Why Go Keyless?

Traditional Connection Methods for Rotating Power Transmission Components

Traditionally, drive elements like gears, sprockets, lever arms, etc. were affixed to rotating shafts using a keyway and key, perhaps with a setscrew to fix axial positioning during operation. These connections, while relatively simple and reliable when transmitting smooth, consistent power, prove inadequate when vibratory, shock or reversing loads are present. Keyed connections subjected to such extreme operating environments will pound out over time, as each time the load reverses or cycles off and on the drive element spins on the shaft through the clearance between key and keyway, then stops abruptly upon contacting the key. This phenomenon is typically referred to as "backlash". Further, the rubbing between shaft and component bore surfaces during this slippage leads to fretting corrosion, which over time can cause cold welding of components and could ultimately lead to weakened shafts and/or shaft failures. Splined connections, albeit to a lesser degree, suffer from the same limitations as keyed connections, with their extremely high fabrication costs an additional drawback.

Interference Fits

A frictional connection between shaft and component solves the problems associated with backlash, and additionally eliminates the machining operations required for keyways. Further, shafts, along with any other required drive elements, can be made smaller once the keyway notch factor is removed. These frictional connections, in the form of heat shrink or press fits, provide an even pressure distribution and are entirely backlash-free. As a result, an interference fit will never pound out or fret, provided the interference preload is sufficiently greater than the applied load. The limitations of this approach, however, quickly become apparent during assembly and removal, where application of heat and/or very high forces is required.

CLIMAX Keyless Locking Devices provide the ultimate solution by delivering all of the advantages of interference fits with none of the installation and removal limitations. Our Locking Assemblies, Shrink Discs and Keyless Rigid Couplings offer a zero-backlash component mounting or coupling solution using multiple high strength screws and opposing tapers to develop a mechanically generated interference fit. Installation and removal is accomplished with simple hand tools, greatly simplifying component positioning and field maintenance.

CLIMAX Keyless Locking Devices offer advantages over all other component mounting technologies:

	CLIMAX Keyless Locking Devices	Key and Keyway	Spline	QD or Taper Lock Bushing	Shrink or Press Fit
Provide a zero-backlash connection	✓	-	-	-	✓
Eliminate keyway notch factor/ allow smaller shafts	✓	-	-	-	✓
Easily installed and removed with hand tools	✓	✓	✓	✓	-
Permit infinite axial and angular timing	✓	-	-	-	-
Transmit torque, bending and axial thrust	✓	-	-	-	✓

Engineering / Technical Information

Selection

CLIMAX Keyless Locking Devices are designed to transmit torque, bending, thrust and radial loads, both static and dynamic, individually and in various combinations. The following information is provided to assist in proper selection:

Torque

Many CLIMAX Keyless Locking Devices will be used in applications subjected to torque only. In these applications the **Peak Torque = T** must be calculated and compared to the **Rated Torque Capacity M_t** of the CLIMAX KLD being considered.

M_t (from specification tables) > **T**

If **Peak Torque T** cannot be determined with accuracy, it is recommended that **Nominal Torque = T_{nom}** be used instead, along with an appropriate **Service Factor** to account for start-up or stall conditions, mass accelerations, impact loads, etc.

Nominal Torque T_{nom} can be calculated as follows:

$$T_{nom}\ (\text{ft-lb}) = \frac{5252 \times HP}{RPM}$$

M_t (from specification tables) > **T_{nom} x Service Factor**

Note that in all cases our published **Rated Torque Capacity M_t** is calculated without using a safety factor. Accordingly, it should be assumed that a CLIMAX Keyless Locking Device connection will slip if a torque higher than **M_t** is applied.

All published capacities and contact pressures assume that locking screws are tightened to the published **Locking Screw Tightening Torque M_a** according to CLIMAX Installation and Removal Instructions. If required, torque capacities and contact pressures for installed units can be manipulated within certain limits by adjusting **Locking Screw Tightening Torque M_a** from its published value, as follows:

Series C200:.. up to 20% higher or up to 40% lower
Series C133/C193:... up to 40% lower
Series C123:.. up to 10% lower
Series C170:.. up to 20% lower
Series C405/C415:... up to 40% lower

Within these limits, **Rated Torque Capacity M_t**, **Rated Thrust Capacity F_{ax}** and **Contact Pressures P_s** and **P_h** are a linear function of **Locking Screw Tightening Torque M_a**.

