greased wheel sliding bearing = 0.99 for wheels with antifriction bearing
$\eta = 0.93 \eta_{tw} (\eta_g)^p$	η_g , efficiency of one gear pair, = 0.95 p , no. of pairs of gears
hand operation:	E , effort applied by operator to crank handle, kgf
$v = \frac{\eta C D_o}{W D} E$	C , operating wheel speed = 0.8 to 1 m/s D_o , diam of operating wheel
Check for adhesive force	ΣP , sum of the minimum forces acting on the driving wheels of trolley or crane
$\left[W - \frac{d}{D} \mu \Sigma P \right] < Z$	Z , adhesive force between driving wheel and rail, (= $f \Sigma P$) $f = 0.15$ to 0.2 for dry rails = 0.1 to 0.12 for damp rails



TROLLEY OR CRANE WHEEL DESIGN

Equation	Nomenclature
$p = \frac{P}{C_1 C_2 D k_0} \leq p_a$	p , pressure between wheel and rail, kgf/cm ²
$k_0 = k - 2 r_1$ (Flat rail)	P , wheel load, kgf
$= k - \frac{4}{3} r_1$ (railway rail)	C_1 , speed factor, see table 1.
$P = P_{max}$ for trolley wheels	C_2 , life factor, see table 2.
$= \frac{P_{min} + 2 P_{max}}{3}$, for crane wheels	k_0 , useful width of rail head, cm
	k , width of rail, cm
	r_1 , corner radius of rail head, cm



D , Wheel diam, cm
 p_a , allowable contact pressure, kgf/cm²
 refer table 3

Values of C_1

Table 1.

rpm of wheel	200	160	125	112	100	90	80	71	63	56	50	45	40	35.5	31.5	28	25	22.4	20
C_1	0.66	0.72	0.77	0.79	0.82	0.84	0.87	0.89	0.91	0.92	0.94	0.96	0.97	0.99	1.0	1.02	1.03	1.04	1.06

Values of C_2

Table 2.

Relative operating period of travel drive, %	upto 16	16 to 25	25 to 40	40 to 63	over 63
C_2	1.25	1.12	1.00	0.9	0.8

Allowable pressure, p_a , kgf/cm²

Table 3.

Material of wheel	CI	Cast or forged steel UTS 45	Steel UTS 50	Steel UTS 60	Steel UTS 70	Hardened steel tread, Rc=36
p_a	28	43	50	56	65	65

SPEEDS FOR EOT CRANES WITH HOOK ATTACHMENT

Table 4

No. OF OPERATIONS PER HOUR															
	≤ 18 light duty					≤ 30 Normal duty					≤ 60 Heavy duty				
	SPEED OF TRAVEL, m/min														
Cross Travel	16	20	25	32		20	25	32	40		25	32	40	50	63
Longitudinal Travel	25	32	40	50	63	50	63	80	100		63	80	100	125	160

STANDARD HOISTING SPEEDS, m/min for EOT CRANES

Table 5

Rated Load, tonne	Light duty	Normal duty	heavy duty
2	6.3, 8, 10	12.5, 16, 20	25, 32, 40
3.2	5, 6.3, 8	—do—	—do—
5	—do—	—do—	—do—
8	4, 5, 6.3	10, 12.5, 16	20, 25, 32
12.5	—do—	—do—	—do—
20	3.15, 4, 5	6.3, 8, 10	12.5, 16, 20
32*	2.5, 3.15, 4	5, 6.3, 8	10, 12.5, 16
for slow hoisting	0.3, 0.5	0.8	1, 1.25

*For rated loads less than 32t, the hoist can also be operated by hand

DESIGN OF SHOE BRAKES FOR CRANES

Equation	Nomenclature
1. Heat dissipating capacity: (holding & lowering brakes)	Q_1 , heat liberated by brake drum, k cal/hr.
$Q_1 = G h z \eta J$	G , = $\frac{2}{3}$ of wt. lifted, kgf
or = $316 N \eta^2 f X$	h , = $\frac{3}{4}$ of full height of raising the load, m
$Q_d = Q_1 + Q_2 + Q_3$	Z , no. of switching in operation of brake per hour
2. Design requirement:	η , efficiency of hoisting mechanism
$Q_d > Q_1$	N , hp of hoist motor
$Q_1 = (1.3 S_1 + 4.3 S_2) 10^{-8}$ [$T_1^4 - T_2^4$]	f , duty factor = $\frac{\text{operating time}}{\text{oper.} + \text{idle times}}$
$Q_2 = 5 S_3 (T_1 - T_2) (1 - \eta)$	X , load lifted expressed as a % of capacity of hoist
$Q_3 = 6.14 f (T_1 - T_2)$	J , mech equiv. of heat, = $\frac{1}{427}$
$\left[S_4 v_0^{0.78} + 2 \sum_{i=1}^n S_i v_i^{0.78} \right]$	Q_d , heat dissipating capacity of brake drum, k cal/hr
	S_1 , area of brake wheel, not enveloped by shoes, m ²
	S_2 , area of the two side disc surfaces of drum, m ²
	T_1 , max permissible abs. temp. of brake drum, °K
	T_2 , temp. of environment, °K
3. For travelling brake	S_3 , total surface area of drum except that wrapped by shoes, m ²
	S_4 , surface area of inside and outside of the rim, m ²
$Q_1 = Z \left[\frac{G_1 v^3}{g} - \frac{W v t}{2} \right] \eta \frac{1}{427}$	v_0 , mean velocity of drum, m/s
	S_i , annular area of the i th ring of the side surface, m ² (2 to 4 annular rings are generally assumed)
	v_i , mean velocity of the i th ring m/s
	G_1 , wt of crane, kgf
	g , 9.81 m/s ²
	W , resistance to motion, kgf
	v , vel of travel, m/s
	t , braking time, s

Equation	Nomenclature
4. Check for shoe wear:	
$A = \frac{Gh\eta}{270000} \text{ or}$	A, work done in one braking operation, hp hr.
$= \frac{M_{br} \omega t_{br}}{540000}$	$M_{br} = 2.5 M\eta^2$, kg. m
	M, hoist motor torque, kg.m
	η , efficiency of hoisting mechanism
	ω , ang. vel of drum, radian/s
	t_{br} mean value of braking time, s
	$= \frac{1}{2} (t_1 + t_2)$
	t_1 braking time during raising
	$= \frac{\omega \Sigma I}{M_{br} + M_{wt}}$
	ΣI , sum of equivalent moments of inertia of brake drum, coupling & c referred to brake drum shaft
	M_{wt} , moment due to weight, kg.m
	$= \frac{974N\eta^2}{n}$
	n, rpm of motor
	t_2 braking time during lowering, s
	$= \frac{\omega \Sigma I}{M_{br} - M_{wt}}$
	y, permissible number of braking operations
	b, width of brake lining, cm
	l, length of each shoe, cm
	Δh , permissible wear in the shoe liner, cm
	p, unit pressure, kg/cm ²
	D, drum diam, cm
	μ , coeff of friction of brake lining
	v, velocity of brake drum, m/s
5. Check for pv value:	
$pv = \frac{Mv}{D\mu bl}$	

For holding brakes,
pv must be less than 30

SIZES OF LOWERING BRAKES

BRAKE WHEEL				Motor Power, hp at n rpm		
Diam, D, mm	Width B, mm	Weight, kgf	Mom of inertia, kgf m.s ²	n = 570	n = 730	n = 960
250	80	16	0.018	7	8	9
320	100	29	0.05	12	13	15
400	125	53	0.14	21	24	28
500	160	90	0.40	37	42	50
630	200	135	1.1	67	77	—
800	250	203	2.2	122	144	—

SIZES OF TRAVELLING BRAKES

BRAKE WHEEL					Motor Power in hp at n rpm					
Diam D	width B	n = 570 & Travel speed, m/min			n = 730 & travel speed, m/min			n = 960 & travel speed, m/min		
mm		90	120	180	90	120	180	90	120	180
250	80	18	13	9	20	15	10	22	17	11
320	100	29	23	15	33	26	17	37	29	19
400	125	50	40	27	56	45	30	65	52	35
500	160	80	65	45	90	73	50	105	85	59
630	200	130	110	80	150	125	90	—	—	—
800	250	210	180	138	250	210	160	—	—	—

SIZES OF HOLDING BRAKES

BRAKE WHEEL		Power of hoist motor, hp at n rpm		
Diam, mm	Width, mm	n = 570	n = 730	n = 960
160	50	9	10	11
200	65	13	15	16
250	80	19	21	24
320	100	31	35	40
400	125	52	59	67
500	160	85	96	112
630	200	135	156	—
800	250	220	260	—

BELT CONVEYORS

Equation

nomenclature

$$W_o = C f L [(G_o + G_b) \cos \delta + G_{ro}] \pm H (G_o + G_b)$$

(minus for conveying down)

$$W_u = C f L [G_b \cos \delta + G_{ro}] \mp H G_b$$

(plus for conveying down)

$$P = W_o + W_u$$

hp of drive,

$$hp = \frac{P \cdot v}{75}$$

TENSIONS IN THE BELT

Head
Drive

Tail
Drive

Both
Driven

$$T_1 = P \left[\frac{e^{\mu \alpha}}{e^{\mu \alpha} - 1} \right] \quad T_1 \left[\frac{e^{\mu \alpha}}{e^{\mu \alpha} - 1} \right]$$

at head end

$$T_2 \text{ or } HG_b \text{ if } \frac{T_1 - P}{e^{\mu \alpha} - 1} < HG_b \quad T_1 - P$$

at head end

$$T_3 = T_2 + W_u \quad T_1 - W_u \quad P_2 \frac{e^{\mu \alpha}}{e^{\mu \alpha} - 1}$$

at tail end

$$W_u \pm HG_b \text{ if } \frac{P}{e^{\mu \alpha} - 1} < HG_b$$

$$T_4 = T_3 \quad T_2 \quad T_3 - P_2$$

at tail end

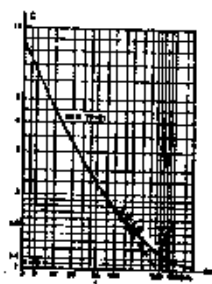
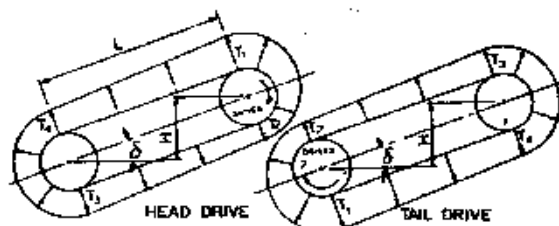
α , angle of lap over pulley in radians

μ , coeff of friction between belt and pulley,
0.1 to 0.4

$P = P_1 + P_2$ when both pulleys are driven.

$$B_{min} = 1.11 \left[\left\{ \frac{Q}{c v} \right\}^{\frac{1}{2}} + 0.05 \right]$$

$$i = \frac{T_1}{B f}$$



- W_o resistance of the belt on the top run, kgf
 W_u resistance of the belt on the bottom run, kgf
 C secondary resistance factor, see fig. p. 9.20
 f friction between idler and belt
 = 0.016 to 0.018 for non-portable conveyors with good idlers
 = 0.02 for standard conveyors
 = 0.023 to 0.027 for idlers in dusty environment
 L Conveyor length, m see fig. p. 9.20
 G_o wt. of conveyed material/meter length, kgf/m
 G_b wt. of belt/metre length, kgf/m, table 1. p. 9.19
 δ inclination of conveyor
 G_{ro} wt. of troughing idlers on the top run/metre length, kgf/m, see table 2. p. 9.19
 G_{ru} wt. of straight idlers on the bottom run/metre length, kgf/m, table 2, p. 9.19
 H height thro' which material is conveyed, m
 B_{min} min width of belt, m
 Q conveyor capacity, tonnes/hr
 v belt speed, m/s, refer. table 3, p. 9.20
 c factor for the type of idler
 = 240, for flat belt
 = 460, for trough angle of 20°
 = 510, for trough angle of 25°
 = 545, for trough angle of 30°
 T_1 max. tension in belt, kgf.
 B width of standard belt, mm
 i number of plies, check for i_{min} & i_{max} table 4, p. 9.21
 f working tension of belt for 1 mm width, kgf/mm per ply, see table 5. p. 9.21

WEIGHT OF CONVEYOR BELTS, kgf/m

Table 1:

Belt width, mm	400	500	650	800	1000
Average weight per metre run, kgf.	5	6.5	9	12	16

WEIGHT OF REVOLVING PARTS OF IDLERS in kgf/idler assembly

Table 2:

Belt width, mm	Tube diam, mm	100		125		140		150	
	Bearing diam (antifriction) mm	20	25	20	25	20	25	20	25

TROUGHING IDLERS

400									
500		13.6	14.1	16.4	20				
650				17.9	21.6	24.4	24.6		
800				19.4	23.1	26.2	27.4		34.7
1000						29.9	30.2		37.8

STRAIGHT IDLERS

400									
500		7.6	7.8	9.5	10.7				
650				11	12.2	15.8	15.9		
800				12.65	13.7	18.2	18.8	—	22.5
1000						21.3	21.4	—	25.1

Maximum spacing for IDLERS, m

Belt width, mm	Density of material conveyed, tonne/m ³				
	Over upto	0.4 1.2	1.2 2	2.0 2.8	Return idler
400		1.6	1.5	1.4	3.0
500		"	"	"	"
650		"	"	"	"
800		1.5	1.3	1.2	"
1000		"	"	"	"

Type of material conveyed	Belt width, mm				
	400	500	650	800	1000
Gravel, stone, coal, ash, ores	1.5	1.75	2	2.75	2.75
Coke, friable materials	1.25	1.5	1.5	1.75	2.0
dry and wet sand, grains, and light materials	2	3	3.5	4	4
abrasive materials, fine coke, slag, crushed ore	1.25	2	2	2.5	2.5
abrasive materials: in large lumps, slaggy rock, ores			1.75	1.75	2

TABLE TO CHECK THE NUMBER OF PLYS OF BELT

Table 4.

TABLE 41

		Density of material conveyed, t/m ³															
Belt	over	0.4				0.85				1.25				1.75			
Width,	upto	0.85				1.25				1.75				2.5			
mm	No. of plies, i	designation of belt fabric, oz															
		28	32	28	32	36	42	32	36	42	48	32	36	42	48		
400	min	3	3	3	3			4									
	max	5	4	5	4			4									
500	min	3	3	4	4	3		4	4								
	max	6	5	6	5	5		5	5								
650	min	4	4	5	4	4	3	5	5	4		5	5	4			
	max	7	6	7	6	5	5	6	5	5		6	5	5			
800	min	4	4	5	5	4	4	5	5	4	3	6	6	4	4		
	max	8	7	8	7	6	6	7	6	6	5	7	6	6	5		
1000	min	4	4	6	5	5	5	7	6	5	4	8	7	6	5		
	max	10	9	10	9	8	8	9	8	8	7	9	8	8	7		

WORKING TENSION IN CONVEYOR BELTS

Table 5.

Designation		28 oz	32 oz	36 oz	42 oz	48 oz
Working tension, kgf/mm width per ply	Vulcanised joint & gravity take up	0.54	0.62	0.71	0.82	1.07
	Mechanical joint & gravity take up or vulcanised & screw take up	0.48	0.57	0.66	0.77	0.98

DENSITY & ANGLE OF REPOSE OF COMMONLY CONVEYED MATERIALS

Table 6.

Material	Recommended max. angle of belt to horiz, deg. δ	Density tonne/m ³	Angle of repose, deg.
anthracite, fine, dry		0.8 — 0.95	45
gypsum, small lump		1.2 — 1.4	40
Clay, dry, lump		1.0 — 1.5	50
gravel	12	1.5 — 1.9	45
earth, dry		1.2	45
foundry sand (shake out)	24—26	1.25 — 1.3	45
ash, dry	23	0.4 — 0.6	50
lime stone, lump	20	1.2 — 1.5	45
Coke	17	0.36 — 0.53	50
Wheat flour	23	0.45 — 0.66	55
Oat	18	0.4 — 0.5	35
saw dust	27	0.16 — 0.32	39
dry sand	18	1.4 — 1.65	45
Wheat	18	0.65 — 0.83	35
iron ore	18—25	2.1 — 2.5	50
peat, dry lump	18	0.33 — 0.41	45
Coal (from mine)	18	0.65 — 0.78	50
dry cement	20	1.0 — 1.3	50
slag, anthracite	22	0.6 — 0.9	45

DESIGN OF BUCKET ELEVATORS

Equation	Nomenclature
$\frac{i_0}{a} = \frac{Q}{3.6 v p \psi}$	i_0 Capacity of each bucket, litre a, pitch of bucket, m $\approx (2.5 \text{ to } 3) h$ h, height of bucket at the belt or chain end, m v, belt or chain velocity, m/s p, bulk density of conveyed material, tonne/cu.m ψ, bucket loading efficiency, table. 1, p. 9.24 Q, capacity of elevator, tonne/hr
	$\frac{i_0}{a}$, values from table 2. p. 9.24
$A \geq a_{\max} \text{ m}$	A, projection of bucket from belt face, mm $a_{\max}$ dimension of the largest lump of material conveyed, mm m, = 2 to 2.5 if 20% of material is of size $a_{\max}$ = 4.25 to 4.75 if 50 to 100% of the material is of size $a_{\max}$ $S_{\max}$, max. static tension in the belt, kgf. H, ht to which the load is elevated, m q, wt. of load/ metre of elevator, kgf/m K_1, factor of resistance, see table 3, p. 9.25 q_0, wt. per meter of belt or chain with buckets, kgf/m $\approx K_2 Q$ (For K_2 see table 3) N, power, kw K_3, factor, see table 3, p. 9.25
$S_{\max} = 1.15 H (q + K_1 q_0)$	
$q = \frac{Q}{3.6 v}$	
Power on the drive shaft:	
$N = \frac{QH}{367} (1.15 + K_1 K_3 v)$	

PARAMETERS OF BUCKET ELEVATORS

Table 1.

Typical loads	Type of elevator	Type of bucket	Loading efficiency, Ψ	Range of Speed, v, m/s	
				belt	chain
Coal dust	slow speed gravity discharge	D	0.85	—	0.6—0.8
Cement, chalk, fertilizer	high speed centrifugal discharge	D	0.75	1.25—1.8	—
Saw dust, dry clay in lumps, coal	„	D	0.7—0.8	1.25—2	1.25—1.6
Gravel, ore. slag.	slow speed directed gravity discharge	V	0.7—0.85	0.8—1	0.8—1
Sand, ash, earth, rock	high speed centrifugal discharge	D	0.7—0.8	1.6—1.8	—
Moist chemicals, wet sand &c.,	high speed centrifugal discharge	Sh	0.4—0.6	1.25—1.8	1.25—1.6
— „ —	slow speed gravity discharge	Sh	— „ —	—	0.6—0.8

D, deep; V, Vee; Sh, Shallow.

SELECTION OF BUCKETS : based on $\frac{i_0}{a}$

Table 2.

Deep buckets		Shallow buckets		V buckets		bucket width, B mm
$\frac{i_0}{a}$ 1/m	i_0 litre	$\frac{i_0}{a}$	i_0	$\frac{i_0}{a}$	i_0	
2.5	0.75	—	—	—	—	135
3.67	1.1	2.17	0.65	9.4	1.5	160
6.67	2.0	3.67	1.1	—	—	200
8	3.2	6.5	2.6	18.0	3.6	250
15.6	7.8	14.0	7.0	31.2	7.8	350
24.2	14.5	25.0	15.0	50.0	16.0	450
				85.0	34	600
				134	67	750
				206	130	900

Conveying capacity Q tonne/hr	Elevator type					
	Belt		Single Chain		Double chain	
	Type of buckets					
	D,sh	V	D,sh	V	D,sh	V
	K ₃					
upto 10	0.6	—	1.1	—	—	—
10 to 25	0.5	—	0.8	1.1	1.2	—
25 to 50	0.45	0.6	0.6	0.85	1	—
50 to 100	0.4	0.55	0.5	0.7	0.8	1.1
Over 100	0.35	0.5	—	—	0.6	0.9
K ₁	2.5	2	1.5	1.25	1.5	1.25
K ₂	1.6	1.1	1.3	0.8	1.3	0.8

DIMENSIONS & CAPACITY OF BUCKETS

Table 4.

Type of bucket	BUCKET			Standard pitch, a. mm	
	width B mm	height h mm	capacity V_0 litre	bucket	chain
deep	135—400	100—240	0.75—14.5	300, 400, }	100, 125,
shallow	160—450	100—285	0.65—15	500, 600 }	160, 200,
Vee	160—960	455—620	1.5—130	160, 200, 250, 315, 400, 500, 630:	250, 315, 400, 500, 630

DESIGN OF SCREW CONVEYORS

Equation	Nomenclature
$Q = 15 \pi D^2 S n \Psi \rho C$	Q, capacity of conveyor, tonne/hr
Power required for driving the screw:	D, screw diameter, m
$N = \frac{QL}{367} \left[w_m \pm \sin \beta \right] \frac{1}{\eta}$	S, pitch of screw, m, = (0.8 to 1) D
i) torque on screw shaft, M,	n, rpm of screw shaft, table 1. below
$M = 975 \frac{N}{n}, \text{ kgf m}$	Ψ , loading efficiency, =0.125 for slow flow abras. material =0.25 for slow flow, mildly abr. material =0.32 for free flow & mildly abr material =0.4 for free flow & non abrasive material
ii) load propulsion speed, v	ρ , bulk density of conveyed material, tonne/cu.m
$v = \frac{\pi n}{60}, \text{ m/s}$	C, factor for inclination to horiz.
iii) load per metre length of conveyor, q	β angle of inclination of screw shaft to horizontal
$q = \frac{Q}{3.6 v}$	
iv) axial thrust on screw, P	
$P = q L \mu, \text{ kgf}$	

β , deg	0	5	10	15	20
C	1.0	0.9	0.8	0.7	0.65

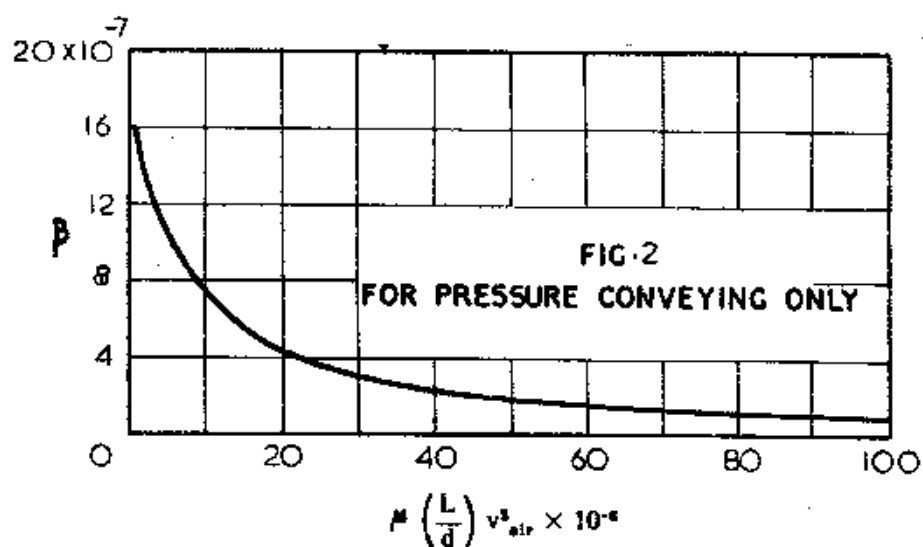
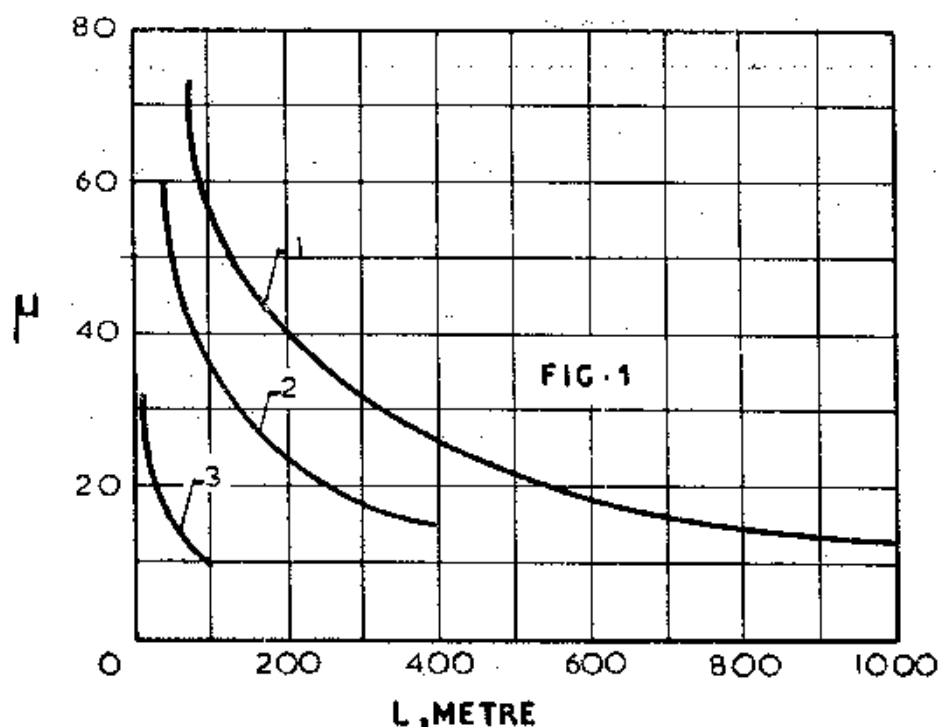
N,	power in kW
L,	length of screw conveyor, m = H, for vertical conveyor
H,	$L \sin \beta$,
w_m ,	material factor =2.5 for coal, rock salt &c., =4.0 for fine dry clay, foundry sand, cement, sulphur, ash, lime &c.,
η	efficiency of gear reducer.
μ	friction factor of the material on trough, 0.6 to 0.9

Recommended speeds for Screw Conveyors

Table 1.

Screw diam, D mm		150	200	250	300	400	500	600
n, rpm	min	23.6	23.6	23.6	19	19	19	15
	max	150	150	118	118	95	95	75

Equation	Nomenclature
i) Equivalent Length: $L = \Sigma l_h + \Sigma l_v + \Sigma l_b + \Sigma l_{air}$	L , total reduced length of conveyor tube, m Σl_h , sum of all the horiz lengths, m Σl_v , sum of all the vertical lengths, m Σl_b , sum of all the equivalent lengths for bends or elbows, m, table. 1 p. 9.29 Σl_{air} , sum of all the equivalent lengths for diverting valves, m
ii) Velocity of conveying air: $v_{air} = \alpha \sqrt{p + (BL)^2}$ *omit this term for suction conveyors.	α , Size factor of particles conveyed, table 2, p. 9.29 p , sp. wt of load particles, tonne/cu.m, see table. 3 B , =(2 to 5) 10^{-4} , lower values for dry powdered materials μ , wt concentration coefft of air-material mixture fig. 1, p. 9.28 Q , capacity of conveyor, tonne/ hour V_{air} , air consumption, cu.m/s d , diam of pipe, m P_1 , inlet pressure in atmos. + sign in the 2nd term for conveying up a pipe - sign for conveying down P_o , outlet pressure in atmos. - sign in 2nd term for up conveying + sign for conveying down β , factor from fig. 2, p. 9.28 $= 1.5 \times 10^{-2}$, for suction conveying H , vertical lift, m ρ^1_{air} , =1.6 to 2, kgf/m ³ for high pressure conveying $= 0.8$ to 0.95 for suction conveying N , power kW η , compressor or blower efficiency, 0.55 to 0.75 P_w , working pressure, atm. $= P_1$ for pressure system $= 1 - P_o$ for suction system P_{loss} , loss in pressure due to leakage in the system, atm. $= 0.3$ for pressure system $= 0.02$ for suction system.
iii) Weight concentration of mixture: $\mu = \frac{Q}{4.32 V_{air}}$	v_{air} , Velocity of conveying air stream m/s (Take 1.5 times value in Table 3, p. 9.29)
iv) Estimation of air consumption: $V_{air} = \frac{\pi d^4}{4} v_{air}$	
v) Inlet pressure of Air: for pressure conveying, $P_1 = \left[1 + \frac{\mu \beta L v_{air}^2}{d} \right]^{\frac{1}{2}} \pm \frac{H \rho^1_{air} \mu}{10^4}$ for suction conveying, $P_o = \left[1 - \frac{\mu \beta L v_{air}^2}{d} \right]^{\frac{1}{2}} \mp \frac{H \rho^1_{air} \mu}{10^4}$	
vi) Driving Power for compressor or blower $N = 248.4 \frac{V_{air}}{\eta} \log (1.2 P_w + P_{loss})$	



EQUIVALENT LENGTHS FOR BENDS AND ELBOWS: (in metres)

Table 1.

Bend radius inner diam of pipe		4	6	10	20
Material conveyed	Powder	4 to 8	5 to 10	6 to 10	8 to 10
	Granules		8 to 10	12 to 16	16 to 20
	Irregular small lumps			28 to 35	38 to 45
	Irregular large lumps			60 to 80	70 to 90

SIZE FACTOR OF PARTICLES

Table 2.

Material	max. particle size, mm	α
Powder	< 1	10 to 16
Granules	1 to 10	17 to 20
Homogeneous lumps, small	10 to 20	17 to 22
„ „ medium	40 to 80	22 to 25

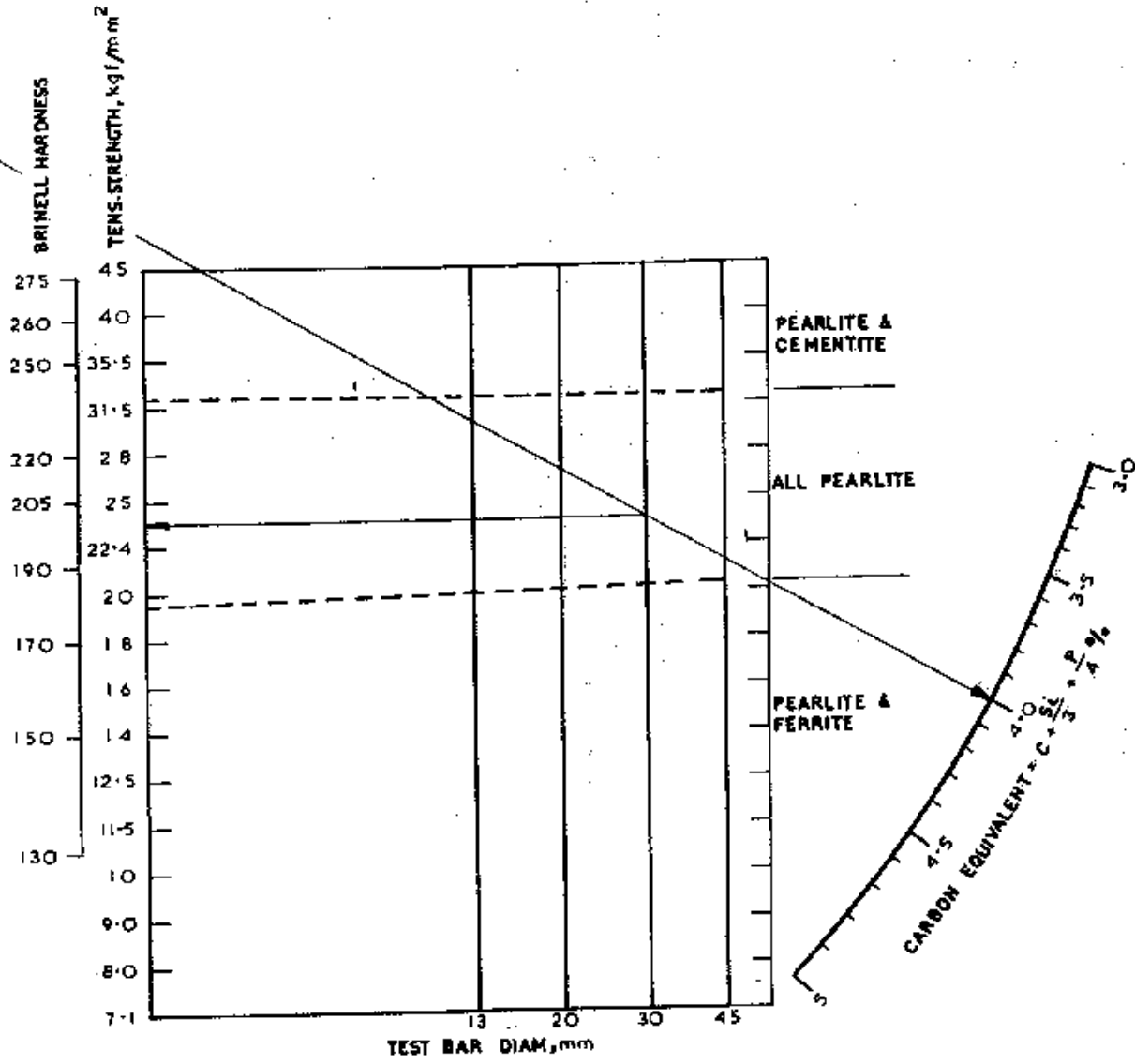
BULK DENSITY, AIR VELOCITY &c., for typical materials

Table 3.

