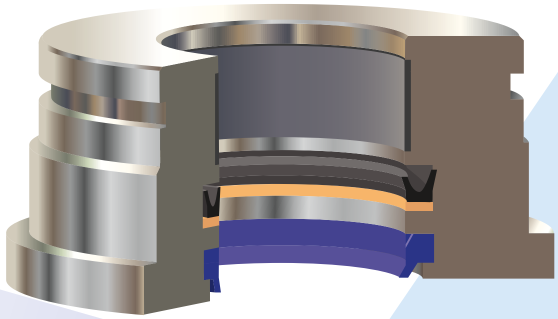
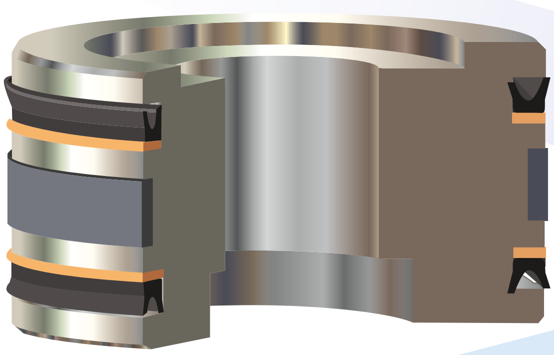
ENGINEERED SEALS & COMPONENTS, LLC.

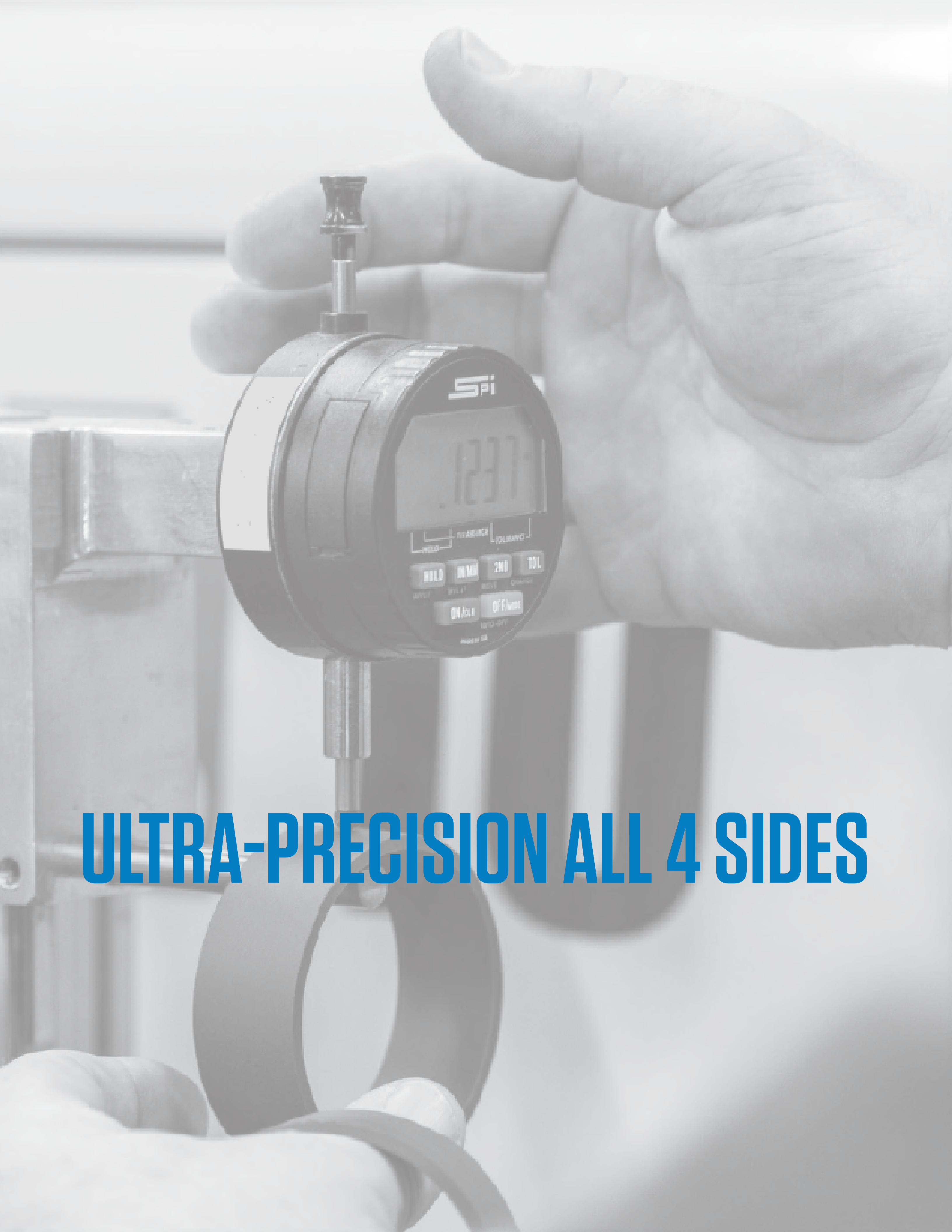
ULTRA-PRECISION WEAR RING DESIGN GUIDE



Rod Style



Piston Style



ULTRA-PRECISION ALL 4 SIDES

WHY WEAR RINGS OR GUIDE RINGS?

Hydraulic / Pneumatic Cylinders:

Hydraulic / Pneumatic cylinders are designed to generate longitudinal force and handle the longitudinal load. But many of these cylinders are also impacted severely by the transverse load.

The engineering rule of thumb says that about 10-15% of the maximum hydraulic force is always applied as a transverse load, even in the most ideal situations.

The mechanical impact of this load can be reduced by using a variety of techniques, but radial load still exists and occurs, causing excessive wear of the internal guide components in the gland and on the piston of the cylinders.

This load will also adversely affect the longevity and seal ability of the sealing components in the cylinder.

Enter: Hydraulic Wear Rings

The use of internal guiding components or "Wear Rings", preferably ESC Ultra- Precision style can dramatically reduce the impact of radial load, especially in horizontal and long stroke applications.

ESC Ultra-Precision Wear Rings can ensure that the sliding components of a cylinder are properly supported against radial loads and move smoothly and properly guided in a longitude direction.

A correctly designed bearing system in combination with the proper, non-metallic, Wear Ring materials, can prolong the lifetime of the sealing components, improving both the reliability and service life of the cylinders.

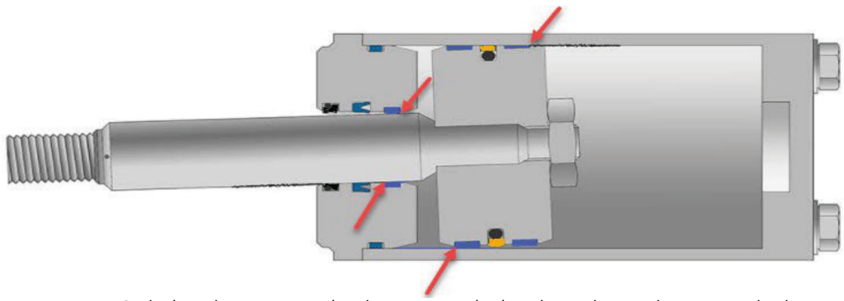
ESC has developed a wide range of materials and shapes to accommodate many bearing applications in service today.

Ultra-precision wear rings will make your cylinders last longer, reduce warranty costs, and add to your bottom line.

The primary function of Wear Rings or Guide Rings in hydraulic or pneumatic cylinders include:

1. Act as a linear (longitudinal) guide for moving metallic components in the cylinder.
2. Provide radial support of the metallic components.
3. Protect the seal components against excessive mechanical radial force and deformation.
4. Protect seal components against uneven wear.
5. Position moving metallic components in a concentric location, maintaining clearances and extrusion gaps.
6. Protect seal components against the radial load-caused momentum.
7. Ultra-precision wear rigs will reduce extrusion gaps, when compared to "standard" tolerance wear rings, this ensures long cylinder and seal life.

AVAILABLE WEAR RING SHAPES AND SPLITS



Side loading on a cylinder, particularly when the rod is extended, can cause damage to the cylinder, and diminish its useful life.

In any hydraulic cylinder, there are "side loads" in existence, of which the values are largely unknown. These side loads translate into "guide forces" on the bearing elements in the cylinders. Some causes of these side loads are:

1. Assembly clearances in the bearing elements, causing a phenomenon called "crookedness".

2. Manufacturing tolerances.

3. Deflection of guide rings under load.

4. Expansion of the cylinder wall under pressure, causing higher clearances.

5. Bending of the cylinder rod (rod deflection).

6. Friction in the mounting attachments.

7. Concentricity, perpendicularity, out of roundness and misalignment issues of assemblies, welded and machined parts.

7.5. External applied side loads.

8. Acceleration forces.

9. Mass of the hydraulic fluid and the mass of the cylinder.

10. Temperature. High temperatures will make the wear rings, if the wrong material is used, deflect too much.

11. Misalignment of mounting point or points

12. Expansion of the cylinder tube.

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ESC-LON ULTRA PRECISION WEAR RING ADVANTAGES

ESC uses the latest, state-of-the-art, injection equipment to injection mold a billet to very close tolerances from only the highest grade materials. Using internal lubricants and proprietary additives, ESC has formulated a version of glass filled nylon to be the best possible wear ring. We then machine each part to EXACTING tolerances. Our material and processes REALLY do make the *ESC*-LON Wear Rings are finished machined to a thickness tolerance of +/-.001 inches unless otherwise specified. The state-of the-art process and continuous improvement, generally keep the process Cpk's above 3.5. This provides better control of the extrusion gap and reduction of the apparatus or cylinder bending loads. *ESC* Ultra Precision Wear Rings are **THE** choice for demanding applications.

