Development of Early Roller Chain

As the industrial revolution gained pace, the need for higher performance chain ensured that the product did not stand still. A quick look at the 1880 patent would give the impression that there is no difference between it and modern chain.

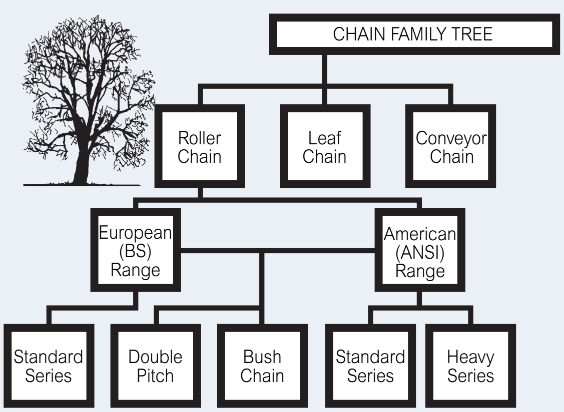
In concept, this is true. However, early chain performance was very much constrained by design knowledge, material sophistication, and production processes. For example, in order to achieve a close tolerance on round parts, Hans Renold also pioneered centerless grinding and, at one time, had a whole section devoted to grinding cold drawn bar to size before further processing.

The shortcomings of available technology meant that, compared with modern chain, there were low strength to weight ratios, erratic pitch control, poor engagement characteristics, and a tendency toward point loading; causing high bearing pressures, wear, and failure. The ever-increasing number of applications for chain resulted in a continuous refinement of our production processes and the introduction of heat treatment, improving Renold Chain to meet these new and arduous demands.

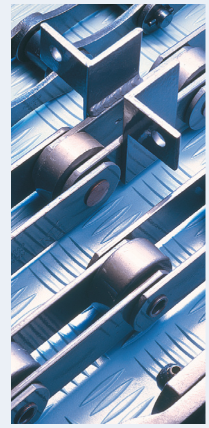
Modern Chain

Today there is a very wide range of chain products available. Some of these are special low-volume products, for example, nuclear-waste-handling chain. Motorcycle chain and other high-volume products are an offshoot of one of the key groups shown below.

At the top level of the chain groups, conveyor chain is perhaps the most difficult to compartmentalize, since most types of chain can be used to convey. There is, however, a range of so-called conveyor chain products typified by their long pitch, large roller diameter, and emphasis on tensile strength rather than fatigue life.







Offset link chain, like conveyor chain, is intended to run only at low speeds, since the presence of an offset link plate will reduce fatigue life. This chain tends to be used in conveying applications where harsh environmental conditions prevail, in mineral excavation, for example.

Leaf chain is similar in construction to the old Galle chain, except that plates are interleaved in various configurations right across the width of the pin. This means that there is no way of providing sprocket engagement and the chain can only be used to transmit force through suitably anchored ends. Chains are guided around simple plain pulleys. Perhaps the best example of the use of leaf chain is in the lifting mechanism of a forklift truck.

This leaves the most important group of chain, the European and American series of transmission roller chain. The European (from the British Standard) range grew out of the early pioneering work of Hans Renold, as mentioned previously, and the size of components through this range therefore reflected a growing understanding of chain design and likely was influenced by the availability of stock material sizes. The American, or ANSI, range, which came later, has a clear mathematical theme, whereby the sizes of components are calculated in accordance with expressions now quoted in the ANSI standard B29.1. The ANSI range of chain is shadowed by a range of similar chains, heavy series, which use the side plate material from the chain of the next highest size. This results in a range of chains with higher fatigue life but not necessarily higher tensile strength, since the pin diameters are unchanged.

Both European and ANSI ranges of chain are available in double pitch and rollerless chain forms. Double pitch is primarily another form of conveyor chain that uses the round parts from a standard chain, but has twice the pitch.

Rollerless chain is simply roller chain without a roller and is also the only design configuration possible on very small pitch chain, such as 4mm and ANSI 25 or 1/4-inch pitch. Rollerless chain is used for lightly loaded applications or those requiring only direct pull.

Modern chain has features that enable demanding applications to be tackled with ease. These include high wear and fatigue resistance, as well as transmission efficiency of approximately 98 percent.

Chain is also now manufactured in multiple strands joined together by a common pin, giving more scope for increased power transmission in restricted space. The range of products — now available with alternative materials, special coatings, endless varieties of attachments, hollow bearing pins, and anti-backbend, to name just a few — give scope for the widest portfolio of design solutions imaginable. Renold Jeffrey's experienced technical staff is available to consult with you as to which design solutions are the most appropriate for your specific use.

Together with improvements to factory-applied greases and better understanding of applications, designers can now specify transmission chain with confidence.

Chain Performance

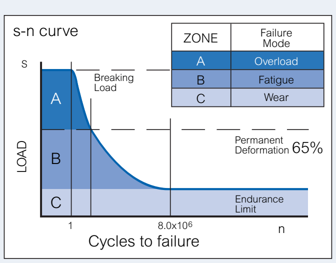
Renold Jeffrey chain products that are dimensionally in line with the ISO standards far exceed the stated minimum tensile strength requirements. However Renold does not consider breaking load to be a key indicator of performance because it ignores the principal factors of wear and fatigue. In these areas, Renold products are designed to produce the best possible results and independent testing proves this.

In this catalog, where the breaking load is quoted, it should be noted that we are stating that the Renold product conforms to the ANSI minimum standard. Independent test results show that the minimum (many companies quote averages) breaking loads were far in excess of the ISO minimum.

Where the quoted breaking load is not described as being the ANSI minimum, the product has no relevant ISO standard. In this case, the breaking loads quoted are the minimum guaranteed.

The performance of a chain is governed by a number of key factors. The tensile strength is the most obvious since this is the means by which a chain installation is roughly sized. However, since a chain is constructed from steel, the yield strength of which is around 65 percent of the ultimate tensile strength, any load above this limit will cause some permanent deformation to take place with consequent rapid failure.

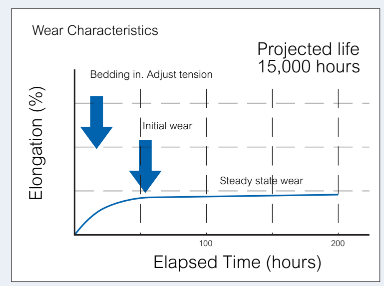
Reference to the s-n curve below shows that at loads below this 65 percent line, finite life may be expected, and, at subsequent reductions in load, the expected life increases until the fatigue endurance limit is reached at around 8,000,000 operations.



