BELT AND CHAIN DRIVES

BELT DRIVES A105
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BELT DRIVES

Belts, pulleys, and sheaves for OEM high-volume-produced products such as home appliances and passenger car engines are usually custom designed and manufactured by the thousands for specific functions and operating conditions. The heavy expense of custom belt design, extensive testing, and special tooling are absorbed easily in the volume production of identical belts. Short delivery time is not expected in the mass produced product until a specific production date is set.

An entirely different set of cost, design, and delivery priorities prevail for belts and sheaves for industrial machines built only a few at a time. The same low-quantity-needs approach must be taken on belt drive systems for own-use machinery, rebuilt machinery, plant pump equipment, compressed air equipment, and the full range of heating, ventilation, and air-conditioning systems. It is difficult to justify the expense of custom belts and sheaves when only a few (and sometimes a few hundred) of any one size are needed. Fortunately, a wide variety of standard sizes and types of industrial belts and sheaves is readily available from stock at industrial power transmission products distributors. Representative standard belts, Figure 1, include flat, classical V, narrow V, double V, V-ribbed, joined V, and synchronous designs.

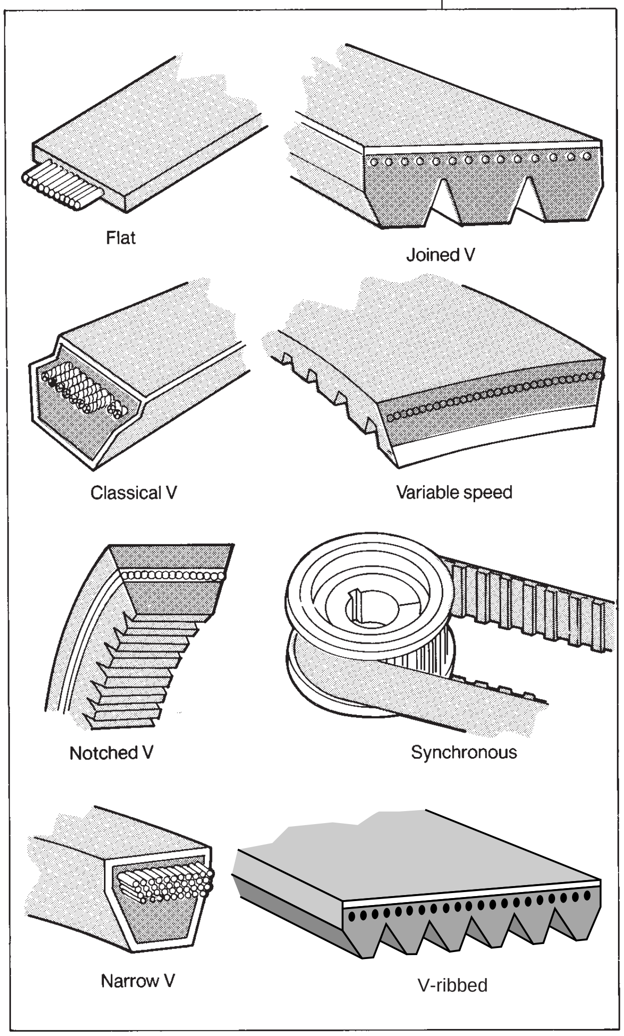


Figure 1 — Representative belt configurations.

Advantages of belt drives include:

1. No lubrication is required, or desired.
2. Maintenance is minimal and infrequent.
3. Belts dampen sudden shocks or changes in loading.
4. Quiet, smooth operation.
5. Sheaves (pulleys) are usually less expensive than chain drive sprockets and exhibit little wear over long periods of operation.

Drawbacks of belt drives that are more important in some applications than others are:

1. Endless belts usually cannot be repaired when they break. They must be replaced.
2. Slippage can occur, particularly if belt tension is not properly set and checked frequently. Also, wear of belts, sheaves, and bearings can reduce tension, which makes retensioning necessary.
3. Adverse service environments (extreme temperature ranges, high moisture, oily or chemically filled atmospheres, etc.) can damage belts or cause severe slipping.
4. Length of endless belts cannot be adjusted.

Design considerations — Belt type, belt materials, belt and sheave construction, power requirements of the drive, speeds of driving and driven sheaves, sheave diameters, and sheave center distance are key belt drive design considerations. Basic to power transmission design with belt drives is to maintain friction developed between the belt and the sheave or pulley contact surface.

Belt creep and slip — All belts (except synchronous) creep, but creep must be differentiated from slip. For example, a V-belt under proper tension creeps about 0.5% because of its elasticity and the changes in cross section and length taking place as a section of the belt moves from the tight side to the slack side of the drive and back. That cyclical stressing, plus the bending action of the belt as it travels around the sheaves, causes only a slight increase in belt temperature. Most of that heat will be dissipated by the sheaves so that they will be only slightly warm if touched. (Of course, the belt drive must be at rest before an operator would dare touch the sheaves.)

Slip, which is a movement greater than the 0.5% creep, can create enough heat to be very uncomfortable if the sheaves are touched (again, when the drive is stopped). Another way to check for slip is to touch the belt (when it is stopped). If the belt is uncomfortable to the touch (over 140 F), it probably needs to be tightened.

Belt tension — Checking operating temperatures of sheaves and belts (the touch test) is but one of several ways experienced machine operators and plant maintenance people check belt tension without the need for complicated measurements and calculations.

Other equally simple and useful belt tensioning approaches involve visual and sound techniques. The bow or sag on the slack side of belt drives increases as a drive approaches full load. Undulations and flutter on the slack side of belts can be very informative to the experienced eye. Proper tensioning can reduce or eliminate these conditions.

Tension adjustment based on belt sound can be a useful technique. Loads such as industrial fans require peak torque at starting. If belts squeal as the motor comes on or at some subsequent peak load, experienced belt people say the belts should be tightened until the squeal disappears.

Calculating V-belt tension — Figure 2 represents a belt drive arrangement which can be used to study factors affecting V-belt tensions and stresses. At standstill, the belt strand tensions T_1 and T_2 are equal. When load is applied to the driving pulley, tension T_1 increases and T_2 decreases.

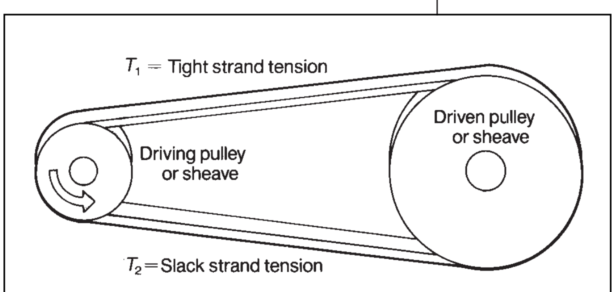


Figure 2 — Effective belt tension is the difference between tight-strand and slack-strand tensions.