ESC-LON wear rings:

- Internally Lubricated. Port
- Passing Capable
- Non-Scoring.
- Highest Compressive Strength.
- Longest Wearing
- Low Moisture Absorption

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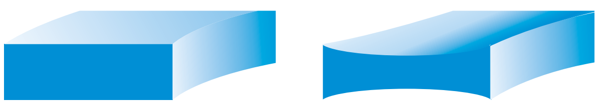
ESC-LON ULTRA PRECISION WEAR RING DESIGN GUIDE

FAQS

There are many factors to consider when designing a sealing system.

Following are a few of the most commonly asked questions requiring bearing design and how to choose the right wear ring



Series 200 & 800 Wear Ring **Conventional Wear Ring**

What is the performance difference between standard tolerance and Ultra Precision Wear Ring?

Standard tolerance wear rings typically have a radial wall that is at best +.0025", while Ultra-Precision wear ring cross sections are held to +.001". Ultra-Precision Wear Rings allow for a more precise fit of components, resulting in less dimensional "play". The benefit is that the extrusion gap will be much less when compared to standard tolerance wear rings. Increasing the seal's pressure rating and the better the alignment the longer the system will last. This is also very important the hotter a system becomes, because the smaller the extrusion gap can be made the better the system will endure. Ultra Precision Wear Rings can have as much as 35% Less extrusion gap than "Standard" Wear Rings.

Example: Based on formula herein, the extrusion gap for an Ultra Precision Piston Wear Ring can be as little as .017". Extrusion gap for a "Standard" wear ring will be .023" or an increase of aproximately 35%.

Wear Ring grooves call for Larger extrusion gaps. How does this affect the seals' pressure rating?

Since wear rings are used to eliminate metal-to- metal contact between moving components, there must be a larger gap between them, thus causing a larger extrusion gap. This will result in the seals pressure rating to be decreased. Per-established gland dimension outlined in the ESC Products Catalog, should always results in a minimum of .005" clearance for metal components. If standard tolerance wear rings are used, the seals pressure capacity may be reduced by about 50%. When Ultra Precision wear rings are used the seals' pressure capacity will be reduced by approximately 30%. In either case it is most important to choose the proper Seal and Back-Up materials to accommodate the increased extrusion gap.

For applications where the seals will be used to their extrusion limit, gland dimensions can be designed using the data supplied by each seal profile. It is critical when determining the metal to metal clearance to be very aware of the Wear Rings compressive strength properties, which are found in the following *Tables 1 & 2* or *Chart 1.* Be aware of the Minimum and Maximum extrusion Gaps, they are the key to making the system operate efficiently.

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ESC-LON ULTRA PRECISION WEAR RING ENGINEERING GUIDE

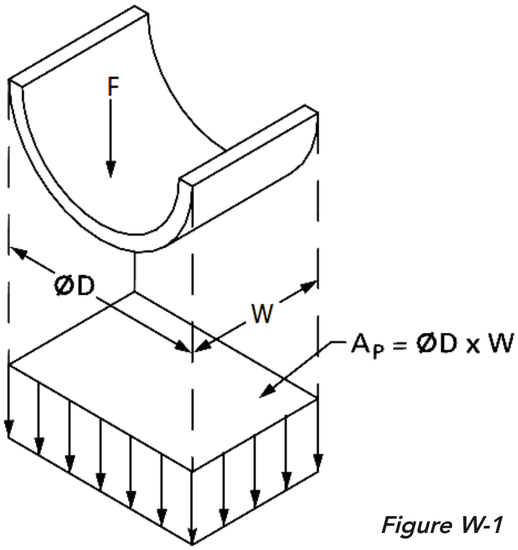

Figure W-1

How is a proper Wear Ring Width selected?

When selecting the proper Wear Ring width, it is critical to evaluate the side loads that the wear ring will have to endure. Figure W-1 shows the total pressure area, A*p*, that a radial force from side loading will affect.
Area A*p* is calculated as follows:

$$Ap = \varnothing D \times W$$

Figure F-1

Where ***D*** is the wear ring O.D. for Pistons or I.D. for Rods and ***W*** is the wear ring width.

It is important to note that the pressure distribution will not be equally dispersed across the area in *Figure W-1*. Instead it will look more like the profile in *Figure W-2*. The assumed bearing area can be calculated as follows:

$$A_L = \frac{Ap}{5} = \frac{\varnothing D \times W}{5}$$

Figure F-2

To calculate the allowable radial force, ***F***, simply multiply the load bearing area A_L, by the permissible compressive load, (compressive strength) of the material ***q***, and divide by the desired safety factor, ***FS***.

To calculate the proper bearing width, ***W***, *based on a known radial force:*

$$W = \frac{5 \times F \times FS}{\varnothing D \times q}$$

Figure F-3

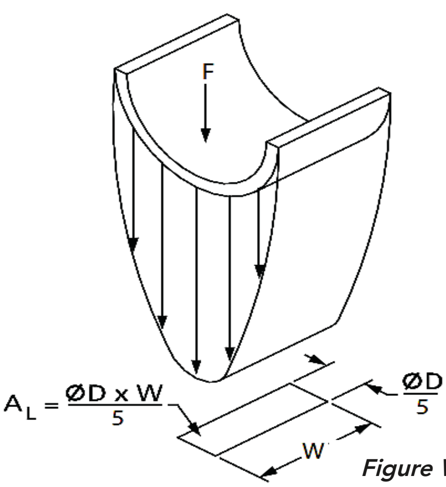

Figure W-2

Once ***W*** is calculated, round up the answer to the next nominal 1/8"
To calculate the allowable radial force, ***F***, based on a known bearing width is as follows:

$$F = \frac{A_L \times q}{FS} = \frac{\varnothing D \times W \times q}{5 \times FS}$$

Figure F-4

Compressive Strength, ***q***, can be found on ***Table 1*** and ***Table 2*** in the following pages. This value is based upon the known material at 73° F and at a specified load. **Engineered Seals & Components recommends a Safety Factor, *FS*, of at lease 3** to account for the changes in physical properties due to increases in the system temperature, moisture, and other factors.

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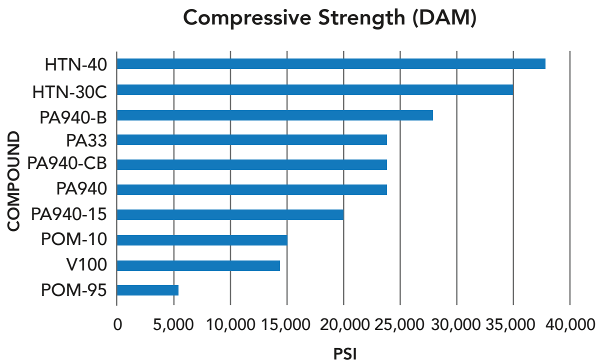

Chart 1

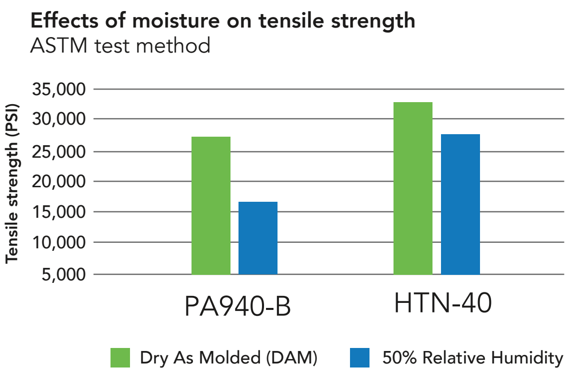

Chart 2

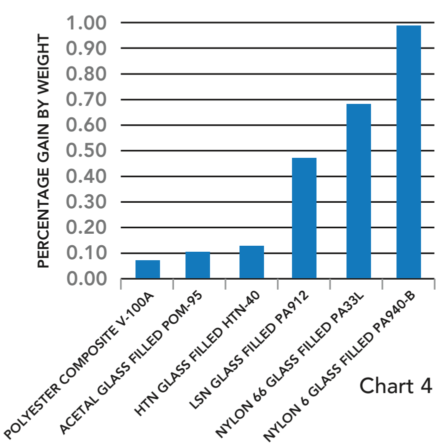

Chart 4

How do the Ultra Precision Wear Ring compounds compare in the same application?

Using the following formula F-4, lets' compare 2 popular compounds. PA940-B and HTN-40. PA940-B is a 40% glass filled nylon 6 and the HTN-40 is a "High temperature Nylon" also 40% glass filled.

$$F = \frac{A_L \times q}{FS} = \frac{ØD \times W \times q}{5 \times FS}$$

Figure F-4

In this instance we are solving for F or the load the wear rings will take.
Given 4.00" O.D. x .500" Wide Wear Ring
Compressive Strength PA940-B from Table 1=27,600 psi
Compressive strength HTN-40-C from Table 2 = 35,000 psi

PA940-B (4.00 x .500 x 27,500) / (5 x 3) = **3,680 Lbs.**
HTN-40-C (4.00 x .500 x 35,000) / (5 x 3) = **4,667 Lbs.**

HTN40-C has 27% more compressive strength, but this is just the beginning of the differences.

How Does Moisture affect Wear Rings?

Because Nylon has the inherent ability to swell in water, it is not recommended to use ESC-Lon™ compounds in or around water or moisture that can get to the Wear Rings. The main reason for this is that some Nylon will absorbed up to 3% moisture. This means the cross section will grow out of tolerance, and the parts may squeak or may not be able to be installed. The other side effect that occurs is the more moisture that a part can absorbs, the lower the compressive and tensile strength will be. See ***Chart 2***.

