THE WORLD OF TIMING BELTS

SECTION 1 INTRODUCTION

Timing belts are parts of synchronous drives which represent an important category of drives. Characteristically, these drives employ the positive engagement of two sets of meshing teeth. Hence, they do not slip and there is no relative motion between the two elements in mesh.

Due to this feature, different parts of the drive will maintain a constant speed ratio or even a permanent relative position. This is extremely important in applications such as automatic machinery in which a definite motion sequence and/or indexing is involved.

The positive nature of these drives makes them capable of transmitting large torques and withstanding large accelerations.

Belt drives are particularly useful in applications where layout flexibility is important. They enable the designer to place components in more advantageous locations at larger distances without paying a price penalty. Motors, which are usually the largest heat source, can be placed away from the rest of the mechanism. Achieving this with a gear train would represent an expensive solution.

Timing belts are basically flat belts with a series of evenly spaced teeth on the inside circumference, thereby combining the advantages of the flat belt with the positive grip features of chains and gears.

There is no slippage or creep as with plain flat belts. Required belt tension is low, therefore producing very small bearing loads. Synchronous belts will not stretch and do not require lubrication. Speed is transmitted uniformly because there is no chordal rise and fall of the pitch line as in the case of roller chains.

The tooth profile of most commonly known synchronous belts is of trapezoidal shape with sides being straight lines which generate an involute, similar to that of a spur gear tooth. As a result, the profile of the pulley teeth is involute. Unlike the spur gear, however, the outside diameter of a timing pulley is smaller than its pitch diameter, thus creating an imaginary pitch diameter which is larger than the pulley itself. This is illustrated in **Figure 1**. Backlash between pulley and belt teeth is negligible.

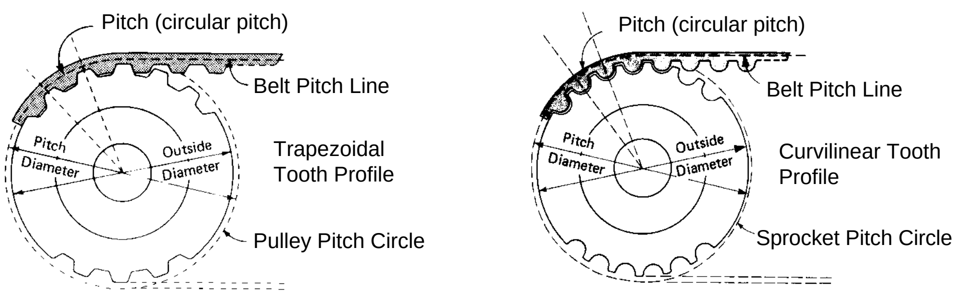
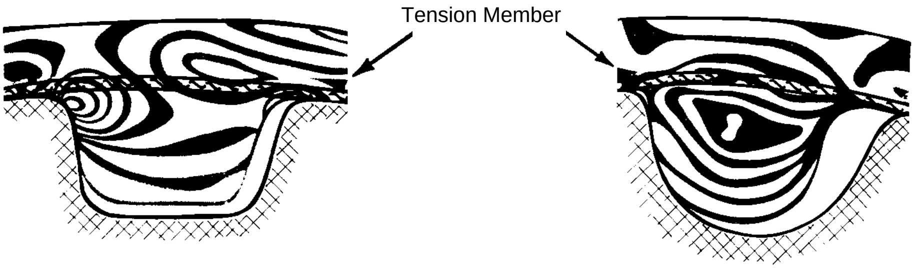


Fig. 1 Pulley and Belt Geometry

The trapezoidal shape timing belt was superseded by a curvilinear tooth profile which exhibited some desirable and superior qualities. Advantages of this type of drive are as follows:

- Proportionally deeper tooth; hence tooth jumping or loss of relative position is less probable.
- Lighter construction, with correspondingly smaller centrifugal loss.
- Smaller unit pressure on the tooth since area of contact is larger.

NOTE: Credit for portions of this technical section are given to: Gates Rubber Co., Sales Engineering Dept., Rubber Manufacturers Association (RMA), International Organization for Standardization (ISO).



Trapezoidal Curvilinear

Fig. 2 Stress Pattern in Belts

- Greater shear strength due to larger tooth cross section.
- Lower cost since a narrower belt will handle larger load.
- Energy efficient, particularly if replacing a "V" belt drive which incurs energy losses due to slippage.
- Installation tension is small, therefore, light bearing loads.

In **Figure 2**, the photoelastic pattern shows the stress distribution within teeth of different geometry. There is a definite stress concentration near the root of the trapezoidal belt tooth, with very low strains elsewhere. For the curvilinear tooth, there is a uniform, nearly constant, strain distribution across the belt. The load is largest in the direction of the tension member to which it is transferred.

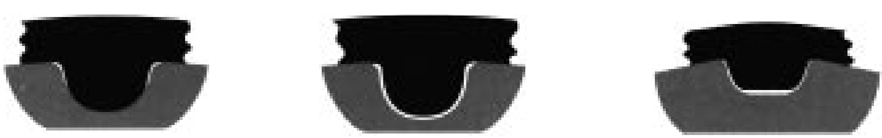
Because of their superior load carrying capabilities, the curvilinear belts are marketed under the name of Gates' HTD drives. This is an abbreviation of High Torque Drives.

As a result of continuous research, a newer version of the curvilinear technology was developed by Gates, which was designated as Gates' PowerGrip GT belt drives.

SECTION 2 GATES POWERGRIP® GT BELT DRIVES

The PowerGrip GT Belt Drive System is an advance in product design over the Gates' older, standard HTD system. The PowerGrip GT System, featuring a modified curvilinear belt tooth profile, provides timing and indexing accuracy superior to the conventional PowerGrip Trapezoidal Belt System. Plus, PowerGrip GT Belts have a higher capacity and longer belt life than trapezoidal belts.

It's difficult to make a true quantitative comparison between the backlash of a trapezoidal tooth drive and PowerGrip GT drive due to the difference in "pulley to belt tooth" fit (see **Figure 3**). Trapezoidal belts contact the pulley in the root radius-upper flank area only, while the PowerGrip GT system permits full flank contact.



PowerGrip® GT® Belt Tooth/Groove Contact **PowerGrip® HTD® Belt Tooth/Groove Contact** **PowerGrip® Trapezoidal Belt Tooth/Groove Contact**

Fig. 3 Comparison of Different Tooth Profiles

The main stress line in a trapezoidal tooth timing belt is at the base of the teeth. During operation, this stress greatly reduces belt life. The PowerGrip GT system overcomes this condition with its complete tooth flank contact which eliminates the tooth stress line area. This greatly increases belt life and prevents tooth distortion caused by drive torque. In addition, the conventional timing belt has a chordal effect as it wraps small pulleys. This is significantly reduced in the PowerGrip GT system because there is full tooth support along the pulley. Full support improves meshing, reduces vibration and minimizes tooth deformation.

On drives using a low installation tension, small pulleys, and light loads, the backlash of the PowerGrip GT system will be slightly better than the trapezoidal timing belt system. However, with increased tension and/or loads and/or pulley sizes, the performance of the PowerGrip GT system becomes significantly better than the trapezoidal timing belt system.

The PowerGrip GT system is an extension of the HTD system with greater load-carrying capacity. HTD was developed for high torque drive applications, but is not acceptable for most precision indexing or registration applications. The HTD design requires substantial belt tooth to pulley groove clearance (backlash) to perform.

As smaller diameter pulleys are used, the clearance required to operate properly is increased. HTD drive clearance, using small diameter pulleys, is approximately four times greater than an equivalent GT timing belt drive.

The PowerGrip GT system's deep tooth design increases the contact area which provides improved resistance to ratcheting. The modified curvilinear teeth enter and exit the pulley grooves cleanly, resulting in reduced vibration. This tooth profile design results in parallel contact with the groove and eliminates stress concentrations and tooth deformation under load. The PowerGrip GT design improves registration characteristics and maintains high torque carrying capability.

PowerGrip GT belts are currently available in 2 mm, 3 mm and 5 mm pitches. Specific advantages of the PowerGrip GT system can be summarized as follows:

- **Longer belt life**
  The strong fiberglass tensile cords wrapped in a durable neoprene body provide the flexibility needed for increased service life. The deep tooth profile provides superior load-carrying strength and greatly reduces ratcheting when used with pulleys provided by a licensed supplier.
- **Precision registration**
  PowerGrip GT belts provide timing and synchronization accuracy that make for flawless registration, with no loss of torque carrying capacity.
- **Increased load-carrying capacity**
  Load capacities far exceed HTD and trapezoidal belt capabilities making PowerGrip GT belts the choice for accurate registration, heavy loads and small pulleys.
- **Quieter operation**
  The PowerGrip GT belt's specially engineered teeth mesh cleanly with pulley grooves to reduce noise and vibration. Clean meshing and reduced belt width result in significant noise reduction when compared to Trapezoidal and HTD belts.
- **Precise positioning**
  PowerGrip GT belts are specifically designed for applications where precision is critical, such as computer printers and plotters, laboratory equipment and machine tools.

Some of the many applications of PowerGrip GT belts are:

- data storage equipment
- machine tools
- hand power tools
- postage handling equipment
- DC stepper/servo applications
- food processors
- centrifuges
- printers
- floor care equipment
- money handling equipment
- medical diagnostic equipment
- sewing machines
- automated teller machines
- ticket dispensers
- plotters
- copiers
- robotics equipment
- vending equipment
- vacuum cleaners
- office equipment

SECTION 3 COMPARISON GRAPHS

In order to provide comparison of performances of different pitch drives, several graphs have been developed.

Figure 4 shows numerical values, plotted in logarithmic scale, of Rated Horsepower vs. Speed (rpm) of faster shaft.

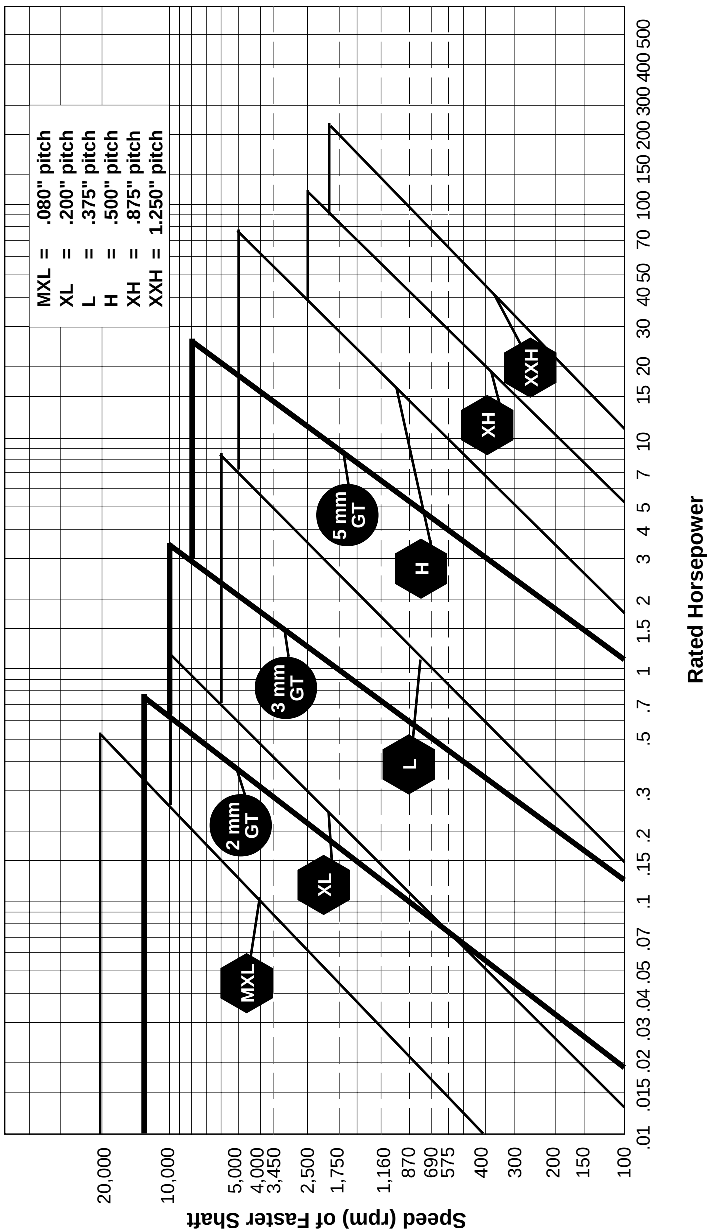


Fig. 4 Comparative Belt Pitch Selection Guide

Figure 5 shows an illustrative graph representation of horsepower ratings over a wide speed range of the belt types commonly used. The graph assumes that belt widths and pulley diameters have been chosen such that they provide realistic comparison of product capability.

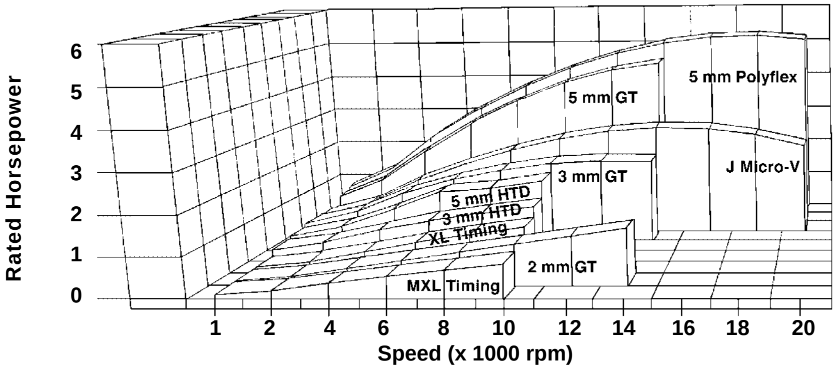


Fig. 5 Horsepower Ratings at High Speed

Figure 6 provides a comparison of the rated torque carrying capabilities of synchronous belts, on small diameter pulleys at low speeds. The pulley diameters and belt widths represent a realistic comparison.

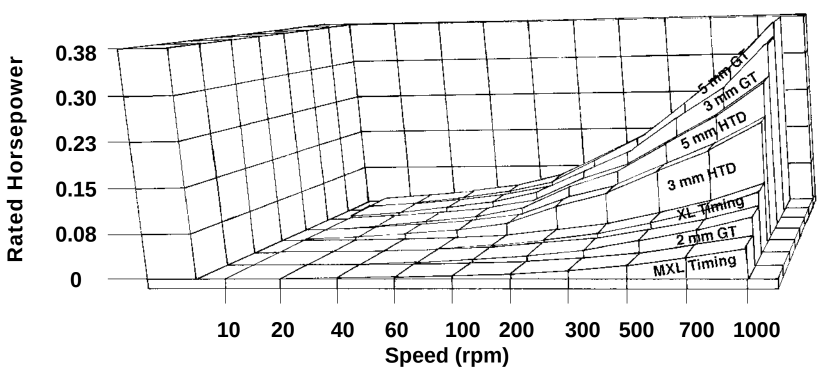


Fig. 6 Horsepower Ratings at Low Speed

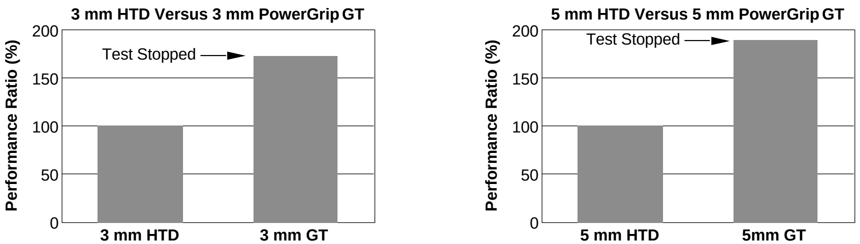
SECTION 4 DRIVE COMPARATIVE STUDIES

The development of the PowerGrip GT belt has produced an impressive range of enhanced properties and subsequent design opportunities for engineers.

Comparative studies, shown in **Figures 7** through **10**, allow designers to make quantitative assessments and to highlight the most significant improvements and design opportunities. Particularly significant points from the comparative studies follow:

4.1 Durability

The greatly increased durability of the PowerGrip GT design has resulted in power capacities far above those quoted for similar size belts of previous designs. The resulting small drive packages will increase design flexibility, space utilization and cost effectiveness.



TEST CONDITIONS: Speed = 6000 rpm
Power = 1.00 lb·in/mm width
Pulleys: Driver = 20 grooves
Driven = 20 grooves

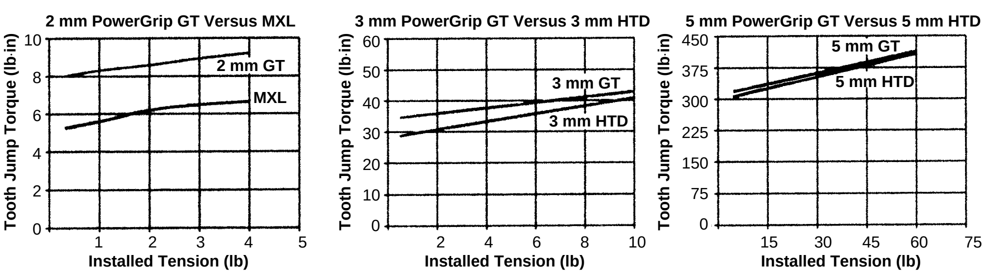
TEST CONDITIONS: Speed = 2300 rpm
Power = 3.35 lb·in/mm width
Pulleys: Driver = 20 grooves
Driven = 20 grooves

Fig. 7 Comparison of Performance Ratios for Various Belts

4.2 Tooth Jump Resistance

The very significant improvement in tooth jump resistance of PowerGrip GT when compared to similar belts has several important advantages.

1. Ratcheting resistance during high start-up torques.
2. Reduced bearing loads, particularly in fixed-center drives. Lower average tensions can be used without encountering tooth jump at the low tension end of the tolerance ranges.
3. Reduced system losses result from lower pre-tensioning, with less potential for tooth jumping.



TEST CONDITIONS:
Speed = 1130 rpm
Belt Width = 4.8 mm
Pulleys: Driver = 20 grooves
Driven = 20 grooves

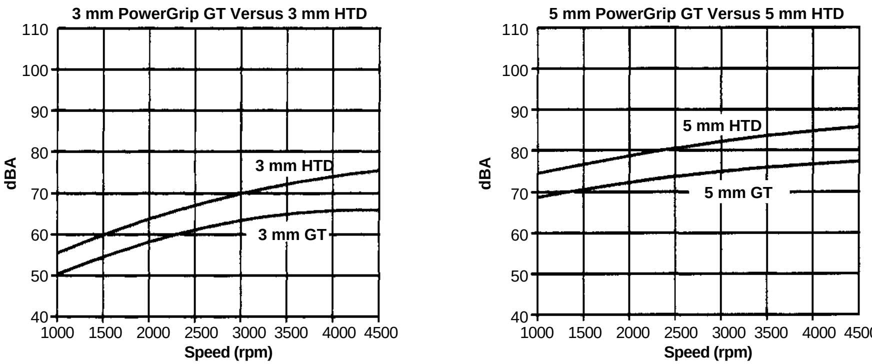
TEST CONDITIONS:
Speed = 750 rpm
Belt Width = 6 mm
Pulleys: Driver = 30 grooves
Driven = 30 grooves

TEST CONDITIONS:
Speed = 2300 rpm
Belt Width = 15 mm
Pulleys: Driver = 20 grooves
Driven = 20 grooves

Fig. 8 Comparison of Tooth Jump Torques for Various Belts

4.3 Noise

The smoother meshing action of the PowerGrip GT belt, with its optimized design, produces significantly lower noise levels when compared with other similar sized belt types operating under similar speeds and tensions. These improvements are enhanced by the fact that narrower belts can be used due to increased power capacities.



Belt: No. of teeth = 188
Width = 15 mm
Pulleys: Driver = 26 grooves
Driven = 26 grooves
Microphone location midway between the pulleys, 100 mm from the belt edge.

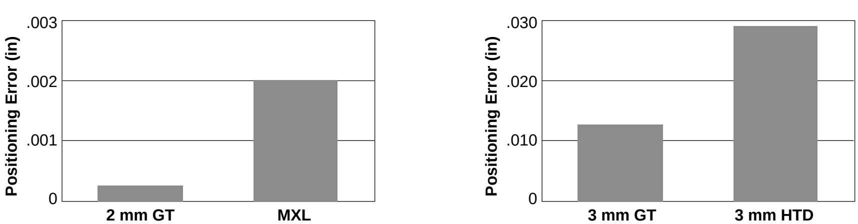
Belt: No. of teeth = 118
Width = 30 mm
Pulleys: Driver = 20 grooves
Driven = 20 grooves
Microphone location midway between the pulleys, 100 mm from the belt edge.

Fig. 9 Comparison of Noise Levels for Various Belts

4.4 Positioning Accuracy

The PowerGrip HTD belt tooth forms were primarily designed to transmit high torque loads. This requirement increased tooth to groove clearances which resulted in increased backlash when compared with the original trapezoidal designs.

PowerGrip GT has reversed this problem with power capacities now exceeding those of PowerGrip HTD while giving equivalent or higher levels of positional accuracy than trapezoidal timing belts.



APPLICATION: Motion Transfer
Belt: No. of teeth = 126
Width = 8 mm
Pulleys: Driver = 12 grooves
Driven = 40 grooves
Installed tension = 1.8 lb
Motor = 200 steps/cycle

APPLICATION: Motion Transfer
Belt: No. of teeth = 92
Width = 6 mm
Pulleys: Driver = 20 grooves
Driven = 20 grooves
Installed tension = 6.6 lb
Motor = 200 steps/cycle

Fig. 10 Comparison of Positioning Errors of Various Belts

SECTION 5 DIFFERENT BELT CONFIGURATIONS

5.1 Double Sided Twin Power Belt Drives

Timing belts are also available in double sided designs, which offer an infinite number of new design possibilities on computer equipment, business machines, office equipment, textile machines and similar light-duty applications. Belts with driving teeth on both sides make it possible to change the direction of rotation of one or more synchronized pulleys with only one belt. The inside and outside teeth are identical as to size and pitch and operate on standard pitch diameter pulleys.

If the belts have nylon facing on both sides, then the same design parameters can be used for the drives on both sides of the belt. In case the outside teeth do not have nylon facing, the horsepower rating of the outside teeth is only 45% of the total load.

For example: assuming the drive pulley and belt are capable of transmitting 1 horsepower, 0.55 hp can be transmitted from the inside teeth of the pulley (A), and 0.45 hp can be transmitted by the outside teeth to pulley (B) for a total of 1 hp, the rated capacity of the driver pulley.

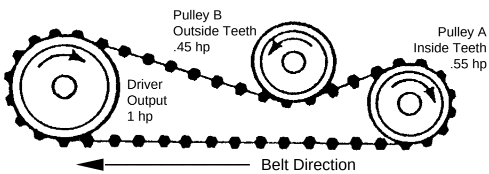


Fig. 11 Double Sided Timing Belt

5.2 Long Length Timing Belt Stock

These belts are an excellent solution for drives that require belt lengths longer than those produced in conventional endless form. Long length belting has the same basic construction as conventional timing belts. These belts are usually produced by spiral cut of large diameter endless belts.

These belts are creatively used in:

- reciprocating carriage drives
- rack and pinion drives
- large plotters

An example of application is shown in **Figure 13**. A complete timing belt and a timing belt segment reduce vibration and chatter in this oscillating drive for a surface grinder.

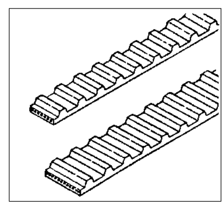


Fig. 12 Timing Belt Stock

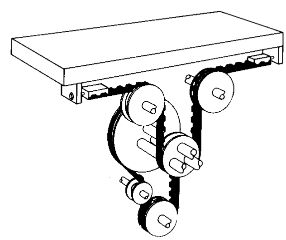


Fig. 13 Example of Timing Belt Stock Use

SECTION 6 BELT CONSTRUCTION

The load-carrying elements of the belts are the tension members built into the belts (see **Figure 14**). These tension members can be made of:

1. Spirally wound steel wire.
2. Wound glass fibers.
3. Polyester cords.
4. Kevlar.

Trapezoidal Curvilinear

Fig. 14 Belt Construction

The tension members are embedded in neoprene or polyurethane. The neoprene teeth are protected by a nylon fabric facing which makes them wear resistant.

The contributions of the construction members of these belts are as follows:

1. **Tensile Member** – Provides high strength, excellent flex life and high resistance to elongation.
2. **Neoprene Backing** – Strong neoprene bonded to the tensile member for protection against grime, oil and moisture. It also protects from frictional wear if idlers are used on the back of the belt.
3. **Neoprene Teeth** – Shear-resistant neoprene compound is molded integrally with the neoprene backing. They are precisely formed and accurately spaced to assure smooth meshing with the pulley grooves.
4. **Nylon Facing** – Tough nylon fabric with a low coefficient of friction covers the wearing surfaces of the belt. It protects the tooth surfaces and provides a durable wearing surface for long service.

6.1 Characteristics Of Reinforcing Fibers

Polyester

Tensile Strength	160,000 lbs/in^2
Elongation at break	14.0%
Modulus (approx.)	2,000,000 lbs/in^2

One of the main advantages of polyester cord over higher tensile cords is the lower modulus of polyester, enabling the belt to rotate smoothly over small diameter pulleys. Also, the elastic properties of the material enable it to absorb shock and dampen vibration.

In more and more equipment, stepping motors are being used. Polyester belts have proven far superior to fiberglass or Kevlar reinforced belts in these applications.

High-speed applications with small pulleys are best served by polyester belts under low load.

Kevlar

Tensile Strength	400,000 lbs/in^2
Elongation at break	2.5%
Modulus	18,000,000 lbs/in^2

High tensile strength and low elongation make this material very suitable for timing belt applications. Kevlar has excellent shock resistance and high load capacity.

Fiberglass

Tensile Strength	350,000 lbs/in^2
Elongation at break	2.5 – 3.5%
Modulus	10,000,000 lbs/in^2

The most important advantages are:

1. High strength.
2. Low elongation or stretch.
3. Excellent dimensional stability.
4. Excellent chemical resistance.
5. Absence of creep, 100% elongation recovery.

Disadvantages:

1. High modulus (difficult to bend).
2. Brittleness of glass. Improper handling or installation can cause permanent damage.
3. Poor shock resistance. No shock absorbing quality when used in timing belts.

Steel

Tensile Strength	360,000 lbs/in^2
Elongation at break	2.5%
Modulus (approx.)	15,000,000 lbs/in^2

Additional characteristics of tension members and their effect on the drive design are shown in tabulated form in **Table 1**.

Table 1 Comparison of Different Tension Member Materials*

E = Excellent **G** = Good **F** = Fair **P** = Poor

Belt Requirements	**Nylon**	**Polyester Cont.Fil. Yarn**	**Polyester Spun Yarn**	**Kevlar-Polyester Mix**	**Kevlar Cont.Fil. Yarn**	**Kevlar Spun Yarn**	**Glass**	**Stainless Steel**	**Polyester Film Reinforcement**
Operate over Small Pulley	**E**	**G**	**E**	**F**	**P**	**F**	**P**	**P**	**G**
High Pulley Speed	**E**	**E**	**E**	**F**	**P**	**F**	**P**	**P**	**G**
High Intermittent Shock Loading	**F**	**G**	**G**	**E**	**E**	**E**	**P**	**G**	**F**
Vibration Absorption	**E**	**G**	**E**	**G**	**F**	**F**	**P**	**P**	**F**
High Torque Low Speed	**P**	**P**	**P**	**F**	**G**	**F**	**E**	**E**	**F**
Low Belt Stretch	**P**	**P**	**P**	**P**	**G**	**F**	**E**	**E**	**G**
Dimensional Stability	**P**	**P**	**P**	**F**	**G**	**G**	**E**	**E**	**G**
High Temperature 200° F	**P**	**P**	**P**	**P**	**E**	**E**	**E**	**E**	**F**
Low Temperature	**F**	**G**	**G**	**G**	**G**	**E**	**E**	**E**	**G**
Good Belt Tracking	**E**	**G**	**E**	**G**	**F**	**G**	**F**	**P**	**E**
Rapid Start/Stop Operation	**F**	**G**	**E**	**G**	**P**	**G**	**P**	**E**	**G**
Close Center-Distance Tolerance	**P**	**P**	**P**	**P**	**G**	**F**	**E**	**E**	**G**
Elasticity Required in Belt	**E**	**G**	**E**	**G**	**P**	**P**	**P**	**P**	**P**

* Courtesy of Chemiflex, Inc.

6.2 Cord Twist And Its Effect On The Drive

There is a specific reason for not applying the yarn directly in the form of untwisted filaments around the mold. If the filament would be applied continuously, the top and bottom of the belt body would be prevented from being properly joined, and separation could result. See **Figure 15**.

Two strands each composed of several filaments are twisted around each other, thus forming a cord which is subsequently wound in a helical spiral around the mold creating a space between subsequent layers, which corresponds to the step of the helix. The two strands, however, can be twisted two ways in order to create an "S" or a "Z" twist construction. See **Figure 16**.

