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**Other Self-lubricating Bearings from Garlock Bearings**

In addition to the DU and DX bearings described in this catalog, Garlock Bearings also offers a wide range of other self-lubricating bearings, including:

**GAR-MAX®** impact resistant bearings combine a rugged filament wound glass-epoxy backing with a surface of wound PTFE and polyester fibers for low friction.

**GAR-FIL®** filament wound bearings with a filled PTFE tape bearing surface for long life without lubrication.

**MULTIFIL™** 426 bearing tape for remarkable performance with or without lubrication in machine tool ways, gibs and other sliding applications.

**MULTILUBE®** bearings which combine the convenience, economy and flexibility of injection molding with outstanding friction and wear properties.

Garlock Bearings also offers filled PTFE bearings, integral lip seal bushings and a variety of other types of self-lubricating bearing materials to meet specialized application needs.

Your inquiry is invited on any of these bearings.

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700 Mid-Atlantic Parkway, P.O. Box 189
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Fax (856) 848-5115
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INTRODUCTION
DU® is the highest performance self-lubricating bearing material available anywhere. It offers a combination of properties and capabilities unmatched by any other self-lubricating bearing material and, consequently, has the broadest application range.

DU®...the high performance self-lubricating bearing material

DU bearings combine the advantages of many conventionally lubricated, metallic plain bearings—particularly high load capacity and dimensional rigidity—with the design freedoms of self-lubricating materials, including the ability to operate successfully well beyond the scope of conventional lubricants.

The material: a steel backed composite

The key to the remarkable performance capabilities of DU is its unique method of manufacture. By employing the unique method of sintering and mechanical interlocking by impregnation, DU bearings eliminate the problems of temperature and aging faced by bonded films and fabrics. In addition, the polymeric self-lubricating material in the DU structure does not have to provide structural support. Furthermore, the metal components provide maximum heat dissipation. The photomicrograph above (Figure 1-1) shows the three main elements that make up this composite:

1. Steel backing
This steel backing gives DU its exceptionally high load carrying capacity, thin, compact design, excellent heat dissipation, and dimensional and structural rigidity.

2. Porous bronze innerstructure
This comprises a nominal 0.010 inch (0.25 mm) thick layer of carefully sized bearing quality bronze powder which is sintered onto the steel backing. This porous structure is impregnated with a homogenous mixture of PTFE (polytetra-fluoroethylene) and lead. In addition to providing maximum thermal conductivity away from the bearing surface, this unique bronze innerstructure also serves as a reservoir for the PTFE-lead mixture.

3. PTFE-lead overlay
This low friction overlay, approximately 0.001 inch (0.025 mm) thick, provides an excellent initial transfer film which effectively coats the mating surface of the bearing assembly, forming an oxide type solid lubricant film. As this film is depleted, the relative motion of the mating surface continues to draw material from the porous bronze layer.

When conditions are severe, the feed of lubrication is increased. The peaks of porous bronze coming in contact with the mating surface generate localized heat and, due to the high thermal expansion rate of the PTFE, force additional lubricant to the bearing surface. The relative motion of the mating parts wipes the lubricant over the interface, continuously restoring the low friction surface film.

The limits: beyond any self-lubricating bearing material

DU bearings—including plain bearings, thrust washers, flanged bearings and slides—offer these remarkable operating parameters:

Loads – P
Dynamic pressures up to 20,000 psi (140 N/mm²) and compressive yield strength of 44,000 psi (310 N/mm²), assuring high load carrying capacity and excellent resistance to shock loading.

Speeds – V
Speeds up to 1000 fpm (5 m/s) without lubrication; 2000 fpm (10 m/s) with lubrication.

Performance – PV
PVs to 50,000 psi-fpm (1.75 N/mm²x m/s) for continuous operation, 100,000 psi-fpm (3.50 N/mm²x m/s) for short-term use. In actual operation, DU bearings have been successfully used at levels which approach 3,000,000 psi-fpm (105 N/mm²x m/s) lubricated.

Temperatures
From -328 to +536ºF ( -200 to +280ºC), making it suitable for use in applications well beyond the scope of most liquid lubricants.

Motion
Ideal for all types of rotating, oscillating, and sliding motion, and both radial and thrust loading.

Lubrication
Can be used totally dry, fully lubricated, or with intermittent lubrication and can be used in the presence of many industrial liquids.
DX™...the bearings that can do more

The key to the superior performance capabilities of DX bearings is their unique construction incorporating a highly effective grease retention system.

The bearings exhibit extremely low friction during operation and are highly resistant to wear. By taking advantage of the low friction and longer service life provided by DX bearings, designers now have the opportunity to improve the performance of their product while increasing its effective operating life. The designer can also be assured that frequency of maintenance is minimized due to the greatly extended lubrication cycle of DX bearings.

DX prelubricated bearings effectively fill the gap between fully lubricated bearings and dry bearings. They are referred to as “prelubricated” because they require only a trace of lubricant to operate satisfactorily and will, therefore, run for very long periods by drawing only upon the lubricant introduced on initial assembly.

DX is a steel-backed material from which bearings, thrust washers, and other shapes can be made. The DX material can be sized in place by boring, reaming, etc. This ability to resize the DX is of particular value in the control of initial starting clearance and the correction of misalignment. The wall thickness of DX bearings is held to close limits so that machining should be unnecessary for most applications.

DX is recommended for conditions of intermittent operation or boundary lubrication, and for situations in which lubricant cannot be supplied continuously or repeatedly. The time during which a DX bearing will operate without further lubrication will depend on operating conditions.

3. Acetal resin liner

The acetal resin forms a nominal 0.010 inch thick (0.25 mm) liner that gives the DX bearing its distinctive yellow color. This acetal resin has the outstanding property of high wear resistance and low friction even when only minute quantities of lubricant are supplied to the polymer surface. Although DX bearings only have moderate performance in the complete absence of lubricant, the response of the polymer provides superior bearing performance in the presence of even a trace of conventional oil or grease. Under conditions of marginal lubrication or those which do not favor the formation of a complete film—oscillating or fretting conditions, high loads, low speeds, frequent stop/start or starting under load—DX is the preferred material.

Grease pockets must be filled with a suitable lubricant before assembly. See page 5-9 for a discussion on grease lubrication. DX is available in bearings, thrust washers, and strip. Furthermore, DX is also available, on special order, with a non-indented bearing surface.

The following is a summary of DX performance capabilities:

- **Loads** – **P**
  Dynamic pressures up to 20,000 psi (140 N/mm²) assuring high load carrying capacity and resistance to shock loading.

- **Speeds** – **V**
  Speeds up to 500 fpm (2.5 m/s) with grease lubrication.

- **Performance – PV**
  PVs to 80,000 psi-fpm (2.8 N/mm² x m/s) for continuous operation.

- **Temperatures**
  From -40 to +210ºF (-40 to +100ºC) continuous and up to 260ºF (125ºC) for short periods.

- **Motion**
  Ideal for all types of rotating, oscillating, and sliding motion, and both radial and thrust loading.

- **Lubrication**
  Typically grease lubricated. Can also be lubricated with oil, other lubricants, and can be used in the presence of many industrial liquids. DX is not recommended for dry applications; instead we recommend DU.

