## SELF-LUBRICATING BEARINGS

Self-lubricating bearings are available in spherical, journal, flanged journal, and rod end bearing configurations. They were originally developed to eliminate the need for relubrication, to provide lower torque, and to solve application problems where conventional metal-to-metal bearings would not perform satisfactorily; such as with high frequency vibration.

The liner systems for self-lubricating bearings do not require supplemental lubrication. The polytetrafluoroethylene (PTFE) fibers in the liner act as the lubricant. When a bearing is operated, the pressure and movement of the inner ring shears PTFE from the liner system. As the bearing operates, the PTFE is burnished into the metal and also into the liner surfaces, thereby reducing the coefficient of friction. After the coefficient of friction becomes sufficiently low, no further PTFE is sheared from the liner. Through continued use, some PTFE on the surfaces may exit the bearing. When this occurs, friction increases and more PTFE is sheared from the liner and deposited on the ring and liner surfaces.

**Self-lubricating spherical bearings** are available in many combinations of ring and liner materials. Typically, inner rings (balls) used in SAE/Military Standards are 440C or PH13-8Mo, and outer rings (races) are 17-4PH. High temperature materials are also available.

**Self-lubricating journal bearings** are available with a variety of backing materials. Standard materials for SAE/Military standards include 17-4PH CRES steel and 7075-T6 and 2024-T851 aluminum alloys.

**Rod ends** have the bodies manufactured from 17-4PH or PH13-8Mo CRES steel or cadmium plated 4340 steel.

**Light weight rod ends and spherical bearings** are now being offered by RBC with titanium components to meet demanding aerospace application requirements.

## LINER SYSTEMS

RBC provides five standard liner systems, that are qualified to SAE and AECMA performance standards. These are shown in Table 1 below:

| Bearing Configuration | Standard Liner Systems |
|---|---|
| Spherical | Uniflon® E |
| | Fabroid® IIG2 |
| | Fibriloid® |
| Journal | Uniflon® E |
| | Fiberglide® V |
| | Fabroid® IIG2 |
| | Fibriloid® |
| | Uniflon® HP |
| Rod end | Uniflon® E |
| | Fabroid® IIG2 |
| | Fibriloid® |

**TABLE 1: Standard RBC liner systems**

RBC Bearings manufactures four different self-lubricating liner materials that are qualified to AS81820. In addition, over 60 other self-lubricating materials are available for specific characteristics; such as high temperature for turbine engine applications or machinability for airframe, helicopter, and landing gear applications.

The construction of most RBC liner systems revolves around a woven fabric where PTFE fibers are woven with other supporting and bondable fibers. The process used to produce the PTFE fibers results in a fiber, which has 25 times the tensile strength of that of the base resin. The weave of the fabric exposes the PTFE fibers on the working surface. The supporting fibers are interwoven with the PTFE fibers and are predominantly exposed on the surface that is bonded. This construction provides a positive locking of the PTFE fibers for strength and resistance to cold flow. It also provides a high strength bond to the backing material of the bearing.

Figure 4 depicts the basic liner system used for Fiberglide® and Fabroid® liners. In this system the entire fabric structure is flooded with resin, which locks the fibers in place. Then the liner is bonded to the outer ring, or backing material, with an adhesive resin. This type of liner system is referred to as a flooded liner, since the working surface of the fabric is flooded with binding resin. It provides a positive locking of the PTFE fibers for strength and resistance to cold flow; a bearing surface, that is almost entirely PTFE; and a high strength surface, that is bonded to the backing material of the bearing.

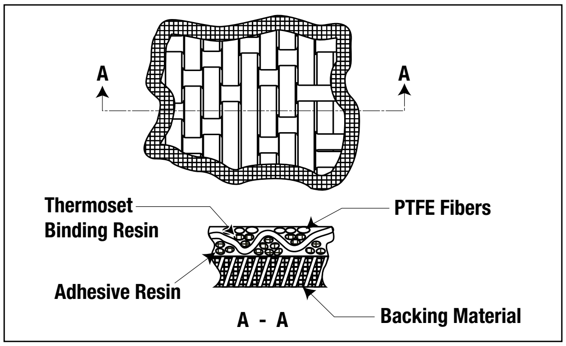


**FIGURE 4: Fiberglide® and Fabroid® liner systems**

Figure 5 depicts the construction of the Uniflon® E and Fibriloid® liner systems. This system is a flooded type of composite material with a thermoset resin binding the fibers in position. A thermoset adhesive resin is used to bond the liner to the outer ring or to the backing material. The interwoven fibers in this case are mainly to provide structural strength. Additives to the thermoset resin provide the lubrication. This construction provides exceptional strength and wear resistance.