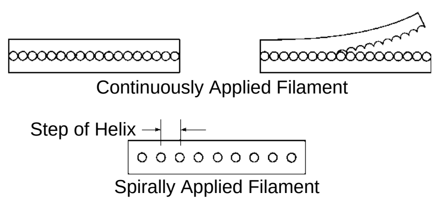


Fig. 15 Belt Cross Section

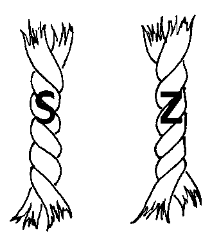
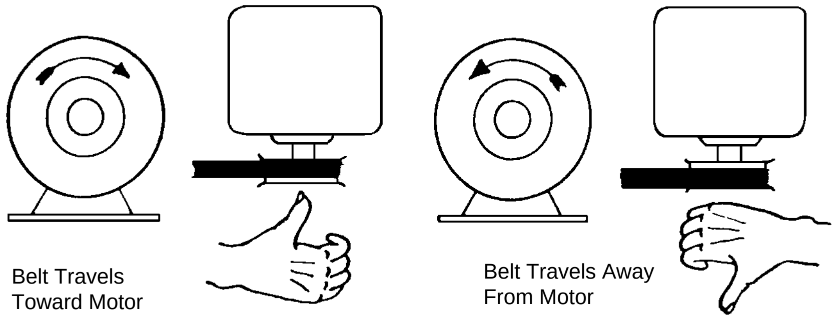


Fig. 16 Cord Twist

The "S" twist is obtained if we visualize the two strands being held stationary with our left hand on one end, while a clockwise rotation is imparted by our right hand to the two strands, thus creating a twisted cord. The "Z" twist is obtained similarly, if a counterclockwise rotation is imparted to the two strands.

Different types of cord twist will cause side thrust in opposite directions. The "S" twist will cause a lateral force direction which will obey the "Right Hand" rule as shown in **Figure 17**.



(a) Clockwise Rotation (b) Counterclockwise Rotation

Fig. 17 Right Hand Rule Applicable to "S" Twist

A "Z" type cord twist will produce a direction of lateral force opposite to that of "S" cord. Therefore, in order to produce a belt with minimum lateral force, standard belts are usually made with "S" and "Z" twist construction, in which alternate cords composed of strands twisted in opposite directions are wound in the belt. This is illustrated in **Figure 18**.

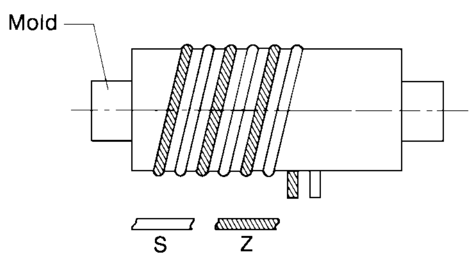


Fig. 18 "S" and "Z" Cord Lay of the Mold

The lay of the cord is standard, as shown in **Figure 18**, and it is wound from left to right with the cord being fed under the mold. The smaller the mold diameter and the fewer the strands of cord per inch, the greater will be the helix angle, and the greater the tendency of the lay of the cord to make the belt move to one side.

In general, a standard belt of "S" and "Z" construction, as shown in **Figure 18**, will have a slight tendency to behave as a predominantly "S" twist belt, and will obey the "Right Hand" rule accordingly.

6.3 Factors Contributing To Side Travel

The pulleys in a flat belt drive are crowned to keep the belt running true. Since crowned pulleys are not suitable for a timing belt, the belt will always track to one side. Factors contributing to this condition include:

I. In the Drive

1. Misalignment – A belt (any belt – any construction) will normally climb to the high end (or tight) side.
2. Tensioning – In general, lateral travel can be altered or modified by changing tension.
3. Location of plane – Vertical drives have a greater tendency to move laterally due to gravity.

4. Belt width greater than O.D. of pulley – This condition creates an abnormal degree of lateral travel.
5. Belt length – The greater the ratio of length/width of the belt, the less the tendency to move laterally.

II. In the Belt

1. Direction of the lay of the cords in the belt. See **Figure 18**.
2. Twist of the strands in the cord. See **Figure 16**.

6.4 Characteristics Of Belt Body Materials

Basic characteristics of the three most often used materials are shown in **Table 2**. The tabulated characteristics give rise to the following assessment of these materials:

Natural Rubber

- High resilience, excellent compression set, good molding properties
- High coefficient of friction; does not yield good ground finish
- High tear strength, low crack growth
- Can withstand low temperatures
- Poor oil and solvent resistance; unable for ketones and alcohol
- Ozone attacks rubber, but retardants can be added

Neoprene

- High resilience
- Flame resistant
- Aging good with some natural ozone resistance
- Oil and solvent resistance fair

Polyurethane

- Excellent wear resistance, poor compression set
- Low coefficient of friction
- Oil and ozone resistance good
- Low-temperature flexibility good
- Not suitable for high temperatures

Table 2 Comparison of Different Belt Body Materials*

Common Name	Natural Rubber	Neoprene	Urethane, Polyurethane
Chemical Definition	Polyisoprene	Polychloroprene	Polyester/Polyether Urethane
Durometer Range (Shore A)	20 – 100	20 – 95	35 – 100
Tensile Range (p.s.i.)	500 – 3500	500 – 3000	500 – 6000
Elongation (Max. %)	700	600	750
Compression Set	Excellent	Good	Poor
Resilience – Rebound	Excellent	Excellent	Good
Abrasion Resistance	Excellent	Excellent	Excellent
Tear Resistance	Excellent	Good	Excellent
Solvent Resistance	Poor	Fair	Poor
Oil Resistance	Poor	Fair	Good
Low Temperature Usage (°F)	–20° to –60°	+10° to –50°	–10° to –30°
High Temperature Usage (°F)	to 175°	to 185°	to 175°
Aging Weather – Sunlight	Poor	Good	Excellent
Adhesion to Metals	Excellent	Good to Excellent	Fair to Good

***** Courtesy of Robinson Rubber Products

SECTION 7 BELT TOOTH PROFILES

There are several belt tooth profiles (**Figure 19**, **Table 3**) which are the result of different patented features, marketing and production considerations.

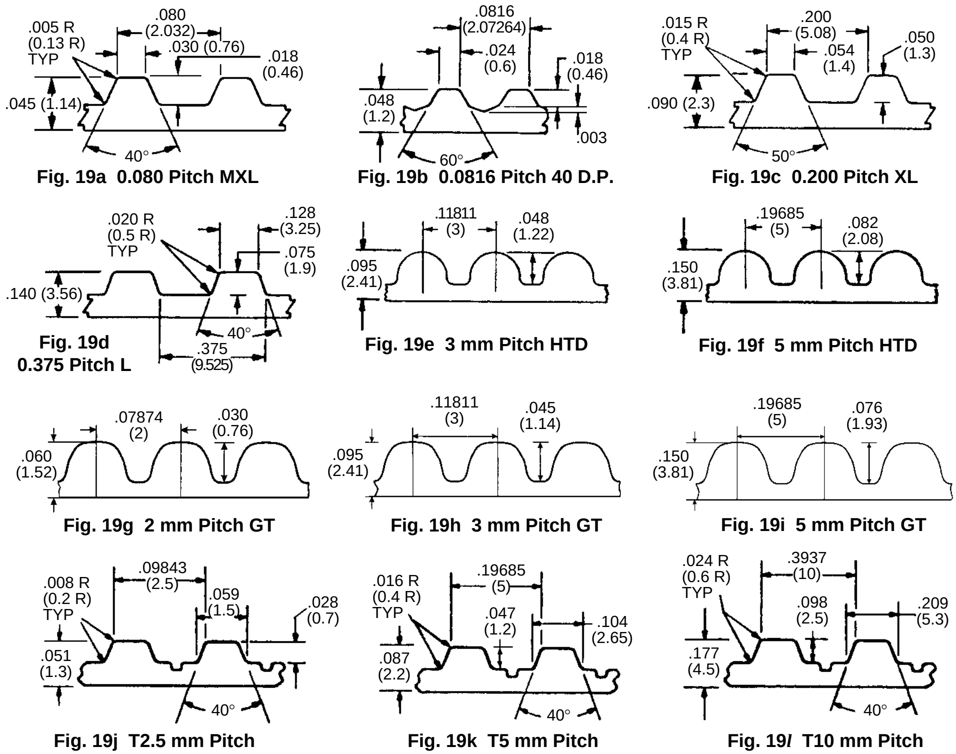


Fig. 19 Belt Tooth Configuration Dimensions in ( ) are mm

Table 3 Allowable Working Tension of Different Belt Constructions

	Belt Type	Pitch		Allowable Working Tension Per 1 Inch of Belt Width	
		Inch	mm	lbs	N
19a	MXL	0.080	2.032	32	142
19b	40DP	0.0816	2.07	21.4	95
19c	XL	0.200	5.08	41	182
19d	L	0.375	9.525	55	244
–	H	0.500	12.7	140	622
19e	HTD	0.118	3	64	285
19f		0.197	5	102	454
–		0.315	8	138	614
19g	GT	0.079	2	25	111
19h		0.118	3	114	507
19i		0.197	5	160	712
19j	T	–	2.5	32	142
19k		–	5	41	182
19*l*		–	10	55	244

For the sake of completeness, the three additional belt profiles shown in **Figure 19j**, **19k** and **19*l*** are used in Europe and are sometimes found on machinery imported from Europe and Japan. They are not produced in the U.S.A. and are not covered by RMA standards. The belts are made of polyurethane, and steel is usually used as the tension member.

As described in previous sections, the presently known most advantageous belt tooth configuration is the Gates PowerGrip GT. This is a result of continuous improvement of the previous HTD tooth profile. The HTD profile is protected by U.S. Patent Number 4,337,056, whereas the GT profile is described in U.S. Patent Number 4,515,577.

Pulleys for these belt profiles are available only from manufacturers licensed by Gates Rubber Company. Stock Drive Products is one of the licensees who can supply a full range of these pulleys as standards or specials, per customers' drawings.

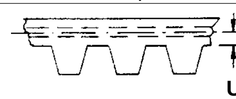
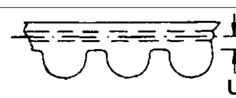
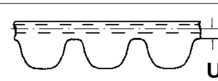
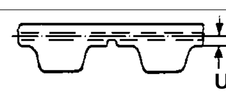
SECTION 8 PULLEY PITCH AND OUTSIDE DIAMETERS

Pulley and belt geometry as indicated in **Figure 1** shows reference to a Pitch Circle, which is larger than the pulley itself. Its size is determined by the relationship:

$$pd = \frac{P \cdot N}{\pi} \qquad \textbf{(8-1)}$$

where P is the belt tooth spacing (pitch) and N is the number of teeth on the pulley. The reinforcing cord centerline will coincide with the pulley pitch diameter while the belt is in contact with the pulley. At the same time, the outside diameter of the pulley will be in contact with the bottom of the belt tooth. Hence, the distance "U" between the reinforcing cord centerline and the bottom of the belt tooth will determine the outside diameters of pulleys for different pitches. See **Table 4**.

Table 4 Basic Belt Dimensions

Distance from Pitch Line to Belt Tooth Bottom "*U*"	Common Description	Pulley O.D. O.D. = $pd - 2U$
.010 inches .007 inches .010 inches .015 inches	Minipitch 0.080" MXL 40 D.P. 1/5" XL 3/8" L	
.015 inches .0225 inches .027 inches	3 mm HTD 5 mm HTD 8 mm HTD	
.010 inches .015 inches .0225 inches	2 mm GT 3 mm GT 5 mm GT	
0.3 millimeters 0.5 millimeters 1.0 millimeters	T2.5 (2.5 mm) T5 (5 mm) T10 (10 mm)	

Due to the particular geometry of the 8 mm HTD belts, some corrections are needed for small-size pulleys only. Hence, consult pulley specifications tables given later in this text, pertaining to the 8 mm HTD pulley.

As previously noted, the pitch and the number of teeth will determine the pitch diameter of the pulley, whereas its outside diameter will depend on the *"U"* dimension (distance from tooth bottom to centerline of cord) as shown in **Table 4**.

In order to provide fast reference, the following tables show pitch and outside diameters of different pitch pulleys:

Table 5: 0.080" MXL Pitch

Table 6: 0.0816" (40 D.P.) Pitch

Table 7: 1/5" – XL Pitch

Table 8: 3/8" – L Pitch

Table 9: 3 mm Pitch HTD

Table 10: 5 mm Pitch HTD

Table 11: 8 mm Pitch HTD

Table 12: 2 mm Pitch GT

Table 13: 3 mm Pitch GT

Table 14: 5 mm Pitch GT

These tables enable the designer to judge immediately the space requirements for a particular drive. In many instances, the torque transmission capability of the drive can be satisfied by a less voluminous solution. This is one of the excellent features of the GT profile; it facilitates miniaturization. The size of the small pulley of the drive, however, is subject to some limitations. The suggested minimum size of the pulley related to a particular pitch and rpm is given in **Table 15**.

INCH .080" (2.03 mm) MXL Pitch Pulley Dimensions

Table 5

No. of Grooves	Pitch Diameter		Outside Diameter		No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm		Inch	mm	Inch	mm
10	.255	6.47	.235	5.96	**60**	1.528	38.81	1.508	38.30
11	.280	7.11	.260	6.61	**61**	1.553	39.46	1.533	38.95
12	.306	7.76	.286	7.25	**62**	1.579	40.10	1.559	39.59
13	.331	8.41	.311	7.90	**63**	1.604	40.75	1.584	40.24
14	.357	9.06	.337	8.55	**64**	1.630	41.40	1.610	40.89
15	.382	9.70	.362	9.19	**65**	1.655	42.04	1.635	41.53
16	.407	10.35	.387	9.84	**66**	1.681	42.69	1.661	42.18
17	.433	11.00	.413	10.49	**67**	1.706	43.34	1.686	42.83
18	.458	11.64	.438	11.13	**68**	1.732	43.98	1.712	43.47
19	.484	12.29	.464	11.78	**69**	1.757	44.63	1.737	44.12
20	.509	12.94	.489	12.43	**70**	1.783	45.28	1.763	44.77
21	.535	13.58	.515	13.07	**71**	1.808	45.92	1.788	45.42
22	.560	14.23	.540	13.72	**72**	1.833	46.57	1.813	46.06
23	.586	14.88	.566	14.37	**73**	1.859	47.22	1.839	46.71
24	.611	15.52	.591	15.02	**74**	1.884	47.86	1.864	47.36
25	.637	16.17	.617	15.66	**75**	1.910	48.51	1.890	48.00
26	.662	16.82	.642	16.31	**76**	1.935	49.16	1.915	48.65
27	.688	17.46	.668	16.96	**77**	1.961	49.80	1.941	49.30
28	.713	18.11	.693	17.60	**78**	1.986	50.45	1.966	49.94
29	.738	18.76	.718	18.25	**79**	2.012	51.10	1.992	50.59
30	.764	19.40	.744	18.90	**80**	2.037	51.74	2.017	51.24
31	.789	20.05	.769	19.54	**81**	2.063	52.39	2.043	51.88
32	.815	20.70	.795	20.19	**82**	2.088	53.04	2.068	52.53
33	.840	21.34	.820	20.84	**83**	2.114	53.68	2.094	53.18
34	.866	21.99	.846	21.48	**84**	2.139	54.33	2.119	53.82
35	.891	22.64	.871	22.13	**85**	2.165	54.98	2.145	54.47
36	.917	23.29	.897	22.78	**86**	2.190	55.63	2.170	55.12
37	.942	23.93	.922	23.42	**87**	2.215	56.27	2.195	55.76
38	.968	24.58	.948	24.07	**88**	2.241	56.92	2.221	56.41
39	.993	25.23	.973	24.72	**89**	2.266	57.57	2.246	57.06
40	1.019	25.87	.999	25.36	**90**	2.292	58.21	2.272	57.70
41	1.044	26.52	1.024	26.01	**91**	2.317	58.86	2.297	58.35
42	1.070	27.17	1.050	26.66	**92**	2.343	59.51	2.323	59.00
43	1.095	27.81	1.075	27.30	**93**	2.368	60.15	2.348	59.64
44	1.120	28.46	1.100	27.95	**94**	2.394	60.80	2.374	60.29
45	1.146	29.11	1.126	28.60	**95**	2.419	61.45	2.399	60.94
46	1.171	29.75	1.151	29.25	**96**	2.445	62.09	2.425	61.59
47	1.197	30.40	1.177	29.89	**97**	2.470	62.74	2.450	62.23
48	1.222	31.05	1.202	30.54	**98**	2.496	63.39	2.476	62.88
49	1.248	31.69	1.228	31.19	**99**	2.521	64.03	2.501	63.53
50	1.273	32.34	1.253	31.83	**100**	2.546	64.68	2.526	64.17
51	1.299	32.99	1.279	32.48	**101**	2.572	65.33	2.552	64.82
52	1.324	33.63	1.304	33.13	**102**	2.597	65.97	2.577	65.47
53	1.350	34.28	1.330	33.77	**103**	2.623	66.62	2.603	66.11
54	1.375	34.93	1.355	34.42	**104**	2.648	67.27	2.628	66.76
55	1.401	35.57	1.381	35.07	**105**	2.674	67.91	2.654	67.41
56	1.426	36.22	1.406	35.71	**106**	2.699	68.56	2.679	68.05
57	1.451	36.87	1.431	36.36	**107**	2.725	69.21	2.705	68.70
58	1.477	37.51	1.457	37.01	**108**	2.750	69.86	2.730	69.35
59	1.502	38.16	1.482	37.65	**109**	2.776	70.50	2.756	69.99

Continued on the next page

INCH .080" (2.03 mm) MXL Pitch Pulley Dimensions

Table 5 (Cont.)

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
110	2.801	71.15	2.781	70.64
111	2.827	71.80	2.807	71.29
112	2.852	72.44	2.832	71.93
113	2.878	73.09	2.858	72.58
114	2.903	73.74	2.883	73.23
115	2.928	74.38	2.908	73.87
116	2.954	75.03	2.934	74.52
117	2.979	75.68	2.959	75.17
118	3.005	76.32	2.985	75.82
119	3.030	76.97	3.010	76.46
120	3.056	77.62	3.036	77.11
121	3.081	78.26	3.061	77.76
122	3.107	78.91	3.087	78.40
123	3.132	79.56	3.112	79.05
124	3.158	80.20	3.138	79.70
125	3.183	80.85	3.163	80.34
126	3.209	81.50	3.189	80.99
127	3.234	82.14	3.214	81.64
128	3.259	82.79	3.239	82.28
129	3.285	83.44	3.265	82.93
130	3.310	84.08	3.290	83.58
131	3.336	84.73	3.316	84.22
132	3.361	85.38	3.341	84.87
133	3.387	86.03	3.367	85.52
134	3.412	86.67	3.392	86.16
135	3.438	87.32	3.418	86.81
136	3.463	87.97	3.443	87.46
137	3.489	88.61	3.469	88.10
138	3.514	89.26	3.494	88.75
139	3.540	89.91	3.520	89.40
140	3.565	90.55	3.545	90.04
141	3.591	91.20	3.571	90.69
142	3.616	91.85	3.596	91.34
143	3.641	92.49	3.621	91.99
144	3.667	93.14	3.647	92.63
145	3.692	93.79	3.672	93.28
146	3.718	94.43	3.698	93.93
147	3.743	95.08	3.723	94.57
148	3.769	95.73	3.749	95.22
149	3.794	96.37	3.774	95.87
150	3.820	97.02	3.800	96.51

40 D.P. (2.07 mm) Pitch Pulley Dimensions

Table 6

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
10	.260	6.60	.246	6.24
11	.286	7.26	.272	6.90
12	.312	7.92	.298	7.56
13	.338	8.58	.324	8.22
14	.364	9.24	.350	8.88
15	.390	9.90	.376	9.54
16	.416	10.56	.402	10.20
17	.442	11.22	.428	10.86
18	.468	11.88	.454	11.52
19	.494	12.54	.480	12.18
20	.520	13.22	.506	12.86
21	.546	13.88	.532	13.52
22	.572	14.54	.558	14.18
23	.598	15.20	.584	14.84
24	.624	15.86	.610	15.50
25	.650	16.52	.636	16.16
26	.676	17.18	.662	16.82
27	.702	17.84	.688	17.48
28	.728	18.50	.714	18.14
29	.754	19.16	.740	18.80
30	.780	19.82	.766	19.46
31	.806	20.48	.792	20.12
32	.832	21.14	.818	20.78
33	.858	21.80	.844	21.44
34	.884	22.46	.870	22.10
35	.910	23.12	.896	22.76
36	.936	23.78	.922	23.42
37	.962	24.44	.948	24.08
38	.988	25.10	.974	24.74
39	1.014	25.76	1.000	25.40
40	1.040	26.42	1.026	26.06
41	1.066	27.07	1.052	26.72
42	1.092	27.73	1.078	27.38
43	1.118	28.39	1.104	28.04
44	1.144	29.05	1.130	28.70
45	1.170	29.71	1.156	29.36
46	1.196	30.37	1.182	30.02
47	1.222	31.03	1.208	30.68
48	1.248	31.69	1.234	31.34
49	1.274	32.35	1.260	32.00
50	1.300	33.01	1.286	32.66
51	1.326	33.67	1.312	33.32
52	1.352	34.33	1.338	33.98
53	1.378	34.99	1.364	34.64
54	1.404	35.65	1.390	35.30
55	1.430	36.31	1.416	35.96
56	1.456	36.97	1.442	36.62
57	1.482	37.63	1.468	37.28
58	1.507	38.29	1.493	37.93
59	1.534	38.98	1.520	38.62
60	1.560	39.64	1.546	39.28

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
61	1.586	40.30	1.572	39.94
62	1.612	40.95	1.598	40.60
63	1.638	41.61	1.624	41.26
64	1.664	42.27	1.650	41.92
65	1.690	42.93	1.676	42.58
66	1.716	43.59	1.702	43.24
67	1.742	44.25	1.728	43.90
68	1.768	44.91	1.754	44.56
69	1.794	45.57	1.780	45.22
70	1.820	46.23	1.806	45.88
71	1.846	46.89	1.832	46.54
72	1.872	47.55	1.858	47.20
73	1.898	48.21	1.884	47.86
74	1.924	48.87	1.910	48.52
75	1.950	49.53	1.936	49.18
76	1.976	50.19	1.962	49.84
77	2.002	50.85	1.988	50.50
78	2.028	51.51	2.014	51.16
79	2.054	52.17	2.040	51.81
80	2.080	52.83	2.066	52.47
81	2.106	53.49	2.092	53.13
82	2.132	54.15	2.118	53.79
83	2.158	54.81	2.144	54.45
84	2.184	55.47	2.170	55.11
85	2.210	56.13	2.196	55.77
86	2.236	56.79	2.222	56.43
87	2.262	57.45	2.248	57.09
88	2.288	58.11	2.274	57.75
89	2.314	58.77	2.300	58.41
90	2.340	59.43	2.326	59.07
91	2.366	60.09	2.352	59.73
92	2.392	60.75	2.378	60.39
93	2.418	61.41	2.404	61.05
94	2.444	62.07	2.430	61.71
95	2.470	62.73	2.456	62.37
96	2.496	63.39	2.482	63.03
97	2.522	64.07	2.508	63.72
98	2.548	64.73	2.534	64.38
99	2.574	65.39	2.560	65.04
100	2.600	66.05	2.586	65.69
101	2.626	66.71	2.612	66.35
102	2.652	67.37	2.638	67.01
103	2.678	68.03	2.664	67.67
104	2.704	68.69	2.690	68.33
105	2.730	69.35	2.716	68.99
106	2.756	70.01	2.742	69.65
107	2.782	70.67	2.768	70.31
108	2.808	71.33	2.794	70.97
109	2.834	71.99	2.820	71.63
110	2.860	72.65	2.846	72.29
111	2.886	73.31	2.872	72.95

Continued on the next page

40 D.P. (2.07 mm) Pitch Pulley Dimensions

Table 6 (Cont.)

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
112	2.912	73.97	2.898	73.61
113	2.938	74.63	2.924	74.27
114	2.964	75.29	2.950	74.93
115	2.990	75.95	2.976	75.59
116	3.016	76.61	3.002	76.25
117	3.042	77.27	3.028	76.91
118	3.068	77.93	3.054	77.57
119	3.094	78.59	3.080	78.23
120	3.120	79.25	3.106	78.89
121	3.146	79.90	3.132	79.55
122	3.172	80.56	3.158	80.21
123	3.198	81.22	3.184	80.87
124	3.224	81.88	3.210	81.53
125	3.250	82.54	3.236	82.19
126	3.276	83.20	3.262	82.85
127	3.302	83.86	3.288	83.51
128	3.328	84.52	3.314	84.17
129	3.354	85.18	3.340	84.83
130	3.380	85.84	3.366	85.49
131	3.406	86.50	3.392	86.15

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
132	3.432	87.16	3.418	86.81
133	3.458	87.82	3.444	87.47
134	3.484	88.48	3.470	88.13
135	3.510	89.14	3.496	88.79
136	3.536	89.83	3.522	89.47
137	3.562	90.49	3.548	90.13
138	3.588	91.15	3.574	90.79
139	3.614	91.81	3.600	91.45
140	3.640	92.47	3.626	92.11
141	3.666	93.13	3.652	92.77
142	3.692	93.78	3.678	93.43
143	3.718	94.44	3.704	94.09
144	3.744	95.10	3.730	94.75
145	3.770	95.76	3.756	95.41
146	3.796	96.42	3.782	96.07
147	3.822	97.08	3.808	96.73
148	3.848	97.74	3.834	97.39
149	3.874	98.40	3.860	98.05
150	3.900	99.06	3.886	98.71

1/5" (5.08 mm) XL Pitch Pulley Dimensions

Table 7

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
10	.637	16.17	.617	15.66
11	.700	17.79	.680	17.28
12	.764	19.40	.744	18.90
13	.828	21.02	.808	20.51
14	.891	22.64	.871	22.13
15	.955	24.26	.935	23.75
16	1.019	25.87	.999	25.36
17	1.082	27.49	1.062	26.98
18	1.146	29.11	1.126	28.60
19	1.210	30.72	1.190	30.22
20	1.273	32.34	1.253	31.83
21	1.337	33.96	1.317	33.45
22	1.401	35.57	1.381	35.07
23	1.464	37.19	1.444	36.68
24	1.528	38.81	1.508	38.30
25	1.592	40.43	1.572	39.92
26	1.655	42.04	1.635	41.53
27	1.719	43.66	1.699	43.15
28	1.783	45.28	1.763	44.77
29	1.846	46.89	1.826	46.39
30	1.910	48.51	1.890	48.00
31	1.974	50.13	1.954	49.62
32	2.037	51.74	2.017	51.24
33	2.101	53.36	2.081	52.85
34	2.165	54.98	2.145	54.47
35	2.228	56.60	2.208	56.09
36	2.292	58.21	2.272	57.70
37	2.355	59.83	2.335	59.32
38	2.419	61.45	2.399	60.94
39	2.483	63.06	2.463	62.56
40	2.546	64.68	2.526	64.17
41	2.610	66.30	2.590	65.79
42	2.674	67.91	2.654	67.41
43	2.737	69.53	2.717	69.02
44	2.801	71.15	2.781	70.64
45	2.865	72.77	2.845	72.26
46	2.928	74.38	2.908	73.87
47	2.992	76.00	2.972	75.49
48	3.056	77.62	3.036	77.11
49	3.119	79.23	3.099	78.73
50	3.183	80.85	3.163	80.34
51	3.247	82.47	3.227	81.96
52	3.310	84.08	3.290	83.58
53	3.374	85.70	3.354	85.19
54	3.438	87.32	3.418	86.81
55	3.501	88.94	3.481	88.43
56	3.565	90.55	3.545	90.04
57	3.629	92.17	3.609	91.66
58	3.692	93.79	3.672	93.28
59	3.756	95.40	3.736	94.90
60	3.820	97.02	3.800	96.51
61	3.883	98.64	3.863	98.13
62	3.947	100.25	3.927	99.75
63	4.011	101.87	3.991	101.36
64	4.074	103.49	4.054	102.98
65	4.138	105.11	4.118	104.60
66	4.202	106.72	4.182	106.22
67	4.265	108.34	4.245	107.83
68	4.329	109.96	4.309	109.45
69	4.393	111.57	4.373	111.07
70	4.456	113.19	4.436	112.68
71	4.520	114.81	4.500	114.30
72	4.584	116.42	4.564	115.92
73	4.647	118.04	4.627	117.53
74	4.711	119.66	4.691	119.15
75	4.775	121.28	4.755	120.77
76	4.838	122.89	4.818	122.39
77	4.902	124.51	4.882	124.00
78	4.966	126.13	4.946	125.62
79	5.029	127.74	5.009	127.24
80	5.093	129.36	5.073	128.85
81	5.157	130.98	5.137	130.47
82	5.220	132.59	5.200	132.09
83	5.284	134.21	5.264	133.70
84	5.348	135.83	5.328	135.32
85	5.411	137.45	5.391	136.94
86	5.475	139.06	5.455	138.56
87	5.539	140.68	5.519	140.17
88	5.602	142.30	5.582	141.79
89	5.666	143.91	5.646	143.41
90	5.730	145.53	5.710	145.02
91	5.793	147.15	5.773	146.64
92	5.857	148.76	5.837	148.26
93	5.921	150.38	5.901	149.87
94	5.984	152.00	5.964	151.49
95	6.048	153.62	6.028	153.11
96	6.112	155.23	6.092	154.73
97	6.175	156.85	6.155	156.34
98	6.239	158.47	6.219	157.96
99	6.303	160.08	6.283	159.58
100	6.366	161.70	6.346	161.19
101	6.430	163.32	6.410	162.81
102	6.494	164.94	6.474	164.43
103	6.557	166.55	6.537	166.04
104	6.621	168.17	6.601	167.66
105	6.684	169.79	6.664	169.28
106	6.748	171.40	6.728	170.90
107	6.812	173.02	6.792	172.51
108	6.875	174.64	6.855	174.13
109	6.939	176.25	6.919	175.75

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Table 7 (Cont.)

