TRANSMISSION CHAINS

Types of Chains

In addition to the standard roller and inverted tooth types, a wide variety of drive chains of different construction is available. Such chains are manufactured to various degrees of precision ranging from unfinished castings or forgings to chains having certain machined parts. Practically all of these chains as well as standard roller chains can be equipped with attachments to fit them for conveyor use. A few such types are briefly described in the following paragraphs. Detailed information about them can be obtained from the manufacturers.

Types of chains.—*Detachable Chains:* The links of this type of chain, which are identical, are easily detachable. Each has a hook-shaped end in which the bar of the adjacent link articulates. These chains are available in malleable iron or pressed steel. The chief advantage is the ease with which any link can be removed.

Cast Roller Chains: Cast roller chains are constructed, wholly or partly, of cast metal parts and are available in various styles. In general the rollers and side bars are accurately made castings without machine finish. The links are usually connected by means of forged pins secured by nuts or cotters. Such chains are used for slow speeds and moderate loads, or where the precision of standard roller chains is not required.

Pintle Chains: Unlike the roller chain, the pintle chain is composed of hollow-cored cylinders cast or forged integrally with two offset side bars and each link identical. The links are joined by pins inserted in holes in the ends of the side bars and through the cored holes in the adjacent links. Lugs prevent turning of the pins in the side bars ensuring articulation of the chain between the pin and the cored cylinder.

Standard Roller Transmission Chains

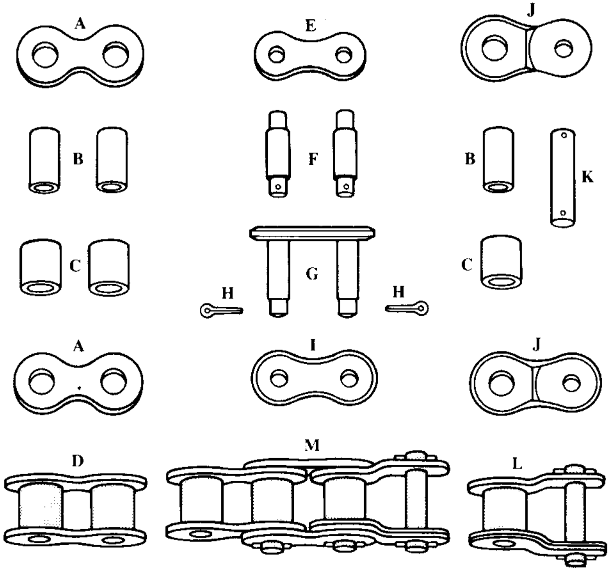
A roller chain is made up of two kinds of links: roller links and pin links alternately spaced throughout the length of the chain as shown in Table 1.

Roller chains are manufactured in several types, each designed for the particular service required. All roller chains are so constructed that the rollers are evenly spaced throughout the chain. The outstanding advantage of this type of chain is the ability of the rollers to rotate when contacting the teeth of the sprocket. Two arrangements of roller chains are in common use: the single-strand type and the multiple-strand type. In the latter type, two or more chains are joined side by side by means of common pins which maintain the alignment of the rollers in the different strands.

Types of roller chains.—*Standard roller chains* are manufactured to the specifications in the American National Standard for precision power transmission roller chains, attachments, and sprockets ANSI/ASME B29.1M-1993 and, where indicated, the data in the subsequent tables have been taken from this standard. These roller chains and sprockets are commonly used for the transmission of power in industrial machinery, machine tools, motor trucks, motorcycles, tractors, and similar applications. In tabulating the dimensional information in ANSI/ASME B29.1M, customary inch-pound units were used. Metric (SI) units are given in separate tabulations in the Standard.

Nonstandard roller chains, developed individually by various manufacturers prior to the adoption of the ANSI standard, are similar in form and construction to standard roller chains but do not conform dimensionally to standard chains. Some sizes are still available from the originating manufacturers for replacement on existing equipment. They are not recommended for new installations, since their manufacture is being discontinued as rapidly as possible.

Table 1. ANSI Nomenclature for Roller Chain Parts *ANSI/ASME B29.1M-1993*



Roller Link D. — An inside link consisting of two inside plates, two bushings, and two rollers.

Pin Link G and E. — An outside link consisting of two pin-link plates assembled with two pins.

Inside Plate A. — One of the plates forming the tension members of a roller link.

Pin Link Plate E. — One of the plates forming the tension members of a pin link.

Pin F. — A stud articulating within a bushing of an inside link and secured at its ends by the pin-link plates.

Bushing B. — A cylindrical bearing in which the pin turns.

Roller C. — A ring or thimble which turns over a bushing.

Assembled Pins G. — Two pins assembled with one pin-link plate.

Connecting-Link G and I. — A pin link having one side plate detachable.

Connecting-Link Plate I. — The detachable pin-link plate belonging to a connecting link. It is retained by cotter pins or by a one-piece spring clip (not shown).

Connecting Link Assembly M. — A unit designed to connect two roller links.

Offset Link L. — A link consisting of two offset plates assembled with a bushing and roller at one end and an offset link pin at the other.

Offset Plate J. — One of the plates forming the tension members of the offset link.

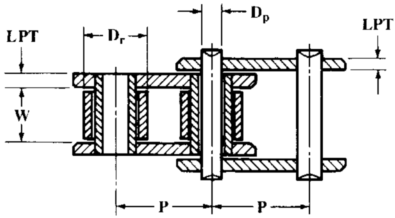
Offset Link Pin K. — A pin used in offset links.

Standard double-pitch roller chains are like standard roller chains, except that their link plates have twice the pitch of the corresponding standard-pitch chain. Their design conforms to specifications in the ANSI Standard for double-pitch power transmission roller chains and sprockets ANSI/ASME B29.3M-1994. They are especially useful for low speeds, moderate loads, or long center distances.

Transmission Roller Chain

Standard Roller Chain Nomenclature, Dimensions and Loads.—Standard nomenclature for roller chain parts are given in Table 1. Dimensions for Standard Series roller chain are given in Table 2.

Table 2. ANSI Roller Chain Dimensions *ASME/ANSI B29.1M-1986*



Pitch P	Max. Roller Diameter D_r	Standard Series					Heavy Series
		Standard Chain No.	Width W	Pin Diameter D_p	Thickness of Link Plates *LPT*	Measuring Load,† Lb.	Thickness of Link Plates *LPT*
0.250	[a]0.130	25	0.125	0.0905	0.030	18	…
0.375	[a]0.200	35	0.188	0.141	0.050	18	…
0.500	0.306	41	0.250	0.141	0.050	18	…
0.500	0.312	40	0.312	0.156	0.060	31	…
0.625	0.400	50	0.375	0.200	0.080	49	…
0.750	0.469	60	0.500	0.234	0.094	70	0.125
1.000	0.625	80	0.625	0.312	0.125	125	0.156
1.250	0.750	100	0.750	0.375	0.156	195	0.187
1.500	0.875	120	1.000	0.437	0.187	281	0.219
1.750	1.000	140	1.000	0.500	0.219	383	0.250
2.000	1.125	160	1.250	0.562	0.250	500	0.281
2.250	1.406	180	1.406	0.687	0.281	633	0.312
2.500	1.562	200	1.500	0.781	0.312	781	0.375
3.000	1.875	240	1.875	0.937	0.375	1000	0.500

[a] Bushing diameter. This size chain has no rollers.

All dimensions are in inches.

Roller Diameters D_r are approximately $\frac{5}{8}P$.

The *width W* is defined as the distance between the link plates. It is approximately $\frac{5}{8}$ of the chain pitch.

Pin Diameters D_p are approximately $\frac{5}{16}P$ or $\frac{1}{2}$ of the roller diameter.

Thickness LPT of Inside and Outside Link Plates for the standard series is approximately $\frac{1}{8}P$.

Thickness of Link Plates for the heavy series of any pitch is approximately that of the next larger pitch Standard Series chain.

Maximum Height of Roller Link Plates = 0.95 *P*.
Maximum Height of Pin Link Plates = 0.82 *P*.
Maximum Pin Diameter = nominal pin diameter + 0.0005 inch.
Minimum Hole in Bushing = nominal pin diameter + 0.0015 inch.
Maximum Width of Roller Link = nominal width of chain + (2.12 × nominal link plate thickness.)
Minimum Distance between Pin Link Plates = maximum width of roller link + 0.002 inch.

Chain Pitch: Distance in inches between centers of adjacent joint members. Other dimensions are proportional to the pitch.

Tolerances for Chain Length: New chains, under standard measuring load, must not be underlength. Overlength tolerance is $0.001/(\text{pitch in inches})^2 + 0.015$ inch per foot. Length measurements are to be taken over a length of at least 12 inches.

Measuring Load: The load in pounds under which a chain should be measured for length. It is equal to one per cent of the ultimate tensile strength, with a minimum of 18 pounds and a maximum of 1000 pounds for both single and multiple-strand chain.

Minimum Ultimate Tensile Strength: For single-strand chain, equal to or greater than $12{,}500 \times (\text{pitch in inches})^2$ pounds. The minimum tensile strength or breaking strength of a multiple-strand chain is equal to that of a single-strand chain multiplied by the number of strands. Minimum ultimate tensile strength is indicative only of the tensile strength quality of the chain, not the maximum load that can be applied.

Standard Roller Chain Numbers.—The right-hand figure in the chain number is zero for roller chains of the usual proportions, 1 for a lightweight chain, and 5 for a rollerless bushing chain. The numbers to the left of the right-hand figure denote the number of $\frac{1}{8}$ inches in the pitch. The letter *H* following the chain number denotes the heavy series; thus the number 80 *H* denotes a 1-inch pitch heavy chain. The hyphenated number 2 suffixed to the chain number denotes a double strand, 3 a triple strand, 4 a quadruple strand chain and so on.

Heavy Series: These chains, made in $\frac{3}{4}$-inch and larger pitches, have thicker link plates than those of the regular standard. Their value is only in the acceptance of higher loads at lower speeds.

Light-weight Machinery Chain: This chain is designated as No. 41. It is $\frac{1}{2}$ inch pitch; $\frac{1}{4}$ inch wide; has 0.306-inch diameter rollers and a 0.141-inch pin diameter. The minimum ultimate tensile strength is 1500 pounds.

Multiple-strand Chain: This is essentially an assembly of two or more single-strand chains placed side by side with pins that extend through the entire width to maintain alignment of the different strands.

Types of Sprockets.—Four different designs or types of roller-chain sprockets are shown by the sectional views, Fig. 1. Type *A* is a plain plate; type *B* has a hub on one side only; type *C*, a hub on both sides; and type *D*, a detachable hub. Also used are shear pin and slip clutch sprockets designed to prevent damage to the drive or to other equipment caused by overloads or stalling.

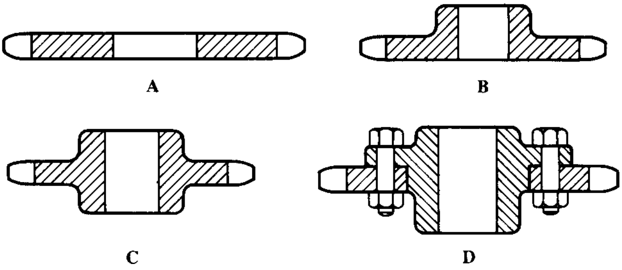
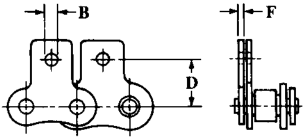


Fig. 1. Types of Sprockets

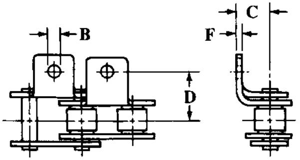
Attachments.—Modifications to standard chain components to adapt the chain for use in conveying, elevating, and timing operations are known as “attachments.” The components commonly modified are: 1) the link plates, which are provided with extended lugs which may be straight or bent; and 2) the chain pins, which are extended in length so as to project substantially beyond the outer surface of the pin link plates.

Hole diameters, thicknesses, hole locations and offset dimensions for straight link and bent link plate extensions and lengths and diameters of extended pins are given in Table 3.

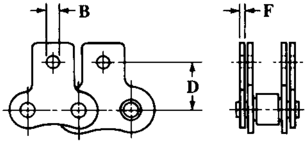
Table 3. Straight and Bent Link Plate Extensions and Extended Pin Dimensions
ANSI/ASME B29.1M-1993



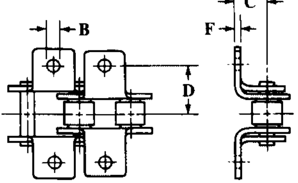
Straight Link Plate Extension, One Side of Chain.



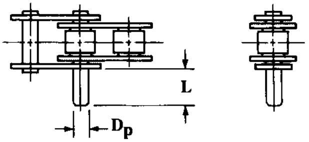
Bent Link Plate Extension, One Side of Chain.



Straight Link Plate Extension, Both Sides of Chain.



Bent Link Plate Extension, Both Sides of Chain.



Extended Pin, One Side of Chain.

Chain No.	Straight Link Plate Extension			Bent Link Plate Extension				Extended Pin	
	B min.	*D*	*F*	*B* min.	*C*	*D*	*F*	D_p Nominal	*L*
35	0.102	0.375	0.050	0.102	0.250	0.375	0.050	0.141	0.375
40	0.131	0.500	0.060	0.131	0.312	0.500	0.060	0.156	0.375
50	0.200	0.625	0.080	0.200	0.406	0.625	0.080	0.200	0.469
60	0.200	0.719	0.094	0.200	0.469	0.750	0.094	0.234	0.562
80	0.261	0.969	0.125	0.261	0.625	1.000	0.125	0.312	0.750
100	0.323	1.250	0.156	0.323	0.781	1.250	0.156	0.375	0.938
120	0.386	1.438	0.188	0.386	0.906	1.500	0.188	0.437	1.125
140	0.448	1.750	0.219	0.448	1.125	1.750	0.219	0.500	1.312
160	0.516	2.000	0.250	0.516	1.250	2.000	0.250	0.562	1.500
200	0.641	2.500	0.312	0.641	1.688	2.500	0.312	0.781	1.875

All dimensions are in inches.

Sprocket Classes.—The American National Standard ANSI/ASME B29.1M-1993 provides for two classes of sprockets designated as Commercial and Precision. The selection of either is a matter of drive application judgment. The usual moderate to slow speed commercial drive is adequately served by Commercial sprockets. Where extreme high speed in combination with high load is involved, or where the drive involves fixed centers, critical timing, or register problems, or close clearance with outside interference, then the use of Precision sprockets may be more appropriate.

As a general guide, drives requiring Type A or Type B lubrication (see page 2443) would be served by Commercial sprockets. Drives requiring Type C lubrication may require Precision sprockets; the manufacturer should be consulted.

Keys, Keyways, and Set Screws.—To secure sprockets to the shaft, both keys and set screws should be used. The key is used to prevent rotation of the sprocket on the shaft. Keys should be fitted carefully in the shaft and sprocket keyways to eliminate all backlash, especially on the fluctuating loads. A set screw should be located over a flat key to secure it against longitudinal displacement.

Where a set screw is to be used with a parallel key, the following sizes are recommended by the American Chain Association. For a sprocket bore and shaft diameter in the range of

$\frac{1}{2}$ through $\frac{7}{8}$ inch, a $\frac{1}{4}$-inch set screw
$\frac{15}{16}$ through $1\frac{3}{4}$ inches, a $\frac{3}{8}$-inch set screw
$1\frac{13}{16}$ through $2\frac{1}{4}$ inches, a $\frac{1}{2}$-inch set screw
$2\frac{5}{16}$ through $3\frac{1}{4}$ inches, a $\frac{5}{8}$-inch set screw
$3\frac{3}{8}$ through $4\frac{1}{2}$ inches, a $\frac{3}{4}$-inch set screw
$4\frac{3}{4}$ through $5\frac{1}{2}$ inches, a $\frac{7}{8}$-inch set screw
$5\frac{3}{4}$ through $7\frac{3}{8}$ inches, a 1-inch set screw
$7\frac{1}{2}$ through $12\frac{1}{2}$ inches, a $1\frac{1}{4}$-inch set screw

Sprocket Diameters.—The various diameters of roller chain sprockets are shown in Fig. 2. These are defined as follows.

Pitch Diameter: The pitch diameter is the diameter of the pitch circle that passes through the centers of the link pins as the chain is wrapped on the sprocket.

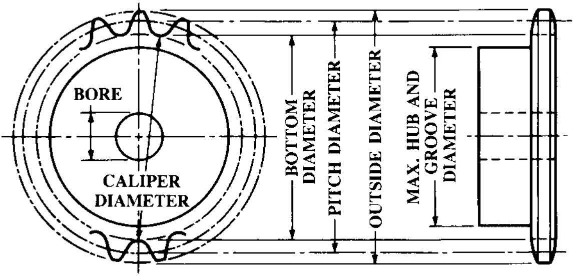


Fig. 2. Sprocket Diameters

Because the chain pitch is measured on a straight line between the centers of adjacent pins, the chain pitch lines form a series of chords of the sprocket pitch circle. Sprocket pitch diameters for one-inch pitch and for 9 to 108 teeth are given in Table 4. For lower (5 to 8) or higher (109 to 200) numbers of teeth use the following formula in which P = pitch, N = number of teeth: Pitch Diameter = $P \div \sin(180° \div N)$.

Table 4. ANSI Roller Chain Sprocket Diameters *ANSI/ASME B29.1M-1993*

These diameters and caliper factors apply only to chain of 1-inch pitch. For any other pitch, multiply the values given below by the pitch.

Caliper Dia. (even teeth) = Pitch Diameter − Roller Dia.
Caliper Dia. (odd teeth) = Caliper factor × Pitch − Roller Dia.

See Table 5 for tolerances on Caliper Diameters.

