ENGINEERING

Shafting

Table 17: Typical Commercial Shaft Tolerances

Shaft Size	Plus	Minus
Up to 1-1/2"	.000	.002
Over 1-1/2 to 2-1/2"	.000	.003
Over 2-1/2 to 4"	.000	.004
Over 4 to 6"	.000	.005
Over 6 to 8"	.000	.006
Over 8 to 9"	.000	.007
Over 9"	.000	.008

Table 18: Shaft Tolerances

Shaft Size	Tolerance, Inches
Up to 1-1/2"	+.0000 -.0005"
1-5/8 to 4"	+.000 -.001"
4-7/16 to 6"	+.000 -.0015"
6-7/16 to 8"	+.000 -.002"

Table 18 lists the recommended tolerances for all setscrew locking, eccentric locking and D-LOK locking ball and roller bearings

Table 19: Shaft Tolerances

Shaft Size	Tolerance, Inches
Up to 1-1/2"	+.000 -.002"
1-9/16 to 2-1/2"	+.000 -.003"
2-5/8 to 4"	+.000 -.004"
4-3/16 to 6"	+.000 -.005"
6-7/16" and above	+.000 -.006"

Table 19 list the recommended tolerances for all tapered adapter sleeve ball and roller bearings

Standard Shafting-Table 17 indicates standard shafting is cold drawn in the smaller sizes and turned and polished in the larger diameters. It has a smooth surface, is commercially straight and is readily machinable; suitable and recommended for general power transmission and material handling service.

Special Shafting-While standard shafting is suitable for most installations, special shafting is sometimes required for certain chemical, temperature or physical requirements. Such materials as high carbon steel, alloy steel, stainless steel, brass, Monel metal, etc., can be furnished plain or heat treated. Stepped, flanged, hollow or other special forms are available.

Special shafting should be avoided in favor of standard shafting wherever possible because special shafting is usually considerably more expensive and requires a greater length of time to obtain, which is an especially important consideration should quick replacement ever become necessary.

Ordering Shafting-Standard shafting can be obtained from most supply houses and dealers who handle power transmission material.

Turning Down Shaft Ends-When necessary to turn down shaft ends, use as large a fillet as possible to keep the stress concentration to a minimum. The radius of this fillet should preferably be not less than the difference in the two diameters joined by the fillet. The fillet should be finished and polished as smoothly as possible to avoid scratches which might start cracks and lead to failure of the shaft by fatigue.

Selection of Shaft Diameters

Tables 21 - 24 inclusive can be used to find approximate shaft diameter for various service conditions For greater accuracy use chart under heading “Combined Torsion and Bending of Standard Shafts” (B20-17).

Tables and chart are based upon a safe shear stress of 6,000 pounds per square inch for standard keyseated shafting. Be generous in the selection of shaft diameters as liberal diameters not only reduce deflection and vibration but also generally increase bearing life.

When necessary to use other than standard shafting, find the required diameter for standard shafting as outlined above and multiply by proper factor shown in Table 25, under heading “Factors for Shafting Other than Standard Shafting, “(B20-16).

Table 20: No Bending Moment (Shafts without pulleys, sprockets or gears - Torsion only)