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
110	7.003	177.87	6.983	177.36
111	7.066	179.49	7.046	178.98
112	7.130	181.11	7.110	180.60
113	7.194	182.72	7.174	182.21
114	7.257	184.34	7.237	183.83
115	7.321	185.96	7.301	185.45
116	7.385	187.57	7.365	187.07
117	7.448	189.19	7.428	188.68
118	7.512	190.81	7.492	190.30
119	7.576	192.42	7.556	191.92
120	7.639	194.04	7.619	193.53
121	7.703	195.66	7.683	195.15
122	7.767	197.28	7.747	196.77
123	7.830	198.89	7.810	198.38
124	7.894	200.51	7.874	200.00
125	7.958	202.13	7.938	201.62
126	8.021	203.74	8.001	203.24
127	8.085	205.36	8.065	204.85
128	8.149	206.98	8.129	206.47
129	8.212	208.59	8.192	208.09
130	8.276	210.21	8.256	209.70
131	8.340	211.83	8.320	211.32
132	8.403	213.45	8.383	212.94
133	8.467	215.06	8.447	214.56
134	8.531	216.68	8.511	216.17
135	8.594	218.30	8.574	217.79
136	8.658	219.91	8.638	219.41
137	8.722	221.53	8.702	221.02
138	8.785	223.15	8.765	222.64
139	8.849	224.76	8.829	224.26
140	8.913	226.38	8.893	225.87
141	8.976	228.00	8.956	227.49
142	9.040	229.62	9.020	229.11
143	9.104	231.23	9.084	230.73
144	9.167	232.85	9.147	232.34
145	9.231	234.47	9.211	233.96
146	9.295	236.08	9.275	235.58
147	9.358	237.70	9.338	237.19
148	9.422	239.32	9.402	238.81
149	9.486	240.93	9.466	240.43
150	9.549	242.55	9.529	242.04
151	9.613	244.17	9.593	243.66
152	9.677	245.79	9.657	245.28
153	9.740	247.40	9.720	246.90
154	9.804	249.02	9.784	248.51
155	9.868	250.64	9.848	250.13
156	9.931	252.25	9.911	251.75
157	9.995	253.87	9.975	253.36
158	10.059	255.49	10.039	254.98
159	10.122	257.10	10.102	256.60

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
160	10.186	258.72	10.166	258.21
161	10.250	260.34	10.230	259.83
162	10.313	261.96	10.293	261.45
163	10.377	263.57	10.357	263.07
164	10.441	265.19	10.421	264.68
165	10.504	266.81	10.484	266.30
166	10.568	268.42	10.548	267.92
167	10.632	270.04	10.612	269.53
168	10.695	271.66	10.675	271.15
169	10.759	273.27	10.739	272.77
170	10.823	274.89	10.803	274.38
171	10.886	276.51	10.866	276.00
172	10.950	278.13	10.930	277.62
173	11.013	279.74	10.993	279.24
174	11.077	281.36	11.057	280.85
175	11.141	282.98	11.121	282.47
176	11.204	284.59	11.184	284.09
177	11.268	286.21	11.248	285.70
178	11.332	287.83	11.312	287.32
179	11.395	289.44	11.375	288.94
180	11.459	291.06	11.439	290.55
181	11.523	292.68	11.503	292.17
182	11.586	294.30	11.566	293.79
183	11.650	295.91	11.630	295.41
184	11.714	297.53	11.694	297.02
185	11.777	299.15	11.757	298.64
186	11.841	300.76	11.821	300.26
187	11.905	302.38	11.885	301.87
188	11.968	304.00	11.948	303.49
189	12.032	305.61	12.012	305.11
190	12.096	307.23	12.076	306.72
191	12.159	308.85	12.139	308.34
192	12.223	310.47	12.203	309.96
193	12.287	312.08	12.267	311.58
194	12.350	313.70	12.330	313.19
195	12.414	315.32	12.394	314.81
196	12.478	316.93	12.458	316.43
197	12.541	318.55	12.521	318.04
198	12.605	320.17	12.585	319.66
199	12.669	321.79	12.649	321.28
200	12.732	323.40	12.712	322.90
201	12.796	325.02	12.776	324.51
202	12.860	326.64	12.840	326.13
203	12.923	328.25	12.903	327.75
204	12.987	329.87	12.967	329.36
205	13.051	331.49	13.031	330.98
206	13.114	333.10	13.094	332.60
207	13.178	334.72	13.158	334.21
208	13.242	336.34	13.222	335.83
209	13.305	337.96	13.285	337.45

Table 8

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
10	1.194	30.32	1.164	29.56
11	1.313	33.35	1.283	32.59
12	1.432	36.38	1.402	35.62
13	1.552	39.41	1.522	38.65
14	1.671	42.45	1.641	41.68
15	1.790	45.48	1.760	44.72
16	1.910	48.51	1.880	47.75
17	2.029	51.54	1.999	50.78
18	2.149	54.57	2.119	53.81
19	2.268	57.61	2.238	56.84
20	2.387	60.64	2.357	59.88
21	2.507	63.67	2.477	62.91
22	2.626	66.70	2.596	65.94
23	2.745	69.73	2.715	68.97
24	2.865	72.77	2.835	72.00
25	2.984	75.80	2.954	75.04
26	3.104	78.83	3.074	78.07
27	3.223	81.86	3.193	81.10
28	3.342	84.89	3.312	84.13
29	3.462	87.92	3.432	87.16
30	3.581	90.96	3.551	90.19
31	3.700	93.99	3.670	93.23
32	3.820	97.02	3.790	96.26
33	3.939	100.05	3.909	99.29
34	4.058	103.08	4.028	102.32
35	4.178	106.12	4.148	105.35
36	4.297	109.15	4.267	108.39
37	4.417	112.18	4.387	111.42
38	4.536	115.21	4.506	114.45
39	4.655	118.24	4.625	117.48
40	4.775	121.28	4.745	120.51
41	4.894	124.31	4.864	123.55
42	5.013	127.34	4.983	126.58
43	5.133	130.37	5.103	129.61
44	5.252	133.40	5.222	132.64
45	5.371	136.44	5.341	135.67
46	5.491	139.47	5.461	138.71
47	5.610	142.50	5.580	141.74
48	5.730	145.53	5.700	144.77
49	5.849	148.56	5.819	147.80
50	5.968	151.59	5.938	150.83
51	6.088	154.63	6.058	153.86
52	6.207	157.66	6.177	156.90
53	6.326	160.69	6.296	159.93
54	6.446	163.72	6.416	162.96
55	6.565	166.75	6.535	165.99
56	6.684	169.79	6.654	169.02
57	6.804	172.82	6.774	172.06
58	6.923	175.85	6.893	175.09
59	7.043	178.88	7.013	178.12
60	7.162	181.91	7.132	181.15
61	7.281	184.95	7.251	184.18
62	7.401	187.98	7.371	187.22
63	7.520	191.01	7.490	190.25
64	7.639	194.04	7.609	193.28
65	7.759	197.07	7.729	196.31
66	7.878	200.11	7.848	199.34
67	7.998	203.14	7.968	202.37
68	8.117	206.17	8.087	205.41
69	8.236	209.20	8.206	208.44
70	8.356	212.23	8.326	211.47
71	8.475	215.26	8.445	214.50
72	8.594	218.30	8.564	217.53
73	8.714	221.33	8.684	220.57
74	8.833	224.36	8.803	223.60
75	8.952	227.39	8.922	226.63
76	9.072	230.42	9.042	229.66
77	9.191	233.46	9.161	232.69
78	9.311	236.49	9.281	235.73
79	9.430	239.52	9.400	238.76
80	9.549	242.55	9.519	241.79
81	9.669	245.58	9.639	244.82
82	9.788	248.62	9.758	247.85
83	9.907	251.65	9.877	250.89
84	10.027	254.68	9.997	253.92
85	10.146	257.71	10.116	256.95
86	10.265	260.74	10.235	259.98
87	10.385	263.77	10.355	263.01
88	10.504	266.81	10.474	266.04
89	10.624	269.84	10.594	269.08
90	10.743	272.87	10.713	272.11
91	10.862	275.90	10.832	275.14
92	10.982	278.93	10.952	278.17
93	11.101	281.97	11.071	281.20
94	11.220	285.00	11.190	284.24
95	11.340	288.03	11.310	287.27
96	11.459	291.06	11.429	290.30
97	11.578	294.09	11.548	293.33
98	11.698	297.13	11.668	296.36
99	11.817	300.16	11.787	299.40
100	11.937	303.19	11.907	302.43
101	12.056	306.22	12.026	305.46
102	12.175	309.25	12.145	308.49
103	12.295	312.29	12.265	311.52
104	12.414	315.32	12.384	314.56
105	12.533	318.35	12.503	317.59
106	12.653	321.38	12.623	320.62
107	12.772	324.41	12.742	323.65
108	12.892	327.44	12.862	326.68
109	13.011	330.48	12.981	329.71

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Table 8 (Cont.)

No. of Grooves	Pitch Diameter		Outside Diameter		No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm		Inch	mm	Inch	mm
110	13.130	333.51	13.100	332.75	**160**	19.099	485.10	19.069	484.34
111	13.250	336.54	13.220	335.78	**161**	19.218	488.14	19.188	487.37
112	13.369	339.57	13.339	338.81	**162**	19.337	491.17	19.307	490.40
113	13.488	342.60	13.458	341.84	**163**	19.457	494.20	19.427	493.44
114	13.608	345.64	13.578	344.87	**164**	19.576	497.23	19.546	496.47
115	13.727	348.67	13.697	347.91	**165**	19.695	500.26	19.665	499.50
116	13.846	351.70	13.816	350.94	**166**	19.815	503.29	19.785	502.53
117	13.966	354.73	13.936	353.97	**167**	19.934	506.33	19.904	505.56
118	14.085	357.76	14.055	357.00	**168**	20.053	509.36	20.023	508.60
119	14.205	360.80	14.175	360.03	**169**	20.173	512.39	20.143	511.63
120	14.324	363.83	14.294	363.07	**170**	20.292	515.42	20.262	514.66
121	14.443	366.86	14.413	366.10	**171**	20.412	518.45	20.382	517.69
122	14.563	369.89	14.533	369.13	**172**	20.531	521.49	20.501	520.72
123	14.682	372.92	14.652	372.16	**173**	20.650	524.52	20.620	523.76
124	14.801	375.95	14.771	375.19	**174**	20.770	527.55	20.740	526.79
125	14.921	378.99	14.891	378.22	**175**	20.889	530.58	20.859	529.82
126	15.040	382.02	15.010	381.26	**176**	21.008	533.61	20.978	532.85
127	15.159	385.05	15.129	384.29	**177**	21.128	536.65	21.098	535.88
128	15.279	388.08	15.249	387.32	**178**	21.247	539.68	21.217	538.92
129	15.398	391.11	15.368	390.35	**179**	21.367	542.71	21.337	541.95
130	15.518	394.15	15.488	393.38	**180**	21.486	545.74	21.456	544.98
131	15.637	397.18	15.607	396.42	**181**	21.605	548.77	21.575	548.01
132	15.756	400.21	15.726	399.45	**182**	21.725	551.80	21.695	551.04
133	15.876	403.24	15.846	402.48	**183**	21.844	554.84	21.814	554.07
134	15.995	406.27	15.965	405.51	**184**	21.963	557.87	21.933	557.11
135	16.114	409.31	16.084	408.54	**185**	22.083	560.90	22.053	560.14
136	16.234	412.34	16.204	411.58	**186**	22.202	563.93	22.172	563.17
137	16.353	415.37	16.323	414.61	**187**	22.321	566.96	22.291	566.20
138	16.472	418.40	16.442	417.64	**188**	22.441	570.00	22.411	569.23
139	16.592	421.43	16.562	420.67	**189**	22.560	573.03	22.530	572.27
140	16.711	424.47	16.681	423.70	**190**	22.680	576.06	22.650	575.30
141	16.831	427.50	16.801	426.74	**191**	22.799	579.09	22.769	578.33
142	16.950	430.53	16.920	429.77	**192**	22.918	582.12	22.888	581.36
143	17.069	433.56	17.039	432.80	**193**	23.038	585.16	23.008	584.39
144	17.189	436.59	17.159	435.83	**194**	23.157	588.19	23.127	587.43
145	17.308	439.62	17.278	438.86	**195**	23.276	591.22	23.246	590.46
146	17.427	442.66	17.397	441.89	**196**	23.396	594.25	23.366	593.49
147	17.547	445.69	17.517	444.93	**197**	23.515	597.28	23.485	596.52
148	17.666	448.72	17.636	447.96	**198**	23.634	600.32	23.604	599.55
149	17.786	451.75	17.756	450.99	**199**	23.754	603.35	23.724	602.59
150	17.905	454.78	17.875	454.02	**200**	23.873	606.38	23.843	605.62
151	18.024	457.82	17.994	457.05	**201**	23.993	609.41	23.963	608.65
152	18.144	460.85	18.114	460.09	**202**	24.112	612.44	24.082	611.68
153	18.263	463.88	18.233	463.12	**203**	24.231	615.47	24.201	614.71
154	18.382	466.91	18.352	466.15	**204**	24.351	618.51	24.321	617.74
155	18.502	469.94	18.472	469.18	**205**	24.470	621.54	24.440	620.78
156	18.621	472.98	18.591	472.21	**206**	24.589	624.57	24.559	623.81
157	18.740	476.01	18.710	475.25	**207**	24.709	627.60	24.679	626.84
158	18.860	479.04	18.830	478.28	**208**	24.828	630.63	24.798	629.87
159	18.979	482.07	18.949	481.31	**209**	24.947	633.67	24.917	632.90

Table 9

No. of Grooves	Pitch Diameter		Outside Diameter		No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm		Inch	mm	Inch	mm
10	.376	9.55	.346	8.79	**60**	2.256	57.30	2.226	56.53
11	.414	10.50	.384	9.74	**61**	2.293	58.25	2.263	57.49
12	.451	11.46	.421	10.70	**62**	2.331	59.21	2.301	58.44
13	.489	12.41	.459	11.65	**63**	2.369	60.16	2.339	59.40
14	.526	13.37	.496	12.61	**64**	2.406	61.12	2.376	60.35
15	.564	14.32	.534	13.56	**65**	2.444	62.07	2.414	61.31
16	.602	15.28	.572	14.52	**66**	2.481	63.03	2.451	62.26
17	.639	16.23	.609	15.47	**67**	2.519	63.98	2.489	63.22
18	.677	17.19	.647	16.43	**68**	2.556	64.94	2.526	64.17
19	.714	18.14	.684	17.38	**69**	2.594	65.89	2.564	65.13
20	.752	19.10	.722	18.34	**70**	2.632	66.84	2.602	66.08
21	.790	20.05	.760	19.29	**71**	2.669	67.80	2.639	67.04
22	.827	21.01	.797	20.25	**72**	2.707	68.75	2.677	67.99
23	.865	21.96	.835	21.20	**73**	2.744	69.71	2.714	68.95
24	.902	22.92	.872	22.16	**74**	2.782	70.66	2.752	69.90
25	.940	23.87	.910	23.11	**75**	2.820	71.62	2.790	70.86
26	.977	24.83	.947	24.07	**76**	2.857	72.57	2.827	71.81
27	1.015	25.78	.985	25.02	**77**	2.895	73.53	2.865	72.77
28	1.053	26.74	1.023	25.98	**78**	2.932	74.48	2.902	73.72
29	1.090	27.69	1.060	26.93	**79**	2.970	75.44	2.940	74.68
30	1.128	28.65	1.098	27.89	**80**	3.008	76.39	2.978	75.63
31	1.165	29.60	1.135	28.84	**81**	3.045	77.35	3.015	76.59
32	1.203	30.56	1.173	29.80	**82**	3.083	78.30	3.053	77.54
33	1.241	31.51	1.211	30.75	**83**	3.120	79.26	3.090	78.50
34	1.278	32.47	1.248	31.71	**84**	3.158	80.21	3.128	79.45
35	1.316	33.42	1.286	32.66	**85**	3.196	81.17	3.166	80.41
36	1.353	34.38	1.323	33.62	**86**	3.233	82.12	3.203	81.36
37	1.391	35.33	1.361	34.57	**87**	3.271	83.08	3.241	82.32
38	1.429	36.29	1.399	35.53	**88**	3.308	84.03	3.278	83.27
39	1.466	37.24	1.436	36.48	**89**	3.346	84.99	3.316	84.23
40	1.504	38.20	1.474	37.44	**90**	3.384	85.94	3.354	85.18
41	1.541	39.15	1.511	38.39	**91**	3.421	86.90	3.391	86.14
42	1.579	40.11	1.549	39.34	**92**	3.459	87.85	3.429	87.09
43	1.617	41.06	1.587	40.30	**93**	3.496	88.81	3.466	88.05
44	1.654	42.02	1.624	41.25	**94**	3.534	89.76	3.504	89.00
45	1.692	42.97	1.662	42.21	**95**	3.572	90.72	3.542	89.96
46	1.729	43.93	1.699	43.16	**96**	3.609	91.67	3.579	90.91
47	1.767	44.88	1.737	44.12	**97**	3.647	92.63	3.617	91.87
48	1.805	45.84	1.775	45.07	**98**	3.684	93.58	3.654	92.82
49	1.842	46.79	1.812	46.03	**99**	3.722	94.54	3.692	93.78
50	1.880	47.75	1.850	46.98	**100**	3.760	95.49	3.730	94.73
51	1.917	48.70	1.887	47.94	**101**	3.797	96.45	3.767	95.69
52	1.955	49.66	1.925	48.89	**102**	3.835	97.40	3.805	96.64
53	1.993	50.61	1.963	49.85	**103**	3.872	98.36	3.842	97.60
54	2.030	51.57	2.000	50.80	**104**	3.910	99.31	3.880	98.55
55	2.068	52.52	2.038	51.76	**105**	3.948	100.27	3.918	99.51
56	2.105	53.48	2.075	52.71	**106**	3.985	101.22	3.955	100.46
57	2.143	54.43	2.113	53.67	**107**	4.023	102.18	3.993	101.42
58	2.181	55.39	2.151	54.62	**108**	4.060	103.13	4.030	102.37
59	2.218	56.34	2.188	55.58	**109**	4.098	104.09	4.068	103.33

Continued on the next page

Table 9 (Cont.)

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
110	4.136	105.04	4.106	104.28
111	4.173	106.00	4.143	105.23
112	4.211	106.95	4.181	106.19
113	4.248	107.91	4.218	107.14
114	4.286	108.86	4.256	108.10
115	4.323	109.82	4.293	109.05
116	4.361	110.77	4.331	110.01
117	4.399	111.73	4.369	110.96
118	4.436	112.68	4.406	111.92
119	4.474	113.64	4.444	112.87
120	4.511	114.59	4.481	113.83
121	4.549	115.55	4.519	114.78
122	4.587	116.50	4.557	115.74
123	4.624	117.46	4.594	116.69
124	4.662	118.41	4.632	117.65
125	4.699	119.37	4.669	118.60
126	4.737	120.32	4.707	119.56
127	4.775	121.28	4.745	120.51
128	4.812	122.23	4.782	121.47
129	4.850	123.19	4.820	122.42
130	4.887	124.14	4.857	123.38
131	4.925	125.10	4.895	124.33
132	4.963	126.05	4.933	125.29
133	5.000	127.01	4.970	126.24
134	5.038	127.96	5.008	127.20
135	5.075	128.92	5.045	128.15
136	5.113	129.87	5.083	129.11
137	5.151	130.83	5.121	130.06
138	5.188	131.78	5.158	131.02
139	5.226	132.73	5.196	131.97
140	5.263	133.69	5.233	132.93
141	5.301	134.64	5.271	133.88
142	5.339	135.60	5.309	134.84
143	5.376	136.55	5.346	135.79
144	5.414	137.51	5.384	136.75
145	5.451	138.46	5.421	137.70
146	5.489	139.42	5.459	138.66
147	5.527	140.37	5.497	139.61
148	5.564	141.33	5.534	140.57
149	5.602	142.28	5.572	141.52
150	5.639	143.24	5.609	142.48
151	5.677	144.19	5.647	143.43
152	5.715	145.15	5.685	144.39
153	5.752	146.10	5.722	145.34
154	5.790	147.06	5.760	146.30
155	5.827	148.01	5.797	147.25
156	5.865	148.97	5.835	148.21
157	5.902	149.92	5.872	149.16
158	5.940	150.88	5.910	150.12
159	5.978	151.83	5.948	151.07

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
160	6.015	152.79	5.985	152.03
161	6.053	153.74	6.023	152.98
162	6.090	154.70	6.060	153.94
163	6.128	155.65	6.098	154.89
164	6.166	156.61	6.136	155.85
165	6.203	157.56	6.173	156.80
166	6.241	158.52	6.211	157.76
167	6.278	159.47	6.248	158.71
168	6.316	160.43	6.286	159.67
169	6.354	161.38	6.324	160.62
170	6.391	162.34	6.361	161.58
171	6.429	163.29	6.399	162.53
172	6.466	164.25	6.436	163.49
173	6.504	165.20	6.474	164.44
174	6.542	166.16	6.512	165.40
175	6.579	167.11	6.549	166.35
176	6.617	168.07	6.587	167.31
177	6.654	169.02	6.624	168.26
178	6.692	169.98	6.662	169.22
179	6.730	170.93	6.700	170.17
180	6.767	171.89	6.737	171.12
181	6.805	172.84	6.775	172.08
182	6.842	173.80	6.812	173.03
183	6.880	174.75	6.850	173.99
184	6.918	175.71	6.888	174.94
185	6.955	176.66	6.925	175.90
186	6.993	177.62	6.963	176.85
187	7.030	178.57	7.000	177.81
188	7.068	179.53	7.038	178.76
189	7.106	180.48	7.076	179.72
190	7.143	181.44	7.113	180.67
191	7.181	182.39	7.151	181.63
192	7.218	183.35	7.188	182.58
193	7.256	184.30	7.226	183.54
194	7.294	185.26	7.264	184.49
195	7.331	186.21	7.301	185.45
196	7.369	187.17	7.339	186.40
197	7.406	188.12	7.376	187.36
198	7.444	189.08	7.414	188.31
199	7.482	190.03	7.452	189.27
200	7.519	190.99	7.489	190.22
201	7.557	191.94	7.527	191.18
202	7.594	192.90	7.564	192.13
203	7.632	193.85	7.602	193.09
204	7.669	194.81	7.639	194.04
205	7.707	195.76	7.677	195.00
206	7.745	196.72	7.715	195.95
207	7.782	197.67	7.752	196.91
208	7.820	198.62	7.790	197.86
209	7.857	199.58	7.827	198.82

Table 10

No. of Grooves	Pitch Diameter Inch	Pitch Diameter mm	Outside Diameter Inch	Outside Diameter mm
10	.627	15.92	.582	14.77
11	.689	17.51	.644	16.36
12	.752	19.10	.707	17.96
13	.815	20.69	.770	19.55
14	.877	22.28	.832	21.14
15	.940	23.87	.895	22.73
16	1.003	25.46	.958	24.32
17	1.065	27.06	1.020	25.91
18	1.128	28.65	1.083	27.50
19	1.191	30.24	1.146	29.10
20	1.253	31.83	1.208	30.69
21	1.316	33.42	1.271	32.28
22	1.379	35.01	1.334	33.87
23	1.441	36.61	1.396	35.46
24	1.504	38.20	1.459	37.05
25	1.566	39.79	1.521	38.65
26	1.629	41.38	1.584	40.24
27	1.692	42.97	1.647	41.83
28	1.754	44.56	1.709	43.42
29	1.817	46.15	1.772	45.01
30	1.880	47.75	1.835	46.60
31	1.942	49.34	1.897	48.19
32	2.005	50.93	1.960	49.79
33	2.068	52.52	2.023	51.38
34	2.130	54.11	2.085	52.97
35	2.193	55.70	2.148	54.56
36	2.256	57.30	2.211	56.15
37	2.318	58.89	2.273	57.74
38	2.381	60.48	2.336	59.34
39	2.444	62.07	2.399	60.93
40	2.506	63.66	2.461	62.52
41	2.569	65.25	2.524	64.11
42	2.632	66.84	2.587	65.70
43	2.694	68.44	2.649	67.29
44	2.757	70.03	2.712	68.89
45	2.820	71.62	2.775	70.48
46	2.882	73.21	2.837	72.07
47	2.945	74.80	2.900	73.66
48	3.008	76.39	2.963	75.25
49	3.070	77.99	3.025	76.84
50	3.133	79.58	3.088	78.43
51	3.196	81.17	3.151	80.03
52	3.258	82.76	3.213	81.62
53	3.321	84.35	3.276	83.21
54	3.384	85.94	3.339	84.80
55	3.446	87.54	3.401	86.39
56	3.509	89.13	3.464	87.98
57	3.572	90.72	3.527	89.58
58	3.634	92.31	3.589	91.17
59	3.697	93.90	3.652	92.76
60	3.760	95.49	3.715	94.35
61	3.822	97.08	3.777	95.94
62	3.885	98.68	3.840	97.53
63	3.948	100.27	3.903	99.12
64	4.010	101.86	3.965	100.72
65	4.073	103.45	4.028	102.31
66	4.136	105.04	4.091	103.90
67	4.198	106.63	4.153	105.49
68	4.261	108.23	4.216	107.08
69	4.323	109.82	4.278	108.67
70	4.386	111.41	4.341	110.27
71	4.449	113.00	4.404	111.86
72	4.511	114.59	4.466	113.45
73	4.574	116.18	4.529	115.04
74	4.637	117.77	4.592	116.63
75	4.699	119.37	4.654	118.22
76	4.762	120.96	4.717	119.81
77	4.825	122.55	4.780	121.41
78	4.887	124.14	4.842	123.00
79	4.950	125.73	4.905	124.59
80	5.013	127.32	4.968	126.18
81	5.075	128.92	5.030	127.77
82	5.138	130.51	5.093	129.36
83	5.201	132.10	5.156	130.96
84	5.263	133.69	5.218	132.55
85	5.326	135.28	5.281	134.14
86	5.389	136.87	5.344	135.73
87	5.451	138.46	5.406	137.32
88	5.514	140.06	5.469	138.91
89	5.577	141.65	5.532	140.50
90	5.639	143.24	5.594	142.10
91	5.702	144.83	5.657	143.69
92	5.765	146.42	5.720	145.28
93	5.827	148.01	5.782	146.87
94	5.890	149.61	5.845	148.46
95	5.953	151.20	5.908	150.05
96	6.015	152.79	5.970	151.65
97	6.078	154.38	6.033	153.24
98	6.141	155.97	6.096	154.83
99	6.203	157.56	6.158	156.42
100	6.266	159.15	6.221	158.01
101	6.329	160.75	6.284	159.60
102	6.391	162.34	6.346	161.19
103	6.454	163.93	6.409	162.79
104	6.517	165.52	6.472	164.38
105	6.579	167.11	6.534	165.97
106	6.642	168.70	6.597	167.56
107	6.705	170.30	6.660	169.15
108	6.767	171.89	6.722	170.74
109	6.830	173.48	6.785	172.34

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Table 10 (Cont.)