No. Teeth[a]	Pitch Diameter	Outside Diameter		Caliper Factor	No. Teeth[a]	Pitch Diameter	Outside Diameter		Caliper Factor
		Turned	Topping Hob Cut				Turned	Topping Hob Cut	
9	2.9238	3.348	3.364	2.8794	59	18.7892	19.363	19.361	18.7825
10	3.2361	3.678	3.676		60	19.1073	19.681	19.680	
11	3.5495	4.006	3.990	3.5133	61	19.4255	20.000	19.998	19.4190
12	3.8637	4.332	4.352		62	19.7437	20.318	20.316	
13	4.1786	4.657	4.666	4.1481	63	20.0618	20.637	20.634	20.0556
14	4.4940	4.981	4.982		64	20.3800	20.956	20.952	
15	4.8097	5.304	5.298	4.7834	65	20.6982	21.274	21.270	20.6921
16	5.1258	5.627	5.614		66	21.0164	21.593	21.588	
17	5.4422	5.949	5.930	5.4190	67	21.3346	21.911	21.907	21.3287
18	5.7588	6.271	6.292		68	21.6528	22.230	22.225	
19	6.0755	6.593	6.609	6.0548	69	21.9710	22.548	22.543	21.9653
20	6.3924	6.914	6.926		70	22.2892	22.867	22.861	
21	6.7095	7.235	7.243	6.6907	71	22.6074	23.185	23.179	22.6018
22	7.0267	7.555	7.560		72	22.9256	23.504	23.498	
23	7.3439	7.876	7.877	7.3268	73	23.2438	23.822	23.816	23.2384
24	7.6613	8.196	8.195		74	23.5620	24.141	24.134	
25	7.9787	8.516	8.512	7.9630	75	23.8802	24.459	24.452	23.8750
26	8.2962	8.836	8.829		76	24.1984	24.778	24.770	
27	8.6138	9.156	9.147	8.5992	77	24.5166	25.096	25.089	24.5116
28	8.9314	9.475	9.465		78	24.8349	25.415	25.407	
29	9.2491	9.795	9.782	9.2355	79	25.1531	25.733	25.725	25.1481
30	9.5668	10.114	10.100		80	25.4713	26.052	26.043	
31	9.8845	10.434	10.418	9.8718	81	25.7896	26.370	26.362	25.7847
32	10.2023	10.753	10.736		82	26.1078	26.689	26.680	
33	10.5201	11.073	11.053	10.5082	83	26.4260	27.007	26.998	26.4213
34	10.8379	11.392	11.371		84	26.7443	27.326	27.316	
35	11.1558	11.711	11.728	11.1446	85	27.0625	27.644	27.635	27.0579
36	11.4737	12.030	12.046		86	27.3807	27.962	27.953	
37	11.7916	12.349	12.364	11.7810	87	27.6990	28.281	28.271	27.6945
38	12.1095	12.668	12.682		88	28.0172	28.599	28.589	
39	12.4275	12.987	13.000	12.4174	89	28.3354	28.918	28.907	28.3310
40	12.7455	13.306	13.318		90	28.6537	29.236	29.226	
41	13.0635	13.625	13.636	13.0539	91	28.9719	29.555	29.544	28.9676
42	13.3815	13.944	13.954		92	29.2902	29.873	29.862	
43	13.6995	14.263	14.272	13.6904	93	29.6084	30.192	30.180	29.6042
44	14.0175	14.582	14.590		94	29.9267	30.510	30.499	
45	14.3355	14.901	14.908	14.3269	95	30.2449	30.828	30.817	30.2408
46	14.6535	15.219	15.226		96	30.5632	31.147	31.135	
47	14.9717	15.538	15.544	14.9634	97	30.8815	31.465	31.454	30.8774
48	15.2898	15.857	15.862		98	31.1997	31.784	31.772	
49	15.6079	16.176	16.180	15.5999	99	31.5180	32.102	32.090	31.5140
50	15.9260	16.495	16.498		100	31.8362	32.421	32.408	
51	16.2441	16.813	16.816	16.2364	101	32.1545	32.739	32.727	32.1506
52	16.5622	17.132	17.134		102	32.4727	33.057	33.045	
53	16.8803	17.451	17.452	16.8729	103	32.7910	33.376	33.363	32.7872
54	17.1984	17.769	17.770		104	33.1093	33.694	33.681	
55	17.5165	18.088	18.089	17.5094	105	33.4275	34.013	34.000	33.4238
56	17.8347	18.407	18.407		106	33.7458	34.331	34.318	
57	18.1528	18.725	18.725	18.1459	107	34.0641	34.649	34.636	34.0604
58	18.4710	19.044	19.043		108	34.3823	34.968	34.954	

[a] For 5 – 8 and 109–200 teeth see text, pages 2426, 2428.

Bottom Diameter: The bottom diameter is the diameter of a circle tangent to the curve (called the seating curve) at the bottom of the tooth gap. It equals the pitch diameter minus the diameter of the roller.

Caliper Diameter: The caliper diameter is the same as the bottom diameter for a sprocket with an even number of teeth. For a sprocket with an odd number of teeth, it is defined as the distance from the bottom of one tooth gap to that of the nearest opposite tooth gap. The caliper diameter for an even tooth sprocket is equal to pitch diameter–roller diameter. The caliper diameter for an odd tooth sprocket is equal to caliper factor–roller diameter. Here, the caliper factor = $PD[\cos(90° \div N)]$, where PD = pitch diameter and N = number of teeth. Caliper factors for 1-in. pitch and sprockets having 9–108 teeth are given in Table 4. For other tooth numbers use above formula. Caliper diameter tolerances are minus only and are equal to $0.002P\sqrt{N} + 0.006$ inch for the Commercial sprockets and $0.001P\sqrt{N} + 0.003$ inch for Precision sprockets. Tolerances are given in Table 5.

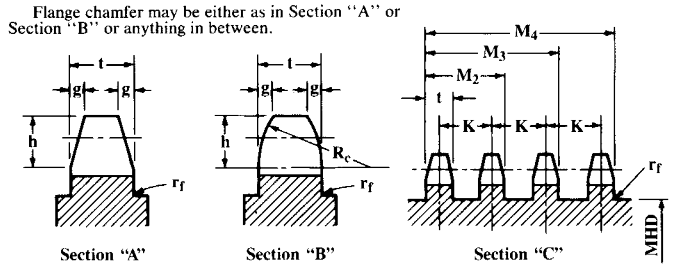
Table 5. Minus Tolerances on the Caliper Diameters of Precision Sprockets
ANSI/ASME B29.1M-1993

	Number of Teeth				
Pitch	Up to 15	16–24	25–35	36–48	49–63
0.250	0.004	0.004	0.004	0.005	0.005
0.375	0.004	0.004	0.004	0.005	0.005
0.500	0.004	0.005	0.0055	0.006	0.0065
0.625	0.005	0.0055	0.006	0.007	0.008
0.750	0.005	0.006	0.007	0.008	0.009
1.000	0.006	0.007	0.008	0.009	0.010
1.250	0.007	0.008	0.009	0.010	0.012
1.500	0.007	0.009	0.0105	0.012	0.013
1.750	0.008	0.010	0.012	0.013	0.015
2.000	0.009	0.011	0.013	0.015	0.017
2.250	0.010	0.012	0.014	0.016	0.018
2.500	0.010	0.013	0.015	0.018	0.020
3.000	0.012	0.015	0.018	0.021	0.024
	Number of Teeth				
Pitch	64–80	81–99	100–120	121–143	144 up
0.250	0.005	0.005	0.006	0.006	0.006
0.375	0.006	0.006	0.006	0.007	0.007
0.500	0.007	0.0075	0.008	0.0085	0.009
0.625	0.009	0.009	0.009	0.010	0.011
0.750	0.010	0.010	0.011	0.012	0.013
1.000	0.011	0.012	0.013	0.014	0.015
1.250	0.013	0.014	0.016	0.017	0.018
1.500	0.015	0.016	0.018	0.019	0.021
1.750	0.017	0.019	0.020	0.022	0.024
2.000	0.019	0.021	0.023	0.025	0.027
2.250	0.021	0.023	0.025	0.028	0.030
2.500	0.023	0.025	0.028	0.030	0.033
3.000	0.027	0.030	0.033	0.036	0.039

Minus tolerances for Commercial sprockets are twice those shown in this table.

Outside Diameter: OD is the diameter over the tips of teeth. Sprocket ODs for 1-in. pitch and 9–108 teeth are given in Table 4. For other tooth numbers the OD may be determined by the following formulas in which O = approximate OD; P = pitch of chain; N = number of sprocket teeth: $O = P[0.6 + \cot(180° \div N)]$, for turned sprocket; O = pitch diameter – roller diameter + 2 × whole depth of topping hob cut, for topping hob cut sprocket.*

Table 6. American National Standard Roller Chain Sprocket Flange Thickness and Tooth Section Profile Dimension *ANSI/ASME B29.1M-1993*


Flange chamfer may be either as in Section "A" or Section "B" or anything in between.

Sprocket Flange Thickness

Std. Chain No.	Width of Chain, *W*	Maximum Sprocket Flange Thickness, *t*			Minus Tolerance on *t*		Tolerance on *M*		Max. Variation of *t* on Each Flange	
		Single	Double & Triple	Quad. & Over	Commercial	Precision	Commercial Plus or Minus	Precision Minus Only	Commercial	Precision
25	0.125	0.110	0.106	0.096	0.021	0.007	0.007	0.007	0.021	0.004
35	0.188	0.169	0.163	0.150	0.027	0.008	0.008	0.008	0.027	0.004
41	0.250	0.226	…	…	0.032	0.009	…	…	0.032	0.004
40	0.312	0.284	0.275	0.256	0.035	0.009	0.009	0.009	0.035	0.004
50	0.375	0.343	0.332	0.310	0.036	0.010	0.010	0.010	0.036	0.005
60	0.500	0.459	0.444	0.418	0.036	0.011	0.011	0.011	0.036	0.006
80	0.625	0.575	0.556	0.526	0.040	0.012	0.012	0.012	0.040	0.006
100	0.750	0.0692	0.669	0.633	0.046	0.014	0.014	0.014	0.046	0.007
120	1.000	0.924	0.894	0.848	0.057	0.016	0.016	0.016	0.057	0.008
140	1.000	0.924	0.894	0.848	0.057	0.016	0.016	0.016	0.057	0.008
160	1.250	1.156	1.119	1.063	0.062	0.018	0.018	0.018	0.062	0.009
180	1.406	1.302	1.259	1.198	0.068	0.020	0.020	0.020	0.068	0.010
200	1.500	1.389	1.344	1.278	0.072	0.021	0.021	0.021	0.072	0.010
240	1.875	1.738	1.682	1.602	0.087	0.025	0.025	0.025	0.087	0.012

Sprocket Tooth Section Profile Dimensions

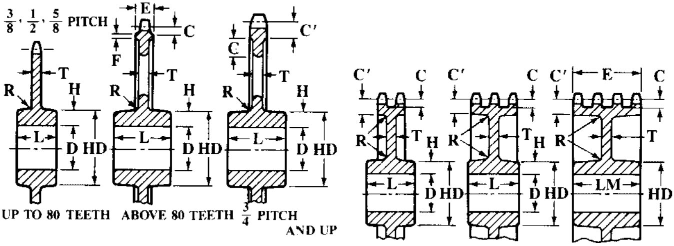
Std. Chain No.	Chain Pitch *P*	Depth of Chamfer *h*	Width of Chamfer *g*	Minimum Radius R_c	Transverse Pitch *K*	
					Standard Series	Heavy Series
25	0.250	0.125	0.031	0.265	0.252	…
35	0.375	0.188	0.047	0.398	0.399	…
41	0.500	0.250	0.062	0.531	…	…
40	0.500	0.250	0.062	0.531	0.566	…
50	0.625	0.312	0.078	0.664	0.713	…
60	0.750	0.375	0.094	0.796	0.897	1.028
80	1.000	0.500	0.125	1.062	1.153	1.283
100	1.250	0.625	0.156	1.327	1.408	1.539
120	1.500	0.750	0.188	1.593	1.789	1.924
140	1.750	0.875	0.219	1.858	1.924	2.055
160	2.000	1.000	0.250	2.124	2.305	2.437
180	2.250	1.125	0.281	2.392	2.592	2.723
200	2.500	1.250	0.312	2.654	2.817	3.083
240	3.000	1.500	0.375	3.187	3.458	3.985

All dimensions are in inches. r_f max = 0.04 *P* for max. hub diameter.

[*] This dimension was added in 1984 as a desirable goal for the future. It should in no way obsolete existing tools or sprockets. The whole depth *WD* is found from the formula: $WD = \frac{1}{2}D_r + P[0.3 - \frac{1}{2}\tan(90\ \text{deg} \div N_a)]$, where N_a is the intermediate number of teeth for the topping hob. For teeth range 5, N_a = 5; 6, 6; 7–8, 7.47; 9–11, 9.9; 12–17, 14.07; 18–34, 23.54; 35 and over, 56.

Proportions of Sprockets.—Typical proportions of single-strand and multiple-strand cast roller chain sprockets, as provided by the American Chain Association, are shown in Table 7. Typical proportions of roller chain bar-steel sprockets, also provided by this association, are shown in Table 8.

Table 7. Typical Proportions of Single-Strand and Multiple-Strand Cast Roller Chain Sprockets



Single-Strand Multiple-Strand

Sprocket Web Thickness, *T*, for Various Pitches *P*

Single-Strand								Multiple-Strand							
P	*T*	*P*	*T*	*P*	*T*	*P*	*T*	*P*	*T*	*P*	*T*	*P*	*T*	*P*	*T*
$\frac{3}{8}$	.312	$\frac{3}{4}$	.437	$1\frac{1}{2}$	.625	$2\frac{1}{4}$	1.000	$\frac{3}{8}$	.375	$\frac{3}{4}$	.500	$1\frac{1}{2}$	.750	$2\frac{1}{4}$	1.125
$\frac{1}{2}$	.375	1	.500	$1\frac{3}{4}$	.750	$2\frac{1}{2}$	1.125	$\frac{1}{2}$	.406	1	.562	$1\frac{3}{4}$	.875	$2\frac{1}{2}$	1.250
$\frac{5}{8}$	.406	$1\frac{1}{4}$	.562	2	.875	3	1.250	$\frac{5}{8}$	.437	$1\frac{1}{4}$	.625	2	1.000	3	1.500

Formulas for Dimensions of Single and Multiple Sprockets

$H = 0.375 + \frac{D}{6} + 0.01\,PD$

$E = 0.625P + 0.93W$

$F = 0.150 + 0.25P$

$L = 4H$ for semi-steel castings

$G = 2T$

$C = 0.5P$

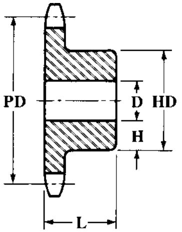
$R = 0.4P$ for single-strand sprockets

$C' = 0.9P$

$R = 0.5T$ for multiple-strand sprockets

All dimensions in inches. Where: P = chain pitch and W = nominal chain width.

Table 8. Typical Proportions of Roller Chain Bar-steel Sprockets



$H = Z + D/6 + 0.01\,PD$

For PD up to 2 inches, Z = 0.125 inch; for 2–4 inches, Z = 0.187 inch; for 4–6 inches, 0.25 inch; and for over 6 inches, 0.375 inch.

Hub length $L = 3.3\,H$, normally, with a minimum of $2.6H$.

Hub diameter $HD = D + 2H$, but not more than the maximum hub diameter MHD given by the formula:

$$MHD = P\left(\cot\frac{180^\circ}{N} - 1\right) - 0.030$$

where: P = Chain pitch, in inches
N = Number of sprocket teeth

When sprocket wheels are designed with spokes, the usual assumptions made in order to determine suitable proportions are as follows: 1) That the maximum torque load acting on a sprocket is the chain tensile strength times the sprocket pitch radius; 2) That the torque load is equally divided between the arms by the rim; and 3) That each arm acts as a cantilever beam.

The arms are generally elliptical in cross section, with the major axis twice the minor axis.

Selection of Chain and Sprockets.—The smallest applicable pitch of roller chain is desirable for quiet operation and high speed. The horsepower capacity varies with the chain pitch as shown in Table . However, short pitch with high working load can often be obtained by the use of multiple-strand chain.

The small sprocket selected must be large enough to accommodate the shaft. Table 9 gives maximum bore and hub diameters consistent with commercial practice for sprockets with up to 25 teeth.

After selecting the small sprocket, the number of teeth in the larger sprocket is determined by the desired ratio of the shaft speed. Overemphasis on the exactness in the speed ratio may result in a cumbersome and expensive installation. In most cases, satisfactory operation can be obtained with a minor change in speed of one or both shafts.

To properly use this table the following factors must be taken into consideration:

1) Service factors
2) Multiple Strand Factors
3) Lubrication

Service Factors: See Table 14.

Multiple Strand Factors: For two strands, the multiple strand factor is 1.7; for three strands, it is 2.5; and for four strands, it is 3.3.

Lubrication:

Required type of lubrication is indicated at the bottom of each roller chain size section of the table. For a description of each type of lubrication, see page 2443.