Material	Bulk density tonne/m ³	(V _{air}) m/s		μ p' air kgf/cu.m	
		vert.	horiz.	vert.	horiz.
Coal	0.72	12	15	16	12
Wheat	0.75	9	12	32	24
Polythene cube	0.48	9	12	32	24
FLUIDSABLE POWDERS:					
Cement	1 — 1.45	1.5	7.5	960	160
Flour	0.56	1.5	4.5	240	80
Pulv. coal	0.72	1.5	4.5	320	112
Pulv. ash	0.72	1.5	4.5	480	160
Common salt	1.36	3	9	240	80
Ground bauxite	1.44	1.5	7.5	640	128
Alumina	0.93	1.5	7.5	480	96
Magnesite	1.6	3	9	480	160

MECHANICAL TEST REQUIREMENTS OF GREY IRON CASTINGS: IS : 210 — 1963

Grade of Cast Iron	Sectional thickness of casting mm		Test bar diam, mm as cast	Tensile strength kgf/mm ² min	TRANSVERSE TEST			BHN
	Over	Upto			Breaking load min. kgf	Rupture Stress kgf/mm ²	Deflection min mm	
15	4	8	13	19	180	41.7	2	149
	8	15	20	17	400	38.2	2.5	to
	15	30	30	15	800	34.0	4.0	197
	30	50	45	13	1700	28.5	6.0	
20	4	8	13	24	200	46.4	2	179
	8	15	20	22	450	43.0	3	to
	15	30	30	20	900	38.2	4.5	223
	30	50	45	17	2000	33.5	6.5	
25	4	8	13	28	220	51.0	2	197
	8	15	20	26	500	47.8	3	to
	15	30	30	25	1000	42.4	5	241
	30	50	45	22	2300	38.6	7	
30	8	15	20	31	550	52.5	3.5	207
	15	30	30	30	1100	46.7	5.5	to
	30	50	45	27	2600	43.6	7.5	241



MATERIALS FOR MAKING PATTERNS

Properties	MATERIAL					
	Wood	Al	Steel	C.I.	Plastic	Resin
Machinability	E	G	F	G	G	G
Wear resistance	P	G	E	G	F	G
Strength	F	G	E	G	G	F
Repairability	E	P	G	E	F	P
Resistance to corrosion	E	E	E	P	E	E
Resistance to swelling	P	E	E	E	E	E

E, excellent; G, Good; F, Fair; P, Poor.

SHRINKAGE ALLOWANCE

Cast metal	over upto	PATTERN DIMENSION, mm			
		—	630	1250	1800
		630	1250	1800	1800
		SHRINKAGE, mm/m			
Grey C.I.:					
Open & cored construction		10	8	7	
Cast STEEL:					
Open construction		20	16	16	13
Cored construction		20	16	13	10
Aluminium:					
open construction		13	13	11	10
Cored construction		13	10 to 5	10	10
Magnesium:					
Open construction		56	56	13	13
Cored construction		13	13 to 10	10	10
Brass		15			
Bronze		16 to 20			

RECOMMENDED NORMAL DRAFT ANGLE & DRAFT AT BORES & GROOVES IN PATTERNS

height of pattern	Normal Draft		Draft in bores & grooves	
	in deg	in mm	in deg	in mm
0 — 10	3	0 — 0.5	5	0 — 0.9
11 — 20	2	0.4 — 0.7	3	0.6 — 1
21 — 40	1.5	0.6 — 1	2	0.7 — 1.4
41 — 70	1	0.7 — 1.2	1.5	1 — 1.8
71 — 100	0.75	1 — 1.4	1.2	1.5 — 2
101 — 130	0.7	1.2 — 1.6	1	1.8 — 2.3
131 — 160	0.65	1.4 — 1.8	0.9	2.1 — 2.5
161 — 200	0.6	1.6 — 2	0.8	2.3 — 3

SHRINKAGE ALLOWANCE, C. I.:

	Section thickness of malleable C.I., mm									
	1.6	3	4.8	6.3	9.5	12.5	16	19	22.5	25
Shrinkage allowance, %	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.6	0.4	0.3

GENERAL TOLERANCES* FOR SAND CASTINGS

METAL	Aluminium alloys	C.I.	Copper base alloys	Cast Steel	Magnesium alloy	Malleable Iron
*Tolerance mm/m, $\pm$	3	4	8	5	3	3

*Tolerances indicated for all dimensions including wall thickness, core shift etc.,

RECOMMENDED MACHINING ALLOWANCES ON CASTINGS

MATERIAL OF CASTING

Dimension of Pattern, mm		Cast Iron		Cast Steel		Malleable Iron		Brass, Bronze, Aluminium	
Over	upto	on bore mm	on surface mm	on bore mm	on surface mm	on bore mm	on surface mm	on bore mm	on surface mm
	160	3	2.5	5	3	1.6	1.6	2.5	1.6
160	250	3	2.5	5	3	2.5	1.6	2.5	1.6
250	315	3	2.5	5	3	2.5	2.5	2.5	1.6
315	630	5	3	6.3	5	4	3	5	3
630	900	6.3	5	8	8	5	5	5	4
900	1120	6.3	5	8	8				
1120	1600	8	6.3	10	10				
1600	2000	10	8	12.5	11.2	Special Instructions			
2000	3150	11.2	10	16	12.5				
3150		Special Instructions							

COLOURING & MARKING SYSTEM FOR WOODEN PATTERNS

Part of Pattern		Colour/Mark
1.	As cast, surfaces which are to be left unmachined	Red or Orange.
2.	Surfaces which are to be machined	Yellow
3.	Core prints for unmachined openings:	
	A. Periphery	Black
	B. Ends	Black
4.	Core prints for machined openings:	
	A. Periphery	Yellow stripes on Black
	B. Ends	Black
5.	Pattern Joint (split Patterns):	
	A. Cored section	Black
	B. Metal section	Clear varnish
6.	Touch Core:	
	Cored shape	Black
7.	Seats of and for loose pieces and loose core prints	Green
8.	Stop-offs	Diagonal black stripes with clear varnish.

MINIMUM SECTIONS FOR CASTING

Metal	Sand Casting mm	Die Casting		Permanent mould castings mm	Plaster mould casting (over small areas) mm
		Over large areas mm	Over small areas mm		
Aluminium alloys	3 to 5	2.0	1.25	3.0 over small areas	1
Copper alloys	2.5	2.5	1.5	3.0 over small areas	2.5
Grey Iron GR 20	3	—	—	4.5 over small areas	1.5
25	3				
30	6				
40	12				
Lead alloy	—	2	1	—	—
Magnesium alloy	4.0	2	1.25	4.0 to 5.0	—
Malleable iron	3	—	—	—	—
Steel	5	—	—	—	—
Tin Alloys	—	1.5	0.8	—	—
White Iron	3	—	—	—	—
Zinc alloys	—	1.25	0.4	—	—

GUIDE TO SELECTION OF CASTING PROCESS

Features	Process of casting					
	Sand mould	Shell mould	Permanent mould	Plaster mould	Investment	Die Cast
Material	ferrous non-ferrous, light metals	except low carbon steels	brass, bronze, Aluminium & grey iron.	Non-ferrous	all materials including those which are hard to forge or machine	Zinc, aluminium, brass, magnesium
Size	no limit	less than 400 sq. cm.	not exceeding 25 kgf.	not exceeding 7 kgf	not exceeding 1 kgf	not exceeding 35 kgf in Al 100 kgf in Zn.
minimum section thickness, mm	3 for non-ferrous 5 for ferrous	1.5	2.5	0.8	0.75	0.6
Surface finish	poor	good	good	good	excellent	good
Lead time	3 to 5 days for pattern making	10 to 20 days for pattern making	Die making will require several weeks	Couple of weeks for making the pattern	Several weeks for making the die	Several weeks for making the die
Dimensional Variation mm/mm	0.06 to 0.03	± 0.003 to 0.005	± 0.06	0.001 to 0.025	± 0.005	± 0.001
Remarks	Some machining before use	low cost	for mass production	No machining required	best for complicated shapes	for mass production

RECOMMENDED PROPERTIES OF MOULDING SAND

Size of casting	Cast Metal	Properties				
		Moisture %	* Permeability ml/min.	Green compression kgf/cm ²	Green Deformation mm	Dry Compression kgf/cm ²
Small	Bronze, brass and aluminium	6—8	130—245	0.40—0.55	0.45—0.60	3.5—5.0
Medium	Aluminium, bronze, brass	6—7.5	245—330	0.50—0.65	0.35—0.50	6.5—8.5
Small	Grey iron, malleable iron	6—8	330—490	0.40—0.55	0.50—0.55	3.5—5.5
Medium	Grey Iron	2—5	820—1310	0.55—0.70	0.25—0.35	7.0—10.5
Heavy	Grey Iron	2—5	1470—2140	0.55—0.85	0.30—0.40	10.5—11.5
Heavy	Malleable iron	2—4	820—1150	0.50—0.70	0.30—0.45	11.5—17.5
Small	Steel	2—4	1640—2460	0.50—0.65	0.50—0.75	5.0—8.5
Heavy	Steel	2—4	3280—4900	0.50—0.70	0.50—0.75	14.0—24.0

* Orifice diam of 1.5 mm

MINIMUM SIZE OF CORED HOLES, mm

Metal	Process		
	Sand casting	Permanent mould	Die casting
Cast Iron	25	6.3	—
Copper base	10	"	5
Aluminium base	10	"	2.5
Zinc base	10	"	1
Magnesium base	10	"	2.5

RECOMMENDED DIAMETER OF BAKED CORES, mm

(to limit the deflection of core due to buoyancy of liquid metal to less than 1 mm)

Condition of support	Length of cored hole, mm	Casting wall thickness, mm					
		20		12.5		6.3	
		ferrous	non ferrous	ferr.	non ferr.	ferr.	non ferr.
†Core positioned horizontally at the parting plane and anchored at both ends.	125	25	20	20	15	20	10
	250	50	45	35	30	25	22
	375	70	65	50	45	35	32
	500	90	80	65	60	—	—
*Core positioned horizontally at the parting plane and anchored at one end only.	125	50	40	30	25	25	20
	250	90	75	65	55	50	45
	375	—	100	90	75	70	65
	500	—	—	—	95	—	—
†Core positioned vertical to the parting plane and anchored at both ends.	125	20	20	25	12.5	20	10
	250	30	30	25	25	30	20
	375	50	50	35	35	30	30
	500	70	70	50	50	40	40

†min. length of core print = 2 (core diam)

*" " " ≥ (length of cored hole)

LIFE OF PERMANENT MOULDS

METAL	Pouring temp. °C	Approx. mould life, castings	Mould operating temp. °C
Grey C.I.	1250 — 1500	5000 — 20000	325 — 450
Aluminium base	720 — 780	upto 100000	360 — 450
Copper base	1050 — 1175	5000 — 20000	140 — 280
Magnesium base	660 — 725	20000 — 100000	170 — 340
Zinc base	400 — 450	100000 & above	220 — 280

TIME REQUIRED TO FORM 5 mm SHELL IN 6% RESIN SAND

Pattern plate temp, °C	170	195	220	250
required time, sec.	21	12	10	7

SELECTION OF FURNACES

Type of furnace	To melt	Fuel	obtainable metal temp, °C	Capacity tonne/hr	Lining	Possible range obtainable in ferrous metals, %				
						C	Si	Mn	S	P
Cupola	C.I	Coke	1450 max	1 to 35	Acid basic	2.5 to 3.8 2.7 to 4.4	4 max 4 max	4 max 4 max	0.08 min 0.01 min	0.05 min 0.04 min
Air furnace	CI, malleable iron & non ferrous metals	Coal & oil	1560—1650	10 to 40	Acid	1.5 to 3.5	optional	optional	0.03 min	0.04 min
Open hearth	Steel	Fuel oil, coke oven gas, producer gas	1590—1650	25 to 300	Acid Basic	0.05 — 1.5 0.02 — 1.5	optional	optional	0.03 min 0.03 min	0.03 min 0.02 min
Direct Arc	CI, Steel & non ferrous metals	electric	1560—1760	upto 150	Acid basic	0.02 — 3.8 0.02 — 3.8	optional	optional	0.3 min 0.1 min	0.02 min 0.01 min
Induction	Steel, CI	electric	1560—1760	0.001 to 15	Acid basic	0.02 — 4.2 "	optional	optional	0.03 min 0.02 min	0.03 min 0.02 min
Converter	to convert liquid pig iron to steel	oxygen	1650—1700	10 to 60	Acid	0.02 — 0.2	0.1 max	0.1 max	0.04 min	0.04 min
Indirect Arc	ferrous & non ferr. metals	electric	1560—1700	upto 600 for ferrous upto 320 for non-ferrous	Acid	0.5 — 3.8	optional	optional	0.03 min	0.03 min

DATA ON CUPOLA OPERATION

Characteristic	Designation of cupola					
	C450	C600	C750	C900	C1050	C1200
Nominal capacity, t/h	0.5	1	2	3	4	5
Inner diameter of lining, mm	450	600	750	900	1050	1200
Inner diam of shell, mm	780	930	1360	1510	1660	1810
Bed coke height above tuyers, mm	710—900	900—1060	950—1100	1060—1180	1060—1250	1120—1280
Charge layers: (Coke: metal::1:6)						
Coke, kgf	9	16	25	35	45	63
Flux, limestone, kgf	1.8	3.15	5	7	9	12.5
Air thro' tuyers, m ³ /min (minimum)	18	25	50	75	90	110
Pressure of air, mm (water gauge)	600	600	600	600	600	600
Number of tuyers	4	4	6	6	8	8
Area of each tuyer, mm ²	13000	13000	15000	15000	20000	20000

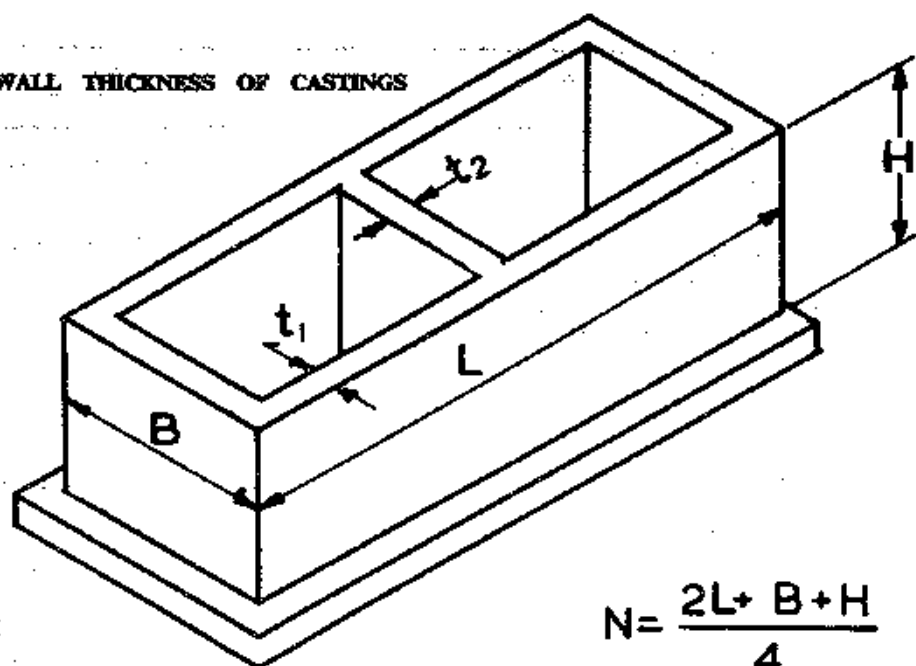
CASTING DEFECTS — CAUSES AND REMEDIES WITH PARTICULAR APPLICATION TO IRON CASTINGS

Defects	Appearance	Cause	Remedies
MISRUN	May appear as — 1. Holes in thin sections of a casting. Edges are smooth and well rounded: surface of metal around holes smooth and often shiny. 2. As a line, when two streams of metal have met but not fused together.	1. Low pouring temperature 2. Low fluidity 3. Hard mould (mainly on very thin casting). 4. Core shift causing uneven thicknesses. 5. Very high moisture content.	1. Provide hotter metal at cupola spout; reduce heat losses in ladles by using flux coverings. 2. Increase carbon and phosphorous. 3. Avoid excessive ramming. 4. Reduce moisture content. 5. Keep runner bush full of metal during pouring.
SHRINKAGE DRAWS & HOTSPOT	Rough cavities entering casting on heavy sections, or at the joint of change of sections. Saucer shaped depressions on heavy sections.	1. Incorrect gating and feeding	1. Use risers to feed heavy sections. 2. Ensure that they are filled with hot metal. For open risers use feeding flux, for blind risers use feeding cores.
SLAG	Similar to appearance for shrinkage and draws defects. Cavities are generally more saucer shaped and smoother.	1. Dirty metal. 2. Incorrect gating.	1. Remove all slag from metal before pouring. 2. Incorporate skim gates or strainer cores in runner systems.
POROSITY	Casting "weep" under pressure test: machined surfaces show cavities in thick sections	1. Wrong type of metal 2. Running and feeding system. 3. Gassy metal.	1. Reduce silicon or phosphorous content 2. Degas and scavenge well.
HARD METAL	Bright areas on machined faces, often at corners or edges of thinner sections.	1. Wrong type of metal. 2. High moisture content. 3. Pouring practice.	1. Increase silicon content. 2. Reduce moisture. 3. Avoid splashing metal down runners and risers.

CASTING DEFECT—CAUSES AND REMEDIES WITH PARTICULAR APPLICATION TO IRON CASTINGS. (Contd.)

Defects	Appearance	Cause	Remedies
SCABS	Rough incrustation of sand & metal on surface of castings mainly on heavy sections.	1. Uneven ramming 2. Incorrect gating. 3. Improperly dried moulds 4. High clay content in moulding sand.	1. Ram more evenly. 2. Gate so that an even flow of metal is obtained. 3. Avoid too rapid drying. 4. Change moulding sand.
DISTORTION	Casting shows swelling on surface.	1. Uneven mould hardness due to insufficient ramming to withstand metal pressure. 2. Poor weighting practice.	1. Ram evenly and firmly. 2. Increase weight on moulds and ensure it is distributed evenly.
ROUGH SURFACE	Casting surface rough	1. Metal penetration. 2. Low coal dust content. 3. Hard sand surface with low permeability. 4. Moulding sand too "open".	1. Use finer sand or rise mould dressing. 2. Make additions of coal dust. 3. Open up the sand.
CRACKS	Hairline crack showing on casting. When broken discolouration shows that crack was produced while casting was hot. No discolouration shows cold crack.	1. High dry strength of sand 2. Cores too hard. 3. Casting strains. 4. Mechanical reasons.	1. Ram softer to allow casting to contract 2. Reduce oil in cores. 3. Gate evenly.
BLOWHOLES	Rough shaped holes occurring on the outside of the casting or in thicker sections. May be found just below surface on machining. In severe cases, section of casting may be hollow.	1. Low vent on moulding or core sands 2. Hard ramming. 3. High moisture content. 4. Very hard cores. 5. Insufficient venting in cores	1. Increase vent by use of vent wire. 2. Avoid excess ramming. 3. Reduce moisture to minimum. 4. Reduce oil in sand. 5. Ensure vents are clear.

RECOMMENDED WALL THICKNESS OF CASTINGS



$$N = \frac{2L + B + H}{4}$$

$$N = \frac{2L + B + H}{4}$$

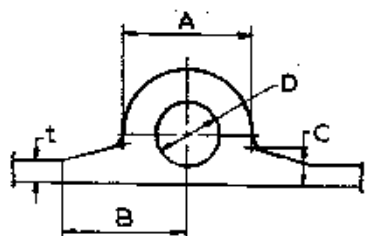
Characteristic dimension N of the casting, m		t ₁ , thickness of outer walls, mm	t ₂ , thickness of inner walls, mm
Over	Upto		
	0.75	8	6
0.75	1.0	10	8
1.0	1.5	12	10
1.5	1.8	14	12
1.8	2.0	16	12
2.0	2.5	18	14
2.5	3.0	20	16
3.0	3.5	22	18
3.5	4.5	25	20

RECOMMENDED MINIMUM WALL THICKNESS AND MAXIMUM LENGTH OF CASTINGS

Grade of cast iron	Minimum wall thickness, mm	Maximum Length, mm
15	4	1000
	8	1500
20	10	1000
	12	2000
	15	1500
25	18	3000

CASTING DESIGN SITUATION

RECOMMENDED PROPORTIONS

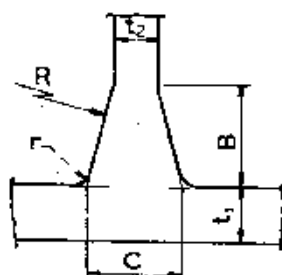


$$A = 2.25D$$

$$B = 1.5 A$$

$$C = 0.4 A$$

t_1 minimum wall thickness of casting



t_1 thick section

t_2 thin section

$$\text{If } t_1/t_2 > 4, B = 2t_1$$

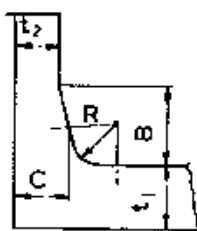
$$2 < t_1/t_2 < 4, B = 1.5 t_1$$

$$t_1/t_2 < 2, B = \text{Zero}$$

$$r_1 = 0.5 t_1$$

$$C = 0.6 \text{ to } 0.8 t_1$$

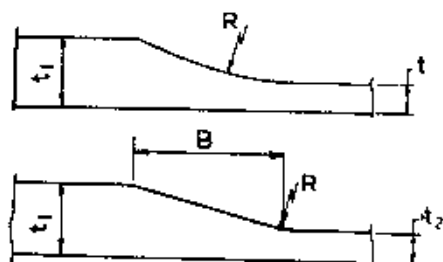
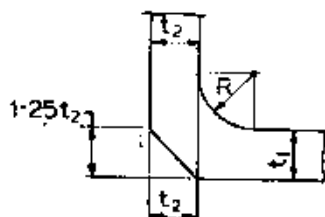
$$R = 4 t_1$$



$$C = 0.6 \text{ to } 0.8 t_1$$

$$B_{min} = 5 (C - t_2)$$

R decide from graph on p. 10.16



Variation in wall thickness

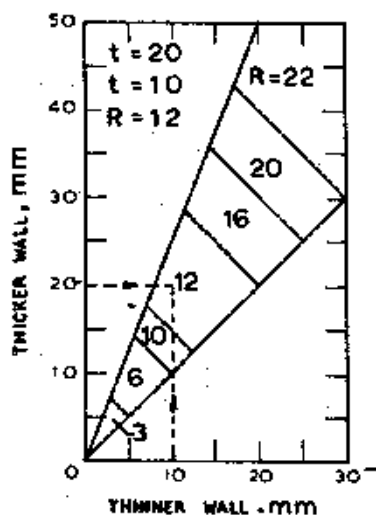
$$\text{If } \frac{t_1}{t_2} < 1.5, R = \frac{t_1 + 2t_2}{2}$$

$$\text{If } \frac{t_1}{t_2} > 1.5, B = 4 (t_1 + t_2)$$

$$R = 4t_2$$

GOVERNING RULES IN CASTING DESIGN

1. Locate the riser at the heaviest section.
2. Avoid sharp angles and corners.
3. Avoid crossing of intersecting walls.
Stagger them so that a junction has no more than three branches.
4. Design all sections as nearly uniform in thickness as possible.
5. Avoid abrupt changes in sections.
6. Give angular forms ample fillet radius.
7. Avoid the use of ribs meeting at an acute angle.
8. Avoid, if possible, bosses, lugs and pads.
9. Avoid cores, if feasible.

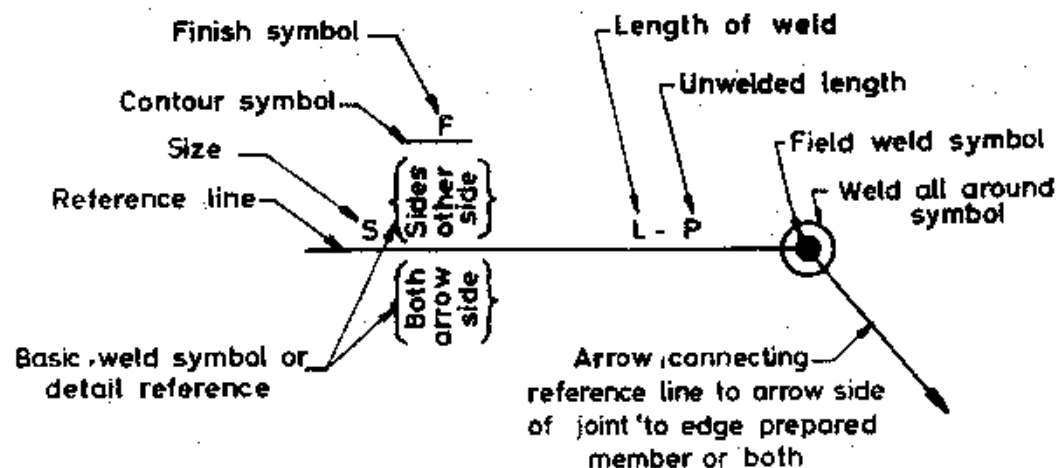


WELDING - 11

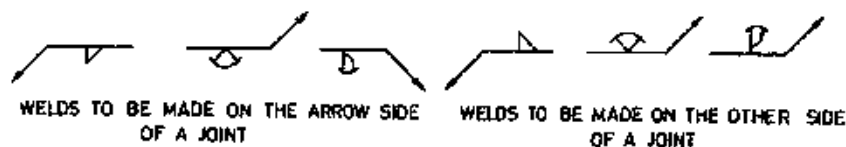
WELDED JOINTS

TYPE OF WELDS AND SYMBOLS

Form of weld	Sectional representation	Appropriate symbol	Form of weld	Sectional Representation	Appropriate Symbol
Fillet			Plug or slot		
Square butt			Backing strip		
Single-V butt			Spot		
Double-V butt			Seam		
Single-U butt			Mashed Seam		
Double-U butt			Stitch		
Single bevel butt			Mashed Stitch		
Double bevel butt			Projection		
Single-J butt			Flash		
Double-J butt			Butt resistance or Pressure (upset)		
Stud					
Bead (edge or seal)					
Sealing run					



STANDARD LOCATION OF ELEMENTS OF
A WELDING SYMBOL



Special Instructions	Drawing Representation	Symbol
Weld all-round		
Site weld (field weld)		
Flush contour		
Convex contour		
Concave contour		
Grinding finish		
Machining finish		
Chipping finish		

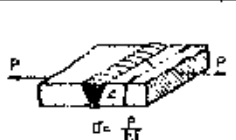
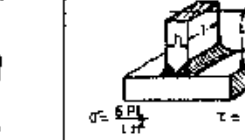
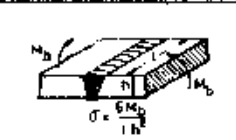
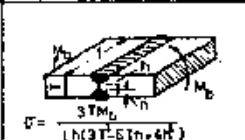
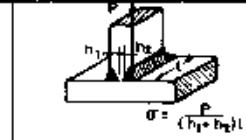
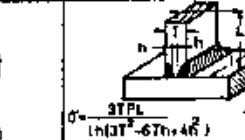
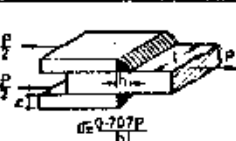
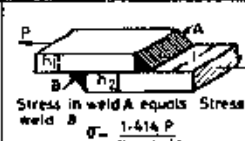
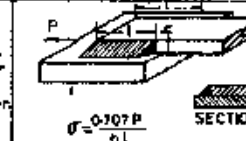
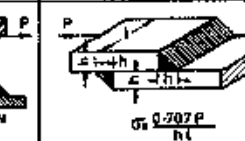
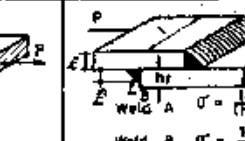
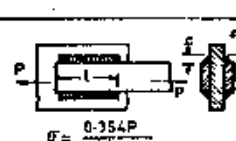
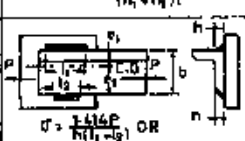
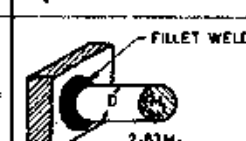
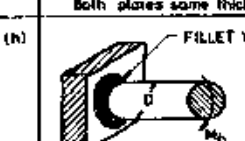
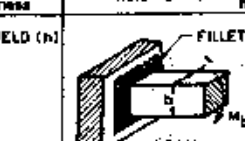
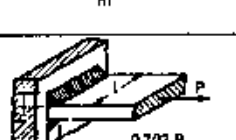
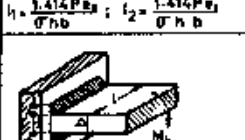
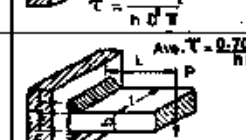
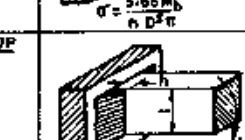
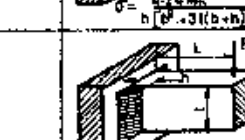
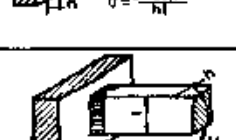
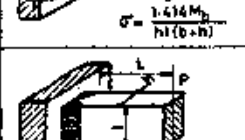
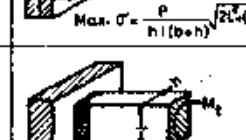
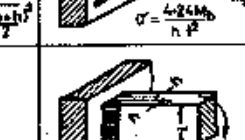
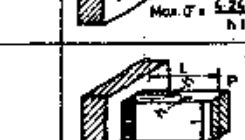
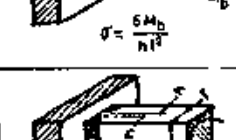
 $\sigma = \frac{P}{hl}$	 $\sigma = \frac{P}{(h_1 + h_2)l}$	 $\sigma = \frac{P}{hl}$	 $\sigma = \frac{6M_b}{hl^2}$	 $\sigma = \frac{6Pl}{l^3}$ $\tau = \frac{P}{hl}$
 $\sigma = \frac{6M_b}{hl^2}$	 $\sigma = \frac{3M_b}{ln(3T^2 - 6Th + 4h^2)}$	 $\sigma = \frac{P}{(h_1 + h_2)l}$	 $\sigma = \frac{3M_b}{ln(3T^2 - 6Th + 4h^2)}$	 $\sigma = \frac{3Pl}{ln(3T^2 - 6Th + 4h^2)}$ $\tau = \frac{P}{2hl}$
 $\sigma = \frac{0.707P}{hl}$	 Stress in weld A equals Stress in weld B $\sigma = \frac{1.414P}{(h_1 + h_2)l}$	 $\sigma = \frac{0.707P}{hl}$ SECTION	 $\sigma = \frac{0.707P}{hl}$ Both plates same thickness	 Weld A $\sigma = \frac{1.414P}{(h_1 + h_2)l}$ Weld B $\sigma = \frac{1.414Ph_2}{h_1(l_1 + l_2)}$
 $\sigma = \frac{0.354P}{hl}$	 $\sigma = \frac{1.414P}{hl_1 + l_2}$ OR $h_1 = \frac{1.414Ph_2}{\sigma h b}$; $l_2 = \frac{1.414Ph_1}{\sigma h b}$	 FILLET WELD (h) $\tau = \frac{2.83M_b}{h^2 D^2 \pi}$	 FILLET WELD (h) $\sigma = \frac{5.65M_b}{h^2 D^2 \pi}$	 FILLET WELD (h) $\sigma = \frac{4.24M_b}{b^2 [D^2 + 3(b+h)^2]}$
 $\sigma = \frac{0.707P}{hl}$	 $\sigma = \frac{1.414M_b}{hl(b+h)}$	 Ave. $\tau = \frac{0.707P}{hl}$ Max. $\sigma = \frac{P}{hl(b+h)} \sqrt{\frac{2L^2 + (b+h)^2}{2}}$	 $\sigma = \frac{4.24M_b}{h^2}$	 Ave. $\tau = \frac{0.707P}{hl}$ Max. $\sigma = \frac{5.25Pl}{h^2}$
 $\sigma = \frac{6M_b}{hl^2}$	 $\sigma = \frac{6Pl}{hl^2}$ $\tau = \frac{P}{hl}$	 $\tau = \frac{M_t(3l + 1.6h)}{hl^2}$	 $\sigma = \frac{3M_b}{hl^2}$	 $\sigma = \frac{3Pl}{hl^2}$ $\tau = \frac{P}{2hl}$
 $\tau = \frac{M_t}{2(lh - h_1l_1 - h_2l_2)}$	 Fillet weld $\sigma = \frac{1.414P}{2hl_1h_2l_3}$ Butt weld $\sigma = \frac{P}{2hl_1h_2l_3}$	σ = Normal Stress τ = Shear Stress M_b = Bending moment M_t = Twisting moment P = External Load L = Linear Distance h = Size of weld l = Length of weld WELD STRESS FORMULAE		