Shaft Size	Horse Power at Various Revolutions per Minute																		
	25	50	75	100	125	150	175	200	225	250	275	300	350	400	500	600	700	800	900
15/16	0.30	0.70	1.10	1.50	1.90	2.30	2.60	3.00	3.40	3.80	4.20	4.60	5.30	6.10	7.70	9.20	10.70	12.30	13.80
1-3/16	0.70	1.50	2.30	3.10	3.90	4.60	5.40	6.20	7.00	7.80	8.60	9.30	10.90	12.50	15.60	18.70	21.90	25.00	28.10
1-7/16	1.30	2.70	4.10	5.50	6.90	8.30	9.70	11.10	12.40	13.80	15.20	16.60	19.40	22.20	27.70	33.30	38.80	44.40	49.90
1-11/16	2.20	4.40	6.60	8.90	11.20	13.40	15.70	17.90	20.20	22.40	24.70	26.90	31.40	35.90	44.90	53.80	62.80	71.80	80.80
1-15/16	3.30	6.70	10.10	13.50	16.90	20.30	23.70	27.10	30.50	33.90	37.30	40.70	47.50	54.30	67.90	81.50	95.10	108.00	122.00
2-3/16	4.90	9.80	14.60	19.50	24.40	29.30	34.20	39.10	44.00	48.90	53.80	58.60	68.40	78.20	97.80	117.00	136.00	156.00	176.00
2-7/16	6.70	13.50	20.20	27.00	33.80	40.60	47.30	54.10	60.90	67.60	74.40	81.20	94.70	108.00	135.00	162.00	189.00	216.00	243.00
2-11/16	9.00	18.10	27.10	36.20	45.30	54.40	63.40	72.50	81.60	90.70	99.70	108.00	126.00	145.00	181.00	217.00	253.00	290.00	326.00
2-15/16	11.80	23.60	35.40	47.30	59.20	71.00	82.90	94.70	106.00	118.00	130.00	142.00	165.00	189.00	236.00	284.00	331.00	379.00	426.00
3-7/16	19.00	37.90	57.00	75.90	94.90	113.00	132.00	151.00	170.00	189.00	208.00	227.00	265.00	303.00	379.00	455.00	531.00	607.00	683.00
3-15/16	28.50	57.00	85.50	114.00	142.00	171.00	199.00	228.00	256.00	285.00	313.00	342.00	399.00	456.00	570.00	684.00	798.00	912.00	1026.00
4-7/16	40.80	81.60	122.00	163.00	204.00	245.00	286.00	327.00	367.00	408.00	449.00	490.00	572.00	653.00	816.00	980.00	1143.00	1306.00	1470.00

Table 21: Limited Bending Moment (Pulleys, sprockets or gears near bearings. Ordinary line shafts.)

Shaft Size	Horse Power at Various Revolutions per Minute																		
	25	50	75	100	125	150	175	200	225	250	275	300	350	400	500	600	700	800	900
15/16	0.20	0.50	0.70	1.00	1.20	1.50	1.70	2.00	2.30	2.50	2.80	3.00	3.50	4.10	5.10	6.10	7.10	8.20	9.20
1-3/16	0.50	1.00	1.50	2.00	2.60	3.10	3.60	4.10	4.70	5.20	5.70	6.20	7.30	8.30	10.40	12.50	14.60	16.70	18.80
1-7/16	0.90	1.80	2.70	3.70	4.60	5.50	6.40	7.40	8.30	9.20	10.10	11.10	12.90	14.80	18.50	22.20	25.90	29.60	33.30
1-11/6	1.40	2.90	4.30	5.90	7.40	8.90	10.40	11.90	13.40	14.90	16.40	17.90	20.90	23.90	29.90	35.90	41.90	47.90	53.90
1-15/16	2.20	4.50	6.70	9.00	11.30	13.60	15.80	18.10	20.40	22.60	24.90	27.20	31.70	36.20	45.30	54.40	63.40	72.50	81.60
2-3/16	3.20	6.50	9.70	13.00	16.30	19.50	22.80	26.10	29.30	32.60	35.80	39.10	45.60	52.20	65.20	78.30	91.30	104.00	117.00
2-7/16	4.50	9.00	13.50	18.00	22.50	27.00	31.60	36.10	40.60	45.10	49.60	54.10	63.20	72.20	90.20	108.00	126.00	144.00	162.00
2-11/16	6.00	12.10	18.10	24.20	30.20	36.30	42.30	48.40	54.40	60.50	66.50	72.60	84.70	96.80	121.00	145.00	169.00	193.00	217.00
2-15/16	7.90	15.80	23.70	31.60	39.50	47.40	55.30	63.20	71.10	79.00	86.90	94.80	110.00	126.00	158.00	189.00	221.00	252.00	284.00
3-7/16	12.60	25.30	37.90	50.60	63.30	75.90	88.60	101.00	113.00	126.00	139.00	151.00	177.00	202.00	253.00	303.00	354.00	405.00	455.00
3-15/16	19.00	38.00	57.00	76.10	94.10	114.00	133.00	152.00	171.00	190.00	209.00	228.00	266.00	304.00	380.00	456.00	532.00	608.00	685.00
4-7/16	27.00	54.00	81.00	108.00	136.00	163.00	190.00	217.00	245.00	272.00	299.00	326.00	381.00	435.00	544.00	653.00	762.00	871.00	980.00
4-15/16	37.00	75.00	112.00	150.00	187.00	225.00	262.00	300.00	337.00	375.00	412.00	450.00	525.00	600.00	750.00	900.00	1050.00	1200.00	1350.00
5-7/16	50.00	100.00	150.00	200.00	250.00	300.00	350.00	400.00	451.00	501.00	551.00	601.00	701.00	801.00	1002.00	1202.00	1403.00	1603.00	1804.00
5-15/16	65.00	130.00	195.00	261.00	326.00	391.00	456.00	522.00	587.00	652.00	717.00	783.00	913.00	1044.00	1305.00	1566.00	1827.00	2088.00	2349.00
6-1/2	85.00	171.00	256.00	342.00	427.00	513.00	598.00	684.00	769.00	855.00	940.00	1026.00	1197.00	1368.00	1710.00	2052.00	2394.00	2736.00	3078.00