Type A — Manual or Drip Lubrication
Type B — Bath or Disc Lubrication
Type C — Oil Stream Lubrication

To find the required horsepower table rating, use the following formula:

$$\text{Required hp Table Rating} = \frac{\text{hp to be Transmitted} \times \text{Service Factor}}{\text{Multiple-Strand Factor}}$$

	No. of Teeth Small Spkt.	Revolutions per Minute — Small Sprocket[a]												
		50	100	300	500	700	900	1200	1500	1800	2100	2500	3000	3500
		Horsepower Rating												
$\frac{1}{4}$-inch Pitch Standard Single-Strand Roller Chain — No. 25	11	0.03	0.05	0.14	0.23	0.31	0.39	0.50	0.62	0.73	0.83	0.98	1.15	1.32
	12	0.03	0.06	0.16	0.25	0.34	0.43	0.55	0.68	0.80	0.92	1.07	1.26	1.45
	13	0.04	0.06	0.17	0.27	0.37	0.47	0.60	0.74	0.87	1.00	1.17	1.38	1.58
	14	0.04	0.07	0.19	0.30	0.40	0.50	0.65	0.80	0.94	1.08	1.27	1.49	1.71
	15	0.04	0.08	0.20	0.32	0.43	0.54	0.70	0.86	1.01	1.17	1.36	1.61	1.85
	16	0.04	0.08	0.22	0.34	0.47	0.58	0.76	0.92	1.09	1.25	1.46	1.72	1.98
	17	0.05	0.09	0.23	0.37	0.50	0.62	0.81	0.99	1.16	1.33	1.56	1.84	2.11
	18	0.05	0.09	0.25	0.39	0.53	0.66	0.86	1.05	1.24	1.42	1.66	1.96	2.25
	19	0.05	0.10	0.26	0.41	0.56	0.70	0.91	1.11	1.31	1.50	1.76	2.07	2.38
	20	0.06	0.10	0.28	0.44	0.59	0.74	0.96	1.17	1.38	1.59	1.86	2.19	2.52
	21	0.06	0.11	0.29	0.46	0.62	0.78	1.01	1.24	1.46	1.68	1.96	2.31	2.66
	22	0.06	0.11	0.31	0.48	0.66	0.82	1.07	1.30	1.53	1.76	2.06	2.43	2.79
	23	0.06	0.12	0.32	0.51	0.69	0.86	1.12	1.37	1.61	1.85	2.16	2.55	2.93
	24	0.07	0.13	0.34	0.53	0.72	0.90	1.17	1.43	1.69	1.94	2.27	2.67	3.07
	25	0.07	0.13	0.35	0.56	0.75	0.94	1.22	1.50	1.76	2.02	2.37	2.79	3.21
	26	0.07	0.14	0.37	0.58	0.79	0.98	1.28	1.56	1.84	2.11	2.47	2.91	3.34
	28	0.08	0.15	0.40	0.63	0.85	1.07	1.38	1.69	1.99	2.29	2.68	3.15	3.62
	30	0.08	0.16	0.43	0.68	0.92	1.15	1.49	1.82	2.15	2.46	2.88	3.40	3.90
	32	0.09	0.17	0.46	0.73	0.98	1.23	1.60	1.95	2.30	2.64	3.09	3.64	4.18
	35	0.10	0.19	0.51	0.80	1.08	1.36	1.76	2.15	2.53	2.91	3.41	4.01	4.61
	40	0.12	0.22	0.58	0.92	1.25	1.57	2.03	2.48	2.93	3.36	3.93	4.64	5.32
	45	0.13	0.25	0.66	1.05	1.42	1.78	2.31	2.82	3.32	3.82	4.47	5.26	6.05
		Type A				Type B								

3/8-inch Pitch Standard Single-Strand Roller Chain — No. 35

No. of Teeth Small Spkt.	Revolutions per Minute — Small Sprocket[a]												
	50	100	300	500	700	900	1200	1500	1800	2100	2500	3000	3500
	Horsepower Rating												
11	0.10	0.18	0.49	0.77	1.05	1.31	1.70	2.08	2.45	2.82	3.30	2.94	2.33
12	0.11	0.20	0.54	0.85	1.15	1.44	1.87	2.29	2.70	3.10	3.62	3.35	2.66
13	0.12	0.22	0.59	0.93	1.26	1.57	2.04	2.49	2.94	3.38	3.95	3.77	3.00
14	0.13	0.24	0.63	1.01	1.36	1.71	2.21	2.70	3.18	3.66	4.28	4.22	3.35
15	0.14	0.25	0.68	1.08	1.47	1.84	2.38	2.91	3.43	3.94	4.61	4.68	3.71
16	0.15	0.27	0.73	1.16	1.57	1.97	2.55	3.12	3.68	4.22	4.94	5.15	4.09
17	0.16	0.29	0.78	1.24	1.68	2.10	2.73	3.33	3.93	4.51	5.28	5.64	4.48
18	0.17	0.31	0.83	1.32	1.78	2.24	2.90	3.54	4.18	4.80	5.61	6.15	4.88
19	0.18	0.33	0.88	1.40	1.89	2.37	3.07	3.76	4.43	5.09	5.95	6.67	5.29
20	0.19	0.35	0.93	1.48	2.00	2.51	3.25	3.97	4.68	5.38	6.29	7.20	5.72
21	0.20	0.37	0.98	1.56	2.11	2.64	3.42	4.19	4.93	5.67	6.63	7.75	6.15
22	0.21	0.38	1.03	1.64	2.22	2.78	3.60	4.40	5.19	5.96	6.97	8.21	6.59
23	0.22	0.40	1.08	1.72	2.33	2.92	3.78	4.62	5.44	6.25	7.31	8.62	7.05
24	0.23	0.42	1.14	1.80	2.44	3.05	3.96	4.84	5.70	6.55	7.66	9.02	7.51
25	0.24	0.44	1.19	1.88	2.55	3.19	4.13	5.05	5.95	6.84	8.00	9.43	7.99
26	0.25	0.46	1.24	1.96	2.66	3.33	4.31	5.27	6.21	7.14	8.35	9.84	8.47
28	0.27	0.50	1.34	2.12	2.88	3.61	4.67	5.71	6.73	7.73	9.05	10.7	9.47
30	0.29	0.54	1.45	2.29	3.10	3.89	5.03	6.15	7.25	8.33	9.74	11.5	10.5
32	0.31	0.58	1.55	2.45	3.32	4.17	5.40	6.60	7.77	8.93	10.4	12.3	11.6
35	0.34	0.64	1.71	2.70	3.66	4.59	5.95	7.27	8.56	9.84	11.5	13.6	13.2
40	0.39	0.73	1.97	3.12	4.23	5.30	6.87	8.40	9.89	11.4	13.3	15.7	16.2
45	0.45	0.83	2.24	3.55	4.80	6.02	7.80	9.53	11.2	12.9	15.1	17.8	19.3
	Type A		Type B							Type C			

1/2-inch Pitch Standard Single-Strand Roller Chain — No. 40

No. of Teeth Small Spkt.	Revolutions per Minute — Small Sprocket[a]												
	50	100	200	300	400	500	700	900	1000	1200	1400	1600	1800
	Horsepower Rating												
11	0.23	0.43	0.80	1.16	1.50	1.83	2.48	3.11	3.42	4.03	4.63	5.22	4.66
12	0.25	0.47	0.88	1.27	1.65	2.01	2.73	3.42	3.76	4.43	5.09	5.74	5.31
13	0.28	0.52	0.96	1.39	1.80	2.20	2.97	3.73	4.10	4.83	5.55	6.26	5.99
14	0.30	0.56	1.04	1.50	1.95	2.38	3.22	4.04	4.44	5.23	6.01	6.78	6.70
15	0.32	0.60	1.12	1.62	2.10	2.56	3.47	4.35	4.78	5.64	6.47	7.30	7.43
16	0.35	0.65	1.20	1.74	2.25	2.75	3.72	4.66	5.13	6.04	6.94	7.83	8.18
17	0.37	0.69	1.29	1.85	2.40	2.93	3.97	4.98	5.48	6.45	7.41	8.36	8.96
18	0.39	0.73	1.37	1.97	2.55	3.12	4.22	5.30	5.82	6.86	7.88	8.89	9.76
19	0.42	0.78	1.45	2.09	2.71	3.31	4.48	5.62	6.17	7.27	8.36	9.42	10.5
20	0.44	0.82	1.53	2.21	2.86	3.50	4.73	5.94	6.53	7.69	8.83	9.96	11.1
21	0.46	0.87	1.62	2.33	3.02	3.69	4.99	6.26	6.88	8.11	9.31	10.5	11.7
22	0.49	0.91	1.70	2.45	3.17	3.88	5.25	6.58	7.23	8.52	9.79	11.0	12.3
23	0.51	0.96	1.78	2.57	3.33	4.07	5.51	6.90	7.59	8.94	10.3	11.6	12.9
24	0.54	1.00	1.87	2.69	3.48	4.26	5.76	7.23	7.95	9.36	10.8	12.1	13.5
25	0.56	1.05	1.95	2.81	3.64	4.45	6.02	7.55	8.30	9.78	11.2	12.7	14.1
26	0.58	1.09	2.04	2.93	3.80	4.64	6.28	7.88	8.66	10.2	11.7	13.2	14.7
28	0.63	1.18	2.20	3.18	4.11	5.03	6.81	8.54	9.39	11.1	12.7	14.3	15.9
30	0.68	1.27	2.38	3.42	4.43	5.42	7.33	9.20	10.1	11.9	13.7	15.4	17.2
32	0.73	1.36	2.55	3.67	4.75	5.81	7.86	9.86	10.8	12.8	14.7	16.5	18.4
35	0.81	1.50	2.81	4.04	5.24	6.40	8.66	10.9	11.9	14.1	16.2	18.2	20.3
40	0.93	1.74	3.24	4.67	6.05	7.39	10.0	12.5	13.8	16.3	18.7	21.1	23.4
45	1.06	1.97	3.68	5.30	6.87	8.40	11.4	14.2	15.7	18.5	21.2	23.9	26.6
	Type A		Type B								Type C		

½-inch Pitch Light Weight Machinery Roller Chain — No. 41

No. of Teeth Small Spkt.	Revolutions per Minute — Small Sprocket[a]												
	10	25	50	100	200	300	400	500	700	900	1000	1200	1400
	Horsepower Rating												
11	0.03	0.07	0.13	0.24	0.44	0.64	0.82	1.01	1.37	1.71	1.88	1.71	1.36
12	0.03	0.07	0.14	0.26	0.49	0.70	0.91	1.11	1.50	1.88	2.07	1.95	1.55
13	0.04	0.08	0.15	0.28	0.53	0.76	0.99	1.21	1.63	2.05	2.25	2.20	1.75
14	0.04	0.09	0.16	0.31	0.57	0.83	1.07	1.31	1.77	2.22	2.44	2.46	1.95
15	0.04	0.09	0.18	0.33	0.62	0.89	1.15	1.41	1.91	2.39	2.63	2.73	2.17
16	0.04	0.10	0.19	0.36	0.66	0.95	1.24	1.51	2.05	2.57	2.82	3.01	2.39
17	0.05	0.11	0.20	0.38	0.71	1.02	1.32	1.61	2.18	2.74	3.01	3.29	2.61
18	0.05	0.12	0.22	0.40	0.75	1.08	1.40	1.72	2.32	2.91	3.20	3.59	2.85
19	0.05	0.12	0.23	0.43	0.80	1.15	1.49	1.82	2.46	3.09	3.40	3.89	3.09
20	0.06	0.13	0.24	0.45	0.84	1.21	1.57	1.92	2.60	3.26	3.59	4.20	3.33
21	0.06	0.14	0.26	0.48	0.89	1.28	1.66	2.03	2.74	3.44	3.78	4.46	3.59
22	0.06	0.14	0.27	0.50	0.93	1.35	1.74	2.13	2.89	3.62	3.98	4.69	3.85
23	0.06	0.15	0.28	0.53	0.98	1.41	1.83	2.24	3.03	3.80	4.17	4.92	4.11
24	0.07	0.16	0.29	0.55	1.03	1.48	1.92	2.34	3.17	3.97	4.37	5.15	4.38
25	0.07	0.17	0.31	0.57	1.07	1.55	2.00	2.45	3.31	4.15	4.57	5.38	4.66
26	0.07	0.17	0.32	0.60	1.12	1.61	2.09	2.55	3.46	4.33	4.76	5.61	4.94
28	0.08	0.19	0.35	0.65	1.21	1.75	2.26	2.77	3.74	4.69	5.16	6.08	5.52
30	0.08	0.20	0.38	0.70	1.31	1.88	2.44	2.98	4.03	5.06	5.56	6.55	6.13
32	0.09	0.22	0.40	0.75	1.40	2.02	2.61	3.20	4.33	5.42	5.96	7.03	6.75
35	0.10	0.24	0.44	0.83	1.54	2.22	2.88	3.52	4.76	5.97	6.57	7.74	7.72
40	0.12	0.27	0.51	0.96	1.78	2.57	3.33	4.07	5.50	6.90	7.59	8.94	9.43
45	0.14	0.31	0.58	1.08	2.02	2.92	3.78	4.62	6.25	7.84	8.62	10.2	11.3
	Type A				Type B							Type C	

⅝-inch Pitch Standard Single-Strand Roller Chain — No. 50

No. of Teeth Small Spkt.	Revolutions per Minute — Small Sprocket[a]												
	25	50	100	200	300	400	500	700	900	1000	1200	1400	1600
	Horsepower Rating												
11	0.24	0.45	0.84	1.56	2.25	2.92	3.57	4.83	6.06	6.66	7.85	8.13	6.65
12	0.26	0.49	0.92	1.72	2.47	3.21	3.92	5.31	6.65	7.31	8.62	9.26	7.58
13	0.29	0.54	1.00	1.87	2.70	3.50	4.27	5.78	7.25	7.97	9.40	10.4	8.55
14	0.31	0.58	1.09	2.03	2.92	3.79	4.63	6.27	7.86	8.64	10.2	11.7	9.55
15	0.34	0.63	1.17	2.19	3.15	4.08	4.99	6.75	8.47	9.31	11.0	12.6	10.6
16	0.36	0.67	1.26	2.34	3.38	4.37	5.35	7.24	9.08	9.98	11.8	13.5	11.7
17	0.39	0.72	1.34	2.50	3.61	4.67	5.71	7.73	9.69	10.7	12.6	14.4	12.8
18	0.41	0.76	1.43	2.66	3.83	4.97	6.07	8.22	10.3	11.3	13.4	15.3	13.9
19	0.43	0.81	1.51	2.82	4.07	5.27	6.44	8.72	10.9	12.0	14.2	16.3	15.1
20	0.46	0.86	1.60	2.98	4.30	5.57	6.80	9.21	11.5	12.7	15.0	17.2	16.3
21	0.48	0.90	1.69	3.14	4.53	5.87	7.17	9.71	12.2	13.4	15.8	18.1	17.6
22	0.51	0.95	1.77	3.31	4.76	6.17	7.54	10.2	12.8	14.1	16.6	19.1	18.8
23	0.53	1.00	1.86	3.47	5.00	6.47	7.91	10.7	13.4	14.8	17.4	20.0	20.1
24	0.56	1.04	1.95	3.63	5.23	6.78	8.29	11.2	14.1	15.5	18.2	20.9	21.4
25	0.58	1.09	2.03	3.80	5.47	7.08	8.66	11.7	14.7	16.2	19.0	21.9	22.8
26	0.61	1.14	2.12	3.96	5.70	7.39	9.03	12.2	15.3	16.9	19.9	22.8	24.2
28	0.66	1.23	2.30	4.29	6.18	8.01	9.79	13.2	16.6	18.3	21.5	24.7	27.0
30	0.71	1.33	2.48	4.62	6.66	8.63	10.5	14.3	17.9	19.7	23.2	26.6	30.0
32	0.76	1.42	2.66	4.96	7.14	9.25	11.3	15.3	19.2	21.1	24.9	28.6	32.2
35	0.84	1.57	2.93	5.46	7.86	10.2	12.5	16.9	21.1	23.2	27.4	31.5	35.5
40	0.97	1.81	3.38	6.31	9.08	11.8	14.4	19.5	24.4	26.8	31.6	36.3	41.0
45	1.10	2.06	3.84	7.16	10.3	13.4	16.3	22.1	27.7	30.5	35.9	41.3	46.5
	Type A			Type B					Type C				

¾-inch Pitch Standard Single-Strand Roller Chain — No. 60

No. of Teeth Small Spkt.	Revolutions per Minute — Small Sprocket[a]												
	25	50	100	150	200	300	400	500	600	700	800	900	1000
	Horsepower Rating												
11	0.41	0.77	1.44	2.07	2.69	3.87	5.02	6.13	7.23	8.30	9.36	10.4	11.4
12	0.45	0.85	1.58	2.28	2.95	4.25	5.51	6.74	7.94	9.12	10.3	11.4	12.6
13	0.50	0.92	1.73	2.49	3.22	4.64	6.01	7.34	8.65	9.94	11.2	12.5	13.7
14	0.54	1.00	1.87	2.69	3.49	5.02	6.51	7.96	9.37	10.8	12.1	13.5	14.8
15	0.58	1.08	2.01	2.90	3.76	5.41	7.01	8.57	10.1	11.6	13.1	14.5	16.0
16	0.62	1.16	2.16	3.11	4.03	5.80	7.52	9.19	10.8	12.4	14.0	15.6	17.1
17	0.66	1.24	2.31	3.32	4.30	6.20	8.03	9.81	11.6	13.3	15.0	16.7	18.3
18	0.70	1.31	2.45	3.53	4.58	6.59	8.54	10.4	12.3	14.1	15.9	17.7	19.5
19	0.75	1.39	2.60	3.74	4.85	6.99	9.05	11.1	13.0	15.0	16.9	18.8	20.6
20	0.79	1.47	2.75	3.96	5.13	7.38	9.57	11.7	13.8	15.8	17.9	19.8	21.8
21	0.83	1.55	2.90	4.17	5.40	7.78	10.1	12.3	14.5	16.7	18.8	20.9	23.0
22	0.87	1.63	3.05	4.39	5.68	8.19	10.6	13.0	15.3	17.5	19.8	22.0	24.2
23	0.92	1.71	3.19	4.60	5.96	8.59	11.1	13.6	16.0	18.4	20.8	23.1	25.4
24	0.96	1.79	3.35	4.82	6.24	8.99	11.6	14.2	16.8	19.3	21.7	24.2	26.6
25	1.00	1.87	3.50	5.04	6.52	9.40	12.2	14.9	17.5	20.1	22.7	25.3	27.8
26	1.05	1.95	3.65	5.25	6.81	9.80	12.7	15.5	18.3	21.0	23.7	26.4	29.0
28	1.13	2.12	3.95	5.69	7.37	10.6	13.8	16.8	19.8	22.8	25.7	28.5	31.4
30	1.22	2.28	4.26	6.13	7.94	11.4	14.8	18.1	21.4	24.5	27.7	30.8	33.8
32	1.31	2.45	4.56	6.57	8.52	12.3	15.9	19.4	22.9	26.3	29.7	33.0	36.3
35	1.44	2.69	5.03	7.24	9.38	13.5	17.5	21.4	25.2	29.0	32.7	36.3	39.9
40	1.67	3.11	5.81	8.37	10.8	15.6	20.2	24.7	29.1	33.5	37.7	42.0	46.1
45	1.89	3.53	6.60	9.50	12.3	17.7	23.0	28.1	33.1	38.0	42.9	47.7	52.4
	Type A		Type B							Type C			