Plate thickness and weld size :

Plate thickness, mm	3 to 5	6 to 8	10 to 16	18 to 24	26 to 35	over 38
Weld size, mm	3	5	6	10	14	20

* Permissible static load per cm length: (Mild steel Fillet welds)

Weld size mm	Permissible static load, kgf/cm			
	Bare Electrode		Covered Electrode	
	in tension	in shear	in tension	in shear
3	170	135	210	170
4	225	180	280	225
5	280	225	350	280
6	335	270	420	335
8	450	360	560	450
10	560	450	700	560
12	670	540	840	670
14	785	630	980	785
16	900	720	1120	900
20	1120	900	1400	1120

*For machine welding increase the permissible load by 25 to 30%

Design stresses for welded joints, kgf/cm²

Kind of weld and stresses	Bare Electrodes		Covered Electrodes		Fatigue Design stresses			
	Steady load	Reversed load	Steady load	Reversed load	Structural steels		Alloy steels	
					2×10^6 cycles	10^5 cycles	2×10^6 cycles	10^5 cycles
Butt Welds								
Tension	900	350	1100	550	$\frac{1100}{1-0.8r}$	$\frac{1250}{1-0.5r}$	$\frac{1150}{1-0.8r}$	$\frac{2300}{1-0.6r}$
Compression	1000	350	1250	550	$\frac{1250}{1-r}$	$\frac{1250}{1-0.5r}$	—	—
Shear	550	210	700	350	$\frac{625}{1-0.5r}$	$\frac{900}{1-0.5r}$	—	—
Fillet Welds All	790	210	950	350	—	—	—	—

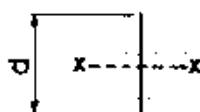
$$r = \frac{F_{min}}{F_{max}}$$

PROPERTIES OF WELD TREATED AS A LINE

Outline of welded joint

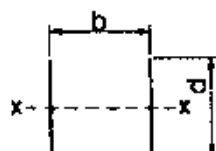
BENDING
about horiz. axis XX, Z_w

TWISTING
about centroidal axis, J_w



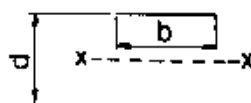
$$\frac{d^2}{6}$$

$$\frac{d^3}{12}$$



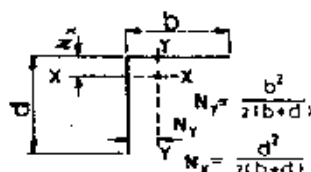
$$\frac{d^2}{3}$$

$$\frac{d(3b^2 + d^2)}{6}$$



$$bd$$

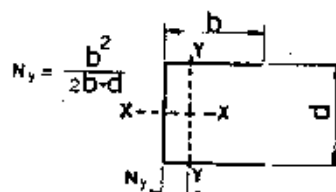
$$\frac{b^3 + 3bd^2}{6}$$



$$\frac{4bd + d^2}{6}, \text{ top}$$

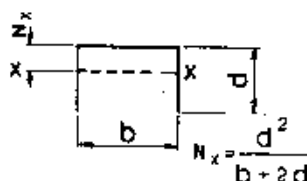
$$\frac{d^2(4bd + d)}{6(2b + d)}, \text{ bottom}$$

$$\frac{(b+d)^3 - 6b^2d^2}{12(b+d)}$$



$$bd + \frac{d^2}{6}$$

$$\frac{(2b + d)^3}{12} - \frac{b^2(b+d)^2}{2b+d}$$

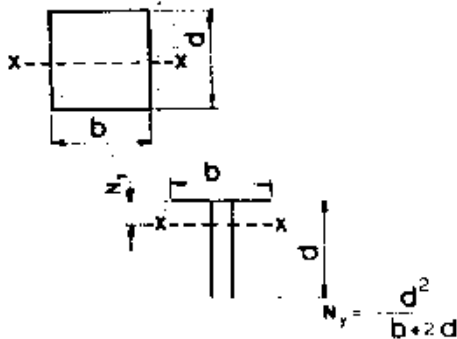
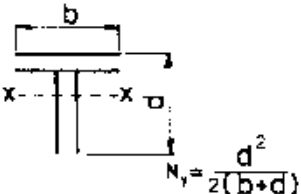
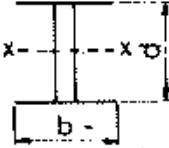
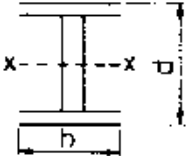
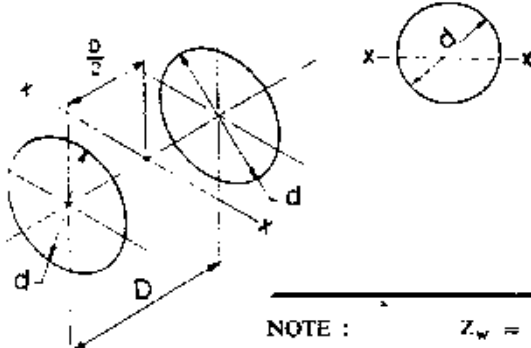


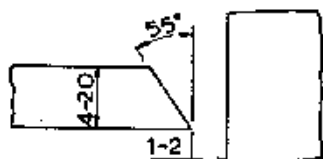
$$\frac{2bd + d^2}{3}, \text{ top}$$

$$\frac{d^2(2b + d)}{3(b + d)}, \text{ bottom}$$

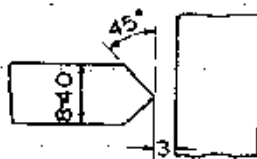
$$\frac{(b + 2d)^3}{12} - \frac{d^2(b + d)^2}{b + 2d}$$

PROPERTIES OF WELD TREATED AS A LINE (Contd.)

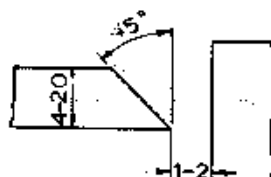
Outline of welded joint	BENDING about horiz. axis XX, Z_w	TWISTING about centroidal axis, J_w
 $I_y = \frac{d^2}{b + 2d}$	$bd + \frac{d^2}{3}$	$\frac{(b+d)^2}{6}$
 $I_y = \frac{d^2}{2(b+d)}$	$\begin{aligned} &\frac{4bd + d^2}{3} \text{ top} \\ &\frac{4bd^2 + d^3}{6b + 3d} \text{ bottom} \end{aligned}$	$\frac{d^2(4b+d)}{6(b+d)} + \frac{b^2}{6}$
	$bd + \frac{d^2}{3}$	$\frac{b^2 + 3bd^2 + d^3}{6}$
	$\frac{2bd + d^2}{3}$	$\frac{2b^2 + 6bd^2 + d^3}{6}$
 $I_y = \frac{\pi d^2}{4}$	$\frac{\pi d^2}{4}$	$\frac{\pi d^3}{4}$
NOTE : $Z_w = \frac{I_{xx}}{C}$ $J_w = \frac{I_p}{(\text{max dist from centroid})}$		



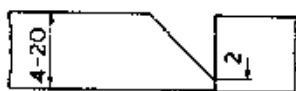
SINGLE BEVEL GROOVE
(WITH SHARP EDGE)



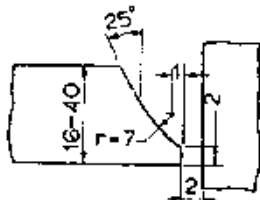
DOUBLE BEVEL GROOVE



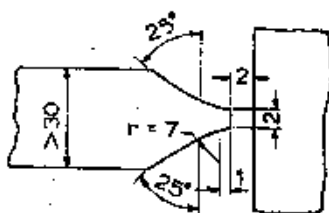
SINGLE BEVEL GROOVE



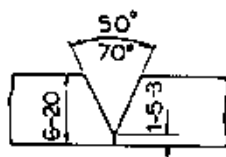
SINGLE BEVEL GROOVE
(WITH ROOT FACE)



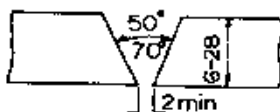
SINGLE J GROOVE



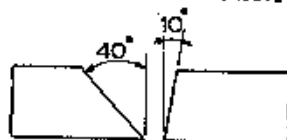
DOUBLE J GROOVE



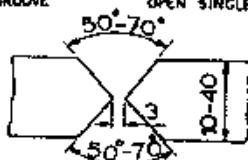
CLOSED SINGLE V GROOVE



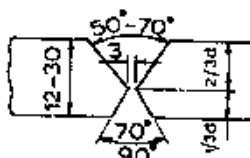
OPEN SINGLE V GROOVE



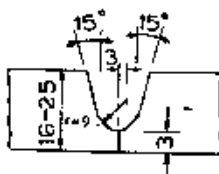
INEQUILATERAL SINGLE V GROOVE



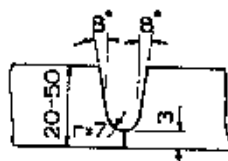
SYMMETRICAL DOUBLE VEE



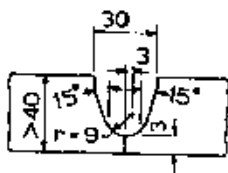
ASYMMETRICAL DOUBLE VEE



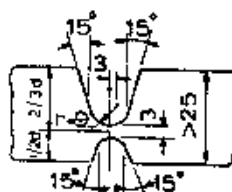
WIDE SINGLE U GROOVE



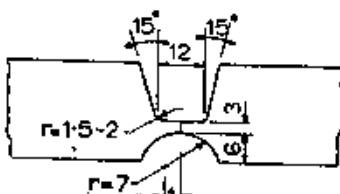
NARROW SINGLE U GROOVE



WIDE SINGLE U WITH
VERTICAL TOP



ASYMMETRICAL WIDE DOUBLE U



U GROOVE OF WHICH THE BACK IS DIFFICULT
TO PROCESS

RECOMMENDED WELDING PROCESSES

		Process	Shielded metal arc	Submerged arc	Atomic hydrogen	Inert Gas Metal arc MIG	TIG	Flash weld	Spot weld	Seam weld	Thermit weld	Gas oxy.-Acetyl.	Brazing (furnace)	Brazing (torch)
BASED ON MATERIAL	Material													
	C10, C20		R	R	S	S	S	R	R	R	S	R	R	S
	C30, C50		"	"	"	"	"	"	"	S	"	"	"	"
	Ni-Cr. Alloy Steel,		"	"	"	"	"	"	"		"	S	S	
	High alloy 309		"	"	"	"	"	"	"		"	S	S	
	Stainless AISI 301		"	"	R	R	R	"	"	R	"	"	"	S
	316		"	"	"	"	"	"	"		"	"	"	
	Stainless steels		"	"	"	"	"	"	"		"	"	"	
	AISI 405, 430		"	S	S	S	S	S	S	S	"	"	"	"
	high temp. alloys		"	"	"	"	"	"	"	R	"	"	"	"
	Grey Cast Iron		S				"				R			R
	Alum. alloys		"		S	R	R	S	R	S	S	R	R	"
BASED ON JOINT	Nickel alloys		R	S	"	"	"	"	"	"	"	"	S	"
	Copper alloys					"	"	"	S		"	"	"	"
	Titanium alloys						"	"	"					S
	JOINT	Plate thickness, mm												
	BUTT	0.125—3	S	S	R		R					R		S
		above 3	R	R	S	R	S	R			R	S		"
	LAP	0.125-3	"	S	"		R		R	R		R	R	R
		above-3	"	R	"	R	S		"	"		S	"	"
	FILLET	0.125-3	"	S	"		R					R	"	"
		above 3	"	R	R	R	S					S	"	"
	EDGE	0.125-3			"		R			R		R		S
		above 3	R	S	S	S	S			"		S		"
	OVERLAY WELD		S	R	R	R	R					R		"

R, recommended; S, satisfactory

INDIAN STANDARD FOR CLASSIFICATION OF COVERED ELECTRODES FOR ARC WELDING OF STEEL

M 330524 H

M	3	3	0	5	2			4		H
Prefix	Type of Covering	Position of Welding	Welding current condition	Tensile strength of deposited metal kgf/mm ²	Percentage elongation in the tensile test of deposited metal Gauge length 44 √S ₀ 5.65 √S ₀			Impact value of deposited metal Min. Impact value kgf m at 27±2°C		Suffix to denote special properties
M—Manual arc welding	1—high Cellulose	0—F,H,V,D,O	0—D+	1—42 Min	1	18	15	1	4.8	H—hydrogen controlled
	2—high titania, fluid slag	1— F,H,V,O	1—D+, A90	2—44 "	2	20	17	2	5.7	J—Iron powder covering with 110 to 130% recovery
A—Automatic or semi automatic Arc welding	3—Appreciable titania, fluid slag	2—F,H	2—D—,A70	3—50 "						
	4—high in oxides and/or silicates of iron and manganese, inflated slag	3—F	3—D—,A50	4—55 "	3	22	18	3	6.2	K—Iron powder covering with recovery above 130%
	5—high in iron oxides and/or silicates, heavy slag	4—F,H _t	4—D+,A70	5—60 "						
	6—high in calcium carbonate and fluoride	9—others	5—D±,A90	6—66 "	4	24	20	4	7.0	P—Deep penetration
	9—Others	F—Flat	6—D±,A70	7—70 "						
		H—horizontal	7—D±,A50	8—77—85	5	26	22	5	8.3	
		V—vertical	9—others	9—Above 85	6	28	24	6	9.6	
		D—Downhand			7	30	26	7	11.0	
		O—over head			8	33	29	8	13.8	
		H _t —horizontal fillet						9	15.0	

EXPLANATION OF AWS CLASSIFICATION NUMBERS OF STEEL ARC WELDING ELECTRODES

AMERICAN WELDING SOCIETY

E 6010*

E denotes electrode

60 denotes tensile strength in thousands of psi.

1 denotes position of welding

0 denotes DC reverse polarity

† Position of welding.

1. all positions
2. horiz. and flat positions only.
3. flat positions only.

* type of coating and welding current

0		
1	Cellulose potassium	AC or DC reverse or straight
2	titania sodium	AC or DC straight
3	titania potassium	AC or DC straight or reverse
4	Iron powder titania	" "
5	low hydrogen sodium	DC reverse
6	" " potassium	AC or DC reverse
7	Iron Powder Iron Oxide	AC or DC
8	Iron powder low hydrogen	AC or DC straight or reverse

SELECTION OF ELECTRODES (ARC WELDING)

1. MILD STEEL ELECTRODES:

CODE		APPLICATION
AWS	I.S.	
E 6013	M 317 443	Structurals, vessels, tanks, bridges, rail wagons, boilers, ships, pressure pipe lines which cannot be welded from inside, loco fire boxes, steel furniture, scooter frames.
E 7014	M 916 354	
E 6010	M 110 343	pipe lines, tanks, pressure vessels, structurals
E 6020	M 452 354	Heavy structural work, bridges, cranes, loco fire boxes, truck chassis.
E 6027	M 922 x x x P	for deep penetration welding

2. HIGH TENSILE STEEL ELECTRODES

E 7014	M 916 354	best suited for repairing steel castings.
E 7024	M 923 343	heavy structurals, crane and bridge girders.
E 7018	M 615 499	Blast furnace steel work, heavy fabrication, bridges and low alloy Steel fabrication under severe shock
E 100 18	M 611 81	
E 7016	M 611 599	Railway class 3 steels, repairs in Cast iron, joining M.S. to Cast Iron. Structural steel wagons, high sulphur steel, Cast steel.
	M 614 599	
	M 611 459	
E 7013—A1	M 316 443	high temperature pressure pipe lines, boiler tubes, boiler plates.
7010—A1	110 443	
7016—A1	611 443	
E 9018—B2	M 611 63	Repairing automobile parts, railway class 4 steels, boilers
E 9018—B3	M 611 72	Oil refinery, power house, chemical plants
E 9016	M 611 82	
E 100 16	M 611 81	high tensile steel machinery parts, automobile parts
E 120 16		for chemical plants, steam turbine rotors, highly resistant to corrosion.

SELECTION OF ELECTRODES (Contd.)

3. HARD FACING ELECTRODES

Designation	APPLICATION
CITORAIL I	Gear teeth, railway and tram rails, m/c parts where moderate hardness and toughness are required. 250—280 BHN
CITORAIL II	Shear Blades, hot punch dies, rail ends and crossings, brake shoes, cams 350—380 BHN
CITORAIL III TOOL CORD	Metal cutting and forming tools, punches, Dies, drill bits, shears, oil expellers, crusher hammers, crane wheels, conveyor buckets. 600—625 BHN
CITORAIL IV SUPERESIST	Earth moving and mining equipment, concrete mixer blades, oil expeller worms. 600—675 BHN
CITOMANGAN SUPER MANGANESE	Dredger bucket teeth, rock crushing jaws, Manganese steel rails; as deposited 200 BHN, and increases to 500 BHN under impact in service.
CITOCROMAX	Dipper teeth, shovel tracks, rock crushers, Coal mining cutters, mill hammers, truck chains, scraper blades, conveyor rolls and buckets 250 BHN as deposited and increases to 500 BHN in service.

SELECTION OF ELECTRODES (Contd.)

4. STAINLESS STEEL ELECTRODES

CODE		APPLICATION
AWS	Trade	
E 308-16	INOX-AW	AISI 301, 302, 303, 308 steels, for building up stainless steel surface on pump impellers and shafts, valve faces and seats and chemical plants.
E 308L-16	INOX-AW (Elc)	
E 347-16	INOX-AW + Cb	AISI 321, 347 steels chemical, food and aircraft industries.
E 316-16	INOX-BW	AISI 316, 317 steels tanks, coils and vats used in pulp, paper and textile industries and chemical mixers.
E 318-16	INOX-BW + Cb	Paper mill, bleaching, dyeing, pickling, bakery equipments.
E 316L-16	INOX-BW (Elc)	Stainless steel sheets having very low carbon content
	Ferinox	Joining MS to stainless steels
E 310-16	INOX-C	25/20 Stainless steel
E 309 cb-15	INOX-D2	for 25/12 Stainless steel
	Cito chromax-N	Welding Austenitic Manganese steel to mild steel

SELECTION OF ELECTRODES (Contd.)

5. NON FERROUS ELECTRODES

CODE		Application
AWS	Trade	
ENiCu-4	CITOMONEL	welding monel to monel, monel to MS, monel to steel, to build a corrosion resistant layer of monel on MS.
	BRONZE	welding of copper and bronze copper and bronze to steel, welding of cast iron

6. CAST IRON ELECTRODES

E St.	CITOCAST	Cast iron parts where further machining is not required. Joining C.I. to M.S.
	CITOPONTE—Mo	Cold welding on CI parts for repair and surfacing.
	SUPERNICRON	Cold welding on C.I.

7. CUTTING & CHAMFERING ELECTRODES

CITOCUT	for electric arc cutting and piercing of MS, Cast steel, alloy steel and CI at high speeds.
CHAMFER CORD	for joint preparation and removal of metal.

8. ALUMINIUM ELECTRODES

ALCORD 5 Si	for welding Al and its alloys
ALCORD 12 Si	for welding aluminium

RECOMMENDED PRACTICES FOR INERT GAS METAL ARC (MIG) WELDING OF ALUMINIUM ALLOYS

Material thickness mm	Welding position	Joint design	Current amp, AC	AC Voltage	Filler wire dia, mm	Argon gas flow m ³ /hr	No. of passes
2.5	Flat	None	70—110	18—22	0.8	0.84	1
			100—120	18—22	1.2	0.84	1
3.2	Flat	None	100—130	20	1.2	0.84	1
	Hor. & Ver.	None	100—120	20	1.2	0.84	1
	Overhead	None	100—120	20	1.2	1.12	1
	Flat	None or single bevel	200—225	26—28	1.6	1.12	1
6.3	Hor. & Ver.	Single bevel	170—190	26—28	1.6	1.15	2 or 3
	Overhead	"	180—240	26—28	1.6	1.4	2 or 3
	Flat	Single or double bevel	230—320	26—28	1.6	1.4	1 or 2
10	Hor. & Ver.	"	180—225	26—28	1.6	1.4	3
	Overhead	"	200—240	26—28	1.6	1.4	5
	Flat	"	280—340	26—30	2.4	1.4	2 or 3
12.5	Hor. & Ver.	"	210—250	26—30	1.6	1.4	3 or 4
	Overhead	"	225—275	26—30	1.6	2.24	8—10
	Flat	"	230—420	26—30	2.4	1.68	4—5
25	Hor. & Vert.	"	225—285	26—30	1.6	1.68	4—6
	Overhead	"	225—285	26—30	1.6	2.24	15 or more
50	Flat	"	350—450	26—30	2.4	1.68	12 or more
75	Flat	"	350—450	26—30	2.4	1.68	20 or more

RECOMMENDED PRACTICES FOR INERT GAS TUNGSTEN ARC (TIG) WELDING OF ALUMINIUM

Material thickness mm	Welding position	Joint	Current Amp, AC	Dia of Tungsten Electrode, mm	Argon Gas Flow m ³ /h	Filler rod diam mm	No. of passes
1.6	Flat	Sq. butt	70—100	1.6	0.56	2.4	1
	Hor. & Ver.	„	70—100	1.6	0.56	2.4	1
	Overhead	„	60—90	1.6	0.70	2.4	1
3.2	Flat	„	125—160	2.4	0.56	3.2	1
	Hor. & Vert.	„	115—150	2.4	0.56	3.2	1
	Overhead	„	115—150	2.4	0.70	3.2	1
6.3	Flat	60° single bevel	225—275	4.0	0.84	4.8	2
	Hor. & Vert.	60° „	200—240	4.0	0.84	4.8	2
	Overhead	100° „	210—260	4.0	0.98	4.8	2
10.0	Flat	60° „	325—400	6.4	0.98	6.4	2
	Hor. & Vert.	60° „	250—320	4.8	0.98	6.4	3
	Overhead	100° „	275—350	4.8	1.12	6.4	3
12.5	Flat	60° „	375—450	6.4	0.98	6.4	3
	Hor. & Vert.	60° „	250—320	4.8	0.98	6.4	3
	Overhead	100° „	275—340	4.8	1.12	6.4	4
25	Flat	60° „	500—600	8—10	0.98—1.25	6—10	8—10

NOTE: For thoriated tungsten electrode, the current rating may be increased by 30%.

CONSUMPTION OF GASES AND FILLER WIRES IN GAS WELDING

Type of welding	Plate Thickness, mm	Filler wire dia mm	Oxygen & Acetylene consumption (m ³ /min)	Root opening mm	Welding time per meter (min)	Length of filler wire used per meter weld m
LEFTWARD*	1	1	0.04—0.07	0	9—11	1.0
	2	2	0.07—0.12	1.5	11—13	1.5
	3	2.5	0.15—0.20	1.5	14—16	1.65
	4	3	0.20—0.30	2	15—17	2.0
	5	3	0.30—0.40	2.5	17—19	4.8
RIGHTWARD	5	2.5	0.4 —0.5	2.5	17—19	3.3
	6	3	0.5 —0.7	3	19—21	3.4
	7	3.5	0.7 —0.8	3	22—25	3.4
	8	4	0.75—0.85	3	28—30	3.4
	9	4.5	0.90—1.20	3	30—33	4.0
	10	5	1.00—1.30	3	32—35	4.5
	15	6	1.30—1.40	3	50—60	4.8
	20	6	1.50—1.60	3	58—70	6.8

*Not recommended for thicker plates.

GAS CONSUMPTION & CUTTING SPEED IN GAS CUTTING

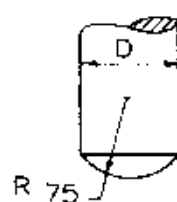
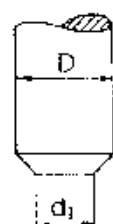
Plate thickness (mm)	Nozzle dia (mm)	Cutting speed m/hr		Oxygen pressure kgf/cm ²		Gas consumption m ³ /hr			
		Hand	Machine	Hand	Machine	Oxygen		Acetylene	
						Hand	Machine	Hand	Machine
3	0.80	30—45	30—50	1.0—1.6	1.0—2.0	1.3—1.4	1.2—1.4	0.2—0.3	0.2—0.3
5	0.80 or 1.20	20—30	18—32	0.8—1.5	0.8—2.0	0.8—2.0	0.8—2.0	0.1—0.2	0.1—0.2
10	1.20 or 1.60	15—30	15—30	1.5—2.0	1.5—3.0	1.2—2.4	1.0—2.4	0.2—0.3	0.2—0.3
15	1.60	18—27	18—30	1.7—2.5	1.5—3.5	3.4—4.0	3.5—4.5	0.3—0.5	0.3—0.4
20	1.60	18—25	18—27	2.0—2.5	1.7—2.5	3.5—4.0	3.5—4.5	0.4—0.5	0.3—0.4
25	1.60	15—28	18—30	2.0—2.8	2.0—2.8	3.6—4.5	3.5—5.0	0.4—0.5	0.4—0.5
50	1.60 or 2.40	9—18	10—18	2.8—3.8	2.8—4.0	5.0—6.5	5.0—6.8	0.5—0.6	0.5—0.6

GAS WELDING OF FERROUS METALS

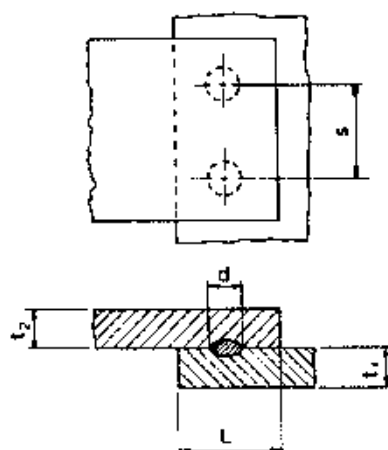
Metal	Flame Adjustment	Flux	Welding rod
Cast Steel	Neutral	No	Steel
Steel pipe	Neutral	No	Steel
Steel Plate	Neutral	No	Steel
Steel Sheet	Neutral	No	Steel
High carbon steel	Reducing	No	Steel
Manganese Steel	Slightly oxidising	No	Base metal composition
Chromanil Steel	Neutral	No	Steel
Wrought Iron	Slightly oxidising	No	Steel
Galvanised Iron	Neutral	Yes	Bronze
Grey Cast Iron	Slightly oxidising	Yes	Cast Iron
Malleable Cast Iron	Slightly oxidising	Yes	Bronze
Grey Cast Iron Pipe	Neutral	Yes	Cast iron, bronze
Cast Iron Pipe	Neutral	Yes	Cast iron or base metal composition
Chromium Nickel	Slightly oxidising	Yes	Bronze
Chromium-nickel steel castings	Neutral	Yes	Base metal composition
Chromium Steel	Neutral	Yes	Columbium Stainless steel or basemetal composition
Chromium Iron	Neutral	Yes	—do—

SPOT WELDING

	Thickness of thinner sheet, t	Electrode	Diam., mm	Electrode force kgf	Welding current amp	min. overlap L mm	min pitch S mm	Diam of nugget d mm	Weld time sec.
	mm	D min	d ₁ max						
CARBON STEEL	0.25	9.5	3.2	90	4000	10	6	2.5	0.08
	0.5	"	5	140	6500	11	10	3.2	0.10
	0.8	"	"	180	8000	"	13	4	0.16
	1	12.5	6.3	224	9500	13	19	5	0.20
	1.25	"	"	300	10500	14	22	5.6	0.25
	1.6	"	"	355	12000	16	25	6.3	0.28
	2	16	8	500	14000	18	32	7.1	0.35
	2.5	"	10	630	16000	20	40	8	0.40
	3.2	22	"	800	19000	22	44	8.5	0.5
STAINLESS STEEL	0.25	5	3.2	105	2000	5	5	1.6	0.06
	0.5	6.3	4	180	4000	8	8	2.5	0.08
	0.8	10	5	300	6000	10	12.5	3.2	0.10
	1	"	5	410	7800	13.2	16	4.0	0.12
	1.25	12.5	6.3	550	9500	12.5	18	5	0.16
	1.6	"	"	680	11000	16	25	5.6	0.20
	2	16	8	860	14000	18	32	7.1	0.28
	2.5	18	10	1250	17700	20	38	7.5	0.36
	3.2	"	"	1500	18000	22	50	7.5	0.40



SHAPE OF THE ELECTRODE



SPOT WELDING OF ALUMINIUM

Sheet thickness, mm	Electrode			Electrode force kgf	Welding current, ≈ amp	≈ Weld time sec.
	diam D mm	tip radius, mm				
		top	bottom			
0.4	16	25	Flat	150	15000	0.08
0.5	"	"	"	160	18000	0.1
0.63	"	50	"	180	21800	0.12
0.8	"	"	"	225	26000	0.14
1.0	"	75	"	280	30700	0.16
1.25	"	"	"	300	33000	0.16
1.6	"	"	"	340	36000	0.2
1.8	"	100	100	360	38000	"
2.0	32	"	"	400	42000	"
2.25	"	150	150	430	46000	0.24
2.5	"	"	"	480	56000	0.3
3.2	"	"	"	600	76000	"

MACHINING - 12

POWER REQUIRED AND CUTTING FORCE IN MACHINING

Machining Process	Power (kW) and Force (N)
Drilling	Power * $= 2.82 \cdot 10^{-3} K n z (D^3 - d^3) (0.15 + 7.87 s)$
Boring	$= 1.80 \cdot 10^{-3} K v z (D - d) (0.15 + 7.87 s)$
Spot facing	
Counter boring	Axial thrust, $= 630 K z (D - d) s^{0.66}$
Counter sinking	* includes 30% for dull tool
Reaming	
Core drilling	
Face Milling	Power* $= 13.2 \cdot 10^{-3} K z v (1.55 a s)^{0.8}$
Slot milling	Feed force $= \frac{3.9 \cdot 10^4 [kW]}{D_1 n}$
	* includes 30% for dull tool and 20% head friction
Turning	Power $= 13.2 \cdot 10^{-3} K z v (1.55 a s)^{0.8}$
Boring	
Facing	Tangential cutting force component $= \frac{19.5 \cdot 10^4 [kW]}{D_1 n}$
Tapping 60° V thread	Power $= 6.27 \cdot 10^{-3} K v h G \left(0.15 + \frac{1.75 h}{G} \right)$
where	n , rpm z , no of cutting edges in contact D_1 , Larger diameter of hole, mm d , smaller diameter of hole, mm s , feed/blade/rev, mm v , cutting speed, m/min a , depth of cut, mm D_1 , maximum diameter of milling cutter, mm D_2 , maximum diameter on which cut is taken, mm h , pitch of thread, mm G , no of chamfered threads K , material factor β , machining exponent

} see p. 12.2

VALUES OF K & β FOR THE CALCULATION OF POWER AND CUTTING FORCE

Material	Brinell Hardness Number	Material factor K	Machining Exponent, β
Cast iron	110 — 140	0.66	0.865
	140 — 190	0.83	
	190 — 220	1.3	
	220 — 260	1.7	
Malleable iron	110 — 160	0.61	0.850
	160 — 200	0.74	
	200 — 240	0.83	
Nodular iron	140 — 190	0.43	0.850
	190 — 225	0.71	
	225 — 260	1.0	
Carbon Steel	120 — 175	1.88	0.803
	175 — 225	2.4	
	225 — 275	2.91	
	275 — 325	3.44	
Alloy Steel	170 — 220	2.1	
	190 — 230	2.2	
	220 — 240	2.7—2.8	
Aluminium	80 — 110	0.55	0.940

STANDARD SPINDLE SPEEDS FOR MACHINE TOOLS

Basic Range R 20 $\phi = 1.12$	Range R 20/2 $\phi = 1.25$	Range R 20/3 $\phi = 1.4$	Range R 20/4 $\phi = 1.6$ (1400) (2800)	Range R 20/6 $\phi = 2$
100			1000	
112	112	11.2		11.2
125		125		
140	140		1400	1400
160		16		
180	180	180	180	180
200			2000	
224	224	22.4	224	22.4
250		250		
280	280		2800	2800
315		31.5		
355	355	355	355	355
400			4000	
450	450	45		45
500		500		
560	560		5600	5600
630		63		
710	710	710	710	710
800			8000	
900	900	90	900	90
1000		1000		

1. Input speed to the gear box to be taken 6% less than the synchronous speed of motor.
2. Allowable variation on the spindle speed is within ± 6 & -2% of the preferred speed.