For applications requiring 2 or more CLIMAX Keyless Locking Devices installed in series, please consult with CLIMAX for proper selection.

Engineering / Technical Information *(Continued)*

Thrust

The radial force applied to the shaft and mounted component by a CLIMAX KLD will resist a significant amount of axial thrust. The **Rated Thrust Capacity F_{ax}** of any CLIMAX KLD is determined using the following equation:

$$F_{ax}\ (\text{lbs.F}) = \frac{24 \times M_t}{d}$$

M_t = **Rated Torque Capacity** (from specification tables)
d = shaft diameter (in)

Bending Moments

Reversing bending moments are a frequently overlooked sizing factor in mechanical power transmission applications. Bending loads are present whenever a radial load – from the weight of components, belt or chain tension, etc. – acts outside the centerline of the shaft/hub connection. Reversing bending moments occur when such loads cycle between tension and compression as a mounted component rotates through 360 degrees, as is the case on rolls or conveyor pulleys. Most traditional component mounting technologies – keys and keyways, QD-style or Taper-Lock bushing systems, etc. – are not designed to transmit reversing bending loads and these conditions will typically lead to failure, whether of the connection itself, the mounted component or the shaft.

CLIMAX Keyless Locking Devices are specifically designed to transmit reversing bending moments within the following limits:

CLIMAX Series	Rated Bending Moment Capacity M_b
C200	22% of M_t
C733, C732 and C600	25% of M_t
C123, C133, C192 and C193	28% of M_t
C415	32% of M_t
C405	35% of M_t

Combined Loads

It is not uncommon for CLIMAX Keyless Locking Devices to be subjected to some combination of **torque, axial thrust** and **reversing bending**. Our products are well suited for these environments, but proper selection requires calculating a **resultant torque** using the various applied loads, as follows:

$$T_{res} = \sqrt{T^2 + (F \times \frac{d}{2})^2 + (2 \times B)^2}$$

T = Peak Torque (ft-lbs)
F = Peak Thrust (lbs.F)
B = Peak Bending Moment (ft-lbs)
d = shaft diameter (ft)

M_t (from specification tables) > **T_{res}** and **M_b** (see above) > **B**

Engineering / Technical Information *(Continued)*

Radial Loads

Radial loads, typically associated with pin or axle connections, occur when an applied load F_{rad} acts perpendicular to the centerline of the shaft. Selection of a suitable CLIMAX Keyless Locking Device is based on determining the equivalent contact pressure on the shaft P_{rad}, as follows:

$$P_{rad} = \frac{F_{rad}}{d \times L}$$

F_{rad} = applied radial load (lbs.F)
d = shaft diameter (in)
L = KLD contact length (in) (from specification tables)

Then an acceptable radial load application is one in which $P_s > P_{rad}$, AND $P_s + P_{rad} < YP$, where:

P_s = shaft contact pressure (from specification tables)
YP = tensile yield point of shaft material (psi)

Material

CLIMAX Keyless Locking Devices are manufactured from high carbon and alloy steel.

Surface Finish and Lubricity

CLIMAX Keyless Locking Devices carry rated capacities that rely upon both lubricity and surface finish. Components to be mounted using a CLIMAX KLD should be machined to achieve a surface finish of between 63 and 125 µIN RMS. A surface finish outside this range could result in a reduction of the load carrying capacity of the connection. Lubricity is likewise critically important to the successful application of our products, as it directly affects the Coefficient of Friction (COF) between mated components. Our internal Locking Assemblies are supplied and installed with ordinary machine oil on all locking screws and mated surfaces to achieve a COF equal to .12. Our external Shrink Discs and Keyless Rigid Couplings require a solvent cleaned and dry shaft interface to achieve a COF equal to .15.