If the wear rings will be used in a water based fluid or where there is a high moisture content, we would recommend the "Zero Swell" Family of compounds for Water based or higher heat applications. See the ***Table 2***.

What about fluid compatibility?

All *ESC*-LON ™, and all HTN Compounds, are compatible with petroleum-based hydraulic fluids, transmission fluid, phosphate esters, and many other fluids. All ESC-TAL™ compounds are water compatible as well as petroleum based fluids. Please contact ESC, for specific applications.

Which End Cut should be used?

There are 3 types of end cuts available. Butt cut is the most common and economical. Angle cut, provides added performance by ensuring bearing area over lap at the wear ring's gap. Step cut has added performance by total bearing over lap at it's gap as well as. In certain application the Step Cut may be used like a buffer seal protecting the primary seal from pressure spikes.

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ESC-LON ULTRA PRECISION WEAR RING ENGINEERING GUIDE

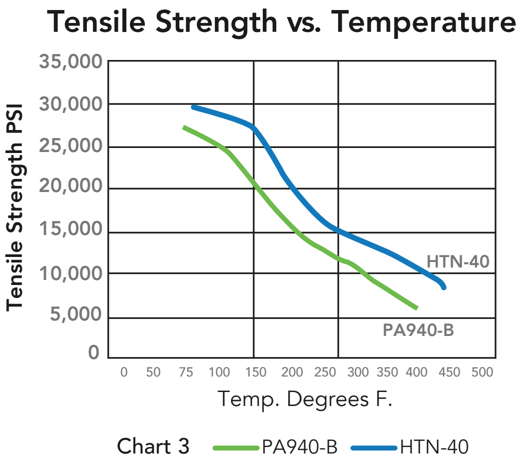


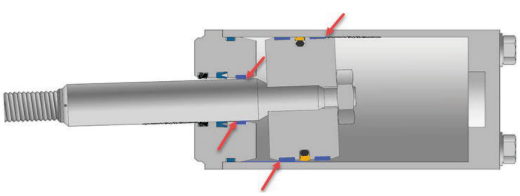
Chart 3

How does Temperature effect Wear Rings?

As in all plastic the temperature has a great deal to do with the performance or lack there of in plastic bearing materials. In most hydraulic applications the maximum operating temperature should be under 200° F. **Chart 3** shows a comparison between tensile strength of our 2 most popular wear ring materials. As shown the, HTN-40, at 200°F has about a **35%** more tensile strength than PA940-B. Tensile strength will follow compressive strength in these materials. This means that the compressive strength of HTN-40 will be about **35%** more.

What is the *Tg* or glass transition temperature important in choosing a wear ring material?

Tg or glass transition temperature is the temperature where the material changes from a glassy, rigid state a more flexible state. The higher the *Tg* as it relates to a wear ring means the higher the number in degrees, the stronger the part will be at a given temperature. See **Table 1** & **Table 2** for specifications.



Picture 1

Where should the Wear Ring be installed relative to the seals?

Wear rings should always be installed on the lubrication (wet) side of the seal for best performance. For rod glands, the wear ring should be on the pressure side of the rod seal. For pistons, if only one bearing is to be used, it should be on the side of the piston opposite the rod.

What should you use if you have a wear ring outboard the seals?

ESC has several compounds that are specifically designed to be used out board the seals. Two things come into play, moisture and no lubrication. First ESC has "Zero Swell" compounds that resist swelling in a highly moist applications.

Second ESC has several internally lubricated materials with very low coefficient of friction valves to choose from. Third, if your clearances are large enough, a "Standard" compound on Table 1 will work, but you must take moisture into consideration. See **Table 1** and **Table 2** for specifications and **Chart 4** for a quick look at Moisture vs. ESC compounds.

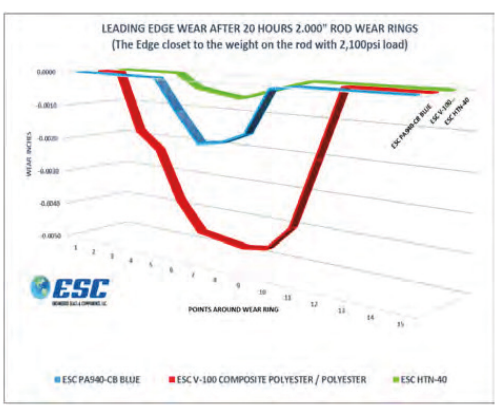


Chart 5

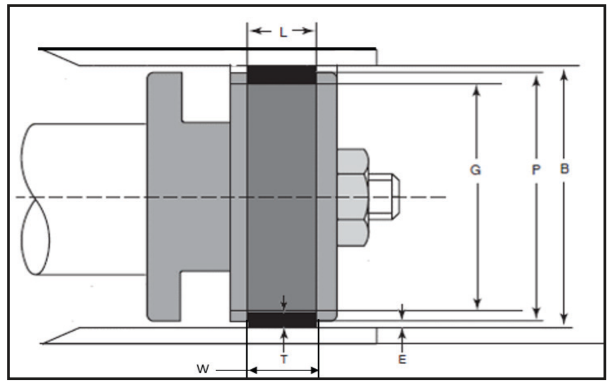
What is Edge Loading of the Wear Ring?

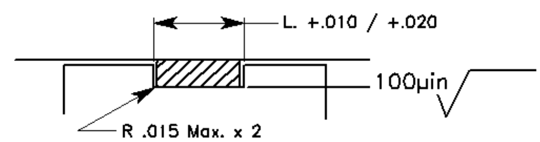
Edge loading is the load on the edge of the wear ring that see the most load. Typically it would be in 4 places on a cylinder with 1 rod and 1 piston wear ring. See **Picture 1** and it should become clear. **Chart 5** shows the wear pattern on the edge of a rod wear ring that is closest to the load. Three different materials, and 3 different outcomes. It does matter which material you choose. **Chart 5** shows wear rings that were measured in 15 places around the rings leading edge and then charted.

ESC-LON ULTRA PRECISION WEAR RING ENGINEERING GUIDE - INCH

Piston Groove Calculations - INCH

Formula for calculating Piston Wear Ring grooves using alternative extrusion gaps, metal-to-metal clearances and machining tolerances:





Groove Detail

1. Maximum Groove Diameter, G_1:

G_1= Minimum Bore Diameter B_1 (-.002") -2x (Max Wear Ring Cross Section, T_1)

2. Minimum Groove Diameter, *G*:

Minimum Groove Diameter G=G_{1} - (M machining tolerances)

3. Maximum Piston Diameter, P_1:

P_1= Minimum Groove Diameter G +2x [Minimum Wear Ring Cross Section] -2x [Desired minimum radial Metal-to-metal Clearance CL]

4. Minimum Groove Width, *L*:

L = (Nominal Width W_1) + .010

5. Maximum Extrusion gap, E_1:

$$E_1 = B\ max - \left(G\ min. + T\ min. + \frac{P\ min. - G\ min.}{2}\right)$$

Notes:

* Subtract this amount (-.001 or -.002) from Minimum Bore to allow for Bore ovality and Installation.

1. Tolerance for L is +.010 / +.020.
2. Groove radii must not exceed .015" max.
3. ESC recommends a minimum of 0.005" metal-to-metal clearance. Using the above calculations may result in metal to metal contact if the wear ring material's compressive strength properties are not considered. *See **Table 1** and **Table 2** for further details.* Contact ESC if additional assistant is required.

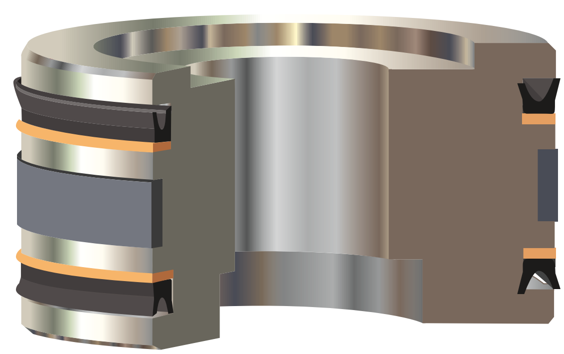
*** Extrusion Gap *DOES NOT* take into consideration tube swell under pressure.**

Example for above Formulas:

Given: Bore 3.000/3.003 (***B***) Wear Ring thickness 0.123/0.125 and 0.500 (***L***) wide. Piston machining tolerance is -0.002. Minimum desired radial metal-to-metal clearance is 0.005 per side.

1. 3.000 - 0.002 -0.250 = 2.748 (G1 Maximum Groove Diameter)
2. 2.748 -0 .002 = 2.746 (G Minimum Groove Diameter)
3. 2.746 +(2x 0.123) - (2x 0.005) = 2.982 Maximum Piston Diameter, P_1
4. 0.500 + 0.010 = 0.510 Minimum Groove Width, ***L min.***
5. 3.003 - (2.746 + 0.123) + ((2.980-2.746)/2)) = 0.017 Extrusion Gap Maximum ***E*** max.

