YEOMANS
CHICAGO
CORPORATION

SUBMERSIBLE NON-CLOG PUMPS
MECHANICAL SEALS

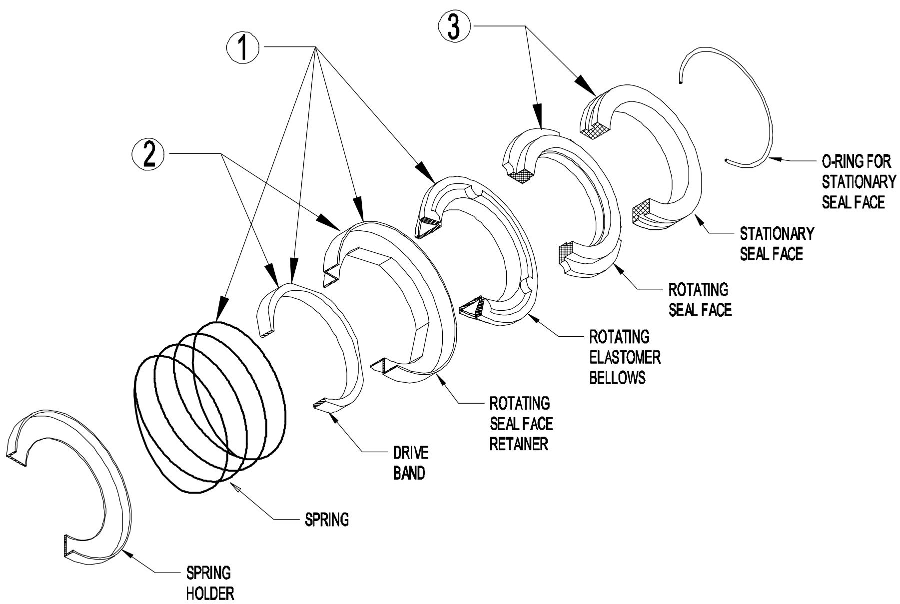
INTRODUCTION

Yeomans® and Chicago Pump® submersible non-clog pumps are furnished with a tandem mechanical seal arrangement consisting of two (2) independent Type-21 mechanical seals running in an oil reservoir. The Type-21 mechanical seal is the industry standard for original equipment manufacturers. The seals are readily available from many commercial sources on a worldwide basis thereby providing the customer with easy access to repair or replacement seal parts. The modest cost of Type-21 seals helps reduce the customer's spare parts expense. Non U.S. manufactured seal designs supplied by some competitors can be very costly to replace and hard to find from local sources.

BASIC APPLICATION AND FEATURES

For most average sewage and wastewater applications, the standard Silicon Carbide vs. Silicon Carbide seal face combination is the ideal choice. This hard seal face combination is suitable for most applications including abrasion service with high grit content, standard water and wastewater, high temperature service (up to 90° C), and most chemicals. On the standard seals, the secondary sealing element (flexible elastomer bellows) and the o-ring are Viton material for maximum performance. All metal seal parts, including the spring, are made of Stainless Steel. The upper seal is normally constructed using Silicon Carbide vs. Carbon since the environment of the upper seal is an oil bath and is normally not subjected to the pumped media.

Please refer to the following drawing and notations for detail of specific seal features and benefits:

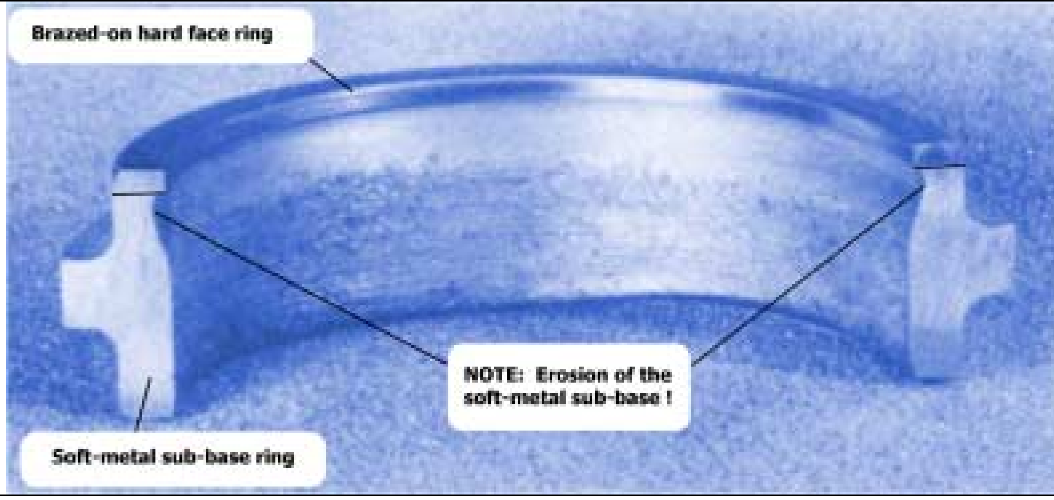


1. The single coil-spring and flexible bellows design provides self-alignment which automatically adjusts to compensate for shaft endplay, run out, primary sealing ring wear, reverse pressure and equipment tolerances. This feature will help increase the seal life and prevent premature failure.

2. The drive band and retainer feature a hex-drive system to distribute drive loading evenly and eliminate over-stressing of the flexible elastomer bellows. The crimped head design, prevents solids from dislodging the seal face, allows the seal to withstand higher pressure and rotational speed, and eliminates the metal shell from contacting the seal ring.

3. The primary and mating seal faces are lapped to 3-helium light bands (0.0000033") flatness to provide effective sealing and leakage protection. Both primary and mating ring are made of solid-block construction for greater reliability and longer service life compared to the soldered, welded or sprayed hard-face designs used by other manufacturers.

The following image illustrates an inferior seal ring design utilizing a soldered (brazed) hard face ring affixed to a soft metal sub-base ring. The hard-face is typically made of Tungsten Carbide and the sub-base material is typically 316 SS.



This cross-cut view reveals the erosion damage which has begun to destroy the soft sub-base base after a relatively short period of operation under abrasive pumping conditions.

In addition to erosion of the soft-metal sub-base, the following results can occur with this type of seal ring:

- Differing thermal expansion rates between the hard-surface layer and the sub-base ring can cause separation of the layers, resulting in catastrophic seal failure.
- The small thickness of the hard face ring provides for a shortened wear life compared with solid-block ring types
- The metal sub-base and solder/brazing materials may be subject to corrosive attack

SEAL FACE MATERIALS – OVERVIEW AND COMPARISON

The correct choice of materials for the seal faces can increase seal life fivefold in some cases. In the wastewater pump industry the most common materials are carbon-graphite, silicon carbide, tungsten carbide, and alumina oxide. Alumina oxide seals are commonly referred to as “ceramic”; however, technically speaking, silicon carbide seals are also a type of “ceramic” seal. In common wastewater pump terminology, “ceramic seals” most often refers to alumina oxide 99.5% material.

When a seal fails, a considerable amount of expense is involved in replacing it. Though the cost of the bare seal may be relatively insignificant, the cost of pump downtime and labor expense can greatly increase the overall cost of a seal failure. In submersible wastewater applications, the mechanical seals provide a “front line” of defense against motor damage and catastrophic failure. Another important consideration in seal design and face material selection is energy consumption. The frictional properties of the seal can have a big impact on the amount of power consumed by the machinery on which it is used. Therefore, the correct choice of seal face materials can result in power cost savings to the end user.

Carbon-Graphite

Carbon-graphite seals are self-lubricating. When this material is rubbed against carbides, metals, or ceramics, a microscopically thin transfer film of graphite is quickly laid down. This low-friction film plays a vital role in controlling temperature rise if the interface becomes dry during rubbing. The formation of a proper transfer film requires the presence of absorbable vapors such as water.

Carbon-graphite seal grades are available in a range of abrasion resistances. The softer, low-hardness grades are preferred where the mating face is a relatively soft metal. Harder, more abrasion-resistant grades are preferred where the fluid sealed contains suspended or dissolved solids.