Selection of Shaft Diameters (Continued)

Table 22: Heavy Bending Moment. (Use for main or important shafts.)

Shaft Size	Horse Power at Various Revolutions per Minute																		
	25	50	75	100	125	150	175	200	225	250	275	300	350	400	500	600	700	800	900
1-11/16	0.80	1.70	2.50	3.50	4.40	5.30	6.20	7.10	8.00	8.90	9.80	10.70	12.50	14.30	17.90	21.50	25.10	28.70	32.30
1-15/16	1.30	2.70	4.00	5.40	6.70	8.10	9.50	10.80	12.20	13.50	14.90	16.30	19.00	21.70	27.10	32.60	38.00	43.50	48.90
2-3/16	1.90	3.90	5.80	7.80	9.70	11.70	13.70	15.60	17.60	19.50	21.50	23.40	27.40	31.30	39.10	46.90	54.80	62.60	70.40
2-7/16	2.70	5.40	8.10	10.80	13.50	16.20	18.90	21.60	24.30	27.00	29.70	32.40	37.90	43.30	54.10	64.90	75.80	86.60	97.40
2-11/16	3.60	7.20	10.80	14.50	18.10	21.70	25.40	29.00	32.60	36.20	39.90	43.50	50.80	58.00	72.50	87.10	101	116	130
2-15/16	4.70	9.40	14.10	18.90	23.60	28.40	33.10	37.90	42.60	47.30	52.10	56.80	66.30	75.80	94.70	113	132	151	170
3-7/16	7.50	15.10	22.60	30.30	37.90	45.50	53.10	60.70	68.30	75.90	83.50	91.10	106	121	151	182	212	243	273
3-15/16	11.40	22.80	34.20	45.60	57.00	68.40	79.90	91.30	102	114	125	136	159	182	228	273	319	365	410
4-7/16	16.30	32.60	48.90	65.30	81.60	98.00	114	130	147	163	179	196	228	261	326	392	457	522	588
4-15/16	22.50	45.00	67.50	90.00	112	135	157	180	202	225	247	270	315	360	450	540	630	720	810
5-7/16	30.00	60.00	90.00	120	150	180	210	240	270	300	330	360	420	480	601	721	841	961	1082
5-15/16	39.00	78.00	117	156	195	234	273	313	352	391	430	469	547	626	782	939	1095	1252	1409
6-1/2	51.00	102	153	205	256	308	359	410	462	513	564	616	718	821	1027	1232	1437	1643	1848
7	64.00	128	192	256	320	384	448	513	577	641	705	769	897	1026	1282	1539	1795	2052	2308
7-1/2	78.50	157	235	315	394	473	552	631	709	788	867	946	1104	1262	1577	1893	2208	2524	2839
8	95.50	191	286	382	478	574	670	765	861	957	1053	1148	1340	1531	1914	2297	2680	3063	3446
8-1/2	114	229	343	459	574	688	803	918	1033	1148	1263	1377	1607	1837	2296	2755	3215	3674	4133
9	136	272	408	545	681	817	954	1090	1226	1363	1499	1635	1908	2181	2726	3271	3816	4362	4907
9-1/2	160	320	480	641	801	961	1122	1282	1442	1603	1763	1923	2244	2565	3206	3847	4488	5130	5771
10	186	373	559	747	934	1121	1308	1495	1682	1869	2056	2243	2617	2991	3739	4487	5235	5983	6731

Table 23: Severe Conditions (Heavy shock loads. Excessively tight belts, long clutch sleeves.)