B.= Bore Dia. 3.003 / 3.000
P.= Piston Dia.2.982 / 2.980
G. = Groove Dia. 2.746 / 2.748
L. = Groove Width 0.510 / 0.520
E. = TOTAL Extrusion Gap 0.017



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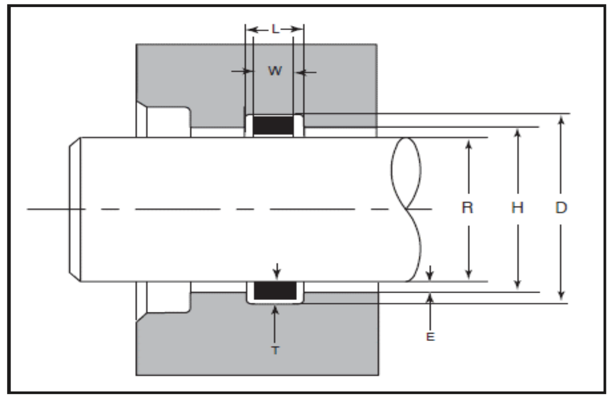
ESC-LON ULTRA PRECISION WEAR RING ENGINEERING GUIDE - INCH

Rod Groove Calculations- INCH

Formula for calculating Rod Wear Ring grooves using alternative extrusion gaps, metal-to-metal clearances and machining tolerances:



1. Minimum Groove Diameter, ***D***:

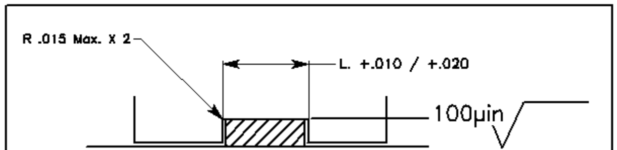
$$D = \text{Maximum ROD Diameter } R \; (+0.001'') + 2x \,(\text{Max Wear Ring Cross Section, } T_1)$$

2. Maximum Groove Diameter, D_1:

$$\text{Maximum Groove Diameter } D_1 = D + (M \text{ machining tolerances})$$

3. Minimum Throat Diameter, ***H***:

$$H = \text{Maximum Groove Diameter } D_1 - 2x \left[\text{Minimum Wear Ring Cross Section}\right] + 2x \left[\text{Desired minimum radial Metal-to-metal Clearance CL}\right]$$



Groove Detail

4. Minimum Groove Width, ***L***:

$$L = (\text{Nominal Width } W_1) + .010$$

5. Maximum Extrusion gap, (total) E_1:

$$E_1 = H_1 \text{ max} + \frac{(D_1 \text{ max.} - H_1 \text{ max.})}{2} - (T \text{ min.} - R_1 \text{ min.})$$

Notes:

* Add (0.001" to 0.002") to Maximum Rod to compensate for ovality and assembly.

1. Tolerance for ***L*** is +0.010 / +0.020.
2. Groove radii must not exceed 0.015" max.
3. ESC recommends a minimum of 0.005" metal-to-metal clearance. Using the above calculations may result in metal to metal contact if the wear ring material's compressive strength properties are not considered. *See **Table 1** and **Table 2** for further details.* Contact ESC if additional assistant is required.

For Large Extrusion Gap Seals, Consider using a series 757 Back-up Ring.

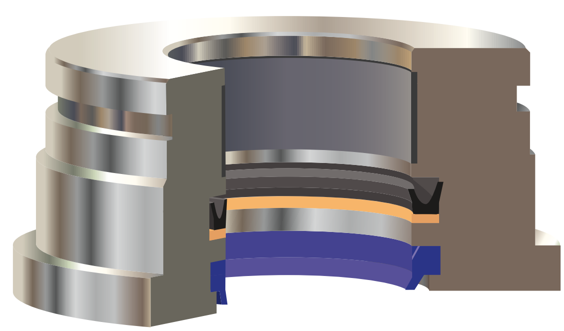
Example for above Formulas:

Given: Bore 1.499/1.500 (***B***) Wear Ring thickness 0.123 / 0.125 and 0.500 (***L***) wide. Rod machining tolerance is 0.002. Minimum desired radial metal-to-metal clearance is 0.005.

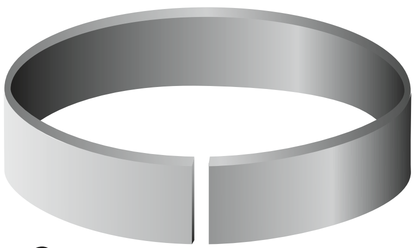
1. 1.500 + 0.001 -0.250 = 1.751 (***D*** Minimum Groove Diameter)
2. 1.751 + 0.002 = 1.753 (D_1 Maximum Groove Diameter)
3. 1.753 - (2x 0.123) + (2x 0.005) = 1.517 Minimum Throat Diameters, ***H***
4. 0.500 + .010 = .510 Minimum Groove Width, ***L* min.**
5. 1.519 + (1.753-1.519 / 2) - (0.123 + 1.499) = 0.014

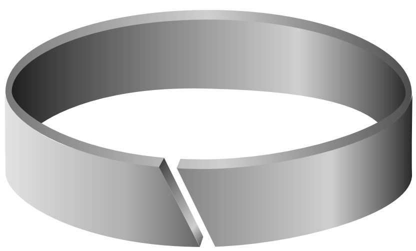
Extrusion Gap Maximum *E* max

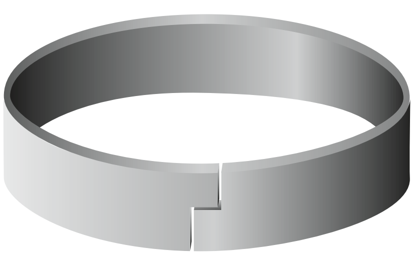
R= Rod Dia. = 1.498 / 1.500
H = Throat Dia. = 1.517 / 1.519
L. = Groove Width = 0.510 /0 .520
E. = TOTAL Extrusion Gap = 0.014



ULTRA-PRESISION WEAR RING JOINT STYLES
ADVANATAGE - INSTALATION - PREFORMANCE

	Advantages	Installation	Performance
 **Butt-Cut**	Easiest Joint style to install in many applications	 1 2 3 4 5 6 7 8 9 10 Easy More Complex	 1 2 3 4 5 6 7 8 9 10 Good Best

	Advantages	Installation	Performance
 **Angle-Cut**	Improves bearing stress at split and offers more coverage at split	 1 2 3 4 5 6 7 8 9 10 Easy More Complex	 1 2 3 4 5 6 7 8 9 10 Good Best

	Advantages	Installation	Performance
 **Step-Cut**	More difficult to install Improves bearing stress at gap Better resistance to contaminants & pressure spike loads	 1 2 3 4 5 6 7 8 9 10 Easy More Complex	 1 2 3 4 5 6 7 8 9 10 Good Best

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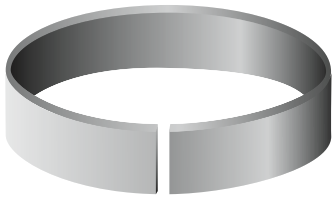
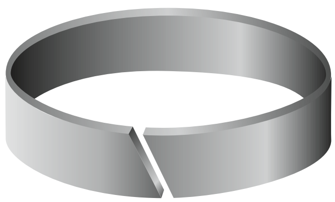
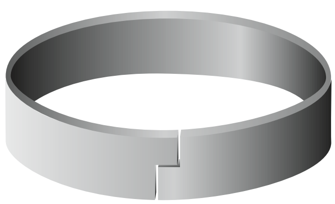
ULTRA-PRESISION WEAR RING CROSS SECTIONS AND C/S INSTALATION GUIDE LINES - INCH



BUTT CUT



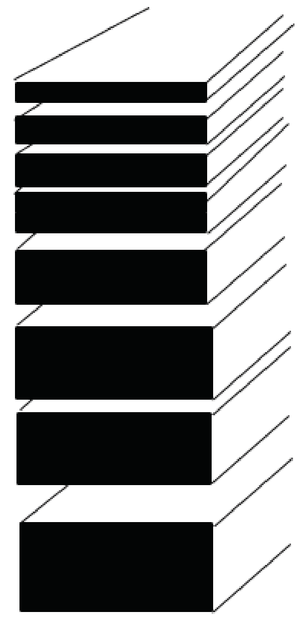
ANGLE CUT



STEP CUT

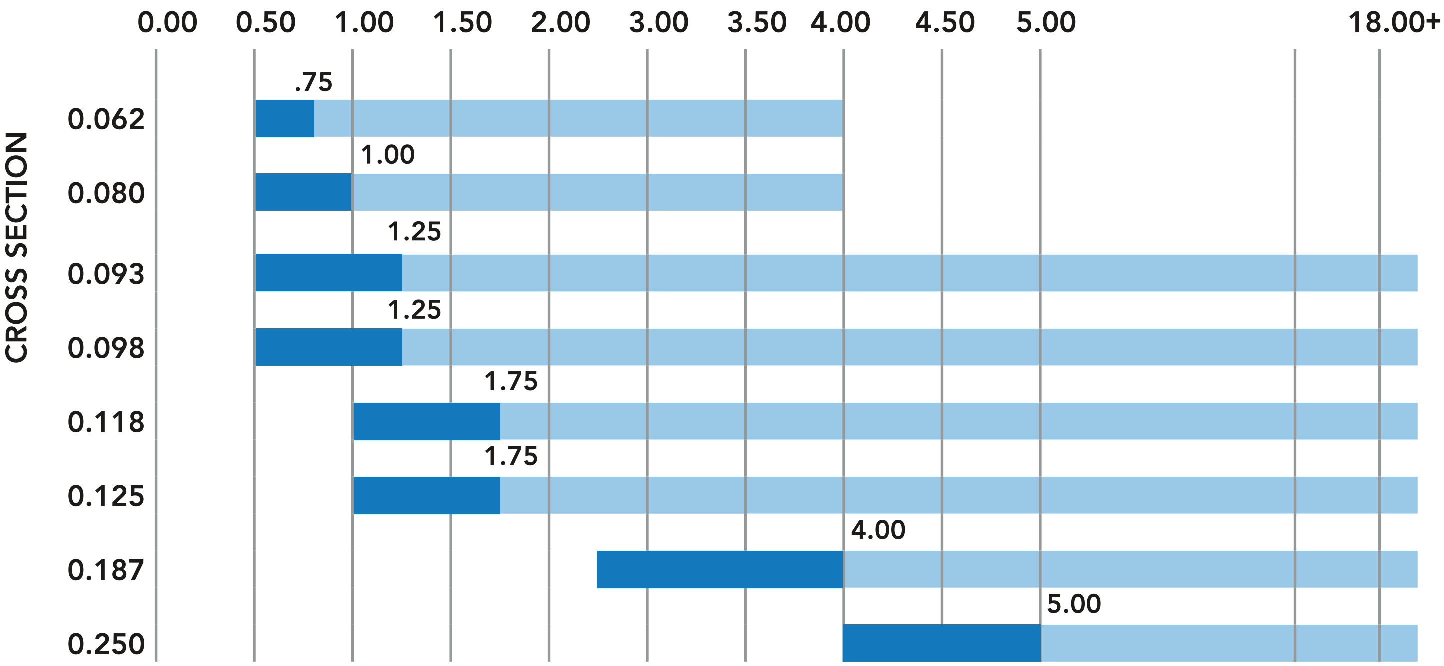
RADIAL CROSS SECTIONS

Nominal Inches	Actual Inches
0.062	.062 / .060
0.080	.080 / .078
0.093	.093 / .091
0.098	.098 / .096
0.100	.100 / .098
0.125	.125 / .123
0.187	.187 / .186
0.250	.250 / .248