T_1, tight side tension, divided by T_2 slack side tension, is the tension ratio of a belt drive. The formula for tension ratio is as follows:

Where:

$$\frac{T_1}{T_2} = e^{kf\phi}$$

e = 2.718 (the base of natural logarithm).

k = Wedging factor, from Figure 3, which is considered constant for a given drive.

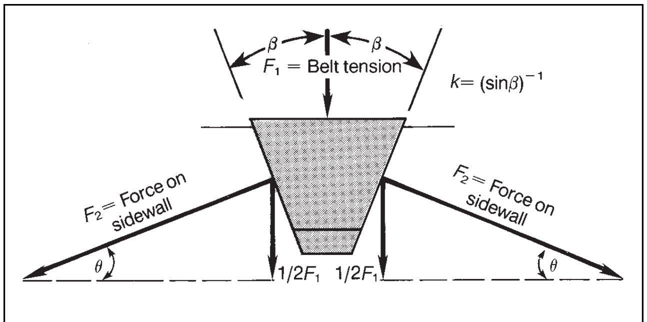


Figure 3 — Wedging action of V-belt increases force of belt against sheave groove and helps prevent slip.

f = Dynamic coefficient of friction between belt and sheave.

ϕ = Wrap angle (arc of contact on the smaller sheave in radians).

K applies only to V-belt drives. A practical tension ratio of 5 for V-belts allows for such variations as lack of rigidity of mountings, low initial tension, moisture, and load fluctuations. For rubber flat belt drives, a tension ratio of 2.5 is considered most efficient.

The difference between tight-strand and slack-strand tensions is effective tension, or $T_e = T_1 - T_2$. Effective tension is the actual force that turns the driven sheave.

Stress and power ratings — The usable strength of a belt is the tensile stress the belt withstands for a specified number of stress cycles, usually the equivalent of 3 years of continuous operation, or about 25,000 hr. The relationships of effective tension, T_e (lb), belt stress ratings, S_p (psi), and cross-sectional area, A (in.^{2}), of the belt are given in the formula $T_e = AS_p$.

For belt drive transmitted horsepower:

Where:

$$hp = \frac{T_e V}{33{,}000}$$

V = Belt velocity, fpm = 0.262DN

D = Pulley diameter, in.

N = Pulley speed, rpm

Great advancements have been made in various materials used in V-belts in recent years. Horsepower ratings may vary considerably from one belt to another. It's important to provide greater tension for belts carrying higher power. Otherwise the newly designed belts will not run properly; they may slip, vibrate too much, or turn over in the grooves.

All torque is transmitted through the belts, and torque does not change for a given horsepower and speed. This basic concept is best revealed in a multiple-belt drive. For example, a multiple V-belt drive formerly requiring seven belts may need only five higher-rated belts with the same cross section. For five belts to deliver the same horsepower as seven belts, each of the five new belts must carry more load. Increased tension in the individual belts will not overload the bearings, as some engineers may fear, because total tension in the drive should be exactly the same value. Each belt has a higher tension, but there are fewer belts to transmit the tension to bearings.

Belt types

Flat belts — Most of the general principles of belt drive operation discussed earlier apply to flat belt drives. In calculating tension ratios for flat belts, consult the manufacturer for typical values of the friction coefficient, f. For a flat belt drive, k = 1. Several useful formulas for endless belts follow (refer to Figure 4). For belt length in an open belt drive:

$$L_0 = 2C + 1.57(D+d) + \frac{(D-d)^2}{4C}$$

Belt length in a crossed belt drive:

$$L_x = 2C + 1.57(D+d) + \frac{(D+d)^2}{4C}$$

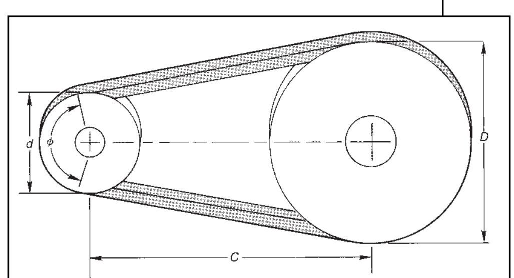


Figure 4 — Basic dimensions for calculating open and crossed belt lengths and arc of contact on smaller pulley or sheave.

Where:
C = Center distance, in.
d = Small pulley diam., in.
D = Large pulley diam., in.

Wrap angle or arc of contact on the smaller pulley in degrees is:

$$\phi = 180 - 57.3\frac{(D-d)}{C}$$

Drive system torque transmitted, lb-in., is:

$$T = \frac{T_e d}{2}$$

One version of flat belting is an endless woven type that is made in seamless tubes. Materials are cotton and synthetic yarns, both spun filament and continuous filament. Belt carcasses can be impregnated and coated with elastomers or synthetic resin. If an endless belt less than 0.010 in. thick is needed, specify one made of polyester film.

Another material used for flat belting is leather. The National Industrial Belting Association (NIBA) provides information on belt speeds for standard pulley diameters and widths. NIBA divides pulleys into three standard series: light duty (up to 40 hp), medium duty (40 to 75 hp), and heavy duty (75 to 150 hp).

Flat belts with tension members made of nylons and polyesters are popular because they offer high strength-to-weight ratios and negligible permanent stretch. More favorable friction characteristics can be achieved by laminating nylon or polyester flat belting with a friction surface of chrome leather, polyurethane, rubber, PVC, or other material. Laminated belts are used widely in industrial drives ranging from fractional horsepower to more than 6,000 hp at belt speeds to 20,000 fpm.

Metal belts — Flat belts made of metal offer lightweight, compact drives with little or no stretch. Endless belts are made by butt welding the ends with laser or electron-beam methods. Belts are generally available in thicknesses ranging from 0.002 to 0.030 in. and widths from 0.030 to 24 in. Circumferential length ranges from 6 in. to about 100 ft. Usually made of stainless steel, metal belts have a high strength-to-weight ratio, low creep, high accuracy, and resistance to corrosion and high temperature. Some applications take advantage of the electrical conductivity of metal belts to ground conveyed parts that are sensitive to static electricity.

Attachments, such as pins and brackets, can be provided on metal belts to carry, position, or locate parts being transported on the belt. Perforations in the belts enable their use in sprocket-driven applications for greater positioning accuracy, Figure 5.

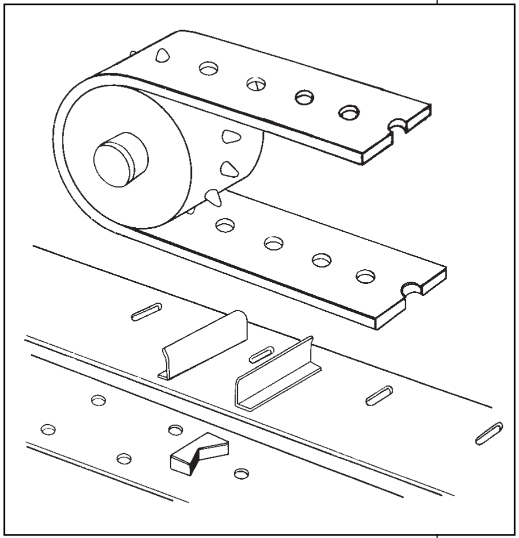


Figure 5 — Metal belt attachments transport or position parts. Perforated belts are used with sprockets to improve accuracy.