1-inch Pitch Standard Single-Strand Roller Chain — No. 80

No. of Teeth Small Spkt.	Revolutions per Minute — Small Sprocket[a]												
	25	50	100	150	200	300	400	500	600	700	800	900	1000
	Horsepower Ratings												
11	0.97	1.80	3.36	4.84	6.28	9.04	11.7	14.3	16.9	19.4	21.9	23.0	19.6
12	1.06	1.98	3.69	5.32	6.89	9.93	12.9	15.7	18.5	21.3	24.0	26.2	22.3
13	1.16	2.16	4.03	5.80	7.52	10.8	14.0	17.1	20.2	23.2	26.2	29.1	25.2
14	1.25	2.34	4.36	6.29	8.14	11.7	15.2	18.6	21.9	25.1	28.4	31.5	28.2
15	1.35	2.52	4.70	6.77	8.77	12.6	16.4	20.0	23.6	27.1	30.6	34.0	31.2
16	1.45	2.70	5.04	7.26	9.41	13.5	17.6	21.5	25.3	29.0	32.8	36.4	34.4
17	1.55	2.88	5.38	7.75	10.0	14.5	18.7	22.9	27.0	31.0	35.0	38.9	37.7
18	1.64	3.07	5.72	8.25	10.7	15.4	19.9	24.4	28.7	33.0	37.2	41.4	41.1
19	1.74	3.25	6.07	8.74	11.3	16.3	21.1	25.8	30.4	35.0	39.4	43.8	44.5
20	1.84	3.44	6.41	9.24	12.0	17.2	22.3	27.3	32.2	37.0	41.7	46.3	48.1
21	1.94	3.62	6.76	9.74	12.6	18.2	23.5	28.8	33.9	39.0	43.9	48.9	51.7
22	2.04	3.81	7.11	10.2	13.3	19.1	24.8	30.3	35.7	41.0	46.2	51.4	55.5
23	2.14	4.00	7.46	10.7	13.9	20.1	26.0	31.8	37.4	43.0	48.5	53.9	59.3
24	2.24	4.19	7.81	11.3	14.6	21.0	27.2	33.2	39.2	45.0	50.8	56.4	62.0
25	2.34	4.37	8.16	11.8	15.2	21.9	28.4	34.7	40.9	47.0	53.0	59.0	64.8
26	2.45	4.56	8.52	12.3	15.9	22.9	29.7	36.2	42.7	49.1	55.3	61.5	67.6
28	2.65	4.94	9.23	13.3	17.2	24.8	32.1	39.3	46.3	53.2	59.9	66.7	73.3
30	2.85	5.33	9.94	14.3	18.5	26.7	34.6	42.3	49.9	57.3	64.6	71.8	78.9
32	3.06	5.71	10.7	15.3	19.9	28.6	37.1	45.4	53.5	61.4	69.2	77.0	84.6
35	3.37	6.29	11.7	16.9	21.9	31.6	40.9	50.0	58.9	67.6	76.3	84.8	93.3
40	3.89	7.27	13.6	19.5	25.3	36.4	47.2	57.7	68.0	78.1	88.1	99.0	108
45	4.42	8.25	15.4	22.2	28.7	41.4	53.6	65.6	77.2	88.7	100	111	122
	Type A	Type B						Type C					

1¼-inch Pitch Standard Single-Strand Roller Chain — No. 100

No. of Teeth Small Spkt.	Revolutions per Minute — Small Sprocket[a]												
	10	25	50	100	150	200	300	400	500	600	700	800	900
	Horsepower Rating												
11	0.81	1.85	3.45	6.44	9.28	12.0	17.3	22.4	27.4	32.3	37.1	32.8	27.5
12	0.89	2.03	3.79	7.08	10.2	13.2	19.0	24.6	30.1	35.5	40.8	37.3	31.3
13	0.97	2.22	4.13	7.72	11.1	14.4	20.7	26.9	32.8	38.7	44.5	42.1	35.3
14	1.05	2.40	4.48	8.36	12.0	15.6	22.5	29.1	35.6	41.9	48.2	47.0	39.4
15	1.13	2.59	4.83	9.01	13.0	16.8	24.2	31.4	38.3	45.2	51.9	52.2	43.7
16	1.22	2.77	5.17	9.66	13.9	18.0	26.0	33.6	41.1	48.4	55.6	57.5	48.2
17	1.30	2.96	5.52	10.3	14.8	19.2	27.7	35.9	43.9	51.7	59.4	63.0	52.8
18	1.38	3.15	5.88	11.0	15.8	20.5	29.5	38.2	46.7	55.0	63.2	68.6	57.5
19	1.46	3.34	6.23	11.6	16.7	21.7	31.2	40.5	49.5	58.3	67.0	74.4	62.3
20	1.55	3.53	6.58	12.3	17.7	22.9	33.0	42.8	52.3	61.6	70.8	79.8	67.3
21	1.63	3.72	6.94	13.0	18.7	24.2	34.8	45.1	55.1	65.0	74.6	84.2	72.4
22	1.71	3.91	7.30	13.6	19.6	25.4	36.6	47.4	58.0	68.3	78.5	88.5	77.7
23	1.80	4.10	7.66	14.3	20.6	26.7	38.4	49.8	60.8	71.7	82.3	92.8	83.0
24	1.88	4.30	8.02	15.0	21.5	27.9	40.2	52.1	63.7	75.0	86.2	97.2	88.5
25	1.97	4.49	8.38	15.6	22.5	29.2	42.0	54.4	66.6	78.4	90.1	102	94.1
26	2.05	4.68	8.74	16.3	23.5	30.4	43.8	56.8	69.4	81.8	94.0	106	99.8
28	2.22	5.07	9.47	17.7	25.5	33.0	47.5	61.5	75.2	88.6	102	115	112
30	2.40	5.47	10.2	19.0	27.4	35.5	51.2	66.3	81.0	95.5	110	124	124
32	2.57	5.86	10.9	20.4	29.4	38.1	54.9	71.1	86.9	102	118	133	136
35	2.83	6.46	12.0	22.5	32.4	42.0	60.4	78.3	95.7	113	130	146	156
40	3.27	7.46	13.9	26.0	37.4	48.5	69.8	90.4	111	130	150	169	188
45	3.71	8.47	15.8	29.5	42.5	55.0	79.3	103	126	148	170	192	213
	Type A		Type B				Type C						

1½-inch Pitch Standard Single-Strand Roller Chain — No. 120

No. of Teeth Small Spkt.	Revolutions per Minute — Small Sprocket[a]												
	10	25	50	100	150	200	300	400	500	600	700	800	900
	Horsepower Rating												
11	1.37	3.12	5.83	10.9	15.7	20.3	29.2	37.9	46.3	54.6	46.3	37.9	31.8
12	1.50	3.43	6.40	11.9	17.2	22.3	32.1	41.6	50.9	59.9	52.8	43.2	36.2
13	1.64	3.74	6.98	13.0	18.8	24.3	35.0	45.4	55.5	65.3	59.5	48.7	40.8
14	1.78	4.05	7.56	14.1	20.3	26.3	37.9	49.1	60.1	70.8	66.5	54.4	45.6
15	1.91	4.37	8.15	15.2	21.9	28.4	40.9	53.0	64.7	76.3	73.8	60.4	50.6
16	2.05	4.68	8.74	16.3	23.5	30.4	43.8	56.8	69.4	81.8	81.3	66.5	55.7
17	2.19	5.00	9.33	17.4	25.1	32.5	46.8	60.6	74.1	87.3	89.0	72.8	61.0
18	2.33	5.32	9.92	18.5	26.7	34.6	49.8	64.5	78.8	92.9	97.0	79.4	66.5
19	2.47	5.64	10.5	19.6	28.3	36.6	52.8	68.4	83.6	98.5	105	86.1	72.1
20	2.61	5.96	11.1	20.7	29.9	38.7	55.8	72.2	88.3	104	114	92.9	77.9
21	2.75	6.28	11.7	21.9	31.5	40.8	58.8	76.2	93.1	110	122	100	83.8
22	2.90	6.60	12.3	23.0	33.1	42.9	61.8	80.1	97.9	115	131	107	89.9
23	3.04	6.93	12.9	24.1	34.8	45.0	64.9	84.0	103	121	139	115	96.1
24	3.18	7.25	13.5	25.3	36.4	47.1	67.9	88.0	108	127	146	122	102
25	3.32	7.58	14.1	26.4	38.0	49.3	71.0	91.9	112	132	152	130	109
26	3.47	7.91	14.8	27.5	39.7	51.4	74.0	95.9	117	138	159	138	115
28	3.76	8.57	16.0	29.8	43.0	55.7	80.2	104	127	150	172	154	129
30	4.05	9.23	17.2	32.1	46.3	60.0	86.4	112	137	161	185	171	143
32	4.34	9.90	18.5	34.5	49.6	64.3	92.6	120	147	173	199	188	158
35	4.78	10.9	20.3	38.0	54.7	70.9	102	132	162	190	219	215	180
40	5.52	12.6	23.5	43.9	63.2	81.8	118	153	187	220	253	…	…
45	6.27	14.3	26.7	49.8	71.7	92.9	134	173	212	250	287	…	…
	Type A	Type B					Type C						

[a] For lower or higher rpm, larger chain sizes, and rpm above 3500, see B29.1M-1993.

For use of table see page 2431.

Table 9. Recommended Roller Chain Sprocket Maximum Bore and Hub Diameters

	Roller Chain Pitch									
	3/8		1/2		5/8		3/4		1	
No. of Teeth	Max. Bore	Max. Hub Dia.	Max. Bore	Max. Hub Dia.	Max. Bore	Max. Hub Dia.	Max. Bore	Max. Hub Dia.	Max. Bore	Max. Hub Dia.
11	19/32	55/64	25/32	1 11/64	31/32	1 15/32	1 1/4	1 49/64	1 5/8	2 3/8
12	5/8	63/64	7/8	1 21/64	1 5/32	1 43/64	1 9/32	2 1/64	1 25/32	2 45/64
13	3/4	1 7/64	1	1 1/2	1 9/32	1 7/8	1 1/2	2 1/4	2	3 1/64
14	27/32	1 15/64	1 5/32	1 21/32	1 5/16	2 5/64	1 3/4	2 1/2	2 9/32	3 11/32
15	7/8	1 23/64	1 1/4	1 13/16	1 17/32	2 9/32	1 25/32	2 3/4	2 13/32	3 43/64
16	31/32	1 15/32	1 9/32	1 63/64	1 11/16	2 31/64	1 31/32	2 63/64	2 23/32	3 63/64
17	1 3/32	1 19/32	1 3/8	2 9/64	1 25/32	2 11/16	2 7/32	3 7/32	2 13/16	4 5/16
18	1 7/32	1 23/32	1 17/32	2 19/64	1 7/8	2 57/64	2 9/32	3 15/32	3 1/8	4 41/64
19	1 1/4	1 27/32	1 11/16	2 29/64	2 1/16	3 5/64	2 7/16	3 45/64	3 5/16	4 61/64
20	1 9/32	1 61/64	1 25/32	2 5/8	2 1/4	3 9/32	2 11/16	3 61/64	3 1/2	5 9/32
21	1 5/16	2 5/64	1 25/32	2 25/32	2 9/32	3 31/64	2 13/16	4 3/16	3 3/4	5 19/32
22	1 7/16	2 13/16	1 15/16	2 15/16	2 7/16	3 11/16	2 15/16	4 7/16	3 7/8	5 59/64
23	1 9/16	2 5/16	2 3/32	3 3/32	2 5/8	3 57/64	3 1/8	4 43/64	4 3/16	6 15/64
24	1 11/16	2 7/16	2 1/4	3 17/64	2 13/16	4 5/64	3 1/4	4 29/32	4 9/16	6 9/16
25	1 3/4	2 9/16	2 9/32	3 27/64	2 27/32	4 9/32	3 3/8	5 5/32	4 11/16	6 7/8

	Roller Chain Pitch									
	1 1/4		1 1/2		1 3/4		2		2 1/2	
No. of Teeth	Max. Bore	Max. Hub Dia.	Max. Bore	Max. Hub Dia.	Max. Bore	Max. Hub Dia.	Max. Bore	Max. Hub Dia.	Max. Bore	Max. Hub Dia.
11	1 31/32	2 31/32	2 5/16	3 37/64	2 13/16	4 11/64	3 9/32	4 25/32	3 15/16	5 63/64
12	2 9/32	3 3/8	2 3/4	4 1/16	3 1/4	4 3/4	3 5/8	5 27/64	4 23/32	6 51/64
13	2 17/32	3 25/32	3 1/16	4 35/64	3 9/16	5 5/16	4 1/16	6 5/64	5 3/32	7 39/64
14	2 11/16	4 3/16	3 5/16	5 1/32	3 7/8	5 7/8	4 11/16	6 23/32	5 23/32	8 27/64
15	3 3/32	4 19/32	3 3/4	5 33/64	4 7/16	6 29/64	4 7/8	7 3/8	6 1/4	9 7/32
16	3 9/32	5	4	6	4 11/16	7 1/64	5 1/2	8 1/64	7	10 1/32
17	3 21/32	5 13/32	4 15/32	6 31/64	5 1/16	7 37/64	5 11/16	8 21/32	7 7/16	10 27/32
18	3 25/32	5 51/64	4 21/32	6 31/32	5 5/8	8 9/64	6 1/4	9 5/16	8 1/8	11 41/64
19	4 3/16	6 13/64	4 15/16	7 29/64	5 11/16	8 45/64	6 7/8	9 61/64	9	12 7/16
20	4 19/32	6 39/64	5 7/16	7 15/16	6 1/4	9 17/64	7	10 19/32	9 3/4	13 1/4
21	4 11/16	7	5 11/16	8 27/64	6 13/16	9 53/64	7 3/4	11 15/64	10	14 3/64
22	4 7/8	7 13/32	5 7/8	8 57/64	7 1/4	10 25/64	8 3/8	11 7/8	10 7/8	14 27/32
23	5 5/16	7 13/16	6 3/8	9 3/8	7 7/16	10 15/16	9	12 33/64	11 5/8	15 21/32
24	5 11/16	8 13/64	6 13/16	9 55/64	8	11 1/2	9 5/8	13 5/32	13	16 29/64
25	5 23/32	8 39/64	7 1/4	10 11/32	8 9/16	12 1/16	10 1/4	13 51/64	13 1/2	17 1/4

All dimensions in inches.

For standard key dimensions see pages 2342 through 2343.

Source: American Chain Association.

Center Distance between Sprockets.—The center-to-center distance between sprockets, as a general rule, should not be less than 1 1/2 times the diameter of the larger sprocket and not less than thirty times the pitch nor more than about 50 times the pitch, although much depends upon the speed and other conditions. A center distance equivalent to 80 pitches may be considered an approved maximum. Very long center distances result in catenary tension in the chain. If roller-chain drives are designed correctly, the center-to-center distance for some transmissions may be so short that the sprocket teeth nearly touch each other, assuming that the load is not too great and the number of teeth is not too small. To avoid interference of the sprocket teeth, the center distance must, of course, be somewhat greater than one-half the sum of the outside diameters of the sprockets. The chain should extend around at least 120 degrees of the pinion circumference, and this minimum amount of contact is obtained for all center distances provided the ratio is less than 3½ to 1. Other things being equal, a fairly long chain is recommended in preference to the shortest one allowed by the sprocket diameters, because the rate of chain elongation due to natural wear is inversely proportional to the length, and also because the greater elasticity of the longer strand tends to absorb irregularities of motion and to decrease the effect of shocks.

If possible, the center distance should be adjustable in order to take care of slack due to elongation from wear and this range of adjustment should be at least one and one-half pitches. A little slack is desirable as it allows the chain links to take the best position on the sprocket teeth and reduces the wear on the bearings. Too much sag or an excessive distance between the sprockets may cause the chain to whip up and down — a condition detrimental to smooth running and very destructive to the chain. The sprockets should run in a vertical plane, the sprocket axes being approximately horizontal, unless an idler is used on the slack side to keep the chain in position. The most satisfactory results are obtained when the slack side of the chain is on the bottom.

Center Distance for a Given Chain Length.—When the distance between the driving and driven sprockets can be varied to suit the length of the chain, this center distance for a tight chain may be determined by the following formula, in which c = center-to-center distance in inches; L = chain length in pitches; P = pitch of chain; N = number of teeth in large sprocket; n = number of teeth in small sprocket.

$$c = \frac{P}{8}\left(2L - N - n + \sqrt{(2L - N - n)^2 - 0.810(N - n)^2}\right)$$

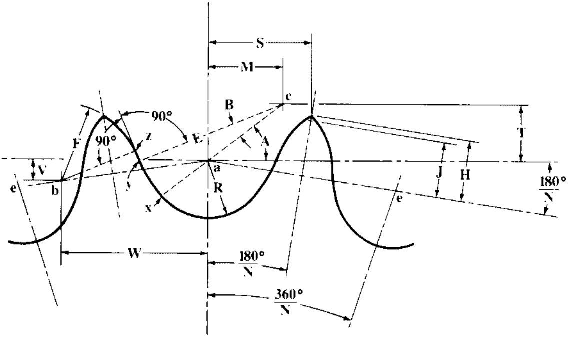
This formula is approximate, but the error is less than the variation in the length of the best chains. The length L in pitches should be an even number for a roller chain, so that the use of an offset connecting link will not be necessary.