While carbon-graphite is one of the most chemically inert materials available, some grades can be attacked by highly corrosive chemicals such as hydrofluoric acid. With few exceptions, carbon and the resin sealer impregnant are completely unaffected by solvents, acids, or caustics. Only strong oxidizing agents such as boiling concentrated nitric acid are not compatible.

Impregnation of carbon seals can be done with a variety of materials to control permeability. In addition to thermoset resins, other types of impregnants include metals, inorganic salts, or ceramics.

The standard upper mechanical seal on Yeomans and Chicago Pump submersible non-clog pumps consists of a primary seal ring of carbon-graphite material versus a mating ring made of a sintered silicon carbide graphite composite material. This material combination provides superior pressure-velocity characteristics and optimum performance in the non-abrasive environment of the oil-filled upper seal chamber.

Silicon Carbide

When evaluating wastewater pumps with silicon carbide seals, it is important to evaluate the specific material type being offered by the pump manufacturer. Not all types of silicon carbide material are desirable for optimum wastewater pump performance.

The following is a brief overview of some common types of silicon carbide seal face material:

- **Solid Silicon Carbide**

  Seal face components made from solid silicon carbide are particularly well suited to abrasive and corrosive applications and can handle a wide range of temperature extremes. These components are excellent thermal conductors and can be specified where high strength and stiffness are required.

- **Siliconized Graphite**

  Siliconized graphite, is made by exposing specially formulated graphite to silicon monoxide vapor in a chemical vapor reaction (CVR) process. This process converts the graphite surfaces to silicon carbide, and a percentage of free graphite is dispersed throughout the surface. This material has improved lubricity and resistance to wear.

- **Reaction Bonded Silicon Carbide**

  Another type of silicon carbide is fine-grain reaction-bonded silicon carbide. This consists of a silicon-carbide matrix that has been infiltrated with molten silicon. This is an excellent material for wear applications. The presence of approximately 10-12% free silicon prevents its use in strong acids or caustics, but the free silicon metal plays a role in reducing friction and wear. When used in mechanical face seals, this reaction-bonded material is an outstanding mating face for carbon graphite seal noses.

- **Self-Sintered Silicon Carbide**

  Self-sintered silicon carbide consists of high-density alpha silicon carbide in granular form that is molded and sintered at high temperatures to form a solid part. No free graphite or silicon are present. This is the hardest of all the silicon carbides and is the most corrosion resistant seal material avail able. It has a temperature limit of 2500°F. Sintered silicon carbide is the most widely used seal and bearing material in the CPI.

- **Self-Sintered Silicon Carbide Graphite Composite (SSC-GC)**

  In recent years, self-sintered silicon carbide graphite composite has been introduced as an alternative for a hard surface against hard-surface (such as tungsten carbide) applications. This material is produced by bonding a matrix of silicon carbide and graphite by an infiltration of molten silicon. This silicon carbide combines some of the best characteristics of siliconized graphite with the best of the reaction-bonded materials. This material is applicable for high performance pressure-velocity applications or where abrasion resistance is crucial due to solids in the material being pumped. ***This is the standard type of silicon carbide seal material furnished on Yeomans and Chicago Pump submersible non-clog pumps.***

Silicon carbide materials, in general, exhibit outstanding characteristics providing excellent performance and long life in "regular service." However, field results indicate that “regular service” does not always determine seal or bearing life. Often, unusual or upset conditions cause premature failure.

Silicon carbide is sensitive to operating conditions, particularly to a lack of lubricating product flow to seals and bearings. If product lubrication is lost, or the pump is started without fluid, this dry-run condition can result in pump failure. This can happen when a valve is incorrectly positioned, if there is loss of suction pressure at the pump, or in cases of inadequate submergence on wet-pit installations.

Tests of seals in adverse conditions show that reaction bonded silicon carbide and self-sintered have the poorest dry running and marginally lubricated capabilities. Under such conditions, siliconized graphites and a reaction-bonded silicon carbide composite with graphite show the highest capability and low wear, approaching the capability of carbon-graphite.

Development of the new sintered silicon carbide graphite composite material has shown great improvement of marginally lubricated rubbing characteristics.