- **Frictional properties**
  The dynamic coefficient of friction is very low, between 0.01 and 0.1, depending on speed, load, and lubrication conditions. The coefficient of static friction of DX bearings ranges from about 0.015 to 0.15.

The key to the superior performance capabilities of DX bearings is their unique construction incorporating a highly effective grease retention system.
## Properties of DU® and DX™ Compared

<table>
<thead>
<tr>
<th>Properties</th>
<th>DU Bearing Material</th>
<th>DX Bearing Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>Steel</td>
<td>Steel</td>
</tr>
<tr>
<td>Backing</td>
<td>Porous copper-tin bronze</td>
<td>Porous copper-tin bronze</td>
</tr>
<tr>
<td>Innerstructure</td>
<td>PTFE / Lead</td>
<td>Acetal with pin indentations</td>
</tr>
<tr>
<td>Lubrication</td>
<td>Not required</td>
<td>Initial prelubrication at assembly required</td>
</tr>
<tr>
<td>Load Capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>44,000 psi (310 N/mm²)</td>
<td>44,000 psi (310 N/mm²)</td>
</tr>
<tr>
<td>Static Load Capacity</td>
<td>36,000 psi (250 N/mm²)</td>
<td>36,000 psi (250 N/mm²)</td>
</tr>
<tr>
<td>Dynamic Load Capacity</td>
<td>20,000 psi (140 N/mm²)</td>
<td>20,000 psi (140 N/mm²)</td>
</tr>
<tr>
<td>Speeds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,000 fpm (5 m/s), dry</td>
<td>100 fpm (0.5 m/s), greased</td>
<td>500 fpm (2.5 m/s), in oil</td>
</tr>
<tr>
<td>2,000 fpm (10 m/s), lubricated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV Limits</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous</td>
<td>50,000 psi-fpm (1.75 N/mm² x m/s)</td>
<td>80,000 psi-fpm (2.8 N/mm² x m/s)</td>
</tr>
<tr>
<td>Intermittent</td>
<td>100,000 psi-fpm (3.50 N/mm² x m/s)</td>
<td></td>
</tr>
<tr>
<td>Temperature Range</td>
<td>-328 to +536°F (-200 to +280°C)</td>
<td>-40 to +210°F (-40 to +100°C) intermittent to +260°F (+125°C)</td>
</tr>
<tr>
<td>Coefficient of Friction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Static*</td>
<td>0.02 – 0.20</td>
<td>0.015 – 0.15</td>
</tr>
<tr>
<td>Dynamic</td>
<td>0.02 – 0.20</td>
<td>0.01 – 0.10</td>
</tr>
<tr>
<td>Standard Products</td>
<td>Refer to pages 3-2 to 3-11</td>
<td>Refer to pages 3-12 to 3-13</td>
</tr>
<tr>
<td>Sleeve Bearings</td>
<td>Inch and Metric Sizes</td>
<td>Inch (metrics on special order)</td>
</tr>
<tr>
<td>Thrust Washers</td>
<td>Inch and Metric Sizes</td>
<td>Inch (metrics on special order)</td>
</tr>
<tr>
<td>Flanged Bearings</td>
<td>Inch and Metric Sizes</td>
<td>Not available</td>
</tr>
<tr>
<td>Flat Strip</td>
<td>Inch, 18 inch and 8 foot lengths</td>
<td>Inch, 18 inch and 8 foot lengths</td>
</tr>
<tr>
<td>Sizing Bearing ID at Assembly</td>
<td>Burnishing</td>
<td>Boring, turning, reaming, broaching</td>
</tr>
</tbody>
</table>

*Static coefficient of friction of the first movement may be greater for a long dwell period under load. Refer to page 4-4.

### Table 1-1

## APPLICATIONS
DU® gives you the widest application range of any self-lubricating bearing

Because of the unique combination of properties and performance capabilities noted on page 1-3 and detailed in later sections, DU bearings have a far greater application range than any other self-lubricating bearing. In fact, in some applications, DU is the only bearing material that can meet the demanding criteria for long life and trouble-free performance, with or without lubrication.

For decades, DU bearings have proven to be the economical solution to a wide range of bearing problems. In many cases, DU bearings completely eliminate the need for lubrication, as well as maintenance, while extending the life of the assembly. These superior bearings can also eliminate the need for hardened shafts and other expensive surface preparation, further reducing the total cost of the bearing assembly.

In lubricated applications, DU bearings provide a margin of safety—particularly during start-up, in the event of interruption of lubrication feed, and in highly loaded applications.

Millions of DU bearings are purchased annually for applications as diverse as low speed, high load pivots to high speed, low load gear pump bearings, and virtually everything in between. These are just a few of the reasons why design engineers throughout the world specify DU bearings for their applications.

DU with or without lubrication

DU's unique PTFE-based bearing surface permits smooth, low friction operation with no lubrication, no maintenance, no costly lubrication systems. Where permissible, lubrication further improves the performance of these bearings.

DU bearings provide highest performance

As noted on page 1-3, DU bearings take PVs to 100,000 psi-fpm (3,500 N/mm² x m/s) or more, operate at temperatures from -328°F (-200°C) to +536°F (+280°C). DU bearings can be used with fully rotational, oscillatory, and axial sliding motion, take both radial and thrust loads, and resist shock loadings.

DU bearings are reliable

The performance capabilities and predictable wear patterns of DU bearings have been more thoroughly documented, both in the field and in the laboratory, than any other self-lubricating bearing. These bearings are noted for their long, trouble-free life, their tolerance of dusty, dirty environments, and their ability to withstand operating extremes and perform in the presence of most solvents and industrial fluids.

DU bearings are convenient to use

The prefinished surface of DU bearings requires no machining. These thin, compact bearings require minimum space and are located within the housing by interference fit. DU bearings are supplied from stock in a wide range of inch and metric sizes, as outlined on pages 3-2 through 3-11. And these superior bearings are readily available worldwide through an extensive network of distributors and licensees. Special sizes are also available upon request.

The following list covers some of the many types of successful DU bearing applications, as well as some of the special problems solved by this unique bearing material.

**Agricultural equipment**

A wide range of agricultural vehicles and implements such as tractors, combines, crop sprayers, tillers, harvesters, grain dryers, etc. use DU bearings to eliminate lubrication points. Specific applications include clutches, governor linkage, brake pedals, control pivots, cross shaft linkage, and parking brakes.

**Off-highway, truck, and automotive**

Typical applications in these areas include earth-movers, graders and other constructional and off-the-highway equipment, trucks, and autos. Specific uses include steering columns, shock absorbers, steering linkage, brake components, differential bearings, and other applications. DU bearings are chosen to minimize the need for lubrication and servicing, and for their high reliability even in dirty environments.

**Aviation**

Aircraft engines, controls, landing gears, sliding wing supports, linkages, brakes, etc. DU bearings are particularly ideal for applications where parts requiring lubrication or servicing are inaccessible, and for their indifference to extremely low temperatures, tolerance of autohome dirt, and ability to operate in the vacuum of outer space.

**Hydraulics and valves**

Pumps, including gear, rotary, water, axial piston, and other types; ball, butterfly, poppet, steam, check and other valves and valve trunnions; pump pressure and thrust plates, reciprocating and rotary compressors, hydraulic actuators, centrifugal compressors, water hydrants, air regulator lever points, bellows compressors, etc. Several of these applications dramatically demonstrate the unmatched capabilities of DU bearings.