Loads below the endurance limit will result in infinite fatigue life. The failure mode will then become wear related, which is far safer, since a controlled monitor of chain extension can take place at suitable planned intervals. In practice, if a load ratio of tensile strength to maximum working load of 8:1 is chosen, then the endurance limit will not normally be exceeded. Careful consideration of the expected maximum working loads should be given since these are often much higher than the designer may think! It is also a requirement that any passenger lift applications are designed with a safety factor of not less than 10:1.

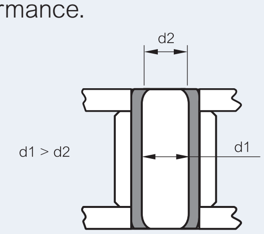
In most applications, wear is the designed failure mode and therefore, some consideration of how a chain behaves in this mode are shown below.

Examination of the wear characteristics graph below shows that chain tends to wear in three distinct phases. The first phase, shown as “bedding in,” is a very rapid change in chain length associated with components adjusting to the loads imposed on them. The degree of this initial movement will depend to a large extent on the quality of chain used — for example, good component fits, chain pre-loaded at manufacture, plates assembled squarely, etc. Renold Chain has many features that minimize the degree of bedding in.



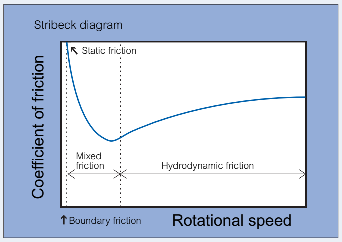
The second phase, shown as “initial wear,” might also be described as secondary bedding in. This is caused first by the rapid abrasion of local high spots between the mating surfaces of the pin and bushing, and secondly, by displacement of material at the bushing ends. This is explained more clearly by the inner link assembly diagram shown, which demonstrates that in order to ensure good fatigue life, the bushing and plate have a high degree of interference fit resulting in a tendency of the bushing ends to collapse inwards slightly. This localized bulge will wear rapidly until the pin bears equally along the length of the bushing. Renold limits this effect by introducing special manufacturing techniques. Some manufacturers maintain cylindricity by reducing the interference fit to a very low level. This reduces fatigue performance.

The final steady state of wear will continue at a very low rate until the chain needs renewal. In a correctly designed and lubricated system, 15,000 hours of continuous operation should be expected.



Tendency of bushing to collapse at assembly

The reason why wear takes place at all is demonstrated with reference to the Stribeck diagram below. It shows that where two mating surfaces are in contact, the coefficient of friction is very high at the point of initial movement, known as static friction. The reason for this is because the surface irregularities of the two bodies are interlocked with little or no separating lubrication layer. As the surface speeds increase, lubricant is drawn between the two surfaces and friction takes place with some surface contact. This condition is known as "mixed friction." These two conditions result in material loss over time. With a continuing increase in surface speed, hydrodynamic friction occurs during which there is no metal-to-metal contact.



If we consider the action of the mating surfaces of the bushing and pin during one cycle of a two-sprocket system, it will quickly be realized that these components are stationary with respect to each other during travel from one sprocket to the other, and accelerate rapidly through a very small angle when engaging with the sprocket before coming to rest once more. This means that the pin/bushing combination is operating between the static and mixed friction states and that lubrication will therefore be an important aspect of system design.

Wear Factors

As already shown, wear takes place from the friction between the mating of the pin and bushing. The rate of wear is primarily determined by the bearing area and the specific pressure on these surfaces. The hardened layers of the pin and bushing are eroded in such a way that the chain will become elongated.

ELONGATION may amount to a MAXIMUM of 2 percent of the nominal length of the chain. Above 2 percent elongation, there can be problems with the chain riding up and jumping the sprocket teeth.

Elongation should be limited to 1 percent when:

- A sprocket in the system has 90 teeth or more.
- Perfect synchronization is required.
- Center distances are greater than recommended and not adjustable.

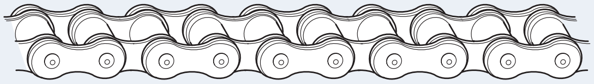
When the demands of the system become even higher, it is necessary to reduce the allowable percentage of elongation further.

Wear depends on the following variables in a drive system:

- SPEED - The higher the speed of a system, the higher the frequency of bearing articulations, so accelerating wear.
- NUMBER OF SPROCKETS - The more sprockets used in a drive system, the more frequently the bearings articulate.
- NUMBER OF TEETH - The fewer the number of teeth in a sprocket, the greater the degree of articulation, the higher the wear.
- CHAIN LENGTH - The shorter the length of chain, the more frequently the bearings in the chain will have to operate, the faster wear takes place.
- LUBRICATION - As already shown, using the correct lubrication is critical to giving good wear life.

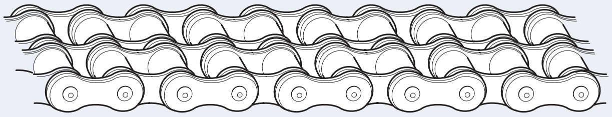
Chain Types

SINGLE-STRAND CHAIN



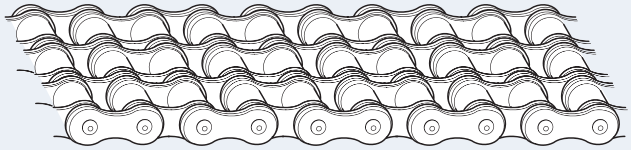
STANDARD ISO 606 ANSI B29.1

DOUBLE-STRAND CHAIN



STANDARD ISO 606 ANSI B29.1

TRIPLE-STRAND CHAIN



STANDARD ISO 606 ANSI B29.1

As with all engineered products, industry demands that chain be produced to a formal standard. The key roller chain standards are summarized on page 218.

International Standards

European Standard

ISO 606 and DIN 8187 cover chains manufactured to the above standards. These standards cover three versions:

- Single-Strand
- Double-Strand
- Triple-Strand

The range of pitch sizes can vary from 4mm (0.158 inch) to 114.3mm (4.500 inch).

They are characterized by a large pin diameter, especially for the larger pitch sizes. This results in better wear resistance due to the greater bearing area.

The ISO standard has a simple form of part numbering, for example, 1/2-inch pitch double-strand chain would be 08B-2.

- The first two digits are the pitch size in 1/16ths of an inch, therefore 08 = 8/16 or 1/2 inch.
- The letter B indicates European Standard.
- The suffix “2” indicates the number of strands in the chain, in this case a double-strand chain.

American Standard

American standard chains are covered by ISO 606, ANSI B29.1, and DIN 8188. Eight versions are covered.

- Single-Strand
- Double-Strand
- Triple-Strand
- Multiple-Strand (4-, 5-, 6-, 8-, and 10-strand)

The pitch sizes covered by this standard are 1/4 to 3 inch pitch.

American standard chains have a smaller pin diameter than their European standard equivalent. Wear resistance is therefore reduced when compared with European standard chains, with one exception, 5/8-inch pitch. In this case the pin and bushing diameter is larger in American standard chain.