Tungsten Carbide

Tungsten carbide is still commonly used in mechanical seals. This cermet (ceramic-metal) is extremely tough and stiff and has very good abrasion resistance. Two common metal binders, cobalt and nickel, are used. Typically 6% binder materials are used in mechanical seals, although a wide range is available. Nickel-bonded tungsten carbides are more prevalent in the wastewater pump market due to their improved corrosion resistance compared with cobalt bound materials.

Compared with self-sintered silicon carbide graphite composites, tungsten carbide provides less thermal conductivity, lower hardness and a greater coefficient of friction.
(For further details please refer to the comparison information later in this section.)

Alumina Oxide

In the wastewater pump market, alumina oxide seals are commonly known as “ceramic” type. Aluminum oxide ceramic is commonly used as a mating ring together with a carbon-graphite opposing seal face. Alumina exhibits high hardness and good abrasion resistance, but its thermal shock resistance is low. This ceramic material has been used in mechanical seals for years, but continues to be replaced by higher-performance materials such as silicon carbide. Several alumina purities are available, with higher levels such as 99.5% still used in sewage and wastewater service.

Comparison: Sintered Silicon Carbide - Graphite Composite (SSC-GC) vs. Tungsten Carbide

1. **Apparent Density**
SSC-GC has an apparent density of approximately 3 gm/cc. This compares to Tungsten Carbide at approximately 15 gm/cc. The lower density is a benefit in mechanical seals since it is advantageous to rotate a smaller mass. The more mass, the more exaggerated the effects of misalignment and the more stress is placed on the flexible members of the seal, i.e. the elastomer bellows and spring.

2. **Vickers Hardness**
SSC-GC has a Vickers hardness of approximately 2200 kg/mm^2. This compares to Tungsten Carbide at approximately 1500 kg/mm^2. Carbon-Graphite faces are approximately 75 kg/square mm. Carbon faces are obviously too soft to handle abrasives. Any of the “hard-faces”, with Vickers numbers starting at about 1300 kg/mm^2, are considered abrasion resistant.

3. **Modulus of Elasticity**
SSC-GC has a modulus of elasticity of approximately 30 Million PSI. This compares to Tungsten Carbide at approximately 90 Million PSI. In other words, TC is much stiffer than SSC-GC. Mechanical seals, especially when new, rely on the faces to deflect to maintain a mated pair. TC is unable to deflect except under the most extreme pressures. SSC-GC, in addition to containing graphite to help form a film between the faces, will allow the narrow primary ring to deflect the small amount required to maintain contact between the faces. This results in less weepage.

4. **Thermal Conductivity**
SSC-GC has a thermal conductivity of approximately 90 (BTU/hr • ft2 • °F/ft). This compares to Tungsten Carbide at approximately 58 (BTU/hr • ft2 • °F/ft). This is a 55% improvement in thermal conductivity over Tungsten Carbide. Coupled with an o-ring mounted seat, it will help to ensure that seals with SSC-GC faces run cooler than any other hard-faced material.