Shaft Size	Horse Power at Various Revolutions per Minute																		
	25	50	75	100	125	150	175	200	225	250	275	300	350	400	500	600	700	800	900
1-11/16	0.4	0.89	1.20	1.70	2.20	2.60	3.10	3.50	4.00	4.40	4.90	5.30	6.20	7.10	8.90	10.70	12.50	14.30	16.10
1-15/16	0.6	1.39	2.00	2.70	3.30	4.00	4.70	5.40	6.10	6.70	7.40	8.10	9.50	10.80	13.50	16.30	19.00	21.70	24.40
2-3/16	0.90	1.90	2.90	3.90	4.80	5.80	6.80	7.80	8.80	9.70	10.70	11.70	13.70	15.60	19.50	23.40	27.40	31.30	35.20
2-7/16	1.30	2.70	4.00	5.40	6.70	8.10	9.40	10.80	12.10	13.50	14.80	16.20	18.90	21.60	27.00	32.40	37.90	43.30	48.70
2-11/16	1.80	3.60	5.40	7.20	9.00	10.80	12.70	14.50	16.30	18.10	19.90	21.70	25.40	29.00	36.20	43.50	50.50	58.00	65.00
2-15/16	2.30	4.70	7.00	9.40	11.80	14.20	16.50	18.90	21.30	23.60	26.00	28.40	33.10	37.90	47.30	56.50	66.00	75.50	85.00
3-7/16	3.70	7.50	11.30	15.10	18.90	22.70	26.50	30.30	34.10	37.90	41.70	45.50	53.00	60.50	75.50	91.00	106	121	136
3-15/16	5.70	11.40	17.10	22.80	28.50	34.20	39.90	45.60	51.00	57.00	62.50	68.00	79.50	91.00	114	136	159	182	205
4-7/16	8.10	16.30	24.40	32.60	40.80	49.00	57.00	65.00	73.50	81.50	89.50	98.00	114	130	163	196	228	261	294
4-15/16	11.20	22.50	33.70	45.00	56.00	67.50	78.50	90.00	101	112	123	135	157	180	225	270	315	360	405
5-7/16	15.00	30.00	45.00	60.00	75.00	90.00	105	120	135	150	165	180	210	240	300	360	420	480	541
5-15/16	19.50	39.00	58.50	78.00	97.10	117	136	156	171	195	215	234	273	313	391	469	547	626	704
6-1/2	25.50	51.00	76.50	102.5	128	154	179	205	231	256	282	308	359	410	513	616	718	821	924
7	32.00	64.90	96.00	128	160	192	224	256	288	320	352	384	448	513	641	769	897	1026	1154
7-1/2	39.20	78.50	117	157	197	236	276	315	354	394	433	473	552	631	788	946	1104	1262	1419
8	47.70	95.50	143	191	239	287	335	382	430	478	526	574	670	765	957	1148	1340	1531	1723
8-1/2	57.00	114	171	229	287	344	401	459	516	574	631	688	803	918	1148	1377	1607	1837	2066
9	68.00	136	204	272	340	408	477	545	613	681	749	817	954	1090	1363	1635	1908	2181	2453
9-1/2	80.00	160	240	320	400	480	561	641	721	801	881	961	1122	1282	1603	1923	2244	2565	2885
10	93.00	186	279	373	467	560	654	747	841	934	1028	1121	1308	1495	1869	2243	2617	2991	3365

Caution: Be generous in the selection of shaft diameters as liberal diameters not only reduce deflection and vibration but also generally increase bearing life. See notes on next page.

Selection of Shaft Diameters (Continued)

Shaft Stiffness, Shaft Deflection-Standard shafting of adequate strength usually has a sufficiently large diameter to prevent excessive deflection in ordinary installations. It is wise to select shafting of generous diameter, as the greater the diameter, the greater the stiffness. A high tensile strength alloy shaft, although stronger, is no stiffer than a standard shaft of the same diameter.

While it is sometimes possible to use an alloy shaft of less diameter than a standard shaft of equal strength, this practice is usually inadvisable, as the deflection is increased.