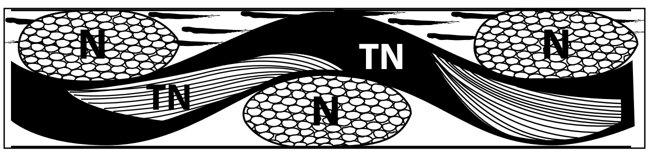


**FIGURE 5: Uniflon® E and Fibriloid® liner systems**

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There are eight liner systems presented in this catalog (and many others for special application).

**Uniflon® E** liner system. The Uniflon® E liner system comprises of a heat stabilized nylon polyamide fabric that is coated with a high temperature resin containing PTFE particles. The fabric provides high compressive strength while the resin/ PTFE wear coating provides the low coefficient of sliding friction. The bond side of the liner is coated with a high temperature resin only. This liner system was developed for airframe control applications and to meet the low wear requirements and high bearing pressures of the SAE AS81820 bearing specification (formerly MIL-B-81820).

**Fiberglide® V** liner system is a flooded liner system constructed of PTFE fibers interwoven with polyester fibers. The fabric is flooded with a phenolic thermoset resin. This system is ideally suited for demanding helicopter applications, where high oscillating speeds are encountered along with moderate impact or reverse loading. This system is highly fatigue resistant and able to absorb vibration.

**Fabroid® IIG2** liner system is a flooded liner system. The fabric is a satin weave of PTFE fibers interwoven with glass fibers. The fabric is flooded with a modified thermoset resin. This system is the most widely accepted self-lubricating liner system in the aerospace industry, and is used on a wide variety of fixed wing aircraft applications. This system provides high speed oscillation capability under moderate loads with low wear rates.

**Uniflon® HP** is an advanced polymer resin system that is combined with a structural and self-lubricating additive to yield a high strength, low wear, and low friction bearing material. Since the material is homogeneous from bearing surface to substrate, it can be machined by the customer to their own demanding requirements. Uniflon® HP is also specially suited for coating unique part geometries and for other special applications. (At the time of catalog printing, the Uniflon® HP liner system is pending approval to the AS81934 specification.)

**Fibriloid®** liner system is constructed of interwoven compound fiber bundles of PTFE and polyamide fibers. The fabric is flooded with a thermoset resin. Fibriloid® is recognized as the strongest and most fatigue resistant bearing liner system in the aerospace industry. This proprietary system is covered by US Patent numbers 3,037,893 and 3,582,166. Characteristics of this liner system include very low wear rates at high psi loads, excellent temperature capability, and fatigue resistance in pounding or reverse load conditions.

**Fabroid® X** is a special liner system, that is engineered for very high temperature and high frequency vibration applications. Gas turbine engines and nacelles are examples of applications where Fabroid® X excels in performance.

**Fiberglide® VI** is a special liner system that is fine tuned to support reversing loads with low friction; Because of its low coefficient of friction, Fiberglide® VI is used in manual control linkages and in helicopter pitch link applications. The **Dyflon®** liner material is machinable and resistant to water/salt water/grease environments.

**Special liner materials** are also available and are engineered to provide optimum life in specific applications. For more technical data on these special liner systems, consult the appropriate RBC Aerospace Bearings engineering department.

### PERFORMANCE CHARACTERISTICS

Radial Static Limit loads shown in this catalog are the ratings based on the requirements of SAE and Military specifications, such as SAE AS81820 (formerly MIL-B-81820). They are the maximum static radial loads that can be applied to the bearings, which will result in a maximum permanent set of 0.003 in. (0.076 mm) after three minutes of loading. It should be noted that for -3 and -4 size spherical bearings the static load rating is limited due to deflection/bending of the mounting pin. The Static Radial Limit loads that can be supported by the RBC liner systems in aerospace bearings are shown in Table 2 below.