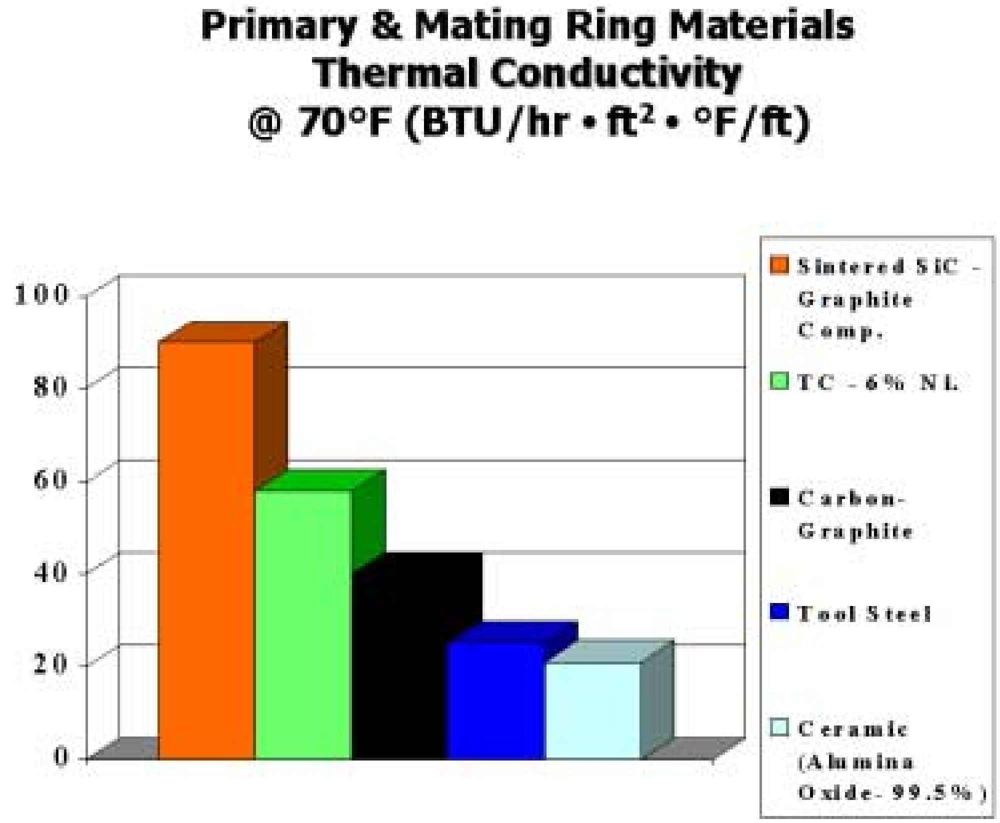
5. **Average Coefficient of Friction**
SSC-GC has an average coefficient of friction of approximately 0.05. This compares to Tungsten Carbide at approximately 0.10. This reduced coefficient of friction ensures that there will be far less heat generated by seals with SSC-GC faces than with Tungsten Carbide faces.

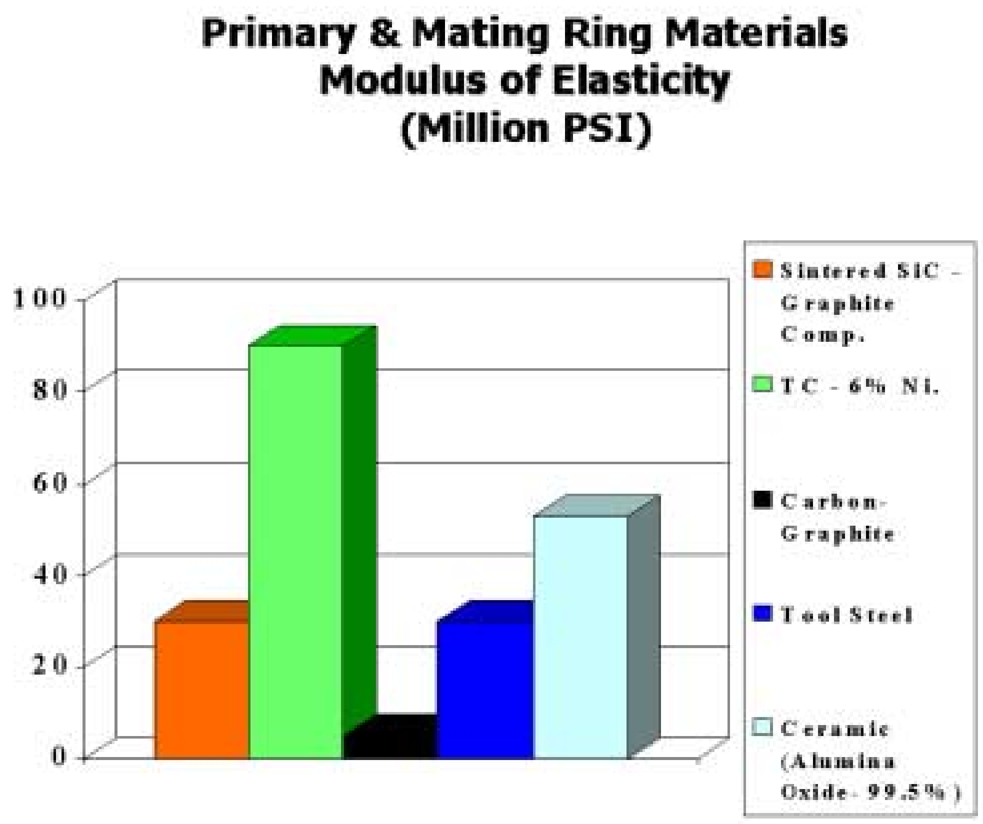
The physical properties do not tell the entire story about SSC-GC. The combination of the graphite loading, low coefficient of friction, and excellent thermal conductivity, means that seals with SSC-GC faces offer dry-run survivability. The duration of the survivability depends upon shaft size, speed, the fluid that was present at the seal faces, and the features and dimensions of the seal cavity.