Idler Sprockets.—When sprockets have a fixed center distance or are non-adjustable, it may be advisable to use an idler sprocket for taking up the slack. The idler should preferably be placed against the slack side between the two strands of the chain. When a sprocket is applied to the tight side of the chain to reduce vibration, it should be on the lower side and so located that the chain will run in a straight line between the two main sprockets. A sprocket will wear excessively if the number of teeth is too small and the speed too high, because there is impact between the teeth and rollers even though the idler carries practically no load.

Length of Driving Chain.—The total length of a block chain should be given in multiples of the pitch, whereas for a roller chain, the length should be in multiples of twice the pitch, because the ends must be connected with an outside and inside link. The length of a chain can be calculated accurately enough for ordinary practice by the use of the following formula, in which L = chain length in pitches; C = center distance in pitches; N = number of teeth in large sprocket; n = number of teeth in small sprocket:

$$L = 2C + \frac{N}{2} + \frac{n}{2} + \left(\frac{N - n}{2\pi}\right)^2 \times \frac{1}{C}$$

Table 10. ANSI Sprocket Tooth Form for Roller Chain *ANSI/ASME B29.1M-1993*



Seating Curve Data—Inches

P	D_r	Min. R	Min. D_s	D_s Tol.[a]	P	D_r	Min. R	Min. D_s	D_s Tol.[a]
0.250	0.130	0.0670	0.134	0.0055	1.250	0.750	0.3785	0.757	0.0070
0.375	0.200	0.1020	0.204	0.0055	1.500	0.875	0.4410	0.882	0.0075
0.500	0.306	0.1585	0.317	0.0060	1.750	1.000	0.5040	1.008	0.0080
0.500	0.312	0.1585	0.317	0.0060	2.000	1.125	0.5670	1.134	0.0085
0.625	0.400	0.2025	0.405	0.0060	2.250	1.406	0.7080	1.416	0.0090
0.750	0.469	0.2370	0.474	0.0065	2.500	1.562	0.7870	1.573	0.0095
1.000	0.625	0.3155	0.631	0.0070	3.000	1.875	0.9435	1.887	0.0105

[a] Plus tolerance only.

P = pitch (ae)

N = number of teeth D_r = nominal roller diameter

D_s = seating curve diameter = $1.005\,D_r + 0.003$ (in inches)

$R = \frac{1}{2}D_s$ (D_s has only plus tolerance)

$A = 35° + (60° \div N)$ $B = 18° - (56° \div N)$ $ac = 0.8\,D_r$

$M = 0.8\,D_r \cos(35° + (60° \div N))$

$T = 0.8\,D_r \sin(35° + (60° \div N))$

$E = 1.3025\,D_r + 0.0015$ (in inches)

Chord $xy = (2.605\,D_r + 0.003) \sin 9° - (28° \div N))$ (in inches)

$yz = D_r\,[1.4 \sin(17° - (64° \div N)) - 0.8 \sin(18° - (56° \div N))]$

Length of a line between a and $b = 1.4\,D_r$

$W = 1.4\,D_r \cos(180° \div N)$; $V = 1.4\,D_r \sin(180° \div N)$

$F = D_r\,[0.8 \cos(18° - (56° \div N)) + 1.4 \cos(17° - (64° \div N)) - 1.3025] - 0.0015$ inch

$H = \sqrt{F^2} - (1.4D_r - 0.5P)^2$

$S = 0.5\,P \cos(180° \div N) + H \sin(180° \div N)$

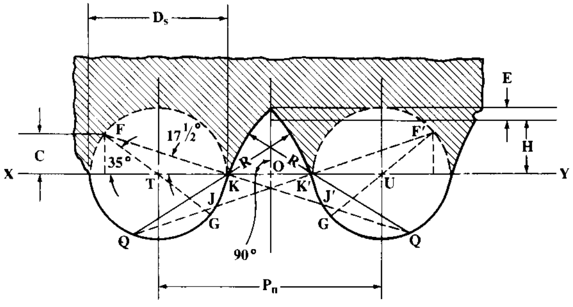
Approximate O.D. of sprocket when J is $0.3\,P = P\,[0.6 + \cot(180° \div N)]$

O.D. of sprocket when tooth is pointed $+ P \cot(180° \div N) + \cos(180° \div N)\,(D_s - D_r) + 2H$

Pressure angle for new chain $= xab = 35° - (120° \div N)$

Minimum pressure angle $= xab - B = 17° - (64° \div N)$;
Average pressure angle $= 26° - (92° \div N)$

Table 11. Standard Hob Design for Roller Chain Sprockets



Section Normal to Hob Teeth

Data for Laying Out Hob Outlines — Inches

P	P_n	H	E	O.D.	W	Bore	Keyway	No. Gashes
$\frac{1}{4}$	0.2527	0.0675	0.0075	$2\frac{5}{8}$	$2\frac{1}{2}$	1.250	$\frac{1}{4}\times\frac{1}{8}$	13
$\frac{3}{8}$	0.379	0.101	0.012	$3\frac{1}{8}$	$2\frac{1}{2}$	1.250	$\frac{1}{4}\times\frac{1}{8}$	13
$\frac{1}{2}$	0.506	0.135	0.015	$3\frac{3}{8}$	$2\frac{1}{2}$	1.250	$\frac{1}{4}\times\frac{1}{8}$	12
$\frac{5}{8}$	0.632	0.170	0.018	$3\frac{5}{8}$	$2\frac{1}{2}$	1.250	$\frac{11}{4}\times\frac{1}{8}$	12
$\frac{3}{4}$	0.759	0.202	0.023	$3\frac{3}{4}$	$2\frac{7}{8}$	1.250	$\frac{1}{4}\times\frac{1}{8}$	11
1	1.011	0.270	0.030	$4\frac{3}{8}$	$3\frac{3}{4}$	1.250	$\frac{1}{4}\times\frac{1}{8}$	11
$1\frac{1}{4}$	1.264	0.337	0.038	$4\frac{3}{4}$	$4\frac{1}{2}$	1.250	$\frac{1}{4}\times\frac{1}{8}$	10
$1\frac{1}{2}$	1.517	0.405	0.045	$5\frac{3}{8}$	$5\frac{1}{4}$	1.250	$\frac{1}{4}\times\frac{1}{8}$	10
$1\frac{3}{4}$	1.770	0.472	0.053	$6\frac{3}{8}$	6	1.500	$\frac{3}{8}\times\frac{3}{16}$	9
2	2.022	0.540	0.060	$6\frac{7}{8}$	$6\frac{3}{4}$	1.500	$\frac{3}{8}\times\frac{3}{16}$	9
$2\frac{1}{4}$	2.275	0.607	0.068	8	$8\frac{1}{2}$	1.750	$\frac{3}{8}\times\frac{3}{16}$	8
$2\frac{1}{2}$	2.528	0.675	0.075	$8\frac{5}{8}$	$9\frac{3}{8}$	1.750	$\frac{3}{8}\times\frac{3}{16}$	8
3	3.033	0.810	0.090	$9\frac{3}{4}$	$11\frac{1}{4}$	2.000	$\frac{1}{2}\times\frac{3}{6}$	8

Hobs designed for a given roller diameter (D_r) and chain pitch (P) will cut any number of teeth.

P = Pitch of Chain
P_n = Normal Pitch of Hob = $1.011\,P$ inches
D_s = Minimum Diameter of Seating Curve = $1.005\,D_r + 0.003$ inches
F = Radius Center for Arc GK; $TO = OU = P_n \div 2$
$H = 0.27\,P$; $E = 0.03\,P$ = Radius of Fillet Circle

Q is located on line passing through F and J. Point J is intersection of line XY with circle of diameter D_s. R is found by trial and the arc of this radius is tangent to arc KG at K and to fillet radius.

OD = Outside Diameter = $1.7\,(\text{Bore} + D_r + 0.7\,P)$ approx.
D_h = Pitch Diameter = $OD - D_s$; M = Helix Angle; $\sin M = P_n \div \pi D_h$
L = Lead = $P_n \div \cos M$; W = Width = Not less than $2 \times$ Bore, or $6\,D_r$, or $3.2\,P$

To the length obtained by this formula, add enough to make a whole number (and for a roller chain, an even number) of pitches. If a roller chain has an odd number of pitches, it will be necessary to use an offset connecting link.

Another formula for obtaining chain length in which D = distance between centers of shafts; R = pitch radius of large sprocket; r = pitch radius of small sprocket: N = number of teeth in large sprocket; n = number of teeth in small sprocket; P = pitch of chain and sprockets; and l = required chain length in inches, is:

$$l = \frac{180^\circ + 2\alpha}{360^\circ}NP + \frac{180^\circ - 2\alpha}{360^\circ}nP + 2D\cos\alpha \qquad \text{where } \sin\alpha = \frac{R-r}{D}$$

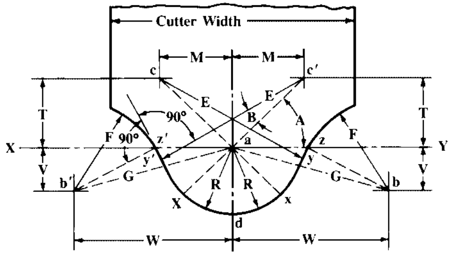
Cutting Standard Sprocket Tooth Form.—The proportions and seating curve data for the standard sprocket tooth form for roller chain are given in Table 10. Either formed or generating types of sprocket cutters may be employed.

Hobs: Only one hob will be required to cut any number of teeth for a given pitch and roller diameter. All hobs should be marked with pitch and roller diameter to be cut. Formulas and data for standard hob design are given in Table 11.

Space Cutters: Five cutters of this type will be required to cut from 7 teeth up for any given roller diameter. The ranges are, respectively, 7–8, 9–11, 12–17, 18–34, and 35 teeth and over. If less than 7 teeth is necessary, special cutters conforming to the required number of teeth should be used.

The regular cutters are based upon an intermediate number of teeth N_a, equal to $2N_1N_2 \div (N_1 + N_2)$ in which N_1 = minimum number of teeth and N_2 = maximum number of teeth for which cutter is intended; but the topping curve radius F (see diagram in Table 12) is designed to produce adequate tooth height on a sprocket of N_2 teeth. The values of N_a for the several cutters are, respectively, 7.47, 9.9, 14.07, 23.54, and 56. Formulas and construction data for space cutter layout are given in Table 12 and recommended cutter sizes are given in Table 13.

Table 12. Standard Space Cutters for Roller-Chain Sprockets



Data for Laying Out Space Cutter				
Range of Teeth	*M*	*T*	*W*	*V*
7–8	0.5848 D_r	0.5459 D_r	1.2790 D_r	0.5694 D_r
9–11	0.6032 D_r	0.5255 D_r	1.3302 D_r	0.4365 D_r
12–17	0.6194 D_r	0.5063 D_r	1.3694 D_r	0.2911 D_r
18–34	0.6343 D_r	0.4875 D_r	1.3947 D_r	0.1220 D_r
35 up	0.6466 D_r	0.4710 D_r	1.4000 D_r	0
Range of Teeth	*F*	Chord *xy*	*yz*	Angle *Yab*
7–8	0.8686 D_r – 0.0015	0.2384 D_r + 0.0003	0.0618 D_r	24°
9–11	0.8554 D_r – 0.0015	0.2800 D_r + 0.0003	0.0853 D_r	18° 10′
12–17	0.8364 D_r – 0.0015	0.3181 D_r + 0.0004	0.1269 D_r	12°
18–34	0.8073 D_r – 0.0015	0.3540 D_r + 0.0004	0.1922 D_r	5°
35 up	0.7857 D_r – 0.0015	0.3850 D_r + 0.0004	0.2235 D_r	0°

E (same for all ranges) = $1.3025\,D_r + 0.0015$; G (same for all ranges) = $1.4\,D_r$

See Table 13 for recommended cutter sizes.

Angle *Yab* is equal to 180° ÷ N when the cutter is made for a specific number of teeth. For the design of cutters covering a range of teeth, angle *Yab* was determined by layout to ensure chain roller clearance and to avoid pointed teeth on the larger sprockets of each range. It has values as given below for cutters covering the range of teeth shown. The following formulas are for cutters covering the standard ranges of teeth where N_a equals intermediate values given on page 2440.

$$W = 1.4D_r \cos Yab \qquad V = 1.4D_r \sin Yab$$

$$yz = D_r\left[1.4\sin\left(17^\circ + \frac{116^\circ}{N_a} - Yab\right) - 0.8\sin\left(18^\circ - \frac{56^\circ}{N_a}\right)\right]$$

$$F = D_r\left[0.8\cos\left(18^\circ - \frac{56^\circ}{N_a}\right) + 1.4\cos\left(17^\circ + \frac{116^\circ}{N_a} - Yab\right) - 1.3025\right] - 0.0015 \text{ in.}$$

For other points, use the value of N_a for N in the standard formulas in Table 10.

Table 13. Recommended Space Cutter Sizes for Roller-Chain Sprockets

		Number of Teeth					
		6	7–8	9–11	12–17	18–34	35 up
Pitch	Roller Dia.	Cutter Diameter (Minimum)					
0.250	0.130	2.75	2.75	2.75	2.75	2.75	2.75
0.375	0.200	2.75	2.75	2.75	2.75	2.75	2.75
0.500	0.312	3.00	3.00	3.12	3.12	3.12	3.12
0.625	0.400	3.12	3.12	3.25	3.25	3.25	3.25
0.725	0.469	3.25	3.25	3.38	3.38	3.38	3.38
1.000	0.625	3.88	4.00	4.12	4.12	4.25	4.25
1.250	0.750	4.25	4.38	4.50	4.50	4.62	4.62
1.500	0.875	4.38	4.50	4.62	4.62	4.75	4.75
1.750	1.000	5.00	5.12	5.25	5.38	5.50	5.50
2.000	1.125	5.38	5.50	5.62	5.75	5.88	5.88
2.250	1.406	5.88	6.00	6.25	6.38	6.50	6.50
2.500	1.563	6.38	6.62	6.75	6.88	7.00	7.12
3.000	1.875	7.50	7.75	7.88	8.00	8.00	8.25
Pitch	Roller Dia.	Cutter Width (Minimum)					
0.250	0.130	0.31	0.31	0.31	0.31	0.28	0.28
0.375	0.200	0.47	0.47	0.47	0.44	0.44	0.41
0.500	0.312	0.75	0.75	0.75	0.75	0.72	0.69
0.625	0.400	0.75	0.75	0.75	0.75	0.72	0.69
0.750	0.469	0.91	0.91	0.91	0.88	0.84	0.81
1.000	0.625	1.50	1.50	1.47	1.47	1.41	1.34
1.250	0.750	1.81	1.81	1.78	1.75	1.69	1.62
1.500	0.875	1.81	1.81	1.78	1.75	1.69	1.62
1.750	1.000	2.09	2.09	2.06	2.03	1.97	1.88
2.000	1.125	2.41	2.41	2.38	2.31	2.25	2.16
2.250	1.406	2.69	2.69	2.66	2.59	2.47	2.41
2.500	1.563	3.00	3.00	2.94	2.91	2.75	2.69
3.000	1.875	3.59	3.59	3.53	3.47	3.34	3.22

Where the same roller diameter is commonly used with chains of two different pitches it is recommended that stock cutters be made wide enough to cut sprockets for both chains.

Marking of Cutters.— All cutters are to be marked, giving pitch, roller diameter and range of teeth to be cut.

Bores for Sprocket Cutters (recommended practice) are approximately as calculated from the formula:

$$\text{Bore} = 0.7\sqrt{(\text{Width of Cutter} + \text{Roller Diameter} + 0.7 \text{ Pitch})}$$

and are equal to 1 inch for ¼- through ¾-inch pitches; 1¼ inches for 1- through 1½-inch for 1¾- through 2¼-inch pitches; 1¾ inches for 2½-inch pitch; and 2 inches for 3-inch pitch.

Minimum Outside Diameters of Space Cutters for 35 teeth and over (recommended practice) are approximately as calculated from the formula:

$$\text{Outside Diameter} = 1.2(\text{Bore} + \text{Roller Diameter} + 0.7 \text{ Pitch}) + 1 \text{ in.}$$

Shaper Cutters: Only one will be required to cut any number of teeth for a given pitch and roller diameter. The manufacturer should be referred to for information concerning the cutter form design to be used.

Sprocket Manufacture.—Cast sprockets have cut teeth, and the rim, hub face, and bore are machined. The smaller sprockets are generally cut from steel bar stock, and are finished all over. Sprockets are often made from forgings or forged bars. The extent of finishing depends on the particular specifications that are applicable. Many sprockets are made by welding a steel hub to a steel plate. This process produces a one-piece sprocket of desired proportions and one that can be heat-treated.

Sprocket Materials.—For large sprockets, cast iron is commonly used, especially in drives with large speed ratios, since the teeth of the larger sprocket are subjected to fewer chain engagements in a given time. For severe service, cast steel or steel plate is preferred.

The smaller sprockets of a drive are usually made of steel. With this material the body of the sprocket can be heat-treated to produce toughness for shock resistance, and the tooth surfaces can be hardened to resist wear.

Stainless steel or bronze may be used for corrosion resistance, and Formica, nylon or other suitable plastic materials for special applications.

Roller Chain Drive Ratings.—In 1961, under auspices of The American Sprocket Chain Manufacturers Association (now called American Chain Association), a joint research program was begun to study pin-bushing interaction at high speeds and to gain further data on the phenomenon of chain joint galling among other research areas. These studies have shown that a separating film of lubricant is formed in chain joints in a manner similar to that found in journal bearings. These developments appear in ANSI/ASME B29.1M-1993, and are contained in Table . The ratings shown in Table are below the galling range.

The horsepower ratings in Table 14 apply to lubricated, single-pitch, single-strand roller chains, both ANSI Standard and Heavy series. To obtain ratings of multiple-strand chains, a multiple-strand factor is applied.

The ratings in Table 14 are based upon: 1) A service factor of 1.; 2) A chain length of approximately 100 pitches.; 3) Use of recommended lubrication methods.; and 4) A drive arrangement where two aligned sprockets are mounted on parallel shafts in a horizontal plane..