No. of Grooves	Pitch Diameter Inch	Pitch Diameter mm	Outside Diameter Inch	Outside Diameter mm
110	6.893	175.07	6.848	173.93
111	6.955	176.66	6.910	175.52
112	7.018	178.25	6.973	177.11
113	7.080	179.84	7.035	178.70
114	7.143	181.44	7.098	180.29
115	7.206	183.03	7.161	181.88
116	7.268	184.62	7.223	183.48
117	7.331	186.21	7.286	185.07
118	7.394	187.80	7.349	186.66
119	7.456	189.39	7.411	188.25
120	7.519	190.99	7.474	189.84
121	7.582	192.58	7.537	191.43
122	7.644	194.17	7.599	193.03
123	7.707	195.76	7.662	194.62
124	7.770	197.35	7.725	196.21
125	7.832	198.94	7.787	197.80
126	7.895	200.53	7.850	199.39
127	7.958	202.13	7.913	200.98
128	8.020	203.72	7.975	202.57
129	8.083	205.31	8.038	204.17
130	8.146	206.90	8.101	205.76
131	8.208	208.49	8.163	207.35
132	8.271	210.08	8.226	208.94
133	8.334	211.68	8.289	210.53
134	8.396	213.27	8.351	212.12
135	8.459	214.86	8.414	213.72
136	8.522	216.45	8.477	215.31
137	8.584	218.04	8.539	216.90
138	8.647	219.63	8.602	218.49
139	8.710	221.22	8.665	220.08
140	8.772	222.82	8.727	221.67
141	8.835	224.41	8.790	223.26
142	8.898	226.00	8.853	224.86
143	8.960	227.59	8.915	226.45
144	9.023	229.18	8.978	228.04
145	9.086	230.77	9.041	229.63
146	9.148	232.37	9.103	231.22
147	9.211	233.96	9.166	232.81
148	9.274	235.55	9.229	234.41
149	9.336	237.14	9.291	236.00
150	9.399	238.73	9.354	237.59
151	9.462	240.32	9.417	239.18
152	9.524	241.91	9.479	240.77
153	9.587	243.51	9.542	242.36
154	9.650	245.10	9.605	243.96
155	9.712	246.69	9.667	245.55
156	9.775	248.28	9.730	247.14
157	9.837	249.87	9.792	248.73
158	9.900	251.46	9.855	250.32
159	9.963	253.06	9.918	251.91
160	10.025	254.65	9.980	253.50
161	10.088	256.24	10.043	255.10
162	10.151	257.83	10.106	256.69
163	10.213	259.42	10.168	258.28
164	10.276	261.01	10.231	259.87
165	10.339	262.61	10.294	261.46
166	10.401	264.20	10.356	263.05
167	10.464	265.79	10.419	264.65
168	10.527	267.38	10.482	266.24
169	10.589	268.97	10.544	267.83
170	10.652	270.56	10.607	269.42
171	10.715	272.15	10.670	271.01
172	10.777	273.75	10.732	272.60
173	10.840	275.34	10.795	274.19
174	10.903	276.93	10.858	275.79
175	10.965	278.52	10.920	277.38
176	11.028	280.11	10.983	278.97
177	11.091	281.70	11.046	280.56
178	11.153	283.30	11.108	282.15
179	11.216	284.89	11.171	283.74
180	11.279	286.48	11.234	285.34
181	11.341	288.07	11.296	286.93
182	11.404	289.66	11.359	288.52
183	11.467	291.25	11.422	290.11
184	11.529	292.84	11.484	291.70
185	11.592	294.44	11.547	293.29
186	11.655	296.03	11.610	294.88
187	11.717	297.62	11.672	296.48
188	11.780	299.21	11.735	298.07
189	11.843	300.80	11.798	299.66
190	11.905	302.39	11.860	301.25
191	11.968	303.99	11.923	302.84
192	12.031	305.58	11.986	304.43
193	12.093	307.17	12.048	306.03
194	12.156	308.76	12.111	307.62
195	12.219	310.35	12.174	309.21
196	12.281	311.94	12.236	310.80
197	12.344	313.53	12.299	312.39
198	12.407	315.13	12.362	313.98
199	12.469	316.72	12.424	315.57
200	12.532	318.31	12.487	317.17
201	12.594	319.90	12.549	318.76
202	12.657	321.49	12.612	320.35
203	12.720	323.08	12.675	321.94
204	12.782	324.68	12.737	323.53
205	12.845	326.27	12.800	325.12
206	12.908	327.86	12.863	326.72
207	12.970	329.45	12.925	328.31
208	13.033	331.04	12.988	329.90
209	13.096	332.63	13.051	331.49

8 mm Pitch HTD® Pulley Dimensions

Table 11

No. of Grooves	Pitch Diameter		Outside Diameter		No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm		Inch	mm	Inch	mm
22	2.206	56.02	2.152	54.65	**67**	6.717	170.61	6.663	169.24
23	2.306	58.57	2.252	57.20	**68**	6.817	173.16	6.763	171.79
24	2.406	61.12	2.352	59.74	**69**	6.918	175.71	6.864	174.34
25	2.506	63.66	2.452	62.29	**70**	7.018	178.25	6.964	176.88
26	2.607	66.21	2.553	64.84	**71**	7.118	180.80	7.064	179.43
27	2.707	68.75	2.653	67.38	**72**	7.218	183.35	7.164	181.97
28	2.807	71.30	2.753	69.93	**73**	7.319	185.89	7.265	184.52
29	2.907	73.85	2.853	72.48	**74**	7.419	188.44	7.365	187.07
30	3.008	76.39	2.954	75.02	**75**	7.519	190.99	7.465	189.61
31	3.108	78.94	3.054	77.57	**76**	7.619	193.53	7.565	192.16
32	3.208	81.49	3.154	80.12	**77**	7.720	196.08	7.666	194.71
33	3.308	84.03	3.254	82.66	**78**	7.820	198.63	7.766	197.25
34	3.409	86.58	3.355	85.21	**79**	7.920	201.17	7.866	199.80
35	3.509	89.13	3.455	87.76	**80**	8.020	203.72	7.966	202.35
36	3.609	91.67	3.555	90.30	**81**	8.121	206.26	8.067	204.89
37	3.709	94.22	3.655	92.85	**82**	8.221	208.81	8.167	207.44
38	3.810	96.77	3.756	95.39	**83**	8.321	211.36	8.267	209.99
39	3.910	99.31	3.856	97.94	**84**	8.421	213.90	8.367	212.53
40	4.010	101.86	3.956	100.49	**85**	8.522	215.45	8.468	215.08
41	4.110	104.41	4.056	103.03	**86**	8.622	219.00	8.568	217.63
42	4.211	106.95	4.157	105.58	**87**	8.722	221.54	8.668	220.17
43	4.311	109.50	4.257	108.13	**88**	8.822	224.09	8.768	222.72
44	4.411	112.05	4.357	110.67	**89**	8.923	226.64	8.869	225.27
45	4.511	114.59	4.457	113.22	**90**	9.023	229.18	8.969	227.81
46	4.612	117.14	4.558	115.77	**91**	9.123	231.73	9.069	230.36
47	4.712	119.68	4.658	118.31	**92**	9.223	234.28	9.169	232.90
48	4.812	122.23	4.758	120.86	**93**	9.324	236.82	9.270	235.45
49	4.912	124.78	4.858	123.41	**94**	9.424	239.37	9.370	238.00
50	5.013	127.32	4.959	125.95	**95**	9.524	241.92	9.470	240.54
51	5.113	129.87	5.059	128.50	**96**	9.624	244.46	9.570	243.09
52	5.213	132.42	5.159	131.05	**97**	9.725	247.01	9.671	245.64
53	5.314	134.96	5.260	133.59	**98**	9.825	249.55	9.771	248.18
54	5.414	137.51	5.360	136.14	**99**	9.925	252.10	9.871	250.73
55	5.514	140.06	5.460	138.68	**100**	10.026	254.65	9.972	253.28
56	5.614	142.60	5.560	141.23	**101**	10.126	257.19	10.072	255.82
57	5.715	145.15	5.661	143.78	**102**	10.226	259.74	10.172	258.37
58	5.815	147.70	5.761	146.32	**103**	10.326	262.29	10.272	260.92
59	5.915	150.24	5.861	148.87	**104**	10.427	264.83	10.373	263.46
60	6.015	152.79	5.961	151.42	**105**	10.527	267.38	10.473	266.01
61	6.116	155.34	6.062	153.96	**106**	10.627	269.93	10.573	268.56
62	6.216	157.88	6.162	156.51	**107**	10.727	272.47	10.673	271.10
63	6.316	160.43	6.262	159.06	**108**	10.828	275.02	10.774	273.65
64	6.416	162.97	6.362	161.60	**109**	10.928	277.57	10.874	276.19
65	6.517	165.52	6.463	164.15	**110**	11.028	280.11	10.974	278.74
66	6.617	168.07	6.563	166.70	**111**	11.128	282.66	11.074	281.29

Continued on the next page

Table 11 (Cont.)

No. of Grooves	Pitch Diameter		Outside Diameter		No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm		Inch	mm	Inch	mm
112	11.229	285.21	11.175	283.83	**157**	15.740	399.80	15.686	398.43
113	11.329	287.75	11.275	286.38	**158**	15.840	402.34	15.786	400.97
114	11.429	290.30	11.375	288.93	**159**	15.941	404.89	15.887	403.52
115	11.529	292.85	11.475	291.47	**160**	16.041	407.44	15.987	406.07
116	11.630	295.39	11.576	294.02	**161**	16.141	409.98	16.087	408.61
117	11.730	297.94	11.676	296.57	**162**	16.241	412.53	16.187	411.16
118	11.830	300.48	11.776	299.11	**163**	16.342	415.08	16.288	413.70
119	11.930	303.03	11.876	301.66	**164**	16.442	417.62	16.388	416.25
120	12.031	305.58	11.977	304.21	**165**	16.542	420.17	16.488	418.80
121	12.131	308.12	12.077	306.75	**166**	16.642	422.72	16.588	421.34
122	12.231	310.67	12.177	309.30	**167**	16.743	425.26	16.689	423.89
123	12.331	313.22	12.277	311.85	**168**	16.843	427.81	16.789	426.44
124	12.432	315.76	12.378	314.39	**169**	16.943	430.35	16.889	428.98
125	12.532	318.31	12.478	316.94	**170**	17.043	432.90	16.989	431.53
126	12.632	320.86	12.578	319.48	**171**	17.144	435.45	17.090	434.08
127	12.732	323.40	12.678	322.03	**172**	17.244	437.99	17.190	436.62
128	12.833	325.95	12.779	324.58	**173**	17.344	440.54	17.290	439.17
129	12.933	328.50	12.879	327.12	**174**	17.444	443.09	17.390	441.72
130	13.033	331.04	12.979	329.67	**175**	17.545	445.63	17.491	444.26
131	13.133	333.59	13.079	332.22	**176**	17.645	448.18	17.591	446.81
132	13.234	336.14	13.180	334.76	**177**	17.745	450.73	17.691	449.36
133	13.334	338.68	13.280	337.31	**178**	17.845	453.27	17.791	451.90
134	13.434	341.23	13.380	339.86	**179**	17.946	455.82	17.892	454.45
135	13.534	343.77	13.480	342.40	**180**	18.046	458.37	17.992	456.99
136	13.635	346.32	13.581	344.95	**181**	18.146	460.91	18.092	459.54
137	13.735	348.87	13.681	347.50	**182**	18.246	463.46	18.192	462.09
138	13.835	351.41	13.781	350.04	**183**	18.347	466.01	18.293	464.63
139	13.935	353.96	13.881	352.59	**184**	18.447	468.55	18.393	467.18
140	14.036	356.51	13.982	355.14	**185**	18.547	471.10	18.493	469.73
141	14.136	359.05	14.082	357.68	**186**	18.647	473.65	18.593	472.27
142	14.236	361.60	14.182	360.23	**187**	18.748	476.19	18.694	474.82
143	14.336	364.15	14.282	362.77	**188**	18.848	478.74	18.794	477.37
144	14.437	366.69	14.383	365.32	**189**	18.948	481.28	18.894	479.91
145	14.537	369.24	14.483	367.87	**190**	19.048	483.83	18.994	482.46
146	14.637	371.79	14.583	370.41	**191**	19.149	486.38	19.095	485.01
147	14.737	374.33	14.683	372.96	**192**	19.249	488.92	19.195	487.55
148	14.838	376.88	14.784	375.51	**193**	19.349	491.47	19.295	490.10
149	14.938	379.43	14.884	378.05	**194**	19.449	494.02	19.395	492.65
150	15.038	381.97	14.984	380.60	**195**	19.550	496.56	19.496	495.19
151	15.139	384.52	15.085	383.15	**196**	19.650	499.11	19.596	497.74
152	15.239	387.06	15.185	385.69	**197**	19.750	501.66	19.696	500.28
153	15.339	389.61	15.285	388.24	**198**	19.851	504.20	19.797	502.83
154	15.439	392.16	15.385	390.79	**199**	19.951	506.75	19.897	505.38
155	15.540	394.70	15.486	393.33	**200**	20.051	509.30	19.997	507.92
156	15.640	397.25	15.586	395.88	**201**	20.151	511.84	20.097	510.47

Table 12

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
10	.251	6.37	.231	5.86
11	.276	7.01	.256	6.50
12	.301	7.64	.281	7.13
13	.326	8.28	.306	7.77
14	.351	8.91	.331	8.40
15	.376	9.55	.356	9.04
16	.401	10.19	.381	9.68
17	.426	10.82	.406	10.31
18	.451	11.46	.431	10.95
19	.476	12.10	.456	11.59
20	.501	12.73	.481	12.22
21	.526	13.37	.506	12.86
22	.551	14.01	.531	13.50
23	.576	14.64	.556	14.13
24	.602	15.28	.582	14.77
25	.627	15.92	.607	15.41
26	.652	16.55	.632	16.04
27	.677	17.19	.657	16.68
28	.702	17.83	.682	17.32
29	.727	18.46	.707	17.95
30	.752	19.10	.732	18.59
31	.777	19.74	.757	19.23
32	.802	20.37	.782	19.86
33	.827	21.01	.807	20.50
34	.852	21.65	.832	21.14
35	.877	22.28	.857	21.77
36	.902	22.92	.882	22.41
37	.927	23.55	.907	23.05
38	.952	24.19	.932	23.68
39	.977	24.83	.957	24.32
40	1.003	25.46	.983	24.96
41	1.028	26.10	1.008	25.59
42	1.053	26.74	1.033	26.23
43	1.078	27.37	1.058	26.87
44	1.103	28.01	1.083	27.50
45	1.128	28.65	1.108	28.14
46	1.153	29.28	1.133	28.78
47	1.178	29.92	1.158	29.41
48	1.203	30.56	1.183	30.05
49	1.228	31.19	1.208	30.69
50	1.253	31.83	1.233	31.32
51	1.278	32.47	1.258	31.96
52	1.303	33.10	1.283	32.60
53	1.328	33.74	1.308	33.23
54	1.353	34.38	1.333	33.87
55	1.379	35.01	1.359	34.51
56	1.404	35.65	1.384	35.14
57	1.429	36.29	1.409	35.78
58	1.454	36.92	1.434	36.42
59	1.479	37.56	1.459	37.05
60	1.504	38.20	1.484	37.69
61	1.529	38.83	1.509	38.33
62	1.554	39.47	1.534	38.96
63	1.579	40.11	1.559	39.60
64	1.604	40.74	1.584	40.24
65	1.629	41.38	1.609	40.87
66	1.654	42.02	1.634	41.51
67	1.679	42.65	1.659	42.15
68	1.704	43.29	1.684	42.78
69	1.729	43.93	1.709	43.42
70	1.754	44.56	1.734	44.06
71	1.780	45.20	1.760	44.69
72	1.805	45.84	1.785	45.33
73	1.830	46.47	1.810	45.97
74	1.855	47.11	1.835	46.60
75	1.880	47.75	1.860	47.24
76	1.905	48.38	1.885	47.88
77	1.930	49.02	1.910	48.51
78	1.955	49.66	1.935	49.15
79	1.980	50.29	1.960	49.79
80	2.005	50.93	1.985	50.42
81	2.030	51.57	2.010	51.06
82	2.055	52.20	2.035	51.69
83	2.080	52.84	2.060	52.33
84	2.105	53.48	2.085	52.97
85	2.130	54.11	2.110	53.60
86	2.155	54.75	2.135	54.24
87	2.181	55.39	2.161	54.88
88	2.206	56.02	2.186	55.51
89	2.231	56.66	2.211	56.15

Continued on the next page

Table 12 (Cont.)

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
90	2.256	57.30	2.236	56.79
91	2.281	57.93	2.261	57.42
92	2.306	58.57	2.286	58.06
93	2.331	59.21	2.311	58.70
94	2.356	59.84	2.336	59.33
95	2.381	60.48	2.361	59.97
96	2.406	61.12	2.386	60.61
97	2.431	61.75	2.411	61.24
98	2.456	62.39	2.436	61.88
99	2.481	63.03	2.461	62.52
100	2.506	63.66	2.486	63.15
101	2.531	64.30	2.511	63.79
102	2.557	64.94	2.537	64.43
103	2.582	65.57	2.562	65.06
104	2.607	66.21	2.587	65.70
105	2.632	66.85	2.612	66.34
106	2.657	67.48	2.637	66.97
107	2.682	68.12	2.662	67.61
108	2.707	68.75	2.687	68.25
109	2.732	69.39	2.712	68.88
110	2.757	70.03	2.737	69.52
111	2.782	70.66	2.762	70.16
112	2.807	71.30	2.787	70.79
113	2.832	71.94	2.812	71.43
114	2.857	72.57	2.837	72.07
115	2.882	73.21	2.862	72.70
116	2.907	73.85	2.887	73.34
117	2.932	74.48	2.912	73.98
118	2.958	75.12	2.938	74.61
119	2.983	75.76	2.963	75.25
120	3.008	76.39	2.988	75.89
121	3.033	77.03	3.013	76.52
122	3.058	77.67	3.038	77.16
123	3.083	78.30	3.063	77.80
124	3.108	78.94	3.088	78.43
125	3.133	79.58	3.113	79.07
126	3.158	80.21	3.138	79.71
127	3.183	80.85	3.163	80.34
128	3.208	81.49	3.188	80.98
129	3.233	82.12	3.213	81.62
130	3.258	82.76	3.238	82.25
131	3.283	83.40	3.263	82.89
132	3.308	84.03	3.288	83.53
133	3.333	84.67	3.313	84.16
134	3.359	85.31	3.339	84.80
135	3.384	85.94	3.364	85.44
136	3.409	86.58	3.389	86.07
137	3.434	87.22	3.414	86.71
138	3.459	87.85	3.439	87.35
139	3.484	88.49	3.464	87.98
140	3.509	89.13	3.489	88.62
141	3.534	89.76	3.514	89.26
142	3.559	90.40	3.539	89.89
143	3.584	91.04	3.564	90.53
144	3.609	91.67	3.589	91.17
145	3.634	92.31	3.614	91.80
146	3.659	92.95	3.639	92.44
147	3.684	93.58	3.664	93.08
148	3.709	94.22	3.689	93.71
149	3.735	94.86	3.715	94.35
150	3.760	95.49	3.740	94.99
151	3.785	96.13	3.765	95.62
152	3.810	96.77	3.790	96.26
153	3.835	97.40	3.815	96.89
154	3.860	98.04	3.840	97.53
155	3.885	98.68	3.865	98.17
156	3.910	99.31	3.890	98.80
157	3.935	99.95	3.915	99.44
158	3.960	100.59	3.940	100.08
159	3.985	101.22	3.965	100.71
160	4.010	101.86	3.990	101.35

Table 13

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
10	.376	9.55	.346	8.79
11	.414	10.50	.384	9.74
12	.451	11.46	.421	10.70
13	.489	12.41	.459	11.65
14	.526	13.37	.496	12.61
15	.564	14.32	.534	13.56
16	.602	15.28	.572	14.52
17	.639	16.23	.609	15.47
18	.677	17.19	.647	16.43
19	.714	18.14	.684	17.38
20	.752	19.10	.722	18.34
21	.790	20.05	.760	19.29
22	.827	21.01	.797	20.25
23	.865	21.96	.835	21.20
24	.902	22.92	.872	22.16
25	.940	23.87	.910	23.11
26	.977	24.83	.947	24.07
27	1.015	25.78	.985	25.02
28	1.053	26.74	1.023	25.98
29	1.090	27.69	1.060	26.93
30	1.128	28.65	1.098	27.89
31	1.165	29.60	1.135	28.84
32	1.203	30.56	1.173	29.80
33	1.241	31.51	1.211	30.75
34	1.278	32.47	1.248	31.71
35	1.316	33.42	1.286	32.66
36	1.353	34.38	1.323	33.62
37	1.391	35.33	1.361	34.57
38	1.429	36.29	1.399	35.53
39	1.466	37.24	1.436	36.48
40	1.504	38.20	1.474	37.44
41	1.541	39.15	1.511	38.39
42	1.579	40.11	1.549	39.34
43	1.617	41.06	1.587	40.30
44	1.654	42.02	1.624	41.25
45	1.692	42.97	1.662	42.21
46	1.729	43.93	1.699	43.16
47	1.767	44.88	1.737	44.12
48	1.805	45.84	1.775	45.07
49	1.842	46.79	1.812	46.03
50	1.880	47.75	1.850	46.98
51	1.917	48.70	1.887	47.94
52	1.955	49.66	1.925	48.89
53	1.993	50.61	1.963	49.85
54	2.030	51.57	2.000	50.80
55	2.068	52.52	2.038	51.76
56	2.105	53.48	2.075	52.71
57	2.143	54.43	2.113	53.67
58	2.181	55.39	2.151	54.62
59	2.218	56.34	2.188	55.58
60	2.256	57.30	2.226	56.53
61	2.293	58.25	2.263	57.49
62	2.331	59.21	2.301	58.44
63	2.369	60.16	2.339	59.40
64	2.406	61.12	2.376	60.35
65	2.444	62.07	2.414	61.31
66	2.481	63.03	2.451	62.26
67	2.519	63.98	2.489	63.22
68	2.556	64.94	2.526	64.17
69	2.594	65.89	2.564	65.13
70	2.632	66.84	2.602	66.08
71	2.669	67.80	2.639	67.04
72	2.707	68.75	2.677	67.99
73	2.744	69.71	2.714	68.95
74	2.782	70.66	2.752	69.90
75	2.820	71.62	2.790	70.86
76	2.857	72.57	2.827	71.81
77	2.895	73.53	2.865	72.77
78	2.932	74.48	2.902	73.72
79	2.970	75.44	2.940	74.68
80	3.008	76.39	2.978	75.63
81	3.045	77.35	3.015	76.59
82	3.083	78.30	3.053	77.54
83	3.120	79.26	3.090	78.50
84	3.158	80.21	3.128	79.45
85	3.196	81.17	3.166	80.41
86	3.233	82.12	3.203	81.36
87	3.271	83.08	3.241	82.32
88	3.308	84.03	3.278	83.27
89	3.346	84.99	3.316	84.23
90	3.384	85.94	3.354	85.18
91	3.421	86.90	3.391	86.14
92	3.459	87.85	3.429	87.09
93	3.496	88.81	3.466	88.05
94	3.534	89.76	3.504	89.00
95	3.572	90.72	3.542	89.96
96	3.609	91.67	3.579	90.91
97	3.647	92.63	3.617	91.87
98	3.684	93.58	3.654	92.82
99	3.722	94.54	3.692	93.78
100	3.760	95.49	3.730	94.73
101	3.797	96.45	3.767	95.69
102	3.835	97.40	3.805	96.64
103	3.872	98.36	3.842	97.60
104	3.910	99.31	3.880	98.55
105	3.948	100.27	3.918	99.51
106	3.985	101.22	3.955	100.46
107	4.023	102.18	3.993	101.42
108	4.060	103.13	4.030	102.37
109	4.098	104.09	4.068	103.33

Continued on the next page

Table 13 (Cont.)

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
110	4.136	105.04	4.106	104.28
111	4.173	106.00	4.143	105.23
112	4.211	106.95	4.181	106.19
113	4.248	107.91	4.218	107.14
114	4.286	108.86	4.256	108.10
115	4.323	109.82	4.293	109.05
116	4.361	110.77	4.331	110.01
117	4.399	111.73	4.369	110.96
118	4.436	112.68	4.406	111.92
119	4.474	113.64	4.444	112.87
120	4.511	114.59	4.481	113.83
121	4.549	115.55	4.519	114.78
122	4.587	116.50	4.557	115.74
123	4.624	117.46	4.594	116.69
124	4.662	118.41	4.632	117.65
125	4.699	119.37	4.669	118.60
126	4.737	120.32	4.707	119.56
127	4.775	121.28	4.745	120.51
128	4.812	122.23	4.782	121.47
129	4.850	123.19	4.820	122.42
130	4.887	124.14	4.857	123.38
131	4.925	125.10	4.895	124.33
132	4.963	126.05	4.933	125.29
133	5.000	127.01	4.970	126.24
134	5.038	127.96	5.008	127.20
135	5.075	128.92	5.045	128.15
136	5.113	129.87	5.083	129.11
137	5.151	130.83	5.121	130.06
138	5.188	131.78	5.158	131.02
139	5.226	132.73	5.196	131.97
140	5.263	133.69	5.233	132.93
141	5.301	134.64	5.271	133.88
142	5.339	135.60	5.309	134.84
143	5.376	136.55	5.346	135.79
144	5.414	137.51	5.384	136.75
145	5.451	138.46	5.421	137.70
146	5.489	139.42	5.459	138.66
147	5.527	140.37	5.497	139.61
148	5.564	141.33	5.534	140.57
149	5.602	142.28	5.572	141.52
150	5.639	143.24	5.609	142.48
151	5.677	144.19	5.647	143.43
152	5.715	145.15	5.685	144.39
153	5.752	146.10	5.722	145.34
154	5.790	147.06	5.760	146.30
155	5.827	148.01	5.797	147.25
156	5.865	148.97	5.835	148.21
157	5.902	149.92	5.872	149.16
158	5.940	150.88	5.910	150.12
159	5.978	151.83	5.948	151.07

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
160	6.015	152.79	5.985	152.03
161	6.053	153.74	6.023	152.98
162	6.090	154.70	6.060	153.94
163	6.128	155.65	6.098	154.89
164	6.166	156.61	6.136	155.85
165	6.203	157.56	6.173	156.80
166	6.241	158.52	6.211	157.76
167	6.278	159.47	6.248	158.71
168	6.316	160.43	6.286	159.67
169	6.354	161.38	6.324	160.62
170	6.391	162.34	6.361	161.58
171	6.429	163.29	6.399	162.53
172	6.466	164.25	6.436	163.49
173	6.504	165.20	6.474	164.44
174	6.542	166.16	6.512	165.40
175	6.579	167.11	6.549	166.35
176	6.617	168.07	6.587	167.31
177	6.654	169.02	6.624	168.26
178	6.692	169.98	6.662	169.22
179	6.730	170.93	6.700	170.17
180	6.767	171.89	6.737	171.12
181	6.805	172.84	6.775	172.08
182	6.842	173.80	6.812	173.03
183	6.880	174.75	6.850	173.99
184	6.918	175.71	6.888	174.94
185	6.955	176.66	6.925	175.90
186	6.993	177.62	6.963	176.85
187	7.030	178.57	7.000	177.81
188	7.068	179.53	7.038	178.76
189	7.106	180.48	7.076	179.72
190	7.143	181.44	7.113	180.67
191	7.181	182.39	7.151	181.63
192	7.218	183.35	7.188	182.58
193	7.256	184.30	7.226	183.54
194	7.294	185.26	7.264	184.49
195	7.331	186.21	7.301	185.45
196	7.369	187.17	7.339	186.40
197	7.406	188.12	7.376	187.36
198	7.444	189.08	7.414	188.31
199	7.482	190.03	7.452	189.27
200	7.519	190.99	7.489	190.22
201	7.557	191.94	7.527	191.18
202	7.594	192.90	7.564	192.13
203	7.632	193.85	7.602	193.09
204	7.669	194.81	7.639	194.04
205	7.707	195.76	7.677	195.00
206	7.745	196.72	7.715	195.95
207	7.782	197.67	7.752	196.91
208	7.820	198.62	7.790	197.86
209	7.857	199.58	7.827	198.82

5 mm Pitch GT® Pulley Dimensions

Table 14

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
10	.627	15.92	.582	14.77
11	.689	17.51	.644	16.36
12	.752	19.10	.707	17.96
13	.815	20.69	.770	19.55
14	.877	22.28	.832	21.14
15	.940	23.87	.895	22.73
16	1.003	25.46	.958	24.32
17	1.065	27.06	1.020	25.91
18	1.128	28.65	1.083	27.50
19	1.191	30.24	1.146	29.10
20	1.253	31.83	1.208	30.69
21	1.316	33.42	1.271	32.28
22	1.379	35.01	1.334	33.87
23	1.441	36.61	1.396	35.46
24	1.504	38.20	1.459	37.05
25	1.566	39.79	1.521	38.65
26	1.629	41.38	1.584	40.24
27	1.692	42.97	1.647	41.83
28	1.754	44.56	1.709	43.42
29	1.817	46.15	1.772	45.01
30	1.880	47.75	1.835	46.60
31	1.942	49.34	1.897	48.19
32	2.005	50.93	1.960	49.79
33	2.068	52.52	2.023	51.38
34	2.130	54.11	2.085	52.97
35	2.193	55.70	2.148	54.56
36	2.256	57.30	2.211	56.15
37	2.318	58.89	2.273	57.74
38	2.381	60.48	2.336	59.34
39	2.444	62.07	2.399	60.93
40	2.506	63.66	2.461	62.52
41	2.569	65.25	2.524	64.11
42	2.632	66.84	2.587	65.70
43	2.694	68.44	2.649	67.29
44	2.757	70.03	2.712	68.89
45	2.820	71.62	2.775	70.48
46	2.882	73.21	2.837	72.07
47	2.945	74.80	2.900	73.66
48	3.008	76.39	2.963	75.25
49	3.070	77.99	3.025	76.84
50	3.133	79.58	3.088	78.43
51	3.196	81.17	3.151	80.03
52	3.258	82.76	3.213	81.62
53	3.321	84.35	3.276	83.21
54	3.384	85.94	3.339	84.80
55	3.446	87.54	3.401	86.39
56	3.509	89.13	3.464	87.98
57	3.572	90.72	3.527	89.58
58	3.634	92.31	3.589	91.17
59	3.697	93.90	3.652	92.76
60	3.760	95.49	3.715	94.35
61	3.822	97.08	3.777	95.94
62	3.885	98.68	3.840	97.53
63	3.948	100.27	3.903	99.12
64	4.010	101.86	3.965	100.72
65	4.073	103.45	4.028	102.31
66	4.136	105.04	4.091	103.90
67	4.198	106.63	4.153	105.49
68	4.261	108.23	4.216	107.08
69	4.323	109.82	4.278	108.67
70	4.386	111.41	4.341	110.27
71	4.449	113.00	4.404	111.86
72	4.511	114.59	4.466	113.45
73	4.574	116.18	4.529	115.04
74	4.637	117.77	4.592	116.63
75	4.699	119.37	4.654	118.22
76	4.762	120.96	4.717	119.81
77	4.825	122.55	4.780	121.41
78	4.887	124.14	4.842	123.00
79	4.950	125.73	4.905	124.59
80	5.013	127.32	4.968	126.18
81	5.075	128.92	5.030	127.77
82	5.138	130.51	5.093	129.36
83	5.201	132.10	5.156	130.96
84	5.263	133.69	5.218	132.55
85	5.326	135.28	5.281	134.14
86	5.389	136.87	5.344	135.73
87	5.451	138.46	5.406	137.32
88	5.514	140.06	5.469	138.91
89	5.577	141.65	5.532	140.50
90	5.639	143.24	5.594	142.10
91	5.702	144.83	5.657	143.69
92	5.765	146.42	5.720	145.28
93	5.827	148.01	5.782	146.87
94	5.890	149.61	5.845	148.46
95	5.953	151.20	5.908	150.05
96	6.015	152.79	5.970	151.65
97	6.078	154.38	6.033	153.24
98	6.141	155.97	6.096	154.83
99	6.203	157.56	6.158	156.42
100	6.266	159.15	6.221	158.01
101	6.329	160.75	6.284	159.60
102	6.391	162.34	6.346	161.19
103	6.454	163.93	6.409	162.79
104	6.517	165.52	6.472	164.38
105	6.579	167.11	6.534	165.97
106	6.642	168.70	6.597	167.56
107	6.705	170.30	6.660	169.15
108	6.767	171.89	6.722	170.74
109	6.830	173.48	6.785	172.34

Continued on the next page

Table 14 (Cont.)