The thermal shock resistance of SSC-GC is approximately 650°C ΔT, depending on the shape of the part and the stresses that are being placed on the part. This is likely higher than other components in a pump, and is significantly better than other silicon carbide materials. Even if a SSC-GC part is thermally shocked, it is unlikely to fail. This is because the resulting cracks are micro-fissures, and they stop growing when they hit a pocket of graphite. Other silicon carbides fail catastrophically when thermally shocked. Tungsten Carbide will "heat-check", as opposed to thermally shocking, at high ΔT.

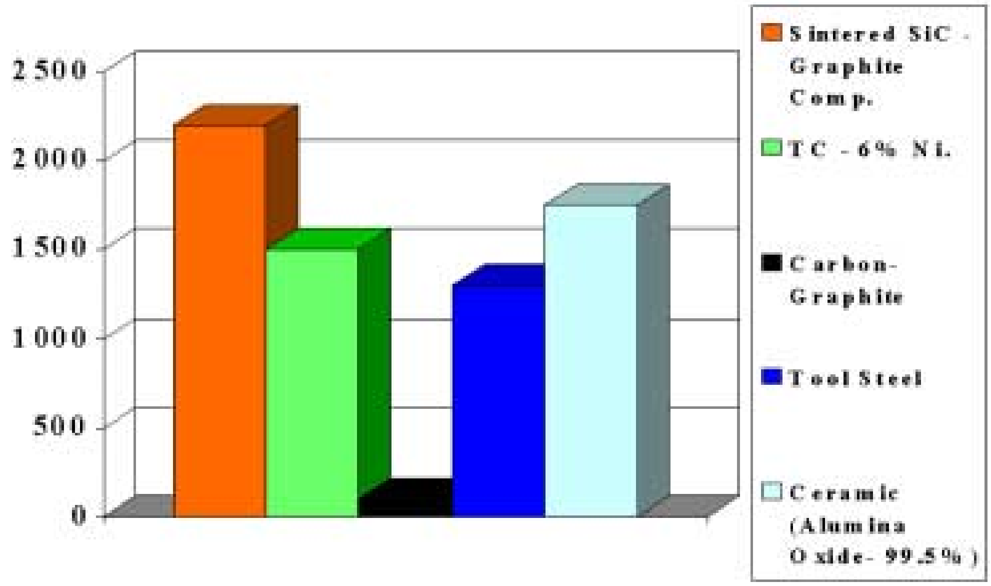
The P-V capability of two SSC-GC faces exceeds that of all other hard faced combinations. This is especially important at high RPM, with large shaft sizes, or when there is high pressure in the seal chamber. With higher P-V capability, lower heat generation and less weepage can be expected.

For seals with a carbon primary ring, silicon carbide is the optimum choice for a mating ring. This combination offers the highest P-V, along with the lowest amount of seal nose wear for extended seal life.