Endless round belts — An elastomeric O-belt is a seamless, circular belt that features a round cross section and an ability to stretch. Although O-belts look like O-rings, they are designed for power transmission applications. The elasticity of O-belts simplifies design problems and reduces costs. However, they are limited to subfractional horsepower applications such as recorders, projectors, and business machines. O-belt materials include natural rubber and four polymers — neoprene, urethane, ethylene-propylene-terpolymer (EPT), and ethylene-propylene-dienemonomer.

Minimum pulley diameter is 6 times the belt cross section. Pulley grooves should be semicircular with a radius 0.45 of the cross-sectional diameter of the belt. Manufacturers can supply charts showing the relationship of O-belt horsepower and belt speeds for various cross sections.

V-belts — Available from virtually all power transmission components distributors, standard V-belts are adaptable to practically any drive, although sometimes they may not be optimal in terms of life-cycle cost or compactness.

Besides their wide availability, V-belts are often used in industrial and commercial applications because of their relative low cost, ease of installation and maintenance, and wide range of sizes. The V shape obviously makes it easier to keep fast-moving belts in sheave grooves than it is to keep a flat belt on a pulley. Probably the biggest operational advantage of a V-belt is that it is designed to wedge into the sheave groove, Figure 3, which multiplies the frictional force it produces in tension and, in turn, reduces the tension required to produce equivalent torque. Naturally, wedging action requires adequate clearance between the bottom of the belt and the bottom of the sheave groove. The effect of the wedging factor, k, on the belt tension ratio is shown in the section that discusses V-belt tension calculations.

When V-belts first appeared in industrial applications to replace wide flat belts, it was not unusual to use 10 to 15 belts between a single pair of shafts. Thus the term "multiple" belts originated, which today is referred to as "classical multiple" or "heavy-duty conventional" belts.

Classical V-belts and mating sheaves have been standardized with letter designations from A through E, small to large cross sections. Those standard sizes are recognized worldwide. A and B sizes are frequently used individually but not the C, D, and E sizes because of cost and efficiency penalties. Belts with cogged or notched bases permit more severe bends, which allows operation over smaller diameter sheaves.

Although classical V-belts can be used in some applications individually, they tend to be over designed for a number of light duty applications. Thus, a special category of belts has evolved under the description *single V-belts*; they are also denoted as fractional horsepower and light duty. Cross-sectional size designations run from 2L (the smallest) to 5L (the largest). The 4L and 5L sections are dimensionally similar to A and B classical belts and can operate inter-

Table 1 — Standard dimensions of conventional synchronous belts

Pitch, in.	Length, in.	Width, in.
0.080	3.6 to 20.8	1/8, 3/16, 1/4
1/5	6 to 26	1/4, 3/8
3/8	12.4 to 60	1/2, 3/4, 1
1/2	24 to 180	3/4, 1, 1 1/2, 2, 3
`7/8	50.7 to 180	2, 3, 4
1 1/4	70 to 180	2, 3, 4, 5

changeably on A and B sheaves.

Narrow V-belts are the latest step in the evolution of a single-belt configuration. For a given belt width, narrow belts offer higher power ratings than conventional V-belts. Narrow belt size designations are standardized as 3V, 5V, and 8V. They are also available in notched designs to maximize bending capability.

Cogged, raw-edge belts have no cover, thus the cross-sectional area normally occupied by the cover is used for more load-carrying cord. Cogs on the inner surface of the belt increase air flow to enhance cooler running. They also increase flexibility, enabling the belt to operate with smaller sheaves. Cogged belts are available in both AX, BX, and CX Classical V shapes plus 3VX and 5VX narrow V configurations.

Double sided or hexagonal belts come in AA, BB, and CC narrow V-belt cross sections. These belts transfer power from either side in serpentine drive configurations where a single belt operates with multiple pulleys.

Joined V-belts solve special problems for conventional multiple V-belt drives produced by pulsating loads, such as those generated by internal combustion engines driving compressors. The intermittent forces can produce a whipping action in multiple belt systems, which sometimes causes belts to turn over in the grooves. The basic belt element can be either classical or narrow. The joined configuration avoids the need to order multiple belts as matched sets. Joined 5V and 8V belts are available with aramid fiber reinforcement which offer extremely high power capacity — up to 125 hp per inch of width.

V-ribbed belts combine some of the best features of flat belts and V-belts. Tensioning requirements are not as high as flat belts but are about 20% more than V-belts. Five standard configurations are available, with designations H, J, K, L, and M. The M section is capable of transmitting up to 1,000 hp. The power density permits compact drive configurations, but the belt is usually applied only in mass-produced products.

Belts for variable-speed drives require special care in selection. Those for fixed-pitch drives, in which the speed ratios are changed only at standstill, are offered with sheaves for 3L through 5L, A through D classical, and 5V and 8V narrow belts.

For the adjustable (while running) variable speed drives, 4L, 5L, A, or B belts can be used if power requirements are less than 2 hp and speed variations are limited to 4.5:1. Special wide belts have been developed for variable-speed applications that accommodate speed variations of up to 9:1. There are 12 standard belt sections denoted by a four-digit number followed by the letter V. Refer to the Adjustable-Speed Drives Product Department of this handbook for a discussion on these drives.

Synchronous (timing) belts are used where input and output shafts must be synchronized. Trapezoidally shaped teeth of the belt mate with matching grooves in the pulleys to provide the same positive, no-slip engagement of chain or gears. Standard sections are designated MXL, XL, L, H, XH, and XXH. Table 1 shows typical synchronous belt dimensions.

Because stable belt length is essential for synchronous belts, they were originally reinforced with steel. Today, glass fiber reinforcement is common and aramid is used if maximum capacity is required.

Modifications of traditional trapezoidal tooth profiles to more circular forms offer more uniform load distribution, increased capacity, and smoother, quieter action. These newer synchronous belts incorporate a rounded curvilinear tooth design to handle the higher torque capabilities normally associated with chain drives, Figure 6.