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
110	6.893	175.07	6.848	173.93
111	6.955	176.66	6.910	175.52
112	7.018	178.25	6.973	177.11
113	7.080	179.84	7.035	178.70
114	7.143	181.44	7.098	180.29
115	7.206	183.03	7.161	181.88
116	7.268	184.62	7.223	183.48
117	7.331	186.21	7.286	185.07
118	7.394	187.80	7.349	186.66
119	7.456	189.39	7.411	188.25
120	7.519	190.99	7.474	189.84
121	7.582	192.58	7.537	191.43
122	7.644	194.17	7.599	193.03
123	7.707	195.76	7.662	194.62
124	7.770	197.35	7.725	196.21
125	7.832	198.94	7.787	197.80
126	7.895	200.53	7.850	199.39
127	7.958	202.13	7.913	200.98
128	8.020	203.72	7.975	202.57
129	8.083	205.31	8.038	204.17
130	8.146	206.90	8.101	205.76
131	8.208	208.49	8.163	207.35
132	8.271	210.08	8.226	208.94
133	8.334	211.68	8.289	210.53
134	8.396	213.27	8.351	212.12
135	8.459	214.86	8.414	213.72
136	8.522	216.45	8.477	215.31
137	8.584	218.04	8.539	216.90
138	8.647	219.63	8.602	218.49
139	8.710	221.22	8.665	220.08
140	8.772	222.82	8.727	221.67
141	8.835	224.41	8.790	223.26
142	8.898	226.00	8.853	224.86
143	8.960	227.59	8.915	226.45
144	9.023	229.18	8.978	228.04
145	9.086	230.77	9.041	229.63
146	9.148	232.37	9.103	231.22
147	9.211	233.96	9.166	232.81
148	9.274	235.55	9.229	234.41
149	9.336	237.14	9.291	236.00
150	9.399	238.73	9.354	237.59
151	9.462	240.32	9.417	239.18
152	9.524	241.91	9.479	240.77
153	9.587	243.51	9.542	242.36
154	9.650	245.10	9.605	243.96
155	9.712	246.69	9.667	245.55
156	9.775	248.28	9.730	247.14
157	9.837	249.87	9.792	248.73
158	9.900	251.46	9.855	250.32
159	9.963	253.06	9.918	251.91

No. of Grooves	Pitch Diameter		Outside Diameter	
	Inch	mm	Inch	mm
160	10.025	254.65	9.980	253.50
161	10.088	256.24	10.043	255.10
162	10.151	257.83	10.106	256.69
163	10.213	259.42	10.168	258.28
164	10.276	261.01	10.231	259.87
165	10.339	262.61	10.294	261.46
166	10.401	264.20	10.356	263.05
167	10.464	265.79	10.419	264.65
168	10.527	267.38	10.482	266.24
169	10.589	268.97	10.544	267.83
170	10.652	270.56	10.607	269.42
171	10.715	272.15	10.670	271.01
172	10.777	273.75	10.732	272.60
173	10.840	275.34	10.795	274.19
174	10.903	276.93	10.858	275.79
175	10.965	278.52	10.920	277.38
176	11.028	280.11	10.983	278.97
177	11.091	281.70	11.046	280.56
178	11.153	283.30	11.108	282.15
179	11.216	284.89	11.171	283.74
180	11.279	286.48	11.234	285.34
181	11.341	288.07	11.296	286.93
182	11.404	289.66	11.359	288.52
183	11.467	291.25	11.422	290.11
184	11.529	292.84	11.484	291.70
185	11.592	294.44	11.547	293.29
186	11.655	296.03	11.610	294.88
187	11.717	297.62	11.672	296.48
188	11.780	299.21	11.735	298.07
189	11.843	300.80	11.798	299.66
190	11.905	302.39	11.860	301.25
191	11.968	303.99	11.923	302.84
192	12.031	305.58	11.986	304.43
193	12.093	307.17	12.048	306.03
194	12.156	308.76	12.111	307.62
195	12.219	310.35	12.174	309.21
196	12.281	311.94	12.236	310.80
197	12.344	313.53	12.299	312.39
198	12.407	315.13	12.362	313.98
199	12.469	316.72	12.424	315.57
200	12.532	318.31	12.487	317.17
201	12.594	319.90	12.549	318.76
202	12.657	321.49	12.612	320.35
203	12.720	323.08	12.675	321.94
204	12.782	324.68	12.737	323.53
205	12.845	326.27	12.800	325.12
206	12.908	327.86	12.863	326.72
207	12.970	329.45	12.925	328.31
208	13.033	331.04	12.988	329.90
209	13.096	332.63	13.051	331.49

Table 15

Belt Type	Pitch		rpm Max.	Suggested Minimum*		
	Inch	mm		No. of Grooves	Pitch Diameter inch	Pitch Diameter mm
MXL	**0.080**	2.03	10000	14	.357	9.07
			7500	12	.306	7.77
			5000	11	.280	7.11
			3500	10	.255	6.48
XL	**0.200**	5.08	3500	12	.764	19.41
			1750	11	.700	17.78
			1160	10	.637	16.18
L	**0.375**	9.525	3500	16	1.910	48.51
			1750	14	1.671	42.44
			1160	12	1.432	36.37
H	**0.500**	12.7	3500	20	3.182	80.82
			1750	18	2.865	72.77
			1160	16	2.546	64.67
HTD	0.118	**3**	3500	20	.752	19.1
			1750	18	.677	17.2
			1160	17	.639	16.23
	0.197	**5**	3500	30	1.880	47.75
			1750	26	1.629	41.38
			1160	22	1.379	35.03
	0.315	**8**	3500	32	3.208	81.48
			1750	28	2.807	71.3
			1160	24	2.406	61.11
GT	0.079	**2**	14000	16	.401	10.19
			7500	14	.351	8.92
			5000	12	.301	7.65
	0.118	**3**	5000	20	.752	19.1
			2800	18	.677	17.2
			1600	16	.602	15.29
	0.197	**5**	2000	22	1.379	35.03
			1400	20	1.253	31.83
			1000	18	1.128	28.65
"T" Series	.0984	**2.5**	3600 1800 1200	14	.417	10.6
			< 1200	16	.480	12.2
	.19685	**5**	3600 1800 1200	14	.844	21.45
			< 1200	16	.969	24.6
	.3937	**10**	3600 1800 1200	16	1.931	49.05
			< 1200	18	2.183	55.45

* Smaller pulleys than shown under "Suggested Minimum" may be used if a corresponding reduction in belt life is satisfactory. Use of pulleys smaller than those shown will be at customers' own responsibility for performance and belt life.

SECTION 9 DESIGN AND INSTALLATION SUGGESTIONS

There are some general guidelines which are applicable to all timing belts, including miniature and double sided belts:

1. Drives should always be designed with ample reserve horsepower capacity. Use of overload service factors is important. Belts should be rated at only 1/15th of their respective ultimate strength.
2. For MXL pitch belts, the smallest recommended pulley will have 10 teeth. For other pitches, **Table 15** should be used.
3. The pulley diameter should never be smaller than the width of the belt.
4. Belts with Fibrex-glass fiber tension members should not be subjected to sharp bends or rough handling, since this could cause breakage of the fibers.
5. In order to deliver the rated horsepower, a belt must have six or more teeth in mesh with the grooves of the smaller pulley. The number of teeth in mesh may be obtained by formula given in **SECTION 24 TIMING BELT DRIVE SELECTION PROCEDURE**. The shear strength of a single tooth is only a fraction of the belt break strength.
6. Because of a slight side thrust of synchronous belts in motion, at least one pulley in the drive must be flanged. When the center distance between the shafts is 8 or more times the diameter of the smaller pulley, or when the drive is operating on vertical shafts, both pulleys should be flanged.
7. Belt surface speed should not exceed 5500 feet per minute (28 m/s) for larger pitch belts and 10000 feet per minute (50 m/s) for minipitch belts. For the HTD belts a speed of 6500 feet per minute (33 m/s) is permitted, whereas for GT belts the maximum permitted speed is 7500 feet per minute (38 m/s).
8. Belts are, in general, rated to yield a minimum of 3000 hours of useful life if all instructions are properly followed.
9. Belt drives are inherently efficient. It can be assumed that the efficiency of a synchronous belt drive is greater than 95%.
10. Belt drives are usually a source of noise. The frequency of the noise level increases proportionally with the belt speed. The higher the initial belt tension, the greater the noise level. The belt teeth entering the pulleys at high speed act as a compressor and this creates noise. Some noise is the result of a belt rubbing against the flange, which in turn may be the result of the shafts not being parallel. As shown in **Figure 9** (page T-9), the noise level is substantially reduced if the PowerGrip GT belt is being used.
11. If the drive is part of a sensitive acoustical or electronics sensing or recording device, it is recommended that the back surfaces of the belt be ground to assure absolutely uniform belt thickness.
12. For some applications, no backlash between the driving and the driven shaft is permitted. For these cases, special profile pulleys can be produced without any clearance between the belt tooth and pulley. This may shorten the belt life, but it eliminates backlash. **Figure 10** (page T-9) shows the superiority of PowerGrip GT profile as far as reduction of backlash is concerned.
13. Synchronous belts are often driven by stepping motors. These drives are subjected to continuous and large accelerations and decelerations. If the belt reinforcing fiber, i.e., tension member, as well as the belt material, have high tensile strength and no elongation, the belt will not be instrumental in absorbing the shock loads. This will result in sheared belt teeth. Therefore, take this into account when the size of the smallest pulley and the materials for the belt and tension member are selected.
14. The choice of the pulley material (metal vs. plastic) is a matter of price, desired precision, inertia, color, magnetic properties and, above all, personal preference based on experiences. Plastic pulleys with metal inserts or metal hubs represent a good compromise.

The following precautions should be taken when installing all timing belt drives:

1. Timing belt installation should be a snug fit, neither too tight nor too loose. The positive grip of the belt eliminates the need for high initial tension. Consequently, a belt, when installed with a snug fit (that is, not too taut) assures longer life, less bearing wear and quieter operation. Preloading (often the cause of premature failure) is not necessary.
   When torque is unusually high, a loose belt may "jump teeth" on starting. In such a case, the tension should be increased gradually, until satisfactory operation is attained. A good rule of thumb for installation tension is as shown in **Figure 20**, and the corresponding tensioning force is shown in **Table 16**, both shown in **SECTION 10 BELT TENSIONING**. For widths other than shown, increase force proportionally to the belt width. Instrumentation for measuring belt tension is available. Consult the product section of this catalog.
2. Be sure that shafts are parallel and pulleys are in alignment. On a long center drive, it is sometimes advisable to offset the driven pulley to compensate for the tendency of the belt to run against one flange.
3. On a long center drive, it is imperative that the belt sag is not large enough to permit teeth on the slack side to engage the teeth on the tight side.
4. It is important that the frame supporting the pulleys be rigid at all times. A nonrigid frame causes variation in center distance and resulting belt slackness. This, in turn, can lead to jumping of teeth – especially under starting load with shaft misalignment.
5. Although belt tension requires little attention after initial installation, provision should be made for some center distance adjustment for ease in installing and removing belts. Do not force belt over flange of pulley.
6. Idlers, either of the inside or outside type, are not recommended and should not be used except for power takeoff or functional use. When an idler is necessary, it should be on the slack side of the belt. Inside idlers must be grooved, unless their diameters are greater than an equivalent 40-groove pulley. Flat idlers must not be crowned (use edge flanges). Idler diameters must exceed the smallest diameter drive pulley. Idler arc of contact should be held to a minimum.

In addition to the general guidelines enumerated previously, specific operating characteristics of the drive must be taken into account. These may include the following:

9.1 Low Speed Operation

Synchronous drives are especially well suited for low speed, high torque applications. Their positive driving nature prevents potential slippage associated with V-belt drives , and even allows significantly greater torque carrying capability. Small pitch synchronous drives operating at speeds of 50 ft/min (0.25 m/s) or less are considered to be low speed. Care should be taken in the drive selection process as stall and peak torques can sometimes be very high. While intermittent peak torques can often be carried by synchronous drives without special considerations, high cyclic peak torque loading should be carefully reviewed.

Proper belt installation tension and rigid drive bracketry and framework is essential in preventing belt tooth jumping under peak torque loads. It is also helpful to design with more than the normal minimum of 6 belt teeth in mesh to ensure adequate belt tooth shear strength.

Newer generation curvilinear systems like PowerGrip GT and PowerGrip HTD should be used in low speed, high torque applications, as trapezoidal timing belts are more prone to tooth jumping, and have significantly less load carrying capacity.

9.2 High Speed Operation

Synchronous belt drives are often used in high speed applications even though V-belt drives are typically better suited. They are often used because of their positive driving characteristic (no creep or slip), and because they require minimal maintenance (don't stretch significantly). A significant drawback of high speed synchronous drives is drive noise. High speed synchronous drives will nearly always produce more noise than V-belt drives. Small pitch synchronous drives operating at speeds in excess of 1300 ft/min (6.6 m/s) are considered to be high speed.

Special consideration should be given to high speed drive designs, as a number of factors can significantly influence belt performance. Cord fatigue and belt tooth wear are the two most significant factors that must be controlled to ensure success. Moderate pulley diameters should be used to reduce the rate of cord flex fatigue. Designing with a smaller pitch belt will often provide better cord flex fatigue characteristics than a larger pitch belt. PowerGrip GT is especially well suited for high speed drives because of its excellent belt tooth entry/exit characteristics. Smooth interaction between the belt tooth and pulley groove minimizes wear and noise. Belt installation tension is especially critical with high speed drives. Low belt tension allows the belt to ride out of the driven pulley, resulting in rapid belt tooth and pulley groove wear.

9.3 Smooth Running

Some ultrasensitive applications require the belt drive to operate with as little vibration as possible, as vibration sometimes has an effect on the system operation or finished manufactured product. In these cases, the characteristics and properties of all appropriate belt drive products should be reviewed. The final drive system selection should be based upon the most critical design requirements, and may require some compromise.

Vibration is not generally considered to be a problem with synchronous belt drives. Low levels of vibration typically result from the process of tooth meshing and/or as a result of their high tensile modulus properties. Vibration resulting from tooth meshing is a normal characteristic of synchronous belt drives, and cannot be completely eliminated. It can be minimized by avoiding small pulley diameters, and instead choosing moderate sizes. The dimensional accuracy of the pulleys also influences tooth meshing quality. Additionally, the installation tension has an impact on meshing quality. PowerGrip GT drives mesh very cleanly, resulting in the smoothest possible operation. Vibration resulting from high tensile modulus can be a function of pulley quality. Radial run out causes belt tension variation with each pulley revolution. V-belt pulleys are also manufactured with some radial run out, but V-belts have a lower tensile modulus resulting in less belt tension variation. The high tensile modulus found in synchronous belts is necessary to maintain proper pitch under load.

9.4 Drive Noise

Drive noise evaluation in any belt drive system should be approached with care. There are many potential sources of noise in a system, including vibration from related components, bearings, and resonance and amplification through framework and panels.

Synchronous belt drives typically produce more noise than V-belt drives. Noise results from the process of belt tooth meshing and physical contact with the pulleys. The sound pressure level generally increases as operating speed and belt width increase, and as pulley diameter decreases. Drives designed on moderate pulley sizes without excessive capacity (over designed) are generally the quietest. PowerGrip GT drives have been found to be significantly quieter than other systems due to their improved meshing characteristic (see **Figure 9**, page T-9). Polyurethane belts generally produce more noise than neoprene belts. Proper belt installation tension is also very important in minimizing drive noise. The belt should be tensioned at a level that allows it to run with as little meshing interference as possible.

Drive alignment also has a significant effect on drive noise. Special attention should be given to minimizing angular misalignment (shaft parallelism). This assures that belt teeth are loaded uniformly and minimizes side tracking forces against the flanges. Parallel misalignment (pulley offset) is not as critical of a concern as long as the belt is not trapped or pinched between opposite flanges (see the special section dealing with drive alignment). Pulley materials and dimensional accuracy also influence drive noise. Some users have found that steel pulleys are the quietest, followed closely by aluminum. Polycarbonates have been found to be noisier than metallic materials. Machined pulleys are generally quieter than molded pulleys. The reasons for this revolve around material density and resonance characteristics as well as dimensional accuracy.

9.5 Static Conductivity

Small synchronous rubber or urethane belts can generate an electrical charge while operating on a drive. Factors such as humidity and operating speed influence the potential of the charge. If determined to be a problem, rubber belts can be produced in a conductive construction to dissipate the charge into the pulleys, and to ground. This prevents the accumulation of electrical charges that might be detrimental to material handling processes or sensitive electronics. It also greatly reduces the potential for arcing or sparking in flammable environments. Urethane belts cannot be produced in a conductive construction.

RMA has outlined standards for conductive belts in their bulletin IP-3-3. Unless otherwise specified, a static conductive construction for rubber belts is available on a made-to-order basis. Unless otherwise specified, conductive belts will be built to yield a resistance of 300,000 ohms or less, when new.

Nonconductive belt constructions are also available for rubber belts. These belts are generally built specifically to the customers conductivity requirements. They are generally used in applications where one shaft must be electrically isolated from the other.

It is important to note that a static conductive belt cannot dissipate an electrical charge through plastic pulleys. At least one metallic pulley in a drive is required for the charge to be dissipated to ground. A grounding brush or similar device may also be used to dissipate electrical charges.

Urethane timing belts are not static conductive and cannot be built in a special conductive construction. Special conductive rubber belts should be used when the presence of an electrical charge is a concern.

9.6 Operating Environments

Synchronous drives are suitable for use in a wide variety of environments. Special considerations may be necessary, however, depending on the application.

Dust: Dusty environments do not generally present serious problems to synchronous drives as long as the particles are fine and dry. Particulate matter will, however, act as an abrasive resulting in a higher rate of belt and pulley wear. Damp or sticky particulate matter deposited and packed into pulley grooves can cause belt tension to increase significantly. This increased tension can impact shafting, bearings, and framework. Electrical charges within a drive system can sometimes attract particulate matter.

Debris: Debris should be prevented from falling into any synchronous belt drive. Debris caught in the drive is generally either forced through the belt or results in stalling of the system. In either case, serious damage occurs to the belt and related drive hardware.

Water: Light and occasional contact with water (occasional wash downs) should not seriously affect synchronous belts. Prolonged contact (constant spray or submersion) results in significantly reduced tensile strength in fiberglass belts, and potential length variation in aramid belts. Prolonged contact with water also causes rubber compounds to swell, although less than with oil contact. Internal belt adhesion systems are also gradually broken down with the presence of water. Additives to water, such as lubricants, chlorine, anticorrosives, etc. can have a more detrimental effect on the belts than pure water. Urethane timing belts also suffer from water contamination. Polyester tensile cord shrinks significantly and experiences loss of tensile strength in the presence of water. Aramid tensile cord maintains its strength fairly well, but experiences length variation. Urethane swells more than neoprene in the presence of water. This swelling can increase belt tension significantly, causing belt and related hardware problems.

Oil: Light contact with oils on an occasional basis will not, generally damage synchronous belts. Prolonged contact with oil or lubricants, either directly or airborne, results in significantly reduced belt service life. Lubricants cause the rubber compound to swell, breakdown internal adhesion systems, and reduce belt tensile strength. While alternate rubber compounds may provide some marginal improvement in durability, it is best to prevent oil from contacting synchronous belts.

Ozone: The presence of ozone can be detrimental to the compounds used in rubber synchronous belts. Ozone degrades belt materials in much the same way as excessive environmental temperatures. Although the rubber materials used in synchronous belts are compounded to resist the effects of ozone, eventually chemical breakdown occurs and they become hard and brittle and begin cracking. The amount of degradation depends upon the ozone concentration and duration of exposure. For good performance of rubber belts, the following concentration levels should not be exceeded: (parts per hundred million)

Standard Construction:	100 pphm
Non Marking Construction:	20 pphm
Conductive Construction:	75 pphm
Low Temperatures Construction:	20 pphm

Radiation: Exposure to gamma radiation can be detrimental to the compounds used in rubber and urethane synchronous belts. Radiation degrades belt materials much the same way excessive environmental temperatures do. The amount of degradation depends upon the intensity of radiation and the exposure time. For good belt performance, the following exposure levels should not be exceeded:

Standard Construction:	10^8 rads
Non Marking Construction:	10^4 rads
Conductive Construction:	10^6 rads
Low Temperatures Construction:	10^4 rads

Dust Generation: Rubber synchronous belts are known to generate small quantities of fine dust, as a natural result of their operation. The quantity of dust is typically higher for new belts, as they run in. The period of time for run in to occur depends upon the belt and pulley size, loading and speed. Factors such as pulley surface finish, operating speeds, installation tension, and alignment influence the quantity of dust generated.

Clean Room: Rubber synchronous belts may not be suitable for use in clean room environments, where all potential contamination must be minimized or eliminated. Urethane timing belts typically generate significantly less debris than rubber timing belts. However, they are recommended only for light operating loads. Also, they cannot be produced in a static conductive construction to allow electrical charges to dissipate.

Static Sensitive: Applications are sometimes sensitive to the accumulation of static electrical charges. Electrical charges can affect material handling processes (like paper and plastic film transport), and sensitive electronic equipment. Applications like these require a static conductive belt, so that the static charges generated by the belt can be dissipated into the pulleys, and to ground. Standard rubber synchronous belts do not meet this requirement, but can be manufactured in a static conductive construction on a made-to-order basis. Normal belt wear resulting from long term operation or environmental contamination can influence belt conductivity properties.

In sensitive applications, rubber synchronous belts are preferred over urethane belts since urethane belting cannot be produced in a conductive construction.

9.7 Belt Tracking

Lateral tracking characteristics of synchronous belts is a common area of inquiry. While it is normal for a belt to favor one side of the pulleys while running, it is abnormal for a belt to exert significant force against a flange resulting in belt edge wear and potential flange failure. Belt tracking is influenced by several factors. In order of significance, discussion about these factors is as follows:

Tensile Cord Twist: Tensile cords are formed into a single twist configuration during their manufacture. Synchronous belts made with only single twist tensile cords track laterally with a significant force. To neutralize this tracking force, tensile cords are produced in right and left hand twist (or "S" and "Z" twist) configurations. Belts made with "S" twist tensile cords track in the opposite direction to those built with "Z" twist cord. Belts made with alternating "S" and "Z" twist tensile cords track with minimal lateral force because the tracking characteristics of the two cords offset each other. The content of "S" and "Z" twist tensile cords varies slightly with every belt that is produced. As a result, every belt has an unprecedented tendency to track in either one direction or the other. When an application requires a belt to track in one specific direction only, a single twist construction is used. See **Figures 16** & **17**, previously shown, on pages T-12 and T-13.

Angular Misalignment: Angular misalignment, or shaft nonparallelism, cause synchronous belts to track laterally. The angle of misalignment influences the magnitude and direction of the tracking force. Synchronous belts tend to track "downhill" to a state of lower tension or shorter center distance.

Belt Width: The potential magnitude of belt tracking force is directly related to belt width. Wide belts tend to track with more force than narrow belts.

Pulley Diameter: Belt operating on small pulley diameters can tend to generate higher tracking forces than on large diameters. This is particularly true as the belt width approaches the pulley diameter. Drives with pulley diameters less than the belt width are not generally recommended because belt tracking forces can become excessive.

Belt Length: Because of the way tensile cords are applied on to the belt molds, short belts can tend to exhibit higher tracking forces than long belts. The helix angle of the tensile cord decreases with increasing belt length.

Gravity: In drive applications with vertical shafts, gravity pulls the belt downward. The magnitude of this force is minimal with small pitch synchronous belts. Sag in long belt spans should be avoided by applying adequate belt installation tension.

Torque Loads: Sometimes, while in operation, a synchronous belt will move laterally from side to side on the pulleys rather than operating in a consistent position. While not generally considered to be a significant concern, one explanation for this is varying torque loads within the drive. Synchronous belts sometimes track differently with changing loads. There are many potential reasons for this; the primary cause is related to tensile cord distortion while under pressure against the pulleys. Variation in belt tensile loads can also cause changes in framework deflection, and angular shaft alignment, resulting in belt movement.

Belt Installation Tension: Belt tracking is sometimes influenced by the level of belt installation tension. The reasons for this are similar to the effect that varying torque loads have on belt tracking.

When problems with belt tracking are experienced, each of these potential contributing factors should be investigated in the order that they are listed. In most cases, the primary problem will probably be identified before moving completely through the list.

9.8 Pulley Flanging

Pulley guide flanges are necessary to keep synchronous belts operating on their pulleys. As discussed previously in **Section 9.7** on belt tracking, it is normal for synchronous belts to favor one side of the pulleys when running.

Proper flange design is important in preventing belt edge wear, minimizing noise and preventing the belt from climbing out of the pulley. Dimensional recommendations for custom-made or molded flanges are included in tables dealing with these issues.

Proper flange placement is important so that the belt is adequately restrained within its operating system. Because design and layout of small synchronous drives is so diverse, the wide variety of flanging situations potentially encountered cannot easily be covered in a simple set of rules without finding exceptions. Despite this, the following broad flanging guidelines should help the designer in most cases:

Two Pulley Drives: On simple two pulley drives, either one pulley should be flanged on both sides, or each pulley should be flanged on opposite sides.

Multi Pulley Drives: On multiple pulley (or serpentine) drives, either every other pulley should be flanged on both sides, or every pulley should be flanged on alternating sides around the system.

Vertical Shaft Drives: On vertical shaft drives, at least one pulley should be flanged on both sides, and the remaining pulleys should be flanged on at least the bottom side.

Long Span Lengths: Flanging recommendations for small synchronous drives with long belt span lengths cannot easily be defined due to the many factors that can affect belt tracking characteristics. Belts on drives with long spans (generally 12 times the diameter of the smaller pulley or more) often require more lateral restraint than with short spans. Because of this, it is generally a good idea to flange the pulleys on both sides.

Large Pulleys: Flanging large pulleys can be costly. Designers often wish to leave large pulleys unflanged to reduce cost and space. Belts generally tend to require less lateral restraint on large pulleys than small and can often perform reliably without flanges. When deciding whether or not to flange, the previous guidelines should be considered. The groove face width of unflanged pulleys should also be greater than with flanged pulleys. See **Table 34**, on page T-65 for recommendations.

Idlers: Flanging of idlers is generally not necessary. Idlers designed to carry lateral side loads from belt tracking forces can be flanged if needed to provide lateral belt restraint. Idlers used for this purpose can be used on the inside or backside of the belts. The previous guidelines should also be considered.

9.9 Registration

The three primary factors contributing to belt drive registration (or positioning) errors are belt elongation, backlash, and tooth deflection. When evaluating the potential registration capabilities of a synchronous belt drive, the system must first be determined to be either static or dynamic in terms of its registration function and requirements.

Static Registration: A static registration system moves from its initial static position to a secondary static position. During the process, the designer is concerned only with how accurately and consistently the drive arrives at its secondary position. He/she is not concerned with any potential registration errors that occur during transport. Therefore, the primary factor contributing to registration error in a static registration system is backlash. The effects of belt elongation and tooth deflection do not have any influence on the registration accuracy of this type of system.

Dynamic Registration: A dynamic registration system is required to perform a registering function while in motion with torque loads varying as the system operates. In this case, the designer is concerned with the rotational position of the drive pulleys with respect to each other at every point in time. Therefore, belt elongation, backlash and tooth deflection will all contribute to registrational inaccuracies.

Further discussion about each of the factors contributing to registration error is as follows:

Belt Elongation: Belt elongation, or stretch, occurs naturally when a belt is placed under tension. The total tension exerted within a belt results from installation, as well as working loads. The amount of belt elongation is a function of the belt tensile modulus, which is influenced by the type of tensile cord and the belt construction. The standard tensile cord used in rubber synchronous belts is fiberglass. Fiberglass has a high tensile modulus, is dimensionally stable, and has excellent flex-fatigue characteristics. If a higher tensile modulus is needed, aramid tensile cords can be considered, although they are generally used to provide resistance to harsh shock and impulse loads. Aramid tensile cords used in small synchronous belts generally have only a marginally higher tensile modulus in comparison to fiberglass. When needed, belt tensile modulus data is available from our Application Engineering Department.

Backlash: Backlash in a synchronous belt drive results from clearance between the belt teeth and the pulley grooves. This clearance is needed to allow the belt teeth to enter and exit the grooves smoothly with a minimum of interference. The amount of clearance necessary depends upon the belt tooth profile. Trapezoidal Timing Belt Drives are known for having relatively little backlash. PowerGrip HTD Drives have improved torque carrying capability and resist ratcheting, but have a significant amount of backlash. PowerGrip GT Drives have even further improved torque carrying capability, and have as little or less backlash than trapezoidal timing belt drives. In special cases, alterations can be made to drive systems to further decrease backlash. These alterations typically result in increased belt wear, increased drive noise and shorter drive life. Contact our Application Engineering Department for additional information.

Tooth Deflection: Tooth deformation in a synchronous belt drive occurs as a torque load is applied to the system, and individual belt teeth are loaded. The amount of belt tooth deformation depends upon the amount of torque loading, pulley size, installation tension and belt type. Of the three primary contributors to registration error, tooth deflection is the most difficult to quantify. Experimentation with a prototype drive system is the best means of obtaining realistic estimations of belt tooth deflection.

Additional guidelines that may be useful in designing registration critical drive systems are as follows:

- Select PowerGrip GT or trapezoidal timing belts.