**Business machines**

Photo copy machines, typewriters, mail sorters, postage meter systems, computer terminal printers and peripheral equipment, automatic printing devices, mail processing machinery, electric staplers, high speed business machines, photo processing machines, etc.

**Garden, lawn, and outdoor equipment**

Lawnmowers, garden tractors, farm equipment, chainsaws. Specific applications include starter mechanisms, drive shafts, gears, front mounts, and clutches.

**Tape recorders, refrigerators, air conditioners, cleaners, polishers, sewing machines, ovens, dishwashers, clothes washing machines, and other appliances.**
Pivot linkages of the gutter brush assembly; inroad sweepers; trolley casters, industrial and medical; right ascension axis and declination axis shafts of an astronomical telescope.

Engineering and general applications
Made of DX material will give satisfactory operation under conditions of marginal lubrication. DX thrust washers are... or the quantity of lubrication insufficient to maintain the hydrodynamic film required by most metallic bearing materials.

Thrust washers
Support bearings in rotary actuators; support bearings for noise piece in hydraulic rams; and... and acceleration pedal shafts for log skidders and loaders.

Hydraulics
Support bearings in rotary actuators; support bearings for noise piece in hydraulic rams; variable swashplate transition bearings in hydraulic pumps; piston rod guide in hydraulic and pneumatic cylinders; oil gear pumps.

Engineering and general applications
Pivot linkages of the gutter brush assembly... of an astronomical telescope.
**Applications**

**Self-Lubricating Bearings, Prelubricated Bearings**

Garlock Bearings LLC
700 Mid Atlantic Parkway, P.O. Box 189, Thorofare, New Jersey 08086
Phone 1-800-222-0147 • Fax 856-848-5115 • www.garlockbearings.com

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### DU® and DX™ Bearings Application Data Sheet

<table>
<thead>
<tr>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company</td>
<td>Address</td>
</tr>
<tr>
<td>Bearing to be used for</td>
<td>ε New Design</td>
</tr>
<tr>
<td>If not new, what type of bearing has been used?</td>
<td>Part Number</td>
</tr>
</tbody>
</table>

#### Service Conditions

**Speeds (Max., Min., Average RPM or Cycles per minute)**

- Radial
- Axial
- Constant
- Fluctuating
- Shock
- Vibratory

** Loads (lbs. or psi)**

- Radial
- Axial
- Constant
- Fluctuating
- Shock
- Vibratory

**Motion**

- Rotating shaft with unidirectional load
- Rotating load with Stationary shaft
- Oscillating shaft
- Angle
- Reciprocating Stroke

**Shaft**

- Diameter
- Misalignment anticipated
- Material
- Hardness
- Surface Finish

**Housing**

- Length
- I.D.
- O.D.
- Material
- Construction:
  - Horizontal
  - Vertical

#### Service Life Required

- Total Life (operating hours)
- Total Allowable Wear (inches)

- ε Continuous
- ε Intermittent (describe)

#### Environmental Conditions

- ε Air
  - Clean
  - Contaminated-Type
- ε Gas
  - Clean
  - Contaminated-Type
- ε Liquid-Type
  - Clean
  - Contaminated-Type
  - Concentration

- Lubricating properties

- ε Sealing available? Type

#### Environmental Temperature

- ε Maximum
- ε Minimum
- ε Normal

**Table 2-1

<table>
<thead>
<tr>
<th>Quantity required per year?</th>
</tr>
</thead>
</table>

---

**SIZES and ORDERING**
When installed in a rigid steel or cast-iron housing. See page 6-2.

DU* Bearings

Inch Sizes

Ordering Information
To determine Part Number, read down the first column to find the desired Bearing Bore, and across to the desired Bearing Length in a tinted column; the Part Number is shown to the right. Part Numbers are expressed in 1/16 inch increments, bore x length.

For example:
12DU16 = 3/4 inch bore x 1 inch length.

Length Tolerances
Up to and including 3/8 inch I.D. or length — ±0.015 inch.
Above 3/8 inch I.D. or length — ±0.010 inch.

Chamfers
Bearings between 3/8 inch and 2 inches in diameter and lengths of 3/8 inch or more are normally furnished with 0.015/0.047 inch x 12º/28º chamfers. All other bearings will have deburred edges, unless otherwise specified.

Special Bearings
Special Lengths
In addition to the lengths listed, DU bearings of over 2 inch I.D. or larger can be supplied in any desired length from 0.5 to 6 inches.

Special I.D. Measurements
DU bearings can be produced in any diameter 3/8 inch and over to 6 inches in length. In addition, DU bearings with heavier or thinner walls than shown can be furnished.

Please consult the Garlock Bearings Marketing Department about special bearings and any special tooling changes that may be required.

DU* Bearings

Inch Sizes Up to 2"

<table>
<thead>
<tr>
<th>Nominal Bearing</th>
<th>Recommended</th>
<th>Bearing Length and Part Number</th>
<th>Bearing Length and Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8</td>
<td>1/16</td>
<td>1/16</td>
<td>1/16</td>
</tr>
<tr>
<td>1/32</td>
<td>1/32</td>
<td>1/32</td>
<td>1/32</td>
</tr>
<tr>
<td>1/32</td>
<td>1/32</td>
<td>1/32</td>
<td>1/32</td>
</tr>
</tbody>
</table>

Length Tolerances
Up to and including 3/8 inch I.D. or length — ±0.015 inch.
Above 3/8 inch I.D. or length — ±0.010 inch.

Chamfers
Bearings between 3/8 inch and 2 inches in diameter and lengths of 3/8 inch or more are normally furnished with 0.015/0.047 inch x 12º/28º chamfers. All other bearings will have deburred edges, unless otherwise specified.

Special Bearings
Special Lengths
In addition to the lengths listed, DU bearings of over 2 inch I.D. or larger can be supplied in any desired length from 0.5 to 6 inches.

Special I.D. Measurements
DU bearings can be produced in any diameter 3/8 inch and over to 6 inches in length. In addition, DU bearings with heavier or thinner walls than shown can be furnished.

Please consult the Garlock Bearings Marketing Department about special bearings and any special tooling changes that may be required.
### DU® Bearings Inch Sizes Over 2"

<table>
<thead>
<tr>
<th>Number +.010</th>
<th>–.010</th>
<th>+.0020</th>
<th>+.010</th>
<th>–.010</th>
<th>+.010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part Dia.</td>
<td>Dia.</td>
<td>Thickness</td>
<td>Dia.</td>
<td>Circle</td>
<td>Dia.</td>
</tr>
</tbody>
</table>

### DU® Thrust Washers Inch Sizes

<table>
<thead>
<tr>
<th>Number +.010</th>
<th>–.010</th>
<th>+.0020</th>
<th>+.010</th>
<th>–.010</th>
<th>+.010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part Dia.</td>
<td>Dia.</td>
<td>Thickness</td>
<td>Dia.</td>
<td>Circle</td>
<td>Dia.</td>
</tr>
</tbody>
</table>

### DU® Flat Strip Material Inch Sizes

<table>
<thead>
<tr>
<th>Group</th>
<th>Thickness</th>
<th>Usable Width</th>
<th>Approx. Loss</th>
<th>Per Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>.0276/0.0296</td>
<td>5 1/4</td>
<td>.50</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>.0300/0.0320</td>
<td>5</td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>.0320/0.0340</td>
<td>5</td>
<td>1.33</td>
<td>5.00</td>
</tr>
<tr>
<td>3</td>
<td>.0340/0.0360</td>
<td>5</td>
<td>1.61</td>
<td>15.00</td>
</tr>
<tr>
<td>4</td>
<td>.0360/0.0380</td>
<td>5</td>
<td>2.36</td>
<td>15.00</td>
</tr>
</tbody>
</table>

*When installed in a straight steel or carbon steel housing. See page 3-4.