Link-type V-belts consist of removable links that are joined by T-shaped rivets or interlocking tabs. These belts offer application advantages such as installation without dismantling drive components, reduced belt inventory (no need for different lengths), wide temperature range, and resistance to chemicals, abrasion, and shock loads. A matrix of polyester fabric and polyurethane elastomer enables link-type belts to meet the horsepower ratings of classical V-

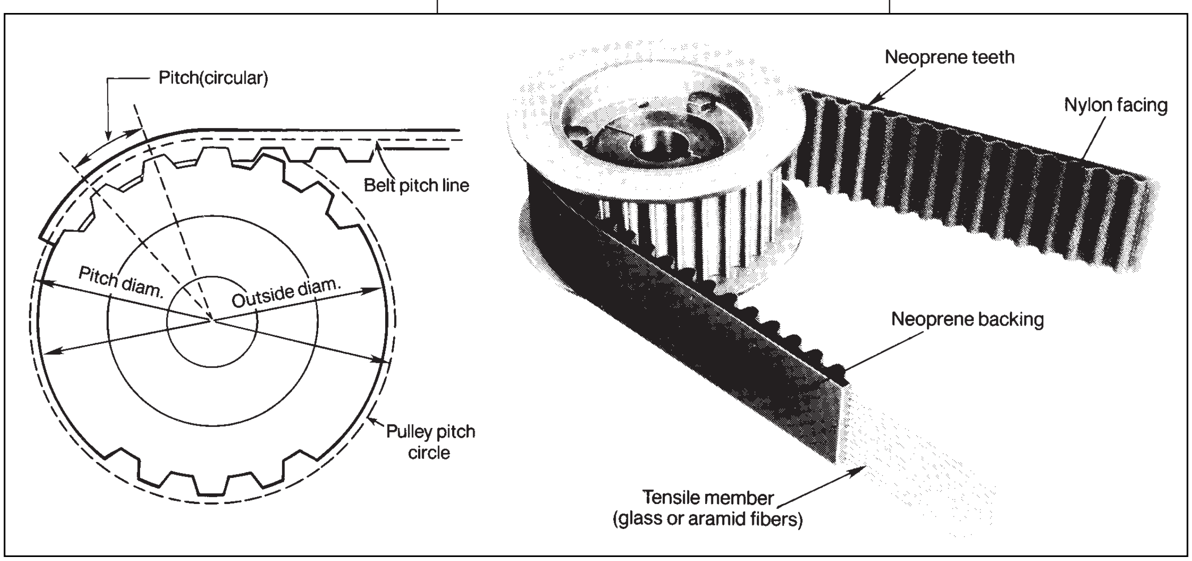


Figure 6 — Typical synchronous belt and pulley with trapezoidal teeth, left, and curvilinear-tooth, high-torque drive, right.

belts. They are available in 3/8 through 7/8-in. widths for speeds up to 6,000 rpm.

CHAIN DRIVES

Power transmission chains can be categorized as roller chain, engineering steel chain, silent chain, detachable chain, and offset sidebar chain. Some of the advantages of chain drives over belt drives are:

- No slippage between chain and sprocket teeth.
- Negligible stretch, allowing chains to carry heavy loads.
- Long operating life expectancy because flexure and friction contact occur between hardened bearing surfaces separated by an oil film.
- Operates in hostile environments such as high temperatures, high moisture or oily areas, dusty, dirty, and corrosive atmospheres, etc., especially if high alloy metals and other special materials are used.
- Long shelf life because metal chain ordinarily doesn't deteriorate with age and is unaffected by sun, reasonable ranges of heat, moisture, and oil.
- Certain types can be replaced without disturbing other components mounted on the same shafts as sprockets.

Drawbacks of chain drives that might affect drive system design are:

- Noise is usually higher than with belts or gears, but silent chain drives are relatively quiet.
- Chain drives can elongate due to wearing of link and sprocket teeth contact surfaces.
- Chain flexibility is limited to a single plane whereas some belt drives are not.
- Usually limited to somewhat lower-speed applications compared to belts or gears.
- Sprockets usually should be replaced because of wear when worn chain is replaced. V-belt sheaves exhibit very low wear.

Each link of a chain drive transmits load in tension to and from sprocket teeth. Because of the positive driving characteristics of a chain drive, it requires only a few sprocket teeth for effective engagement that allows higher reduction ratios than are usually permitted with belts. Load capacity of chain drives can be increased with multiple-strand chains.

Types of chains and sprockets

There is a wide variety of standard and nonstandard chain and sprocket designs. The American National Standards Institute (ANSI) has set standards for chain that are prefixed ANSI B29. The standards cover transmission and conveyor chain as well as sprocket tooth dimensions, pitch diameters, and sprocket measuring procedures. The best known of all chain is roller chain, the first to be standardized by ANSI.

Roller chain — Flexure joints in roller chain contain pins that pivot inside the roller bushings. The pins are usually press fitted into the pin link plates, and roller bushings are press fitted into roller link plates, Figure 7. The ANSI standard for single pitch roller chain is B29.1. A free-turning roller encircles each bushing to provide rolling engagement and contact with sprocket teeth.

The distance between flexing joints in roller chain is the pitch, which is the basic designation for different chain sizes. Larger pitch indicates larger links with higher load ratings. Although a small pitch chain carries less load, it offers smoother, quieter operation than a chain of larger pitch. Standard sizes of roller chain vary from 1/2 to 3-in. pitch. A nominal size is designated by multiplying pitch by 80. Thus, a chain with a 1/2-in. pitch is No. 40.

Also included in the roller chain standard are two sizes that have no rollers but are proportioned much like larger-pitch roller chain. These rollerless sizes have 1/4 and 3/8-in. pitches and are designated No. 25 and No. 35, respectively, with the 5 indicating the rollerless design. The outside surface of each chain link bushing contacts the sprocket teeth directly.

The right-hand digit in roller chain designation is 0 for roller chains of the usual proportions, 1 for lightweight chain, and 5 for rollerless bushed chain. A hyphenated numeral 2 suffixed to the chain number denotes a double-strand, 3 a triple-strand, etc. Example numbers for single-strand roller chain are: No. 50 chain indicates a 5/8-in. pitch chain of basic proportions; and No. 35 indicates a 3/8-in. pitch rollerless bushed design. In multiple strand roller chain, 60-2 designates two strands of a No. 60 chain in parallel having common chain assembly pins, and 60-3 designates a triple strand.

Double-pitch roller chain — Also known as extended pitch chain, double-pitch roller chain dimensions, which are listed in the ANSI B29.3 standard, are the same as standard roller chain with comparable load capacity except the pitch is doubled, Figure 8. Because a given length of double-pitch chain contains only half as many pitches, it is lighter and less expensive than standard roller chain. It is especially suitable for long center distance applications. Double-pitch roller chain offers essentially the same strength characteristics as B29.1 chain because all dimensions are the same except pitch. Double-pitch chain designation numbers add "20" preceding what would be a standard roller chain number. For example, 2050 designates a $5/8 \times 2$ or 1 1/4-in. double-pitch roller chain. (Multiplying $5/8 \times 80 = 50$ preceded by 20 for the double pitch.)