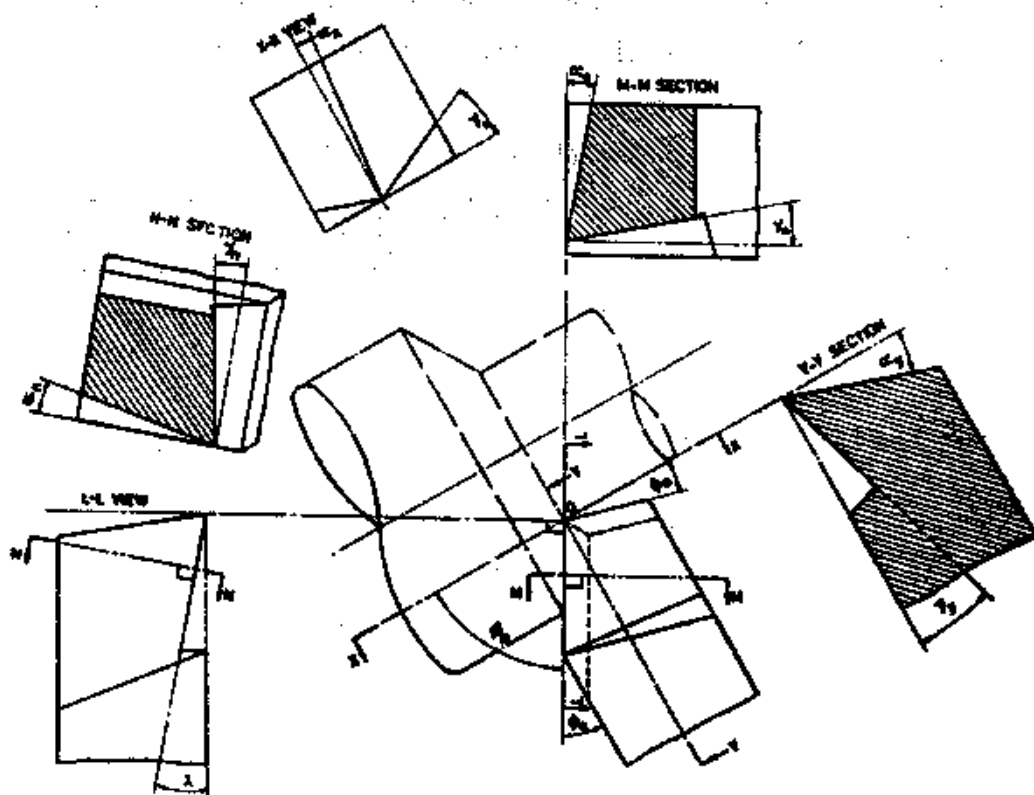
The feed rate can be referred either to the spindle speed (mm/rev), as in the case of turning, drilling or boring, or independently of the spindle speed—to time (m/min), as in milling.

Feed rate in mm per min. = spindle speed in rpm $\times$ feed rate in mm per rev.

STANDARD FEEDS mm/min

$\phi=1.12$	$\phi=1.25$	$\phi=1.4$	$\phi=1.6$	$\phi=2$
1	1	1	1	1
1.12		11.2		
1.25	1.25	0.125		0.125
1.4		1.4		
1.6	1.6	16	1.6	16
1.8		0.18		
2	2	2		2
2.24		22.4		
2.5	2.5	0.25	2.5	0.25
2.8		2.8		
3.15	3.15	31.5		31.5
3.55		0.355		
4	4	4	4	4
4.5		45		
5	5	0.5		0.5
5.6		5.6		
6.3	6.3	63	6.3	63
7.1		0.71		
8	8	8		8
9		90		
10	10	1	10	1

CUTTING TOOLS



γ_s Side rake angle

γ_b Back rake angle

γ_o Orthogonal rake angle

γ_n Normal rake angle

λ Inclination angle of principal side cutting edge

α_s Side clearance angle of principal flank

α_e End clearance angle of auxiliary flank

α_o Orthogonal clearance angle of principal flank

α_n Normal clearance angle of principal flank

ϕ_s Principal cutting edge angle

ϕ_e Side cutting edge angle

ϕ_o End cutting edge angle

RECOMMENDED ANGLES FOR HSS SINGLE POINT TOOLS

Workpiece Material	Back rake angle Degrees	Side rake angle Degrees	End relief angle Degrees	Side relief angle Degrees
STEELS :				
High speed, alloy and high Carbon tool steels and stainless steels	5 to 7	8 to 10	6 to 8	7 to 9
C15 - C40	10 to 12	10 to 12	8 to 10	8 to 10
C45 - C90	10 to 12	10 to 12	8 to 10	7 to 9
14 Mn 1 S <u>14</u> , 40 Mn 2 S <u>12</u>	12 to 14	12 to 14	7 to 9	7 to 9
40 Ni2 Cr 1 Mo <u>28</u> ,	6 to 8	8 to 10	7 to 9	7 to 9
T 50 Cr 1 V <u>23</u>	6 to 8	8 to 10	7 to 9	7 to 9
Aluminium	30 to 35	14 to 16	8 to 10	12 to 14
Bakelite	0	0	8 to 10	10 to 12
Brass	0	1 to 3	8 to 10	10 to 12
Bronze	0	-2 to -4	8 to 10	8 to 10
Grey cast iron	3 to 5	10 to 12	6 to 8	8 to 10
Copper	14 to 16	18 to 20	12 to 14	12 to 14
Copper alloys, soft	0 to 2	0	8 to 10	10 to 12
Copper alloys, hard	0	0	6 to 8	8 to 10
Fibre	0 to 2	0	12 to 14	14 to 16
Formica	14 to 16	10 to 12	10 to 12	14 to 16
Monel, Nickel	8 to 10	12 to 14	12 to 14	14 to 16
Rubber, hard	0 to -2	0 to -2	14 to 16	18 to 20

RECOMMENDED ANGLES FOR CARBIDE SINGLE POINT TOOLS

Work piece material	Back rake angle degrees	Side rake angle degrees	End relief degrees	End clearance degrees	Side relief degrees	Side clearance degrees	End cutting edge degrees	Side cutting edge degrees	Nose radius mm
Chilled iron, very brittle brass and bronze	0	0	3	2 to 3	6	2 to 3	10	10	2
Steel and steel castings of more than 70 kgf/mm ² UTS, hard casting and malleable iron of more than 200 HB Hard brass and bronze	0	4	6	2 to 3	6	2 to 3	10	10	1
Steel and steel castings of 51 to 63 kgf/mm ² UTS, cast iron of less than 200 HB	4	8	6	2 to 3	6	2 to 3	10	10	0.75
Steel of 32 to 48 kgf/mm ² UTS, soft cast iron	4	12	6	2 to 3	6	2 to 3	10	10	0.75
Soft bronze, Hard aluminium alloys	10	15	6	2 to 3	6	2 to 3	10	10	0.4
Soft aluminium alloys	15	25	6	2 to 3	6	2 to 3	10	10	0.4
Soft copper	25	25	6	2 to 3	6	2 to 3	10	10	0.4

CLASSIFICATION OF CARBIDE TIPS ACCORDING TO THEIR RANGES OF APPLICATION

Symbol	Identification colour for Carbide	Designation	Composition %			Range of Application		Increasing Direction of the Characteristic of	
			W	TiC + TaC	Co	Material to be Machined	Machining Conditions	Carbide Tip	Cutting
P	French Blue	P01	51	43	6	Steel, Steel casting	Precision turning and boring requiring high finish and close tolerance, high cutting speed, small chip sections, not subject to vibrations.	↑ Resistance to wear ↓	↑ Toughness ↓
		P10	65	26	9	Steel, Steel casting	Turning, Threading and Milling, high cutting speed, small or medium chip section.		
		P20	76	14	10	Steel, Steel casting, Malleable cast iron forming long chips	Turning, Milling, medium cutting speed and medium chip section, Planing with small chip section.		
		P30	82	8	10	Steel, Steel casting, Malleable cast iron forming long chips	Turning, Milling, Planing, medium or low cutting speed, medium or large chip section and machining under unfavourable conditions such as heterogeneous materials, changing hardness or chip sections, intermittent turning or subject to vibrations.		
		P40	74	12	14	Steel, Steel casting with sand inclusions or shrinkage cavities	Turning, Planing, Shaping, low cutting speed, large chip section with possibility of using large rake angle; for machining under unfavourable conditions, such as heterogeneous materials, changing hardness or chip sections, intermittent turning or subject to vibrations; and work on automatic machines.		
		P50	67	15	18	Steel, Steel casting of medium or low tensile strength with sand inclusions or shrinkage cavities	Operations requiring high toughness of the carbide, turning, planing, shaping with low cutting speed, large chip section with possibility of large rake angle; for machining under unfavourable conditions such as heterogeneous materials, changing hardness or chip sections, intermittent turning or subject to vibrations; and work on automatic machines.	↑ Resistance to wear ↓	↑ Toughness ↓

CLASSIFICATION OF CARBIDE TIPS ACCORDING TO THEIR RANGES OF APPLICATION (Contd.)

Range of Application

Symbol	Identification colour for Carbide	Designation	Composition %			Material to be Machined	Machining Conditions	Increasing Direction of the Characteristic of	
			W	TiC + TaC	Co			Carbide Tip	Cutting
M	Lemon Yellow	M10	84	10	6	Steel, Steel casting, Manganese steel, Grey cast iron, Alloyed cast iron	Turning, medium or high cutting speed small or medium chip section.	↑	↑
		M20	82	10	8	Steel, Steel casting, Austenitic steel, Manganese steel, Grey cast iron, Spheroidized cast iron and Malleable cast iron	Turning, milling, medium cutting speed and medium chip section.	↑	↑
		M30				Steel, Steel casting, Austenitic steel, Grey cast iron, Heat resisting alloys	Turning, milling, Planing, medium cutting speed, medium or large chip section.	↑	↑
		M40	79	6	15	Free cutting steel, Low tensile strength steel, Brass and light alloy	Turning, Profile turning, Parting off especially in automatic machines.	↑	↑
K	Signal Red	K01	92	4	4	Very hard grey cast iron, Chilled casting of hardness upto 60 HRC, Aluminium alloys with high silicon content Hardened steel, Plastics of abrasive type, Hard-board and ceramics	Turning, Precision turning and boring, Milling, Scraping.	↑	↑
		K10	92	2	6	Grey cast iron of hardness more than 220HB, Malleable cast iron forming short chips, Tempered steel, Aluminium alloys containing silicon, Copper alloys, Plastics, Glass, Hard rubber, Hard cardboard, Porcelain, Stone	Turning, Milling, boring, Reaming, Broaching, Scraping.	↑	↑
		K20	92	2	6	Grey cast iron of hardness up to 220HB, Non ferrous metals, such as copper, Brass, Aluminium, Laminated wood of abrasive type	Turning, Milling, Planing, Reaming, Broaching, requiring high toughness of carbide tip.	↑	↑
		K30	91	—	9	Soft grey cast iron, Low tensile strength steel, Laminated wood	Turning, Reaming, Planing, Shaping, under unfavourable conditions, such as heterogeneous materials, changing hardness or chip sections, intermittent turning or subject to vibrations, with possibility of large rake angle.	↑	↑
		K40	88	—	12	Soft or hard natural wood, Non ferrous metals	Turning, Milling, Planing, Shaping, under unfavourable conditions, such as heterogeneous materials, changing hardness or chip sections, intermittent turning or subject to vibrations, with possibility of large rake angle.	↑	↑

SPEEDS AND FEEDS FOR TURNING OF CARBON AND LOW ALLOY STEELS WITH HSS TOOLS

Typical steels	Brinell Hardness	Single Point Tools		Speed m/min	Form Tools			Speed m/min	Cut off Tools		
		Speed m/min*			Feed mm/rev.				Feed mm/rev		
		Roughing	Finishing		Tool 12.5	width 25.0	mm 50.0		Tool Width, mm		
									1.5	3.0	6.0
C20, C45,	85—125	40	55	30	0.067	0.04	0.025	30	0.04	0.05	0.067
40 Cr1 Mo 2, 20Ni55 Cr 5 Mo2	125—175	35	45	25	0.067	0.04	0.025	25	0.04	0.05	0.067
	175—225	30	40	20	0.067	0.04	0.017	20	0.04	0.05	0.067
	225—275	25	32	17	0.04	0.025	0.017	17	0.025	0.04	0.050
	275—325	20	25	15	0.04	0.025	0.017	15	0.025	0.04	0.05
	325—375	16	20	12	0.04	0.025	0.017	12	0.025	0.025	0.04
	375—425	12	17	10	0.025	0.017	0.013	10	0.025	0.025	0.025
	Rc 50—52	6	10								
12 S 12 (Free cutting Steel)	100—150	47	63	35	0.075	0.067	0.04	35	0.05	0.067	0.071
	150—200	51	70	38	0.075	0.067	0.04	38	0.05	0.067	0.071
	200—250	32	45	25	0.067	0.05	0.025	25	0.04	0.05	0.065
17 S 11 (Free cutting Steel)	100—150	42	55	32	0.05	0.067	0.04	32	0.050	0.067	0.071
	150—200	45	63	34	0.075	0.067	0.04	34	0.050	0.067	0.071
35 S 11 (Free cutting Steel)	175—225	40	58	29	0.075	0.067	0.04	29	0.050	0.067	0.071
	275—325	27	34	21	0.040	0.025	0.017	21	0.025	0.040	0.050
	325—375	17	21	12	0.04	0.025	0.017	12	0.025	0.025	0.040
	375—425	12	17	9	0.025	0.017	0.013	9	0.025	0.025	0.025

*These speeds are recommended for
roughing with depth of cutting 4 mm & feed 0.4 mm/rev.
finishing with depth of cut 0.6 mm & feed 0.04 mm/rev.

SPEEDS AND FEEDS FOR TURNING OF CARBON AND LOW ALLOY STEELS WITH CARBIDE TOOLS

Typical steels	Brinell Hardness	Single point tools				Speed m/min	Form Tools			Speed m/min	Cut off Tools		
		Brazed		Disposable			Feed mm/rev				Feed mm/rev		
		R	speed m/min*	R	F		12.5	Tool width, mm			1.5	Tool width, mm	
			F					25.0	50.0			3.0	6.0
C20, C45,	85—125	140	165	185	200	105	0.125	0.090	0.067	105	0.090	0.160	0.190
40Cr1Mo2 20Ni	125—175	116	140	140	180	87	0.125	0.090	0.067	87	0.118	0.160	0.190
55Cr 5Mo2	175—225	105	135	135	160	76	0.125	0.090	0.067	76	0.118	0.160	0.190
	225—275	95	130	120	145	70	0.075	0.067	0.04	70	0.075	0.118	0.160
	275—325	83	120	105	135 ¹	61	0.075	0.067	0.04	61	0.075	0.118	0.160
	325—375	69	88	84	110	52	0.075	0.050	0.04	52	0.075	0.075	0.118
	375—425	53	69	65	85	46	0.067	0.04	0.025	40	0.050	0.050	0.075
	Re50—52	30.5	38	38	46								
	Re54—56	18	23	21	27								

FREE CUTTING CARBON AND LOW ALLOY STEELS

12 S 12 (Free cutting steel)	100—150	168	220	210	280	125	0.180	0.160	0.10	125	0.180	0.20	0.300
	150—200	185	250	230	305	140	0.180	0.160	0.10	140	0.180	..	0.236
	200—250	110	135	135	170	82	0.122	0.100	0.05	82	0.120	0.160	0.180
35 S 11 (Free cutting steel)	175—225	150	220	185	270	115	0.180	0.160	0.10	115	0.180	0.200	0.236
	275—325	105	125	130	160	77	0.075	0.067	0.04	78	0.090	0.118	0.160
	325—375	68	88	84	110	52	0.075	0.050	0.04	52	0.075	0.075	0.160
	375—425	53	69	66	85	40	0.067	0.04	0.025	40	0.050	0.050	0.075

*These speeds are recommended for:

Roughing	Finishing	
depth of cut, mm	0.60	R, Roughing
Feed, mm/rev	0.04	F, Finishing

CUTTING SPEEDS FOR TURNING, BORING AND FACING OF NON-FERROUS AND NON-METALLIC MINERALS WITH PLAIN HSS AND CARBIDE TOOLS

Speed (at average Brinell) for tool life of 1½ to 2 hours between grinds, m/min.

Depth of Cut	Feed mm	Hard Brass, Hard Bronze, Hard Rubber, Paper Rolls, Marble and Slate		Soft Brass, Soft Bronze, Copper, Fibre and Plastic Aluminium Alloys		Aluminium, Magnesium Hardwood	
		HSS	Carbide	HSS	Carbide	HSS	Carbide
0.8	0.1	90	250	150	400	200	500
	0.2	71	200	120	300	150	360
	0.4	56	150	90	220	110	280
1.6	0.1	71	220	120	300	150	400
	0.2	63	180	100	250	120	300
	0.4	45	140	71	180	71	220
	0.8	32	100	56	140	71	180
3.2	0.1	63	180	95	250	120	300
	0.2	50	140	80	200	100	250
	0.4	36	110	63	150	71	200
	0.8	25	71	45	110	56	140
	1.6	20	63	32	71	40	110
6.4	0.1	45	140	80	180	110	250
	0.2	40	120	63	140	80	180
	0.4	32	90	50	110	60	140
	0.8	20	63	36	90	45	110
	1.6	16	40	25	45	36	71
9.6	0.1	40	140	71	150	90	200
	0.2	36	110	56	120	70	150
	0.4	25	80	45	90	56	120
	0.8	20	50	32	71	40	90
	1.6	16	32	20	40	25	63
	2.4	9	25	16	32	20	40

Note 1: For jump cuts, 80% of above speeds for HSS Tools, 70% of above speeds for Carbide tools.

Note 2: Above speeds are for dry cutting.

CUTTING SPEED FOR TURNING, BORING AND FACING OF CAST IRON WITH HSS AND CARBIDE TOOLS

Speed (at average Brinell) for a tool life of $1\frac{1}{2}$ or 2 hours between grinds speed in m/min

Depth of Cut	Feed	Soft iron (Upto 160 HB) (Average 140 HB)		Medium hard iron (From 160 to 220 HB) (Average 190 HB)		Hard Iron (From 220 to 360 HB) (Average 290 HB)	
		HSS	Carbide	HSS	Carbide	HSS	Carbide
0.8	0.2	90	160	50	120	32	100
	0.4	70	120	40	90	25	71
	0.8	63	110	32	71	20	63
1.6	0.2	80	140	45	110	25	90
	0.4	63	110	32	80	20	71
	0.8	50	100	25	63	16	56
3.2	0.2	71	140	40	90	25	71
	0.4	56	110	32	71	20	63
	0.8	45	90	25	63	16	50
	1.6	32	63	20	45	10	40
4.8	0.2	63	125	32	80	20	71
	0.4	50	100	25	63	16	56
	0.8	40	80	20	50	10	45
	1.6	32	63	16	36	9	32
6.4	0.2	63	120	32	71	20	63
	0.4	45	90	25	63	16	50
	0.8	40	80	20	45	10	40
	1.6	25	56	16	36	8	25
9.6	0.4	40	80	20	36	16	45
	0.8	36	71	16	45	10	36
	1.6	25	50	10	32	7	25
	3.2	20	36	9	—	5	—
12.7	0.4	40	80	20	50	10	40
	0.8	32	60	16	40	9	32
	1.6	25	45	10	32	7	20
	2.4	16	25	8	—	5	—
19.0	0.4	36	71	20	45	10	32
	0.8	25	50	16	36	7	25
	1.6	20	36	10	25	5	20
	3.2	10	20	7	—	4	—

Note 1: For jump cuts, use 80% of above speeds of HSS tools, 70% of above speeds for carbide tools.

Note 2: Above speeds are for Cast Iron with no alloy content. For soft medium, hard, hard alloy and malleable irons, a 10% reduction in speed is recommended.

Note 3: Above speeds are for dry cutting.

RECOMMENDED SPEEDS & FEEDS FOR PLANING WITH HSS TOOLS

Material	Brinell Hardness	Roughing								Finishing Speed m/min
		Depth of cut 3.15 mm		Depth of cut 6.3 mm		Depth of cut 12.5 mm		Depth of cut 25 mm		
		Speed m/min	Feed mm/stroke	Speed m/min	Feed mm/stroke	Speed m/min	Feed mm/Stroke	Speed m/min	Feed mm/Stroke	
Cast Iron	230	15	2.25—3.15	15	1.50—2.25	13	1.18—1.60	12	0.75—1.18	13
	175	21	2.25—3.15	18	1.50—2.25	15	1.18—1.60	13	1.18—1.60	22
Steel	270	11	1.60—2.25	9	1.50—2.25	8	1.18—1.60	7	1.18—1.60	7
	200	11	2.25—3.15	11	1.50—2.25	9	1.60—2.25	9	1.18—1.60	11
	130	18	2.25—3.15	15	2.25—3.15	13	1.60—2.25	11	1.18—1.60	15
Bronze	Hard	18	2.25—3.15	18	2.25—3.15	15	2.25—3.15	13	1.60—2.25	22
	Soft	43	4.0—5.0	36	3.15—4.00	31	3.15—3.75	31	2.25—3.15	43

PLANING WITH CARBIDE TOOLS

Cast Iron	230	61	2.25—3.15	61	1.9—2.25	61	1.60—1.80	61	1.18—1.60	55
	115	91	2.25—3.15	91	2.25—3.15	91	1.80—2.25	91	1.60—1.80	67
Steel	270	76	1.50—2.25	76	1.50—1.90	76	1.18—1.60			61
	200	Max	1.50—2.25	Max	1.50—1.90	91	1.60—1.80			91
	130	Max	1.50—2.25	Max	1.50—2.25	Max	1.60—2.25			91
Bronze	Hard	Max	2.25—3.15	Max	2.25—3.15	Max	2.25—2.50	Max	1.60—2.25	Max
	Soft	Max	2.25—4.00	Max	2.25—3.15	Max	2.25—3.15	Max	2.25—2.50	Max

**SPEEDS AND FEEDS FOR DEEP HOLE TREPPANNING OF CARBON AND
LOW ALLOY STEELS WITH HSS AND CARBIDE TOOLS**

Typical steel	Brinell Hardness	Speed, m/min		Feed, mm/rev	
		HSS	CARBIDE	HSS	CARBIDE
CARBON AND LOW ALLOY STEELS					
C20, C45	85—125	34	200	0.2	0.2
40Cr1Mo 2	125—175	27	200	0.2	0.2
20Ni 55 Cr 5 Mo 2	175—225	23	200	0.18	0.18
	225—275	22	200	0.15	0.18
	275—325	18	180	0.15	0.18
	325—375	15	135	0.125	0.15
	375—425	9	115	0.1	0.125
FREE CUTTING AND LOW ALLOY STEELS					
12 S 12	100—150	37	200	0.2	0.2
	150—200	41	200	0.2	0.2
35 S 12	100—150	38	200	0.2	0.2
	150—200	32	200	0.18	0.18
	200—250	28	200	0.18	0.18
	275—325	23	170	0.15	0.18
	325—375	14	120	0.15	0.18
	375—425	9	105	0.125	0.15

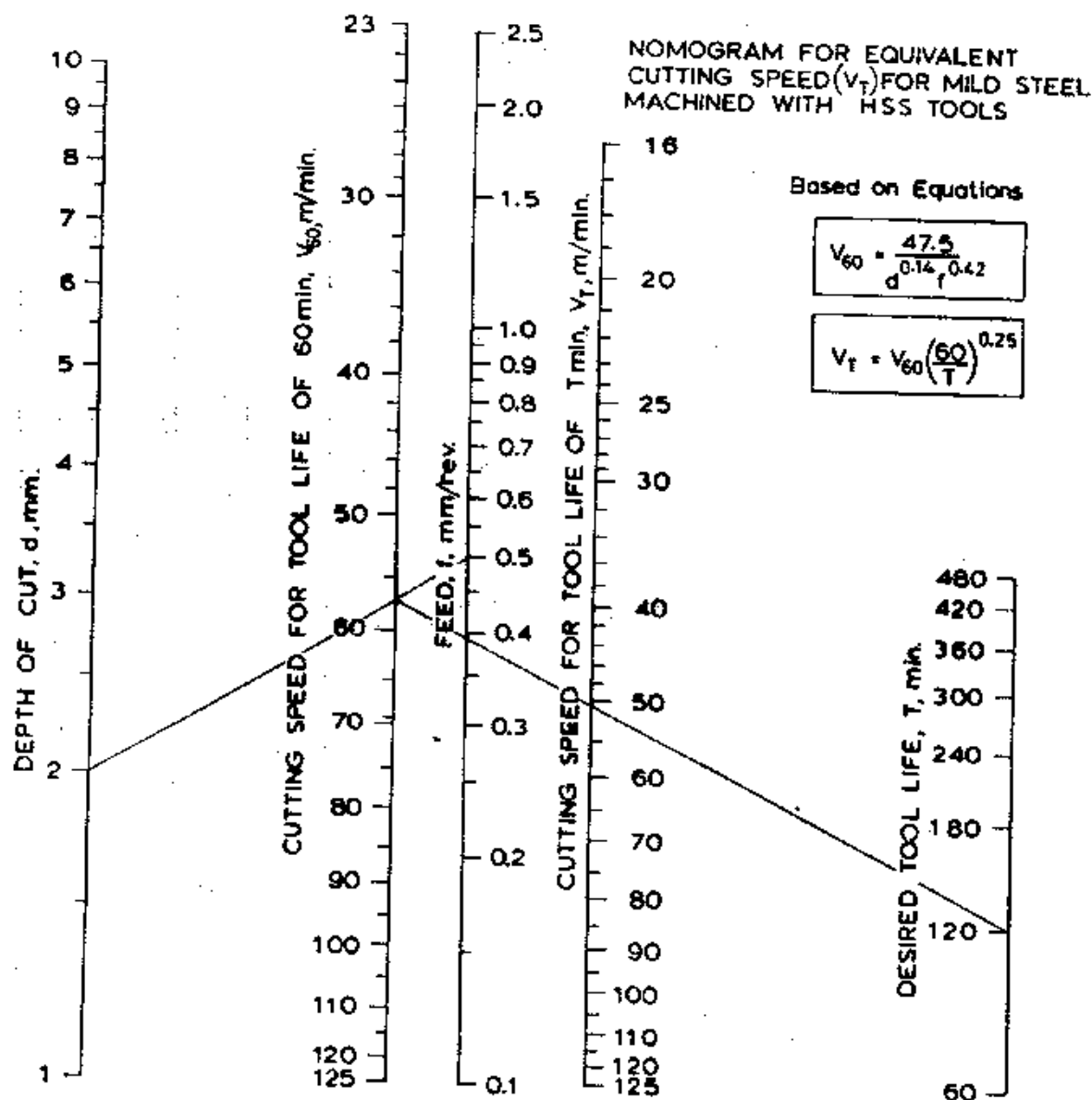
SPEEDS AND FEEDS FOR BORING OF CARBON AND LOW ALLOY STEELS WITH HSS AND CARBIDE TOOLS

Typical Steel	Brinell Hardness	Rough boring (depth of cut 2.5 mm)				Finish Boring (depth of cut 0.25mm)			
		Speed, m/min		Feed, mm/rev		Speed, m/min		Feed, mm/rev	
		HSS	Carbide	HSS	Carbide	HSS	Carbide	HSS	Carbide
C20, C45, 40Cr 1Mo2, 20Ni 55Cr5 Mo2	85—125	37	125	0.25	0.375	41	140	0.125	0.160
	125—175	31	105	0.25	0.375	33	115	0.125	0.160
	175—225	24	93	0.236	0.335	27	105	0.125	0.160
	225—275	20	85	0.18	0.225	23	95	0.100	0.125
	275—325	18	75	0.18	0.225	20	82	0.100	0.125
	325—375	15	63	0.18	0.225	17	69	0.075	0.100
	375—425	10	49	0.16	0.180	12	53	0.075	0.100
	Rc50—52	6	27	0.16	0.200	61	31	0.075	0.100
	Rc54—56		17		0.160		18		0.075
12 S 12	100—150	41	155	0.25	0.375	46	170	0.125	0.150
17 S 11									
(Free cutting steel)	150—200	44	170	0.25	0.375	50	190	0.125	0.150
35 S 11	100—150	41	157	0.25	0.375	46	175	0.125	0.150
(Free cutting steel)	150—200	35	132	0.25	0.375	38	145	0.125	0.150
	200—250	29	100	0.20	0.300	32	110	0.125	0.150
	275—325	25	93	0.20	0.250	27	105	0.100	0.125
	325—375	15	63	0.18	0.225	17	69	0.075	0.100
	375—425	10	47	0.16	0.200	12	53	0.075	0.100