| RADIAL STATIC LIMIT LOAD RATINGS | | |
|---|---|---|
| **Liner System** | **Load, psi** | **Load, MPa** |
| Fiberglide® V | 60,000 | 410 |
| Fabroid® IIG2 | 60,000 | 410 |
| Uniflon® E | 80,000 | 550 |
| Fibriloid® | 80,000 | 550 |
| Uniflon® HP | 160,000* | 1100 |

*.0015 in. permanent set

**TABLE 2: Static Limit Load Ratings in pounds per square inch (Megapascals) for RBC liner systems**

The radial static limit load of a spherical bearing may be calculated using the following formula:

Radial static limit load = 0.85 x d x H x ML

Where: d = Ball spherical diameter
H = Outer ring width
ML = Max. load, psi (MPa)

The radial static limit load for journal bearings may be calculated using the following formula:

Radial Static Limit Load = B x (L- .100 in.) x ML

Where: B = Inner Diameter
L = Length
ML = Max. Load, psi (MPa)

For rod ends, the radial static limit load is based on the strength of the rod end body.

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**Radial static ultimate load ratings** are 1.5 times the radial static limit load rating.

**Axial Static Limit loads (spherical bearings)** shown in this catalog are the maximum static axial loads that will result in a maximum permanent axial deformation of 0.005 in. (0.127 mm) after three minutes of loading. It may be calculated using the following formula:

$$\text{Axial static limit load} = \pi \times H^2 \div 4 \times ML$$

Where: H = Outer ring width
ML = Max. load, psi (MPa)

**Oscillating load ratings** given in the tables of this catalog are also based on the requirements of SAE, Military, and EN specifications. To meet this standard, bearings must have less than 0.0045 in. (.127 mm) wear when tested for 25,000 cycles at +/-25° of oscillation and 10 cycles per minute.

**Radial oscillating load ratings** may be calculated using the same radial projected area formula as used to calculate the radial limit load. The maximum load in psi for the oscillating load rating is shown in the Table 3 below.

**RADIAL OSCILLATING LOAD RATINGS**

| Liner System | Load, Psi | Load, MPa |
|---|---|---|
| Fiberglide® V | 30,000 | 207 |
| Fabroid® IIG2 | 30,000 | 207 |
| Uniflon® E | 37,500 | 258.5 |
| Fibriloid® | 37,500 | 258.5 |
| Uniflon® HP | 37,500 | 258.5 |

**TABLE 3: Oscillating Load Ratings**

**Wear rate or bearing life** is the most difficult area to define for lined bearings because of the variety of operating conditions in which these bearings operate. Life under controlled laboratory test conditions can be predicted fairly accurately. In actual applications, variations in load, speed, angle of oscillation, temperature, contamination, and other environmental conditions all affect wear. The air frame control liner systems shown herein are generally intended for high load, low speed aircraft applications as specified in the SAE, Military, and EN specifications. RBC has other liner systems for special applications, such as high speed and high temperature. Wear/life and PV data can be used to determine if a particular liner system should meet the requirements of a particular application. These curves are based on laboratory data and, therefore, specific operational and environmental conditions should be analyzed for each application.

**Pressure (P) times velocity (V) or PV** values are shown in Table 4 for the RBC liner systems. Many factors can affect PV, such as load, speed, surface finish, and material, and much of the test data is for slow speed, high load aerospace applications. Therefore, RBC has shown conservative PV values for the liner systems in Table 4. Short PV excursions up to 150% of the values shown can usually be applied without a detrimental effect on the bearing.

**RADIAL OSCILLATING LOAD RATINGS**

| Liner System System | Typ. Dynamic P(lbs./Sq. in.) | Maximum V (ft/min) | Continuous PV |
|---|---|---|---|
| Fibriloid® | 15,000-40,000 | 10 | 75,000 |
| Fabroid® IIG2 | 5,000-25,000 | 15 | 60,000 |
| Fiberglide® V | 2,000-20,000 | 18 | 35,000 |
| Uniflon® E | 5,000-40,000 | 12 | 80,000 |
| Uniflon® HP | 5,000-40,000 | 10 | 75,000 |

**TABLE 4: PV values for RBC liner systems**

To determine the actual PV for a specific spherical bearing application P (psi or MPa) and V (feet per minute or meters per minute) may be determined as follows:

$$P = \text{Radial load} / 0.85 \times d \times H$$

and

$$V = (4 \times A \times CPM / 360)(d \times \pi / 12)$$

Where: d = Ball spherical diameter
H = Outer ring width
A = Angle of oscillation
CPM = Frequency of oscillation in cycles per minute

Please note that for journal bearings the same formulae may be used except that the 0.85 (% factor) is eliminated and that “L” replaces “H”. The angle of oscillation is the angular movement of a bearing inner ring from its neutral or start position. If the angle of oscillation is 25°, a complete cycle will be 100°, because the inner ring moves from the neutral position to +25°, back to neutral, to -25° and back to neutral again. In the above formula for V, the angle of oscillation has been multiplied by 4 to account for the complete travel of the inner ring in 1 full cycle.