American standard chains are normally referred to under the ANSI standard numbering system, for example, a 1/2-inch pitch double-strand chain would be ANSI 40-2.

The ANSI numbering system works as follows:

- The first number is the pitch size in 1/8ths of an inch, i.e., 4/8 = 1/2-inch pitch.
- The second number indicates that the chain is a roller chain (0 = roller chain). A “5” instead of a “0” indicates a rollerless chain.
- The suffix, as with European standard chain, refers to the number of strands in the chain, i.e., 2 = double-strand chain.

ANSI chain is also available in heavy-duty options with thicker plates (H) and through-hardened pins (V). An ANSI heavy-duty chain would be specified using these suffixes:

i.e. ANSI 140-2HV	Double-strand, thick plates, through hardened pin
ANSI 80H	Single-strand, thick plates

Range of Application

The roller chain market worldwide is divided between these two chain standards, based on the economic and historical influences within their regions.

- American standard chain is used primarily in the USA, Canada, Australia, Japan, and some Asiatic countries.
- European standard chains dominate in Europe, the British Commonwealth, Africa, and Asian countries with a strong British historical involvement.

In Europe, approximately 85 percent of the total market uses European standard chain. The remaining 15 percent are American standard chains found on:

- Machinery imported from countries where American standard chain dominates.
- Machinery manufactured in Europe under license from American-dominated markets.

Chain Not Conforming to ISO Standards

There are also Renold Jeffrey manufacturing standards for special or engineered chain, which can be categorized as follows:

1. HIGHER BREAKING-LOAD CHAIN – This chain usually has plates that undergo a special treatment, has thicker side plate material and/or pin diameters that slightly deviate from the standards.
2. SPECIAL DIMENSIONS – Some chains can be a mixture of American and European standard dimensions or have inner widths and roller diameters that vary, such as in motorcycle chains.
3. APPLICATIONAL NEEDS – Special or engineered chain is manufactured for specific applications, examples being:
    - Stainless steel chain
    - Zinc- or nickel-plated chain
    - Chain with plastic lubricating bushings
    - Chains with hollow bearing pins
    - Chain that can bend sideways, (Sidebow chain)

In applications requiring a special or engineered chain, contact our technical sales staff for more information.

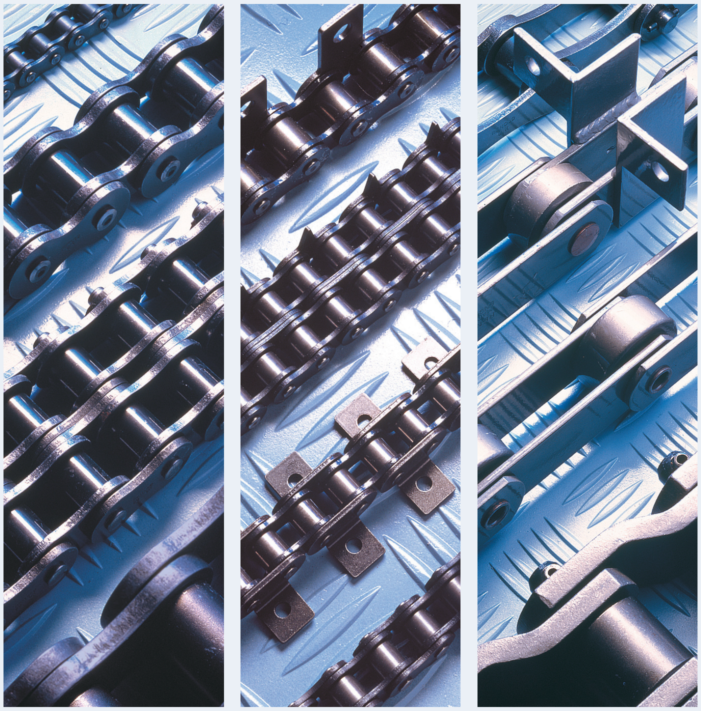
Standards Reference Guide

Roller Chain Types

	ISO	ANSI	OTHER
Short Pitch Roller Chain and Sprockets	606	B29.1M DIN8188	DIN8187
Short Pitch Rollerless Chains and Sprockets	1395	—	DIN8154
Double Pitch Roller Chain and Sprockets	1275	B29.3M	DIN8181
Oilfield Chain and Sprockets	606	B29.1M	API Spec 7F
Cycle Chains	9633	—	—
Motorcycle Chains	10190	—	—
Offset Link Chain and Sprockets	3512	B29.1M	DIN8182

Lifting Chain Types

	ISO	ANSI	OTHER
Leaf Chain, Clevises, and Sheaves	4347	B29.8M	DIN8152
Roller Load Chains for Overhead Hoists	—	B29.24M	—



Advantages of Chain Drives

Steel transmission roller chain is made to close tolerances with excellent joint articulation, permitting a smooth, efficient flow of power. Any friction between the chain rollers and sprocket teeth is virtually eliminated because the rollers rotate on the outside of the bushings, independent of bearing pin articulation inside the bushing. As a result, very little energy is wasted. Tests have shown chain to have an efficiency of between 98.4 and 98.9 percent.

This high level of efficiency, achieved by a standard stock chain drive under the correct conditions of lubrication and installation, is equaled only by gears of the highest standard, with teeth ground to very close tolerances.

Roller chain offers a positive, non-slip, driving medium. It provides an accurate pitch-by-pitch positive drive, which is essential on synchronized drives, such as those to automobile and marine camshafts, and packaging and printing machinery. Under conditions of high speed and peak load when efficiency is also required, roller chain has proved consistently quiet and reliable.

Center distances between shafts can range from about two inches (50mm) to more than 29 feet (9 meters) in a very compact installation envelope. Drives can be engineered so that the sprocket teeth just clear each other or so that the chain traverses a considerable span. In this later category, double pitch chain comes into its own.

Roller chain has a certain degree of inherent elasticity, and this, plus the cushioning effect of an oil film in the chain joints, provides good shock absorbing properties. In addition, the load distribution between a chain and sprocket takes place over a number of teeth, which assists in reducing wear. When, after lengthy service, it becomes necessary to replace a chain, the procedure is simple and does not normally entail sprocket or bearing removal.

Roller chain minimizes loads on the drive motor and driven shaft bearings since no pre-load is required to tension the chain in the static condition.

One chain can drive several shafts simultaneously and in almost any configuration of center distance or layout. Its adaptability is not limited to driving one or more shafts from a common drive point. It can be used for a wide variety of devices, including reciprocation, racks, cam motions, internal or external gearing, counterbalancing, hoisting, or weight suspension. Segmental tooth or “necklace” chain sprocket rims can be fitted to large diameter drums.