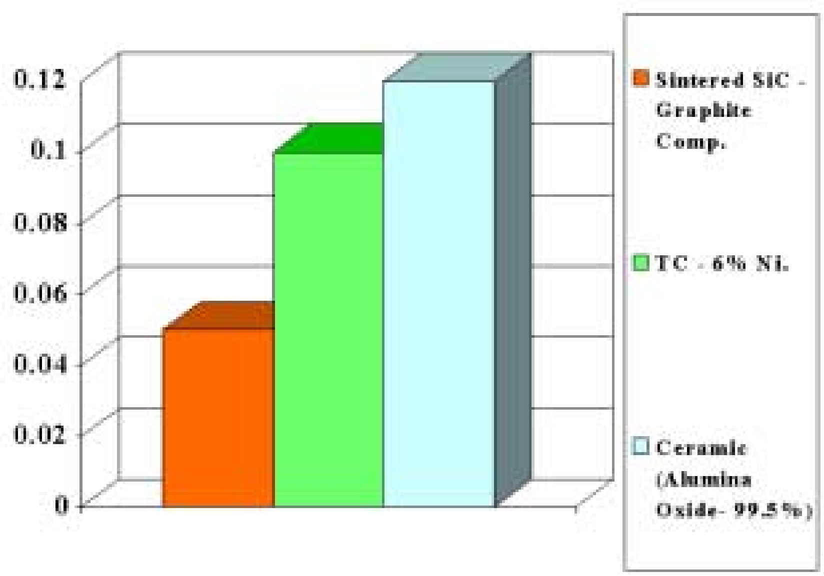

Primary & Mating Ring Materials
Thermal Conductivity
@ 70°F (BTU/hr • ft² • °F/ft)
100
80
60
40
20
0
Sintered SiC - Graphite Comp.
TC - 6% Ni.
Carbon-Graphite
Tool Steel
Ceramic (Alumina Oxide- 99.5%)


Primary & Mating Ring Materials
Modulus of Elasticity
(Million PSI)
100
80
60
40
20
0
Sintered SiC - Graphite Comp.
TC - 6% Ni.
Carbon-Graphite
Tool Steel
Ceramic (Alumina Oxide- 99.5%)

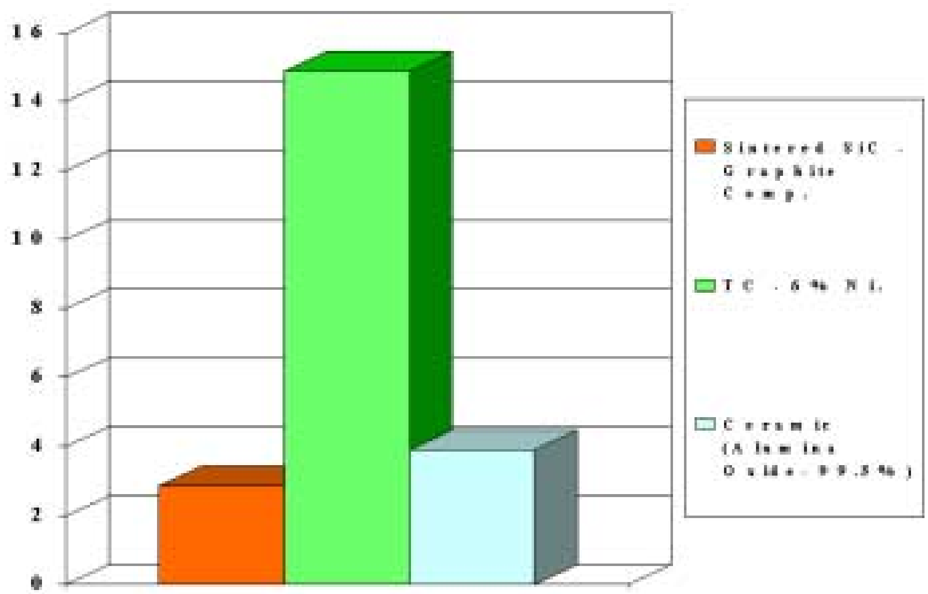
Primary & Mating Ring Materials Vickers Hardness (kg/mm^2)