*When installed in a straight steel or carbon steel housing. See page 3-5.
## DU® Bearings Metric Sizes

### Ordering Information

To determine Part Number, read down the first column to find the desired Bearing Bore, and across to the desired Bearing Length in a tinted column; the Part Number is shown to the right. Part Numbers are expressed in millimeters, bore x length.

- **For example:** MI6060DU = 6 mm bore x 8 mm length.

### Length Tolerances

- **Up to and Including 10 mm I.D. or length — ±0.38 mm.**
- **Above 10 mm I.D. or length — ±0.25 mm.**

### Charners

Bearings between 10 mm and 50 mm diameter and lengths of 10 mm or more are normally furnished with O.381.19 mm x 120°GIF charniers. All other bearings will have deburred edges, unless otherwise specified.

### Special Bearings

#### Special Lengths

In addition to the lengths listed, DU bearings over 50 mm I.D. or larger can be supplied in any desired length from 13 to 150 mm.

#### Special Diameters

DU bearings can be produced in any diameter from 3 mm and over, and up to 150 mm in length. In addition, DU bearings with heavier or thinner walls than shown can be furnished. Please consult the Garlock Bearings Marketing Department about special bearings and any partial tooling charges that may be required.

---

### DU® Bearings Metric Sizes Up to 45 mm

<table>
<thead>
<tr>
<th>Nominal Bearing Bore</th>
<th>Recommended</th>
<th>Installed Bearing Diameter</th>
<th>Bearing Length and Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>1.994</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>2.094</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>2.994</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>3.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>4.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>5.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>6.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nominal Bearing Bore</th>
<th>Recommended</th>
<th>Installed Bearing Diameter</th>
<th>Bearing Length and Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>7.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>8.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>9.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>10.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>11.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>12.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>13.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>14.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>15.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
<tr>
<td><strong>16.992</strong></td>
<td><strong>3.000</strong></td>
<td><strong>3.000</strong></td>
<td><strong>50</strong></td>
</tr>
</tbody>
</table>

---

### DU® Bearings Metric Sizes Up to 45 mm

To determine Part Number, read down the first column to find the desired Bearing Bore, and across to the desired Bearing Length in a tinted column; the Part Number is shown to the right. Part Numbers are expressed in millimeters, bore x length.

- **When installed in a rigid steel or cast-iron housing. See page 6-2.**

---

### Garlock Bearings Pocket Sheets

- **Phone 1-800-222-0147 • Fax 856-848-5115 • www.garlockbearings.com**

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### Garlock Bearings LLC

700 Mid Atlantic Parkway, P.O. Box 189, Thorofare, New Jersey 08086

Phone 1-800-222-0147 • Fax 856-848-5115 • www.garlockbearings.com

---

### DU® Self-Lubricating Bearings

Sizes and Ordering: Metric Sizes

Up to 45 mm
### DU® Thrust Washers

<table>
<thead>
<tr>
<th>Metric Sizes</th>
<th>Over 45 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part Number</strong></td>
<td><strong>Inside Dia.</strong></td>
</tr>
<tr>
<td>80DU</td>
<td>50.000</td>
</tr>
<tr>
<td>90DU</td>
<td>60.000</td>
</tr>
<tr>
<td>100DU</td>
<td>70.000</td>
</tr>
<tr>
<td>110DU</td>
<td>80.000</td>
</tr>
<tr>
<td>120DU</td>
<td>90.000</td>
</tr>
</tbody>
</table>

*When installed in a rigid steel or cast iron housing. See page 20.*

---

### DU® Bearings

<table>
<thead>
<tr>
<th>Metric Sizes</th>
<th>Over 45 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Part Dia.</strong></td>
<td><strong>Dia.</strong></td>
</tr>
<tr>
<td>50.000</td>
<td>60.000</td>
</tr>
<tr>
<td>60.000</td>
<td>70.000</td>
</tr>
<tr>
<td>70.000</td>
<td>80.000</td>
</tr>
</tbody>
</table>

*When installed in a rigid steel or cast iron housing. See page 20.*
### DU® Flanged Bearings Inch Sizes

**Ordering Information**
To determine Part Number, read down the first column to find the desired Bearing Bore, and across to the desired Bearing Length in the first column. The Part Number is shown to the right. Part Numbers are expressed in 1/16 inch increments (inch series) or in 1. millimeter increments (metric series), bore x length.

For example:
- 1/2FDU08 = 3/4 inch bore x 1/2 inch length.
- or
- FMB1512DU = 15 mm bore x 1.2 mm length.

**Length Tolerances**
+0.003 inch (0.025 mm)/
-0.032 inch (0.50 mm).

**Flange O.D. Tolerances**
Up to and including 1 inch or 25 mm nominal bearing I.D. — ±0.032 inch (±0.50 mm).
Over 1 inch or 25 mm nominal bearing I.D. — ±0.030 inch (±0.75 mm).

**Chamfers**
Standard flanged DU® bearings are supplied with 0.015/0.047 inch (0.381/0.12 mm) x 12° chamfers.

**Special Bearings**
Please consult the Garlock Bearings Marketing Department about special bearings and any partial tooling charges that may be required.

### DU® Flanged Bearings Metric Sizes

**Ordering Information**
To determine Part Number, read down the first column to find the desired Bearing Bore, and across to the desired Bearing Length in the first column. The Part Number is shown to the right. Part Numbers are expressed in 1/16 inch increments (inch series) or in 1. millimeter increments (metric series), bore x length.

For example:
- 1/2FDU08 = 3/4 inch bore x 1/2 inch length.
- or
- FMB1512DU = 15 mm bore x 1.2 mm length.

**Length Tolerances**
+0.003 inch (0.025 mm)/
-0.032 inch (0.50 mm).

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Up to and including 1 inch or 25 mm nominal bearing I.D. — ±0.032 inch (±0.50 mm).
Over 1 inch or 25 mm nominal bearing I.D. — ±0.030 inch (±0.75 mm).

**Chamfers**
Standard flanged DU® bearings are supplied with 0.015/0.047 inch (0.381/0.12 mm) x 12° chamfers.

**Special Bearings**
Please consult the Garlock Bearings Marketing Department about special bearings and any partial tooling charges that may be required.
Metric Sizes are available by special order.

Lubrication Holes: 016DXR and larger have a 5/32" diameter hole; all others have a 5/64" diameter hole.

DX bearings between 1/2 inch and 2 inches in diameter and lengths of 3/8 to 3 inches are normally furnished with 0.015/0.047 inch x 12º/28º machine chamfers. All other DX bearings will have deburred edges, unless otherwise specified.

The length tolerance for all DX bearings is ±0.010 inch.

To determine Part Number, read down the first column to find the desired Bearing Bore and across to the desired Bearing Length in a tinted column, the Part Number is shown to the right. Part Numbers are expressed in 1/16 inch increments, bore x length.