Sprockets for double-pitch roller chain are either single-cut (one wide-tip tooth between each pair of chain rollers) or double-cut (two teeth between each pair of chain rollers).

Silent (inverted tooth) chain — Quieter running and more flexible

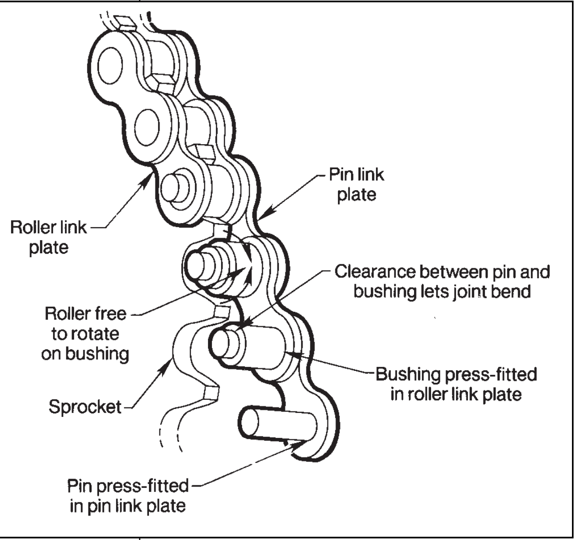


Figure 7 — Single pitch roller chain is available in pitch sizes above 3/8 in. Single and multiple-strand versions are available.

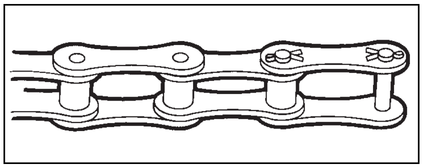


Figure 8 — Double pitch roller chain.

than conventional roller chain, silent chain, Figure 9, is available in $\frac{3}{16}$ to 2-in. pitch sizes. Standards for inverted-tooth chain are ANSI B29.2 and B29.9.

The several different types of silent chain construction prohibit mixing chains in a strand, but a chain of the correct size usually will operate on sprockets from a different manufacturer. Load capacity is increased by widening silent chain rather than using multiple strands.

For silent chain with a $\frac{3}{8}$-in. pitch or greater, an SC prefix in the chain size designation indicates conformance to ANSI B29.2. The first one or two digits following the SC indicate pitch in eighths of an inch followed by the next two to three digits, which indicate chain width in $\frac{1}{4}$-in. increments. For example, SC1012 designates ANSI standard silent chain with a $1\frac{1}{4}$-in. pitch and a 3-in. width.

For silent chain with a $\frac{3}{16}$-in. pitch, numbers following the 03 (which identifies the chain as $\frac{3}{16}$-in. pitch) indicate the total number of chain links wide. Width (or thickness) of each link is approximately $\frac{1}{32}$-in. Therefore, the number SC0314 designates a $\frac{3}{16}$-in. pitch silent chain that is approximately $\frac{7}{16}$-in. wide.

Any of several techniques can be used to position silent chain axially on sprockets. In one technique, center link plates ride in circumferential grooves in the sprocket. In another method, side link plates hold the chain in place on the sprocket axially.

Detachable link chain — The ANSI standard for detachable link chain is B29.6. The major advantage of chain with detachable links is that they can be separated at any joint without using special tools. Of course, the mountings for one or both sprockets must be loosened and the sprockets moved closer together to loosen the chain. This procedure allows positioning adjacent links at such an angle to each other that they can be taken apart by sliding a pair of connecting links sideways.

Detachable link chains are fabricated with one-piece elements; either press-formed from flat rolled steel, Figure 10A, or cast in malleable iron or other ferrous metals with comparable properties, Figure 10B. Pressed-steel detachable chain links (ANSI B29.6) typically range in size from 0.9 to 2.3-in. pitch. The typical pitch range for cast detachable chain links (formerly ANSI B29.7, now withdrawn) is 0.9 to 4 in.

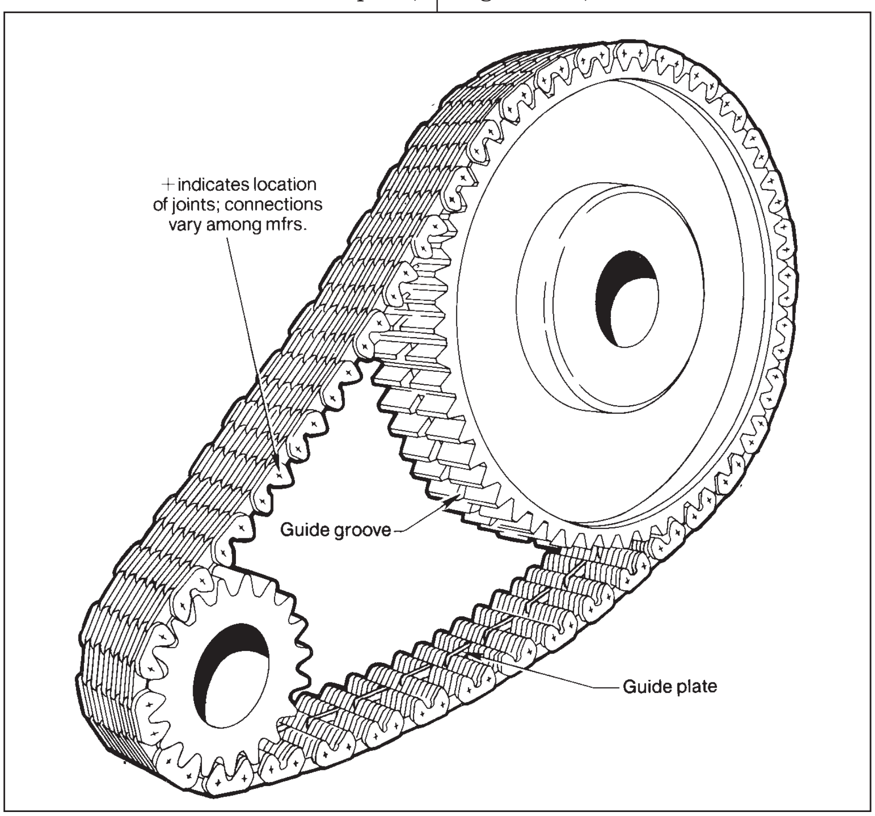


Figure 9 — Inverted tooth (silent) chain drive. These sprockets are grooved for center guide chain.

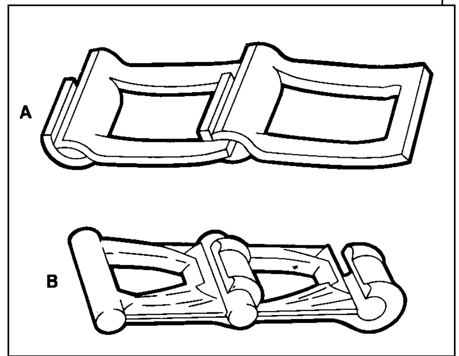


Figure 10 — Pressed steel detachable link chain, A, and malleable iron detachable link chain, B.