Temperature

CLIMAX Keyless Locking Devices are designed to operate through a temperature range of 0º to 400º F. Note that mated components of dissimilar materials may react to temperature increases at different rates. Please consult with CLIMAX regarding such applications.

Mounting Over Existing Keyways

CLIMAX Keyless Locking Devices can be installed over existing empty keyways. Both CLIMAX Locking Assemblies and Shrink Discs should be rotated to position inner ring radial slits approximately opposite the keyway and a locking screw directly over the keyway. CLIMAX Keyless Locking Devices are not de-rated when installed over existing empty keyways.

Engineering / Technical Information *(Continued)*

Non-Standard Shaft Diameters

In situations where the measured shaft diameter does not match any standard CLIMAX Locking Assembly, perhaps as a result of damage or excessive wear, a simple adaptor sleeve can be fabricated to effectively "shim" the existing shaft to a standard nominal diameter. These adaptor sleeves can be slit lengthwise or left solid, with slit sleeves allowing more relaxed machining tolerances. Wall thickness should not exceed 12.5% of measured shaft diameter. Recommended machining tolerances are as follows:

+0 / -.002" on the sleeve OD;
-0 / +.001" – .002" on the bore of a solid sleeve;
-0 / +.002" – .004" on the bore of a slit sleeve.

For slit adaptor sleeves rated torque capacities for these connections is taken directly from the CLIMAX Locking Assembly selected, provided the adaptor sleeve/shaft interface is clean and dry (for a coefficient of friction equal to .15) and the adaptor wall thickness is within prescribed limits.

Plating

CLIMAX Locking Assemblies and Keyless Rigid Couplings are stocked unplated, while Shrink Discs are supplied with zinc-plated outer rings. Upon request, all CLIMAX Keyless Locking Devices can be quoted with either of two after-market plating options: industry-standard electroless Nickel or Armoloy® Thin Dense Chrome (TDC). Both plating solutions offer excellent corrosion resistance with no reduction of rated torque capacity.

Hub Strength

Calculations to Ensure Adequate Hub Dimensions

As CLIMAX Keyless Locking Devices exert high compression and expansion forces, the following formulas are presented to assist with calculations required to ensure that components mounted with our products are of adequate strength.

Applications Using CLIMAX Locking Assemblies

To ensure adequate wall thickness of the mounted component, use the following equation:

$$D_n = D\sqrt{\frac{YP + (P_h \times C)}{YP - (P_h \times C)}}$$

D = the published OD (in inches) of the Locking Assembly selected (from specification tables)
P_h = hub contact pressure (in psi) of the Locking Assembly selected (from specification tables)
YP = the tensile yield point (in psi) of the mounted component
C = a Pressure Reduction Factor selected based on the relationship between the length-thru-bore (LTB) of the mounted component and the contact length (L) of the Locking Assembly selected, as shown below:

For C123, C133, C192, C193, C200 and C170
When LTB < 1.5 x L, C = 1.0
When 1.5 x L ≤ LTB < 2 x L, C = .8
When LTB ≥ 2 x L, C = .6

For C405 and C415
When LTB < 1.25 x L, C = 1.0
When 1.25 x L ≤ LTB < 1.5 x L, C = .8
When LTB ≥ 1.5 x L, C = .6

Engineering / Technical Information *(Continued)*

Applications Using CLIMAX Shrink Discs

The component hub wall thickness for Shrink Disc applications is nominally the difference between the Shrink Disc ID and the shaft diameter. As we do not wish for the use of our products to weaken the drive system, our specifications limit the size of the shaft diameter recommended for use with each Shrink Disc to a size which results in a component hub that is at least as strong, both in bending and in torsion, as the underlying shaft.

In general, component hub material with a minimum tensile yield point of 45ksi is recommended. Cast iron component hubs are acceptable, but we recommend selecting the next larger size Shrink Disc for these applications.

To eliminate possible fretting corrosion and associated complications, when machining a hub for use under a Shrink Disc, it is recommended that the fit length be limited to the Shrink Disc inner ring length (L from the specification tables), with the remaining LTB relieved using a non-toleranced clearance. See the illustration atop Page 28.