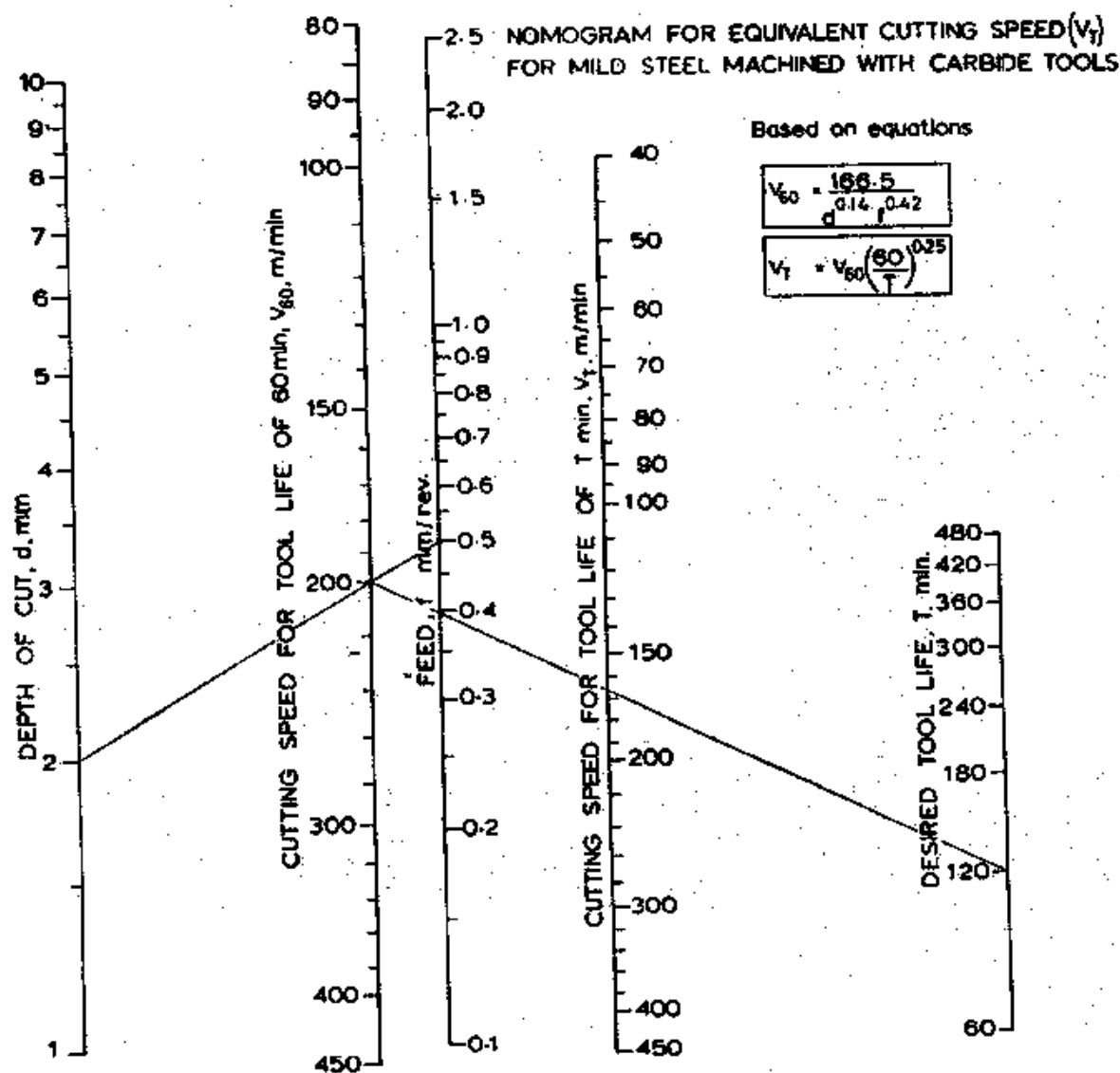
DEEP HOLE DRILLING

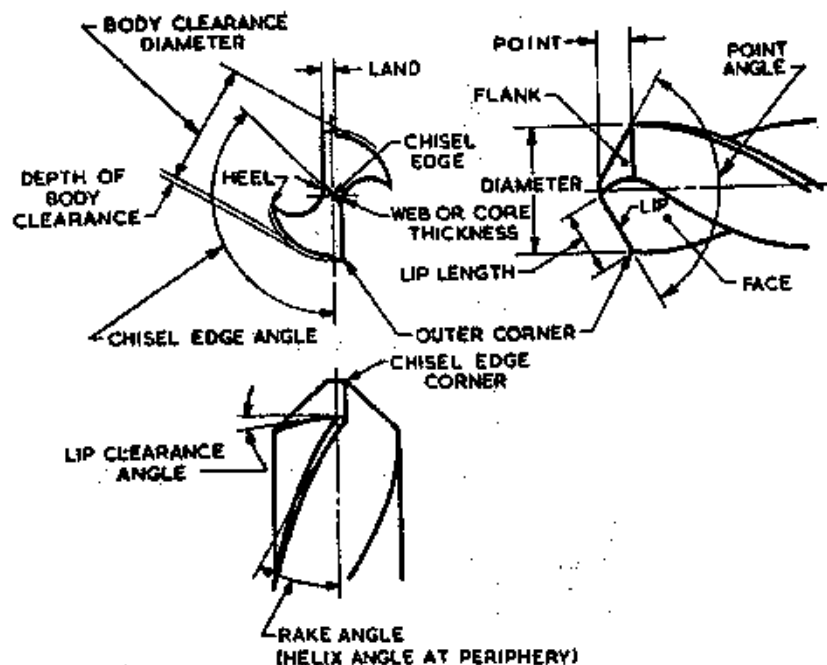
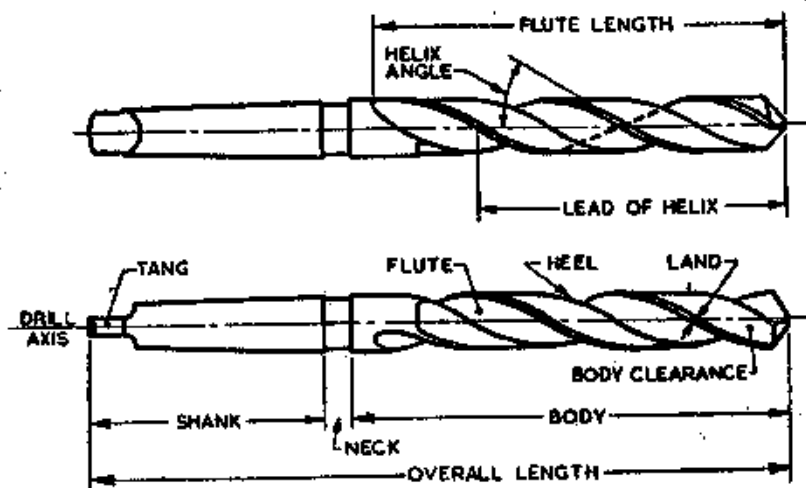
Ratio of hole depth to drill diameter	Speed reduction %	Feed reduction %
3:1	10	10
4:1	20	10
5:1	30	20
6—8:1	35—40	20

TOOL LIFE NOMOGRAM HSS TOOLS



TOOL LIFE NOMOGRAM CARBIDE TIPS





RECOMMENDED DRILL ANGLES, SPEEDS, FEEDS AND CUTTING FLUIDS FOR DRILLING VARIOUS MATERIALS WITH HSS DRILLS

Material	Hardness HB	Point angle degrees	Lip clearance angle, degrees	Chisel edge angle, degrees	Helix angle degrees	Peripheral speed m/min	Feed rate mm/rev.	Cutting fluid
Aluminium	99—101	90—140	12—17	125—135	24—48	195—390	0.127—0.89	Kerosene
Brass	192—202	118	12—15	125—135	0—17	60—75	Heavy	Kerosene
Bronze	166—183	118	12—15	125—135	0—17	60—75	Heavy	Soluble oil or dry
Cast Iron, soft	126	90—100	12	125—135	24—32	42—45	Heavy	None
Cast iron, medium	196	90—100	12	125—135	24—32	24—33	Medium	None

RECOMMENDED DRILL ANGLES, SPEEDS, FEEDS AND CUTTING FLUIDS FOR DRILLING VARIOUS MATERIALS WITH HSS DRILLS (Contd.)

Materials	Hardness HB	Point angle degrees	Lip clearance angle, degrees	Chisel edge angle, degrees	Helix angle degrees	Peripheral speed m/min	Feed rate mm/rev.	Cutting fluid
Cast iron, hard	293—302	118	10—12	125—135	24—32	13—15	Light	Soluble oil
Cast iron chilled†	402	150	5—7	115—125	24—32	4—5	Light	Lard oil and turpentine
Cast steel	286—302	118	12—15	125—135	24—32	12—15	Light	Lard or soluble oil
Copper	80—85	100—118	12—15	125—135	28—40	21	Light	Soluble oil
Duralumin	90—104	118	12	125—135	32—45	60	Medium	Kerosene
Formica	—	90—100	12—15	125—135	10—17	16	Light	None
Magnesium	—	70—118	12	120—135	10—30	90—600	0.127—0.9	Mineral oil
Marble	—	90—130	10—12	125—135	28—40	4.5	Light	None
Monel metal	149—170	118	12—15	125—135	24—32	15	Medium	Lard oil
Nickel pure	187—202	118	12	125—135	24—32	23	Medium	Lard oil
STEELS :								
C15, C20, C30	170—202	118	12—15	125—135	24—32	33—37	Heavy	Soluble oil
C40, C50	170—196	118	12—15	125—135	24—32	24	Medium	Soluble oil
Tool steels	196	118	12—15	125—135	24—32	18	Medium	Soluble oil
	241	125	10—12	125—135	24—32	15	Medium	Soluble oil

† Use cobalt drills

RECOMMENDED DRILL ANGLES, SPEEDS, FEEDS AND CUTTING FLUIDS FOR DRILLING VARIOUS MATERIALS WITH HSS DRILLS (Contd.)

Material	Hardness HB	Point angle degrees	Lip clearance angle, degrees	Chisel edge angle, degrees	Helix angle degrees	Peripheral speed m/min	Feed rate mm/rev.	Cutting fluid
Tool Steel	302	125	10—12	125—135	24—32	12	Light	Soluble oil
	351	150	7—10	125—135	24—32	6	Light	Sulphur base oil
	402	150	7—10	125—135	24—32	4.5	Light	Sulphur base oil
Spring steel	402	150	7—10	115—125	24—32	6	Light	Sulphur base oil
Stainless steel	146—149	118	12	125—135	24—32	15	Medium	Sulphur base oil
Wood		60	15—20	135	20—32	150	Light	None

KEY TO FEED RATE IN DRILLING*

Drill dia. mm	Heavy feed mm/rev.	Medium feed mm/rev.	Light feed mm/rev.
6	0.2	0.125	0.063
12	0.25	0.19	0.1
20	0.4	0.25	0.16
25	0.51	0.3	0.19

SPEEDS AND FEEDS FOR HSS DRILLS

Drill Size	Aluminium and Copper		Mild Steel (C 15)		Cast Iron		Brass or Bronze		Steel Castings, Monel Metal, Drop Forged Tool Steel & Stainless Steel		Drop Forgings Alloy Steel	
	mm	Feed mm Speed rpm	Feed mm Speed rpm	Feed mm Speed rpm	Feed mm Speed rpm	Feed mm Speed rpm	Feed mm Speed rpm	Feed mm Speed rpm	Feed mm Speed rpm	Feed mm Speed rpm	Feed mm Speed rpm	Feed mm Speed rpm
1.5	0.05 to 0.125	1500 to 1800	0.05 to 0.075	4275 to 5500	0.05 to 0.10	4575 to 6700	0.05 to 0.1	9150 to 12000	0.05 to 0.075	3650 to 4550	0.05 to 0.075	4275 to 5500
3.0	0.05 to 0.075	7600 to 9100	0.05 to 0.075	2100 to 2800	0.05 to 0.10	2300 to 3350	0.05 to 0.1	4575 to 6100	0.05 to 0.075	1800 to 2250	0.05 to 0.075	2100 to 2800
6.0	0.075 to 0.125	3800 to 4600	0.075 to 0.125	1050 to 1375	0.1 to 0.15	1150 to 1675	0.1 to 0.175	2300 to 3000	0.075 to 0.1	925 to 1150	0.075 to 0.1	1050 to 1375
10.0	0.075 to 0.125	2500 to 3000	0.125 to 0.175	700 to 925	0.15 to 0.225	750 to 1125	0.175 to 0.25	1525 to 2025	0.1 to 0.15	600 to 750	0.1 to 0.125	700 to 925
13	0.15 to 0.2	1900 to 2280	0.150 to 0.25	525 to 700	0.2 to 0.3	575 to 850	0.25 to 0.35	1150 to 1525	0.15 to 0.225	450 to 575	0.125 to 0.15	525 to 700
16	0.2 to 0.25	1500 to 1800	0.25 to 0.35	425 to 550	0.3 to 0.4	450 to 675	0.35 to 0.45	900 to 1200	0.2 to 0.3	350 to 450	0.175 to 0.25	425 to 550
20	0.2 to 0.25	1250 to 1500	0.25 to 0.35	350 to 450	0.3 to 0.4	375 to 550	0.35 to 0.45	750 to 1000	0.2 to 0.3	300 to 375	0.175 to 0.25	350 to 450
22	0.25 to 0.325	1095 to 1300	0.35 to 0.4	300 to 400	0.35 to 0.5	325 to 475	0.4 to 0.55	650 to 875	0.25 to 0.35	260 to 325	0.225 to 0.3	300 to 400
25	0.25 to 0.325	950 to 1125	0.35 to 0.4	265 to 340	0.35 to 0.5	280 to 425	0.4 to 0.55	575 to 750	0.25 to 0.35	225 to 280	0.225 to 0.3	265 to 340

FEEDS FOR DRILLING IN STEEL WITH HSS DRILLS

Drill dia. mm	TENSILE STRENGTH, kgf/mm ²								
	Upto 80			80 to 100			Over 100		
	FEED GROUP								
	I	II	III	I	II	III	I	II	III
Up to									
2	0.05—0.06	0.04—0.05	0.03—0.04	0.04—0.05	0.03—0.04	0.02—0.03	0.03—0.04	0.03—0.04	0.02—0.03
4	0.08—0.10	0.06—0.08	0.04—0.05	0.06—0.08	0.04—0.06	0.03—0.04	0.04—0.06	0.04—0.05	0.03—0.04
6	0.14—0.18	0.11—0.13	0.07—0.09	0.10—0.12	0.07—0.09	0.05—0.06	0.08—0.10	0.06—0.08	0.04—0.05
8	0.18—0.22	0.13—0.17	0.09—0.11	0.13—0.15	0.09—0.11	0.06—0.08	0.11—0.13	0.08—0.10	0.05—0.07
10	0.22—0.28	0.16—0.20	0.11—0.13	0.17—0.21	0.13—0.15	0.08—0.11	0.13—0.17	0.10—0.12	0.07—0.09
13	0.25—0.31	0.19—0.23	0.13—0.15	0.19—0.23	0.14—0.18	0.10—0.12	0.15—0.19	0.12—0.14	0.08—0.10
16	0.31—0.37	0.22—0.27	0.15—0.19	0.22—0.28	0.17—0.21	0.12—0.14	0.18—0.22	0.13—0.17	0.09—0.11
20	0.35—0.43	0.26—0.32	0.18—0.22	0.26—0.32	0.20—0.24	0.13—0.17	0.21—0.25	0.15—0.19	0.11—0.13
25	0.39—0.47	0.29—0.35	0.20—0.24	0.29—0.35	0.22—0.26	0.14—0.18	0.23—0.29	0.17—0.21	0.12—0.14
30	0.45—0.55	0.33—0.41	0.22—0.28	0.32—0.40	0.24—0.30	0.16—0.20	0.27—0.33	0.20—0.24	0.13—0.17
Over 30 & upto 60	0.6—0.70	0.45—0.55	0.30—0.35	0.40—0.50	0.30—0.35	0.20—0.25	0.30—0.40	0.22—0.30	0.16—0.23

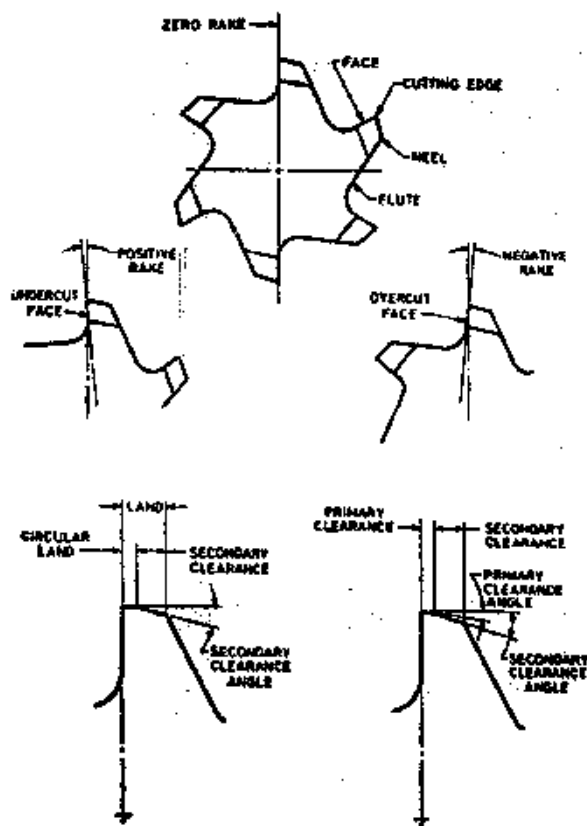
NOTE :—

Feed Group I — drilling holes in rigid workpieces

Feed Group II — drilling holes in workpieces of medium rigidity.

Feed Group III — drilling precision holes, to be followed by reaming.

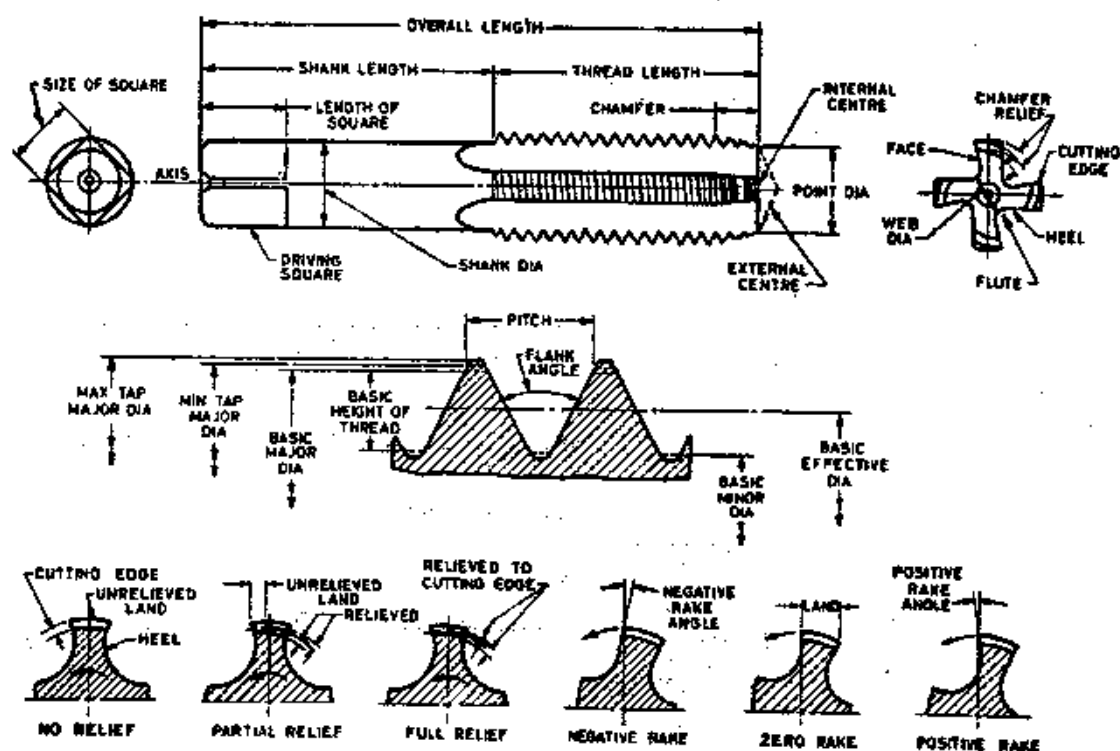
CUTTING TOOLS — REAMERS



Reamer material	HSS, carbon steel
Bevel lead angle	40—50° (usually 45°)
Taper lead angle	1—10°
Hardness	61—65 HRC

Material to be reamed	Speed in m/min.
Aluminium and its alloys	40—60
Bakelite	20—30
Brass	30—48
Bronze	20—40
Cast iron, soft	20—30
Cast iron, medium	15—18
Cast iron, hard	12—15
Copper	20—40
Magnesium and its alloys	50—80
Zinc base alloys	40—60
Steels, free cutting	20—30
Steels, upto 65 kg/mm ² UTS	15—23
Steels, 65—95 kg/mm ² UTS	10—14
Steels, 95—125 kg/mm ² UTS	6—9
Steels, over 125 kg/mm ² UTS	3—5
Stainless steels - free cutting	10—25
Stainless steels	6—15

CUTTING TOOLS — TAPS



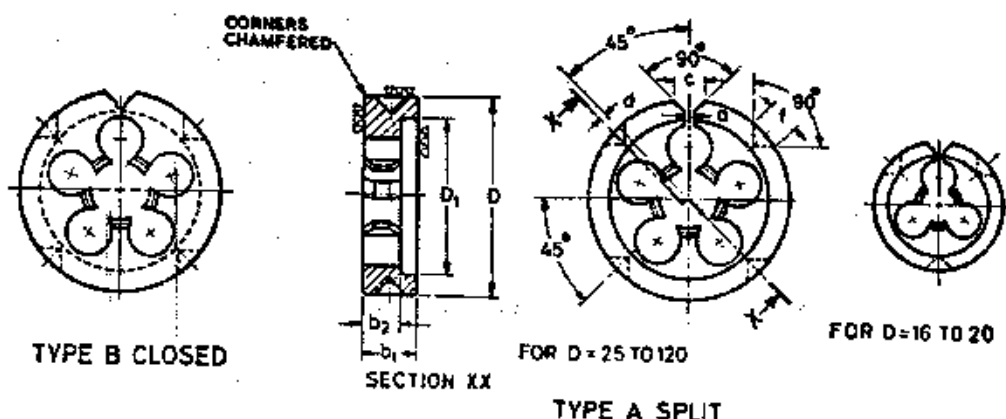
Work material	Rake angle		Relief angle Deg.	Cutting fluids
	Positive Deg.	Hook Deg.		
Aluminium	—	10—15		Kerosene and paraffin 50/50
Brass	0	—		Soluble oil
Bronze	—	20		Soluble oil
Copper	—	20		Skim milk
Cast Iron	0	—	6—12	Soluble oil or dry
Cast steel	10—15	—		sulphur base oil
Fibre, hard rubber phenolic plastics	—	10—15		Dry
Steels (all grades)	10—15	—		Sulphur base oil
Zinc alloys		10—15		Kerosene and paraffin oil

DRILLED HOLES FOR MACHINE TAPPING

Thread diameter in mm	Coarse threads		Fine threads (Pitch in mm)															
			4		3		2		1.5		1.25		1.0		0.75		0.50	
	in cast iron & bronze	in steel & Brass	in cast iron & bronze	in steel & Brass	in cast iron & bronze	in steel & Brass	in cast iron & bronze	in steel & Brass	in cast iron & bronze	in steel & Brass	in cast iron & bronze	in steel & Brass	in cast iron & bronze	in steel & Brass	in cast iron & bronze	in steel & Brass	in cast iron & bronze	in steel & Brass
6	5.1	5.2	—	—	—	—	—	—	—	—	—	—	—	—	5.4	5.4	5.6	5.6
7	6.1	6.2	—	—	—	—	—	—	—	—	—	—	—	—	6.4	6.4	6.5	6.6
8	6.9	7.0	—	—	—	—	—	—	—	—	—	—	7.1	7.2	7.3	7.4	7.5	7.6
9	7.9	8.0	—	—	—	—	—	—	—	—	—	—	8.1	8.2	8.3	8.4	8.5	8.6
10	8.6	8.7	—	—	—	—	—	—	—	—	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6
11	9.6	9.7	—	—	—	—	—	—	—	—	—	—	10.1	10.2	10.3	10.4	10.5	10.6
12	10.4	10.5	—	—	—	—	—	—	10.6	10.7	10.9	11.0	11.2	11.4	11.4	11.4	11.6	11.6
14	12.1	12.2	—	—	—	—	—	—	12.6	12.7	12.9	13.0	13.2	13.2	13.4	13.4	13.6	13.6
15	—	—	—	—	—	—	—	—	13.6	13.7	—	—	14.2	14.2	—	—	—	—
16	14.0	14.2	—	—	—	—	—	—	14.6	14.7	—	—	15.2	15.2	15.4	15.4	15.6	15.6
17	—	—	—	—	—	—	—	—	15.6	15.7	—	—	16.2	16.2	—	—	—	—
18	15.6	15.8	—	—	—	—	16.1	16.2	16.6	16.7	—	—	17.2	17.2	17.4	17.4	17.6	17.6
20	17.6	17.8	—	—	—	—	18.1	18.2	18.6	18.7	—	—	19.2	19.2	19.4	19.4	19.6	19.6
22	19.6	19.8	—	—	—	—	20.1	20.2	20.6	20.7	—	—	21.2	21.2	21.4	21.4	21.6	21.6
24	21.2	21.3	—	—	—	—	22.1	22.2	22.7	22.7	—	—	23.2	23.2	23.4	23.4	—	—
25	—	—	—	—	—	—	23.1	23.2	23.7	23.7	—	—	24.2	24.2	—	—	—	—

RECOMMENDED CUTTING SPEEDS AND CUTTING FLUIDS FOR MACHINE TAPPING

Material	m/min	Lubricant
Aluminium	25	Kerosene and lard oil
Bakelite	18	dry
Brass	25	Light base oil
Bronze	12	
Fibre	25	dry
Copper	25	Light base oil
Cast iron	20	dry or compound oil
Malleable Iron	10	Sulphur base oil
Mild Steel	8	
Medium Steel	6	
Hard Steel	5	
Stainless Steel	5	



DIMENSIONS FOR CIRCULAR THREAD CUTTING DIES FOR METRIC THREADS
All dimensions in millimetres

Nominal Size	D f9	D ₁	For Metric Coarse Pitch	For Metric Fine Pitch P																a	c	d	f			
				0.2	0.25	0.35	0.5	0.75	1.00	1.25	1.5	2.00	3.00	4.00												
				b ₁ b ₂	b ₁ b ₁	b ₁ b ₁	b ₂ b ₁	b ₁ b ₁	b ₁ b ₁	b ₁ b ₁	b ₁ b ₁	b ₁ b ₁	b ₁ b ₁	b ₁ b ₁	b ₁ b ₁	b ₁ b ₁	b ₁ b ₁	b ₁ b ₁								
M 1			5 2	5 2																						
(M 1.1)			5 2	5 2																						
M 1.2			5 2	5 2																						
(M 1.4)			5 2.5	5 2																						
M 1.6	16	11	5 2.5	5 2																						
(M 1.8)			5 2.5	5 2																						
M 2			5 3		5 2															4.5	0.5	3.8				
(M 2.2)			5 3		5 2																					
M 2.5			5 3			5 3																				
M 3			5 —			5 3														1						
(M 3.5)			5 —			5 3																				
M 4	20	15	5 —				3 3.5													0.6	4.5					
(M 4.5)			5 —				5 —																			
M 5			7 —				5 —																			
M 6			7 —					5 —												5						
(M 7)	25	20	9 —					9 6												0.8	5.2					
M 8			9 —					9 6		9 7																
M 10	30	24	11 —					11 7		11 8		10														
M 12	38	30	14 —							10 —		10								1.5	5.5	1 6				
(M 14)			14 —							10 —		10								6	6.5					
M 16			14 —							14 10		10														
(M 18)	45	36	18 —							14 10		14 10								1.2						
M 20			18 —							14 10		14 10		14 —						7	7.5					
(M 22)			22 —							14 10		14 10		14 —						2						
M 24	55	45	22 —							16 10		16 10		16 —												
(M 27)			25 —							16 10		16 10		16 —						8	1.5	8.5				
M 30			25 —							18 12		18 12		18 —												
(M 33)	65	54	25 —							18 12		18 12		18 —	(25) —					9.5	10					
M 36			25 —								18 12	18 —	(25) —						2.5	1.8						
(M 39)			30 —								18 12	18 —	25 —													
M 42	75	63	30 —								20 14	20 —	30 25													
(M 45)			36 —								20 14	20 —	30 25							11	11.5					
M 48	90	75	36 —								22 16	22 —	36 28													
(M 52)			36 —								22 16	22 —	36 28							3	12	2 13				
M 56			36 —								22 16	22 —	36 28													
(M 60)	105	90	36 —									36 22	36 28													
M 64			36 —									36 25	36 28													
(M 68)	120	100	36 —									36 25	36 28							4	14	2.5 15				
												36 25	36 28													

Non-preferred sizes in brackets

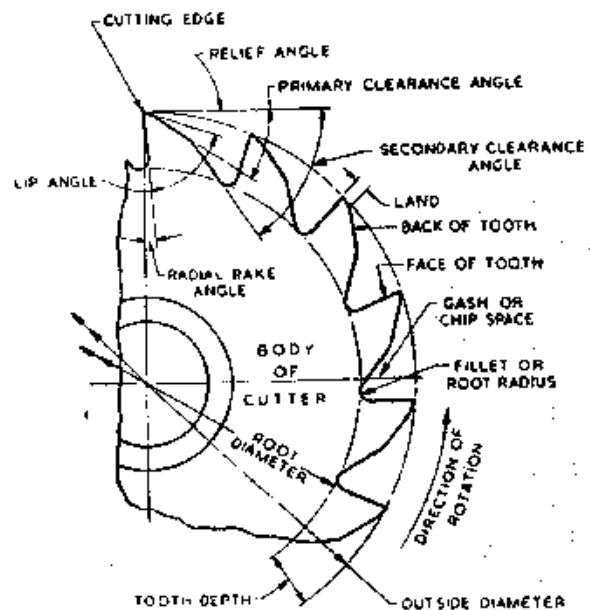
IS: 1859-1961

Designations

Designation of a circular split die of Type A for cutting metric coarse pitch threads M 10, made of carbon tool steel shall be: Thread Cutting Die AM 10 IS: 1859-CS

Designation of a circular closed die of Type B for cutting metric fine threads M 10x1 made of high speed steel shall be: Thread Cutting Die BM 10x1 IS: 1859-HS

CUTTING TOOLS — MILLING



Type of cutter	Cutter outside diameter mm	Normal steels upto 75 kgf/mm ² strength							Tough materials upto 100 kgf/mm ² strength							Light alloys						
		Up-Milling				Down-Milling			Up-Milling				Down-Milling			Up-Milling				Down-Milling		
		Number of Teeth	Primary clearance angle Deg.	Positive radial rake angle Deg.	Helix angle Deg.	Primary clearance angle Deg.	Positive radial rake angle Deg.	Helix angle Deg.	Number of Teeth	Primary clearance angle Deg.	Positive radial rake angle Deg.	Helix angle Deg.	Primary clearance angle Deg.	Positive radial rake angle Deg.	Helix angle Deg.	Number of Teeth	Primary clearance angle Deg.	Positive radial rake angle Deg.	Helix angle Deg.	Primary clearance angle Deg.	Positive radial rake angle Deg.	Helix angle Deg.
Plain milling cutter	40	6							10							4						
	50	6							10							4						
	60	6							10							4						
	75	6	7	10	38	12	16	35	12	5	5	35	8	12	30	5	8	25	45	14	30	45
	90	8							14							5						
	110	8							16							6						
	130	10							16							6						
	150	10							18							8						

CUTTING TOOLS — MILLING (Contd.)

12.30

DESIGN DATA — PSG TECH

Type of cutter	Cutter outside diameter mm	Normal steels upto 75 kgf/mm ² strength							Tough materials upto 100 kgf/mm ² strength							Light alloys												
		Number of Teeth	Up-Milling			Down-Milling				Number of Teeth	Up-Milling			Down-Milling				Number of Teeth	Up-Milling			Down-Milling						
			Primary clearance angle Deg.	Positive radial rake angle Deg.	Helix angle Deg.	Primary clearance angle Deg.	Positive radial rake angle Deg.	Helix angle Deg.	Primary clearance angle Deg.		Positive radial rake angle Deg.	Helix angle Deg.	Primary clearance angle Deg.	Positive radial rake angle Deg.	Helix angle Deg.	Primary clearance angle Deg.	Positive radial rake angle Deg.		Helix angle Deg.									
Face milling or shell end mill cutter	40	8							12											4								
	50	10							14											5								
	60	10							14											6								
	75	10	7	10	20	—	—	—	16	4	5	20	—	—	—					6	8	25	35	—	—	—		
	90	12							18											6								
	110	12							20											7								
	130	14							22											8								
	150	16							24											10								
Side and face milling cutter	50	10							16											4								
	60	10							16											6								
	75	12							18											6								
	90	12							20											8								
	110	14	7	12	15	12	18	15	22	5	6	10	8	14	12					8	8	25	30	14	30	30		
	130	16							24											10								
	150	18							26											10								
	175	18							28											12								
Shank type end milling cutter	200	20							30											12								
	10	4							6											3								
	12	4							6											3								
	14	5							6											3								
	16	5							8											3								
	20	6	7	8	15	—	—	—	8	4	6	15	—	—	—					4	8	20	25	—	—	—		
	24	6							8											4								
	30	6							10											4								
	36	6							10											5								
	40	6							10											5								

**RECOMMENDED CUTTING SPEEDS FOR FACE AND END MILLING WITH
PLAIN HSS AND CARBIDE MILLING CUTTERS IN m/min**

Material to be milled	Depth of cut					
	Roughing Cut 3 to 5 mm		Semi-finishing Cut 1.5 to 3 mm		Finishing Cut Below 1.5 mm	
	HSS	Carbide	HSS	Carbide	HSS	Carbide
Cast Iron - Soft	25	68	30	80	36	105
- Medium	18	50	25	68	30	80
- Hard	12	38	16	50	20	68
Malleable Iron	25	68	30	80	36	105
Steel* : - Soft	28	120	32	150	40	180
- Medium	22	100	28	120	32	135
- Hard	15	75	20	90	25	105
- Stainless	18	50	22	68	28	80
Brass : - Average	30	75	45	120	60	150
Soft yellow	60	120	90	180	120	240
Bronze	28	75	36	100	45	128
Copper	45	100	68	150	90	210
Monel	18	50	22	68	28	80
Aluminium*	75	240	105	300	150	450

*Coolant to be used

Note: Cutting speeds for 12% cobalt HSS should be about 25% to 50% higher than those shown for plain HSS.

Cutting speeds for cast alloy should be about 100% higher than those shown for plain HSS.

Above speeds should be reduced when milling work that has hard spots or when milling castings that are sandy.