Under these conditions, approximately 15,000 hours of service life at full load operation may be expected.

Table 14. Roller Chain Drive Service Factors

Type of Driven Load	Type of Input Power		
	Internal Combustion Engine with Hydraulic Drive	Electric Motor or Turbine	Internal Combustion Engine with Mechanical Drive
Smooth	1.0	1.0	1.2
Moderate Shock	1.2	1.3	1.4
Heavy Shock	1.4	1.5	1.7

Substantial increases in rated speed loads can be utilized, as when a service life of less than 15,000 hours is satisfactory, or when full load operation is encountered only during a portion of the required service life. Chain manufacturers should be consulted for assistance with any special application requirements.

The horsepower ratings shown in Table relate to the speed of the smaller sprocket and drive selections are made on this basis, whether the drive is speed reducing or speed increasing. Drives with more than two sprockets, idlers, composite duty cycles, or other unusual conditions often require special consideration. Where quietness or extra smooth operation are of special importance, small-pitch chain operating over large diameter sprockets will minimize noise and vibration.

When making drive selection, consideration is given to the loads imposed on the chain by the type of input power and the type of equipment to be driven. Service factors are used to compensate for these loads and the *required* horsepower rating of the chain is determined by the following formula:

$$\text{Required hp Table Rating} = \frac{\text{hp to be Transmitted} \times \text{Service Factor}}{\text{Multiple-Strand Factor}}$$

Service Factors: The service factors in Table 14 are for normal chain loading. For unusual or extremely severe operating conditions not shown in this table, it is desirable to use larger service factors.

Multiple-Strand Factors: The horsepower ratings for multiple-strand chains equal single-strand ratings multiplied by these factors: for two strands, a factor of 1.7; for three strands, 2.5; and and for four strands, 3.3.

Lubrication.—It has been shown that a separating wedge of fluid lubricant is formed in operating chain joints much like that formed in journal bearings. Therefore, fluid lubricant must be applied to ensure an oil supply to the joints and minimize metal-to-metal contact. If supplied in sufficient volume, lubrication also provides effective cooling and impact damping at higher speeds. For this reason, it is important that lubrication recommendations be followed. *The ratings in* Table *apply only to drives lubricated in the manner specified in this table*.

Chain drives should be protected against dirt and moisture and the oil supply kept free of contamination. Periodic oil change is desirable. A good grade of non-detergent petroleum base oil is recommended. Heavy oils and greases are generally too stiff to enter and fill the chain joints. The following lubricant viscosities are recommended: For temperatures of 20° to 40°F, use SAE 20 lubricant; for 40° to 100°, use SAE 30; for 100° to 120°, use SAE 40; and for 120° to 140°, use SAE 50.

There are three basic types of lubrication for roller chain drives. The recommended type shown in Table as Type A, Type B, or Type C is influenced by the chain speed and the amount of power transmitted. These are *minimum* lubrication requirements and the use of a better type (for example, Type C instead of Type B) is acceptable and may be beneficial. Chain life can vary appreciably depending upon the way the drive is lubricated. The better the chain lubrication, the longer the chain life. For this reason, it is important that the lubrication recommendations be followed when using the ratings given in Table . The types of lubrication are as follows:

Type A — Manual or Drip Lubrication: In manual lubrication, oil is applied copiously with a brush or spout can at least once every eight hours of operation. Volume and frequency should be sufficient to prevent overheating of the chain or discoloration of the chain joints. In drip lubrication, oil drops from a drip lubricator are directed between the link plate edges. The volume and frequency should be sufficient to prevent discoloration of the lubricant in the chain joints. Precautions must be taken against misdirection of the drops by windage.

Type B — Bath or Disc Lubrication: In bath lubrication, the lower strand of the chain runs through a sump of oil in the drive housing. The oil level should reach the pitch line of the chain at its lowest point while operating. In disc lubrication, the chain operates above the oil level. The disc picks up oil from the sump and deposits it onto the chain, usually by means of a trough. The diameter of the disc should be such as to produce rim speeds of between 600 and 8000 feet per minute.

Type C — Oil Stream Lubrication: The lubricant is usually supplied by a circulating pump capable of supplying each chain drive with a continuous stream of oil. The oil should be applied inside the chain loop evenly across the chain width, and directed at the slack strand.

The chain manufacturer should be consulted when it appears desirable to use a type of lubricant other than that recommended.

Installation and Alignment.—Sprockets should have the tooth form, thickness, profile, and diameters conforming to ASME/ANSI B29.1M. For maximum service life small sprockets operating at moderate to high speeds, or near the rated horsepower, should have hardened teeth. Normally, large sprockets should not exceed 120 teeth.

In general a center distance of 30 to 50 chain pitches is most desirable. The distance between sprocket centers should provide at least a 120 degree chain wrap on the smaller sprocket. Drives may be installed with either adjustable or fixed center distances. Adjustable centers simplify the control of chain slack. Sufficient housing clearance must always be provided for the chain slack to obtain full chain life.

Accurate alignment of shafts and sprocket tooth faces provides uniform distribution of the load across the entire chain width and contributes substantially to optimum drive life.

Shafting, bearings, and foundations should be suitable to maintain the initial alignment. Periodic maintenance should include an inspection of alignment.

Example of Roller Chain Drive Design Procedure.—The selection of a roller chain and sprockets for a specific design requirement is best accomplished by a systematic step-by-step procedure such as is used in the following example.

Example: Select a roller chain drive to transmit 10 horsepower from a countershaft to the main shaft of a wire drawing machine. The countershaft is $1\frac{15}{16}$-inches diameter and operates at 1000 rpm. The main shaft is also $1\frac{15}{16}$-inches diameter and must operate between 378 and 382 rpm. Shaft centers, once established, are fixed and by initial calculations must be approximately $22\frac{1}{2}$ inches. The load on the main shaft is uneven and presents "peaks," which place it in the heavy shock load category. The input power is supplied by an electric motor. The driving head is fully enclosed and all parts are lubricated from a central system.

Step 1. Service Factor: From Table 14 the service factor for heavy shock load and an electric motor drive is 1.5.

Step 2. Design Horsepower: The horsepower upon which the chain selection is based (design horsepower) is equal to the specified horsepower multiplied by the service factor, $10 \times 1.5 = 15$ hp.

Step 3. Chain Pitch and Small Sprocket Size for Single-Strand Drive: In Table under 1000 rpm, a $\frac{5}{8}$-inch pitch chain with a 24-tooth sprocket or a $\frac{3}{4}$-inch pitch chain with a 15-tooth sprocket are possible choices.

Step 4. Check of Chain Pitch and Sprocket Selection: From Table 9 it is seen that only the 24-tooth sprocket in Step 3 can be bored to fit the $1\frac{15}{16}$-inch diameter main shaft. In Table a $\frac{5}{8}$-pitch chain at a small sprocket speed of 1000 rpm is rated at 15.5 hp for a 24-tooth sprocket.

Step 5. Selection of Large Sprocket: Since the driver is to operate at 1000 rpm and the driven at a minimum of 378 rpm, the speed ratio $1000 / 378 = 2.646$. Therefore the large sprocket should have $24 \times 2.646 = 63.5$ (use 63) teeth.

This combination of 24 and 63 teeth will produce a main drive shaft speed of 381 rpm which is within the limitation of 378 to 382 rpm established in the original specification.

Step 6. Computation of Chain Length: Since the 24- and 63-tooth sprockets are to be placed on $22\frac{1}{2}$-inch centers, the chain length is determined from the formula:

$$L = 2C + \frac{N}{2} + \frac{n}{2} + \left(\frac{N-n}{2\pi}\right)^2 \times \frac{1}{C}$$

where L = chain length in pitches; C = shaft center distance in pitches; N = number of teeth in large sprocket; and n = number of teeth in small sprocket.

$$L = 2 \times 36 + \frac{63 + 24}{2} + \left(\frac{63 - 24}{6.28}\right)^2 \times \frac{1}{36} = 116.57 \text{ pitches}$$

Step 7. Correction of Center Distance: Since the chain is to couple at a whole number of pitches, 116 pitches will be used and the center distance recomputed based on this figure using the formula on page 2437 where c is the center distance in inches and P is the pitch.

$$c = \frac{P}{8}\left(2L - N - n + \sqrt{(2L - N - n)^2 - 0.810(N-n)^2}\right)$$

$$c = \frac{5}{64}\left(2 \times 116 - 63 - 24 + \sqrt{(2 \times 116 - 63 - 24)^2 - 0.810(63 - 24)^2}\right)$$

$$c = \frac{5}{64}(145 + 140.69) = 22.32 \text{ inches, say } 22\frac{3}{8} \text{ inches}$$

STANDARDS FOR ELECTRIC MOTORS

Classes of NEMA Standards.—National Electrical Manufacturers Association Standards, available from the Association at 2101 L Street, NW, Washington, DC 20037, are of two classes: 1) *NEMA Standard,* which relates to a product commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 per cent of the members of the Subdivision eligible to vote thereon; and 2) *Suggested Standard for Future Design,* which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development and has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design.

Mounting Dimensions and Frame Sizes for Electric Motors.—Dimensions for foot-mounted electric motors as standardized in the United States by the National Electrical Manufacturers Association (NEMA) include the spacing of bolt holes in the feet of the motor, the distance from the bottom of the feet to the center-line of the motor shaft, the size of the conduit, the length and diameter of shaft, and other dimensions likely to be required by designers or manufacturers of motor-driven equipment. The Standard provides dimensions for face-mounted and flange-mounted motors by means of standard motor frame numbers.

Standard dimensions also are given where the motor is to be mounted upon a belt-tightening base or upon rails.

The NEMA standards also prescribe lettering for dimension drawings, mounting and terminal housing locations and dimensions, symbols and terminal connections, and provision for grounding of field wiring. In addition, the standards give recommended knock-out and clearance hole dimensions; tolerances on shaft extension diameters and keyseats; methods of measuring shaft run-out and eccentricity, also face runout of mounting surfaces; and tolerances of face-mounted and flanged-mounted motors.

Design Letters of Polyphase Integral-horsepower Motors.—Designs A, B, C, and D motors are squirrel-cage motors designed to withstand full voltage starting and developing locked-rotor torque and breakdown torque, drawing locked-rotor current, and having a slip as specified below:

Design A: Locked-rotor torque as shown in Table 2, breakdown torque as shown in Table 3, locked-rotor current higher than the values shown in Table 1, and a slip at rated load of less than 5 per cent. Motors with 10 or more poles may have a slightly greater slip.

Table 1. NEMA Standard Locked-rotor Current of 3-phase 60-hertz Integral-horsepower Squirrel-cage Induction Motors Rated at 230 Volts

Horsepower	Locked-rotor Current, Amps.	Design Letters	Horsepower	Locked-rotor Current, Amps.	Design Letters	Horsepower	Locked-rotor Current, Amps.	Design Letters
½	20	B, D	7½	127	B, C, D	50	725	B, C, D
¾	25	B, D	10	162	B, C, D	60	870	B, C, D
1	30	B, D	15	232	B, C, D	75	1085	B, C, D
1½	40	B, D	20	290	B, C, D	100	1450	B, C, D
2	50	B, D	25	365	B, C, D	125	1815	B, C, D
3	64	B, C, D	30	435	B, C, D	150	2170	B, C, D
5	92	B, C, D	40	580	B, C, D	200	2900	B, C

Note: The locked-rotor current of a motor is the steady-state current taken from the line with the rotor locked and with rated voltage and frequency applied to the motor.

For motors designed for voltages other than 230 volts, the locked-rotor current is inversely proportional to the voltages. For motors larger than 200 hp, see NEMA Standard MG 1-12.34.

Table 2. NEMA Standard Locked-rotor Torque of Single-speed Polyphase 60- and 50-hertz Squirrel-cage Integral-horsepower Motors with Continuous Ratings

Hp	Designs A and B								Design C		
	Synchronous Speed, rpm										
	60 hertz	3600	1800	1200	900	720	600	514	1800	1200	900
	50 hertz	3000	1500	1000	750	…	…	…	1500	1000	750
	Percent of Full-load Torque[a]										
½		…	…	…	140	140	115	110	…	…	…
¾		…	…	175	135	135	115	110	…	…	…
1		…	275	170	135	135	115	110	…	…	…
1½		175	250	165	130	130	115	110	…	…	…
2		170	235	160	130	125	115	110	…	…	…
3		160	215	155	130	125	115	110	…	250	225
5		150	185	150	130	125	115	110	250	250	225
7½		140	175	150	125	120	115	110	250	225	200
10		135	165	150	125	120	115	110	250	225	200
15		130	160	140	125	120	115	110	225	200	200
20		130	150	135	125	120	115	110	200 for all sizes above 15 hp.		
25		130	150	135	125	120	115	110			
30		130	150	135	125	120	115	110			
40		125	140	135	125	120	115	110			
50		120	140	135	125	120	115	110			
60		120	140	135	125	120	115	110			
75		105	140	135	125	120	115	110	For Design D motors, see footnote.		
100		105	125	125	125	120	115	110			
125		100	110	125	120	115	115	110			
150		100	110	120	120	115	115	…			
200		100	100	120	120	115	…	…			

[a] These values represent the upper limit of application for these motors.

Note: The locked-rotor torque of a motor is the minimum torque which it will develop at rest for all angular positions of the rotor, with rated voltage applied at rated frequency.

The locked-rotor torque of Design D, 60- and 50-hertz 4-, 6-, and 8-pole single-speed, polyphase squirrel-cage motors rated 150 hp and smaller, with rated voltage and frequency applied is 275 per cent of full-load torque, which represents the upper limit of application for these motors.

For motors larger than 200 hp, see NEMA Standard MG 1-12.37.

Table 3. NEMA Standard Breakdown Torque of Single-speed Polyphase Squirrel-cage, Integral-horsepower Motors with Continuous Ratings

Horsepower	Synchronous Speed, rpm							
	60 hertz	3600	1800	1200	900	720	600	514
	50 hertz	3000	1500	1000	750	…	…	…
	Per Cent of Full Load Torque							
	Designs A and B[a]							
½		…	…	…	225	200	200	200
¾		…	…	275	220	200	200	200
1		…	300	265	215	200	200	200
1½		250	280	250	210	200	200	200
2		240	270	240	210	200	200	200
3		230	250	230	205	200	200	200
5		215	225	215	205	200	200	200
7½		200	215	205	200	200	200	200
10–125, incl.		200	200	200	200	200	200	200
150		200	200	200	200	200	200	…
200		200	200	200	200	200	…	…
	Design C							
3		…	…	225	200	…	…	…
5		…	200	200	200	…	…	…
7½–200, incl.		…	190	190	190	…	…	…

[a] Design A values are in excess of those shown.

These values represent the upper limit of the range of application for these motors. For above 200 hp, see NEMA Standard MG1-12.38.

Design B: Locked-rotor torque as shown in Table 2, breakdown torque as shown in Table 3, locked-rotor current not exceeding that in Table 1, and a slip at rated load of less than 5 per cent. Motors with 10 or more poles may have a slightly greater slip.

Design C: Locked-rotor torque for special high-torque applications up to values shown in Table 2, breakdown torque up to values shown in Table 3, locked-rotor current not exceeding values shown in Table 1 and a slip at rated load of less than 5 per cent.

Design D: Locked-rotor torque as indicated in Table 2, locked-rotor current not greater than that shown in Table 1 and a slip at rated load of 5 per cent or more.

Torque and Current Definitions.—The definitions which follow have been adopted as standard by the National Electrical Manufacturers Association.

Locked-Rotor or Static Torque: The locked-rotor torque of a motor is the minimum torque which it will develop at rest for all angular positions of the rotor, with rated voltage applied at rated frequency.

Breakdown Torque: The breakdown torque of a motor is the maximum torque which the motor will develop, with rated voltage applied at rated frequency, without an abrupt drop in speed (see Table 4).

Full-Load Torque: The full-load torque of a motor is the torque necessary to produce its rated horsepower at full load speed. In pounds at 1-foot radius, it is equal to the horsepower times 5252 divided by the full-load speed.

Pull-Out Torque: The pull-out torque of a synchronous motor is the maximum sustained torque which the motor will develop at synchronous speed with rated voltage applied at rated frequency and with normal excitation.

Pull-In Torque: The pull-in torque of a synchronous motor is the maximum constant torque under which the motor will pull its connected inertia load into synchronism at rated voltage and frequency, when its field excitation is applied.

Pull-Up Torque: The pull-up torque of an alternating current motor is the minimum torque developed by the motor during the period of acceleration from rest to the speed at which breakdown torque occurs. For motors which do not have a definite breakdown torque, the pull-up torque is the minimum torque developed up to rated speed.

Locked Rotor Current: The locked rotor current of a motor is the steady-state current taken from the line with the rotor locked and with rated voltage (and rated frequency in the case of alternating-current motors) applied to the motor.

Table 4. NEMA Standard Breakdown Torque of Polyphase Wound-rotor Motors with Continuous Ratings — 60- and 50-hertz

Horsepower	Speed, rpm			Horsepower	Speed, rpm		
	1800	1200	900		1800	1200	900
	Per cent of Full-load Torque				Per cent of Full-load Torque		
1	…	…	250	7½	275	250	225
1½	…	…	250	10	275	250	225
2	275	275	250	15	250	225	225
3	275	275	250	20–200, incl.	225	225	225
5	275	275	250	…	…	…	…

These values represent the upper limit of the range of application for these motors.

Standard Direction of Motor Rotation.—The standard direction of rotation for all nonreversing direct-current motors, all alternating-current single-phase motors, all synchronous motors, and all universal motors, is *counterclockwise* when facing that end of the motor opposite the drive.

This rule does not apply to two- and three-phase induction motors, as in most applications the phase sequence of the power lines is rarely known.

Motor Types According to Variability of Speed.—Five types of motors classified according to variability of speed are:

Constant-speed Motors: In this type of motor the normal operating speed is constant or practically constant; for example, a synchronous motor, an induction motor with small slip, or a direct-current shunt-wound motor.