C600 Keyless Rigid Coupling Engineering Information

Our C600 Series Keyless Rigid Coupling is designed to simultaneously transmit the combined torque and reversing bending common to shaft-mounted drive applications. Proper coupling selection is achieved through the following procedure:

Identify nominal diameters of shafts to be joined (note that unequal shaft diameters up to a size ratio of approximately 2:1 can be accommodated). The C600 Type is selected based on the larger shaft diameter.

Refer to Figure 1 below and establish all required dimensions, including:
A = Distance (ft) from Torque Arm fixture point to C600 center
B = Distance (ft) from CG of prime mover to C600 center
L = Torque arm length (ft)
T = Maximum torque (ft-lbs) to be transmitted, including any desired Service Factor
W = weight (lbs.F) of the prime mover

Then…

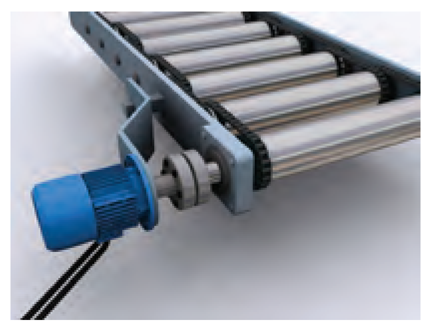
F_{TR} **(lbs.F)** = $T \div L$

M_B **(ft-lbs)** = $(W \times B) + (F_{TR} \times A)$

T_{RES} **(ft-lbs)** = $\sqrt{[(T)^2 + (2 \times M_B)^2]}$

The Series C600 selection is approved provided BOTH:
M_t (from specification tables) > T_{RES} AND $M_B < 0.25 \times M_t$

For applications where the above analysis yields marginal results, please contact us for possible design alternatives that may qualify the application.



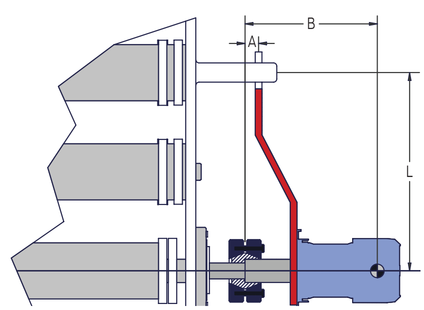


Fig. 1

Shaft and Hub Tolerances

Ø Hub Diameter (inch)									
over		0.24	1	1.97	2.56	4.72	9.25	12.01	14.76
including		1	1.97	2.56	4.72	9.25	12.01	14.76	25*
Ø Hub Diameter (mm)									
over		6	25.4	50	65	120	235	305	375
including		25.4	50	65	120	235	305	375	635
C193 [-0.0]	inch	+0.001	+0.001	+0.001					
	mm	+0.025	+0.025	+0.025					
C123/C133 [-0.0]	inch	+0.002	+0.002	+0.002	+0.002	+0.003	+0.003	+0.004	+0.004
	mm	+0.05	+0.05	+0.05	+0.05	+0.08	+0.08	+0.10	+0.10
C170 [-0.0]	inch	+0.002	+0.002	+0.002	+0.003	+0.003			
	mm	+0.05	+0.05	+0.05	+0.08	+0.08			
C200 [-0.0]	inch	+0.002	+0.002	+0.003	+0.003	+0.004	+0.005	+0.005	+0.006
	mm	+0.05	+0.05	+0.08	+0.08	+0.10	+0.13	+0.13	+0.15
C405/C415 [-0.0]	inch	+0.002	+0.002	+0.002	+0.002	+0.003	+0.003	+0.004	+0.004
	mm	+0.05	+0.05	+0.05	+0.05	+0.08	+0.08	+0.10	+0.10