SUGGESTED FEED PER TOOTH FOR MILLING VARIOUS MATERIALS, mm

Materials to be milled	Face Mills		Helical Mills		Slotting and Side Mills		End Mills		Form relieved Cutters		Circular Saws	
	HSS	Carbide	HSS	Carbide	HSS	Carbide	HSS	Carbide	HSS	Carbide	HSS	Carbide
Cast Iron - Soft (upto 160 HB)	0.40	0.50	0.32	0.40	0.22	0.30	0.20	0.25	0.12	0.15	0.10	0.12
- Medium (160 to 220 HB)	0.32	0.40	0.25	0.32	0.18	0.25	0.18	0.20	0.10	0.12	0.08	0.10
- Hard (220 to 320 HB)	0.28	0.30	0.20	0.25	0.15	0.18	0.15	0.15	0.08	0.10	0.08	0.08
Malleable Iron*	0.30	0.35	0.25	0.28	0.18	0.20	0.15	0.18	0.10	0.10	0.08	0.10
Steel - Soft* (upto 160 HB)	0.20	0.35	0.18	0.28	0.12	0.20	0.10	0.18	0.08	0.10	0.05	0.10
- Medium (160 to 220HB)	0.15	0.30	0.12	0.25	0.10	0.18	0.08	0.15	0.05	0.10	0.05	0.08
- Hard* (220 to 360 HB)	0.10	0.25	0.08	0.20	0.08	0.15	0.05	0.12	0.05	0.08	0.03	0.08
- Stainless*	0.20	0.30	0.15	0.25	0.12	0.18	0.10	0.15	0.05	0.08	0.05	0.08
BRASS AND BRONZE												
soft	0.55	0.50	0.45	0.40	0.32	0.30	0.28	0.25	0.18	0.15	0.12	0.12
Medium	0.35	0.30	0.28	0.25	0.20	0.18	0.18	0.15	0.10	0.10	0.08	0.08
Hard	0.22	0.25	0.18	0.20	0.15	0.15	0.12	0.12	0.08	0.08	0.05	0.08
Copper	0.30	0.30	0.25	0.22	0.18	0.18	0.15	0.15	0.10	0.10	0.08	0.08
Monel	0.20	0.25	0.18	0.20	0.12	0.15	0.10	0.12	0.08	0.08	0.05	0.08
Aluminium*	0.55	0.50	0.45	0.40	0.32	0.30	0.28	0.25	0.18	0.15	0.12	0.12

* coolant to be used.

APPROXIMATE TOOTH RAKE ANGLES FOR BROACHING VARIOUS METALS

Metal	Rake Angle
Aluminium, Magnesium	10° to 15°
Brass; bronze	0° to 10°
Leaded brass	-5° to +5°
Cast iron	6° to 8°
Steel, Rc12 to Rc 22	15° to 20°
Steel, Rc23 to Rc 35	8° to 12°
Stainless steels	12° to 18°

SPEEDS AND FEEDS FOR BROACHING STEEL AND GREY IRON

Work Material	Brinell Hardness	Speed m/min	Feed mm/tooth
Carbon and low alloy steels Non-free cutting	85—125	9.0	0.10
	125—175	7.5	0.10
	175—225	6.0	0.10
	225—275	6.0	0.07
	275—325	4.5	0.07
Free cutting	100—200	9.0	0.10
	200—250	7.5	0.07
	275—325	6.0	0.07
	325—375	6.0	0.05
Stainless Steel:			
Ferrite	135—185	6.0	0.07
Austenitic	135—185	6.0	0.07
	225—275	4.5	0.07
Martensitic	140—225	7.5	0.10
	225—275	6.0	0.07
	275—325	4.5	0.05
	325—425	1.5	0.02
Grey Iron	110—140	9	0.13
	140—190	9	0.10
	190—220	7.5	0.07
	220—250	6.0	0.07
	250—320	4.5	0.05

RECOMMENDATIONS FOR POWER HACKSAW CUTTING

Work material	Teeth/cm	Cutting Speed m/min
Aluminium and its alloys	2—3	45
Angle iron	3—4	37.5—42
Babbitt	2—3	42
Brass	2—3	42
Bronze castings	2—3	35.5
Cast iron	3—4	20—30
Channel (light)	3—4	35.5—42
Channel (Heavy)	2	35.5—42
Copper bars	2—3	30
Die blocks	2—3	15—30
Malleable iron	2—3	27—36
Monel metal	2—3	25—30
Nickel alloys	2—3	25—30
Pipe, iron	3—4	30—40
Steel, carbon steel	2—3	27—30
High speed steel	2—3	25—30
Stainless steel	3—4	18—30
Structural steel	3	30—42
Rails	3—4	18—37.5

BAND SAW: CUTTING SPEEDS (m/min)

Material	Stock thickness (mm)				
	1.6	3.2	6.3	12.5	25.0
Aluminium	450	450	450	450	450
Bakelite	450	450	450	450	450
Beryllium copper	120	100	90	80	75
Roller plate	30	27	22	18	15
Brass (soft)	450	360	220	165	100
Bronze (ordinary)	150	120	90	66	45
Cast iron (soft)	60	53	45	37.5	30
Copper	330	270	210	180	150
Magnesium	450	450	450	450	450
Malleable iron	60	57	53	48	45
Monel	60	48	37.5	33	30
Phenolic	450	450	450	375	300
Plastics	450	450	450	450	450
Rubber (hard)	450	450	450	450	450
Steel (mild)	75	67.5	60	57	53
Steel (medium)	53	45	37.5	33	30
Steel (hard)	30	27	22	18	15

GRINDING WHEEL MARKING SYMBOLS, A 463 K 5 V 10

A		46				3	K	5	V
Grain Type		Grain Size				Grain	Grade	Wheel	Bond Type
Aluminium oxide	Silicon Carbide	A/DA	AA	C	GC	Comb.	Range	structure	
A	C	12	24	12	36	1	Soft	Dense "3"	
AA	GC	14	30	16	46	3	G		
DA		16	36	20	54	5	H		
		20	46	24	60	7	I		
		24	54	30	80		J		V = Vitrified
		30	60	36	100		*J		
		36	80	46	120		K		
		46	100	54	220		L	Normal	
		54	120	60			M		
		60	150	80			N	"5"	R = Resinoid
		80	180	100			O		
		100	220	120			P		
		120		150			Q		
		150		180			R		
				220			S		
				240			T		
				FC280			U		
				FC320			Hard	Open	
				FC400				"16"	

*J Grade for Vitrified bond only

VITRIFIED BONDS (V)

V10	Precision Grinding
V 8	
V30	Off-Hand Tool Grinding
V 6	Fettling and Snagging
V1	Surface Grinding, Cups, Cylinders and Segments
V 7	Pin and Needle Grinding
V1 S	For Precision and Thread grinding
V18P	For Porous Wheels and segments

USED
WITH
ALUMINIUM
OXIDE

RESINOID BONDS (B)

BR	Precision Grinding and Cutting off
BM4	Fettling, Snagging and Cutting off
BFW	Reinforced Cutting-Off Wheels
BN	Cutting-Off and Control Wheels

USED
WITH
ALUMINIUM
OXIDE

VG	Precision Grinding and off hand grinding
VG & VR	With "GC" grain for grinding Tungsten carbide
VR	Fettling and Snagging

USED
WITH
SILICON
CARBIDE

BR &
BFW
bonds

See above

BC4

Fettling, Snagging and Cutting-off

USED
WITH
SILICON
CARBIDE

RECOMMENDED SPEEDS IN CYLINDRICAL GRINDING†

Material	Hardness Rc	Wheel Speed m/min Range	Work Speed m/min Range	Infeed μm/pass		Feed* per rev, k		Wheel Recom- mended
				Rough	Finish	Rough	Finish	
Free machining Carbon Steel	<48	1680—2000	21—30	50	12.5	2	6	A 60 KV
	48—65	"	"	"	"	4	6	A 60 JV
Carbon Steel	<48	"	"	"	"	2	6	A 60 KV
	48—65	"	"	"	"	4	8	A 60 IV
Free machining	<48	"	"	"	"	2	6	A 60 KV
	48—65	"	"	"	"	4	8	A 60 JV
Alloy Steel	<48	"	"	"	10	2	6	A 60 KV
	48—65	"	"	"	"	4	8	A 60 IV
Tool Steel	56—65	"	18—30	50	12.5	"	"	A 60 JV
Stainless Steel	28—47	"	21—30	"	"	"	"	A 60 JV
Grey Cast Iron	<45	"	21—30	50	25	2	6	A 60 LV
	45—52	"	"	"	12.5	3	6	A 60 KV
Aluminium alloy	30—150 BHN	"	15—45	"	"	3	6	C 46 KV
Magnesium Alloy	40—90 BHN	"	21—45	"	"	"	"	C 46 JV
Titanium Alloy	110—275 BHN	460—760	15—30	25	"	5	10	A 60 IV
	"	1200—1800	"	"	"	"	"	C 60 JV
	300—440 BHN	460—760	"	"	"	"	"	A 60 JV
	"	1200—1800	"	"	"	"	"	C 60 JV
Copper Alloys (Cast)	40—200 BHN	1680—2000	21—30	50	12.5	3	6	C 60 KV

$$* \text{feed} = \frac{\text{wheel width}}{k};$$

†For internal grinding, use 25 to 50% of the in-feed values tabulated and work speed 1.5 to 2 times the speeds tabulated.

For surface grinding, data other than work speed will hold good.

TOOL GRINDING DATA

	Type	Grinding Wheel Abrasive	Grit	Grade or Bond	Peripheral Speed m/sec.	Grinding Method
Grinding shank base of new tools	Cup wheel or cylinder	Corundum	36.....46	H.....K	18.....25	Machine
Grinding clearance on shank	Straight wheel	Corundum	36.....46	M, N	18.....25	Offhand
Rough grinding tip	Straight or cup wheel	Silicon carbide	36.....46	L.....K	12.....20 6.....12	Offhand Machine
Finish grinding tip	Cup wheel	Silicon carbide Diamond	80.....100 D100.....D70	L.....K Plastic or metal	12.....18	Offhand
Grinding primary rake land	Straight or cup wheel	Silicon carbide Diamond	150.....200 D100.....D70	J.....K Plastic or metal	12.....18	Offhand
Grinding chip breaker into tip	Straight or cup wheel	Silicon carbide Diamond	100.....200 D100.....D70	K.....M Metal	12.....18	Machine
Grinding clearance lands	Cup wheel	Silicon carbide Diamond	180.....220 D50.....D30	J.....K Plastic or metal	12.....18	Offhand
Fine grinding tip (for precision tools)	Cup wheel	Diamond	D15.....D7	Plastic	12.....18	Offhand
Honing cutting edge*	Hand hone	Silicon or boron carbide	Not coarser than used for preceding grind.	Commercial Type	*The form and extent of the chamfer honed depend on the machining conditions. It is essential to hone the cutting edge if the tool is to be used for roughing or interrupted cuts.	
	Diamond lap	Diamond				

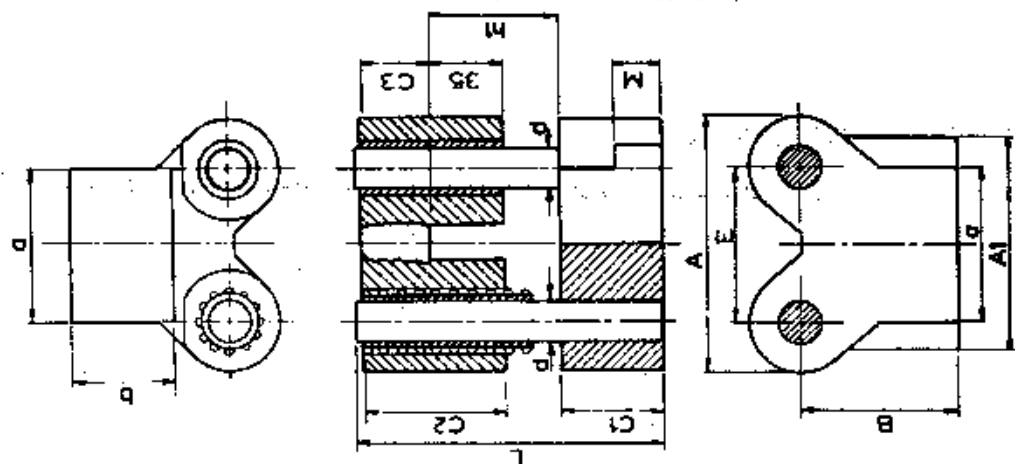
FEEDS AND SPEEDS FOR HOBGING

Type of Gear	Material	Module mm	Feed, mm/rev. of blank			Hob speeds, m/min.
			Roughing (single thread hob)	Roughing (Multi- thread hob)	Finishing	
High speed reduction and step up	Steel	1.5—8	1—1.5	1—1.5	0.8—1.25	9—25
Instrument	Steel	0.4—1.25	0.5—1.5	Upto 3	0.5—1.0	25—60
	Non-ferrous	0.4—1.25	1.0—1.5	Upto 3	0.5—1.0	25—60
Aircraft	Steel	2.0—4.0	1.0—1.5	Upto 3	0.8—1.25	15—45
Machine Tool and printing press	Steel, C.I.	2.0—6.0	2.0—3.2	Upto 2.5	1.0—1.5	15—30
	Non-ferrous	2.0—6.0	2.0—3.2	Upto 2.5	1.0—1.5	25—45
Automotive, including trucks & tractors	Steel	1.5—8.0	2.0—3.2	Upto 2.5 Upto 2.0 (3 starts)	1.25—2.0	15—45
High quality, industrial	Steel	10.0—25.0	2.0—2.5		1.25—2.0	12—30
	Cast iron	2.5—8.0	1.25—3.2			
General Industrial	Steel	10.0—25.0	2.0—2.5		1.50—2.5	12—30
	Cast iron	2.5—8	1.25—3.2			
Splines	Steel		1.25—3.0	1.25—1.5	0.50—1.75	18—45

METAL FORMING - 13

SHEET AND WIRE GAUGE

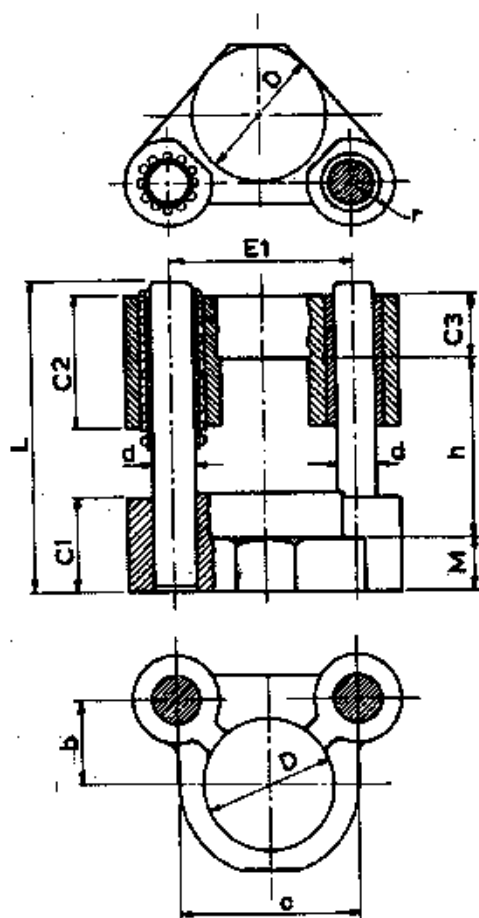
SWG	mm	SWG	mm
7/0	12.70	15	1.83
6/0	11.79	16	1.63
5/0	10.97	17	1.42
4/0	10.16		
3/0	9.45	18	1.22
2/0	8.84	19	1.02
0	8.23	20	0.91
1	7.62	21	0.81
2	7.01	22	0.71
3	6.4	23	0.61
4	5.89	24	0.56
5	5.39	25	0.51
6	4.88	26	0.46
7	4.47	27	0.42
8	4.06	28	0.38
9	3.66	29	0.35
10	3.25	30	0.31
11	2.95	35	0.21
12	2.64		
13	2.34		
14	2.03		



TWO PILLAR DIE SET WITH RECTANGULAR WORKING AREA

All dimensions in mm

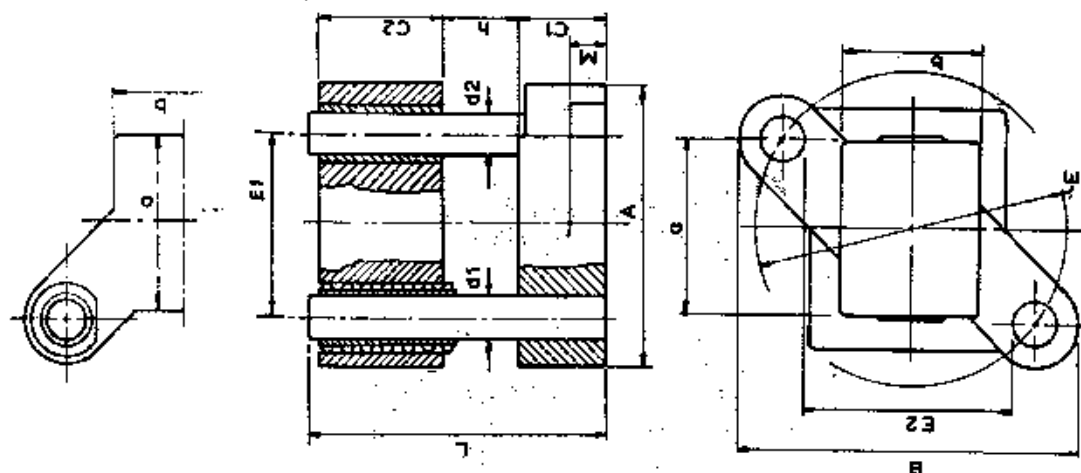
working surface a & b	A	A1	B	C1	C2	C3	d	E	L	M	h1	Standard Threads
80 × 50	125	105	78	50	70	35	20	75	150	22	55	M24 × 1.5
100	150	130	78	50	70	35	20	100	150	22	55	M24 × 1.5
120	176	152	92	50	70	35	24	120	160	22	65	M30 × 2
150	206	182	92	50	75	40	24	150	160	22	65	M30 × 2
150 × 80	206	186	112	50	75	40	24	150	160	25	65	M40 × 2
200	256	236	112	50	75	40	24	200	160	25	65	M40 × 2
150 × 100	206	190	132	55	80	45	25	150	170	25	75	M40 × 2
180	250	220	166	60	85	50	30	180	180	25	75	M50 × 2
200	256	240	132	55	85	50	25	200	170	25	75	M50 × 2
250	306	290	132	55	85	50	25	250	170	25	55	M50 × 2
200 × 130	278	240	200	65	85	50	38	200	200	30	75	M50 × 2
230	300	270	166	60	85	50	38	230	200	30	80	M50 × 2
280	350	320	166	60	85	50	38	280	200	30	80	M50 × 2
250 × 160	328	290	200	765	85	50	38	250	200	30	80	M50 × 2
300	378	340	200	65	85	50	38	300	200	30	80	M50 × 2
375	453	415	200	65	85	50	38	375	200	30	80	M50 × 2
400	480	435	250	65	85	50	38	400	200	30	80	M50 × 2



TWO PILLAR DIE SET WITH CIRCULAR WORKING AREA

All dimensions in mm

diam working surface D	a	b	C1	C2	C3	d	E1	L	M	r	h	Standard Threads
63	95	40	45	65	35	20	85	150	25	25	70	M 24 × 1.5
80	110	50	50	70	35	25	105	160	30	28	75	M 24 × 1.5
100	135	56	50	80	40	25	120	170	30	28	80	M 30 × 2
125	160	63	50	85	40	32	150	180	30	35	90	M 30 × 2
160	200	80	50	90	50	40	200	200	30	39	100	M 30 × 2
200	240	92	60	90	50	40	240	220	30	39	110	M 40 × 2
250	290	110	60	90	50	40	290	220	30	40	110	M 40 × 2

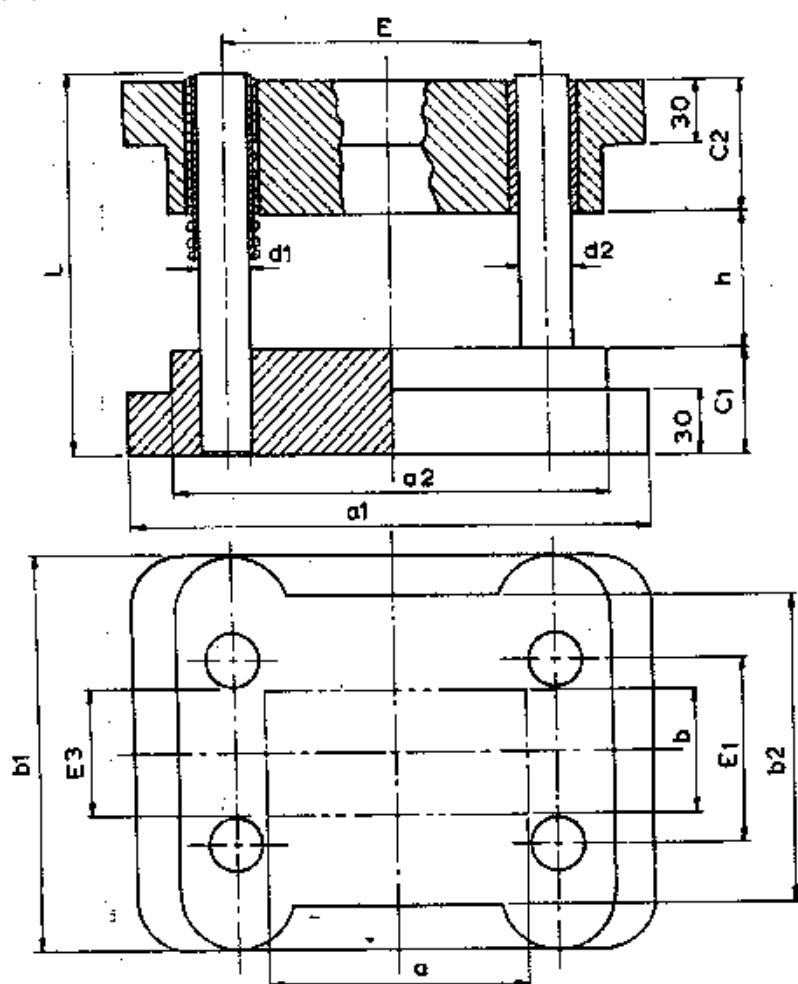


DIAGONAL PILLAR DIE SET WITH RECTANGULAR WORKING AREA

All dimensions in mm

Working surface a × b	A	B	C1	C2	d1	d2	E	E1	E2	L	M	h	Standard Threads
100 × 80	163	204	50	70	24	25	180	80.5	121.5	170	20	50	M 30 × 2
125	187	204	50	70	24	25	195	104.5	121.5	170	30	50	M 30 × 2
160	222	204	50	70	24	25	220	220	121.5	170	40	50	M 30 × 2
200	261	204	50	70	24	25	250	250	121.5	170	40	50	M 30 × 2
250	308	204	50	70	24	25	290	290	121.5	170	40	50	M 30 × 2
125 × 100	187	224	50	70	24	25	210	104	141.5	170	40	50	M 30 × 2
160	217	224	50	70	24	25	230	134.5	141.5	170	40	50	M 40 × 2
200	270	240	50	70	30	32	265	170.5	141	180	40	60	M 40 × 2
250	320	240	50	70	30	32	305	220.5	141	180	40	60	M 40 × 2
315	384	240	50	70	30	32	360	285	141	180	40	60	M 40 × 2
250 × 125	318	268	50	80	30	32	320	218.5	169	190	40	60	M 50 × 2
315	379	268	50	80	30	32	370	280	169	200	40	70	M 50 × 2
400	476	282	50	80	38	40	450	361	167	200	40	70	M 50 × 2
200 × 160	270	304	50	80	30	32	310	172.5	203	200	40	70	M 50 × 2
250	316	304	50	80	30	32	340	215.5	203	200	40	70	M 50 × 2
315	396	316	50	80	38	40	400	281	201	200	40	70	M 50 × 2
400	480	316	50	80	38	40	470	365	201	200	40	70	M 50 × 2
250 × 200	332	368	50	80	38	40	380	211	247	220	40	90	M 50 × 2
315	403	368	50	80	38	40	430	282	247	220	40	90	M 50 × 2
400	480	368	50	80	38	40	490	359	247	220	40	90	M 50 × 2
400 × 250	479	418	60	90	38	40	520	357.5	297	220	40	50	M 50 × 2
500	579	418	60	90	38	40	500	458	297	220	40	50	M 50 × 2
500 × 315	582	482	60	90	38	40	640	460.5	361	220	40	50	M 50 × 2

FOUR PILLAR DIE SET WITH RECTANGULAR WORKING AREA



All dimensions in mm

Working surface a & b	a1	a2	b1	b2	E	d1	d2	E1	E3	C1	C2	h	L	Standard Threads
125 × 63	250	210	190	150	155	24	25	90	61.5	50	65	65	180	M30 × 2
160 × 63	275	240	190	150	190	24	25	95	69.5	50	65	65	180	M30 × 2
200 × 100	340	300	240	200	230	24	25	130	104.5	50	65	85	200	M40 × 2
250 × 100	390	350	240	205	285	30	32	135	104	50	65	85	200	M40 × 2
315 × 160	450	440	340	290	350	30	32	200	169	50	65	85	200	M50 × 2
355 × 250	535	480	430	380	395	38	40	290	253	50	65	85	200	M50 × 2
400 × 250	545	495	430	380	445	38	40	290	253	50	65	85	200	M50 × 2

RECOMMENDED DIE PLATE THICKNESS
(for dies with cutting perimeter less than 50 mm)

Stock thickness, mm	0.25	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5
* Die plate thickness, mm/shear stress kg./mm ² of stock	1	2	3	4	4.5	5.25	5.75	6.3	6.7	7

- * If the die is located on a shoe, the thickness can be decreased upto 50%. Grinding allowance of 2.5 to 5 mm to be added to the thickness calculated. Minimum thickness of die plate shall be 10 mm.

DIE PLATE THICKNESS
(for dies with cutting perimeter greater than 50 mm)

Cutting perimeter, mm	over 50	75	150	300
	upto 75	150	300	500
factor by which the above tabulated values should be multiplied	1.25	1.5	1.75	2.0

MARGIN ON THE SIDES OF DIE OPENING

For small dies (1.5 to 2) Die thickness

for large dies (2 to 3) Die thickness

MINIMUM CRITICAL AREA vs IMPACT LOAD

Impact load, tonne	20	50	75	100
Critical area = margin x thickness of die, sq. mm.	315	625	1000	1250

RECOMMENDED SIZES OF SOCKET HEAD CAP SCREWS FOR FIXING THE DIE

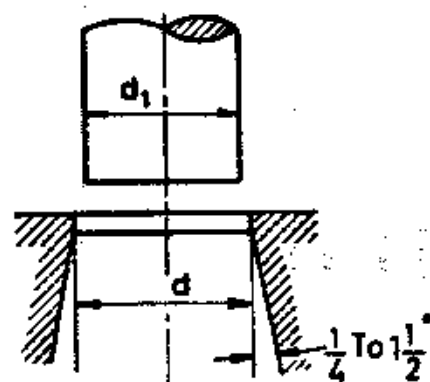
area of die block, mm ²	over upto	4500	4500 6300	6300
* Size of screws		M 10	M 10	M 12
No. of screws		2	3	4
Size of dowel, mm		10	10	12
No. of dowels		2	2	2

- * Counterbore depth for screws should be deeper by grinding allowance.

EFFECT OF PUNCH-TO-DIE CLEARANCE ON TOOL LIFE

Material	Stock thickness, mm	Rockwell Hardness	Initial clearance, mm		Increased clearance		Tool life increase with greater clearance, %
			Clearance per side % of t	Tool life per grind, holes	Clearance per side % of t	Tool life per grind, holes	
Low carbon Steel, Cold Rolled	0.5	C 22	2.5	115000	5.0	120000	100
	1.0		2.8	67000	12.5	204000	205
	1.25		5.0	10000	12.5	68000	580
	1.5	B 77	4.5	130000	12.5	400000	208
	1.8	B 32	5.0	100000	11.0	300000	200
Low carbon Steels, hot rolled	1.32	B 72	5.0	80000	12.5	240000	230
	3.15		5.0	100000	12.5	250000	150
	0.13	C 45	2.0	15000	42.0	125000	900
Stainless Steel	0.50		3.8	5000	12.5	136000	2600
	1.12	C 16	6.5	12000	11.0	30000	150
	1.6	B 89	5.0	175000	9.0	250000	60
High carbon Steel	1.5				15.0	100000	
	2.0	B 73	5.0		7.5	70000	
	3.0	C 9	2.5	30000	8.5	240000	700
Aluminium alloy	0.5		16 to 20	20000	16 to 20	70000	250
	1.06	Soft	5.0		12.5		
	1.32		5.0		8.5		50

Clearances for Punches and Dies

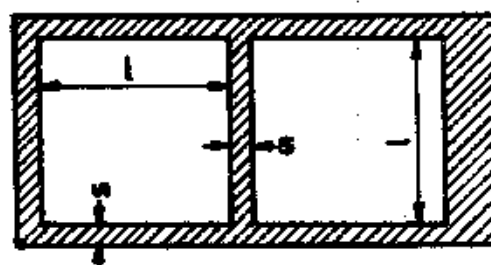


$$\text{Clearance} = d - d_1$$

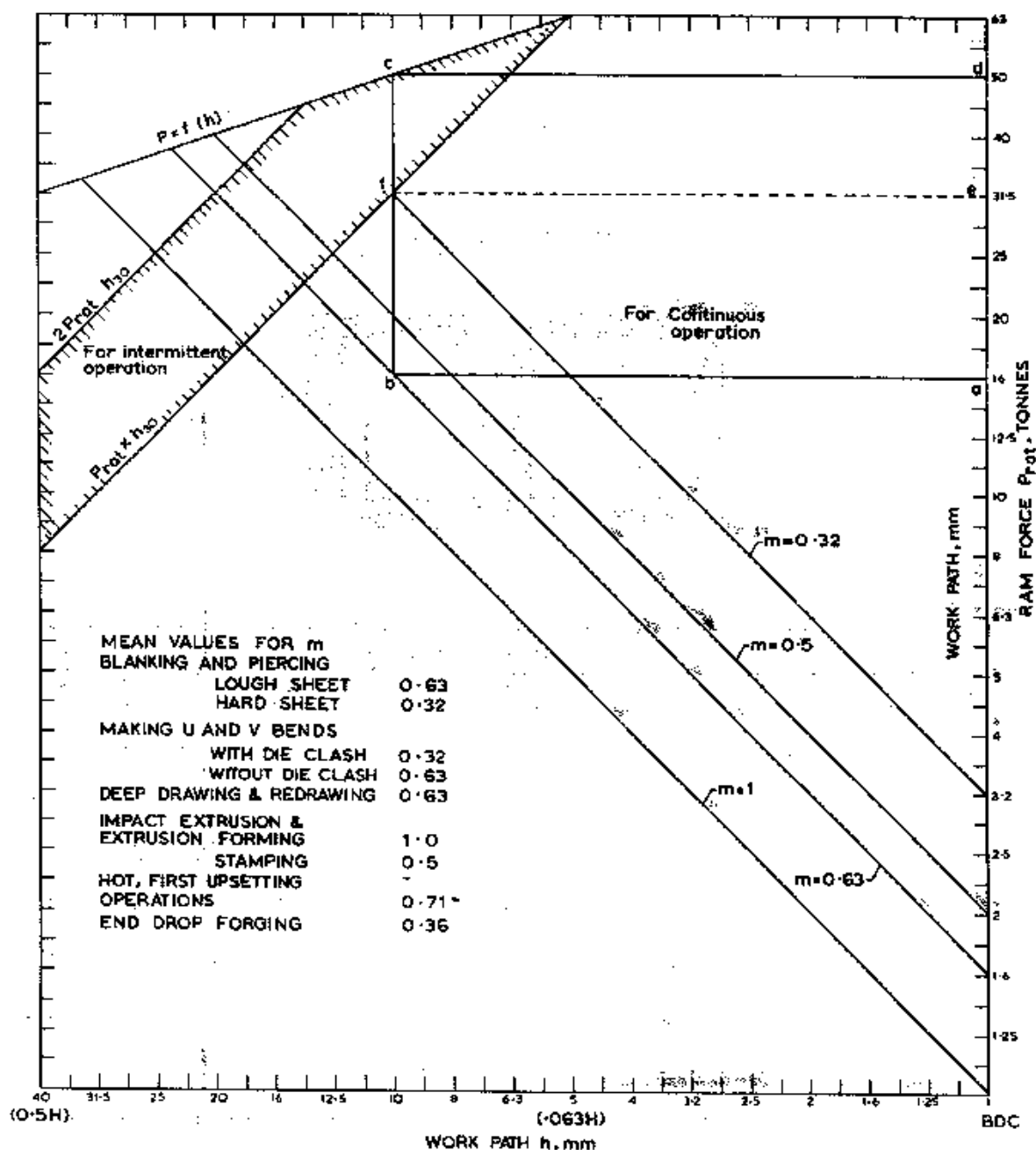
In blanking, the die governs the size of the cut. The punch dimensions are to be reduced by the amount determined by the clearance. In piercing, the punch governs the size of the cut. The die dimension should be increased by the required clearance.