Varying-speed Motor: In this type of motor, the speed varies with the load, ordinarily decreasing when the load increases; such as a series-wound or repulsion motor.

Adjustable-speed Motor: In this type of motor, the speed can be varied gradually over a considerable range, but when once adjusted remains practically unaffected by the load; such as a direct-current shunt-wound motor with field resistance control designed for a considerable range of speed adjustment.

The base speed of an adjustable-speed motor is the lowest rated speed obtained at rated load and rated voltage at the temperature rise specified in the rating.

Adjustable Varying-speed Motor: This type of motor is one in which the speed can be adjusted gradually, but when once adjusted for a given load will vary in considerable degree with the change in load; such as a direct-current compound-wound motor adjusted by field control or a wound-rotor induction motor with rheostatic speed control.

Multispeed Motor: This type of motor is one which can be operated at any one of two or more definite speeds, each being practically independent of the load; such as a direct-current motor with two armature windings or an induction motor with windings capable of various pole groupings. In the case of multispeed permanent-split capacitor and shaded pole motors, the speeds are dependent upon the load.

Pull-up Torque.—NEMA Standard pull up torques for single-speed, polyphase, squirrel-cage integral-horsepower motors, Designs A and B, with continuous ratings and with rated voltage and frequency applied are as follows: When the locked-rotor torque given in Table 2 is 110 per cent or less, the pull-up torque is 90 per cent of the locked-rotor torque;

when the locked-rotor torque is greater than 110 per cent but less than 145 per cent, the pull-up torque is 100 per cent of full-load torque; and when the locked-rotor torque is 145 per cent or more, the pull-up torque is 70 per cent of the locked-rotor torque.

For Design C motors, with rated voltage and frequency applied, the pull-up torque is not less than 70 per cent of the locked-rotor torque as given in Table 2.

Types and Characteristics of Electric Motors

Types of Direct-Current Motors.—Direct-current motors may be grouped into three general classes: series-wound; shunt-wound; and compound-wound.

In the *series-wound motor* the field windings, which are fixed in the stator frame, and the armature windings, which are placed around the rotor, are connected in series so that all current passing through the armature also passes through the field. In the *shunt-wound motor,* both armature and field are connected across the main power supply so that the armature and field currents are separate. In the *compound-wound motor,* both series and shunt field windings are provided and these may be connected so that the currents in both are flowing in the same direction, called *cumulative compounding,* or so that the currents in each are flowing in opposite directions, called *differential compounding.*

Characteristics of Series-wound Direct-Current Motors.—In the series-wound motor, any increase in load results in more current passing through the armature and the field windings. As the field is strengthened by this increased current, the motor speed decreases. Conversely, as the load is decreased the field is weakened and the speed increases and at very light loads may become excessive. For this reason, series-wound direct-current motors are usually directly connected or geared to the load to prevent "runaway." (A series-wound motor, designated as series-shunt wound, is sometimes provided with a light shunt field winding to prevent dangerously high speeds at light loads.) The increase in armature current with increasing load produces increased torque, so that the series-wound motor is particularly suited to heavy starting duty and where severe overloads may be expected. Its speed may be adjusted by means of a variable resistance placed in series with the motor, but due to variation with load, the speed cannot be held at any constant value. This variation of speed with load becomes greater as the speed is reduced. Series-wound motors are used where the load is practically constant and can easily be controlled by hand. They are usually limited to traction and lifting service.

Shunt-wound Direct-Current Motors.—In the shunt-wound motor, the strength of the field is not affected appreciably by change in the load, so that a fairly constant speed (about 10 to 12 per cent drop from no load to full load speed) is obtainable. This type of motor may be used for the operation of machines requiring an approximately constant speed and imposing low starting torque and light overload on the motor.

The shunt-wound motor becomes an adjustable-speed motor by means of field control or by armature control. If a variable resistance is placed in the field circuit, the amount of current in the field windings and hence the speed of rotation can be controlled. As the speed increases, the torque decreases proportionately, resulting in nearly constant horsepower. A speed range of 6 to 1 is possible using field control, but 4 to 1 is more common. Speed regulation is somewhat greater than in the constant-speed shunt-wound motors, ranging from about 15 to 22 per cent. If a variable resistance is placed in the armature circuit, the voltage applied to the armature can be reduced and hence the speed of rotation can be reduced over a range of about 2 to 1. With armature control, speed regulation becomes poorer as speed is decreased, and is about 100 per cent for a 2 to 1 speed range. Since the current through the field remains unchanged, the torque remains constant.

Machine Tool Applications: The adjustable-speed shunt-wound motors are useful on larger machines of the boring mill, lathe, and planer type and are particularly adapted to spindle drives because constant horsepower characteristics permit heavy cuts at low speed and light or finishing cuts at high speed. They have long been used for planer drives because they can provide an adjustable low speed for the cutting stroke and a high speed for the return stroke. Their application has been limited, however, to plants in which direct-current power is available.

Adjustable-voltage Shunt-wound Motor Drive.—More extensive use of the shunt-wound motor has been made possible by a combination drive that includes a means of converting alternating current to direct current. This conversion may be effected by a self-contained unit consisting of a separately excited direct-current generator driven by a constant speed alternating-current motor connected to the regular alternating-current line, or by an electronic rectifier with suitable controls connected to the regular alternating-current supply lines. The latter has the advantage of causing no vibration when mounted directly on the machine tool, an important factor in certain types of grinders.

In this type of adjustable-speed, shunt-wound motor drive, speed control is effected by varying the voltage applied to the armature while supplying constant voltage to the field. In addition to providing for the adjustment of the voltage supplied by the conversion unit to the armature of the shunt-wound motor, the amount of current passing through the motor field may also be controlled. In fact, a single control may be provided to vary the motor speed from minimum to base speed (speed of the motor at full load with rated voltage on armature and field) by varying the voltage applied to the armature and from base speed to maximum speed by varying the current flowing through the field. When so controlled, the motor operates at constant torque up to base speed and at constant horsepower above base speed.

Speed Range: Speed ranges of at least 20 to 1 below base speed and 4 or 5 to 1 above base speed (a total range of 100 to 1, or more) are obtainable as compared with about 2 to 1 below normal speed and 3 or 4 to 1 above normal speed for the conventional type of control. Speed regulation may be as great as 25 per cent at high speeds. Special electronic controls, when used with this type shunt motor drive, make possible maintenance of motor speeds with as little variation as $\frac{1}{2}$ to 1 per cent of full load speed from full load to no load over a line voltage variation of ± 10 per cent and over any normal variation in motor temperature and ambient temperature.

Applications: These direct-current, adjustable-voltage drives, as they are sometimes called, have been applied successfully to such machine tools as planers, milling machines, boring mills and lathes, as well as to other industrial machines where wide, stepless speed control, uniform speed under all operating conditions, constant torque acceleration and adaptability to automatic operation are required.

Compound-wound Motors.—In the compound-wound motor, the speed variation due to load changes is much less than in the series-wound motor, but greater than in the shunt-wound motor (ranging up to 25 per cent from full load to no load). It has a greater starting torque than the shunt-wound motor, is able to withstand heavier overloads, but has a narrower adjustable speed range. Standard motors of this type have a cumulative-compound winding, the differential-compound winding being limited to special applications. They are used where the starting load is very heavy or where the load changes suddenly and violently as with reciprocating pumps, printing presses and punch presses.

Types of Polyphase Alternating-Current Motors.—The most widely used polyphase motors are of the induction type. The *"squirrel cage" induction motor* consists of a wound stator which is connected to an external source of alternating-current power and a laminated steel core rotor with a number of heavy aluminum or copper conductors set into the core around its periphery and parallel to its axis. These conductors are connected together at each end of the rotor by a heavy ring, which provides closed paths for the currents induced in the rotor to circulate. The rotor bars form, in effect, a "squirrel cage" from which the motor takes its name.

Wound-rotor type of *Induction motor:* This type has in addition to a squirrel cage, a series of coils set into the rotor which are connected through slip-rings to external variable resistors. By varying the resistance of the wound-rotor circuits, the amount of current flowing in these circuits and hence the speed of the motor can be controlled. Since the rotor of an induction motor is not connected to the power supply, the motor is said to operate by transfer action and is analogous to a transformer with a short-circuited secondary that is free to rotate. Induction motors are built with a wide range of speed and torque characteristics which are discussed under "Operating Characteristics of Squirrel-cage Induction Motors."

Synchronous Motor: The other type of polyphase alternating-current motor used industrially is the *synchronous motor.* In contrast to the induction motor, the rotor of the synchronous motor is connected to a direct-current supply which provides a field that rotates in step with the alternating-current field in the stator. After having been brought up to synchronous speed, which is governed by the frequency of the power supply and the number of poles in the rotor, the synchronous motor operates at this constant speed throughout its entire load range.

Operating Characteristics of Squirrel-cage Induction Motors.—In general, squirrel-cage induction motors are simple in design and construction and offer rugged service. They are essentially constant-speed motors, their speed changing very little with load and not being subject to adjustment. They are used for a wide range of industrial applications calling for integral horsepower ratings. According to the NEMA (National Electrical Manufacturers Association) Standards, there are four classes of squirrel-cage induction motors designated respectively as *A, B, C,* and *D.*

Design A motors are not commonly used since Design *B* has similar characteristics with the advantage of lower starting current.

Design B: motors may be designated as a general purpose type suitable for the majority of polyphase alternating-current applications such as blowers, compressors, drill presses, grinders, hammer mills, lathes, planers, polishers, saws, screw machines, shakers, stokers, etc. The starting torque at 1800 R.P.M. is 250 to 275 per cent of full load torque for 3 H.P. and below; for 5 H.P. to 75 H. P. ratings the starting torque ranges from 185 to 150 per cent of full load torque. They have low starting current requirements, usually no more than 5 to 6 times full load current and can be started at full voltage. Their slip (difference between synchronous speed and actual speed at rated load) is relatively low.

Design C: motors have high starting torque (up to 250 per cent of full load torque) but low starting current. They can be started at full voltage. Slip at rated load is relatively low. They are used for compressors requiring a loaded start, heavy conveyors, reciprocating pumps and other applications requiring high starting torque.

Design D: motors have high slip at rated load, that is, the motor speed drops off appreciably as the load increases, permitting use of the stored energy of a flywheel. They provide heavy starting torque, up to 275 per cent of full load torque, are quiet in operation and have relatively low starting current. Applications are for impact, shock and other high peak loads or flywheel drives such as trains, elevators, hoists, punch and drawing presses, shears, etc.

Design F: motors are no longer standard. They had low starting torque, about 125 per cent of full-load torque, and low starting current. They were used to drive machines which required infrequent starting at no load or at very light load.

Multiple-Speed Induction Motors.—This type has a number of windings in the stator so arranged and connected that the number of effective poles and hence the speed can be changed. These motors are for the same types of starting conditions as the conventional squirrel-cage induction motors and are available in designs that provide constant horsepower at all rated speeds and in designs that provide constant torque at all rated speeds.

Typical speed combinations obtainable in these motors are 600, 900, 1200 and 1800 R.P.M.; 450, 600, 900 and 1200 R.P.M.; and 600, 720, 900 and 1200 R.P.M.

Where a gradual change in speed is called for, a wound rotor may be provided in addition to the multiple stator windings.

Wound-Rotor Induction Motors.—These motors are designed for applications where extremely low starting current with high starting torque are called for, such as in blowers, conveyors, compressors, fans and pumps. They may be employed for adjustable-varying speed service where the speed range does not extend below 50 per cent of synchronous speed, as for steel plate-forming rolls, printing presses, cranes, blowers, stokers, lathes and milling machines of certain types. The speed regulation of a wound rotor induction motor ranges from 5 to 10 per cent at maximum speed and from 18 to 30 per cent at low speed. They are also employed for reversing service as in cranes, gates, hoists and elevators.

High-Frequency Induction Motors.—This type is used in conjunction with frequency changers when very high speeds are desired, as on grinders, drills, routers, portable tools or woodworking machinery. These motors have an advantage over the series-wound or universal type of high speed motor in that they operate at a relatively constant speed over the entire load range. A motor-generator set, a two-unit frequency converter or a single unit inductor frequency converter may be used to supply three-phase power at the frequency required. The single unit frequency converter may be obtained for delivering any one of a number of frequencies ranging from 360 to 2160 cycles and it is self-driven and self-excited from the general polyphase power supply.

Synchronous Motors.—These are widely used in electric timing devices; to drive machines that must operate in synchronism; and also to operate compressors, rolling mills, crushers which are started without load, paper mill screens, shredders, vacuum pumps and motor-generator sets. Synchronous motors have an inherently high power factor and are often employed to make corrections for the low power factor of other types of motors on the same system.

Types of Single-Phase Alternating-Current Motors.—Most of the single-phase alternating-current motors are basically induction motors distinguished by different arrangements for starting. (A single-phase induction motor with only a squirrel-cage rotor has no starting torque.) In the *capacitor-start* single-phase motor, an auxiliary winding in the stator is connected in series with a capacitor and a centrifugal switch. During the starting and accelerating period the motor operates as a two-phase induction motor. At about two-thirds full-load speed, the auxiliary circuit is disconnected by the switch and the motor then runs as a single-phase induction motor. In the *capacitor-start, capacitor-run* motor, the auxiliary circuit is arranged to provide high effective capacity for high starting torque and to remain connected to the line but with reduced capacity during the running period. In the *single-value capacitor* or *capacitor split-phase* motor, a relatively small continuously-rated capacitor is permanently connected in one of the two stator windings and the motor both starts and runs like a two-phase motor.

In the *repulsion-start* single-phase motor, a drum-wound rotor circuit is connected to a commutator with a pair of short-circuited brushes set so that the magnetic axis of the rotor winding is inclined to the magnetic axis of the stator winding. The current flowing in this rotor circuit reacts with the field to produce starting and accelerating torques. At about two-thirds full load speed the brushes are lifted, the commutator is short circuited and the motor runs as a single-phase squirrel-cage motor. The *repulsion* motor employs a repulsion winding on the rotor for both starting and running. The *repulsion-induction* motor has an outer winding on the rotor acting as a repulsion winding and an inner squirrel-cage winding. As the motor comes up to speed, the induced rotor current partially shifts from the repulsion winding to the squirrel-cage winding and the motor runs partly as an induction motor.

In the *split-phase* motor, an auxiliary winding in the stator is used for starting with either a resistance connected in series with the auxiliary winding (*resistance-start*) or a reactor in series with the main winding (*reactor-start*).

The *series-wound* single-phase motor has a rotor winding in series with the stator winding as in the series-wound direct-current motor. Since this motor may also be operated on direct current, it is called a *universal* motor.

Characteristics of Single-Phase Alternating-Current Motors.—Single-phase motors are used in sizes up to about 7½ horsepower for heavy starting duty chiefly in home and commercial appliances for which polyphase power is not available. The *capacitor-start* motor is available in normal starting torque designs for such applications as centrifugal pumps, fans, and blowers and in high-starting torque designs for reciprocating compressors, pumps, loaded conveyors, or belts. The *capacitor-start, capacitor-run* motor is exceptionally quiet in operation when loaded to at least 50 per cent of capacity. It is available in low-torque designs for fans and centrifugal pumps and in high-torque designs for applications similar to those of the capacitor-start motor.

The *capacitor split-phase* motor requires the least maintenance of all single-phase motors, but has very low starting torque. Its high maximum torque makes it potentially useful in floor sanders or in grinders where momentary overloads due to excessive cutting pressure are experienced. It is also used for slow-speed direct connected fans.

The *repulsion-start, induction-run* motor has higher starting torque than the capacitor motors, although for the same current, the capacitor motors have equivalent pull-up and maximum torque. Electrical and mechanical noise and the extra maintenance sometimes required are disadvantages. These motors are used for compressors, conveyors and stokers starting under full load. The *repulsion-induction* motor has relatively high starting torque and low starting current. It also has a smooth speed-torque curve with no break and a greater ability to withstand long accelerating periods than capacitor type motors. It is particularly suitable for severe starting and accelerating duty and for high inertia loads such as laundry extractors. Brush noise is, however, continuous.

The *repulsion* motor has no limiting synchronous speed and the speed changes with the load. At certain loads, slight changes in load cause wide changes in speed. A brush shifting arrangement may be provided to adjust the speed which may have a range of 4 to 1 if full rated constant torque is applied but a decreasing range as the torque falls below this value. This type of motor may be reversed by shifting the brushes beyond the neutral point. These motors are suitable for machines requiring constant-torque and adjustable speed.

The *split-phase* and *universal* motors are limited to about ⅓ H.P. ratings and are used chiefly for small appliance and office machine applications.

Motors with Built-in Speed Reducers.—Electric motors having built-in speed-changing units are compact and the design of these motorized speed reducers tends to improve the appearance of the machines which they drive. There are several types of these speed reducers; they may be classified according to whether they are equipped with worm gearing, a regular gear train with parallel shafts, or planetary gearing.

The claims made for the worm gearing type of reduction unit are that the drive is quiet in operation and well adapted for use where the slow-speed shaft must be at right angles to the motor shaft and where a high speed ratio is essential.

For very low speeds, the double reduction worm gearing units are suitable. In these units two sets of worm gearing form the gear train, and both the slow-speed shaft and the armature shaft are parallel. The intermediate worm gear shaft can be built to extend from the housing, if required, so as to make two countershaft speeds available on the same unit.

In the parallel-shaft type of speed reducer, the slow-speed shaft is parallel with the armature shaft. The slow-speed shaft is rotated by a pinion on the armature shaft, this pinion meshing with a larger gear on the slow-speed shaft.

Geared motors having built-in speed-changing units are available with constant-mesh change gears for varying the speed ratio.

Planetary gearing permits a large speed reduction with few parts; hence, it is well adapted for geared-head motor units where economy and compactness are essential. The slow-speed shaft is in line with the armature shaft.