RECOMMENDED C/S VS. DIAMETER INSTALLATION GUIDE LINES

Nominal OD

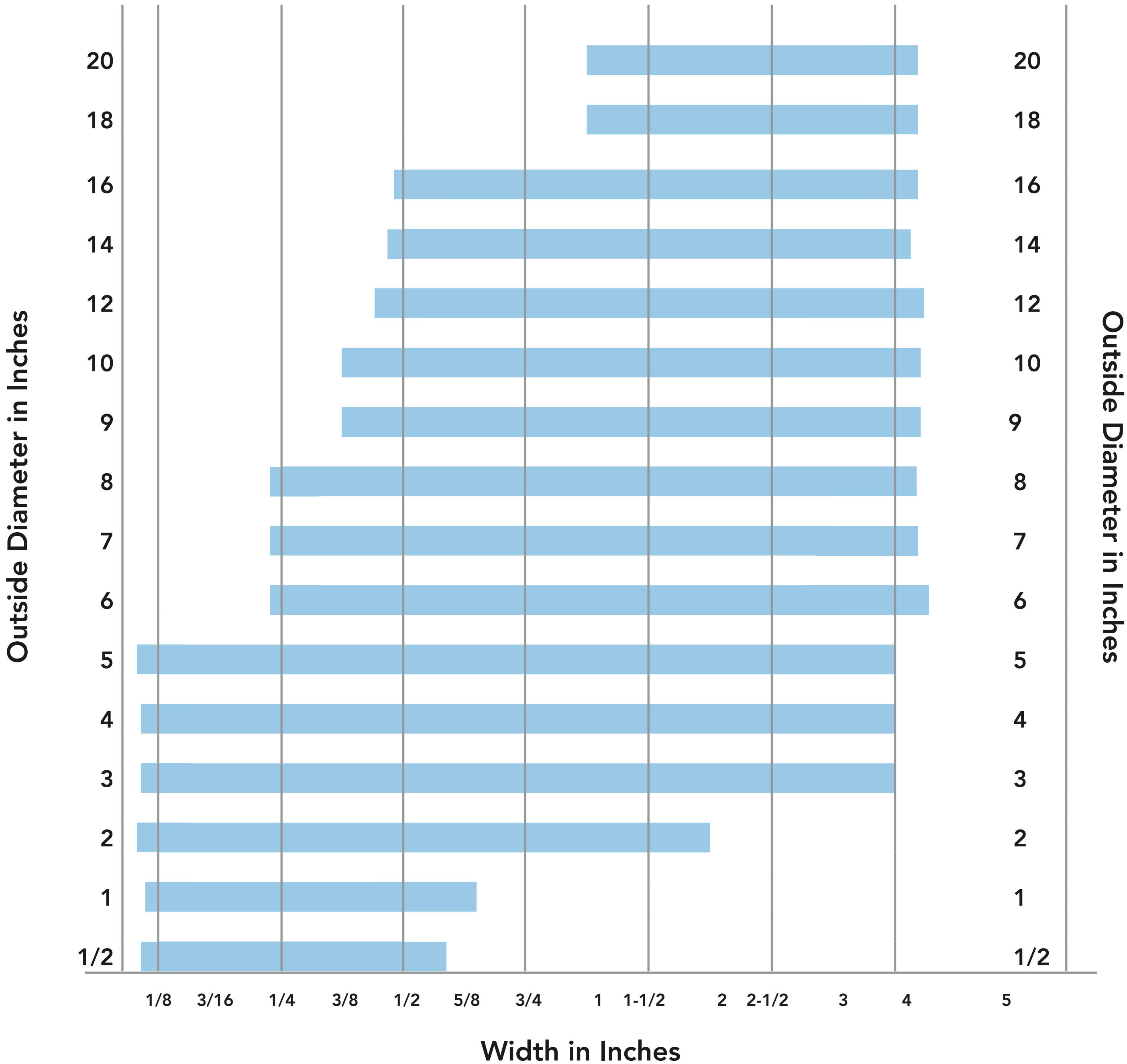


Light sections indicate Rod Guide Installations. Example: .062 cross section wear ring is recommended for .075 to 4.00 Diameter. Anything under .750 inch would be more difficult to install. Light and Dark sections indicate Piston Installations. Example: .125 cross section wear ring is recommended for 1.000 to 18.000+ inches. Anything under 1.000 inch would be more difficult to install.

AVAILABLE WEAR RING WIDTHS BY DIAMETER INCH SIZES

STANDARD WIDTHS BY DIAMETER

.125 CROSS SECTION



The graph above shows the current capability of *ESC* size range,
Consult factory for availability for specific size, cross section and widths.

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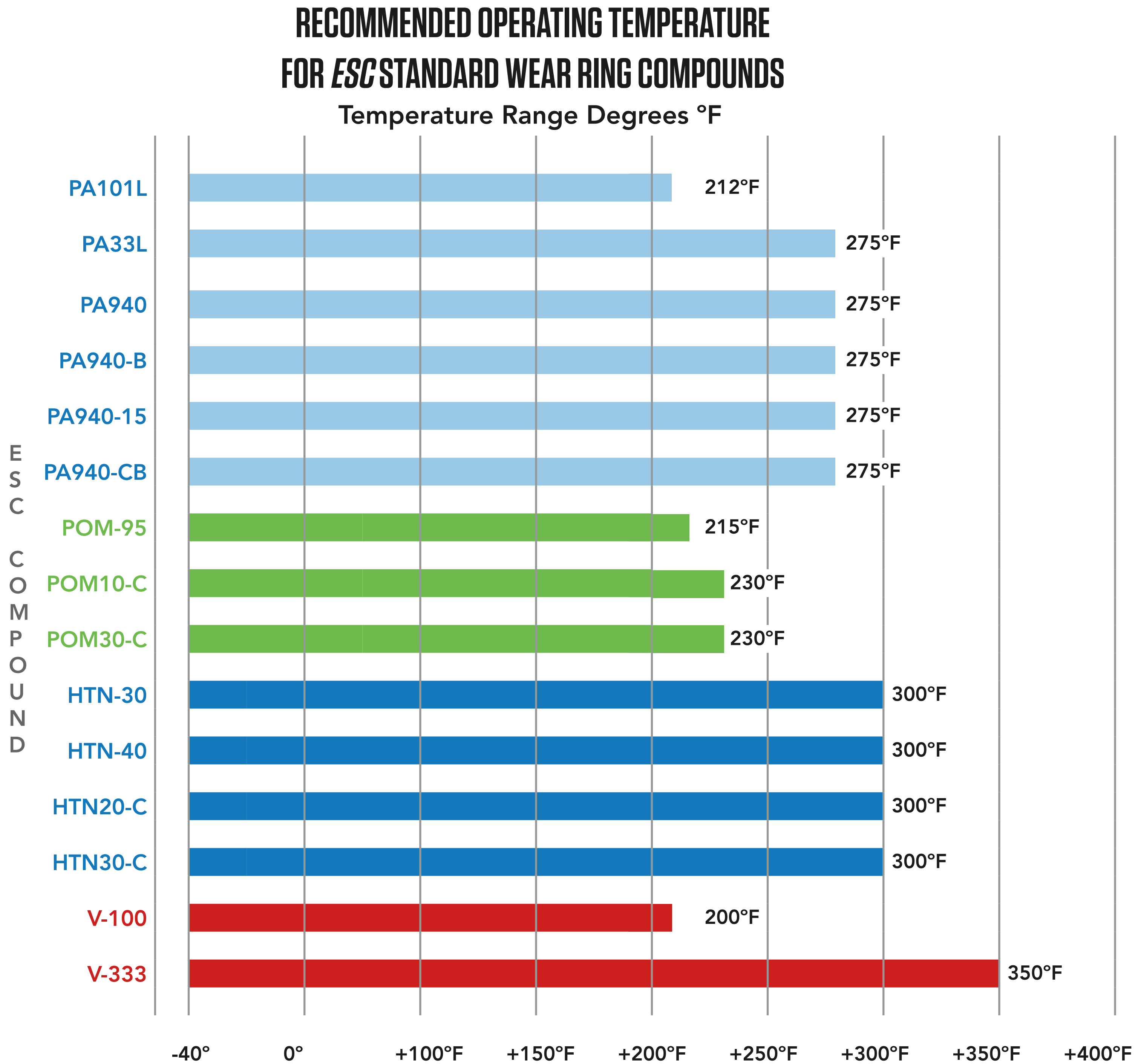
RECOMMENDED TEMPERATURE RANGE FOR *ESC* ULTRA PRECISION WEAR RINGS



When using this chart, keep in mind, as a plastic gets hotter it will loose much of it's tensile and compressive strength. Typically at +65°C most Nylons will loose about 40-50% of the Tensile and Compressive Strength. Refer to the ESC Wear Ring Engineering Guide for more information.