Sheet thickness in mm	Clearance between Punch and die (mm)					
	mild steel	moderately hard Steel	hard steel	soft brass	hard brass	Aluminium
0.25	0.01	0.015	0.02	0.01	0.025	0.02
0.50	0.025	0.03	0.035	0.025	0.03	0.05
0.75	0.04	0.045	0.05	0.03	0.04	0.07
1.0	0.05	0.06	0.07	0.04	0.06	0.10
1.25	0.06	0.075	0.09	0.05	0.07	0.12
1.5	0.075	0.09	0.10	0.06	0.08	0.15
1.75	0.09	0.10	0.12	0.075	0.09	0.17
2.0	0.10	0.12	0.14	0.08	0.10	0.20
2.25	0.11	0.14	0.16	0.09	0.11	0.22
2.5	0.13	0.15	0.18	0.10	0.13	0.25
2.75	0.14	0.17	0.20	0.12	0.14	0.28
3.0	0.15	0.18	0.21	0.13	0.16	0.30
3.3	0.17	0.20	0.23	0.15	0.18	0.33
3.5	0.18	0.21	0.25	0.16	0.19	0.35
3.8	0.19	0.23	0.27	0.19	0.22	0.38
4.0	0.20	0.24	0.28	0.21	0.24	0.40
4.3	0.22	0.26	0.30	0.23	0.27	0.43
4.5	0.23	0.27	0.32	0.26	0.30	0.45
4.8	0.24	0.29	0.34	0.29	0.33	0.48
5.0	0.25	0.30	0.36	0.33	0.36	0.50

LAYING OUT PRACTICE

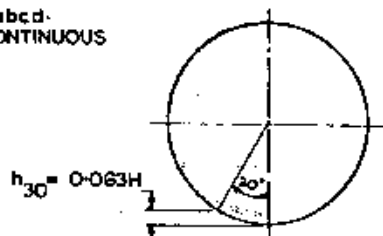


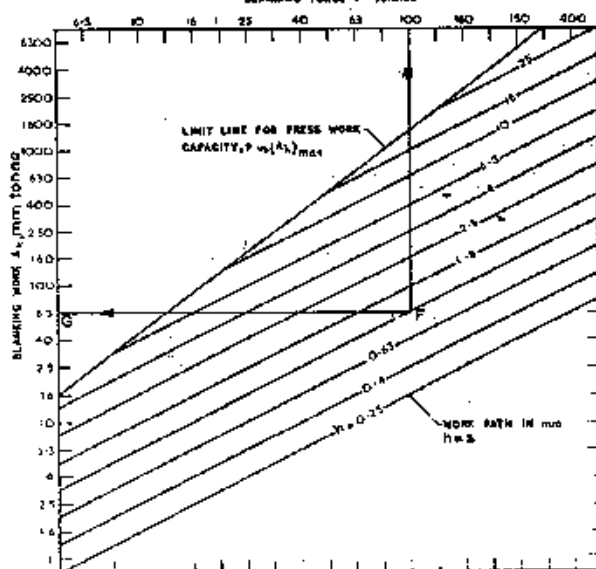
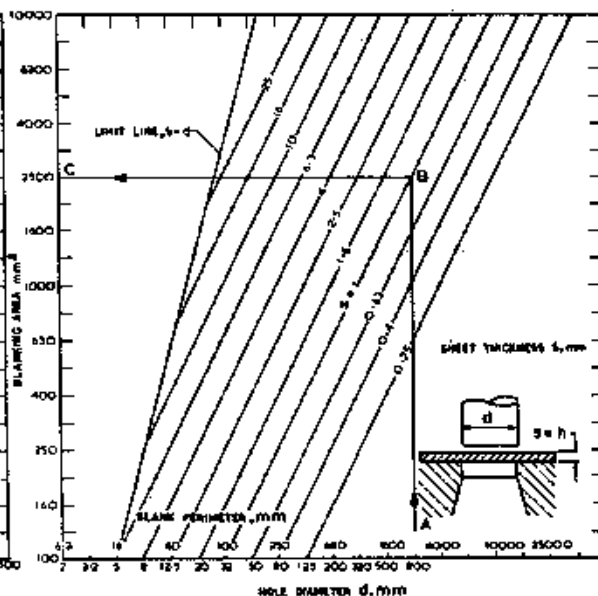
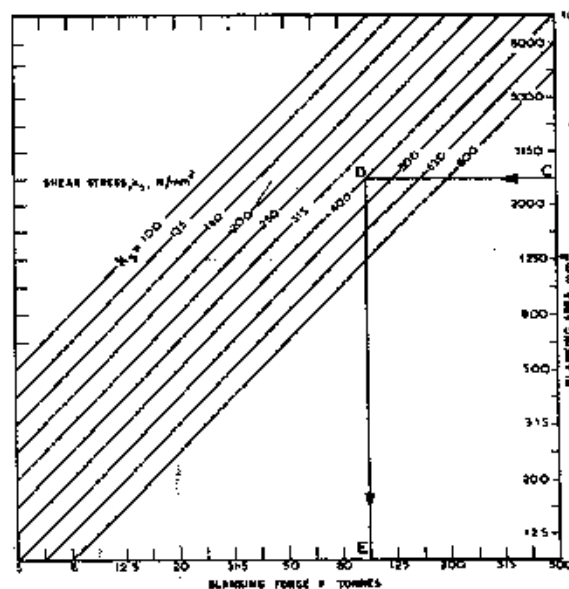
Web length (l) in mm	Thickness of sheet in mm											
	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5	3	3.5	4
	margin, s, mm											
10	1.5	1.2	1	1.4	1.5	1.8	2	2	2	2	2.5	2.5
50	2	1.7	1.75	1.9	2	2.2	2.5	2.8	3	3.5	3.7	4
100	3	2.4	2	2.4	2.5	2.7	3	3.2	3.5	4	4.2	4.5
150	3.5	2.9	2.5	2.9	3	3.2	3.5	3.7	4	4.5	4.7	5
250	4	3.4	3	3.4	3.5	3.7	4	4.2	4.5	5	5.2	5.5
350	4.5	3.9	3.5	3.9	4	4.2	4.5	4.7	5	5.5	5.7	6



Example:

FOR $h=16\text{mm}$, $m=0.63$ AND INTERMITTENT
OPERATION. $P=50\text{TONNES}$. $abcd$.
FOR $P=31.5$, $m=0.63$ AND CONTINUOUS
OPERATION $h=16\text{mm}$, $efba$.





$m = 0.63$ for blanking
A-B-C-D-E, Force
E-F-G, Work

Example: BLANK DIA = 800mm,
Sheet thickness = 1mm,
Shear stress, $k_s = 400\text{N/mm}^2$,
Blanking force = 100 tonnes,
Work = 63mm, tonne

CALCULATION CHART FOR BLANKING
(No shear on punch)

APPROXIMATE PENETRATION OF SHEET THICKNESS BEFORE FRACTURE IN BLANKING

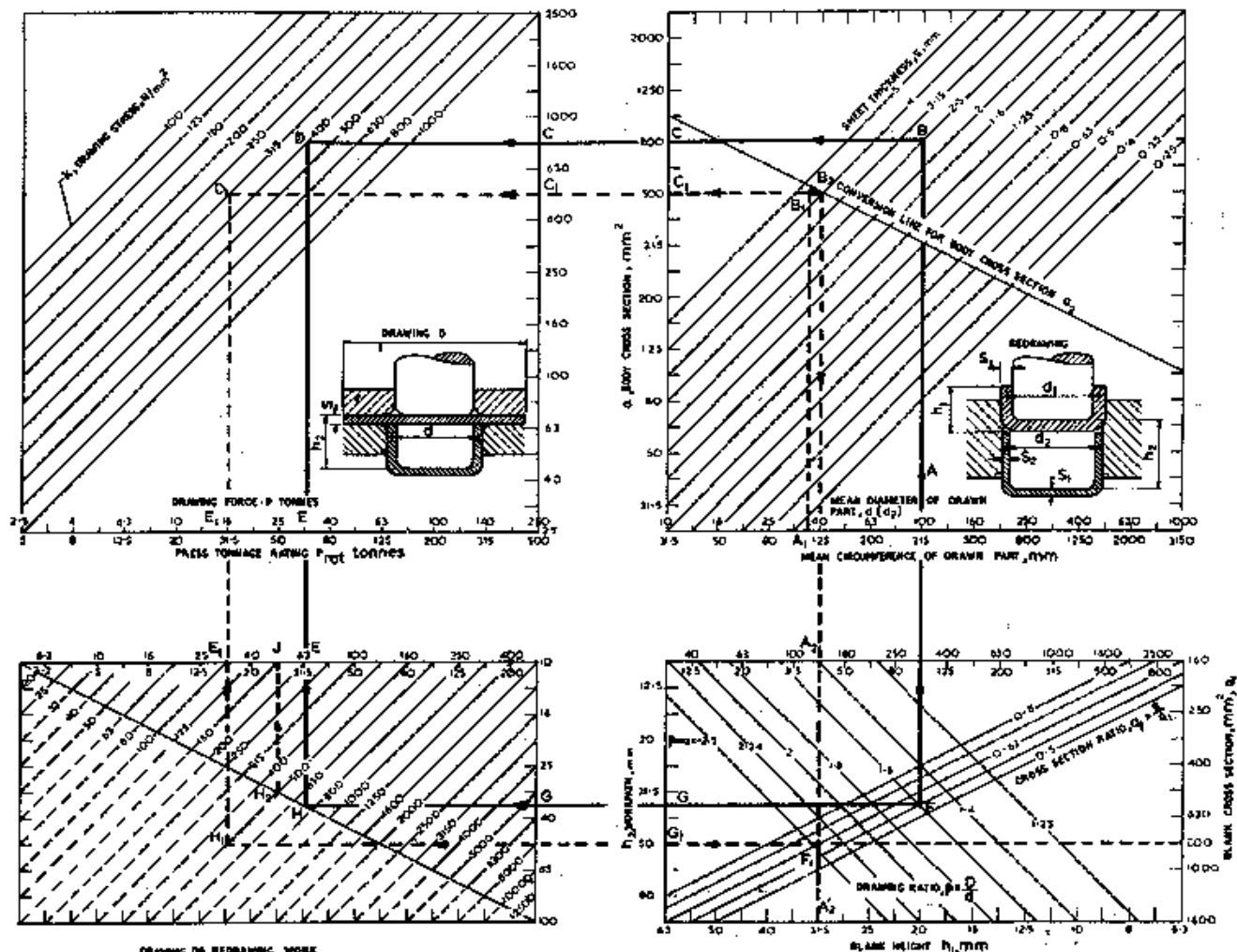
Work Metal	Penetration %	Work Metal	Penetration %
CARBON STEELS: *		NON-FERROUS METAL	
0.10% C Ann	50	Aluminium alloys	60
0.10% C CR	38	Brass	50
0.20% C Ann	40	Bronze	25
0.20% C CR	28	Copper	55
0.30% C Ann	33	Nickel Alloys	55
0.30% C CR	22	Zinc Alloys	50

*Ann = annealed

CR = cold rolled

RECOMMENDED TRIMMING ALLOWANCES

	Blank thickness mm	Allowance per side, mm, for Steel with Rockwell B hardness of		
		50—66	75—90	90—106
First Trim	1.20	0.063	0.075	0.106
	1.60	0.075	0.106	0.125
	or			
	2.00	0.090	0.125	0.15—0.180
	single trim			
	2.36	0.106	0.150	0.18—0.224
	2.80	0.125	0.180	0.224—0.230
	3.15	0.18	0.224	0.3—0.355
Second trim	1.2	0.03	0.035	0.05
	1.60	0.035	0.050	0.063
	2.00	0.045	0.063	0.075—0.09
	or			
	2.36	0.050	0.075	0.09—0.100
(Add to first trim)	2.80	0.063	0.090	0.1—0.14
	3.15	0.09	0.100	0.15—0.18



Example 1 $d = 100\text{mm}$, $S = 2.5\text{mm}$, $k = 400\text{N/mm}^2$.

$B = 1.6$, $m = 0.63$.

Drawing Force = 31.5 tonnes, Press rating = 63 tonnes.

Drawing work = 710 mm tonnes.

A-B-C-D-E
A-F-G

FORCE AND WORK REQUIREMENTS FOR DEEP DRAWING

Example 2 Redrawing: $d_2 = 35.5\text{mm}$, $S_2 = 4.5\text{mm}$, $k = 315\text{N/mm}^2$.

$S_1 = 6.7\text{mm}$, $h_1 = 31.5\text{mm}$, $h_2 = h_1/4$.

Redrawing Force = 16 tonnes.

Redrawing work = 500 mm tonnes.

Press rating = 50 tonnes.

A₁-B₁-C₁-D₁-E₁
B₁-B₂-A₂-F₁-G₁

DRAWING SPEEDS

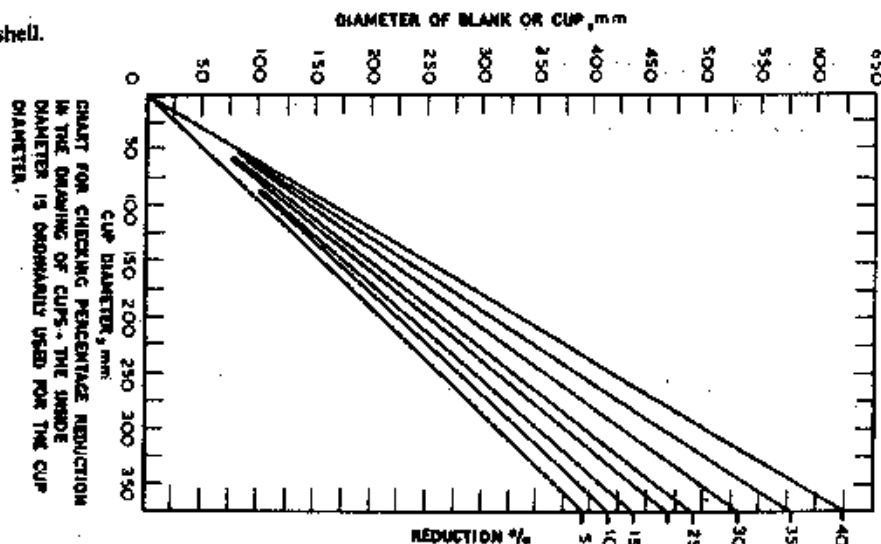
Material	Drawing speed (m/min)	
	Single action	Double action
Aluminium	55	30
Strong Aluminium Alloys	—	10—15
Brass	65	30
Copper	45	25
Steel	18	10—16
Steel in carbide dies	—	20
Stainless steel	—	7—10
Zinc	45	13

Draw radii		Blank holder force in drawing	
Thickness of stock, mm	Drawing Radius, mm	Thickness of stock, mm	Force, kgf per mm
0.4	1.6	0.25	32
0.8	3.2	0.4	31
1.25	4.8	0.5	30
1.6	6.3	0.63	28.5
2	10	0.80	27.5
2.5	11.2	0.9	26.5
3.15	14	1.00	25.5
		1.12	24
		1.25	23
		1.4	22.5
		1.6	21.5
		1.8	20
		2.0	18.5
		2.24	17
		2.5 and over	16

MAXIMUM DEPTH TO DIAMETER (h/d) RATIOS IN DEEP DRAWING WITH C 10 STEEL

At the end of	Ratio, $\frac{1}{D}$, in per cent					
	2 to 1.5	1.5 to 1	1 to 0.6	0.6 to 0.3	0.3 to 0.15	0.15 to 0.08
	Maximum $\frac{h}{d}$ ratio					
1st draw	0.94 — 0.77	0.84 — 0.65	0.70 — 0.57	0.62 — 0.50	0.52 — 0.42	0.46 — 0.38
2nd "	1.88 — 1.54	1.6 — 1.32	1.36 — 1.1	1.13 — 0.94	0.96 — 0.83	0.9 — 0.7
3rd "	3.5 — 2.7	2.8 — 2.2	2.3 — 1.8	1.9 — 1.5	1.6 — 1.3	1.3 — 1.1
4th "	5.6 — 4.3	4.3 — 3.5	3.6 — 2.9	2.9 — 2.4	2.4 — 2.0	2 — 1.5
5th "	8.9 — 6.6	6.6 — 5.1	5.2 — 4.1	4.1 — 3.3	3.3 — 2.7	2.7 — 2

1. Larger $\frac{h}{d}$ ratios, in each range, are for draw die radii of 4t to 8t
2. Smaller " " " " of 8t to 16t
3. Draw die radius increases as $\frac{t}{D}$ ratio decreases.
4. t, stock thickness; D, blank diam; d, shell diam; h, height of shell.



DEEP DRAWING OF RECTANGULAR BOXES WITHOUT FLANGES LOW CARBON SHEET STEEL RECOMMENDED

PUNCH		Stock thickness, t											
		20 gauge				12 gauge				3 gauge			
NOSE		Reduction in drawing %											
RADIUS		20	30	40	50	20	30	40	50	20	30	40	50
81	CD				HD	HD				HC	HD		
160	"	CD	CD		"	HD, CD				"	"	HD	
320	"	"	"	"	"				CD	"	HC	HC	HD
81	CD				HD	CD				HD			
160	"	CD			"	HD	CD			HC	HD	HD	
320	"	"	CD		"	HD, CD	CD				HC	"	HD

CD, Cold rolled drawing quality; CC, Cold rolled commercial quality

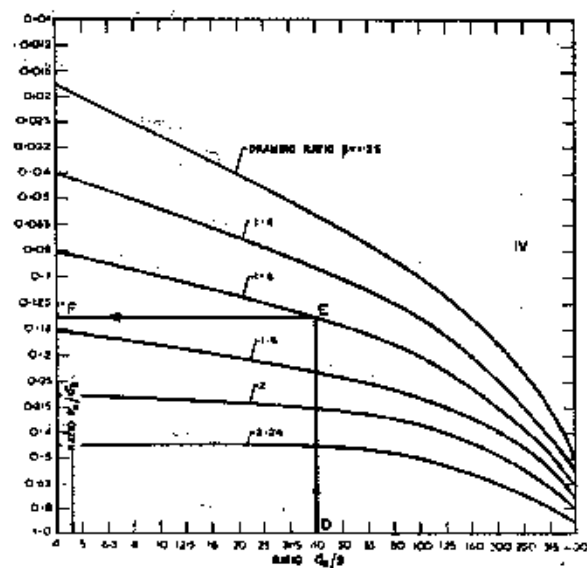
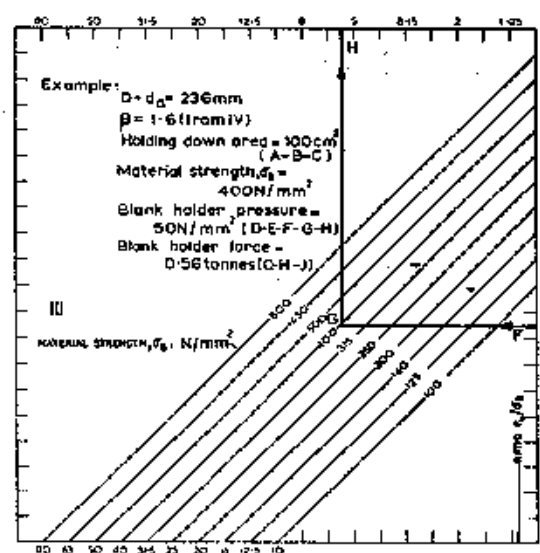
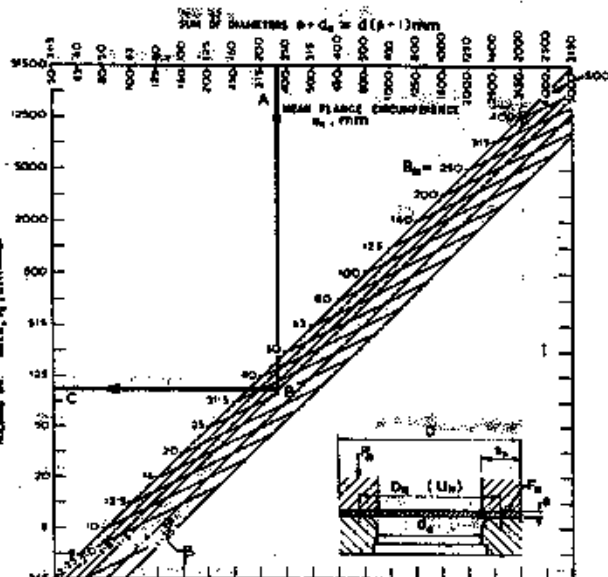
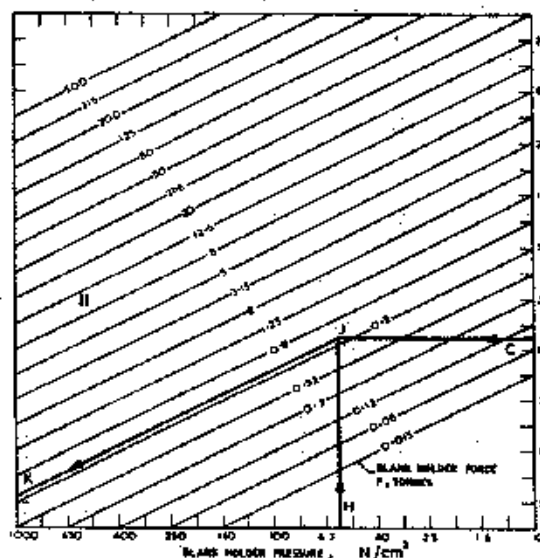
HD, Hot rolled drawing quality; HC, Hot rolled commercial quality.

DRAWING OF CYLINDRICAL CUPS: LOW CARBON SHEET STEEL RECOMMENDED

Condition	Punch Nose Radius	STOCK THICKNESS, t.											
		20 Gauge, 0.914 mm				12 Gauge, 2.642, mm				3 Gauge, 6.4 mm			
		Reduction in drawing, %											
		20	30	40	50	20	30	40	50	20	30	40	50
	2t	CD											
No flange,	4t	"	CD	CD		HD	HD,CC	HD,CD		HC	HC	HD	
No ironing	8t	CC	CC	CD	CD	HC	HC	HD,CC	HD,CD	"	"	"	DH
	16t	"	"	CC	"	"	"	HC	HD,CC	"	"	HC	"
	32t	"	"	"	"	"	"	"	HC,CC	"	"	"	"
	2t	CD											
No flange,	4t	"	CD			HD	HD	HD,CD		HD	HD		
Ironing	8t	"	"	CD		HC	HC	HD	HD,CD	HC	HD	HD	
	16t	"	"	"	CD	CC	HC	"	HD	"	HC	"	HD
	32t	"	"	"	"	HC	"	HC	"	"	"	HC	"
With flange,	2t												
No ironing	4t	CD	CD	CD		CD	CD	CD		HD	HD		
	8t	"	"	"	CD	HD	"	"	CD	"	"	HD	HD
	16t	CC	CC	"	"	HC	HC,CC	HD,CD	"	"	"	"	"
	32t	"	"	CC	"	"	HC	HD,CC	CC	HC	"	"	"
With flange,	2t												
Ironing	4t	CD	CD			CD	CD	CD		HD			
	8t	"	"			HD	"	"		"	HD		
	16t	"	"	CD	CD	"	HD,CD	HD,CD	CD	"	"	HD	HD
	32t	CC	CC	"	"	"	HD	HD	HD,CD	"	"	"	"
CD, Cold Rolled drawing quality;		CC, cold rolled commercial quality				HD, hot Rolled drawing quality; HC, Hot rolled commercial quality.							

CD, Cold Rolled drawing quality; CC, cold rolled commercial quality

HD, hot Rolled drawing quality; HC, Hot rolled commercial quality.



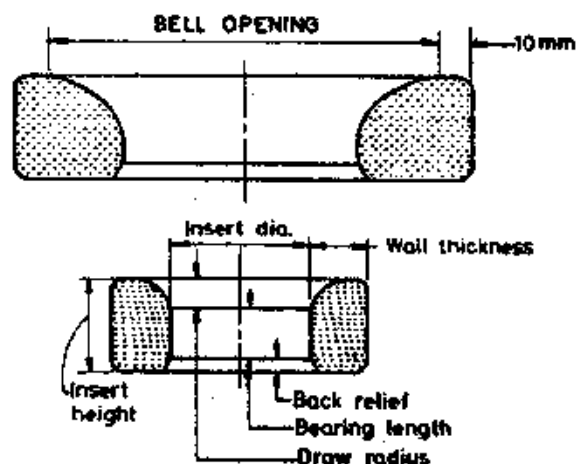
DETERMINATION OF BLANK HOLDER FORCE FOR DEEP DRAWING

CLEARANCE IN DRAW DIES

Blank thickness t , mm	First draw	Redraws	Sizing draw
upto 0.4	$1.07t - 1.09t$	$1.08t - 1.1t$	$1.04t - 1.05t$
0.4 - 1.25	$1.08t - 1.1t$	$1.09t - 1.12t$	$1.05t - 1.06t$
1.25 - 3.15	$1.1t - 1.12t$	$1.12t - 1.14t$	$1.07t - 1.09t$
Above 3.15	$1.12t - 1.14t$	$1.15t - 1.2t$	$1.08t - 1.1t$

Dimension of carbide Draw-die inserts

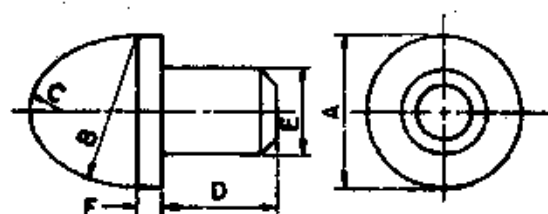
Inside dia, mm		Length of bearing, mm	Back relief mm
From	to		
	12.5	3.15	1.6
12.5	25	4.75	3.15
25	31.5	6.3	
31.5	50	8	4.75
50	up	9.5	



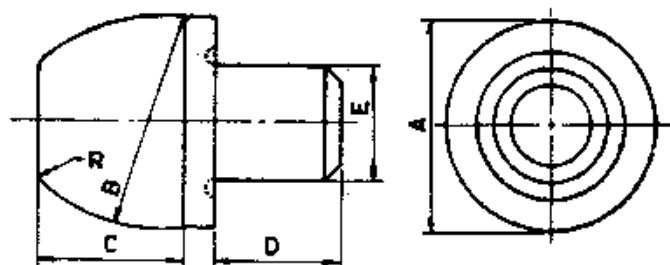
CARBIDE DRAW-DIE INSERTS

Dimensions for pilots

Nominal A mm	B mm	C mm	D mm	E mm
Acorn Type				
3.15	3.15	0.8	6.3	2.5
4.75	4.75	1.18	6.3	3.15
6.3	6.3	1.6	11.2	4.75
8	8	2	11.2	5.6
9.5	9.5	2.5	12.5	6.3
11.2	11.2	3.15	12.5	7.1
12.5	12.5	4	12.5	8
16	16	4.25	16	9
18	18	4.75	16	9.5
Flattened Point Type				
19	19	11.2	16	9.5
22.4	22.4	14	19	11.2
25	25	16	19	12.5
31.5	31.5	19	25	16
35.5	35.5	22.4	25	18
37.5	37.5	25	31.5	19



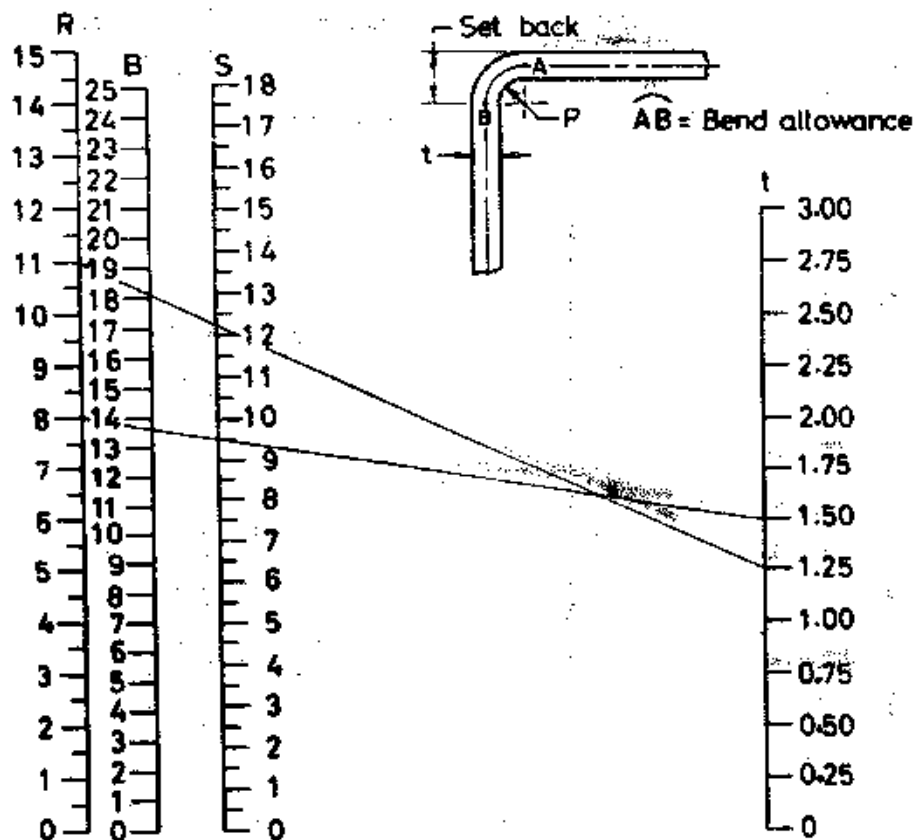
Acorn Type



Flattened-point Type

$F = 1.6$ mm or thickness of stock whichever is greater.