Shafts carrying medium or long clutch sleeves should be especially generous.

High Speed Shafts - High speed sometimes causes shaft whipping or vibration. This can be prevented by making the shaft diameter generous and the distance between bearing centers short.

Location of the bearings close to wheels and couplings is advisable whether the shaft is transmitting heavy or light loads.

The use of high tensile strength alloy shafting instead of standard shafting is of no help in preventing vibration as this will not improve the stiffness nor deflection characteristics of the shaft.

Stepped Shafts - For a heavily loaded wheel, a shaft with a boss or enlarged section under the wheel and turned to a smaller diameter at the bearings often provides the most economical installation. The two different diameters should be joined by a very generous fillet, otherwise a dangerous concentration of stress will occur at the fillet. See heading - "Turning Down Shaft Ends." (B16-15).

Shaft Keyseats - Plain keyseats are preferable to round end keyseats in respect to causing the least concentration of stress. However, round end keyseats are often used because of design and assembly requirements. Ends left by the milling cutter should not project into babbitted or bronze bushed bearing, but may project under the sleeve of any DODGE anti-friction bearing.

Shaft diameters obtained from the tables or chart allow for the use of keyseats.

Shaft Bearings - On ordinary line shafting, bearings are commonly spaced about eight feet centers. On large diameter shafts, the spacing may be somewhat greater.

Wheels and clutches should be located near bearings to avoid dangerous bending, deflection and vibration.

Bearings should be mounted on adequate supports so that accurate alignment may be maintained. Shaft misalignment may cause shaft or bearing failure.

Shaft Couplings - Where a rigid coupling is used, it is preferable to have a bearing fairly close. Where a cutoff coupling or a flexible coupling is used, locate bearings close to each end of the coupling.

Expansion of Shafting - Where changes in the length of the shaft due to changes in temperature are to be expected and the bearings are mounted on supporting structures other than steel, consideration must be given to expansion. For more detailed information see B16-20, headed: "Expansion of Shafting."

Factors for Shafting Other Than Standard Shafting

When it is necessary to use other than standard shafting, multiply required diameter for standard shafting as found in the tables or chart by proper factor from Table 24 below.