For example: 012DXR012 = 3/4 inch bore x 1 inch length.

DX™ Thrust Washers

Sizes and Ordering: Inch Sizes

Prelubricated Bearings

Garlock Bearings LLC
700 Mid Atlantic Parkway, P.O. Box 189, Thorofare, New Jersey 08086
Phone 1-800-222-0147 • Fax 856-848-5115 • www.garlockbearings.com

DX™ Flat Strip

Material

Inch Sizes

Prelubricated Bearings

Garlock Bearings LLC
700 Mid Atlantic Parkway, P.O. Box 189, Thorofare, New Jersey 08086
Phone 1-800-222-0147 • Fax 856-848-5115 • www.garlockbearings.com
**Thermal properties**

DU bearings can be used in ambient temperatures between -328°F and +536°F (-200 and +280°C). As the operating temperature increases, the wear life of the bearing is decreased, but the reliability of the product is maintained.

Heat is generated in all bearings even when lightly loaded. Without lubrication, this heat must be transmitted through the bearing and dissipated by the housing. The DU composite structure provides both high thermal conductivity and the thermal expansion rate of steel.

The poor heat conductivity of solid plastic bearings or bearing housings is the main factor limiting their use for self-lubricated bearing assemblies. When heat is not dissipated rapidly, high thermal expansion rates can cause the bearing to close in and seize on the shaft. With a plastic bearing in a metal housing, heat will affect the plastic material in such a way that housing retention is lost.

**Corrosion protection**

The exposed backing and end faces of standard DU bearings and thrust washers are tin flashed for protection in mildly corrosive environments. DU material can be furnished with a bronze backing (DU(B)). Consult our Applications Engineering Department regarding corrosion protective coatings or DU(B).

Zinc-chromate plating is beneficial in applications where the bearings will be exposed to outdoor conditions. When electrolytic (galvanic) corrosion is possible, tests should be conducted to ensure that all materials in the bearing environment are mutually compatible.

**Electrical resistance**

Unlike solid plastic bearing materials, DU is a good conductor of electricity. The electrical resistance of a DU bearing assembly will depend upon the bearing pressure and contact area. In general, it is in the region of 6 to 60 ohms/inch² (1 to 10 ohms/cm²) of contact area.

No static electricity phenomena have been observed with DU bearing material.

**Wear pattern of DU**

During normal operation, a DU bearing quickly beds in and the overlay material remnenved during this period—an average of 0.0005 inch (0.013 mm) thick—is transferred to the mating surface and forms a physically bonded lubricant film. The rubbing surface of the bearing often acquires a grey-green color, and the bronze matrix is exposed over at least 10% of the bearing surface. Any excess of the PTFE-lead surface layer will be shed as fine, feathery particles.

Following the bedding-in period, the wear rate becomes extremely low and the percentage of bronze exposed gradually increases. After an extended period of operation, the wear rate increases as the component approaches the end of its useful life as a self-lubricating bearing. At this stage, at least 70% of the bearing surface will be exposed bronze, and approximately 0.002 inch (0.05 mm) additional radial wear will have occurred (Figure 4-1).

**Wear of mating surfaces**

There is no measurable wear of mating surfaces made from recommended materials unless a DU bearing is operated beyond its useful life span or becomes seriously contaminated with abrasive particles.

**Effect of contamination**

Generally, DU bearings are more tolerant of dirt-laden environments than lubricated bearings since there is no capillary action to entrain abrasive particles.

Dirt is, of course, undesirable in any bearing, and the longest life and most satisfactory performance will be achieved if abrasive particles are, as far as possible, prevented from reaching the bearing surfaces. This can often be achieved by suitable design of the housing or by the provision of a simple seal or shield.

---

**Table 4-1: Physical Properties of DU Bearing Material**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield strength in compression as measured on a 1 inch (25.4 mm) diameter disc</td>
<td>Approximately 40,000 psi (280 N/mm²)</td>
</tr>
<tr>
<td>Coefficient of linear expansion parallel to surface</td>
<td>6 x 10^-6°F (11 x 10^-6°C)</td>
</tr>
<tr>
<td>Coefficient of linear expansion at right angles to surface on 0.075 inch (1.91 mm) strip</td>
<td>17 x 10^-6°F (30 x 10^-6°C)</td>
</tr>
<tr>
<td>Thermal conductivity after bedding-in measured at right angles to surface</td>
<td>288 BTU/(hr)·(ft.)·°F/ft (60 W/m K)</td>
</tr>
</tbody>
</table>

---

**Figure 4-1. Effect of Wear on DU Bearing Surface**
Fretting corrosion
The type of rapid wear known as “fretting corrosion” often encountered under heavy load and slight relative motion, does not occur with bearings made from DU when used with recommended mating surface materials.

Frictional properties
DU bearings are generally free from “stick-slip” and provide smooth sliding between adjacent surfaces. The coefficient of friction varies in relation to the specific load, velocity, and surface area. A typical relationship is shown in Figure 4-2, which can be used as a guide to establish the actual coefficient of friction under clean, dry conditions after running-in. Exact values of the coefficient of friction, \( \mu \), may vary by ±20%, depending on operating conditions, and should be established by test. Before bedding-in, the coefficient of friction may be up to 50% higher. The coefficient of friction of DU material has also been shown to vary with temperature. For example, experiments under constant conditions of load and speed in vacuum have shown that the coefficient of friction doubles as the temperature is reduced from 140 to -4ºF (60 to -20ºC.)

With frequent starts and stops, the static coefficient of friction is approximately equal to or slightly less than the dynamic coefficient of friction. After progressively longer periods of dwell under load (e.g., of hours or days), the static coefficient of friction of the first movement has been measured to be 50%–200% higher, particularly before bedding-in. This phenomenon must be considered when designing long dwell applications.

Effect of liquids and lubricants
The presence of clean liquids in and around DU bearings will generally reduce the rate of wear and thus increase their useful life by removing heat from the bearing surface. When loads and speeds are such that a hydrodynamic lubricating film is established, even liquids without normal lubricating properties, such as water, will improve bearing life substantially. Additional benefits gained by the use of DU in many lubricated applications have been the elimination of shaft galling and lower torque values at start up. Refer to section on “Lubricated Environments” on pages 4-11 to 4-14 for details.

Grease packing on assembly, without subsequent replenishment, is not recommended. DU bearings can be used in alternately wet and dry conditions, but their life in such environments will be shorter than when completely dry or fully lubricated. With alternating conditions, there is a greater amount of bedding-in occurring which substantially reduces the dry wear resistance.

Table 4-2: Wear Performance Comparisons
This is a guide to the relative service performance of DU bearings and other bearings intended for use without regular lubrication. These were thrust washer tests operating under the conditions described.