- Design with large pulleys with more teeth in mesh.
- Keep belts tight, and control tension closely.
- Design frame/shafting to be rigid under load.
- Use high quality machined pulleys to minimize radial runout and lateral wobble.

SECTION 10 BELT TENSIONING

10.1 What Is Proper Installation Tension

One of the benefits of small synchronous belt drives is lower belt pre-tensioning in comparison to comparable V-belt drives, but proper installation tension is still important in achieving the best possible drive performance. In general terms, belt pre-tensioning is needed for proper belt/pulley meshing to prevent belt ratcheting under peak loading, to compensate for initial belt tension decay, and to prestress the drive framework. The amount of installation tension that is actually needed is influenced by the type of application as well as the system design. Some general examples of this are as follows:

Motion Transfer Drives: Motion transfer drives, by definition, are required to carry extremely light torque loads. In these applications, belt installation tension is needed only to cause the belt to conform to and mesh properly with the pulleys. The amount of tension necessary for this is referred to as the minimum tension (T_{st}). Minimum tensions on a per span basis are included in **Table 16**, on page T-48. Some motion transfer drives carry very little torque, but have right registration requirements. These systems may require additional static (or installation) tension in order to minimize registration error.

Normal Power Transmission Drives: Normal power transmission drives should be designed in accordance with published torque ratings and a reasonable service factor (between 1.5 and 2.0). In these applications, belt installation tension is needed to allow the belt to maintain proper fit with the pulleys while under load, and to prevent belt ratcheting under peak loads. For these drives, proper installation tension can be determined using two different approaches. If torque loads are known and well defined, and an accurate tension value is desired, **Equation** (**10-1**) or **Equation** (**10-2**) should be used. If the torque loads are not as well defined, and a quick value is desired for use as a starting point, values from **Table 17** can be used. All static tension values are on a per span basis.

$$T_{st} = \frac{0.812\, DQ}{d} + mS^2 \quad \text{(lb)} \qquad \textbf{(10-1)}$$

(For drives with a Service Factor of 1.3 or greater)

$$T_{st} = \frac{1.05\, DQ}{d} + mS^2 \quad \text{(lb)} \qquad \textbf{(10-2)}$$

(For drives with a Service Factor less than 1.3)

where:
T_{st} = Static tension per span (lbs)
DQ = Driver design torque (lb·in)
d = Driver pitch diameter (in)
S = Belt speed/1000 (ft/min)
where Belt speed = (Driver pitch diameter x Driver rpm)/3.82
m = Mass factor from **Table 16**

Table 16 Belt Tensioning Force

Belt	Belt Width	*m*	*Y*	Minimum T_{st} (lbs) Per Span
2 mm GT	4 mm	0.026	1.37	1.3
	6 mm	0.039	2.05	2.0
	9 mm	0.058	3.08	3.0
	12 mm	0.077	4.10	4.0
3 mm GT	6 mm	0.077	3.22	2.2
	9 mm	0.120	4.83	3.3
	12 mm	0.150	6.45	4.4
	15 mm	0.190	8.06	5.5
5 mm GT	9 mm	0.170	14.9	8.4
	15 mm	0.280	24.9	14.1
	20 mm	0.380	33.2	18.7
	25 mm	0.470	41.5	23.4
3 mm HTD	6 mm	0.068	3.81	2.5
	9 mm	0.102	5.71	4.3
	15 mm	0.170	9.52	7.8
5 mm HTD	9 mm	0.163	14.9	6.3
	15 mm	0.272	24.9	12.0
	25 mm	0.453	41.5	21.3
MXL	1/8"	0.003	1.40	1.0
	3/16"	0.004	2.11	1.7
	1/4"	0.005	2.81	2.3
XL	1/4"	0.010	3.30	3.2
	3/8"	0.015	4.94	5.1

NOTE: *Y* = constant used in **Equations** (**10-4**) and (**10-5**).

Registration Drives: Registration drives are required to register, or position accurately. Higher belt installation tensions help in increasing belt tensile modulus as well as in increasing meshing interference, both reducing backlash. Tension values for these applications should be determined experimentally to confirm that desired performance characteristics have been achieved. As a beginning point, use values from **Table 17** multiplied by 1.5 to 2.0.

Table 17 Static Belt Tension, T_{st} (lbs) Per Span – General Values

Belt	4 mm	6 mm	9 mm	12 mm	15 mm	20 mm	25 mm
2 mm GT	2	3	4	5	—	—	—
3 mm GT	—	8	11	15	19	25	—
5 mm GT	—	—	18	22	27	35	43
3 mm HTD	—	5	9	12	16	22	—
5 mm HTD	—	—	13	18	24	33	43

Belt	1/8"	3/16"	1/4"	5/16"	3/8"	7/16"	1/2"
MXL	2	3	3	4	5	—	—
XL	2	3	4	5	6	8	9

Most synchronous belt applications often exhibit their own individual operating characteristics. The static installation tensions recommended in this section should serve as a general guideline in determining the level of tension required. The drive system should be thoroughly tested to confirm that it performs as intended.

10.2 Making Measurements

Belt installation tension is generally, measured in the following ways:

Force/Deflection: Belt span tension can be measured by deflecting a belt span 1/64" per inch (0.4 mm per 25 mm) of span length at midspan, with a known force (see **Figure 20**). This method is generally convenient, but not always very accurate, due to difficulty in measuring small deflections and forces common in small synchronous drives. The force/deflection method is most effective on larger drives with long span lengths. The static (or installation) tension (T_{st}) can either be calculated from **Equation** (**10-1**) or **Equation** (**10-2**), or selected from **Table 16** or **Table 17**. The deflection forces can be calculated from **Equation** (**10-4**) and **Equation** (**10-5**). The span length can either be calculated from **Equation** (**10-3**), or measured. If the calculated static tension is less than the minimum T_{st} values in **Table 16**, use the minimum values.

$$t = \sqrt{CD^2 - \left(\frac{PD - pd}{2}\right)^2} \qquad (\mathbf{10\text{-}3})$$

where: t = Span length (in)
CD = Drive center distance (in)
PD = Large pitch diameter (in)
pd = Small pitch diameter (in)

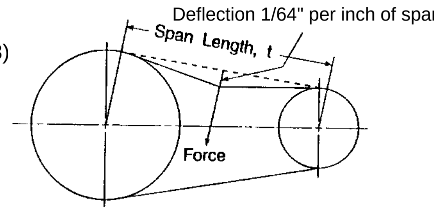


Fig. 20 Force/Deflection Method

$$\text{Deflection force, Min.} = \frac{T_{st} + \left(\frac{t}{L}\right) Y}{16} \quad \text{(lbs)} \qquad (\mathbf{10\text{-}4})$$

$$\text{Deflection force, Max.} = \frac{1.1\ T_{st} + \left(\frac{t}{L}\right) Y}{16} \quad \text{(lbs)} \qquad (\mathbf{10\text{-}5})$$

where: T_{st} = Static tension (lbs)
t = Span length (in)
L = Belt pitch length (in)
Y = Constant, from **Table 16**

Shaft Separation: Belt installation tension can be applied directly by exerting a force against either the driver or driven shaft in a simple 2-point drive system (see **Figure 21**). The resulting belt tension will be as accurate as the force applied to driver or driven shaft. This method is considerably easier to perform than the force/deflection method and, in some cases, more accurate.

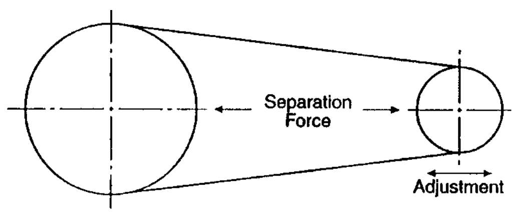


Fig. 21 Shaft Separation Method

In order to calculate the required shaft separation force, the proper static tension (on a per span basis) should first be determined as previously discussed. This tension value will be present in both belt spans as tension is applied. The angle of the spans with respect to the movable shaft should then be determined. The belt spans should be considered to be vectors (force with direction), and be summed into a single tension vector force (see **Figure 22**). Refer to **SECTION 14 BELT PULL AND BEARING LOADS** for further instructions on summing vectors.

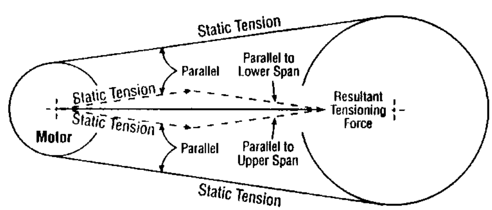


Fig. 22 Single Tension Vector Force

Idler Force: Belt installation tension can also be applied by exerting a force against an idler pulley within the system that is used to take up belt slack (see **Figure 23**). This force can be applied manually, or with a spring. Either way, the idler should be locked down after the appropriate tension has been applied.

Calculating the required force will involve a vector analysis as described above in the shaft separation section.

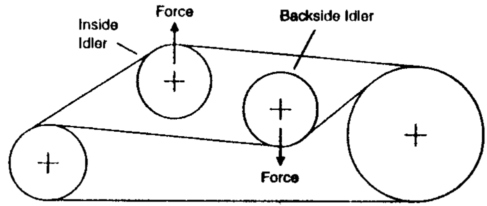


Fig. 23 Idler Forces

Sonic Tension Meter: The Sonic Tension Meter (**Figure 24**) is an electronic device that measures the natural frequency of a free stationary belt span and instantly computes the static belt tension based upon the belt span length, belt width, and belt type. This provides accurate and repeatable tension measurements while using a nonintrusive procedure (the measurement process itself doesn't change the belt span tension). A measurement is made simply by plucking the belt while holding the sensor close to the vibrating belt span.

Fig. 24 Sonic Tension Meter

The unit is about the size of a portable phone (8-1/8" long x 3-3/4" wide x 1-3/8" thick or 206mm long x 95mm wide x 35mm thick) so it can be easily handled. The sensor is about 1/2" (13mm) in diameter for use in cramped spaces, and the unit is either battery operated for portability or AC operated for production use. The unit measures virtually all types of light power and precision belts. A gain adjustment allows measurements to be made in environments with high noise levels. Data can also be collected through an IBM Compatible RS-232 serial port, if desired. For additional details, see the product section of this handbook.

SECTION 11 DRIVE ALIGNMENT

11.1 Angular And Parallel

Drive misalignment is one of the most common sources of drive performance problems. Misaligned drives can exhibit symptoms such as high belt tracking forces, uneven belt tooth wear, high noise levels, and tensile cord failure. The two primary types of drive misalignment are angular and parallel. Discussion about each of these types are as follows:

Angular: Angular misalignment results when the drive shafts are not parallel (see **Figure 25**). As a result, the belt tensile cords are not loaded evenly, resulting in uneven tooth/land pressure and wear. The edge cords on the high tension side are often

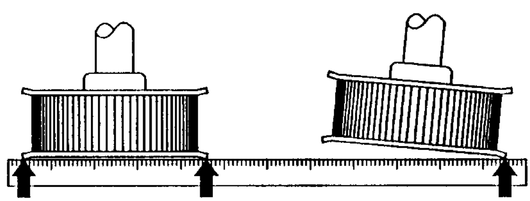


Fig. 25 Angular Misalignment

overloaded which may cause an edge cord failure that propagates across the entire belt width. Angular misalignment often results in high belt-tracking forces as well which cause accelerated belt edge wear, sometimes leading to flange failure or belts tracking off of the pulleys.

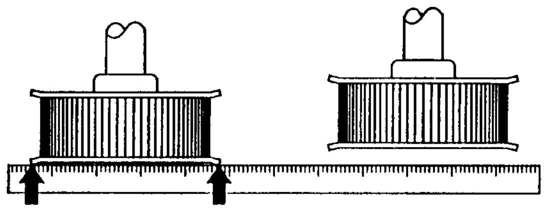


Fig. 26 Parallel Misalignment

Parallel: Parallel misalignment results from pulleys being mounted out of line from each other (see **Figure 26**). Parallel misalignment is generally more of a concern with V-type belts than with synchronous belts because V-type belts run in grooves and are unable to free float on the pulleys. Synchronous belts will generally free float on the pulleys and essentially self-align themselves as they run. This self-aligning can occur as long as the pulleys have sufficient groove face width beyond the width of the belts. If not, the belts can become trapped between opposite pulley flanges causing serious performance problems. Parallel misalignment is not generally a significant concern with synchronous drives as long as the belts do not become trapped or pinched between opposite flanges. For recommendations on groove face width, see **Table 34**, on page T-65.

Allowable Misalignment: In order to maximize performance and reliability, synchronous drives should be aligned closely. This is not, however, always a simple task in a production environment. The maximum allowable misalignment, angular and parallel combined, is 1/4°.

11.2 Practical Tips

Angular misalignment is not always easy to measure or quantify. It is sometimes helpful to use the observed tracking characteristics of a belt, to make a judgment as to the system's relative alignment. Neutral tracking "S" and "Z" synchronous belts generally tend to track "down hill" or to a state of lower tension or shorter center distance when angularly misaligned. This may not always hold true since neutral tracking belts naturally tend to ride lightly against either one flange or the other due to numerous factors discussed in the section on belt tracking. This tendency will generally hold true with belts that track hard against a flange. In those cases, the shafts will require adjustment to correct the problem.

Parallel misalignment is not often found to be a problem in synchronous belt drives. If clearance is always observable between the belt and all flanges on one side, then parallel misalignment should not be a concern.

SECTION 12 INSTALLATION AND TAKE-UP

12.1 Installation Allowance

When designing a drive system for a manufactured product, allowance for belt installation must be built into the system. While specific installation allowances could be published, as they are for larger industrial belt drives, small synchronous drive applications are generally quite diverse, making it nearly impossible to arrive at values that apply in all cases. When space is at a premium, the necessary installation allowance should be determined experimentally using actual production parts for the best possible results.

12.2 Belt Installation

During the belt installation process, it is very important that the belt be fully seated in the pulley grooves before applying final tension. Serpentine drives with multiple pulleys and drives with large pulleys are particularly vulnerable to belt tensioning problems resulting from the belt teeth being only partially engaged in the pulleys during installation. In order to prevent these problems, the belt installation tension should be evenly distributed to all belt spans by rotating the system by hand. After confirming that belt teeth are properly engaged in the pulley grooves, belt tension should be rechecked and verified. Failure to do this may result in an under-tensioned condition with the potential for belt ratcheting.

12.3 Belt Take-up

Synchronous belt drives generally require little if any retensioning when used in accordance with proper design procedures. A small amount of belt tension decay can be expected within the first several hours of operation. After this time, the belt tension should remain relatively stable.

12.4 Fixed Center Drives

Designers sometimes attempt to design synchronous belt drive systems without any means of belt adjustment or take-up. This type of system is called a Fixed Center Drive. While this approach is often viewed as being economical, and is simple for assemblers, it often results in troublesome reliability and performance problems in the long run.

The primary pitfall in a fixed center design approach is failure to consider the effects of system tolerance accumulation. Belts and pulleys are manufactured with industry accepted production tolerances. There are limits to the accuracy that the center distance can be maintained on a production basis as well. The potential effects of this tolerance accumulation is as follows:

Low Tension:
Long Belt with *Small Pulleys* on a *Short Center Distance*

High Tension:
Short Belt with *Large Pulleys* on a *Long Center Distance*

Belt tension in these two cases can vary by a factor of 3 or more with a standard fiberglass tensile cord. This potential variation is great enough to overload bearings and shafting, as well as the belts themselves. The probability of these extremes occurring is a matter of statistics, but however remote the chances may seem, they will occur in a production setting. In power transmission drives, the appearance of either extreme is very likely to impact drive system performance in a negative manner.

The most detrimental aspect of fixed center drives is generally the potentially high tension condition. This condition can be avoided by adjusting the design center distance. A common approach in these designs is to reduce the center distance from the exact calculated value by some small fraction. This results in a drive system that is inherently loose, but one that has much less probability of yielding excessively high shaft loads. NOTE: This approach should not be used for power transmission drives since the potentially loose operating conditions could result in accelerated wear and belt ratcheting, even under nominal loading.

There are times when fixed center drive designs can't be avoided. In these cases, the following recommendations will maximize the probability of success.

1. Do not use a fixed center design for power transmission drives. Consider using a fixed center design only for lightly loaded or motion transfer applications.
2. Do not use a fixed center design for drives requiring high motion quality or registration precision.
3. When considering a fixed center design, the center distance must be held as accurately as possible, typically within 0.002" – 0.003" (0.05 mm – 0.08 mm). This accuracy often requires the use of stamped steel framework. Molding processes do not generally have the capacity to maintain the necessary accuracy.

4. Pulleys for fixed center systems should be manufactured with a process that is capable of producing the required O.D. tolerances accurately enough.
5. The performance capabilities of the drive system should be verified by testing belts produced over their full length tolerance range on drive systems representing the full potential center-distance variation.

SECTION 13 IDLER USAGE

Idlers in synchronous belt drives are commonly used to take up belt slack, apply installation tension or to clear obstructions within a system. While idlers cause additional belt bending, resulting in fatigue, this effect is generally not significant as long as proper design procedures are followed. Synchronous belts elongate very little over time, making them relatively maintenance free. All idlers should be capable of being locked down after being adjusted and should require little additional attention. Specific guidelines and recommendations are given below.

13.1 Inside/Outside

Inside idlers are generally preferred over backside idlers from a belt fatigue standpoint. Both are commonly used with good success. Inside idlers should be pulleys, but can be flat, if the O.D. is equivalent to the pitch diameter of a 40-groove pulley. Backside idlers should be flat and uncrowned.

13.2 Tight Side/Slack Side

Idlers should be placed on the slack (or nonload-carrying) side, if possible. Their effect on belt fatigue is less on the slack side than on the tight (or load-carrying) side. If spring loaded idlers are used, they should never be placed on the tight side (see Spring Loaded Idlers). Also, note that drive direction reversals cause the tight and slack spans to reverse, potentially placing the idler on the tight side.

13.3 Idler Placement

In synchronous belt drives, idlers can be placed nearly anywhere they are needed. Synchronous drives are much less sensitive to idler placement and belt wrap angles than V-belt drives. The designer should make sure that at least 6 belt teeth are in mesh on load-carrying pulleys. For every tooth in mesh less than this (with a minimum of 2), 20% of the belt torque rating must be subtracted. In order to minimize the potential for belt ratcheting, each loaded pulley in the system should also have a wrap angle of at least 60°. If a loaded pulley has less than 6 teeth in mesh and 60° of wrap, idlers can often be used to improve this condition. Nonloaded idler pulleys do not have tooth meshing or wrap angle restriction.

13.4 Spring Loaded Idlers

Using a spring to apply a predetermined force against a tensioning idler to obtain proper belt installation tension is acceptable as long as the idler can be locked down after belt installation.

Dynamic spring loaded idlers are generally not recommended for synchronous belt drives. If used, spring loaded belt idlers should never be used on the tight (or load-carrying) side. Tight side tensions vary with the magnitude and type of load carried by the system. High tight side tensions can overcome the idler spring force allowing the belt to ratchet. In order to prevent this from occurring, an excessively high spring force is required. This high spring force can result in high shaft/bearing loads and accelerated belt wear.

If dynamic spring loaded idlers are to be used, they should be used on the slack (or nonload-carrying) side of the drive. Potential drive loading variations in the system will have the least possible impact on idler movement due to spring compression with the idler placed in this way. Be sure to note that the tight and slack spans shift as the direction of drive rotation reverses. This could place the spring loaded idler on the tight side. In some cases, drive vibration and harmonic problems may also be encountered with the use of spring loaded idlers.

13.5 Size Recommendations

Inside idler pulleys can be used in the minimum recommended size for each particular belt pitch. Inside flat idlers can be used on the tooth side of synchronous belts as long as they are of a diameter equivalent to the pitch diameter of a 40-groove pulley in the same pitch. Drives with inside flat idlers should be tested, as noise and belt wear may occur. Flat backside idlers should be used with diameters at least 30% larger than the minimum recommended inside pulley size.

Table 18 summarizes our idler size recommendations.

Table 18 Idler Size Recommendations

Belt Type	Minimum Inside Idler	Minimum Backside Idler O.D.		Minimum Inside Flat Idler O.D.	
		inch	mm	inch	mm
MXL	12 grooves	0.50	12.7	1.00	25.4
XL	12 grooves	1.00	25.4	2.50	63.5
3 mm HTD	12 grooves	0.75	19.1	1.50	38.1
5 mm HTD	14 grooves	1.25	31.8	2.50	63.5
2 mm GT	12 grooves	0.50	12.7	1.00	25.4
3 mm GT	12 grooves	0.75	19.1	1.50	38.1
5 mm GT	14 grooves	1.25	31.8	2.50	63.5

13.6 Specifying Shaft Locations In Multipoint Drive Layouts

When collecting geometrical layout data for multiple pulley drive layouts, it is important to use a standard approach that is readily understood and usable for drive design calculations. This is of particular importance when the data will be provided to our Application Engineering Department for analysis.

2-Point Drive

When working with a simple 2-point drive (driver/driven only) it is sufficient to specify the desired distance between shaft centers for belt length calculations.

3-Point Drive

When working with a 3-point drive (driver/driven/idler), X-Y coordinates are desirable. It is sufficient, however, to specify desired center distances between each of the three shaft centers to form a triangle. In either case, pulley/idler movement details for belt tensioning and take up are also necessary.

Multi-Point Drive

When working with a drive system having more than 3 shafts, the geometrical layout data must be collected in terms of X-Y coordinates for analysis. For those unfamiliar with X-Y coordinates, the X-Y Cartesian coordinate system is commonly used in mathematical and engineering calculations and utilizes a horizontal and vertical axis as illustrated in **Figure 27**.

The axes cross at the zero point, or origin. Along the horizontal, or "X" axis, all values to the right of the zero point are positive, and all values to the left of the zero point are negative. Along the vertical, or "Y" axis, all values above the zero point are positive, and all values below the zero point are negative. This is also illustrated in **Figure 27**.

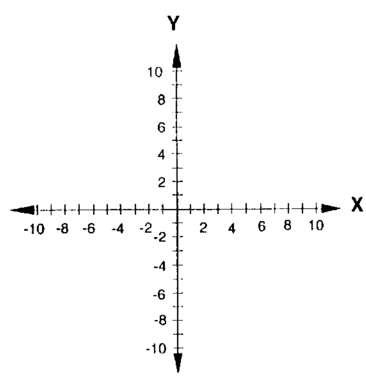


Fig. 27 Cartesian Coordinate System

When identifying a shaft center location, each X-Y coordinate is specified with a measurement in the "X" as well as the "Y" direction. This requires a horizontal and vertical measurement for each shaft center in order to establish a complete coordinate. Either English or Metric units of measurement may be used.

A complete coordinate is specified as follows:

$$(X, Y) \tag{13-1}$$

where: X = measurement along X-axis (horizontal)
Y = measurement along Y-axis (vertical)

In specifying X and Y coordinates for each shaft center, the origin (zero point) must first be chosen as a reference. The driver shaft most often serves this purpose, but any shaft center can be used. Measurements for all remaining shaft centers must be taken from this origin or reference point. The origin is specified as (0, 0).

An example layout of a 5-point drive system is illustrated in **Figure 28**. Here, each of the five shaft centers are located and identified on the X-Y coordinate grid.

When specifying parameters for the movable or adjustable shaft (for belt installation and tensioning), the following approaches are generally used:

Fixed Location: Specify the nominal shaft location coordinate with a movement direction.

Slotted Location: Specify a location coordinate for the beginning of the slot, and a location coordinate for the end of the slot along its path of linear movement.

Pivoted Location: Specify the initial shaft location coordinate along with a pivot point location coordinate and the pivot radius.

Performing belt length and idler movement/positioning calculations by hand can be quite difficult and time consuming. With a complete geometrical drive description, we can make the drive design and layout process quite simple for you.

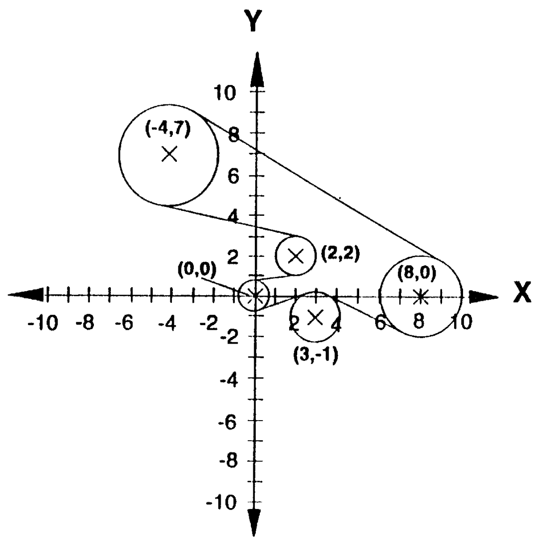


Fig. 28 Example of 5-Point Drive System

SECTION 14 BELT PULL AND BEARING LOADS

Synchronous belt drives are capable of exerting lower shaft loads than V-belt drives in some circumstances. If pre-tensioned according to SDP/SI recommendations for a fully loaded steady state condition, synchronous and V-belt drives will generate comparable shaft loads. If the actual torque loads are reduced and the level of pre-tension remains the same, they will continue to exert comparable shaft loads. In some cases, synchronous belts can be pre-tensioned for less than full loads, under nonsteady state conditions, with reasonable results. Reduced pre-tensioning in synchronous belts can be warranted in a system that operates with uniform loads most of the time, but generates peak loads on an intermittent basis. While V-belt drives require pre-tensioning based upon peak loads to prevent slippage, synchronous drive pre-tensioning can be based upon lower average loads rather than intermittent peak loads, as long as the belt does not ratchet under the peak loads. When the higher peak loads are carried by the synchronous drive, the belt will self-generate tension as needed to carry the load. The process of self-tensioning results in the belt teeth riding out of the pulley grooves as the belt enters the driven pulley on the slack side, resulting in increased belt tooth and pulley wear. As long as peak loads occur intermittently and belts do not ratchet, reduced installation tension will result in reduced average belt pull without serious detrimental effects. Synchronous belts generally require less pretension than V-belts for the same load. They do not require additional installation tension for belt wrap less than 180 degrees on loaded pulleys as V-belt drives do. In most cases, these factors contribute to lower static and dynamic shaft loads in synchronous belt drives.

Designers often wish to calculate how much force a belt drive will exert on the shafting/ bearings/framework in order to properly design their system. It is difficult to make accurate belt pull calculations because factors such as torque load variation, installation tension and pulley runout all have a significant influence. Estimations, however, can be made as follows:

14.1 Motion Transfer Drives

Motion transfer drives, by definition, do not carry a significant torque load. As a result, the belt pull is dependent only on the installation tension. Because installation tensions are provided on a per span basis, the total belt pull can be calculated by vector addition.

14.2 Power Transmission Drives

Torque load and installation tension both influence the belt pull in power transmission drives. The level of installation tension influences the dynamic tension ratio of the belt spans. The tension ratio is defined as the tight side (or load carrying) tension T_T divided by the slack side (or nonload carrying) tension T_S. Synchronous belt drives are generally pre-tensioned to operate dynamically at a 5:1 tension ratio in order to provide the best possible performance. After running for a short time, this ratio is known to increase somewhat as the belt runs in and seats with the pulleys, reducing tension. **Equations** (**14-1**) and (**14-2**) can be used to calculate the estimated T_T and T_S tensions assuming a 5:1 tension ratio. T_T and T_S tensions can then be summed into a single vector force and direction.

$$T_T = \frac{2.5\,(Q)}{Pd}\ \text{(lb)} \qquad \textbf{(14-1)}$$

$$T_S = \frac{0.5\,(Q)}{Pd}\ \text{(lb)} \qquad \textbf{(14-2)}$$

where: T_T = Tight side tension (lbs)
T_S = Slack side tension (lbs)
Q = Torque Load (lb·in)
Pd = Pitch diameter (in)

If both direction and magnitude of belt pull are required, the vector sum of T_T and T_S can be found by graphical vector addition as shown in **Figure 29**. T_T and T_S vectors are drawn parallel to the tight and slack sides at a convenient scale. The magnitude and direction of the resultant vector, or belt pull, can then be measured graphically. The same

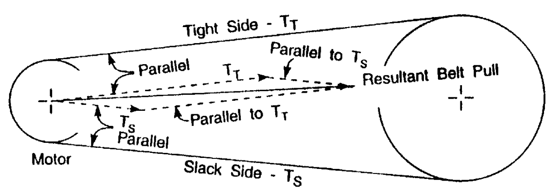


Fig. 29 Belt Pull Vector Diagram

procedures can be used for finding belt pull on the driven shaft. This method can also be used for drives using three or more pulleys or idlers.

For two pulley drives, belt pull on the driver and driven shafts is equal but opposite in direction. For drives using idlers, both magnitude and direction may be different. If only the magnitude of the belt pull is needed in a two pulley drive, use the following procedure:

1. Add T_T and T_S
2. Using the value of $(D - d)/C$ for the drive, find the vector sum correction factor using **Figure 30**. Or, use the known arc of contact on the small pulley, where: D = large diameter
   d = small diameter
   C = center distance
3. Multiply the sum of T_T and T_S by the vector sum correction factor to find the vector sum, or belt pull.

For drives using idlers, either use the graphical method or contact our Application Engineering Department for assistance.

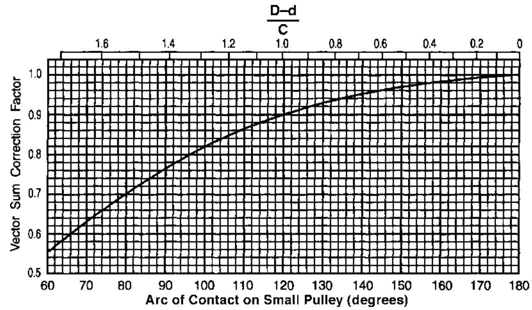


Fig. 30 Vector Sum Correction Factor

14.3 Registration Drives

Synchronous belt drives used for purposes of accurate registration or synchronization generally require the use of higher than normal installation tensions (see section on Belt Tensioning). These drives will operate with higher belt pulls than normal power transmission drives. Belt pull values for these types of applications should be verified experimentally, but can be estimated by adding the installation tension in each belt span vectorially.