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PLAIN BEARINGS

**Surface velocity** of self-lubricated bearings is limited to moderate speeds because the liner systems are not thermally conductive, and the generated heat must be allowed to dissipate. Applications with intermittent high speed are acceptable, if the duty cycle or fluid environments allows for adequate heat dissipation.

Wear rates for the RBC liner systems are shown in Figures 6 and 7 below.

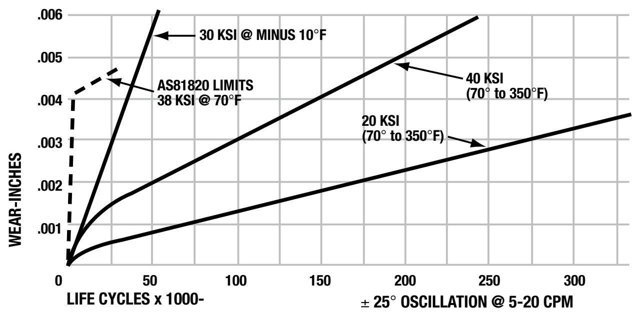


**FIGURE 6: Typical wear rate for Uniflon® E and Fibriloid® liner**

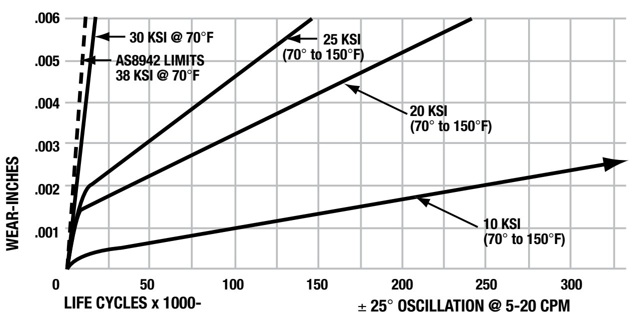


**FIGURE 7: Typical wear rate for Fiberglide® V, Fabroid® IIG2**

**Surface Texture and Hardness of Mating Surfaces** — For maximum life on journal bearings, the shaft on which the bearing runs should have a minimum hardness of Rockwell C 40 and a maximum surface texture of 8 RMS. Tables 5 and 6 show the average reductions in life for surface texture and material hardness.

| Surface Texture (RMS) | Life Factor |
|---|---|
| 4-10 | 1.00 |
| 16 | 0.75 |
| 32 | 0.40 |

**TABLE 5: Life factor reduction due to surface texture**

| Hardness Rc | Life Factor |
|---|---|
| 50 | 1.00 |
| 40 | 0.60 |
| 30 | 0.40 |

**TABLE 6: Life factor reduction due to hardness**

Table 7 gives maximum surface velocities for the standard RBC liner systems operating in dry environments.

| Liner System | Max. Surface Velocity, ft/min @5000 psi | @100 psi |
|---|---|---|
| Fiberglide® V | 15 | 600 |
| Fabroid® IIG2 | 12 | 500 |
| Uniflon® E | 8 | 200 |
| Fibriloid® | 5 | 150 |

| Liner System | Max. Surface Velocity, m/min @34,500 kPa | @690 kPa |
|---|---|---|
| Fiberglide® V | 4.6 | 182.9 |
| Fabroid® IIG2 | 3.7 | 152.4 |
| Uniflon® E | 2.5 | 75 |
| Fibriloid® | 1.5 | 45 |