Since there are no elastomeric components involved, chain is tolerant of a wide variety of environmental conditions, including extremes of temperature. Chain is used successfully in such harsh environments as chemical processing, mining, baking, rock drilling, and wood processing. Renold Jeffrey representatives are available for consultation.

Roller chain can also be fitted with link plate attachments, extended bearing pins, etc., which allow it to be used for mechanical handling equipment and the operation of mechanisms. These attachments are detailed in this catalog.

Roller chain drives are available for ratios up to 9:1 and to transmit up to 697 hp at 550 rpm. Beyond this, four matched strands of triple-strand chain can achieve 4,288 hp at 300 rpm.

Roller chain does not deteriorate with the passage of time; the only evidence of age being elongation due to wear, which normally is gradual and can be accommodated by center distance adjustment or by an adjustable idler sprocket. Provided that a chain drive is selected correctly and properly installed and maintained, a life of 15,000 hours can be reasonably expected without chain failure from either fatigue or wear. Where complete reliability and long life are essential, chains can be selected on their expected performance for applications such as hoists for control rods in nuclear reactors and control systems for aircraft.

Chain is a highly standardized product available in accordance with ISO Standards all over the world. It is also totally recyclable and causes no harmful effects to the environment.

Shown below is a simple table comparing the merits of different transmission/lifting media.

Summary of Advantages

FEATURES	GEARS	ROPE	BELT	CHAIN
Efficiency	A	X	B	A
Positive drive	A	X	B	A
Center distance	C	A	B	A
Elasticity	C	A	A	B
Wear resistance	A	C	B	A
No pre-load	A	C	C	A
Multiple drives	C	X	C	A
Heat resistant	B	B	C	A
Chemical resistant	B	A	C	A
Oil resistant	A	A	C	A
Adaptations	C	B	C	A
Power range	A	X	B	A
Ease of maintenance	C	B	B	A
Standardized	C	B	B	A
Environment	A	A	C	A

A = Excellent
B = Good
C = Poor
X = Not appropriate

Chain Selection

The notes given below are general recommendations and should be followed in the selection and installation of a chain drive, in order that satisfactory performance and drive life may be ensured.

Chain Pitch

The Quick Selector Chart (page 234) gives the alternative sizes of chains that may be used to transmit a load at a given speed. The smallest pitch of a single-strand chain should be used, as this normally results in the most economical drive. If the single-strand chain does not satisfy the requirements dictated by space limitations, high speed, quietness, or smoothness of running, then consider a smaller pitch of double-strand or triple-strand chain.

When the power requirement at a given speed is beyond the capacity of a single strand of chain, then the use of multi-strand drives permits higher powers to be transmitted.

These drives can also be made up from multiples of matched single-, double-, or triple-strand ISO chains, or in the case of ANSI chain, multi-strand chain of up to 10 strands are available.

Please consult our technical staff for further information.

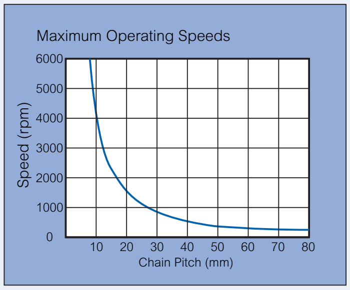
Maximum Operating Speeds

For normal industrial drives, experience has established a maximum sprocket speed for each pitch of chain. These speeds, which relate to driver sprockets having 17 to 25 teeth inclusive, are given in the graph below; they are applicable only if the method of lubrication provided is in line with recommendations.

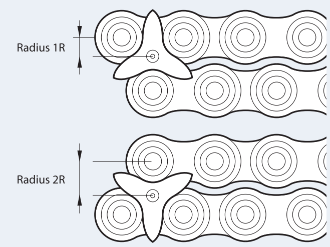
Polygonal Effect

Four important advantages of a chain drive are dependent directly upon the number of teeth in the driver sprocket.

The advantages are smooth uniform flow of power, quietness of operation, high efficiency, and long life; the reason for their dependence being that chain forms a polygon on the sprocket. Thus, when the sprocket speed is constant, the chain speed (due to the many-sided shape of its path around the teeth) is subject to a regular cyclic variation. This cyclic variation becomes less marked as the path of the chain tends towards a true circle and, in fact, becomes insignificant for most applications as the number of teeth in the driver sprocket exceeds 19.

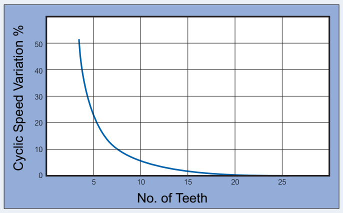


The effect of this cyclic variation can be shown in the extreme case of a driver sprocket with the absolute minimum number of teeth, i.e. three. In this instance, for each revolution of the sprocket, the chain is subjected to a three-phase cycle; each phase being associated with the engagement of a single tooth. As the tooth comes into engagement, for a sixth of a revolution the effective distance, or driving radius, from the sprocket center to the chain is gradually doubled; for the remaining sixth of a revolution, it falls back to its original position. Thus, as the linear speed of the chain is directly related to the effective driving radius of the driver sprocket, the chain speed fluctuates by 50 percent six times during each revolution of the driver sprocket.



As the graph below shows, the percentage of cyclic speed variation decreases rapidly as more teeth are added. With a driver sprocket of 19 teeth, therefore, this cyclic speed variation is negligible; hence we recommend that driver sprockets used in normal application drives running at medium to maximum speeds should not have less than 19 teeth.

There are, however, applications where space saving is a vital design requirement and the speed/power conditions are such that the smaller numbers of teeth (i.e., less than 17) give acceptable performance, so that a compact, satisfactory drive is achieved, i.e., office machinery, hand operated drives, mechanisms, etc.



The limiting conditions with steady loading for using small numbers of teeth are:

Number of Teeth	Percentage of Maximum Rated Speed	Percentage of Maximum Rated Power
11	20	30
13	30	40
15	50	60
17	80	90

Sprocket and Chain Compatibility

Most drives have an even number of chain pitches and, by using a driver sprocket with an odd number of teeth, uniform wear distribution over both chain and sprocket teeth is ensured. Even numbers of teeth for both the driver and driven sprockets can be used, but wear distribution on both the sprocket teeth and the chain is poor.

Number of Teeth

The maximum number of teeth in any driven sprocket should not exceed 114. This limitation is due to the fact that for a given elongation of chain due to wear, the working pitch diameter of the chain on the sprocket increases in relation to the nominal pitch diameter, i.e., the chain assumes a higher position on the sprocket tooth. The allowable safe chain wear is considered to be in the order of 2 percent elongation over nominal length.

A simple formula for determining how much chain elongation a sprocket can accommodate is

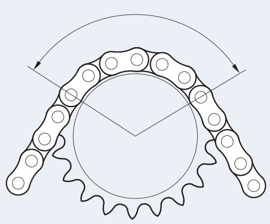
$$\frac{200}{N}$$

expressed as a percentage where N is the number of teeth on the largest sprocket in the drive system.