Detachable chain is low in cost and can transmit up to 25 hp at speeds to 350 fpm. It is not as smooth running as precision chain and does not require lubrication.

Engineering steel chain — Where the transmission of high power is the primary requirement, engineering steel drive chains offer many useful solutions. Engineering steel chains are perhaps the most widely used, with applications mainly in industrial drives and conveyors. Standards for heavy duty, offset sidebar type engineering steel roller chain, Fig. 11A, are given in ANSI B29.10. Specifications for heavy duty straight-sidebar, roller-type conveyor

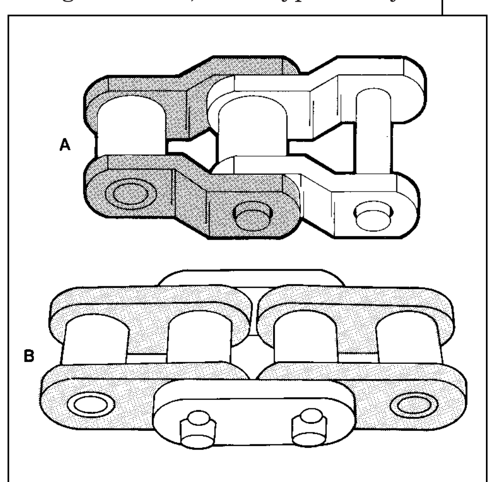


Figure 11 — Heavy duty, offset sidebar engineering steel roller chain, A, and heavy duty, straight sidebar roller type conveyor chain, B.

chain, Fig. 11B, are covered in the ANSI B29.15 standard, steel bushed rollerless chain in B29.12, welded steel mill chain in B29.16, and drag chain in B29.18.

Shaft center distance — In general, the preferred range of center distance for roller chain drives that allow adjustable center distances is 30 to 50 chain pitches, Figure 12. Roller chain drives with fixed centers should be limited to about 30 pitches.

Obviously, the minimum center distance must allow clearance between the teeth of the two sprockets. Other than that requirement, the arc of chain engagement should not be less than 120 deg, Figure 13. For ratios of 3:1 or less, there will be 120 deg or more of wrap.

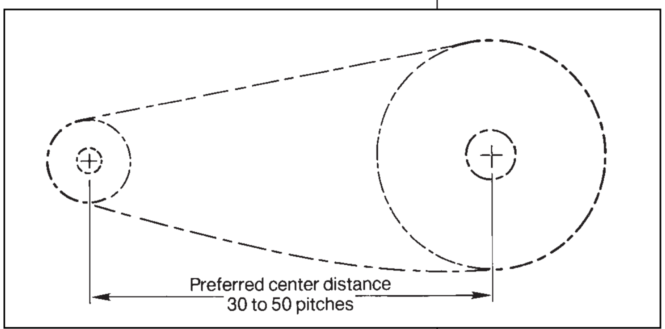


Figure 12 — Preferred range of center distance for roller chain drives.

A center distance equivalent to 80 pitches is usually considered a practical maximum. Very long center distances cause excessive tension and may cause the chain to jump teeth. Long chains may need to be supported by guides or idlers. Idlers are discussed in the PT Accessories Product Department of this handbook. Other drive system design approaches for extremely long center distances are to use two or more chain drives in series, or the lighter-weight double-pitch chain may be the answer where speed is slow and loading is moderate.

Chain application principles — Regardless of the type or class of chain, most of the following items are needed to design a chain drive:

1. Type of input power source (electric motor, internal combustion engine, etc.).
2. Type of driven load (uniform load, moderate shock, heavy shock).
3. Power (hp) to be transferred.
4. Full-load speed of fastest shaft.
5. Desired speed of slow shaft.
6. Shaft diameters.

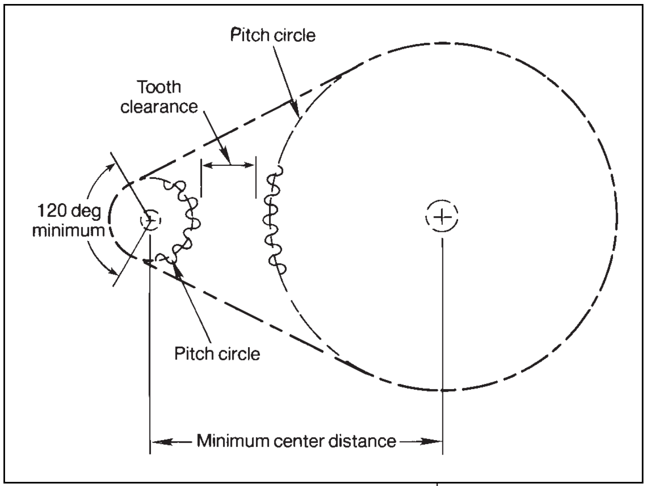


Figure 13 — Arc of roller chain engagement should not be less than 120 deg.

7. Center distance between shafts. (If distance is adjustable, what is the range of adjustment?)
8. Limits on space and position of drive.
9. Proposed lubrication method.
10. Special conditions such as drives with more than two sprockets, use of idlers, abrasive or corrosive environments, extreme temperatures, and wide variations in load and speed.

These data, when used with published chain capacity ratings, allow the designer to select the proper drive for each application. ANSI B29 standards contain capacity ratings as do chain manufacturers' catalogs. Standards covering roller chain and inverted tooth chain provide horsepower-capacity tabulations for a wide range of sprocket sizes and rotational speeds. Standards for detachable chain cover only allowable working loads. Standards and some manufacturers' literature contain both allowable working loads and horsepower-capacity tabulations for offset sidebar chain.

Ratings for most power application chains are based on life of 15,000 to 20,000 hr assuming alignment, lubrication, and maintenance requirements are met. See Table 2 for maximum horsepower vs. sprocket speed data. It is best to apply generous service factors, as high as 1.7, especially if heavy shock loading is anticipated. See Table 3 for recommended service factor data.

Sprockets are also covered by ANSI standards. Various types of sprockets are available including cast iron, powdered metal, flame-cut steel plate, machined metal, and plastic materials. Special-purpose sprockets are offered with shear pins, overload clutches, and other devices to protect against shock or overload.