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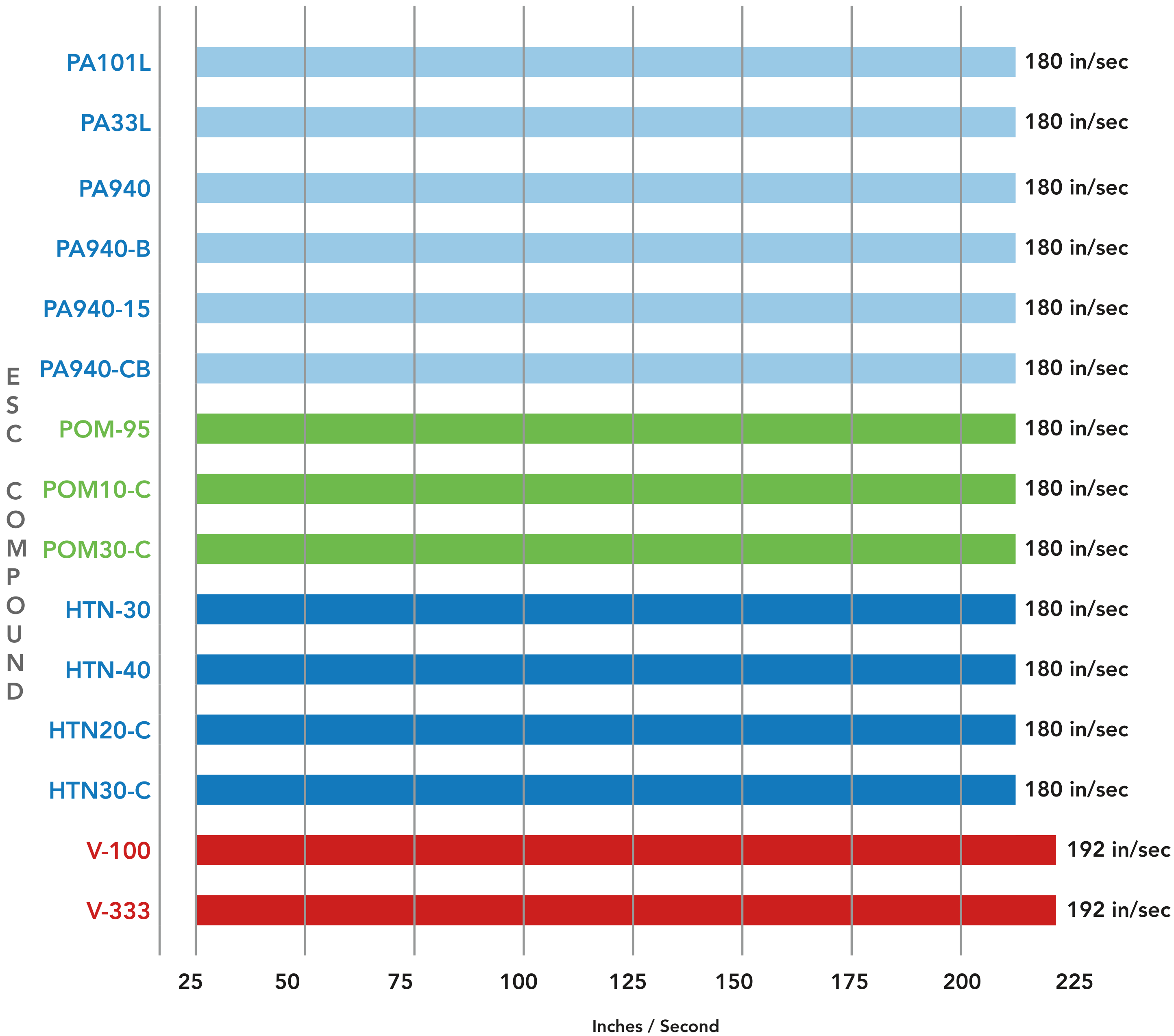
RECOMMENDED OPERATING SPEED RANGE FOR *ESC* ULTRA PRECISION WEAR RINGS

DYNAMIC *SPEED* RANGE: INCHES / SECOND



When picking a compound to use based on the speed the system will be operating at, make sure you look at Table 1 and Table 2 in the *ESC* Engineering Guide to see the strength of material you may need.

As system speed increases, so does friction. As friction increases the strength of the compound will decline. *ESC* has several compounds that have friction reducing modifiers added. In most plastics when you add a friction modifiers, you reduce the strength of the compound.

Please use the formulas in the *ESC* Wear Ring Engineering Guide to determine if you have enough strength for you application. By using a lower coefficient of friction material, one must be careful to take all factors into consideration.

Please consider STAMPS when designing.
S - Speed
T - Temperature
A - Application
M - Media
P - Pressure
S - Size

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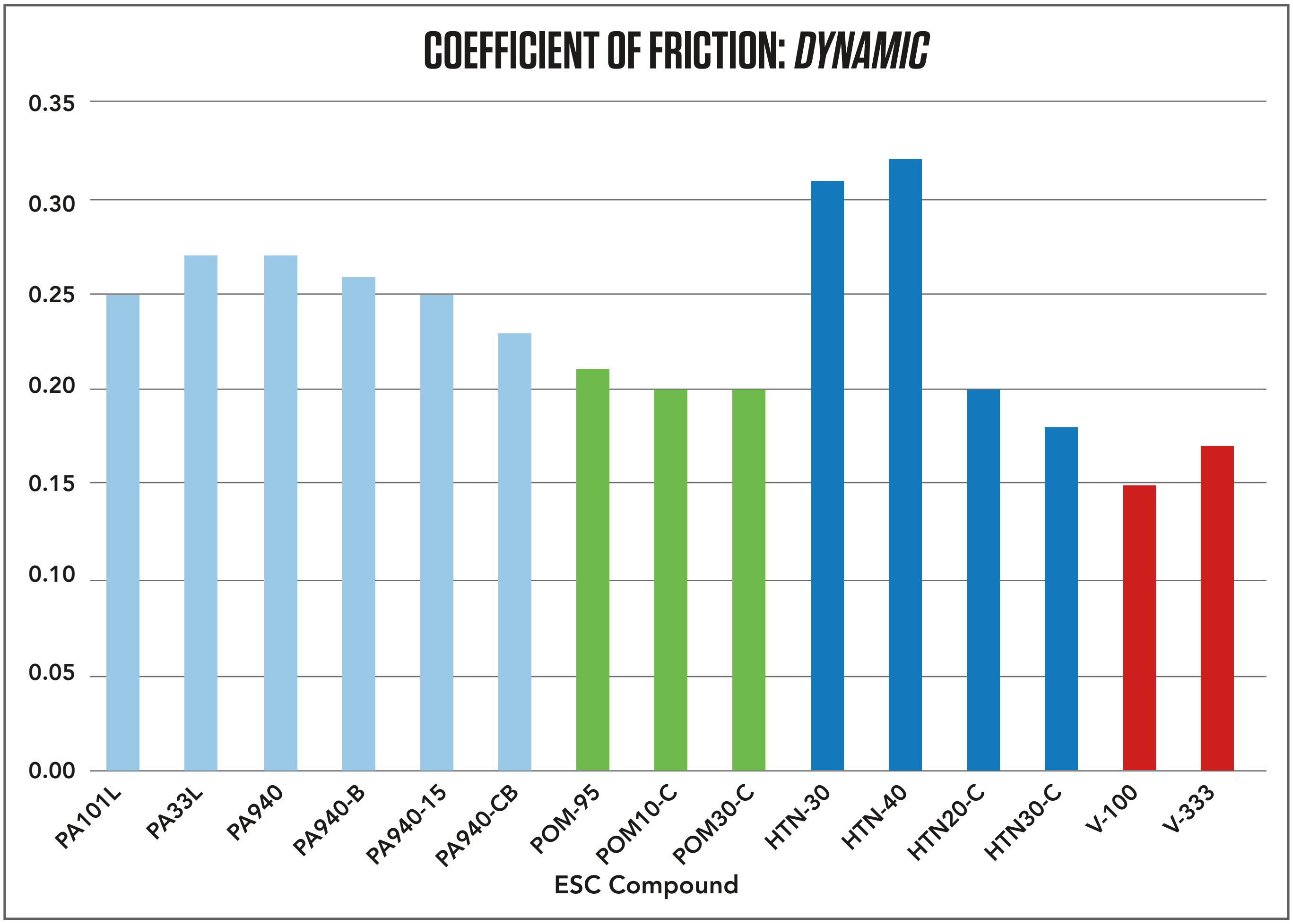
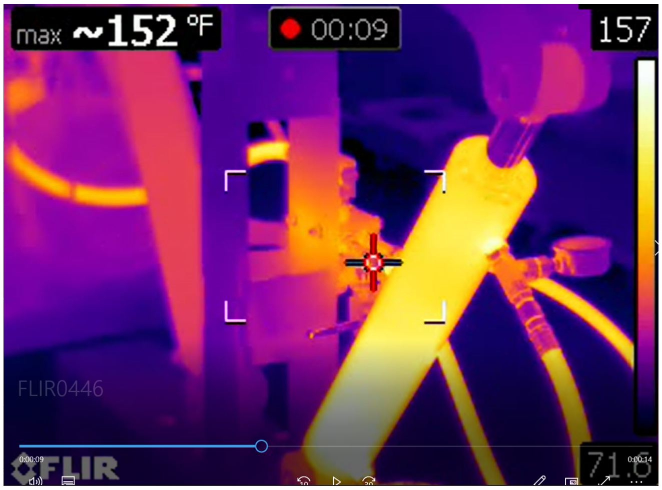
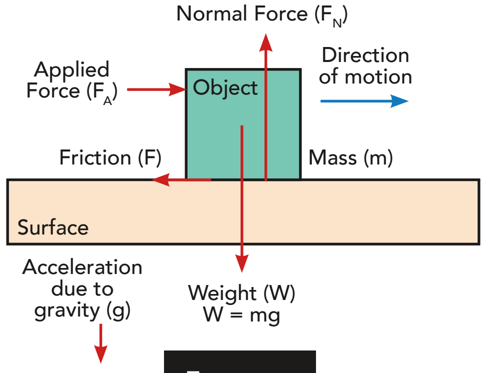
DYNAMIC COEFFICIENT OF FRICTION FOR ESC ULTRA PRECISION WEAR RING COMPOUNDS

One of the main causes of system, seal and wear ring failures is HEAT.
Many things cause heat, but friction is a major contributor. Here is how the ESC Family of compounds Stack up.