**TABLE 7: Surface velocity limits for dry bearings**

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**Operating temperature** capabilities vary among liner systems and are affected by environmental conditions. Extremely low temperatures cause the coefficient of friction to rise and wear rates to increase. High speed operation or high loads will increase the bearing temperature above the ambient temperature. Fluids may lower operating temperature, but they may also be more aggressive at high temperatures. The metal component material of the bearing must also be considered when operating at extreme temperature. For example, an aluminum backed bearing should not be used in applications above 250°F (121°C). Table 8 lists the continuous operating temperature ranges for RBC liner systems in an air environment and under moderate load (5000 psi or 34,500 kPa). Load ratings of bearings should be derated for applications operating at elevated temperatures.

| OPERATING TEMPERATURE RANGES | | |
|---|---|---|
| **Liner System** | **°F** | **°C** |
| Fiberglide® V | -320 to +300 | -195 to +150 |
| Fabroid® IIG2 | -320 to +450 | -195 to +230 |
| Uniflon® E | -320 to +450 | -195 to +230 |
| Fibriloid® | -320 to +450 | -195 to +230 |
| Fabroid® X | -320 to +600 | -195 to +300 |
| Uniflon® HP | -65 to +325 | -55 to +165 |

**TABLE 8: Operating temperature ranges under 5000 psi (34.5 MPa) radial load**

**Coefficient of friction** for a spherical bearing is:

μ = Torque/ Ball Spherical Radius x Load

For a journal bearing, the shaft radius is substituted for the ball spherical radius in the above formula. The coefficient will vary depending on the liner system, and it is also affected by load and temperature. It should be noted that self-lubricating bearings require a break-in period to start the lubrication process. Typically the coefficient of friction will decrease by 50% after break-in. Figure 8 shows the effect of load on the coefficient of friction for the RBC liner systems. Figure 9 shows the effect of temperature on the coefficient of friction.

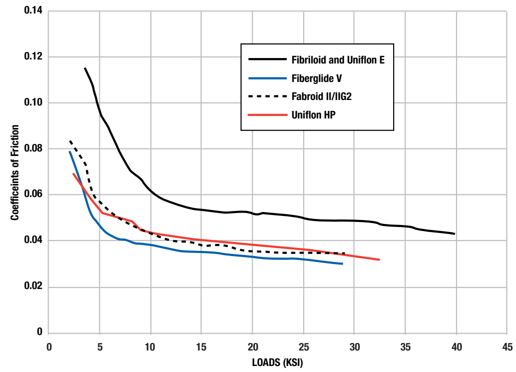


**FIGURE 8: Effect of load on the coefficient of friction**

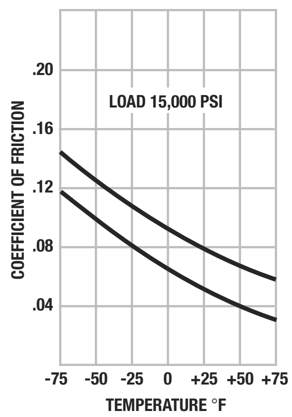


**FIGURE 9: Coefficient of friction vs. temperature**

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**Fluid compatibility and contamination** will affect wear rate or bearing life. RBC liner systems have been extensively tested in many environments. Testing includes both application qualification tests and SAE tests for MS qualifications. The thermoset resins and adhesives used by RBC are essentially impervious to the fluids encountered in aerospace applications. The following is a partial list of the fluids in which various RBC liner systems have been tested:

Phosphate Ester Hyrdaulic Fluid
TT-S-735, Type VII Test Fluid, JP Jet Fuel
MIL-L-7808 Lubricating Oil
MIL H-5606 Hydraulic Oil
MIL-H-83282 Hydraulic Oil
MIL-A-8243 De-Icing Fluid
MIL-T-5624 Turbine Fuel
1-1-1 Trichloroethane
Water
MIL-PRF-87937 Aerospace Detergent
MIL-STD-810, Salt Spray
MIL-STD-810, Fungus
Sand and Dust
Liquid Nitrogen, N2
Vacuum
Aerospace Cleaning Detergents

While these fluids will not attack the liner system, it should be noted that fluids may increase the wear rate of the liners. The fluids tend to flush out the PTFE particles that coat the mating surfaces. This interferes with the natural PTFE self-lubricating process and thus increases wear.

Solid particle contaminants of dirt and dust tend to become imbedded into the relatively soft liner surfaces. If the particle contamination is abrasive, it will begin to wear the mating surface of the ball or shaft. Should contamination be particularly severe, bearings can be provided with card coatings or seals.

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