Speed ratios should not exceed 10:1 for roller or silent chain and a limit of 6:1 for other types. If needed, use double-reduction drives to stay within those limits. For roller chain operat-

Table 2 — Maximum hp capacity at various speeds for 15-tooth sprockets

Sprocket speed, rpm	Maximum horsepower capacity			
	Roller chain		Double pitch	Offset sidebar
	Single strand	Four strand		
100	101	333	21.5	241
200	188	620	21.1	290
400	297	980	8.5	270
600	140	462	6.6	140
800	83.5	276	4.3	
1,000	59.7	197		
1,200	41.4	137		
1,400	29.5	97.4		
1,600	21.3	70.3		
1,800	17.9	59.0		
2,000	13.2	43.5		
2,200	11.4	37.6		
2,400	10.0	33.0		
2,600	7.4	24.6		
2,800	6.7	22.1		
3,000	6.0	19.8		

Table 3—Service factors

Load classification	Type of input power: Internal combustion engine with hydraulic drive	Electric motor or turbine	Internal combustion engine with mechanical drive
U Uniform	1.0	1.0	1.2
M Moderate shock	1.2	1.3	1.4
H Heavy shock	1.4	1.5	1.7

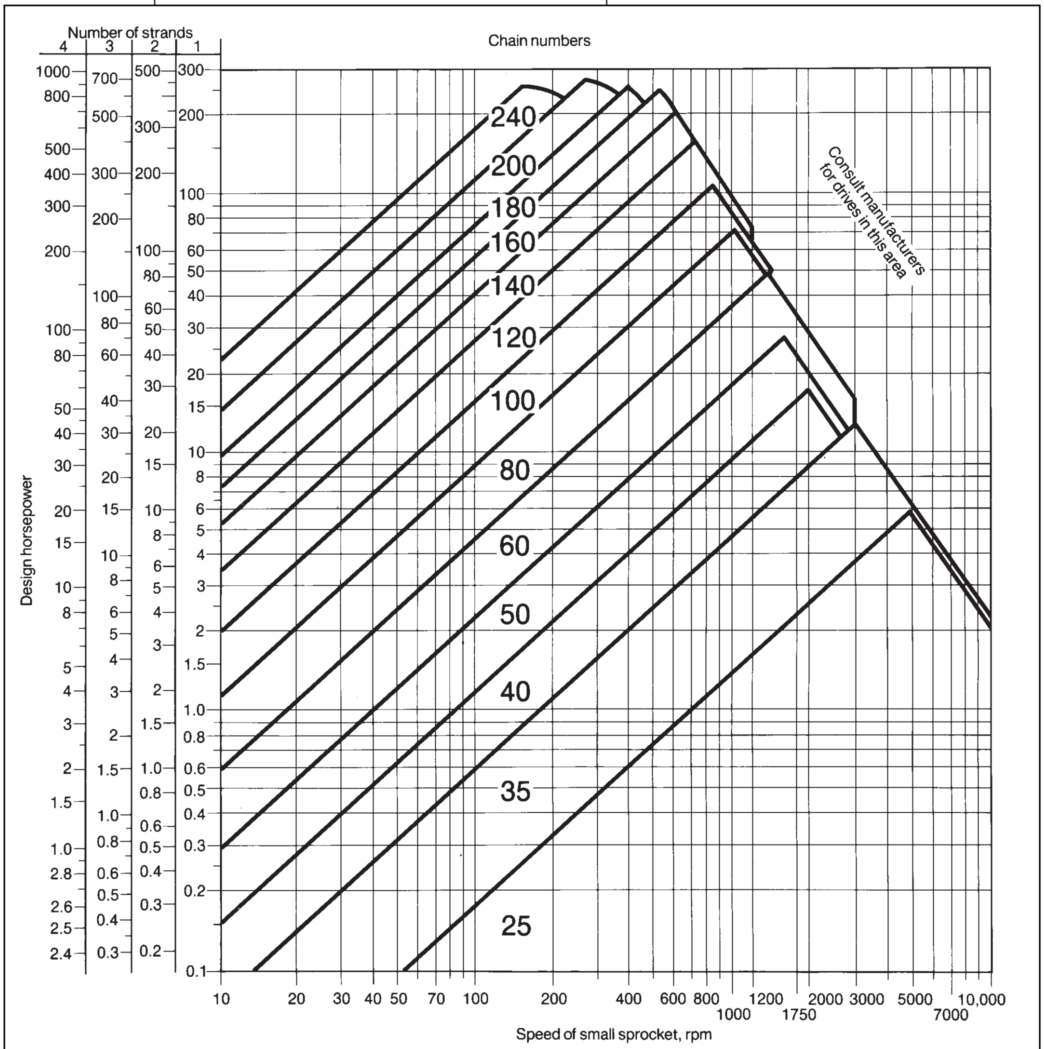
Table 4—Load classifications

Smooth load	Moderate shock load	Heavy shock load
Agitators — Pure liquid	Clay working machinery — Pug mills	Clay working machinery — Brick press, briquetting machinery
Conveyors — Uniformly loaded or fed (apron, assembly, belt, flight, oven, screw)	Conveyors — Heavy duty and *not* uniformly loaded (apron, assembly, belt, bucket, flight, oven, screw)	Conveyors — Reciprocating and shaker
Fans — Centrifugal and light, small diameter	Cranes and hoists — Medium duty, skip hoists (travel motion and trolley motion)	Cranes and hoists — Heavy duty, including logging, lumbering, and rotary drilling rigs
Line shafts — Light	Dredges — Cable, reel, and conveyor	Dredges — Cutter head drives, jig drives, screen drives
Machines — All types with uniform non-reversing loads	Food industry — Beet slicers, dough mixers, meat grinders	Hammer mills
Screens — Rotary (uniformly fed), traveling water intake	Grinders	Machine tools — Punch press, shears, plate planers
Sewage disposal equipment — Inside service (uniformly fed)	Laundry industry — Washers, tumblers	Machines — All types with severe impact shock loads, speed variations, or reversing service
	Line shafts — Heavy service	Metal mills — Draw bench, forming machines, slitters, small rolling mill drives, wire drawing or flattening
	Machine tools — Main and auxiliary drives	Mills — Rotary type (ball, cement kilns, rod mills, tumbling mills)
	Machine — All types with moderate shock and non-reversing loads	Paper industry — Mixers, calenders, rubber mill sheeters
	Screens — Rotary (stone or gravel)	Textile industry — Carding machinery
	Textile industry — Calenders, dyeing machinery, mangles, nappers, soapers, spinners, tenter frames	

Table 5 — Horsepower ratings, standard, single-strand No. 50 roller chain (5/8-in. pitch)