FRICTION



F = μmg

GLASS TRANSITION TEMPERATURE (Tg) OF *ESC* ULTRA-PRECISION WEAR RING COMPOUNDS

Why is Tg or glass transition important when selecting a Wear Ring Material? First let's look at the definition of Glass Transition Temperature.

The glass transition temperature (Tg) is somewhat of a misnomer, as it is actually a range of few degrees, either Celsius or Fahrenheit over which a polymeric material transitions from a glassy (rigid) state to a elastomer (rubbery) state. The Tg can be measured by differential scanning calorimetry (DSC), thermo mechanical analysis (TMA), or dynamic mechanical analysis (DNA).

The Tg of a material helps define its, mechanical properties. For example, Silicones all have a Tg of around -100°C (-212°F). For typical operating temperatures (-40° to +200°C), the silicone will always appear soft and flexible, this is because it is always operating above its Tg.

Another example of why you may need a material with a higher Tg, is that if a wear ring will "squeak" at a certain temperature, then go away, most likely the Tg has been reached and the material is grabbing the mating surface and is the cause in this case. A higher Tg also means a stiffer, stronger material, and is desirable in most cases.

Chart Tg 2 shows graphically what happens to a polymer during the temperature transition

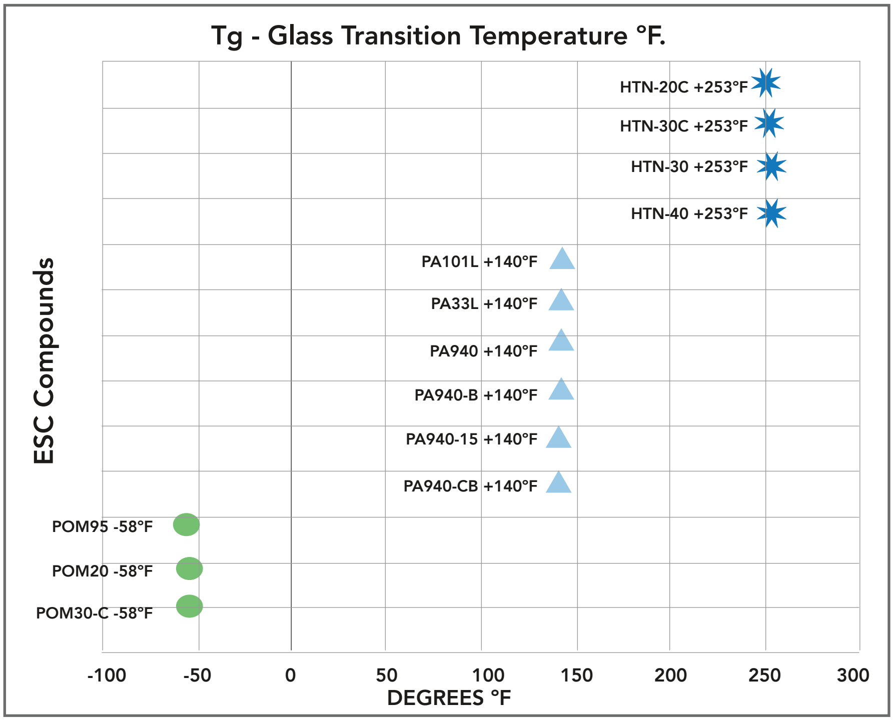


Chart Tg. 1

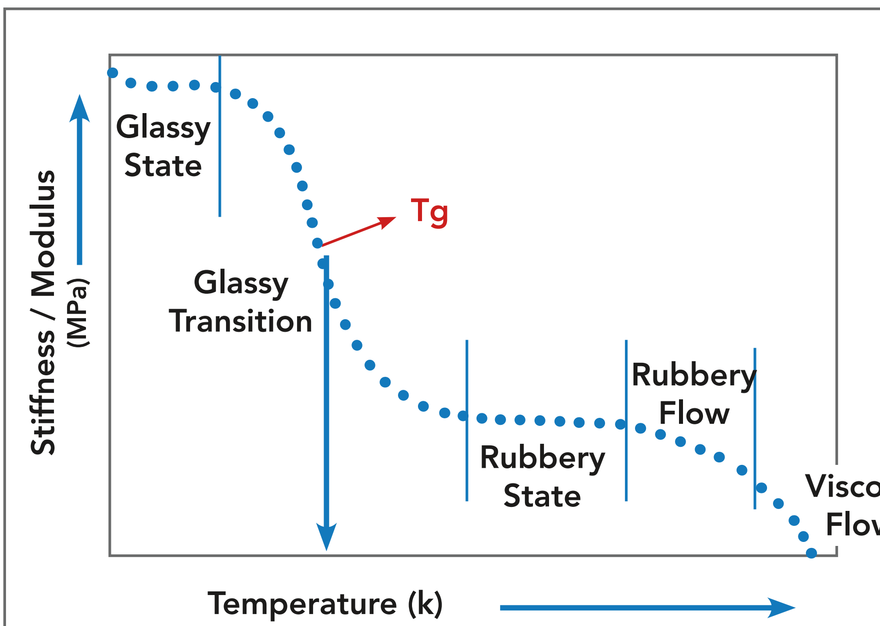


Chart Tg. 2

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ESC ULTRA PRECISION WEAR RING TYPICAL COMPOUND SPECIFICATIONS

ESC's standard materials used in Wear Ring manufacturing. These are the most common materials used. Please contact *ESC* for specialty grades to meet your specific needs.

ESC-Ion™ NYLON Wear Ring Materials

Property			COMPOUND NUMBER				
			PA940-B	PA940	PA940-15	PA940-CB	PA933-BK
			40% GF 6 NYLON / PROPRIETARY LUBRICANT	40% GF 6 NYLON	40% GF 6 NYLON / PTFE	40% GF 6 NYLON / PROPRIETARY LUBRICANT	33% GF 6/6 NYLON / PROPRIETARY LUBRICANT
	Test Method	**Units**	**Value**	**Value**	**Value**	**Value**	**Value**
Tensile Strength	ASTM D638	Mpa (psi)	184 (26,700)	169 (24,500)	138 (20,000)	169 (24,500)	186 (27,000)
Tensile Elongation	ASTM D638	%	2.5	2.5	3	2.5	3
Tensile Modulus	ASTM D638	Mpa (psi)	13,000 (1,980,000)	13,10 (1,900,000)	12,756 (1,850,000)	10,135 (1,470,000)	11,032 (1,600,000)
Flexural Strength	ASTM D790	Mpa (psi)	280 (40,600)	262 (38,000)	234 (34,000)	263 (38,142)	276 (40,000)
Flexural Modulus	ASTM D790	Mpa (psi)	11,721 (1,700,000)	11,031 (1,600,000)	12,066 (1,750,000)	10,273 (1,490,000)	810,800 (1,200,000)
Shear Strength	ASTM D2344	Mpa (psi)					
Compressive Strength	ASTM D695	Mpa (psi)	193 (28,000)	165 (24,000)	138 (20,000)	165 (24,000)	227 (33,000)
Parallel to laminate	ASTM D695	Mpa (psi)					
Normall to laminate	ASTM D695	Mpa (psi)					
Hardness, Rockwell	ASTM D785	R	R120	R120	R120	R120	R120
Specific Gravity	ASTM D792		1.49	1.46	1.60	1.44	1.40
Water Absorption 24 hrs. @ 73 F (23 C)	ASTM D570	%	1.0	1.0	1.0	1.0	0.9
Coefficient of Friction (Dynamic)		40 psi, 50 fpm	0.27	0.30	0.25	0.23	0.27
Deflection Temperature C (F)							
@264 psi (1.8 Mpa)	ASTM D648	°C (°F)	204 (400)	204 (400)	204 (400)	204 (400)	260 (500)
@66 psi (0.45Mpa)	ASTM D648	°C (°F)	210 (410)	210 (410)	210 (410)	210 (410)	252 (486)
Coefficient of Linear Thermal Expansion	ASTM D696	m/m/C (in/in/F)	.000027 (.000015)	.000027 (.000015)	.000027 (.000015)	.000027 (.000015)	.000026 (.000012)
Tg-Glass Transition		C° (F°)	60 (140)	60 (140)	60 (140)	60 (140)	60 (140)
Service Range		Degrees F	-65F to +275F	-65F to +275F	-65F to +275F	-65F to +275F	-65F to +275F
Operating Speed- MAX.		m / sec. (feet / sec)	4.6 (15.0)	4.6 (15.0)	4.6 (15.0)	4.6 (15.0)	4.6 (15.0)
Color			Black	Black	Black	"CB" Blue	Black

TABLE 1

* Estimated By the Laboratory.