14.4 Bearing Load Calculations

In order to find actual bearing loads, it is necessary to know the weights of machine components and the value of all other forces contributing to the load. However, sometimes it helps to know the bearing load contributed by the belt drive alone. The resulting bearing load due to belt pull can be calculated if both bearing spacing with respect to the pulley center and the belt pull are known. For approximate bearing load calculations, machine designers use belt pull and ignore pulley weight forces. If more accurate bearing load calculations are needed, or if the pulley is unusually heavy, the actual shaft load (including pulley weight) should be used.

A. Overhung Pulleys (See **Figure 31**)

$$\text{Load at B} = \frac{\text{Shaft Load x (a + b)}}{\text{a}} \qquad \textbf{(14-3)}$$

$$\text{Load at A} = \frac{\text{Shaft Load x b}}{\text{a}} \qquad \textbf{(14-4)}$$

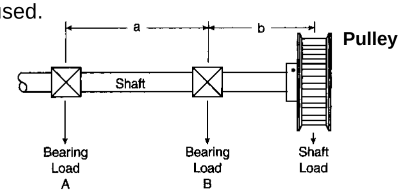


Fig. 31 Overhung Pulley

B. Pulley Between Bearings (See **Figure 32**)

$$\text{Load at D} = \frac{\text{Shaft Load x c}}{\text{(c + d)}} \qquad \textbf{(14-5)}$$

$$\text{Load at C} = \frac{\text{Shaft Load x d}}{\text{(c + d)}} \qquad \textbf{(14-6)}$$

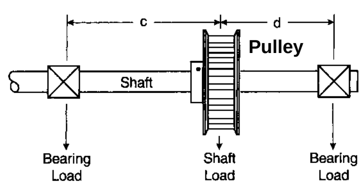


Fig. 32 Pulley Between Bearings

SECTION 15   HANDLING AND STORAGE

The following has been condensed from RMA Bulletin No. IP-3-4: "Storage of Power Transmission Belts":

Recommendations for proper belt storage is of interest to designers as well as to users. Under favorable storage conditions, high quality belts maintain their performance capabilities and manufactured dimensions. Good storage conditions and practices will result in the best value from belt products.

Power transmission belts should ideally be stored in a cool and dry environment. Excess weight against belts resulting in distortion should be avoided. Avoid storing belts in environments that may allow exposure to sunlight, moisture, excessive heat, ozone, or where evaporating solvents or other chemicals are present. Belts have been found to be capable of withstanding storage, without changing significantly, for as long as 8 years at temperatures less than 85° F (30° C) and relative humidity below 70 percent without direct contact with sunlight.

Proper handling of synchronous belts is also important in preventing damage that could reduce their performance capabilities. Synchronous belts should never be crimped or tightly bent. Belts should not be bent tighter than the minimum recommended pulley size specified for each belt section, or pitch. Belt backside bending should be limited to the values specified in **Table 18** for a minimum diameter backside idler.

SECTION 16   STANDARDS APPLICABLE TO BELTS

Different belt tooth configurations are shown in **Figure 19** and their characteristics are described in **Table 3**, both on page T-15. Since synchronous belts are manufactured by several manufacturers, each has established individual standards. Subsequently, the following general standards have been published:

1. Specifications by the Rubber Manufacturers Association for Drives using Synchronous Belts.
2. Synchronous Belt Drives – specification by the International Organization for Standardization.

Based on these, as well as standards developed by belt manufacturers, the following information is presented in this handbook:

Recommended Tension for Length Measurement .... **Table 19**
Belt Width Tolerances .... **Table 20**
Pitch Length Tolerances .... **Table 21**
Center Distance Tolerances .... **Table 22**
Overall Belt Thickness dimensions .... **Table 23**
Overall Belt Thickness Tolerances .... **Table 24**

Length Measurement

The pitch length of a synchronous belt is determined by placing the belt on a measuring fixture comprising two pulleys of equal diameter, applying tension and measuring the center distance between the two pulleys. One of the pulleys is fixed in position, while the other is movable along a graduated scale.

The fixture is shown schematically in **Figure 33**. Any pair of equal-diameter pulleys of the proper pitch and manufactured to specifications may be used for measuring. The measuring tension is given in **Table 19**.

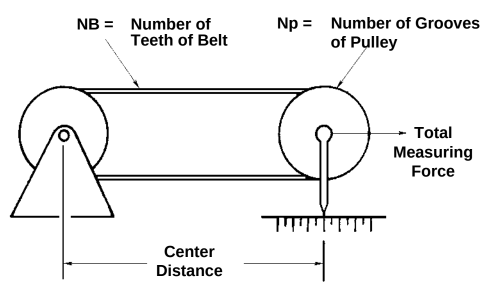


Fig. 33   Length Measuring Fixture

In measuring the length of a synchronous belt, the belt should be rotated at least two revolutions to seat it properly and to divide the tension equally between the two spans.

The pitch length is calculated by adding the pitch circumference of one pulley to twice the center distance:

$$\text{Belt Pitch Length} = 2\,C + 2\,(1/2\ N_{Pulley} \times \text{Pitch})$$

$$C = \frac{\text{Pitch}\,(N_{Belt} - N_{Pulley})}{2}$$

where C is the Center Distance expressed in same units as the Pitch.

Table 19 Recommended Tension for Length Measurement

Total Measuring Tension			
Belt Width		Measuring Force	
in	mm	lbf	N
0.25	6.4	8	36
0.31	7.9	10	44
0.37	9.5	12	53
0.50	12.7	24	105
0.75	19.1	40	180
1.00	25.4	55	245

Table 20 Belt Width Tolerances

Belt Width		Belt Length					
		0 to 33" (0 to 838 mm)		33.01" to 66" (839 to 1676 mm)		Over 66" (Over 1676 mm)	
in	mm	in	mm	in	mm	in	mm
From 0.125 To 0.438	From 3 To 11	+0.016 –0.031	+0.4 –0.8	+0.016 –0.031	+0.4 –0.8	— —	— —
Over 0.438 To 1.500	Over 11 To 38.1	+0.031 –0.031	+0.8 –0.8	+0.031 –0.047	+0.8 –1.2	+0.031 –0.047	+0.8 –1.2
Over 1.500 To 2.000	Over 38.1 To 50.8	+0.031 –0.047	+0.8 –1.2	+0.047 –0.047	+1.2 –1.2	+0.047 –0.063	+1.2 –1.6

Table 21 Pitch Length Tolerances

Belt Pitch Length		Permissible Deviation from Standard		Belt Pitch Length		Permissible Deviation from Standard	
in	mm	in	mm	in	mm	in	mm
Up to 10	Up to 254	±0.016	±0.40	From 70 To 80	From 1778 To 2032	±0.036	±0.91
From 10 To 15	From 254 To 381	±0.018	±0.46	From 80 To 90	From 2032 To 2286	±0.038	±0.96
From 15 To 20	From 381 To 508	±0.020	±0.51	From 90 To 100	From 2286 To 2540	±0.040	±1.02
From 20 To 30	From 508 To 762	±0.024	±0.61	From 100 To 120	From 2540 To 3084	±0.044	±1.12
From 30 To 40	From 762 To 1016	±0.026	±0.66	From 120 To 140	From 3084 To 3556	±0.048	±1.22
From 40 To 50	From 1016 To 1270	±0.030	±0.76	From 140 To 160	From 3556 To 4064	±0.052	±1.32
From 50 To 60	From 1270 To 1524	±0.032	±0.81	From 160 To 170	From 4064 To 4318	±0.054	±1.37
From 60 To 70	From 1524 To 1778	±0.034	±0.86	From 170 To 180	From 4318 To 4572	±0.058	±1.47

Table 22 Center Distance Tolerances

Belt Length		Center Distance Tolerance	
inches	mm	inches	mm
Up to 10	Up to 254	±.008	±.20
Over 10 To 15	Over 254 To 381	±.009	±.23
Over 15 To 20	Over 381 To 508	±.010	±.25
Over 20 To 30	Over 508 To 762	±.012	±.30
Over 30 To 40	Over 762 To 1016	±.013	±.33
Over 40 To 50	Over 1016 To 1270	±.015	±.38
Over 50 To 60	Over 1270 To 1524	±.016	±.41
Over 60 To 70	Over 1524 To 1778	±.017	±.43
Over 70 To 80	Over 1778 To 2032	±.018	±.46
Over 80 To 90	Over 2032 To 2286	±.019	±.48
Over 90 To 100	Over 2286 To 2540	±.020	±.51
Over 100 To 110	Over 2540 To 2794	±.021	±.53
Over 110 To 120	Over 2794 To 3048	±.022	±.56

Table 23 Overall Belt Thickness Dimensions

Belt Type	Belt Pitch	Overall Thickness (ref.)	
		inches	mm
MXL	.080"	.045	1.14
40 D.P.	.0816"	.045	1.14
XL	.200"	.090	2.29
3 mm HTD	3 mm	.095	2.41
5 mm HTD	5 mm	.150	3.81
2 mm GT	2 mm	.060	1.52
3 mm GT	3 mm	.095	2.41
5 mm GT	5 mm	.150	3.81

Table 24 Overall Belt Thickness Tolerances

Standard	Class 2	Class 1
±0.015" ±0.38 mm	±0.010" ±0.25 mm	±0.005" ±0.13 mm

NOTE 1: Belts with pitch lengths greater than 5.5" (140 mm) are furnished with a Class 2 grind unless otherwise specified. Belts with pitch lengths less than 5.5" (140 mm) are unground and produced to standard tolerances.

NOTE 2: A Class 1 grind is available at additional cost for finished belts only.

SECTION 17 STANDARDS APPLICABLE TO PULLEYS AND FLANGES

Pulleys are components manufactured to close tolerances in order to achieve best performance and long belt life. They are available in finished form or as bar stock which can be used for in-house manufacture of prototypes or smaller quantities.

For an uninitiated observer, a pulley may appear simply as a component with some trapezoidal or curvilinear grooves. In fact, the efficiency and integrity of a belt drive is closely attributed to the quality of pulleys involved. The pulleys, therefore, should be supplied by qualified and licensed suppliers. **In case of HTD and GT drives, the suppliers must be licensed by the Gates Rubber Company. Stock Drive Products is one of such licensed full line suppliers.**

To achieve the reproduction of the correct pulley profile, licensed hobs are used. The following inspection and design aids are used as well:

Master Profile: A scaled line drawing of the ideal groove profile with tolerance bands plotted on dimensionally stable translucent material. Suitable for groove inspection purposes on an optical comparator.

Dimensional Profile Drawing: A line drawing of the ideal groove profile with all arcs and radii defined. Suitable for mold design.

Digitized Points: A series of X and Y coordinates defining the ideal groove profile. Available in printed form or on a floppy disk. Suitable for mold design.

Tolerancing/Inspection Procedure: A typical pulley groove tolerance band is illustrated in **Figure 34**. Groove inspection must be made on an optical comparator at a specified magnification. The actual pulley groove profile must fit within the specified tolerance bands without any sharp transition or undercuts.

17.1 Pulley Tolerances

Stock Drive Products has accepted, as a minimum requirement, the Engineering Standards recommended by the Mechanical Power Transmission Association. The Rubber Manufacturers Association, Inc. (RMA), the Rubber Association of Canada and the Gates Rubber Company standards are approved by the Technical Committee of the above associations. These standards are in substantial compliance with standards developed by the International Organization for Standardization (ISO).

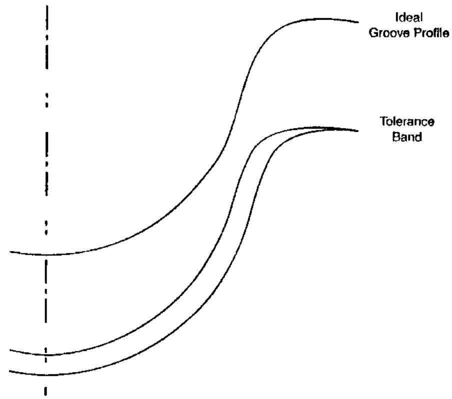


Fig. 34 Typical Pulley Groove Tolerance Band

Requirements of some belt manufacturers exceed those of RMA and ISO. Whenever practicable, Stock Drive Products adheres to those specifications which are more stringent.

The following tables contain the applicable tolerances:

Table 25 Pulley O.D. Tolerances

Pulley O.D.		Pulley O.D. Tollerances	
inches	mm	inches	mm
Up to 1	Up to 25.4	+.002 –.000	+.05 –.00
Over 1 To 2	Over 25.4 To 50.8	+.003 –.000	+.08 –.00
Over 2 To 4	Over 50.8 To 101.6	+.004 –.000	+.10 –.00
Over 4 To 7	Over 101.6 To 177.8	+.005 –.000	+.13 –.00
Over 7 To 12	Over 177.8 To 304.8	+.006 –.000	+.15 –.00
Over 12 To 20	Over 304.8 To 508.0	+.007 –.000	+.18 –.00
Over 20	Over 508.0	+.008 –.000	+.20 –.00

Table 26 Pulley Eccentricity

Outside Diameter		Total Eccentricity Total Indicator Reading	
inches	mm	inches	mm
Up to 2	Up to 50	0.0025	0.06
Over 2 To 4	Over 50 To 100	0.003	0.08
Over 4 To 8	Over 100 To 200	0.004	0.10
Over 8	Over 200	.0005"/inch O.D. > 8"	.013/mm O.D. O.D.> 200mm
		(may not exceed face diameter tolerance)	

The following definitions are being used when considering quality of pulleys:

Eccentricity: The allowable amount of radial run out from the pulley bore to the O.D. is shown in **Table 26**.

Helix Angle: Grooves should be parallel to the axis of the bore within 0.001" per inch (0.025 mm per 25.4 mm) of pulley groove face width.

Draft: The maximum permissible draft on the groove form is 0.001" per inch (0.025 mm per 25.4 mm) of face width and must not exceed the O.D. tolerance.

Parallelism: The bore of the pulley is to be perpendicular to the vertical faces of the pulley within 0.001" per inch (0.025 mm per 25.4 mm) of diameter with a maximum of 0.020" (0.51 mm) total indicator reading.

Pitch Accuracy: Adequate pitch to pitch accuracy is generally more difficult to achieve with molded pulleys than with machined pulleys. Recommended tolerances are listed in **Table 28**.

Balancing: Balancing is often not required on machined metal pulleys. All pulleys should be statically balanced to 1/8 oz (3.5 grams) in all sizes. Drives exceeding 6500 ft/min (33m/s) may require special materials, and should be dynamically balanced to 1/4 oz·in (1.78 N·mm).

Production pulleys should be made as closely to these tolerances as possible in order to maximize drive performance.

In addition to the **Tables 26**, **27** and **28** which define the tolerances related to pulleys manufactured by SDP/SI, **Tables 29** through **32** are given for reference only, as published by ISO (International Organization for Standardization) and RMA (Rubber Manufacturers Association).

Table 27 Bore Tolerance for Pulleys

Bore		Bore Tolerance	
in	mm	in	mm
To 1	To 2.54	+.0010 –.0000	+0.025 –0.000
1 to 2	25.4 to 50.8	+.0015 –.0000	+0.038 –0.000
2 to 3	50.8 to 76.2	+.0020 –.0000	+0.051 –0.000
3 up	76.2 up	+.0025 –.0000	+0.064 –0.000

Table 28 Pulley Pitch Accuracy

Bore		Pitch to Pitch		Accumulative*	
in	mm	in	mm	in	mm
Up to 1.0	Up to 25.4	±.001	±0.025	±.001	±0.025
Over 1.0 To 2.0	Over 25.4 To 50.8	±.001	±0.025	±.001	±0.025
Over 2.0 To 4.0	Over 50.8 To 101.6	±.001	±0.025	±.001	±0.025
Over 4.0 To 7.0	Over 101.6 To 177.8	±.001	±0.025	±.001	±0.025
Over 7.0 To 12.0	Over 177.8 To 304.8	±.001	±0.025	±.001	±0.025
Over 12.0 To 20.0	Over 304.8 To 508.0	±.001	±0.025	±.001	±0.025
Over 20.0	Over 508.0	±.001	±0.025	±.001	±0.025

* Over 90°

Table 29 ISO Axial Pulley Runout

Outside Diameter Range		Total Indicator Reading (max.)	
in	mm	in	mm
≤ 4.000	≤ 101.60	.004	0.10
> 4.000 … ≤ 10.000	> 101.60 … ≤ 254.00	.001/in of O.D.	0.001/mm of O.D.
> 10.000	> 254.00	.010 + .0005/in of O.D. over 10.000"	0.25 + 0.0005/mm of O.D. over 254.00 mm

Table 30 ISO Radial Pulley Runout

Outside Diameter Range		Total Indicator Reading (max.)	
in	mm	in	mm
≤ 8.000	≤ 203.20	.005	0.13
> 8.000	> 203.20	.005 + .0005/in of O.D. over 8.000	0.13 + 0.0005/mm of O.D. over 203.20 mm

Table 31 ISO Pulley O.D. Tolerances

Outside Diameter		Tolerances	
in	mm	in	mm
≤ 1.000	≤ 25.40	+.002 /–.000	+0.05 / 0
> 1.000 … ≤ 2.000	> 25.40 … ≤ 50.80	+.003 /–.000	+0.08 / 0
> 2.000 … ≤ 4.000	> 50.80 … ≤ 101.60	+.004 /–.000	+0.10 / 0
> 4.000 … ≤ 7.000	> 101.60 … ≤ 177.80	+.005 /–.000	+0.13 / 0
> 7.000 … ≤ 12.000	> 177.80 … ≤ 304.80	+.006 /–.000	+0.15 / 0
> 12.000 … ≤ 20.000	> 304.80 … ≤ 508.00	+.007 /–.000	+0.18 / 0
> 20.000	> 508.00	+.008 /–.000	+0.20 / 0

Table 32 RMA Pulley Bore Tolerances

Length / Diameter of Bore	Up thru .75 (19)	Over .75 (19) to and including 1.00 (25.4)	Over 1.00 (25.4) to and including 1.25 (31.8)	Over 1.25 (31.8) to and including 1.50 (38.1)	Over 1.50 (38.1) to and including 2.00 (50.8)	Over 2.00 (50.8) to and including 2.50 (63.5)	Over 2.50 (63.5) to and including 3.00 (76.2)
	Tolerances						
Up thru 0.50 (12.7)	+.0015 +.0005 (+0.038 +0.013)	+.0015 +.0005 (+0.038 +0.013)	+.0015 +.0005 (+0.038 +0.013)	+.0015 +.0005 (+0.038 +0.013)	+.0015 +.0005 (+0.038 +0.013)		
Over 0.50 (12.7) to and including 1.00 (25.4)	+.0015 +.0005 (+0.038 +0.013)	+.0015 +.0005 (+0.038 +0.013)	+.0015 +.0005 (+0.038 +0.013)	+.0015 +.0005 (+0.038 +0.013)	+.0020 +.0005 (+0.051 +0.013)	+.0020 +.0005 (+0.051 +0.013)	+.0020 +.0005 (+0.051 +0.013)
Over 1.00 (25.4) to and including 1.50 (38.1)		+.0015 +.0005 (+0.038 +0.013)	+.0015 +.0005 (+0.038 +0.013)	+.0015 +.0005 (+0.038 +0.013)	+.0020 +.0010 (+0.051 +0.025)	+.0020 +.0010 (+0.051 +0.025)	+.0020 +.0010 (+0.051 +0.025)
Over 1.50 (38.1) to and including 2.00 (50.8)			+.0020 +.0005 (+0.051 +0.013)	+.0020 +.0005 (+0.051 +0.013)	+.0025 +.0010 (+0.064 +0.025)	+.0025 +.0010 (+0.064 +0.025)	+.0025 +.0010 (+0.064 +0.025)
Over 2.00 (50.8) to and including 2.50 (63.5)				+.0020 +.0005 (+0.051 +0.013)	+.0025 +.0010 (+0.064 +0.025)	+.0025 +.0010 (+0.064 +0.025)	+.0025 +.0010 (+0.064 +0.025)

NOTE: Dimensions in ( ) are in mm, all others are in inches

17.2 Pulley Materials

There is a wide variety of materials and manufacturing processes available for the production of synchronous belt pulleys. In selecting an appropriate material and production process, the designer should consider dimensional accuracy, material strength, durability and production quantity. Some broad guidelines and recommendations are as follows:

1. Machining
Excellent dimensional accuracy. Economical for low to moderate production quantities.
Typical materials:
Steel – Excellent Wear Resistance.
Aluminum – Good Wear Resistance; pulleys for power transmission drives should be hard anodized.

2. Powdered Metal and Die Casting
Good dimensional accuracy. Economical for moderate to high production quantities.
Typical materials:
Sintered Iron – Excellent Wear Resistance.
Sintered Aluminum – Good Wear Resistance; Light Weight and Corrosion Resistant.
Zinc Die Cast – Good Wear Resistance.

3. Plastic Molding
Good dimensional accuracy. Economical for high production quantities. Best suited for light to moderate torque loads. Fiber loading improves overall material strength and dimensional stability. However, increased belt wear can result from the presence of sharp abrasive fiber ends on the finished surface.

Assistance for total drive system design is available. Please contact our Application Engineering Department.

17.3 Flange Design And Face Width Guidelines

Figure 35 illustrates the expressions used in flange and pulley design. **Tables 33** and **34** pertain to flange dimensions and pulley face widths respectively.

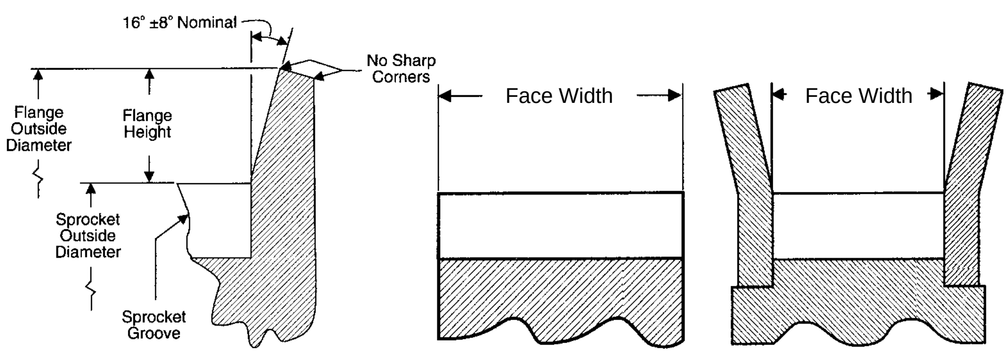


Fig. 35 Expressions Used in Flange and Pulley Design

Table 33 Nominal Flange Dimensions for Molding, Sintering, Casting, etc.

Belt Type	Minimum Flange Height		Nominal Flange Height	
	inches	mm	inches	mm
MXL	0.040	—	0.050	—
XL	0.060	—	0.080	—
2 mm GT	0.043	1.10	0.059	1.50
3 mm GT & HTD	0.067	1.70	0.098	2.50
5 mm GT & HTD	0.091	2.20	0.150	3.80

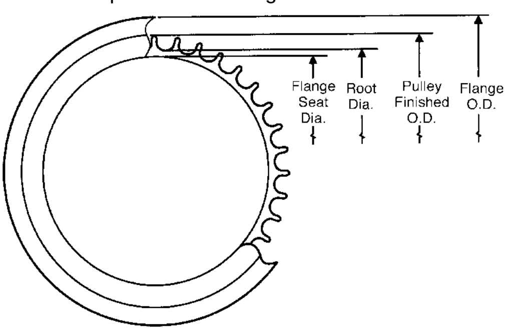
Table 34 Additional Amount of Face Width Recommended over Nominal Belt Width*

Belt Type	Minimum Flange Height		Nominal Flange Height	
	inches	mm	inches	mm
MXL	+0.125	—	+0.040	—
XL	+0.190	—	+0.060	—
2 mm GT	+0.118	+3.00	+0.039	+1.00
3 mm GT & HTD	+0.157	+4.00	+0.049	+1.25
5 mm GT & HTD	+0.197	+5.00	+0.059	+1.50

***** Add Table Values to Nominal Belt Width for Nominal Face Width

17.4 Guidelines For PowerGrip GT Flange Design

In some instances, special pulleys are used whch are made from pulley stock. The following guidelines are given to establish the design parameters for flanges which would fit these special pulleys. If possible, standard available flanges should be used to avoid tooling charges associated with production of special sized flanges.



Nominal PowerGrip GT Groove Depths

2 mm — .030" (0.76 mm)
3 mm — .045" (1.14 mm)
5 mm — .076" (1.93 mm)

PowerGrip GT Pitch Factors

2 mm — .016" (0.41 mm)
3 mm — .050" (1.27 mm)
5 mm — .070" (1.78 mm)

Figure 36 Terms Used for Timing Pulley Flange Design

Steps:

1. Determine pulley size and finished O.D. (See **Tables 12** through **14** on pages T-32 thru T-37).
2. Determine root diameter (Root Diameter = Finished O.D. – 2 x Nominal Groove Depth). See **Figure 19**, page T-15.
3. Determine maximum flange seat diameter (Maximum Flange Seat Diameter = Root Diameter – Pitch Factor).
4. Select flange with inside diameter less than maximum flange seat diameter (see available flange sizes in the product section).
5. Determine flange seat diameter (Flange Seat Diameter = Flange I.D. +.000" –.003")
6. Determine flange seat width (Flange Seat Width = Flange Gauge + .020" ±.005"; see available flange sizes).
7. Flanges can be rolled, staked or punched on.

SECTION 18 DOUBLE SIDED TWIN POWER BELT TOLERANCES

This type of belt was introduced briefly in **Section 5.1**, page T-10. As previously described, this type of belt has teeth on both sides to provide synchronization from both driving surfaces. This special feature makes possible unique drive designs, such as multipoint drives, rotation reversal with one belt, serpentine drives, etc. It may also provide solutions to other difficult design problems.

Twin Power Belts are similar in construction to regular synchronous belts, including nylon-faced teeth on both sides. This construction uses essentially the same design parameters as standard synchronous belts. Their torque ratings are the same as conventional PowerGrip Belts of identical pitch and width.

Twin Power Belts are available in trapezoidal configurations from stock and HTD configurations on a made-to-order basis in lengths from 15" (381mm) through 180" (4572mm).

Twin Power Construction

Tensile members of the PowerGrip Twin Power Belt are helically-wound fiberglass cords providing the same load-carrying capacity as single sided PowerGrip belts. The body is Neoprene rubber providing oil and weather resistance and protection for the fiberglass cords. Both sides of the belt have a specially treated nylon tooth facing that provides a tough wear-resistant surface with minimal friction.

Twin Power Tolerances

Since Twin Power Belts are manufactured and cut to the required width by the same method as standard PowerGrip belts, the same manufacturing tolerances apply, except for the thickness and center distance tolerances listed in **Tables 35** and **36**.

Overall thickness, opposing teeth symmetry and pitch line symmetry are closely controlled during Twin Power Belt manufacture.

Specifying Twin Power Belts

The available Twin Power Belts and other double sided belts from stock can be found from the Timing Belt Locator Chart, on page **1**-2 of the product section.

Twin Power Drive Selection

Twin Power Belts can transmit 100% of their maximum rated load from either side of the belt or in combination where the sum of the loads exerted on both sides does not exceed the maximum rating of the belt. For example, a Twin Power Belt rated at 6 lb·in could be used with 50% of the maximum rated on one side, and 50% on the other; or 90% on one side, and 10% on the other.

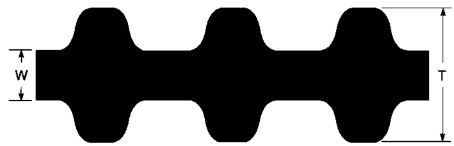


Fig. 37 Twin Power Belt Tolerances

Table 35 Belt Thickness Tolerances

Belt	T (in)	W (in) Ref.
XL (.200")	.120 ± .007	.020
3 mm HTD	.126 ± .006	.030
5 mm HTD	.209 ± .007	.045

Table 36 Center Distance Tolerances

Belt Length (in)	Center Distance Tolerances (in)
15 to 20	± .020
20.01 to 30	± .024
30.01 to 40	± .026
40.01 to 50	± .030
50.01 to 60	± .032
60.01 to 70	± .034
over 70	To be specified

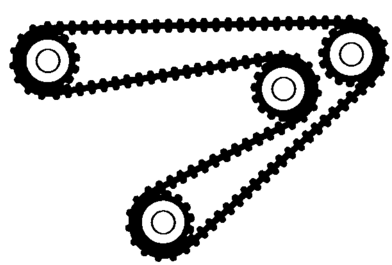


Fig. 38 Twin Power Belt Application

Drive selection procedures for drives using Twin Power Belts are much the same as for drives using conventional belting. Refer to the appropriate product and engineering sections in this catalog for drive torque ratings, engineering information, pulley details, belt tension recommendations, etc.

Some manufacturers, however, are producing double sided belts which have nylon faced teeth on one side only. For those belts, the limitations given in **Section 5.1**, page T-10 apply.

SECTION 19 LONG LENGTH TIMING BELT STOCK SPECIFICATIONS

Brief mention of this type of belt was given in **Section 5.2**, page T-10. As previously indicated, long length belting is produced in spiral form. Spiral cut belting is produced from a belt sleeve by moving the slitter laterally while the belt sleeve is rotating.