Factors Governing Motor Selection

Speed, Horsepower, Torque and Inertia Requirements.—Where more than one speed or a range of speeds are called for, one of the following types of motors may be selected, depending upon other requirements: For direct-current, the standard shunt-wound motor with field control has a 2 to 1 range in some designs; the adjustable speed motor may have a range of from 3 to 1 up to 6 to 1; the shunt motor with adjustable voltage supply has a range up to 20 to 1 or more below base speed and 4 or 5 to 1 above base speed, making a total range of up to 100 to 1 or more. For polyphase alternating current, multi-speed squirrel-cage induction motors have 2, 3 or 4 fixed speeds; the wound-rotor motor has a 2 to 1 range. The two-speed wound-rotor motor has a 4 to 1 range. The brush-shifting shunt motor has a 4 to 1 range. The brush-shifting series motor has a 3 to 1 range; and the squirrel-cage motor with a variable-frequency supply has a very wide range. For single-phase alternating current, the brush-shifting repulsion motor has a 2½ to 1 range; the capacitor motor with tapped winding has a 2 to 1 range and the multi-speed capacitor motor has 2 or 3 fixed speeds. Speed regulation (variation in speed from no load to full load) is greatest with motors having series field windings and entirely absent with synchronous motors.

Horsepower: Where the load to be carried by the motor is not constant but follows a definite cycle, a horsepower-time curve enables the peak horsepower to be determined as well as the root-mean-square-average horsepower, which indicates the proper motor rating from a heating standpoint. Where the load is maintained at a constant value for a period of from 15 minutes to 2 hours depending on the size, the horsepower rating required will usually not be less than this constant value. When selecting the size of an induction motor, it should be kept in mind that this type of motor operates at maximum efficiency when it is loaded to full capacity. Where operation is to be at several speeds, the horsepower requirement for each speed should be considered.

Torque: Starting torque requirements may vary from 10 per cent of full load to 250 per cent of full load torque depending upon the type of machine being driven. Starting torque may vary for a given machine because of frequency of start, temperature, type and amount of lubricant, etc., and such variables should be taken into account. The motor torque supplied to the machine must be well above that required by the driven machine at all points up to full speed. The greater the excess torque, the more rapid the acceleration. The approximate time required for acceleration from rest to full speed is given by the formula:

$$\text{Time} = \frac{N \times WR^2}{T_a \times 308} \text{ seconds}$$

where N = Full load speed in R.P.M.

T_a = Torque = average foot-pounds available for acceleration.

WR^2 = Inertia of rotating part in pounds feet squared (W = weight and R = radius of gyration of rotating part).

308 = Combined constant converting minutes into seconds, weight into mass and radius into circumference.

If the time required for acceleration is greater than 20 seconds, special motors or starters may be required to avoid overheating.

The running torque T_r is found by the formula:

$$T_r = \frac{5250 \times \text{HP}}{N} \text{foot pounds}$$

where *H.P.* = Horsepower being supplied to the driven machine

N = Running speed in R.P.M.

5250 = Combined constant converting horsepower to foot-pounds per minute and work per revolution into torque.

The peak horsepower determines the maximum torque required by the driven machine and the motor must have a maximum running torque in excess of this value.

Inertia: The inertia or flywheel effect of the rotating parts of a driven machine will, if large, appreciably affect the accelerating time and, hence, the amount of heating in the motor. If synchronous motors are used, the inertia (WR^2) of both the motor rotor and the rotating parts of the machine must be known since the pull-in torque (torque required to bring the driven machine up to synchronous speed) varies approximately as the square root of the total inertia of motor and load.

Space Limitations in Motor Selection.—If the motor is to become an integral part of the machine which it drives and space is at a premium, a partial motor may be called for. A complete motor is one made up of a stator, a rotor, a shaft, and two end shields with bearings. A *partial motor* is without one or more of these elements. One common type is furnished without drive-end end shield and bearing and is directly connected to the end or side of the machine which it drives, such as the headstock of a lathe. A so-called *shaftless type of motor* is supplied without shaft, end shields or bearings and is intended for built-in application in such units as multiple drilling machines, precision grinders, deep well pumps, compressors and hoists where the rotor is actually made a part of the driven machine. Where a partial motor is used, however, proper ventilation, mounting, alignment and bearings must be arranged for by the designer of the machine to which it is applied.

Sometimes it is possible to use a motor having a smaller frame size and wound with Class *B* insulation, permitting it to be subjected to a higher temperature rise than the larger-frame Class *A* insulated motor having the same horsepower rating.

Temperatures.—The applicability of a given motor is limited not only by its load starting and carrying ability, but also by the temperature which it reaches under load. Motors are given temperature ratings which are based upon the type of insulation (Class A or Class B are the most common) used in their construction and their type of frame (open, semienclosed, or enclosed).

Insulating Materials: Class A materials are: cotton, silk, paper, and similar organic materials when either impregnated or immersed in a liquid dielectric; molded and laminated materials with cellulose filler, phenolic resins, and other resins of similar properties;

films and sheets of cellulose acetate and other cellulose derivatives of similar properties;

and varnishes (enamel) as applied to conductors.

Class B insulating materials are: materials or combinations of materials such as mica, glass fiber, asbestos, etc., with suitable bonding substances. Other materials shown capable of operation at Class B temperatures may be included.

Ambient Temperature and Allowable Temperature Rise: Normal ambient temperature is taken to be 40°C (104°F). For open general-purpose motors with Class A insulation, the normal temperature rise on which the performance guarantees are based is 40°C (104°F).

Motors with Class A insulation having protected, semiprotected, drip-proof, or splash-proof, or drip-proof protected enclosures have a 50°C (122°F) rise rating.

Motors with Class A insulation and having totally enclosed, fan-cooled, explosion-proof, waterproof, dust-tight, submersible, or dust-explosion-proof enclosures have a 55°C (131°F) rise rating.

Motors with Class B insulation are permissible for total temperatures up to 110 degrees C (230°F) for open motors and 115°C (239°F) for enclosed motors.

Motors Exposed to Injurious Conditions.—Where motors are to be used in locations imposing unusual operating conditions, the manufacturer should be consulted, especially where any of the following conditions apply: exposure to chemical fumes; operation in damp places; operation at speeds in excess of specified overspeed; exposure to combustible or explosive dust; exposure to gritty or conducting dust; exposure to lint; exposure to steam; operation in poorly ventilated rooms; operation in pits, or where entirely enclosed in boxes; exposure to inflammable or explosive gases; exposure to temperatures below 10°C (50°F); exposure to oil vapor; exposure to salt air; exposure to abnormal shock or vibration from external sources; where the departure from rated voltage is excessive; and or where the alternating-current supply voltage is unbalanced.

Improved insulating materials and processes and greater mechanical protection against falling materials and liquids make it possible to use general-purpose motors in many locations where special-purpose motors were previously considered necessary. *Splash-proof motors* having well-protected ventilated openings and specially treated windings are used where they are to be subjected to falling and splashing water or are to be washed down as with a hose. Where climatic conditions are not severe, this type of motor is also successfully used in unprotected outdoor installations.

If the surrounding atmosphere carries abnormal quantities of metallic, abrasive, or non-explosive dust or acid or alkali fumes, a *totally enclosed fan-cooled motor* may be called for. In this type, the motor proper is completely enclosed but air is blown through an outer shell that completely or partially surrounds the inner case. If the dust in the atmosphere tends to pack or solidify and close the air passages of open splash-proof or totally enclosed fan-cooled motors, *totally enclosed (nonventilated) motors* are used. This type, which is limited to low horsepower ratings, is also used for outdoor service in mild or severe climates.

Table 1. Characteristics and Applications of D.C. Motors, 1–300 hp

Type	Starting Duty	Maximum Momentary Running Torque	Speed Regulation	Speed Control[a]	Applications
Shunt-wound, constant-speed	Medium starting torque. Varies with voltage supplied to armature, and is limited by starting resistor to 125 to 200% full-load torque	125 to 200%. Limited by commutation	8 to 12%	Basic speed to 200% basic speed by field control	Drives where starting requirements are not severe. Use constant-speed or adjustable-speed, depending on speed required. Centrifugal pumps, fans, blowers, conveyors, elevators, wood- and metalworking machines
Shunt-wound, adjustable speed			10 to 20%, increases with weak fields	Basic speed to 60% basic speed (lower for some ratings) by field control	
Shunt-wound, adjustable voltage control			Up to 25%. Less than 5% obtainable with special rotating regulator	Basic speed to 2% basic speed and basic speed to 200% basic speed	Drives where wide, stepless speed control, uniform speed, constant-torque acceleration and adaptability to automatic operation are required. Planers, milling machines, boring machines, lathes, etc.
Compound wound, constant-speed	Heavy starting torque, Limited by starting resistor to 130 to 260% of full-load torque	130 to 260%. Limited by commutation	Standard compounding 25%. Depends on amount of series winding	Basic speed to 125% basic speed by field control	Drives requiring high starting torque and fairly constant speed. Pulsating loads. Shears, bending rolls, pumps, conveyors, crushers, etc.
Series-wound, varying-speed	Very heavy starting torque. Limited to 300 to 350% full-load torque	300 to 350%. Limited by commutation	Very high. Infinite no-load speed	From zero to maximum speed, depending on control and load	Drives where very high starting torque is required and speed can be regulated. Cranes, hoists, gates, bridges, car dumpers, etc.

[a] Minimum speed below basic speed by armature control limited by heating.

Table 2. Characteristics and Applications of Polyphase AC Motors

Polyphase Type	Ratings hp	Speed Regulation	Speed Control	Starting Torque	Breakdown Torque	Applications
General-purpose squirrel cage, normal stg current, normal stg torque. Design B	0.5 to 200	Less than 5%	None, except multi-speed types, designed for two to four fixed speeds	100 to 250% of full-load	200 to 300% of full-load	Constant-speed service where starting torque is not excessive. Fans, blowers, rotary compressors, centrifugal pumps, woodworking machines, machine tools, line shafts
Full-voltage starting, high stg torque, normal stg current, squirrel-cage, Design C	3 to 150	Less than 5%	None except multi-speed types, designed for two to four fixed speeds	200 to 250% of full-load	190 to 225% of full-load	Constant-speed service where fairly high starting torque is required at infrequent intervals with starting current of about 500% full-load. Reciprocating pumps and compressors, conveyors, crushers, pulverizers, agitators, etc.
Full-voltage starting, high stg-torque, high-slip squirrel cage, Design D	0.5 to 150	Drops about 7 to 12% from no load to full load	None, except multi-speed types, designed for two to four fixed speeds	275% of full-load depending on speed and rotor resistance	275% of full-load Will usually not stall until loaded to its maximum torque, which occurs at standstill	Constant-speed service and high-starting torque if starting not too frequent, and for taking high-peak loads with or without flywheels. Punch presses, die stamping, shears, bulldozers, bailers, hoists, cranes, elevators, etc.
Wound-rotor, external-resistance starting	0.5 to several thousand	With rotor rings short-circuited drops about 3% for large to 5% for small sizes	Speed can be reduced to 50% of normal by rotor resistance. Speed varies inversely as the load	Up to 300% depending on external resistance in rotor circuit and how distributed	200% when rotor slip rings are short circulated	Where high-starting torque with low-starting current or where limited speed control is required. Fans, centrifugal and plunger pumps, compressors, conveyors, hoists, cranes, ball mills, gate hoists, etc.
Synchronous	25 to several thousand	Constant	None, except special motors designed for two fixed speeds	40% for slow speed to 160% for medium speed 80% p-f designs. Special high-torque designs	Pull-out torque of unity-p-f motors 170%; 80%-p-f motors 225%. Special designs up to 300%	For constant-speed service, direct connection to slow-speed machines and where power-factor correction is required.

In addition to these special-purpose motors, there are two types of *explosion-proof motors* designed for hazardous locations. One type is for operation in hazardous dust locations (Class II, Group *G* of the National Electrical Code) and the other is for atmospheres containing explosive vapors and fumes classified as Class I, Group *D* (gasoline, naphtha, alcohols, acetone, lacquer-solvent vapors, natural gas).

Electric Motor Maintenance

Electric Motor Inspection Schedule.—Frequency and thoroughness of inspection depend upon such factors as 1) importance of the motor in the production scheme; 2) percentage of days the motor operates; 3) nature of service; and 4) winding conditions.

The following schedules, recommended by the General Electric Company, and covering both AC and DC motors are based on average conditions in so far as duty and dirt are concerned.

Weekly Inspection.—1) *Surroundings.* Check to see if the windings are exposed to any dripping water, acid or alcoholic fumes; also, check for any unusual amount of dust, chips, or lint on or about the motor. See if any boards, covers, canvas, etc., have been misplaced that might interfere with the motor ventilation or jam moving parts.

2) *Lubrication of sleeve-bearing motors.* In sleeve-bearing motors check oil level, if a gage is used, and fill to the specified line. If the journal diameter is less than 2 inches, the motor should be stopped before checking the oil level. For special lubricating systems, such as wool-packed, forced lubrication, flood and disk lubrication, follow instruction book. Oil should be added to bearing housing only when motor is at rest. A check should be made to see if oil is creeping along the shaft toward windings where it may harm the insulation.

3) *Mechanical condition.* Note any unusual noise that may be caused by metal-to-metal contact or any odor as from scorching insulation varnish.

4) *Ball or roller bearings.* Feel ball- or roller-bearing housings for evidence of vibration, and listen for any unusual noise. Inspect for creepage of grease on inside of motor.

5) *Commutators and brushes.* Check brushes and commutator for sparking. If the motor is on cyclic duty it should be observed through several cycles. Note color and surface condition of the commutator. A stable copper oxide-carbon film (as distinguished from a pure copper surface) on the commutator is an essential requirement for good commutation. Such a film may vary in color all the way from copper to straw, chocolate to black. It should be clean and smooth and have a high polish. All brushes should be checked for wear and pigtail connections for looseness. The commutator surface may be cleaned by using a piece of dry canvas or other hard, nonlinting material that is wound around and securely fastened to a wooden stick, and held against the rotating commutator.

6) *Rotors and armatures.* The air gap on sleeve-bearing motors should be checked, especially if they have been recently overhauled. After installing new bearings, make sure that the average reading is within 10 per cent, provided reading should be less than 0.020 inch. Check air passages through punchings and make sure they are free of foreign matter.

7) *Windings.* If necessary clean windings by suction or mild blowing. After making sure that the motor is dead, wipe off windings with dry cloth, note evidence of moisture, and see if any water has accumulated in the bottom of frame. Check if any oil or grease has worked its way up to the rotor or armature windings. Clean with carbon tetrachloride in a well-ventilated room.

8) *General.* This is a good time to check the belt, gears, flexible couplings, chain, and sprockets for excessive wear or improper location. The motor starting should be checked to make sure that it comes up to proper speed each time power is applied.

Monthly or Bimonthly Inspection.—1) *Windings.* Check shunt, series, and commutating field windings for tightness. Try to move field spools on the poles, as drying out may have caused some play. If this condition exists, a service shop should be consulted. Check motor cable connections for tightness.

2) *Brushes.* Check brushes in holders for fit and free play. Check the brush-spring pressure. Tighten brush studs in holders to take up slack from drying out of washers, making sure that studs are not displaced, particularly on DC motors. Replace brushes that are worn down almost to the brush rivet, examine brush faces for chipped toes or heels, and for heat cracks. Damaged brushes should be replaced immediately.

3) *Commutators.* Examine commutator surface for high bars and high mica, or evidence of scratches or roughness. See that the risers are clean and have not been damaged.

4) *Ball or roller bearings.* On hard-driven, 24-hour service ball- or roller-bearing motors, purge out old grease through drain hole and apply new grease. Check to make sure grease or oil is not leaking out of the bearing housing. If any leakage is present, correct the condition before continuing to operate.

5) *Sleeve bearings.* Check sleeve bearings for wear, including end-play bearing surfaces. Clean out oil wells if there is evidence of dirt or sludge. Flush with lighter oil before refilling.

6) *Enclosed gears.* For motors with enclosed gears, open drain plug and check oil flow for presence of metal scale, sand, or water. If condition of oil is bad, drain, flush, and refill as directed. Rock rotor to see if slack or backlash is increasing.

7) *Loads.* Check loads for changed conditions, bad adjustment, poor handling, or control.

8) *Couplings and other drive details.* Note if belt-tightening adjustment is all used up. Shorten belt if this condition exists. See if belt runs steadily and close to inside (motor edge) of pulley. Chain should be checked for evidence of wear and stretch. Clean inside of chain housing. Check chain-lubricating system. Note inclination of slanting base to make sure it does not cause oil rings to rub on housing.

Annual or Biannual Inspection.—1) *Windings.* Check insulation resistance by using either a megohmmeter or a voltmeter having a resistance of about 100 ohms per volt. Check insulation surfaces for dry cracks and other evidence of need for coatings of insulating material. Clean surfaces and ventilating passages thoroughly if inspection shows accumulation of dust. Check for mold or water standing in frame to determine if windings need to be dried out, varnished, and baked.

2) *Air gap and bearings.* Check air gap to make sure that average reading is within 10 per cent, provided reading should be less than 0.020 inch. All bearings, ball, roller, and sleeve should be thoroughly checked and defective ones replaced. Waste-packed and wick-oiled bearings should have waste or wicks renewed, if they have become glazed or filled with metal or dirt, making sure that new waste bears well against shaft.

3) *Rotors (squirrel-cage).* Check squirrel-cage rotors for broken or loose bars and evidence of local heating. If fan blades are not cast in place, check for loose blades. Look for marks on rotor surface indicating foreign matter in air gap or a worn bearing.

4) *Rotors (wound).* Clean wound rotors thoroughly around collector rings, washers, and connections. Tighten connections if necessary. If rings are rough, spotted, or eccentric, refer to service shop for refinishing. See that all top sticks or wedges are tight. If any are loose, refer to service shop.

5) *Armatures.* Clean all armature air passages thoroughly if any are obstructed. Look for oil or grease creeping along shaft, checking back to bearing. Check commutator for surface condition, high bars, high mica, or eccentricity. If necessary, remachine the commutator to secure a smooth fresh surface.

6) *Loads.* Read load on motor with instruments at no load, full load, or through an entire cycle, as a check on the mechanical condition of the driven machine.