The information provided in this data sheet corresponds to our knowledge on the subject at the date of this publication. This information may be subject to revision as new knowledge and experience becomes available. The data provided fall within the normal range of product properties and relate only to the specific material designated; these data may not be valid for such materials used in combination with any other material, additives or pigments or in any process, unless expressly indicated otherwise. The data provided should not be used to establish specifications limits or used alone as the basis of design; they are not intended to substitute for any testing you may need to do to determine the suitability of a specific compound for your particular purpose. Since Engineered Seals, LLC cannot anticipate all variation in actual end-use conditions ESC makes no warranties and assumes no liability in connection with any use of this information. Caution: Do not use this product in medical application involving permanent implantation in the human body.We highly recommend testing in your specific application, this is a guide only.

ESC ULTRA PRECISION WEAR RING TYPICAL COMPOUND SPECIFICATIONS

ESC's standard materials used in Wear Ring manufacturing. These are the most common materials used. Please contact *ESC* for specialty grades to meet your specific needs.

ESC-Ion ™ "Zero Swell" / Low Friction Wear Ring Materials

Property	Test Method	Units	COMPOUND NUMBER				
			HTN-40	HTN-30C	V-100	POM-95	POM-10C
			40% Glass Filled	30% Carbon Filled with PROPRIETARY LUBRICANT	COMPOSITE POLYESTER/ POLYESTER	Acetal	Carbon Filled POM
			Value	Value	Value	Value	Value
Tensile Strength	ASTM D638	Mpa (psi)	207 (30,000)	283 (41,000)	76 (11,000)	55 (8,000)	106 (15,500)
Tensile Elongation	ASTM D638	%	2.0	1.4	NA	>10	3-4
Tensile Modulus	ASTM D638	Mpa (psi)	14,135 (2,050,000)	24,821 (3,600,000)	76 (11,000)	241 (35,000)	8,618 (1,250,000)
Flexural Strength	ASTM D790	Mpa (psi)	307 (44,500)	440 (63,870)	NA	90 (13,000)	155 (22,500)
Flexural Modulus	ASTM D790	Mpa (psi)	13,100 (1,900,000)	21,373 (3,100,000)	3,309 (480,000)	2,448 (355,000)	(1,070,000)
Compressive Strength	ASTM D695	Mpa (psi)	207 (30,000*)	241* (35,000*)		62 (9000)	104* (15,000*)
Normal to laminate		Mpa (psi)			345 (50,000)		
Parallel to laminate		Mpa (psi)			100 (14,500)		
Notched 1/8"	ASTM D256	J/m (ft-lb/in)	91 (1.7)	78 (1.60)	NA	80 (1.5)	(1.2)
Unnotched 1/8"	ASTM D256	J/m (ft-lb/in)	641 (12.0)	705 (14.45)	NA	1,495 (28.0)	(10)
Hardness, Rockwell	ASTM D785	R	R125	R125	R135	R80	R110
Specific Gravity	ASTM D792		1.52	1.40	NA	1.41	1.42
Water Absorption 24 hrs. @ 73 F (23 C)	ASTM D570	%	0.23	.20	<0.1	.12	.12
Coefficient of Friction (Dynamic)	40 psi, 50 fpm		0.32	.18	.17-.12	.21	.20
Heat Deflection Temperature							
@264 psi (1.8 Mpa)	ASTM D648	°C (°F)	277 (530)	282 (540)	NA	96 (205)	135 (275)
@66 psi (0.45Mpa)	ASTM D648	°C (°F)			NA	154 (309)	
Coefficient of Linear Thermal Expansion Flow	ASTM D696	m/m/C (in/in/F)	.000022 (.000012)	.000022 (.000012)	NA	(.000060)	(.000051)
Tg-Glass Transition		C° (F°)	123 (253)	123 (253)	121 (250)	-50 (-58)	-50 (-58)
Service Range		Degrees F	-65F to +300F	-65F to +300F	-65F to +200F	-40F to +212F	-40F to +225F
Operating Speed- MAX.		m / sec. (feet / sec)	4.6 (15.0)	4.6 (15.0)	4.69 (16.0)	4.6 (15.0)	4.6 (15.0)
Color			Black	Black	Red or or Pearl	Black or White	Royal BLUE

TABLE 2

* Estimated By the Laboratory.

The information provided in this data sheet corresponds to our knowledge on the subject at the date of this publication. This information may be subject to revision as new knowledge and experience becomes available. The data provided fall within the normal range of product properties and relate only to the specific material designated; these data may not be valid for such materials used in combination with any other material, additives or pigments or in any process, unless expressly indicated otherwise. The data provided should not be used to establish specifications limits or used alone as the basis of design; they are not intended to substitute for any testing you may need to do to determine the suitability of a specific compound for your particular purpose. Since Engineered Seals, LLC cannot anticipate all variation in actual end-use conditions ESC makes no warranties and assumes no liability in connection with any use of this information. Caution: Do not use this product in medical application involving permanent implantation in the human body.We highly recommend testing in your specific application, this is a guide only.

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SEALS & COMPONENTS STORAGE CONDITIONS / SHELF LIFE

Factors that influence the LIFE of elastomer seals & components

The properties profile of an elastomer seal component will normally remain constant for years if it is properly stored. In the event of improper storage, a large number of influencing factors can result in drastically reduced seal life.

Ultimately the seal is no longer fit for use due to cracking, hardening, softening, swelling, permanent deformation, breaking, and surface damage, etc.

To avoid this, Engineered Seals & Components, based on the DIN 7716 and ISO 2230 standards, recommends the following information to be used as a guideline for storage, cleaning, and maintenance of elastomer seals and components.

Cleaning: Contact ESC Engineering for instruction on cleaning of Seals & Components.

ENGINEERED SEALS & COMPONENTS
SEALS & COMPONENTS STORAGE CONDITIONS / SHELF LIFE

Temperature

The recommended storage temperature for elastomer seals and components is +15C (+59F) and should not exceed +25C (+77F). Sources such as radiators, forced air units or boilers should be at least 1 meter or 3 feet away from the product.

Direct sunlight should be avoided. If temperatures drop below -10C (+14F) elastomer products tend to become very stiff. Special care should be taken to prevent the product from becoming deformed. Chloroprene material should not be stored below -12C (-10F).

Humidity

It is very important to ensure that the relative humidity in storage facilities stay below 65%. Storage in humid areas with condensation must be avoided. Sealed polyethylene bags or foil bags are a good choice. By the same token extreamely dry condition will cause will cause premature failures also.

Light / Radiation

Elastomer seals and components must be protected against light with high UV content. This light may cause damage to the products. Examples of light sources with high UV content include intense artificial light or direct sun light.

Light caused damage may be prevented by adding UV barriers or filters to window panes in the storage area. All types of radiation such as gamma or radioactive radiation must be avoided.

Cleaning: Contact ESC Engineering for instruction on cleaning of Seals & Components.

Solvents / Greases

Greases, oils and solvents may cause damage to elastomer seals and components. Therefore it is imperative that seals and other plastic components do not come in contact with these media in storage, unless packaged by the manufacturer this way.

Deformation

Elastomer seals and Thermoplastic components which are packed to tightly or crushed in a box will cause deforming. If the parts are exposed to tensile or compressive stress, the parts may be deformed. Cracking may occur or the parts may not be able to be installed correctly. It is a must that the seals and components be stored without being exposed to strain or deformation.

Oxygen / Ozone

Generally, elastomer seals and components should be protected against circulating air by using stable packaging such as airtight containers or polyethylene bags. This very important for rvery small seals with large surface to volume ratio. Mercury vapor lamps, florescent light sources, electric motors - generally any device that is capable of producing ozone through sparks, electrical discharges or high-voltage fields must be avoided if at all possible. Ozone is harmful to many elastomers, so storage areas must be ozone free. This also applies to organic gases as well as combustion gases as they are capable of producing ozone via a photochemical process.

Storage Period

A key criteria for the storage period of elastomers and components is the time which the product was produced. ESC indicates the date of the manufacture on the packing bags. The manufacture Quarter and the Year are the label in the Cure Date box. The recommended maximum storage period depends on the type of elastomer. **See Table S-1.**

The typical shelf life may be prolonged based on the actual product conditions at the end of the typical shelf life. Trained and experienced experts can approve a prolonged storage period based on a visual inspection of representative samples. The samples should not reveal any permanent distortion, mechanical damage or surface cracking. The material should not show any signs of hardening or softening nor any kind of tackiness.

Table S-1
Shelf Life Recommended in Years

	Typical Shelf Life	Possible Extension
TPU H-Poly	5	2
ESC-Thane	5	2
TPC-ET (Hytrel)	10	5
NBR (Molded)	6	3
NBR (Machined)	4	
HNBR	8	4
FKM, FPM	10	5
MVQ (Silicone)	10	5
PTFE	15	5
PA (ESC-Ion)	10	5
POM (ESC-tal)	10	5
PPA (ESC-HTN)	10	5
PEEK	10	5
UHMWPE	10	5

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Requests for more information are welcome. In particular, we will be glad to provide samples for you to inspect and test in your assemblies and plant before you make a final decision for you application.

Notice of Exclusive Warranty and Remedy

Briefly, our exclusive warranty is against defects in materials and workmanship at the time of shipment. It is in lieu of all other warranties. There is no implied warranty of merchantability or fitness for a particular purpose. The exclusive remedy is replacement of defective products, or at our option, refund of their purchase price. All damages exceeding the purchase price are excluded, weather consequential or otherwise and regardless of cause. The terms and conditions on our printed quotation contain a much more complete statement of our Exclusive Warranty and Remedy.

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