It is good practice to have the sum of teeth not less than 50, where both the driver and driven sprockets are operated by the same chain, i.e., on a 1:1 ratio drive, both sprockets should have 25 teeth each.

Center Distance

For optimum wear life, center distance between two sprockets should normally be within the range 30 to 50 times the chain pitch. On drive proposals with center distances of less than 30 pitches or greater than 6.6 feet (2 m), discuss the drive details with our technical staff.



Minimum 6 Teeth

The minimum center distance is sometimes governed by the amount of chain lap on the driver sprocket. Our normal recommendation in this circumstance is not less than 6 teeth in engagement with the chain.

The center distance is also governed by the desirability of using a chain with an even number of pitches to avoid the use of an offset link, a practice that is not recommended except in special circumstances.

For a drive in the horizontal plane, the shortest center distance possible should be used consonant with recommended chain lap on the driver sprocket.

Recommended center distances for drives are:

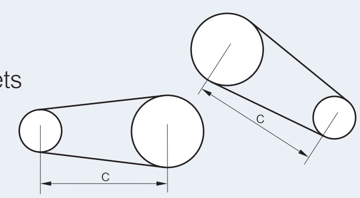
Pitch	inch	3/8	1/2	5/8	3/4	1	1-1/4
	mm	9.525	12.70	15.87	19.05	25.40	31.75
Center	inch	17.715	23.622	29.528	35.433	39.370	47.244
Distance	mm	450	600	750	900	1000	1200
Pitch	**inch**	**1-1/2**	**1-3/4**	**2**	**2-1/2**	**3**	
	mm	**38.10**	**44.45**	**50.80**	**63.50**	**76.20**	
Center	inch	53.150	59.055	66.929	70.866	78.740	
Distance	mm	1350	1500	1700	1800	2000	

Lie of Drive

Drives may be arranged to run horizontally, inclined, or vertically. In general, the loaded strand of the chain may be uppermost or lowermost, as desired. Where the lie of the drive is vertical, or nearly so, it is preferable for the driver sprocket to be above the driven sprocket; however, even with a drive of vertical lie, it is quite feasible for the driver sprocket to be lowermost, provided care is taken that correct chain adjustment is maintained at all times.

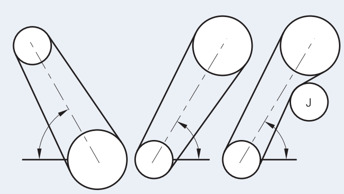
CENTERS

The center distance between the axis of two shafts or sprockets



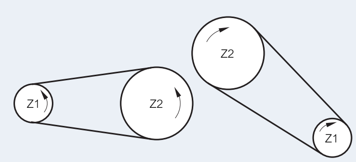
ANGLE

The lie of the drive is given by the angle formed by the line through the shaft centers and a horizontal line



ROTATION

Viewed along the axis of the driven shaft, the rotation can be clockwise or anti-clockwise

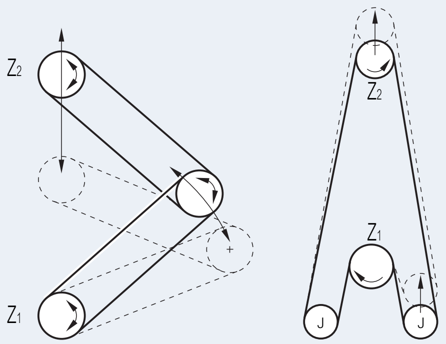


Drive Layout

One chain can be used to drive a number of shafts and due to the ability of roller chains to gear on either face, individual shafts in the same drive can be made to rotate in the same or opposite directions by arranging the driven sprockets to gear in different faces of the chain. The number of driven sprockets permissible in any one drive depends on the layout.

A selection of possible drive layouts is shown below.

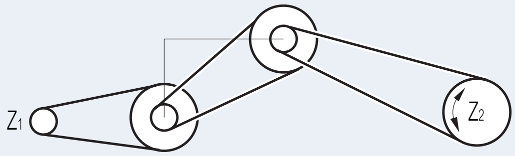
DRIVES WITH VARIABLE SHAFT POSITIONS



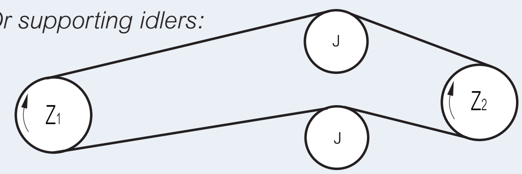
Floating countershaft and floating idler
CHAIN LAP - Recommended 120°. Minimum of 90° permissible for sprockets of 27 teeth or more.
CENTERS - Pitch of chain multiplied by 30 to 50.

DRIVES WITH ABNORMALLY LONG CENTERS

Could incorporate countershafts:

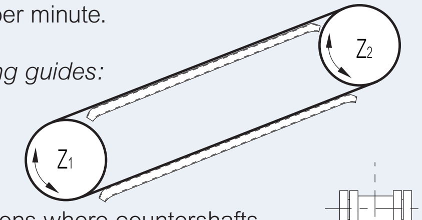


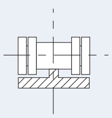
Or supporting idlers:



For slow and medium chain speed applications up to 492 feet per minute.

Or supporting guides:

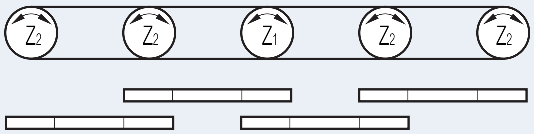




For applications where countershafts or supporting idlers cannot be employed and where the chain speed does not exceed 197 feet per minute.

MULTI-SHAFT DRIVES

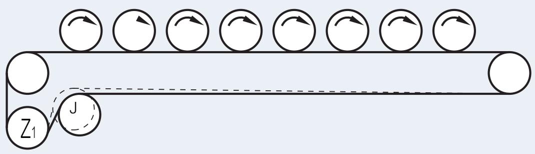
The permissible number of driven shafts will vary according to drive characteristics.
Five sprockets coupled by four simple drives:



The efficiency of a single-stage drive is approximately 98%. However, if a series of drives are interconnected (as in live roller conveyors), the overall efficiency will vary with the number of drives involved. It is necessary in applications of this nature to increase the calculated motor power to allow for this reduced efficiency.

4 drives overall efficiency = 94%
8 drives overall efficiency = 87%
12 drives overall efficiency = 80%

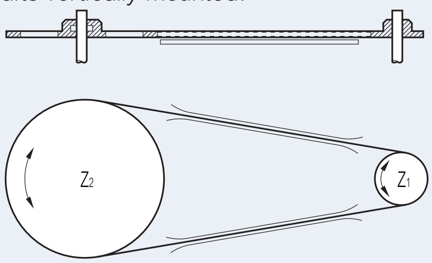
Eight shafts rotated by a single chain with high efficiency but reduced tooth contact:



The idler is used to ensure adequate chain lap on the driven sprockets.