Ø Shaft Diameter (inch)									
over		0.24	1	1.97	2.56	4.72	9.25	12.01	14.76
including		1	1.97	2.56	4.72	9.25	12.01	14.76	25*
Ø Shaft Diameter (mm)									
over		6	25.4	50	65	120	235	305	375
including		25.4	50	65	120	235	305	375	635
C193 [+0.0]	inch	-0.001	-0.001	-0.001					
	mm	-0.025	-0.025	-0.025					
C123/C133 [+0.0]	inch	-0.002	-0.002	-0.002	-0.002	-0.003	-0.003	-0.004	-0.004
	mm	-0.05	-0.05	-0.05	-0.05	-0.08	-0.08	-0.10	-0.10
C170 [+0.0]	inch	-0.002	-0.002	-0.002	-0.003	-0.003			
	mm	-0.05	-0.05	-0.05	-0.08	-0.08			
C200 [+0.0]	inch	-0.002	-0.002	-0.003	-0.003	-0.004	-0.005	-0.005	-0.006
	mm	-0.05	-0.05	-0.08	-0.08	-0.10	-0.13	-0.13	-0.15
C405/C415 [+0.0]	inch	-0.002	-0.002	-0.002	-0.002	-0.003	-0.003	-0.004	-0.004
	mm	-0.05	-0.05	-0.05	-0.05	-0.08	-0.08	-0.10	-0.10
C600 [+0.0]	inch	-0.003	-0.006	-0.006	-0.006	-0.006			
	mm	-0.08	-0.15	-0.15	-0.15	-0.15			

*Consult CLIMAX for diameters in excess of those shown

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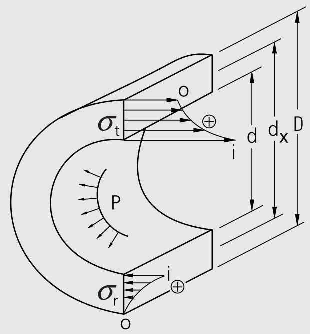
Roark's Formulas for Stress and Strain applied to a thick cylinder subjected to…

Internal Pressure



TANGENTIAL STRESSES "σ_t"

$$\sigma_{tx} = P\frac{Q}{1-Q}\left[1+\frac{D^2}{d_x^2}\right]$$

$$\sigma_{ti} = P\frac{1+Q}{1-Q}$$

$$\sigma_{to} = 2P\frac{Q}{1-Q}$$

RADIAL STRESSES "σ_r"

$$\sigma_{rx} = P\frac{Q}{1-Q}\left[1-\frac{D^2}{d_x^2}\right]$$

$$\sigma_{ri} = -P$$

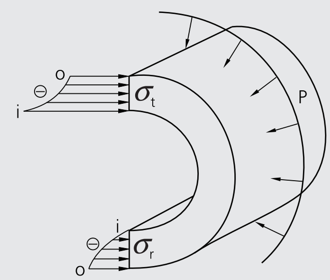
$$\sigma_{ro} = 0$$

EXPANSION - CONTRACTION

$$\Delta d = Pd\,\frac{(\nu+1)+(\nu-1)Q}{\nu E(1-Q)}$$

$$\Delta D = 2P\frac{DQ}{E(1-Q)}$$

External Pressure



TANGENTIAL STRESSES "σ_t"

$$\sigma_{tx} = -\frac{P}{1-Q}\left[1+\frac{d^2}{d_x^2}\right]$$

$$\sigma_{ti} = -\frac{2P}{1-Q}$$

$$\sigma_{to} = -P\frac{1+Q}{1-Q}$$

RADIAL STRESSES "σ_r"

$$\sigma_{rx} = -\frac{P}{1-Q}\left[1-\frac{d^2}{d_x^2}\right]$$

$$\sigma_{ri} = 0$$

$$\sigma_{ro} = -P$$

EXPANSION - CONTRACTION

$$\Delta d = 2P\frac{d}{E(1-Q)}$$

$$\Delta D = PD\,\frac{(\nu-1)+(\nu+1)Q}{\nu E(1-Q)}$$

COMBINED HUB STRESSES $\sigma_v = \sqrt{\sigma_t^2 + \sigma_r^2 - (\sigma_t\sigma_r) + 3\tau^2}$

i = Inside of cylinder
o = Outside of cylinder
ν = Poisson's ration for steel: .3003
E = modulus of elasticity for steel: 30 x 10^6psi
P = pressure
τ = torsional hub stress

$$Q = \left(\frac{d}{D}\right)^2$$