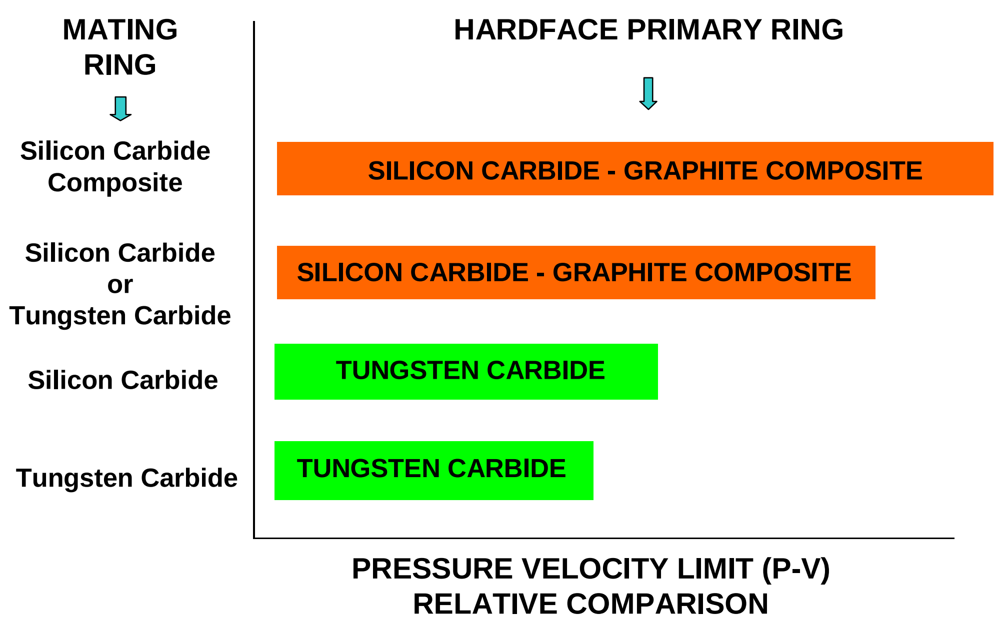
Average Coefficient of Friction @ 300,000 and 500,000 P-V In Deionized Water Standard Carbon Graphite Seal Mating Ring



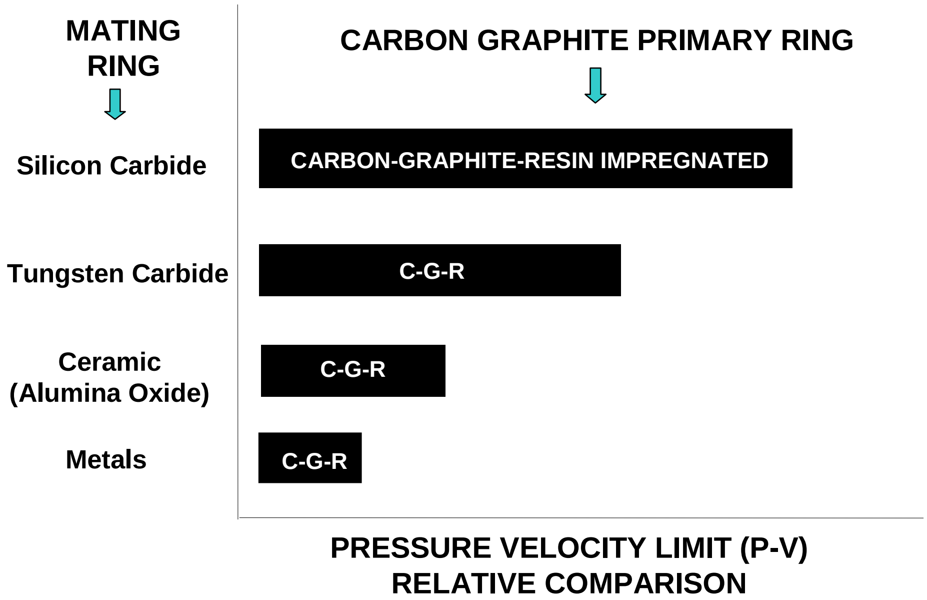
Primary Ring Materials Apparent Density (gm/cc)



Relative Comparison of Hardface Combinations



Relative Comparison of Mating Pair Capability



Prepared by D. Page / 5-8-01