The resulting belting does not have continuous tensile cords, and the teeth are not perfectly perpendicular to the longitudinal axis of the belt. As long as the belt width is narrow, these properties have been found to contribute little if any detrimental effects to belt performance. The maximum belt width available using this process is 1/2" (12 mm). Tensile modulus and strength are equivalent to conventional endless and long length belting.

This innovative product is available in all types of PowerGrip belting in all pitches. Reciprocating carriage drives requiring the use of higher performance curvilinear tooth belt products in long length form can now be easily handled.

This type of belt is called belt stock, and its availability from stock is indicated on the Timing Belt Locator Chart, on page **1**-2, at the beginning of the belt product section.

Table 37 PowerGrip Long-Length Belting Specifications

Belt Type	Stock Width		Rated Working Tension, T_a		Maximum Available Length	
	in	mm	lb	N	ft	m
MXL (.080")	1/8	3	1.8	8	65	19
	3/16	4.5	3.2	14	65	19
	1/4	6	5	22	450	150
	3/8	9.5	8	35	300	90
XL (.200")	1/4	6	7	31	350	120
	3/8	9.5	11	49	250	80
	1/2	13	16	71	150	50
L (.375")	1/2	13	24	106	100	30
	3/4	19	39	173	100	30
	1	25	55	245	100	30
3 mm HTD	.236	6	11	49	450	150
	.354	9	18	80	290	97
	.984	25	60	267	100	30
5 mm HTD	.236	6	18	80	250	80
	.354	9	30	133	275	92
	.512	13	42	187	200	60
	.984	25	100	449	100	30
2 mm GT	.236	6	6	27	250	80
	.354	9	9	40	170	57
	.472	12	12	53	125	42
3 mm GT	.236	6	27	120	375	125
	.354	9	40	178	250	80
	.472	12	54	240	180	60
5 mm GT	.354	9	56	249	250	80
	.472	12	75	334	180	60

Drive Selection With PowerGrip Long-Length Belting

Drive selection procedures for drives using Long-Length Belting are much the same as for drives using conventional endless belting. Refer to the appropriate product and engineering sections in this catalog for drive torque ratings, engineering information, pulley details, belt tension recommendations etc. **Table 37** includes rated belt working tension data, for those applications for which it could be helpful, as well as maximum length available in each pitch. For drive design selection assistance with belt stock, contact our Application Engineering Department.

SECTION 20 COMPANION CD-ROM — BRIEF DESCRIPTION

A companion CD-ROM is made available in conjunction with the publication of Handbook D260. It actually represents a complete computerized catalog containing all the product information presented in this book. In addition, it provides computerized Drive Ratio and Center Distance calculations. The *Center Distance Designer* program on the CD-ROM computes belt lengths for various center distances and checks for the number of teeth in mesh for both pulleys. It calculates pulley drive ratios and the minimal center distance for a designated pulley pair.

It searches and retrieves all pulleys and belts shown in the Handbook that fit within the customer criteria. Once the design is completed, the part numbers can be instantly retrieved from the database with each part number linked to an electronic catalog page which is viewable and can be printed.

The CD-ROM is presented in an interactive format with the navigator program residing on the CD itself. The user can design a drive in a most efficient manner since the program described above presents available alternatives as well as direct reference to catalog page numbers and part numbers involved.

Included with the CD-ROM is a short manual introducing the user step-by-step to the sequence of the operations of this disc.

It is assumed, however, that not all users of this Handbook have access to a computer. Therefore, the Drive Ratio and Center Distance Tables are presented in this Handbook also, in printed format.

SECTION 21 DRIVE RATIO TABLES

In the design of belt drives, we usually know the speed ratio (transmission ratio) and we need to determine pulley sizes, center distance and belt length. These quantities are shown in **Figure 39**, for an open (uncrossed) belt.

The Drive Ratio Tables (**Table 38**, starting on page T-70) are designed to facilitate the determination of these quantities. They list the following information:

- N1/N2 = the transmission ratio obtained when the larger pulley (N1 teeth) is the input and smaller pulley (N2 teeth) is the output. Given to 3 decimal places.
- N2/N1 = the transmission ratio obtained when the larger pulley (N1 teeth) is the output and the smaller pulley (N2 teeth) is the input. Given to 3 decimal places. (Note that N1/N2 is the reciprocal of N2/N1)
- N1 = number of teeth on larger pulley.
- N2 = number of teeth on smaller pulley.
- N1 – N2 = difference between number of teeth on larger and smaller pulleys. This number is useful in center-distance determination.
- C MIN = The minimum center distance between pulleys for a belt of unit pitch. If the pitch is denoted by *p*, the actual minimum center distance is a product of C MIN and *p*. The minimum center distance is determined from the condition that at the minimum center distance, the pitch circles of the pulleys can be assumed to touch. This will generally give a satisfactory approximation to the practical minimum center distance. The table is based on the equation:

$$\text{C MIN} = \frac{\text{N1} + \text{N2}}{2\pi} \times \text{Belt Pitch} \qquad \textbf{(21-1)}$$

At the beginning of the table, a list of standard pulley sizes is shown. The smallest pulley has 10 teeth and the largest, 156 teeth. A standard size will be the most economical. If a nonstandard size is needed, however, please contact Stock Drive Products for assistance.

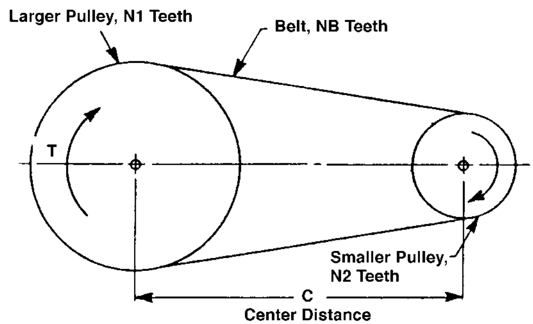


Fig. 39 Belt Nomenclature

The use of the tables is best illustrated by means of examples.

Example 1: For a transmission ratio of 1.067, find the number of teeth of the pulleys and the minimum center distance for a belt of 5 mm pitch.

When the transmission ratio is greater than unity, the larger pulley is the input and the smaller pulley is the output. That is to say, the transmission ratio is equal to N1/N2. The table is organized in order of increasing values of N1/N2 and decreasing values of N2/N1. Referring to the table at this value of N1/N2, we find the following entries:

N1/N2	N2/N1	N1	N2	N1 – N2	C MIN
1.067	0.938	16	15	1	4.934
		32	30	2	9.868

Hence, there are 2 different pulley combinations for the given transmission ratio of 1.067. For each of these, the minimum center distance is 5 x (C MIN) in mm. If the smaller pulley were driving, the transmission ratio would have been 0.938. The quantity (N1 – N2) is needed in center-distance calculations, as described in the next section.

Example 2: Given a transmission ratio of 0.680, determine the pulley sizes.

Since the transmission ratio is less than one, the smaller pulley is the input and the transmission ratio is given by N2/N1 = 0.680. Looking up this ratio in the table, we find N1 = 25, N2 = 17, N1 – N2 = 8. In this case, only one pulley combination is available.

Example 3: Given a driving pulley of 48 teeth and a driven pulley of 19 teeth, find the minimum center distance for a belt pitch of 3 mm.

The transmission ratio is N1/N2 = 48/19 = 2.526. Looking up this ratio in the table, we find C MIN = 10.663. The minimum center distance, therefore, is given by 3 x 10.663 or 31.989 mm.

Example 4: Given a transmission ratio of 2.258, find the pulley sizes.

Looking through the table, there is no entry at this value of the transmission ratio. The nearest entries are:

N1/N2	N2/N1	N1	N2	N1 – N2
2.250	0.444	36	16	20
		72	32	40
2.273	0.440	25	11	14

Since the difference between the desired ratio and the nearest available ratios is only about 0.008, it is likely that the 2.250 or 2.273 ratios will be acceptable. If this is not the case, however, the design may require review, or a nonstandard pulley combination may be considered.

Drive Ratio Tables

Table 38

Definition:

Drive Ratio (Transmission Ratio) is the ratio of number of teeth of the input and output pulleys. If the input pulley is larger than the output, the Drive Ratio will be larger than one and we have a step-up drive. If the input pulley is smaller than the output pulley, the Drive Ratio will be smaller than one and we have a step-down drive.

Nomenclature Used:

N1	=	Number of teeth of large pulley
N2	=	Number of teeth of small pulley
N1/N2	=	Step-up Drive Ratio
N2/N1	=	Step-down Drive Ratio
N1 – N2	=	Pulley tooth differential needed for **Table 39 – Center Distance Factor Table**
C MIN	=	Minimum center distance for particular pulley combination expressed in belt pitches

Pulley Sizes Included:

10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 24, 25,
28, 30, 32, 36, 40, 48, 60, 72, 84, 96, 120, 156

Note:

These pulley sizes reflect the preferred sizes per ISO Standard 5294 for synchronous belt drives – Pulleys (First edition – 1979-07-15). Many other sizes are offered in this catalog. The availability of stock sizes varies depending on the particular choice of pitch, material and configuration. Nonstandard sizes are available as custom made specials. Please submit your requirement for us to quote.

Continued on the next page

Table 38 (Cont.)

N1/N2	N2/N1	N1	N2	N1-N2	C MIN
1.000	1.000	10	10	0	3.183
		11	11	0	3.501
		12	12	0	3.820
		13	13	0	4.138
		14	14	0	4.456
		15	15	0	4.775
		16	16	0	5.093
		17	17	0	5.411
		18	18	0	5.730
		19	19	0	6.048
		20	20	0	6.366
		22	22	0	7.003
		24	24	0	7.639
		25	25	0	7.958
		28	28	0	8.913
		30	30	0	9.549
		32	32	0	10.186
		36	36	0	11.459
		40	40	0	12.732
		48	48	0	15.279
		60	60	0	19.099
		72	72	0	22.918
		84	84	0	26.738
		96	96	0	30.558
		120	120	0	38.197
		156	156	0	49.656
1.042	0.960	25	24	1	7.799
1.053	0.950	20	19	1	6.207
1.056	0.947	19	18	1	5.889
1.059	0.944	18	17	1	5.570
1.063	0.941	17	16	1	5.252
1.067	0.938	16	15	1	4.934
		32	30	2	9.868
1.071	0.933	15	14	1	4.615
		30	28	2	9.231
1.077	0.929	14	13	1	4.297
1.083	0.923	13	12	1	3.979
1.091	0.917	12	11	1	3.661
		24	22	2	7.321
1.100	0.909	11	10	1	3.342
		22	20	2	6.685
1.111	0.900	20	18	2	6.048
		40	36	4	12.096
1.118	0.895	19	17	2	5.730

N1/N2	N2/N1	N1	N2	N1-N2	C MIN
1.120	0.893	28	25	3	8.435
1.125	0.889	18	16	2	5.411
		36	32	4	10.823
1.133	0.882	17	15	2	5.093
1.136	0.880	25	22	3	7.480
1.143	0.875	16	14	2	4.775
		32	28	4	9.549
		96	84	12	28.648
1.154	0.867	15	13	2	4.456
1.158	0.864	22	19	3	6.525
1.167	0.857	14	12	2	4.138
		28	24	4	8.276
		84	72	12	24.828
1.176	0.850	20	17	3	5.889
1.182	0.846	13	11	2	3.820
1.188	0.842	19	16	3	5.570
1.200	0.833	12	10	2	3.501
		18	15	3	5.252
		24	20	4	7.003
		30	25	5	8.754
		36	30	6	10.504
		48	40	8	14.006
		72	60	12	21.008
1.214	0.824	17	14	3	4.934
1.222	0.818	22	18	4	6.366
1.231	0.813	16	13	3	4.615
1.250	0.800	15	12	3	4.297
		20	16	4	5.730
		25	20	5	7.162
		30	24	6	8.594
		40	32	8	11.459
		60	48	12	17.189
		120	96	24	34.377
1.263	0.792	24	19	5	6.844
1.267	0.789	19	15	4	5.411
1.273	0.786	14	11	3	3.979
		28	22	6	7.958
1.280	0.781	32	25	7	9.072
1.286	0.778	18	14	4	5.093
		36	28	8	10.186
1.294	0.773	22	17	5	6.207
1.300	0.769	13	10	3	3.661
		156	120	36	43.927
1.308	0.765	17	13	4	4.775

Continued on the next page

Table 38 (Cont.)

N1/N2	N2/N1	N1	N2	N1-N2	C MIN
1.316	0.760	25	19	6	7.003
1.333	0.750	16	12	4	4.456
		20	15	5	5.570
		24	18	6	6.685
		32	24	8	8.913
		40	30	10	11.141
		48	36	12	13.369
		96	72	24	26.738
1.357	0.737	19	14	5	5.252
1.364	0.733	15	11	4	4.138
		30	22	8	8.276
1.375	0.727	22	16	6	6.048
1.385	0.722	18	13	5	4.934
1.389	0.720	25	18	7	6.844
1.400	0.714	14	10	4	3.820
		28	20	8	7.639
		84	60	24	22.918
1.412	0.708	24	17	7	6.525
1.417	0.706	17	12	5	4.615
1.429	0.700	20	14	6	5.411
		40	28	12	10.823
		120	84	36	32.468
1.440	0.694	36	25	11	9.708
1.455	0.688	16	11	5	4.297
		32	22	10	8.594
1.462	0.684	19	13	6	5.093
1.467	0.682	22	15	7	5.889
1.471	0.680	25	17	8	6.685
1.474	0.679	28	19	9	7.480
1.500	0.667	15	10	5	3.979
		18	12	6	4.775
		24	16	8	6.366
		30	20	10	7.958
		36	24	12	9.549
		48	32	16	12.732
		60	40	20	15.915
		72	48	24	19.099
1.538	0.650	20	13	7	5.252
1.545	0.647	17	11	6	4.456
1.556	0.643	28	18	10	7.321
1.563	0.640	25	16	9	6.525
1.571	0.636	22	14	8	5.730
1.579	0.633	30	19	11	7.799
1.583	0.632	19	12	7	4.934

N1/N2	N2/N1	N1	N2	N1-N2	C MIN
1.600	0.625	16	10	6	4.138
		24	15	9	6.207
		32	20	12	8.276
		40	25	15	10.345
		48	30	18	12.414
		96	60	36	24.828
1.625	0.615	156	96	60	40.107
1.636	0.611	18	11	7	4.615
		36	22	14	9.231
1.647	0.607	28	17	11	7.162
1.667	0.600	20	12	8	5.093
		25	15	10	6.366
		30	18	12	7.639
		40	24	16	10.186
		60	36	24	15.279
		120	72	48	30.558
1.684	0.594	32	19	13	8.117
1.692	0.591	22	13	9	5.570
1.700	0.588	17	10	7	4.297
1.714	0.583	24	14	10	6.048
		48	28	20	12.096
1.727	0.579	19	11	8	4.775
1.750	0.571	28	16	12	7.003
		84	48	36	21.008
1.765	0.567	30	17	13	7.480
1.778	0.563	32	18	14	7.958
1.786	0.560	25	14	11	6.207
1.800	0.556	18	10	8	4.456
		36	20	16	8.913
		72	40	32	17.825
1.818	0.550	20	11	9	4.934
		40	22	18	9.868
1.833	0.545	22	12	10	5.411
1.846	0.542	24	13	11	5.889
1.857	0.538	156	84	72	38.197
1.867	0.536	28	15	13	6.844
1.875	0.533	30	16	14	7.321
		60	32	28	14.642
1.882	0.531	32	17	15	7.799
1.895	0.528	36	19	17	8.754
1.900	0.526	19	10	9	4.615
1.920	0.521	48	25	23	11.618
1.923	0.520	25	13	12	6.048
2.000	0.500	20	10	10	4.775

Continued on the next page

Table 38 (Cont.)

N1/N2	N2/N1	N1	N2	N1-N2	C MIN
2.000	0.500	22	11	11	5.252
		24	12	12	5.730
		28	14	14	6.685
		30	15	15	7.162
		32	16	16	7.639
		36	18	18	8.594
		40	20	20	9.549
		48	24	24	11.459
		60	30	30	14.324
		72	36	36	17.189
		96	48	48	22.918
		120	60	60	28.648
2.083	0.480	25	12	13	5.889
2.100	0.476	84	40	44	19.735
2.105	0.475	40	19	21	9.390
2.118	0.472	36	17	19	8.435
2.133	0.469	32	15	17	7.480
2.143	0.467	30	14	16	7.003
2.143	0.467	60	28	32	14.006
2.154	0.464	28	13	15	6.525
2.167	0.462	156	72	84	36.287
2.182	0.458	24	11	13	5.570
		48	22	26	11.141
2.200	0.455	22	10	12	5.093
2.222	0.450	40	18	22	9.231
2.250	0.444	36	16	20	8.276
		72	32	40	16.552
2.273	0.440	25	11	14	5.730
2.286	0.438	32	14	18	7.321
2.308	0.433	30	13	17	6.844
2.333	0.429	28	12	16	6.366
		84	36	48	19.099
2.353	0.425	40	17	23	9.072
2.400	0.417	24	10	14	5.411
		36	15	21	8.117
		48	20	28	10.823
		60	25	35	13.528
		72	30	42	16.234
		96	40	56	21.645
2.462	0.406	32	13	19	7.162
2.500	0.400	25	10	15	5.570
		30	12	18	6.685
		40	16	24	8.913
		60	24	36	13.369

N1/N2	N2/N1	N1	N2	N1-N2	C MIN
2.500	0.400	120	48	72	26.738
2.526	0.396	48	19	29	10.663
2.545	0.393	28	11	17	6.207
2.571	0.389	36	14	22	7.958
		72	28	44	15.915
2.600	0.385	156	60	96	34.377
2.625	0.381	84	32	52	18.462
2.667	0.375	32	12	20	7.003
		40	15	25	8.754
		48	18	30	10.504
		96	36	60	21.008
2.727	0.367	30	11	19	6.525
		60	22	38	13.051
2.769	0.361	36	13	23	7.799
2.800	0.357	28	10	18	6.048
		84	30	54	18.144
2.824	0.354	48	17	31	10.345
2.857	0.350	40	14	26	8.594
2.880	0.347	72	25	47	15.438
2.909	0.344	32	11	21	6.844
3.000	0.333	30	10	20	6.366
		36	12	24	7.639
		48	16	32	10.186
		60	20	40	12.732
		72	24	48	15.279
		84	28	56	17.825
		96	32	64	20.372
		120	40	80	25.465
3.077	0.325	40	13	27	8.435
3.158	0.317	60	19	41	12.573
3.200	0.313	32	10	22	6.685
		48	15	33	10.027
		96	30	66	20.054
3.250	0.308	156	48	108	32.468
3.273	0.306	36	11	25	7.480
		72	22	50	14.961
3.333	0.300	40	12	28	8.276
		60	18	42	12.414
		120	36	84	24.828
3.360	0.298	84	25	59	17.348
3.429	0.292	48	14	34	9.868
		96	28	68	19.735
3.500	0.286	84	24	60	17.189
3.529	0.283	60	17	43	12.255

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Table 38 (Cont.)

N1/N2	N2/N1	N1	N2	N1-N2	C MIN
3.600	0.278	36	10	26	7.321
		72	20	52	14.642
3.636	0.275	40	11	29	8.117
3.692	0.271	48	13	35	9.708
3.750	0.267	60	16	44	12.096
		120	32	88	24.192
3.789	0.264	72	19	53	14.483
3.818	0.262	84	22	62	16.870
3.840	0.260	96	25	71	19.258
3.900	0.256	156	40	116	31.194
4.000	0.250	40	10	30	7.958
		48	12	36	9.549
		60	15	45	11.937
		72	18	54	14.324
		96	24	72	19.099
		120	30	90	23.873
4.200	0.238	84	20	64	16.552
4.235	0.236	72	17	55	14.165
4.286	0.233	60	14	46	11.777
		120	28	92	23.555
4.333	0.231	156	36	120	30.558
4.364	0.229	48	11	37	9.390
		96	22	74	18.780
4.421	0.226	84	19	65	16.393
4.500	0.222	72	16	56	14.006
4.615	0.217	60	13	47	11.618
4.667	0.214	84	18	66	16.234
4.800	0.208	48	10	38	9.231
		72	15	57	13.846
		96	20	76	18.462
		120	25	95	23.077
4.875	0.205	156	32	124	29.921
4.941	0.202	84	17	67	16.075
5.000	0.200	60	12	48	11.459
		120	24	96	22.918
5.053	0.198	96	19	77	18.303
5.143	0.194	72	14	58	13.687
5.200	0.192	156	30	126	29.603
5.250	0.190	84	16	68	15.915
5.333	0.188	96	18	78	18.144
5.455	0.183	60	11	49	11.300
		120	22	98	22.600
5.538	0.181	72	13	59	13.528
5.571	0.179	156	28	128	29.285

N1/N2	N2/N1	N1	N2	N1-N2	C MIN
5.600	0.179	84	15	69	15.756
5.647	0.177	96	17	79	17.985
6.000	0.167	60	10	50	11.141
		72	12	60	13.369
		84	14	70	15.597
		96	16	80	17.825
		120	20	100	22.282
6.240	0.160	156	25	131	28.807
6.316	0.158	120	19	101	22.123
6.400	0.156	96	15	81	17.666
6.462	0.155	84	13	71	15.438
6.500	0.154	156	24	132	28.648
6.545	0.153	72	11	61	13.210
6.667	0.150	120	18	102	21.963
6.857	0.146	96	14	82	17.507
7.000	0.143	84	12	72	15.279
7.059	0.142	120	17	103	21.804
7.091	0.141	156	22	134	28.330
7.200	0.139	72	10	62	13.051
7.385	0.135	96	13	83	17.348
7.500	0.133	120	16	104	21.645
7.636	0.131	84	11	73	15.120
7.800	0.128	156	20	136	28.011
8.000	0.125	96	12	84	17.189
		120	15	105	21.486
8.211	0.122	156	19	137	27.852
8.400	0.119	84	10	74	14.961
8.571	0.117	120	14	106	21.327
8.667	0.115	156	18	138	27.693
8.727	0.115	96	11	85	17.030
9.176	0.109	156	17	139	27.534
9.231	0.108	120	13	107	21.168
9.600	0.104	96	10	86	16.870
9.750	0.103	156	16	140	27.375
10.000	0.100	120	12	108	21.008
10.400	0.096	156	15	141	27.215
10.909	0.092	120	11	109	20.849
11.143	0.090	156	14	142	27.056
12.000	0.083	120	10	110	20.690
		156	13	143	26.897
13.000	0.077	156	12	144	26.738
14.182	0.071	156	11	145	26.579
15.600	0.064	156	10	146	26.420

SECTION 22 CENTER DISTANCE FORMULAS

22.1 Nomenclature And Basic Equations

Figure 40 illustrates the notation involved.
The following nomenclature is used:

C = Center Distance (in)
L = Belt Length (in) = p·NB
p = Pitch of Belt (in)
NB = Number of Teeth on belt = L/p
N1 = Number of Teeth (grooves) on larger pulley
N2 = Number of Teeth (grooves) on smaller pulley
ϕ = one half angle of wrap on smaller pulley (radians)
θ = $\pi/2 - \phi$ = angle between straight portion of belt and line of centers (radians)
R1 = Pitch Radius of larger pulley (in) = (N1) p/2π
R2 = Pitch Radius of smaller pulley (in) = (N2) p/2π
π = 3.14159 (ratio of circumference to diameter of circle)

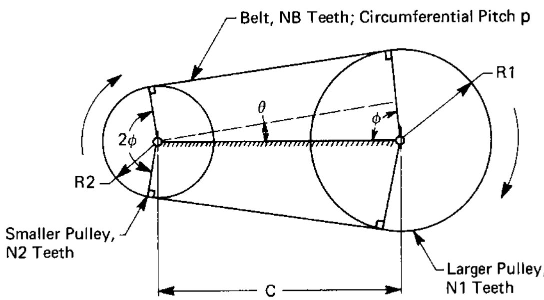

Figure 40 Belt Geometry

The basic equation for the determination of center distance is:

$$2C \sin\phi = L - \pi(R1 + R2) - (\pi - 2\phi)(R1 - R2) \quad \textbf{(22-1)}$$

where $C \cos\phi = R1 - R2$ **(22-2)**

These equations can be combined in different ways to yield various equations for the determination of center distance. We have found the formulations which follow useful.

22.2 Exact Center Distance Determination – Unequal Pulleys

The exact equation is as follows:

$$C = (1/2)p\,[(NB - N1) + k(N1 - N2)] \quad \textbf{(22-3)}$$

where $k = \left(\frac{1}{\pi}\right)\left[\tan\left(\frac{\pi}{4} - \frac{\phi}{2}\right) + \phi\right]$ **(22-4)**

and ϕ is determined from:

$$\left(\frac{1}{\pi}\right)(\tan\phi - \phi) = \frac{(NB - N1)}{(N1 - N2)} = Q \text{ (say)} \quad \textbf{(22-5)}$$

The value of k varies within the range ($1/\pi$, 1/2) depending on the number of teeth on the belt. All angles in **Equations** (**22-4**) through (**22-5**) are in radians.

The procedure for center distance determination is as follows:

1. Select values of N1, N2 (in accordance with desired transmission ratio) and NB.
2. Compute Q = (NB – N1)/(N1 – N2).
3. Compute ϕ by solving **Equation** (**22-5**) numerically.
4. Compute k from **Equation** (**22-4**).
5. Compute C from **Equation** (**22-3**).

22.3 Exact Center Distance Determination – Equal Pulleys

For equal pulleys, N1 = N2 and **Equation** (**22-3**) becomes:

$$C = \frac{p\,(NB - N1)}{2} \qquad \textbf{(22-6)}$$

22.4 Approximate Center Distance Determination

Approximate formulas are used when it is desirable to minimize computation time and when an approximate determination of center distance suffices.

An alternative to **Equation** (**22-1**) for the exact center distance can be shown to be the following:

$$C = \frac{p}{4}\left\{NB - \frac{(N1 + N2)}{2} + \sqrt{\left[NB - \frac{(N1 + N2)}{2}\right]^2 - \frac{2\,(N1 - N2)^2}{\pi^2}(1 + S)}\right\} \qquad \textbf{(22-7)}$$

where S varies between 0 and 0.1416, depending on the angle of wrap of the smaller pulley. The value of S is given very nearly by the expression:

$$S = \frac{(\cos^2\phi)}{12} \qquad \textbf{(22-8)}$$

In the approximate formulas for center distance, it is customary to neglect S and thus to obtain following approximation for C:

$$C = \frac{p}{4}\left\{NB - \frac{(N1 + N2)}{2} + \sqrt{\left[NB - \frac{(N1 + N2)}{2}\right]^2 - \frac{2\,(N1 - N2)^2}{\pi^2}}\right\} \qquad \textbf{(22-9)}$$

The error in **Equation** (**22-9**) depends on the speed ratio and the center distance. The accuracy is greatest for speed ratios close to unity and for large center distances. The accuracy is least at minimum center distance and high transmission ratios. In many cases, the accuracy of the approximate formula is acceptable.

22.5 Number Of Teeth In Mesh (TIM)

It is generally recommended that the number of teeth in mesh be not less than 6. The number, TIM, teeth in mesh is given by:

$$TIM = \lambda \cdot N2 \qquad \textbf{(22-10)}$$

where $\lambda = \frac{\phi}{\pi}$ when ϕ (see **Equation** (**22-5**)) is given in radians (see also the derivation given for TIM in this Handbook).

22.6 Determination Of Belt Size For Given Pulleys And Center Distance

Occasionally, the center distance of a given installation is prescribed and the belt length is to be determined. For given pitch, number of teeth on pulleys and center distance, the number of teeth of the belt can be found from the equation:

$$NB = \frac{(N1 + N2)}{2} + \frac{(N1 - N2)}{\pi} \sin^{-1}\left[\frac{(N1 - N2)p}{2\pi C}\right] + \sqrt{\left(\frac{2C}{p}\right)^2 - \left(\frac{N1 - N2}{\pi}\right)^2} \qquad \textbf{(22-11)}$$

where the arcsin is given in radians and lies between 0 and $\pi/2$. Since NB, in general, will not be a whole number, the nearest whole number less than NB can be used, assuming a slight increase in belt tension is not objectionable.

An approximate formula can be used to obtain the belt length:

$$L = 2C + \frac{(D1 - D2)^2}{4C} + 1.57 \times (D1 + D2) \qquad \textbf{(22-12)}$$

SECTION 23 CENTER DISTANCE FACTOR TABLES (TABLE 39)

TABLE 39

Definition:

The center distance factor is the center distance between two pulleys expressed in a dimensionless unit, which corresponds to the pitch of the pulley and the belt used.

How To Use:

Multiply the center distance factor by the pitch of the belt expressed in inch or metric unit. The number obtained will be the center distance expressed in the same (inch or metric) unit.

Nomenclature Used:

N1 = Number of teeth of larger pulley
N2 = Number of teeth of smaller pulley
NB = Number of teeth of belt used

Example:

From the Transmission Ratio Table, for N1/N2 = 1.750, N1 = 28 and N2 = 16 are chosen. From the same table we also note that N1 – N2 = 12 and C MIN = 7.003. Assume that NB = 80. Then, NB – N1 = 52. Refer to the Center Distance Factor Table for N1 – N2 = 12 and NB – N1 = 52 and obtain the center distance factor of 28.937 which is larger than the required minimum (C MIN = 7.003). Assuming the pitch of the belt to be 5 mm, the actual center distance in mm is 28.937 x 5 = 144.685 mm.
If 3 mm pitch belt is used, the center distance factor 28.937 has to be multiplied by 3, and a center distance of 86.811 mm is obtained.

Note:

For the Center Distance Finder Formular please visit **www.sdp-si.com**. The printed book continues with 64 pages representing the exact solutions of **Equation** (**22-3**) divided by the pitch, p, for various values of (N1 – N2) and (NB – N1).