HORIZONTAL DRIVES

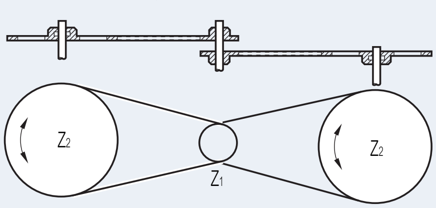
Two shafts vertically mounted:



Plan

When centers are long, use guide strips to support chain strands with generous “lead-in” to ensure smooth entry and exit of chain.

Three shafts vertically mounted:

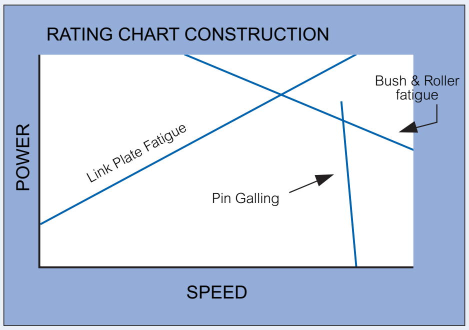


Plan

CHAIN LAP - Recommended 120°. Minimum of 90° permissible for sprockets of 27 teeth or more.
CENTERS - Shortest possible

Quick Selector Chart Construction

The Quick Selector Chart (page 234) may appear complicated at first glance, however, it is constructed from three simple lines. At lower speeds, the failure mode is likely to be plate fatigue if the maximum power recommendation is exceeded. However, pin galling will occur due to boundary lubrication break-down at very high speeds. At the intersection of these lines, the bush and roller fatigue curve comes into play and accounts for the rounded tops to each of the selection curves.



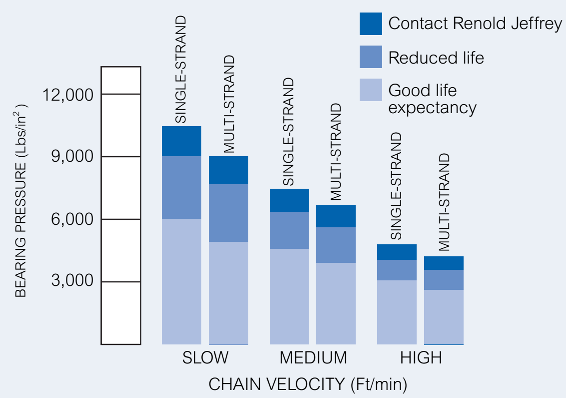
Bearing Pressures

When a chain has been correctly selected, the mode of failure over a very long period of time is most likely to be wear.

The subject of wear, which depends on many factors, has been addressed earlier in this guide. However, a very useful indicator of chain performance is the magnitude of pressure between the key mating surfaces (i.e., pin and bush).

This pressure is known as the bearing pressure and is obtained by dividing the working load by the bearing area. Bearing areas for standard chains are quoted in the designer data at the end of this guide.

The following table gives an indication of the implications of various bearing pressures but should not be used without reference to the other chain selection methods given in this guide.



Slow velocity up to 60% of maximum allowable speed
Medium velocity 60 to 80% of maximum allowable speed
High velocity more than 80% of maximum allowable speed

Note: There is some variation between chains. The above figures should be used as a guide only.

Lifting Applications

This section covers applications such as lifting and moving, where the loads involved are generally static. Obviously, dynamic loads are also involved in most applications and the designer needs to take due consideration of these. The machinery designer should also refer to DTI Publication INDY J1898 40M, which summarizes legislation in place from January 1, 1993 and January 1, 1995 regarding machinery product standards.

Chain for lifting applications falls into two main categories:

- Leaf Chain
- Bush/Roller Chain

Leaf Chain

Leaf chain is generally used for load-balancing lifting applications as illustrated below. They must be anchored at either end since there is no means of geared engagement in the chain itself.

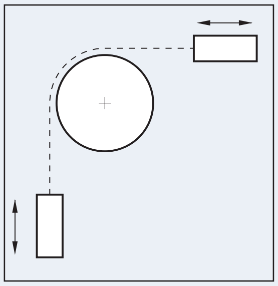
Safety Factors

A safety factor of 7:1 is normal for steady-duty reciprocating motion, i.e., fork lift trucks. For medium shock loads, the ratio is 9:1 and for heavy shock loads, 11:1.

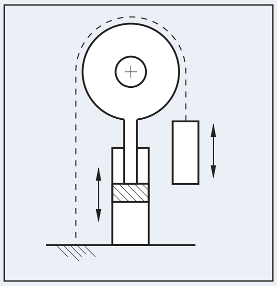
Operating Speed

Applications should not exceed a maximum chain speed of 98 feet/min (30 meters/min).

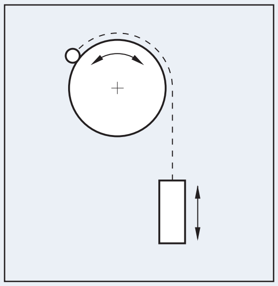
Applications



1. Machine Tools - Planers, Drills, Milling Heads, Machine Centers.



2. Fork Lift Trucks, Lifts, Hoists.



3. Counterweight Balances - Jacks, Doors, Gates, etc.

Roller and Rollerless Chains

Roller and rollerless chains can be used for lifting and moving purposes and have the advantage over leaf chain in that they may be geared into a suitable driving sprocket. Roller chain has a better wear resistance than leaf chain and may be used at higher speeds.

Safety Factors

Applications vary widely in the nature of loads applied, therefore, apply safety factors to allow for some degree of abuse.

A factor of safety of 8:1 in non-passenger applications
A factor of safety of 10:1 in passenger applications

Lower safety factors may not be used in passenger applications. In non-passenger applications and after careful consideration of maximum loads and health and safety implications, lower safety factors may be used. See the section "Influences on Chain Life" below or contact Renold Jeffrey technical staff.

Operating Speeds

Applications should not normally exceed a maximum chain speed of 148 feet/min (45 meters/min). For higher speeds, consider selection as if the chain were in a power drive application converting the chain load to horsepower using the following formula:

$$\text{POWER (HP)} = \frac{FV}{33,000}$$

Where: F = Lbs.
V = Ft./min.

Then apply service factors as shown in Step 2 of Roller Drive Chain Selection on page 231.

Calculate equivalent RPM by using the smallest sprocket in the system and the following formula:

$$\text{SPEED} = \frac{12V}{PZ}$$

Where: P = Chain pitch (in.)
Z = No of teeth in small sprocket
V = Ft./min.