<table>
<thead>
<tr>
<th>Bearing material tested against mild steel with surface finish of 36 microinches (0.9 micrometers)</th>
<th>Testing Time</th>
<th>Wear at End of Test, Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours</td>
<td></td>
</tr>
<tr>
<td>DU (PTFE-lead in porous bronze)</td>
<td>1,000.0</td>
<td>Less than 0.002</td>
</tr>
<tr>
<td>100% PTFE without lead in porous bronze</td>
<td>213.0</td>
<td>0.005</td>
</tr>
<tr>
<td>Graphite and lead bronze</td>
<td>150.0</td>
<td>0.010</td>
</tr>
<tr>
<td>PTFE + 25% graphite</td>
<td>134.0</td>
<td>0.005</td>
</tr>
<tr>
<td>Oil-impregnated porous bronze</td>
<td>105.0</td>
<td>0.020</td>
</tr>
<tr>
<td>Phenolic resin + MoS2</td>
<td>73.0</td>
<td>0.005</td>
</tr>
<tr>
<td>PTFE + 25% glass fiber</td>
<td>48.0</td>
<td>0.005</td>
</tr>
<tr>
<td>MoS2 treated steel</td>
<td>26.0</td>
<td>(Seized)</td>
</tr>
<tr>
<td>Graphite, bearing grade</td>
<td>24.0</td>
<td>0.005</td>
</tr>
<tr>
<td>Porous bronze + 25% MoS2</td>
<td>17.0</td>
<td>0.005</td>
</tr>
<tr>
<td>Asbestos + resin + MoS2</td>
<td>0.8</td>
<td>0.005</td>
</tr>
<tr>
<td>Nylon</td>
<td>0.3</td>
<td>0.010</td>
</tr>
</tbody>
</table>

Figure 4-2. Friction vs. Velocity for Various Loads
Bearing pressure - P
For the purpose of assessing bearing performance, bearing pressure P is defined as the working load divided by the projected area and is expressed as psi (N/mm²). Table 4-4 on page 4-7 lists common DU bearing configurations and their respective bearing pressure formulas.

The maximum pressure which can be supported by a DU bearing will depend upon the type of loading. It will be highest under steady loads whereas dynamic loads or oscillating motions, which produce fatigue stress on the bearings, will result in a reduction in load capacity (Table 4-3).

Surface velocity - V
DU has been particularly successful in applications where the motion will not allow formation of a conventional liquid lubricant film between the mating surfaces. DU can be designed for use at surface velocities up to 1,000 fps (5 m/s), depending upon the operating life required. Refer to Table 4-4 on page 4-7 for velocity calculations.

PV factor
PV factor is used as a guide to the useful operating life of a DU bearing. PV is the product of the bearing pressure P and the surface velocity V. PV is expressed as psi-fpm (N/mm²-mm/minute). At extreme values, each parameter must be considered individually as well as together.

PV factors of up to 100,000 psi-fpm (3.5 N/mm²-mm/minute) can be accommodated for short periods, while for continuous rating, PV factors up to 50,000 psi-fpm (1.75 N/mm²-mm/minute) can be used, depending upon the operating life required. For lubricated applications, PV factors greater than 3,000 psi-fpm (105 N/mm²-mm/minute) are possible. Refer to section “DU in Lubricated Environments” on page 4-11.

Effective PV - EPV factor
The EPV factor takes into account the effect of high load and is used to estimate DU bearing life. Table 4-3 shows the maximum bearing pressure, P, for various loading conditions. If referring to Figure 4-4 for a U value, choose a corresponding U value based upon the desired bearing cycles Lf.

Once the value for U is selected, the EPV can be calculated as follows:

\[ EPV = \frac{U \times P \times V}{U - P} \]

Refer to pages 4-8 to 4-9 for the method of estimating DU bearing life.

Table 4-3: Maximum Pressure, U Factors

<table>
<thead>
<tr>
<th>Type of Loading</th>
<th>Maximum Pressure, U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steady unidirectional loads relative to the bearing surface, with rotation in one direction only.</td>
<td>20,000 psi</td>
</tr>
<tr>
<td>Steady unidirectional loads with oscillating motion (cycles in Figure 4-4 refer to oscillating motion).</td>
<td>See Curve 1, Fig. 4-4</td>
</tr>
<tr>
<td>Dynamic loads, rotating, alternating or fluctuating, with steady or oscillating motion (cycles in Figure 4-4 refer to load cycles).</td>
<td>See Curve 2, Fig. 4-4</td>
</tr>
</tbody>
</table>

Figure 4-3. Oscillation Angle

Figure 4-4. DU Maximum Pressure for Cyclic Applications

**KEY**
- \( d \) = bearing/thrust washer ID
- \( D \) = thrust washer/flange OD
- \( L \) = bearing/slide pad length
- \( L_m \) = slide pad width
- \( S \) = relative surface velocity in ft/min (m/min)
- \( n \) = rotation speed, revs per minute
- \( c \) = cycling rate, cycles per minute
- \( \alpha \) = angle of oscillation, degrees

Dimensions in inches (mm/kilometers)

Table 4-4: DU Design Factors
Calculating DU+ bearing life

A useful approximation of actual performance in a specific application can be made by making allowance for the effect of the most important variables including operating temperature, heat dissipation, mating materials, and bearing size proportions. This section covers the method of estimating bearing life.

Figure 4-5 shows the basic service life in hours, assuming normal room temperature conditions, normal running clearances, and good heat dissipation of a well-proportioned bearing operating against low carbon steel with a surface finish of 16 microinches (0.4 micrometers). The following graphs and tables describe major factors affecting DU bearing life.

Accounting for all the variables in a specific application is difficult, but the following recommended approach will provide a useful guide for the designer.

The calculated EPV factor, as described on page 4-6, is used to determine the basic DU bearing service life $L_b$. The estimated bearing life $L_{DU}$ is calculated by applying various service factors to the basic service life $L_b$. Refer to Figure 4-5 and select the type of bearing, and then read the basic service life based on the calculated EPV. Now you can estimate DU bearing life.

Garlock Bearings offers a computer program that will assist in calculating DU bearing life. Contact our Applications Engineering Department for a copy of this program.

Note: Estimated bearing lives greater than 4,000 hours are subject to error due to inaccuracies in the extrapolation of test data.

The formula for DU bearing life is:

$$ L_{DU} = L_b \times H \times M \times B - A $$

Where:

- $L_{DU}$ = DU bearing life, hours
- $L_b$ = DU basic service life, hours, Figure 4-5
- $H$ = Heat dissipation factor, Figures 4-6 and 4-7
- $M$ = Mating surface factor, see Table 4-5
- $B$ = Bearing size factor, Figure 4-8
- $A$ = Life adjustment factor, hours, Table 4-5

For linear sleeve bearings or slideways (see page 4-7), the above equation is modified as follows:

$$ L_{DU} = \frac{L_b \times L \times H \times M \times B - A}{L + S} $$

Where:

- $L_b$ = for linear sleeve bearings use stationary bearing, rotating shaft basic service life, Figure 4-5; for linear slideways use thrust washer basic service life, Figure 4-5
- $L$ = bearing length, inches (mm)
- $S$ = bearing stroke, inches (mm)

Oscillating, cyclical, and linear motion/fluctuating loads

These conditions require special consideration when calculating bearing life. The maximum bearing pressure, $U$, is a function of the desired bearing life, $L_{DU}$, expressed in cycles. Figure 4-4, page 4-6, shows the $U$ factor as a function of cycles. Bearing life, $L_{DU}$ in hours, can be estimated by using the previously described method. Bearing life is converted into equivalent cycles by the equation:

$$ L_{2} = 60 \times L_{DU} \times c $$

Heat dissipation factor – $H$

In the early stages of design, steps should be taken to obtain maximum heat dissipation, thereby allowing the bearing surface to operate at the lowest possible temperature.