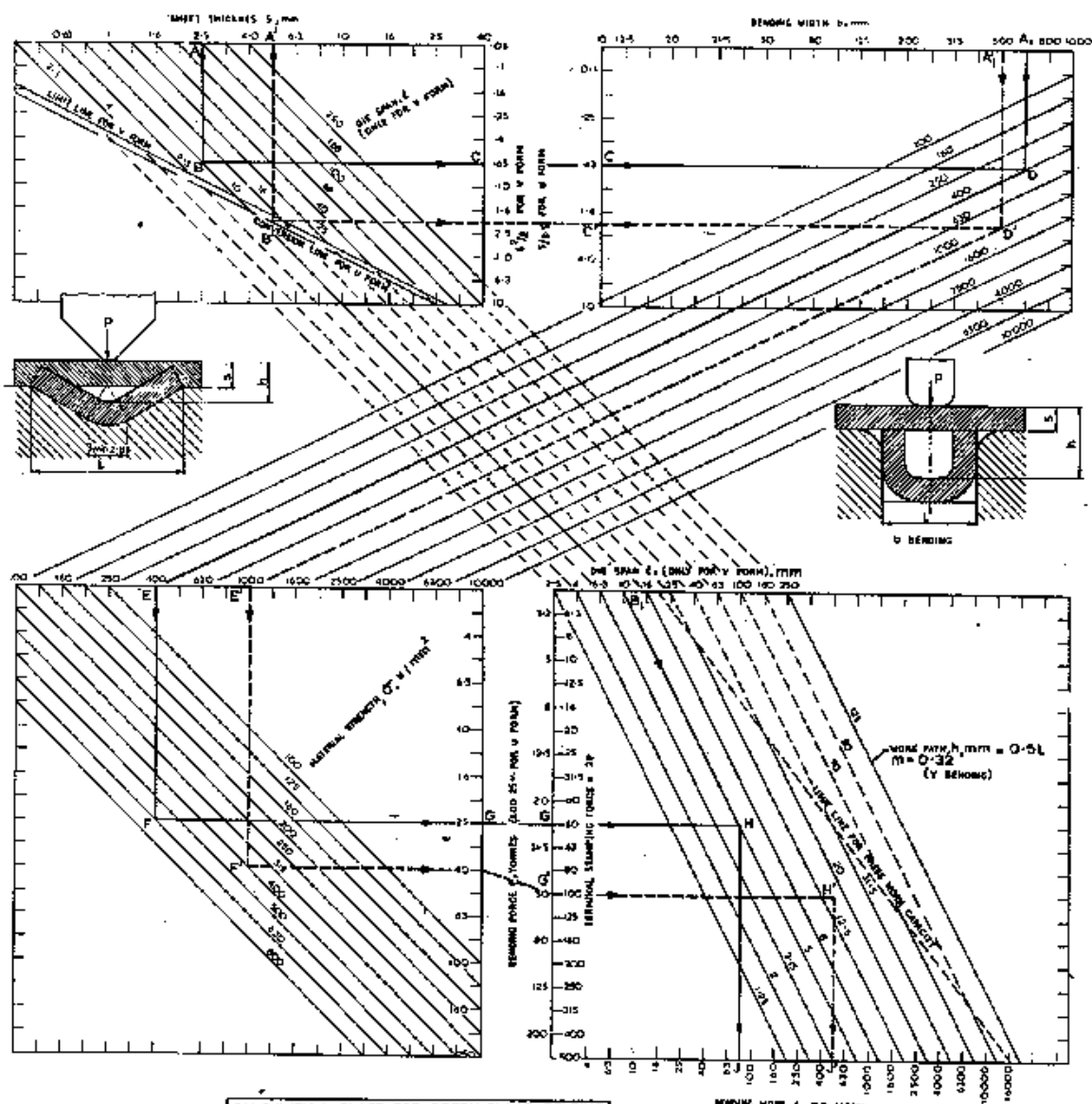
NOMOGRAM FOR BEND ALLOWANCE AND SET BACK FOR 90° BENDS



R = Radius of bend, mm t = Thickness, mm B = Bend allowance, mm
S = Set back, mm

RECOMMENDED REDUCTIONS IN DIAMETERS FOR DRAWING

Material	First draw %	Redraws %
Aluminium, Soft	40	20—25
Aluminium, deep drawing quality	40—50	20—30
Brass	45	20—25
Copper	40	15—20
Steel	35—40	15—20
Steel, deep drawing quality	40—45	15—20
Steel, Stainless	35—40	15—20
Zinc	50	15—20
Tin plate	35—45	10—15



CALCULATION CHART FOR RECTANGULAR BENDING

EXAMPLE 1: V BENDING

$S = 2.5 \text{ mm}$; $L = 10 \text{ mm}$; $b = 630 \text{ mm}$; $\sigma = 830 \text{ N/mm}^2$; $m = 0.51$; $m = 0.32$;
 $P = 28 \text{ tonnes}$; $A = 80 \text{ mm tonnes}$
 $A-B-C-A'$ $D-E-F-G-H-J$

EXAMPLE 2: U BENDING

$S = 5 \text{ mm}$; $b = 500 \text{ mm}$; $\sigma = 400 \text{ N/mm}^2$; $h = 16 \text{ mm}$; $m = 0.83$;
 $P = 50 \text{ tonnes}$; $A = 500 \text{ mm tonnes}$
 $A-B-C-A'$ $D-E-F-G-H-J$

BEND ALLOWANCE FOR 90° BENDS FOR ALUMINIUM ALLOYS

Metal thickness mm	Bend allowance, mm for bends with inside radius of			
	0.75mm	1.5mm	2.25mm	3.0mm
0.85	1.45	1.7	2.1	2.4
1.25	2.0	2.3	2.7	3.0
1.50	2.4	2.7	3.0	3.4
2.00	2.9	3.3	3.6	4.0
3.00	3.3	3.6	4.0	4.3
3.15	4.5	4.8	5.1	5.5
4.75	6.5	5.5	7.2	7.5
6.30	8.5	8.9	9.3	9.6

COMPARATIVE ALLOWABLE IRONING DURING DRAWING

Steel		Permissible reduction in wall thickness, %
C8 —	Drawing quality, special killed	12
	Drawing quality	8
	Commercial quality	7
C20 —	Drawing quality special killed, electric furnace	10
	Drawing quality, annealed	8
	Commercial quality, annealed	6
C30	Special killed, electric furnace annealed	8
	Commercial quality	5

**BENDING LIMIT FOR HOT ROLLED, COMMERCIAL QUALITY CARBON
STEEL STRIP AND COLD OR HOT ROLLED CARBON STEEL SHEET***

Carbon %	Bending Limit
0.15 or less	180° bend flat on itself in any direction
0.15 to 0.25	180° bend around one thickness of the material, in any direction.

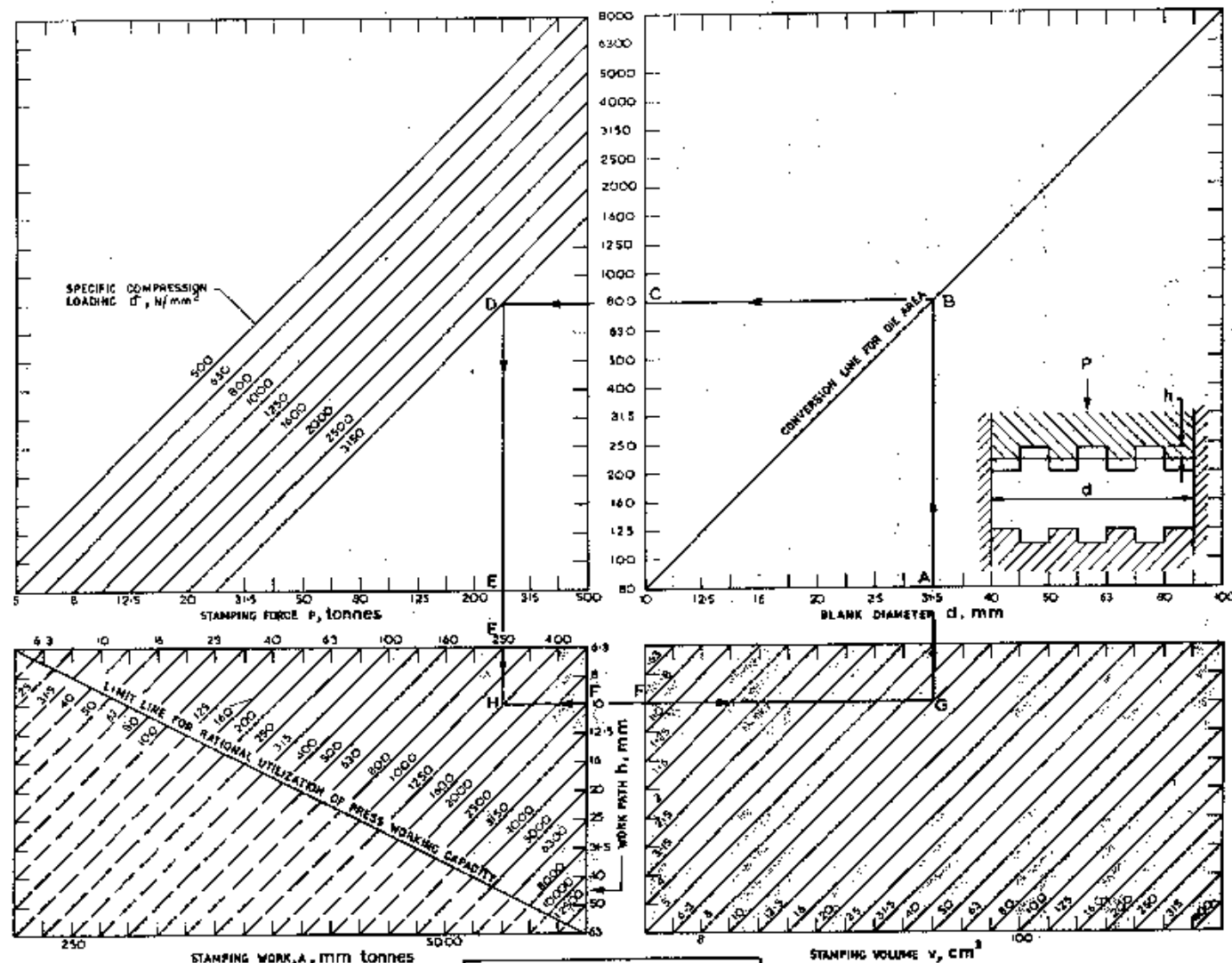
* If greater ductility is needed, drawing quality steel can be selected.

MINIMUM BEND RADII FOR LOW CARBON STEEL SHEETS

Condition	Quality or temper	Minimum bend, radius, mm	
		Parallel to rolling direction	Across rolling direction
Cold rolled	Commercial	0.25	0.25
	Drawing, rimmed	0.25	0.25
	Drawing, killed	0.25	0.25
	Enameling	0.25	0.25
Cold rolled special properties	Quarter hard(a)	1 t	1/2 t
	Half hard(b)	NR	1/t
	Full Hard(c)	NR	NR
Hot rolled	Commercial		
	upto 2.24 mm	3/4 t	1/2 t
	over 2.24 mm	1 1/2 t	1 t
	Drawing		
	upto 2.24 mm	1/2 t	1/4 t
	over 2.24 mm	3/4 t	1/2 t

t — sheet thickness; NR — not recommended.

a — Rockwell B 60 to 75; b — Rockwell B 70 to 85; c — Rockwell B 84 min



STAMPING AND COINING FORCE

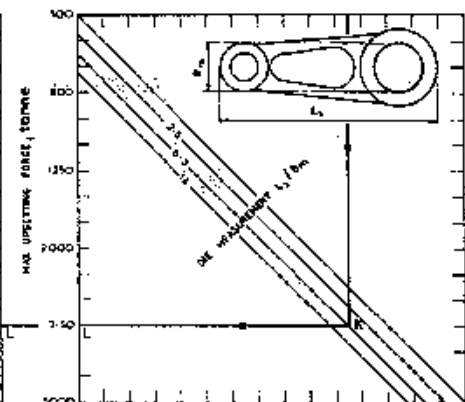
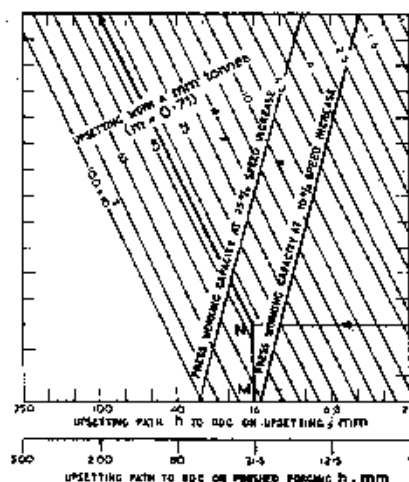
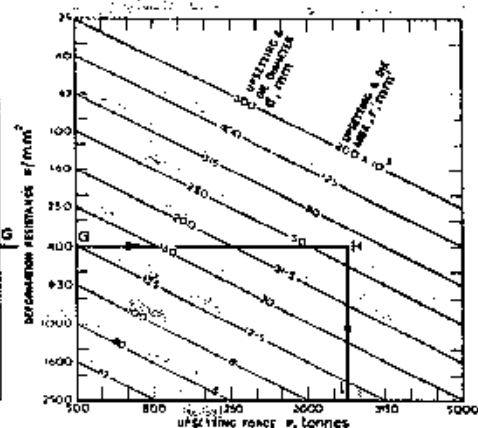
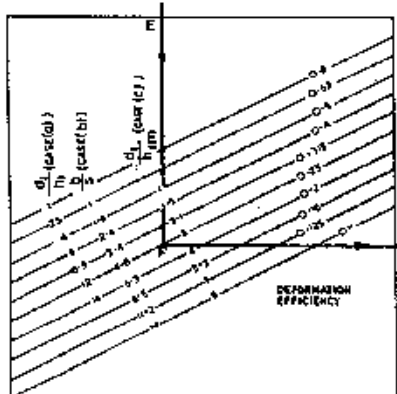
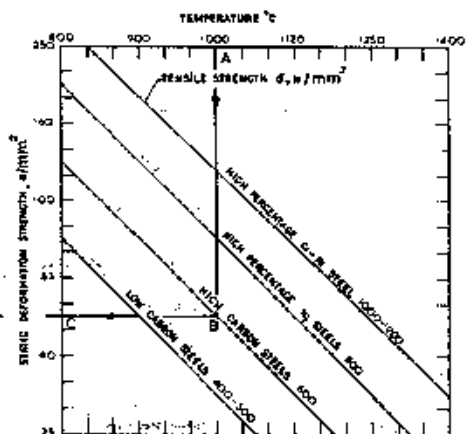
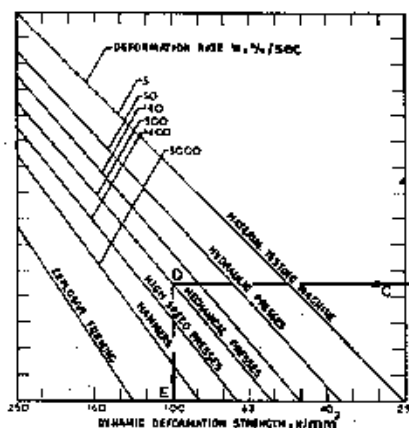
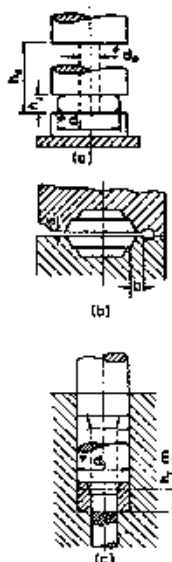


CHART FOR CALCULATING HOT UPSETTING & DROP FORGING

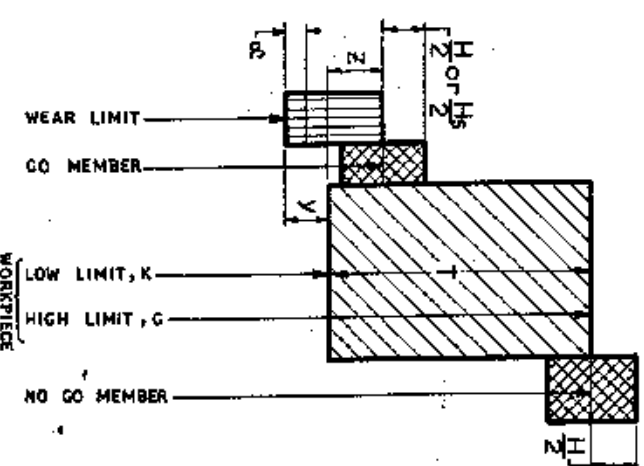
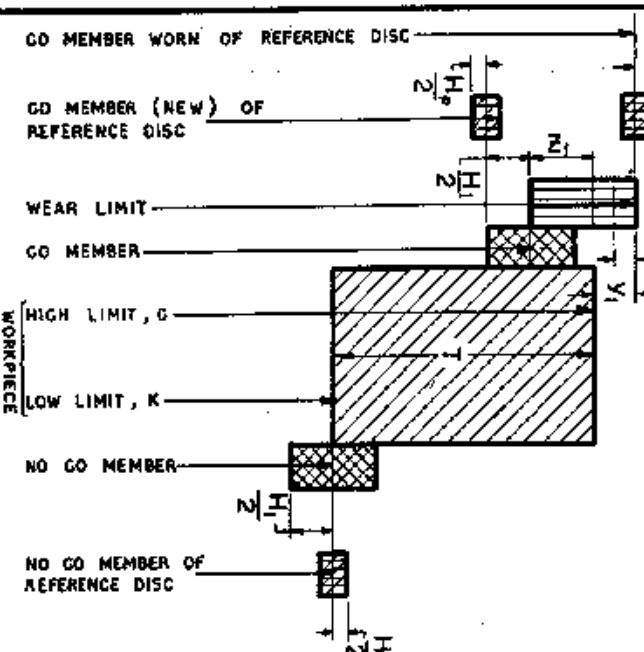
Example:

$T = 1000^{\circ}\text{C}$, Tensile strength of work material $\sigma = 600\text{N/mm}^2$, deformation rate $w = 500\%/ \text{sec}$, $\frac{L}{d} = 4.8$, $\frac{L}{d} = 6.3$, Upsetting die = 280mm, upsetting path $h = 16\text{mm}$.
 Static deformation strength = 50N/mm^2 (A-B-C), Dynamic deformation strength = 100N/mm^2 (C-D-E).
 Deformation resistance = 400N/mm^2 (E-F-G), Upsetting force = 2500 tonnes (G-H-I),
 Max. upsetting force = 3150 tonnes (I-K-L), Work done = $35.8 \times 10^3\text{mm tonnes}$ (M-L-N).

LUBRICANTS COMMONLY USED IN PRESS FORMING

Material	Lubricant
Low carbon sheet steel	1. Water base lubricants a) Water emulsion of 5 — 20% general purpose soluble oil or wax-for low severity operation. b) Soap fat paste, diluted with water for high severity operation. 2. Oil base lubricants a) Mineral oil plus 10 — 30% fatty oil b) Fatty oil for high severity
Stainless Steel	1. Fatty oils and blends 2. Chlorinated oils or waxes
Heat Resisting steels	1. Unpigmented mineral oils and greases — for low severity. 2. Mixture of graphite and oil 3. Sulphur free chlorinated oils or waxes — for high severity.
Aluminium Alloys	1. Mineral oil plus 10% fatty oil and 10 — 15 % sulfurized fatty oil most effective. 2. Fat emulsions in aqueous soap solutions — plus finely divided fillers like chalk, lead, clay etc. — next best alternative.
Copper Alloys	1. Water base lubricants a) Dry soap, Pigmented soap plus fat pastes. 2. Oil base lubricants. a) Stabilized chlorinated oils (30 — 50% combined chlorine, diluted with 20% mineral oil)
Magnesium Alloys	Graphite is the most popular lubricant

LIMIT GAUGES - 14

GAUGES FOR HOLES		GAUGES FOR SHAFTS	
			
FOR ALL NOMINAL SIZES, up to 500mm			
WEAR LIMIT = $K - Y$ for sizes < 180 $= K - Y + \infty$ for sizes > 180		WEAR LIMIT = $G + Y_1$ for sizes < 180 $= G + Y_1 - \infty$ for sizes > 180	
MANUFACTURING TOLERANCE		PERMISSIBLE WEAR FOR LIMIT GAUGE	
REFERENCE GAUGE		HOLES	
LIMIT GAUGE		SHAFTS	
For values refer tables 1, 2 and 3		TOLERANCE ON WORKPIECE, T	

FORMULAE FOR GAUGE DIMENSIONS

Table 1.

GAUGES for	GAUGE size	Nominal size								Nomenclature	
		upto 180 mm				over 180 mm					
		gauges		reference gauge		gauge		reference gauge			
		basic size	mfg tol	basic size	mfg tol	basic size	mfg tol	basic size	mfg tol		
Inside measure- ments	NO GO	G	$\pm \frac{H}{2}$ or $\pm \frac{H_g}{2}$			$G - \alpha$	$\pm \frac{H_g}{2}$ or $\pm \frac{H}{2}$			G,	high limit of workpiece.
										H,	tolerance on cylindrical, plug or cyl. bar gauges,
										H _g ,	tolerance on spherical gauges,
										Z,	distance between centre of tolerance zone of new GO guages for holes and GO workpiece limit.
	GO(new)	K + Z	$\pm \frac{H}{2}$	—		K + Z	$\pm \frac{H}{2}$ or $\pm \frac{H_g}{2}$	—		K,	low limit of workpiece
										y,	margin, outside of the GO work- piece limit, of the wear limit of gauges of holes
	wear limit	K — y	—			K — y + α	—			α ,	safety zone provided for compensating measuring uncertainties of gauges
Outside measure- ments										y _s ,	margin, as of y for shafts instead of holes.
										Z ₁ ,	as of Z above, for shafts instead of holes
										H ₁ ,	tolerance on gauges for shafts
										H _p ,	tolerance on reference discs for gap gauges
	Wear limit	G + y ₁	—	G + y ₁	$\pm \frac{H_p}{2}$	G + y ₁ — α_1	—	G + y ₁ — α	$\pm \frac{H_p}{2}$	α_{11} ,	as of α above, for shafts instead of holes.
	GO (new)	G — Z ₁	$\pm \frac{H_1}{2}$	G — Z ₁	$\pm \frac{H_g}{2}$	G — Z ₁	$\pm \frac{H_1}{2}$	G — Z ₁	$\pm \frac{H_p}{2}$	T,	workpiece tolerance = G — K
	NO GO	K	$\pm \frac{H_1}{2}$	K	$\pm \frac{H_p}{2}$	K + α_1	$\pm \frac{H_1}{2}$	K + α_1	$\pm \frac{H_p}{2}$	for T, H, H _g , y, Z, α refer table 2	

GAUGE TOLERANCES FOR CHECKING HOLES

All dimensions in microns

Table 2

Nominal size, mm		Symbol	WORK TOLERANCE GRADES						
Over	upto & includ		6	7	8	9	10	11	12
—	3	T	6	10	14	25	40	60	100
		H/2	0.6	1	1	1	1	2	2
		y	1	1.5	3	0	0	0	0
		Z	1	1.5	2	5	5	10	10
3	6	T	9	12	18	30	48	75	120
		H/2	0.75	1.25	1.25	1.25	1.25	2.5	2.5
		y	1	1.5	3	0	0	0	0
		Z	1.5	2	3	6	6	12	12
6	10	T	9	15	22	36	58	90	150
		H/2	0.75	1.25	1.25	1.25	1.25	3	3
		H _g /2	0.75	0.75	0.75	0.75	0.75	2	2
		y	1	1.5	3	0	0	0	0
10	18	Z	1.5	2	3	7	7	14	14
		T	11	18	27	43	70	110	180
		H/2	1	1.5	1.5	1.5	1.5	4	4
		H _g /2	1	1	1	1	1	2.5	2.5
18	30	y	1.5	2	4	0	0	0	0
		Z	2	2.5	4	8	8	16	16
		T	13	21	33	52	84	130	210
		H/2	1.25	2	2	2	2	4.5	4.5
30	50	H _g /2	1.25	1.25	1.25	1.25	1.25	3	3
		y	1.5	3	4	0	0	0	0
		Z	2	3	5	9	9	19	19
		T	16	25	39	62	100	160	250
50	80	H/2	1.25	2	2	2	2	5.5	5.5
		H _g /2	1.25	1.25	1.25	1.25	1.25	3.5	3.5
		y	2	3	5	0	0	0	0
		Z	2.5	3.5	6	11	11	22	22
80	120	T	19	30	46	74	120	190	300
		H/2	1.5	2.5	2.5	2.5	2.5	6.5	6.5
		H _g /2	1.5	1.5	1.5	1.5	1.5	4	4
		y	2	3	5	0	0	0	0
120	180	Z	2.5	4	7	13	13	25	25
		T	22	35	54	87	140	220	350
		H/2	2	3	3	3	3	7.5	7.5
		H _g /2	2	2	2	2	2	5	5
180	250	y	3	4	6	0	0	0	0
		Z	3	5	8	15	15	28	28
		T	25	40	63	100	160	250	400
		H/2	2.5	4	4	4	4	9	9
250	350	H _g /2	2.5	2.5	2.5	2.5	2.5	6	6
		y	3	4	6	0	0	0	0
		Z	4	6	9	18	18	32	32
		T	32	50	75	125	200	320	500
		H/2	3	5	5	5	5	10	10
		H _g /2	3	3	3	3	3	7	7
		y	4	6	10	0	0	0	0
		Z	5	10	15	30	30	60	60

GAUGE TOLERANCES FOR CHECKING HOLES

Table 2 (Contd)

All dimensions in microns.

Nominal Size, mm		Symbol	WORK TOLERANCE GRADES						
Over	upto & includ.		6	7	8	9	10	11	12
180	250	T	29	46	72	115	185	290	460
		H/2	3.5	5	5	5	5	10	10
		H _s /2	3.5	3.5	3.5	3.5	3.5	7	7
		y	4	6	7	0	0	0	0
		Z	5	7	12	21	24	40	45
		α	2	3	4	4	7	10	15
250	315	T	32	52	81	130	210	320	520
		H/2	4	6	6	6	6	11.5	11.5
		H _s /2	4	4	4	4	4	8	8
		y	5	7	9	0	0	0	0
		Z	6	8	14	24	27	45	50
		α	3	4	6	6	9	15	20
315	400	T	36	57	89	140	230	360	570
		H/2	4.5	6.5	6.5	6.5	6.5	12.5	12.5
		H _s /2	4.5	4.5	4.5	4.5	4.5	9	9
		y	6	8	9	0	0	0	0
		Z	7	10	16	28	32	50	65
		α	4	6	7	7	11	15	30
400	500	T	40	63	97	155	250	400	630
		H/2	5	7.5	7.5	7.5	7.5	13.5	13.5
		H _s /2	5	5	5	5	5	10	10
		y	7	9	11	0	0	0	0
		Z	8	11	18	32	37	55	70
		α	5	7	9	9	14	20	35

GAUGE TOLERANCES FOR CHECKING SHAFTS

All dimensions in microns : Table 3

Nominal Size, mm		Symbol	WORK TOLERANCE GRADES							
Over	upto & includ.		5	6	7	8	9	10	11	12
—	3	T	4	6	10	14	25	40	60	100
		H _s /2	0.6	1	1	1.5	1.5	1.5	2	2
		H _p /2	0.4	0.4	0.4	0.6	0.6	0.6	0.6	0.6
		y ₁	1	1.5	1.5	3	0	0	0	0
		Z ₁	1	1.5	1.5	2	5	5	10	10
3	6	T	5	8	12	18	30	48	75	120
		H _s /2	0.75	1.25	1.25	2	2	2	2.5	2.5
		H _p /2	0.5	0.5	0.5	0.75	0.75	0.75	0.75	0.75
		y ₁	1	1.5	1.5	3	0	0	0	0
		Z ₁	1	2	2	3	6	6	12	12
6	10	T	6	9	15	22	36	58	90	150
		H _s /2	0.75	1.25	1.25	2	2	2	3	3
		H _p /2	0.5	0.5	0.5	0.75	0.75	0.75	0.75	0.75
		y ₁	1	1.5	1.5	3	0	0	0	0
		Z ₁	1	2	2	3	7	7	14	14
10	18	T	8	11	18	27	43	70	110	180
		H _s /2	1	1.5	1.5	2.5	2.5	2.5	4	4
		H _p /2	0.6	0.6	0.6	1	1	1	1	1
		y ₁	1.5	2	2	4	0	0	0	0
		Z ₁	1.5	2.5	2.5	4	8	8	16	16
18	30	T	9	13	21	33	52	84	130	210
		H _s /2	1.25	2	2	3	3	3	4.5	4.5
		H _p /2	0.75	0.75	0.75	1.25	1.25	1.25	1.25	1.25
		y ₁	2	3	3	4	0	0	0	0
		Z ₁	1.5	3	3	5	9	9	19	19
30	50	T	11	16	25	39	62	100	160	250
		H _s /2	1.25	2	2	3.5	3.5	3.5	5.5	5.5
		H _p /2	0.75	0.75	0.75	1.25	1.25	1.25	1.25	1.25
		y ₁	2	3	3	5	0	0	0	0
		Z ₁	2	3.5	3.5	6	11	11	22	22
50	80	T	13	19	30	46	74	120	190	300
		H _s /2	1.5	2.5	2.5	4	4	4	6.5	6.5
		H _p /2	1	1	1	1.5	1.5	1.5	1.5	1.5
		y ₁	2	3	3	5	0	0	0	0
		Z ₁	2	4	4	7	13	13	25	25
80	120	T	15	22	35	54	87	140	220	350
		H _s /2	2	3	3	5	5	5	7.5	7.5
		H _p /2	1.25	1.25	1.25	2	2	2	2	2
		y ₁	3	4	4	6	0	0	0	0
		Z ₁	2.5	5	5	8	15	15	28	28

GAUGE TOLERANCES FOR CHECKING SHAFTS

All dimensions in microns

Table 3 (Contd.)

Nominal Size, mm		Symbol	WORK TOLERANCE GRADES							
Over	upto & includ		5	6	7	8	9	10	11	12
120	180	T	18	25	40	63	100	160	250	400
		H _i /2	2.5	4	4	6	6	6	9	9
		H _p /2	1.75	1.75	1.75	2.5	2.5	2.5	2.5	2.5
		y _i	3	4	4	6	0	0	0	0
		Z _i	3	6	6	9	18	18	32	32
180	250	T	20	29	46	72	115	185	290	460
		H _i /2	3.5	5	5	7	7	7	10	10
		H _p /2	2.25	2.25	2.25	3.5	3.5	3.5	3.5	3.5
		y _i	3	5	6	7	0	0	0	0
		Z _i	4	7	7	12	21	24	40	45
		α _i	1	2	3	4	4	7	10	15
250	315	T	23	32	52	81	130	210	320	520
		H _i /2	4	6	6	8	8	8	11.5	11.5
		H _p /2	3	3	3	4	4	4	4	4
		y _i	3	6	7	9	0	0	0	0
		Z _i	5	8	8	14	24	27	45	50
		α _i	1.5	3	4	6	6	9	15	20
315	400	T	25	36	57	89	140	230	360	570
		H _i /2	4.5	6.5	6.5	9	9	9	12.5	12.5
		H _p /2	3.5	3.5	3.5	4.5	4.5	4.5	4.5	4.5
		y _i	4	6	8	9	0	0	0	0
		Z _i	6	10	10	16	28	32	50	65
		α _i	2.5	4	6	7	7	11	15	30
400	500	T	27	40	63	97	155	250	400	630
		H _i /2	5	7.5	7.5	10	10	10	13.5	13.5
		H _p /2	4	4	4	5	5	5	5	5
		y _i	4	7	9	11	0	0	0	0
		Z _i	7	11	11	18	32	37	55	70
		α _i	3	5	7	9	9	14	20	35

RECOMMENDED TYPES OF GAUGES

WORKPIECE	GAUGES	Diameter in mm					
		Over	—	6	10	120	315
		upto	6	10	120	315	—
RIGID PARTS (HOLES)	GO	CYL. PLUG			SEG. CYL.	ROD	
	NO GO	CYL. PLUG	SEG. CYL. SEG. SPHER			ROD	
NON RIGID PARTS (HOLES)	GO	CYL. PLUG			SEG. SPHER	ROD	
	NO GO	CYL. PLUG		FULL FORM SPHER		ROD	
RIGID PARTS (SHAFTS)	GO	CYL. RING					
	NO GO	GAP					
NON RIGID PARTS (SHAFTS)	GO & NO GO	CYL. RING					

APPENDIX

METRIC — SI CONVERSION TABLE

Quantity	Metric units	equivalent S.I. units	Dimension
FORCE & Weight	1 kgf	9.81 N	MLT ⁻²
TORQUE	1 kgfm	9.81 Nm	ML ² T ⁻²
Surface tension	1 dyne/cm	10 ⁻³ N/m	MT ⁻²
Spring stiffness	1 kgf/cm	0.981 N/mm	"
pressure, stress	1 kgf/cm ²	98.1 × 10 ³ N/m ²	ML ⁻¹ T ⁻²
	1 mm of water	9.81 N/m ²	"
	1 mm of Hg	133.3 N/m ²	"
	1 atmosphere	101.3 × 10 ³ N/m ²	"
Dynamic Viscosity	1 kgf sec./m ²	9.81 Ns/m ²	ML ⁻¹ T ⁻¹
Kinematic Viscosity	1 cm ² /sec. (=stoke)	10 ⁻⁴ m ² /s	L ² T ⁻¹
Energy, work, heat	1 erg	10 ⁻⁷ J	ML ² T ⁻²
	1 kWh	3.6 × 10 ⁶ J	"
	1 k cal	4.187 × 10 ³ J	"
	1 kgf m	9.81 J	"
Power	1 hp	746 W	ML ² T ⁻²
	1 hp (metric)	736 W	"
	1 kgf m/Sec	9.81 W	"
Temperature	°C + 273	K	θ
Specific enthalpy, latent heat, Calorific Value	1 k cal/kg	4.187 × 10 ³ J/kg	L ² T ⁻²
Specific heat	k cal/kg °C	4.187 J/kg K	L ² T ⁻² θ ⁻¹
Specific entropy	1 k cal/kg	4.187 J/kg	L ² T ⁻²
Heat flow rate	1 k cal/m ² hr	1.163 W/m ²	MT ⁻²
Thermal conductivity	1 k cal/m hr °C	1.163 W/mK	MLT ⁻² θ ⁻¹
Heat transfer Coefft	1 k cal/m ² hr °C	1.163 W/m ² K	MT ⁻² θ ⁻¹
N, Newton L, Length J, Joule M, Mass K, Degree Kelvin T, Time m, metre θ, temperature W, Watt kg, kilogram mass			

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