Select lubrication methods.

ANSI H and HV Series

Drive chain is also available in heavy-duty versions of the ANSI standard range of chain.

These chains are suitable where frequent load reversals are involved. Typical applications are in primary industries such as mining, quarrying, rock drilling, forestry, and construction machinery.

In order to accommodate these higher fatigue-inducing loads, material for inner and outer plates is increased in thickness by approximately 20 percent.

This modification does not improve the tensile strength since the pin then becomes the weakest component. However, heavy-duty chains with higher tensile strength are available. These chains feature through-hardened instead of case-hardened pins, however, wear performance is reduced due to the lower pin hardness.

Renold ANSI H and HV chains are available as follows:

H Series - Thicker plates
HV Series - Thicker plates and through-hardened pins

The H and HV chains are not suitable for high-speed drive applications.

It should also be noted that single-strand chains of standard, H, or HV designs all have identical gearing dimensions and therefore can operate on the same sprockets as standard chains. The thicker plates require a larger chain track, and it may be desirable to use sprockets with heat-treated teeth. Multi-strand chain requires an increased transverse pitch of the teeth but other gearing dimensions are the same.

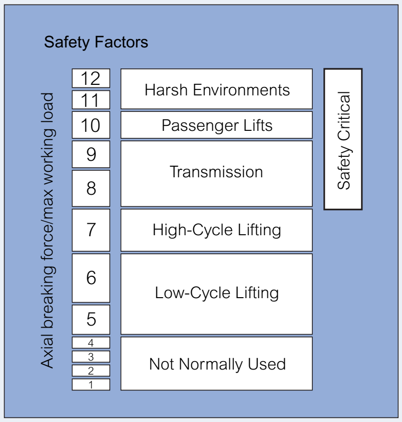
Influences on Chain Life

Factors of Safety

All Renold Chain is specified by its minimum tensile strength. To obtain a design working load it is necessary to apply a "FACTOR OF SAFETY" to the breaking load. However, before considering this, the following points should be noted:

- Most chain side plates are manufactured from low- to medium-carbon steel and are sized to ensure they have adequate strength and ductility to resist shock loading.
- These steels have yield strengths of approximately 65 percent of their ultimate tensile strength. This means that if chains are subjected to loads of greater than this, depending upon the material used in the side plates, then permanent pitch extension will occur.
- Most applications are subjected to intermittent dynamic loads well in excess of the maximum static load and usually greater than the designer's estimate.
- Motors, for example, are capable of up to 200 percent full load torque output for a short period.

As a result, chain confidently selected with a factor of safety of 8:1 on breaking load is, in effect, operating with a factor of safety of around 5:1 on yield and much less than this when the instantaneous overload on the drive is considered.



A further consideration when applying a factor of safety to a chain application is the required chain life.

In a properly maintained application, normal service life is expected to be approximately 8,000,000 cycles or 15,000 hours, whichever comes first. Wear will be the usual mode of failure.

In applications where low factors of safety are required, the service life will be reduced accordingly.

The maximum working load is obtained by dividing the chain minimum tensile strength by the factor of safety.

The table below gives a rough indication of life for various factors of safety.

Factor		Cycles Maximum	Type of Application
Single-strand	Multi-strand		
5.0 6.0	6.0 7.2	1,000,000 2,000,000	Dynamic load does not exceed working load
8.0	8.0	8,000,000	Dynamic loads can occasionally exceed working load by 20%
10.0	10.0	8,000,000	All passenger lifts

It should be noted that at factors below 8:1, bearing pressures increase above the maximum recommended. As a result, increased wear will arise unless special attention is taken with lubrication, i.e.:

- More frequent lubrication
- Higher-performance lubricants
- Better methods of applying lubrication

It is uncertain to what extent such lubrication may slow the increased wear rate.

Important Note

For factors of 5:1, the resulting bearing pressure is 50 percent higher than recommended. Chain working under these conditions will wear prematurely, despite the type of lubrication regime used.

Harsh Environments

In anything other than a clean and well-lubricated environment, the factor of safety should be adjusted if some detriment to the working life of the chain is to be avoided. Low temperatures will also decrease working life, especially if shock loads are involved.

The following tables give a general guide to the appropriate safety factors for different applications for a target life of approximately 8,000,000 cycles.

Lubrication	Cleanliness		
	Clean	Moderately Clean	Dirty/Abrasive
Regular	8	10	12
Occasional	10	12	14
None	12	12	14

Lubrication	Temperature (ºF)		
	+50 to 300	300 to 390	390 to 570
Regular	8	10	12
Occasional	10	12	14
None	12	12	14

Temperature (ºF)	Load Regime		
	Smooth	Moderate Shocks	Heavy Shocks
+50 to 300	8	11	15
32 to 50	10	15	19
-5 to 32	12	20	25
-40 to –5	15	25	33

Chain Extension

When designing lifting applications, it can be useful to know how much a chain will extend under a given load.

The approximate elongation of a chain under a given load can be measured by using the following formulas.

- Single-strand Chain $$\Delta L = \frac{(1.00)\ .10^{-6}.L}{p^2}.F_1$$
- Double-strand Chain $$\Delta L = \frac{(6.70).10^{-7}\ .L}{p^2}.F_1$$
- Triple-strand Chain $$\Delta L = \frac{(5.00)\ .10^{-7}\ .L}{p^2}.F_1$$

Where:
ΔL = Change in chain length (in.)
L = Original length of the chain (in.)
P = Pitch of the chain (in.)
F_1 = Average load in the chain (lbs.)

Matching of Chain

Any application in which two or more strands of drive chain are required to operate side by side in a common drive or conveying arrangement may involve the need for either pairing or matching. Such applications generally fall into one of the following categories :

Length Matching for Conveying and Similar Applications
When length matching of drive chain is necessary, it is dealt with as follows:

- The chains are accurately measured in handling lengths between 10 ft. and 27 ft. (3m to 8m), as appropriate, and then selected to provide a two-or-more-strand drive having overall length uniformity within close limits. Such length uniformity will not necessarily apply to any intermediate sections along the chains, although actual length of all intermediate sections, both along and across the drive, will not vary more than our normal manufacturing limits. However, adapted drive chains are usually manufactured to specific orders which are generally completed in one production run, so it is reasonable to assume that length differences of intermediate sections will be small.
- Chains are supplied in sets that are uniform in overall length within reasonably fine limits and will be within our normal manufacturing limits. It should be noted that chain sets supplied for different orders at different times may not have exactly the same lengths to those supplied originally, but will vary by no more than our normal tolerance of 0.0%, +0.15 percent.

Pitch Matching Drive Chains
Pitch-matched chains are built from shorter subsections (usually about 1 to 3 feet or 300 to 600mm lengths), which are first measured and then graded for length. All subsections in each grade are of closely similar length and those forming any one group across the set of chains are selected from the same length grade.