Number of teeth on small sprocket	Revolutions per minute—small sprocket: 100	200	300	500	700	900	1,000	1,200	1,400	1,600	1,800	2,100	2,400	2,700	3,0
9	0.67	1.26	1.81	2.87	3.89	4.88	5.36	6.32	6.02	4.92	4.13	3.27	2.68	2.25	1.
10	0.76	1.41	2.03	3.22	4.36	5.46	6.01	7.08	7.05	5.77	4.83	3.84	3.14	2.63	2.
11	0.84	1.56	2.25	3.57	4.83	6.06	6.66	7.85	8.13	6.65	5.58	4.42	3.62	3.04	2.
12	0.92	1.72	2.47	3.92	5.31	6.65	7.31	8.62	9.26	7.58	6.35	5.04	4.13	3.46	2.
13	1.00	1.87	2.70	4.27	5.78	7.25	7.97	9.40	10.4	8.55	7.16	5.69	4.65	3.90	3.
14	1.09	2.03	2.92	4.63	6.27	7.86	8.64	10.2	11.7	9.55	8.01	6.35	5.20	4.36	3.
15	1.17	2.19	3.15	4.99	6.75	8.47	9.31	11.0	12.6	10.6	8.88	7.05	5.77	4.83	4.
16	1.26	2.34	3.38	5.35	7.24	9.08	9.98	11.8	13.5	11.7	9.78	7.76	6.35	5.32	4.
18	1.43	2.66	3.83	6.07	8.22	10.3	11.3	13.4	15.3	13.9	11.7	9.26	7.58	6.35	5.
20	1.60	2.98	4.30	6.80	9.21	11.5	12.7	15.0	17.2	16.3	13.7	10.8	8.88	7.44	6.
22	1.77	3.31	4.76	7.54	10.2	12.8	14.1	16.6	19.1	18.8	15.8	12.5	10.2	8.59	7.
24	1.95	3.63	5.23	8.29	11.2	14.1	15.5	18.2	20.9	21.4	18.0	14.3	11.7	9.78	8.
26	2.12	3.96	5.70	9.03	12.2	15.3	16.9	19.9	22.8	24.2	20.3	16.1	13.2	11.0	9.
28	2.30	4.29	6.18	9.79	13.2	16.6	18.3	21.5	24.7	27.0	22.6	18.0	14.7	12.3	10
30	2.49	4.62	6.66	10.5	14.3	17.9	19.7	23.2	26.6	30.0	25.1	19.9	16.3	13.7	11
32	2.66	4.96	7.14	11.3	15.3	19.2	21.1	24.9	28.6	32.2	27.7	22.0	18.0	15.1	12
	Type A					Type B								Type C	

Figure 14 — Roller chain pitch selection chart.



ing at low speed, the smaller sprocket could usually operate effectively with 12 to 17 teeth. At high speeds, the smaller sprocket should have at least 25 teeth.

Roller chain drive design example

Problem: Select an electric-motor-driven roller chain drive to transmit 10 hp from a countershaft to the main shaft of a wire drawing machine. The countershaft has a $1^{15}/_{16}$-in. diam. and operates at 1,200 rpm. The main shaft also has $1^{15}/_{16}$-in. diam. and must operate between 378 and 382 rpm. Shaft centers, once established, are fixed and by initial calculations must be approximately $22^1/_2$ in. The load on the main shaft exhibits "peaks," which places it in the heavy shock load category. All drive parts are pressure lubricated from a central system; therefore, the drive will receive Type C lubrication.

Step 1. Service factor — Classification for this drive is listed in Table 4 as heavy shock load. The service factor from Table 3 for heavy shock load and electric motor is 1.5.

Step 2. Design horsepower — The design horsepower is 10 × 1.5 = 15 hp.

Step 3. Tentative chain selection — On the pitch selection chart, Figure 14, locate 15 hp under the single-strand column at the left, and then follow the horizontal "horsepower" line across the chart to where it intersects with the vertical 1,200-rpm line for the small sprocket. This intersection clearly lies in the diagonal area for No. 50 roller chain.

Step 4. Final selection of chain and small sprocket — On the horsepower rating table, Table 5, for No. 50 chain at 1,200 rpm, the computed design horsepower of 15 hp is realized with a 20-tooth sprocket. Table 6 shows that this sprocket will accept the specified shaft.

Step 5. Selection of the large sprocket — Because the driver is to operate at 1,200 rpm and the driven at a minimum of 378 rpm, the speed ratio = 1,200 ÷ 387 = 3.175 minimum. Therefore, the large sprocket should have 20 × 3.175 teeth = 63.50 teeth (use 63).

This combination of 20 and 63 teeth will produce a main drive shaft speed of 381 rpm, which is within the limitation of 378 to 382 rpm.

Step 6. Possible alternate — Sometimes space for a sprocket is limited, or higher capacity is needed from a given chain size. In this case, select a multiple-strand chain drive. For example, a double-strand drive transmits 1.7 times the power of a single strand drive of the same pitch.

Step 7. Chain length — Because 20 and 63-tooth sprockets are to be placed in $22^1/_2$-in. centers, the calculated chain length is:

$$L = 2C + \frac{N+n}{2} + \frac{(N-n)^2}{4\pi^2 C}$$

3,000	4,000	5,000
1.92	1.25	0.89
2.25	1.46	1.04
2.59	1.68	1.20
2.95	1.92	1.37
3.33	2.16	1.55
3.72	2.42	1.73
4.13	2.68	1.92
4.55	2.95	2.11
5.42	3.52	2.52
6.35	4.13	2.95
7.33	4.76	3.41
8.35	5.42	0
9.42	6.12	0
10.5	6.84	0
11.7	7.58	0
12.9	8.35	0

Table 6 — Maximum bore diameters of roller chain sprockets (with standard keyways)

Number of teeth	Chain pitch, in.							
	3/8	1/2	5/8	3/4	1	1 1/2	2	2 1/2
12	5/8	7/8	1 5/32	1 9/32	1 25/32	2 3/4	3 5/8	4 23/32
14	27/32	1 5/32	1 5/16	1 3/4	2 9/32	3 5/16	4 11/16	5 23/32
16	31/32	1 9/32	1 11/16	1 31/32	2 23/32	4	5 1/2	7
18	1 7/32	1 17/32	1 7/8	2 9/32	3 1/8	4 21/32	6 1/4	8 1/8
20	1 9/32	1 25/32	2 1/4	2 11/16	3 1/2	5 7/16	7	9 3/4
22	1 7/16	1 15/16	2 7/16	2 15/16	3 7/8	5 7/8	8 3/8	10 7/8
24	1 11/16	2 1/4	2 13/16	3 1/4	4 9/16	6 13/16	9 5/8	13

Where:
L = Chain length, pitches
C = Shaft centers, pitches
N = Number of teeth in large sprocket
n = Number of teeth in small sprocket

Substituting values for C, N, and n yields L = 114.8 in.

Step 8. Correction of center distance — Because chain is to couple at an even number of pitches, use 114 pitches and recompute the centers:

$$C = \frac{L - \frac{N+n}{2} + \sqrt{\left(L - \frac{N+n}{2}\right)^2 - \frac{8\left(N-n\right)^2}{4\pi^2}}}{4}$$

$C = 35.6$ pitches or 22.25 in.

Summary — Our final solution is 20 and 63-tooth sprockets mounted on 22.25-in. centers using No. 50, ⅝-in. pitch roller chain. In Table 5, Type B lubrication is indicated and the existing central lubrication system exceeds this requirement. ■

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