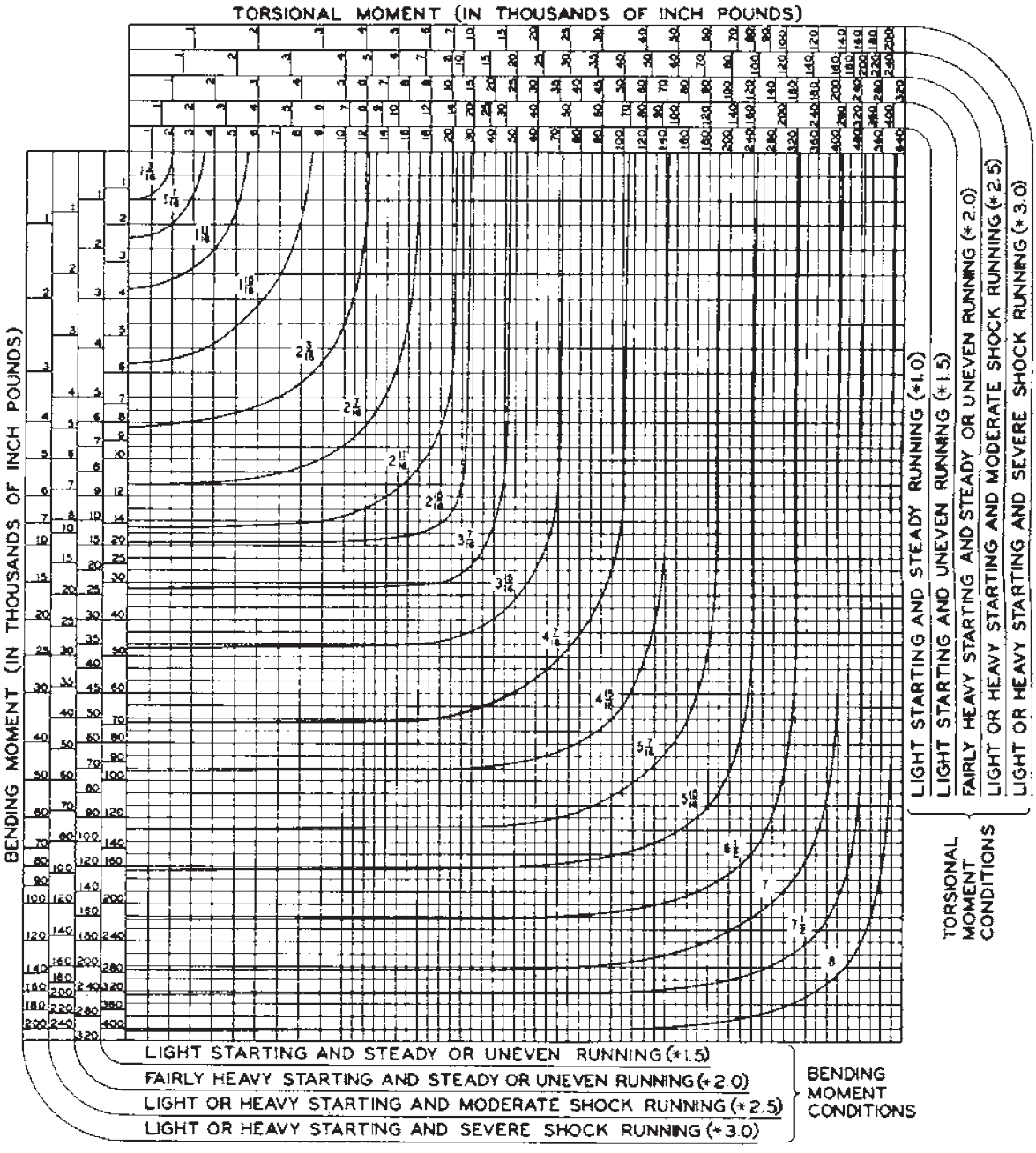
Standard keyseated shafting, using a safe shear stress of 6,000 PSI is the basis of shafting tables and chart. For safe shear stress of other materials, use 1/10 of nominal ultimate tensile strength. For example, use 8,000 for C1045 and 10,000 for 4140 keyseated shafting. When definite physical specifications are known the least of 13.5% of minimum ultimate tensile strength and 22.5% of minimum elastic limit in tension may be used for keyseated shafting; 18% and 30% respectively if not keyseated.

Caution - As the deflection of steel shafting depends upon the diameter and not upon the analysis of the steel, care should be exercised in the use of alloy shafting not to reduce the diameter unduly. Deflection should not be excessive and bearing capacities should be adequate. It is usually best to use standard shafting instead of a smaller diameter alloy shaft. The smaller alloy shaft may safely transmit the torque but often is undesirable in respect to deflection, vibration and bearing life

Table 24: Shear Stress Factors

Safe Shear Stress	Factor	Safe Shear Stress	Factor	Safe Shear Stress	Factor	Safe Shear Stress	Factor	Safe Shear Stress	Factor
500	2.289	3,000	1.260	5,500	1.029	9,000	.874	14,000	.754
1,000	1.817	3,500	1.197	6,000	1.000	10,000	.843	15,000	.737
1,500	1.587	4,000	1.145	6,500	.974	11,000	.817	16,000	.721
2,000	1.442	4,500	1.101	7,000	.950	12,000	.794	17,000	.707
2,500	1.339	5,000	1.063	8,000	.909	13,000	.773	18,000	.693

Combine Torsion and Bending of Standard Shaft (Based on a Safe Shear Stress of 6,000 PS for Keyseated Shafting)



Example: Engine extension shaft driving single cylinder compressor, 15,000 pound-inches torsional moment, 14,000 pound- inches bending moment. Because of the heavy shock running load conditions use scales designated “Light or Heavy Starting and Severe Shock Running”. Project a line down from 15,000 torsional moment. Project a line to the right from 14,000 bending moment. The two lines intersect between 3-7/16 and 3-15/ 16 curves. Use 3-15/16 standard shafting.

Note: The above chart is based on ASME approved standard ASA-B17C-1927 withdrawn in 1954. If the latest shaft selection analysis is required refer to ANSI/ASME B106.1M-1985.

Note: If considering use of other shafting material refer to “Selection of Shaft Diameters” on page B16-18.