The requisite number of groups are then connected to form a pitch-matched set of chains, or alternatively, if this is too long for convenient handling, a set of handling sections for the customer to assemble as a final set of pitch-matched chain. Suitable tags are fixed to the chains to ensure they are connected together in the correct sequence.

Identification of Handling Lengths

	Handling Length 1	Handling Length 2	Handling Length 3
A Strand	A-A1	A1-A2	A2-A3
B Strand	B-B1	B1-B2	B2-B3
C Strand	C-C1	C1-C2	C2-C3

Long chains are made in sections, each section being numbered on end links. Sections should be joined so that end links with similar numbers are connected. When chains are to run in sets of two or more strands, each strand is stamped on end links of each section with a letter, in addition to being numbered. Correct consecutive sections for each strand must be identified from the end links and joined up as indicated.

By these means, the actual length of any intermediate portion of one strand (as measured from any one pitch point to any other) will correspond closely with that of the transversely equivalent portion on the other strands, generally within 0.002 inches (0.05mm), depending on the chain pitch size.

Pitch Matching Attachment Chains
(when attachments are fit to chains)

With the sole exception of extended bearing pins, it is not possible to match the pitch of holes in attachments themselves to within very fine limits. This is due to the additional tolerances that arise with bending, holing, etc.

Color Coding
For customers who wish to match their chains, perhaps in order to fit special attachments, Renold color codes short lengths of chain within specified tolerance bands. These will normally be RED, YELLOW, or GREEN paint marks to indicate lower, middle, and upper thirds of the tolerance band. For even finer tolerance bands, additional colors can be used, but normally a maximum of five colors is more than adequate.

Color	Tolerance
RED	0.05%
YELLOW	0.10%
GREEN	0.15%
BLUE	For finer tolerances
WHITE	

To Measure Chain Wear
A direct measure of chain wear is the extension in excess of the nominal length of the chain. Chain wear can therefore be ascertained by length measurement in line with the instructions given below.

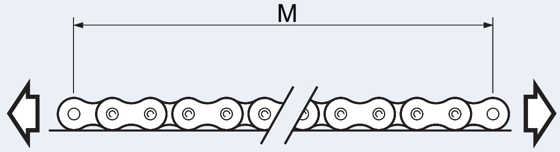
- Lay the chain, which should terminate at both ends with an inner link, on a flat surface, and, after anchoring it at one end, attach to the other end a turnbuckle and a spring balance suitably anchored.
- Apply a tension load by means of the turnbuckle amounting to:

Single-Strand Chain $(25.4 \times P)^2 \times .173$ lbs
Double-Strand Chain $(25.4 \times P)^2 \times .351$ lbs
Triple-Strand Chain $(25.4 \times P)^2 \times .524$ lbs

Where P is the pitch in inches.

In the case of double-pitch chains (i.e., chains having the same breaking load and twice the pitch), apply measuring loads as for the equivalent short-pitch chains.

As an alternative, the chain may be hung vertically and the equivalent weight attached to the lower end.



- Measure length 'M' (see diagram above) in inches from which the percentage extension can be obtained from the following formula:

  $$\text{Percentage Extension} = \frac{M - (N \times P)}{N \times P} \times 100$$

  Where N = Number of pitches measured
  P = Pitch

- As a general rule, the useful life of a chain is terminated and the chain should be replaced when extension reaches 2 percent (1 percent in the case of double-pitch chains). For drives with no provision for adjustment, the rejection limit is lower, dependent upon the speed and layout. A usual figure is between 0.7 and 1.0 percent extension.

Chain Wear Guide

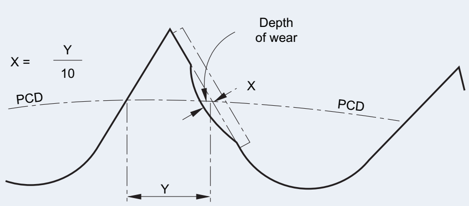
A simple-to-use chain wear guide is available from Renold Jeffrey for most popular sizes of chain pitch. Please contact your sales office for details.

Repair and Replacement

Sprockets

Examination of both flanks will give an indication of the amount of wear that has occurred. Under normal circumstances, this will be evident as a polished worn strip around the pitch circle diameter of the sprocket tooth.

If the depth of this wear "X" has reached an amount equal to 10 percent of the "Y" dimension, steps should be taken to replace the sprocket. Running new chain on sprockets having this amount of tooth wear will cause rapid chain wear.



It should be noted that in normal operating conditions, with correct lubrication the amount of wear "X" will not occur until several chains have been used.

Chain

Chain repair should not be necessary. A correctly selected and maintained chain should gradually wear out over a period of time (approximately 15,000 hours), but it should not fail. Please refer to the Installation and Maintenance section of this catalog, which gives an indication of how to determine the service life remaining.

If a drive chain sustains damage due to an overload, jam-up, or by riding over the sprocket teeth, it should be carefully removed from the drive and given a thorough visual examination. Remove the lubricating grease and oil to make the job easier.

Depending on the damage, it may be practical to effect temporary repairs using replacement links. It is not, however, a guarantee that the chain has not been over-stressed and so made vulnerable to a future failure. The best policy, therefore, is to remove the source of trouble and fit a new chain. This should be done for the following reasons.

1. The cost of downtime to the system or machine can often outweigh the cost of replacing the chain.
2. A new or used portion of chain or joints assembled into the failed chain will cause whipping and load pulsation. This will likely produce rapid failure of the chain and will accelerate wear in both the chain and its sprockets.

If a chain has failed two or more times, it is certain the chain will fail again in time. If no replacement is immediately available, repair the chain, but replace it at the earliest opportunity.

Chain Adjustment

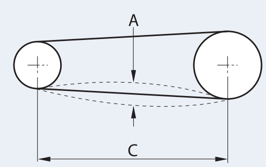
To obtain full chain life, some form of chain adjustment must be provided, preferably by moving one of the shafts. If shaft movement is not possible, an adjustable idler sprocket engaging with the unloaded strand of the chain is recommended. Generally the idler should have the same number of teeth as the driver sprocket and care should be taken to ensure the speed does not exceed the maximum shown in the Quick Selector Chart (see page 234).

The chain should be adjusted regularly so that, with one strand tight, the slack strand can be moved a distance "A" at the midpoint (see diagram below). To cater for any eccentricities of mounting, the adjustment of the chain should be tried through a complete revolution of the large sprocket.

A = Total movement
C = Horizontal center distance

$$\text{Total movement "A" (in.)} = \frac{C \text{ (in.)}}{K}$$

Where K = 25 for smooth drives
50 for shock drives



For vertical drives please consult the Installation and Maintenance section of this catalog, which gives more details on chain adjustment.