Liquids may substantially improve bearing performance if hydrodynamic conditions are established. Boundary lubrication performance will depend upon the nature of the liquid and testing should be conducted. In the absence of test data, the values in Figure 4-6 may be used. DU in lubricated environments is covered in detail on pages 4-11 to 4-13.

If the calculated life cycles, $L_2$, are less than the desired $L_2$ cycles used to select the $U$ value, bearing life will be limited by wear after $L_2$ cycles. If $L_2$ cycles are greater than the desired $L_2$ cycles, bearing life will be limited by fatigue after $L_2$ cycles for oscillating, cyclical, linear, and highly dynamic load situations.
### Table 4-5: Mating Surface Life Adjustment Factors

<table>
<thead>
<tr>
<th>Material</th>
<th>Mating Surface Factor—M</th>
<th>Life Adjustment Factor—A, Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel and Cast Iron</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Case-hardened steel</td>
<td>1.0</td>
<td>200</td>
</tr>
<tr>
<td>Cast iron (32 micrometers)</td>
<td>1.0</td>
<td>200</td>
</tr>
<tr>
<td>Mild steel</td>
<td>1.0</td>
<td>200</td>
</tr>
<tr>
<td>Nitrided steel</td>
<td>1.0</td>
<td>200</td>
</tr>
<tr>
<td>Sprayed stainless steel</td>
<td>1.0</td>
<td>200</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>2.0</td>
<td>200</td>
</tr>
<tr>
<td>Plated Steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hard chrome</td>
<td>2.0</td>
<td>600</td>
</tr>
<tr>
<td>Nickel</td>
<td>0.2</td>
<td>600</td>
</tr>
<tr>
<td>Phosphated</td>
<td>0.2</td>
<td>300</td>
</tr>
<tr>
<td>Tin nitric</td>
<td>1.2</td>
<td>600</td>
</tr>
<tr>
<td>Tungsten carbide frame</td>
<td>3.0</td>
<td>600</td>
</tr>
<tr>
<td>Zinc</td>
<td>0.2</td>
<td>600</td>
</tr>
<tr>
<td>Non-Ferrous Metals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anodized aluminum (decorative)</td>
<td>0.4</td>
<td>200</td>
</tr>
<tr>
<td>Brass and copper base alloys</td>
<td>0.1–0.4</td>
<td>200</td>
</tr>
<tr>
<td>Hard anodized aluminum (0.025 mm thick)</td>
<td>3.0</td>
<td>600</td>
</tr>
</tbody>
</table>

**Bearing size factor – B**

As the bearing size increases, there is a relatively larger running clearance which results in proportionately smaller contact area. This reduction in contact area has the effect of increasing the actual unit load. A size factor (B) must then be considered, as in Figure 4-8.

**Bearing length**

In designing bearings, the shaft diameter is usually determined by the need for physical stability or stiffness, and the main size variable to be determined is the length of the bearing or the width of a thrust washer.

Short or narrow bearings would have reduced wear life, and the design length to diameter ratio should be high, up to a maximum of 2:1. Longer bearings are not recommended as they can be subject to shaft deflection problems. They are also more difficult to manufacture and install.

Although DU material was developed for use as a dry, self-lubricating bearing material, engineers and designers have discovered many years ago that DU also provides excellent performance for lubricated applications. DU bearings are being used successfully in engines, compressors, pumps, transmissions, and countless other demanding applications where conventional bearing materials often fail. DU’s unique combination of properties provides a greater margin of safety for use in lubricated environments. This translates into higher capacity, longer service intervals, less maintenance and improved performance for your application. This section will cover the basics of lubrication and how to design and specify DU bearings for your lubricated applications.

**Lubricated Environments**

As can be seen in Figure 4-9, DU material is particularly effective in the most demanding lubricated applications because of its inherent low friction and excellent wear resistance without lubrication. The following is a summary of application parameters where DU has successfully replaced conventional bearing materials and improved performance.
Highly loaded applications

DU bearings are specified in numerous applications where the loads substantially exceed the ability of the bearings to develop a hydrodynamic film. Extensive testing has proven its superior wear resistance and low friction in highly loaded applications where the bearing is subjected primarily to boundary and mixed film lubrication.

Start-up and shutdown under load

Since there will be insufficient speed to generate a hydrodynamic film under start-up or shutdown, the bearing will operate under boundary and mixed film conditions. In equipment where such conditions are a frequent occurrence, premature bearing failure can be experienced even though the bearing normally operates with a fully hydrodynamic film. DU minimizes wear and requires less start-up torque than conventional plain bearing materials.

Sparse lubrication

Many applications require the bearing to operate with less than ideal lubricant supply, typically a splash or mist lubrication system in which only trace amounts ever reach the bearing surface. The self-lubricating properties of DU material permit successful operation in sparsely lubricated environments which will cause other bearing materials to overheat and fail.

Non-lubricating fluids

Although a hydrodynamic film can be developed using any fluid, successful boundary or mixed film applications require a fluid with some lubricating properties. DU bearings have been used successfully in applications using non-lubricating fluids such as water because DU’s naturally self-lubricating bearing surface can effectively overcome the fluid’s inability to lubricate the bearing.

Designing lubricated applications with DU® bearings

Figure 4-10 shows the three lubrication regimes as areas plotted on a graph of surface speed vs. the ratio of unit load to lubricant viscosity. This illustration is useful in the preliminary analysis of the application to determine in which regime the bearing is operating. The graph is based on steady, unidirectional loading, continuous, non-reversing shaft motion; sufficient clearance between shaft and bearing; and, an adequate supply of lubricant.

In order to use Figure 4-10, first calculate the bearing pressure P and shaft surface speed V using the formulae on page 4-7. Next, determine the viscosity, in centipoise, of the lubricant used. Viscosity is a function of operating temperature. The viscosity-temperature relationships for several fluids are presented in Figure 4-11. If the operating temperature of the fluid is unknown, a provisional temperature of 50ºF (25ºC) above ambient can be used.

Referring to Area 1, (boundary lubrication) in Figure 4-10, PV is the major consideration since there will be no lubricating film to separate the shaft and bearing. DU bearing life can be calculated using the technique given in pages 4-8 to 4-9, with an H factor (Figure 4-7) for bearings continuously immersed in liquids, although this method will probably underestimate bearing life.

In Area 2, (mixed film lubrication), the fluid film generated will be sufficient to permit partial separation of the shaft and bearing surfaces. The PV factor is no longer a significant parameter in determining bearing life. Bearing performance will depend on the nature of the fluid and actual service conditions.

In Area 3, (full hydrodynamic lubrication), the shaft and bearing will be completely separated by a fluid film. Provided the fluid is clean and there are no start-ups and shutdowns, the bearing will last indefinitely. For bearings operating at speeds in excess of 1000 fpm (5 m/s), there is a potential for shaft instability (shaft whirl) and/or excessive operating fluid temperatures to occur. Consult Garlock Bearings LLC for additional advice.

Area 4, which is in the upper right hand corner of Figure 4-10, represents the most demanding operating conditions. In this area, the bearing is subjected to either high speed, high bearing load to viscosity ratio, or, a combination of both. These conditions may cause excessive operating temperature and/or a high wear rate which may result in rapidly deteriorating bearing performance. Although DU bearings are better suited to Area 4 than conventional bearing materials, the addition of one or more (grooves) to the bearing, and specification of a superfinished (1 to 2 microinch [0.02 to 0.05 micrometer]) shaft may be required to achieve satisfactory performance.

Designing lubricated applications with DU® bearings

Lubricants

DU bearings can be used with most fluids including water, lubricating oils, engine oil, turbine oil, hydraulic fluids, ethylene glycol solutions, solvents, fuels, and refrigerants. In general, the fluid will be acceptable if it does not chemically attack the porous bronze ininkerface or PTFE/lead overlay. Acid and alkaline solutions should be avoided as well as some lubricants that contain sulfur as an extreme pressure (EPI) additive. Where there is any doubt about the suitability of a fluid, a simple test is to submerge a sample of DU material in the fluid for 2 to 3 weeks at 10 to 20ºF (5 to 10ºC) above the operating temperature. Any change in thickness and/or weight of the DU material, a visible change in the surface other than some discoloration or staining, or a visible change in the bronze inkerface will usually indicate that the fluid is not suitable for use with DU bearings.
Clearance

The recommended shaft and housing bore diameters given for standard DU bearings will provide sufficient clearance for applications operating under boundary lubrication. Area 1 in Figure 4-10. For bearings operating under mixed film or hydrodynamic lubrication regimes (Areas 2 and 3), the recommended shaft diameter should be reduced by approximately 0.1%, particularly when surface speed exceeds 500 fpm (2.5 m/s). The additional clearance will permit the generation of a fluid film and provide enough clearance for the flow of fluid through the bearing.

In certain applications, the maximum clearance associated with standard DU bearings may result in reduced performance. There are two methods of reducing the clearance range of standard DU bearings: specifying tighter tolerances for the shaft and housing, and, final sizing of the bearing after installation in the housing. Final sizing can be done preferably by burnishing the bearing ID. This method will not remove the overlay from the bearing surface. Refer to page 6-6 for burnishing tool design. Certain specific applications may require closer tolerance bearings. Garlock Bearings can manufacture these on special order. Please contact Garlock Bearings Applications Engineering Department for details.

Shaft finish

A shaft finish of up to 16 microinches (0.4 micrometers) is acceptable for bearings operating exclusively under boundary lubrication. For applications where there will be mixed film or hydrodynamic lubrication, a surface finish of 2 to 8 microinches (0.025 to 0.20 micrometers) is required to achieve optimum performance.

Grooving

Grooves used alone or in combination with a hole will help guarantee an adequate supply of lubricant to the bearing. In most cases, a simple groove extending across the width of the bearing is effective. Figure 4-12 shows the recommended location of the oil groove with respect to the bearing load zone and bearing split. Figure 4-12 shows two different groove profiles that can be simply milled or broached in the bearing. The leading and trailing edges of the groove should be tapered which will help develop a lubricating film. Garlock can furnish special DU bearings with embossed or milled grooves on request. Consult the Garlock Bearings Applications Engineering Department for details.

Figure 4-12. Oil Grooves for DU Bearings

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**DX™ Data for Designers**

**Prelubricated Bearings**

Garlock Bearings LLC
700 Mid Atlantic Parkway, P.O. Box 189, Thorofare, New Jersey 08086
Phone 1-800-222-0147 • Fax 856-848-5115 • www.garlockbearings.com

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**Technical Information**

**Frictional properties**

When DX bearings are used with steel mating surfaces, the dynamic coefficient of friction is very low, varying normally between 0.01 and 0.1 depending on speed, load, and lubrication conditions. Under conditions of boundary lubrication, DX bearings will operate with less friction and wear than bronze-surfaced bearings. The corresponding coefficient of static friction of DX bearings ranges from about 0.015 to 0.15.

---

**Effect of contamination**

DX bearings can tolerate more dirt between the rubbing surfaces than either conventionally lubricated or dry bearings. With all bearings, it is always desirable to minimize intrusion of dirt by using a suitable seal.

---

**Bearing clearance**

Experience has shown that DX bearing should be given more diametrical clearance than conventional plain bearings to allow for the small thermal expansion of the lining when at operating temperature. For slow speed, oscillatory motion, clearance can be at a minimum where the shaft-to-bearing fit will be assembled snug for excellent bearing-to-shaft conformity. When shaft surface speeds exceed 50 fpm (0.25 m/s), additional clearance will be required. Unlike many synthetic materials, the amount of moisture absorbed and consequent swelling of DX material is extremely small. As a result, there is no danger of a DX bearing seizing or even tightening on the shaft when water is present.

---

**Wear rate and relubrication**

DX bearings exhibit an exceptionally low wear rate. Even during the initial stages of use, the bedding-in wear for these lubricated bearings is only about 0.0001 inch (0.003 mm) when the load is less than 14,500 psi (100 N/mm²). Subsequent wear is usually inconsequential as long as there is sufficient amount of lubricant present. Under bearing pressure above 14,500 psi (100 N/mm²), the initial bedding-in wear is greater, about 0.001 inch (0.025 mm), followed by a decreasing wear rate until the bearing exhibits a similar wear/life relationship to that shown in Figure 5-1. If the bearing is regreased before the rate of wear starts to increase rapidly, the material will continue to function satisfactorily with little wear. Figure 5-1 shows the typical wear pattern and the concept of the DX bearing relubrication.

---

The lubricant film that the bearing surface is able to maintain during long periods of sliding contact with a shaft or flat surface ensures negligible wear. Should the bearing be allowed to run after the film of lubricant has disappeared, some wear will occur, but there will be no damage to the mating surface until the bronze substrate surface is exposed.

For assistance in calculating the appropriate relubrication interval for your various applications, please refer to the technical discussion on this subject on page 5-6.

---

**Static electricity**

DX bearing material has not exhibited static electricity phenomena.

---

**Thermal properties**

Using a suitable lubricant, DX bearings can be used continuously at temperatures up to 210°F (100°C), or down to -40°F (-40°C). They can be used at intermittent temperatures up to 260°F (125°C). DX bearings can be used at the full calculated load capacity at temperatures up to 100°F (40°C). However, at temperatures above 100°F (40°C), the load carrying capacity gradually diminishes to about half of the load limit values.

---

**Static electricity**

DX bearing material has not exhibited static electricity phenomena.

---

**Figure 5-1. DX Relubrication Cycle**

*End of useful life of prelubricated bearing – LDX
Initial greasing only.
Recommended regreasing intervals – RDX
DX bearing continues with low wear rate when regreased at intervals – RDX
Radial wear, mm
Radial wear, inch
DX Relubrication Cycle
Recommended regreasing intervals
End of useful life of prelubricated bearing
Initial greasing only
Radial wear, mm
Radial wear, inch
DX bearing continues with low wear rate when regreased at intervals
Operating Life
RDX RDX RDX
DX Relubrication Cycle*
Bearing pressure – P

For the purpose of assessing bearing performance, bearing pressure \( P \) is defined as the working load divided by the projected area and is expressed as psi (N/mm\(^2\)). Table 5-2 lists common DX bearing configurations and their respective bearing pressure formulas.

The maximum pressure which can be supported by a DX bearing will depend upon the type of loading. It will be highest under steady loads whereas dynamic loads or oscillating motions, which produce fatigue stress on the bearings, will result in a reduction in load capacity (Table 5-1).

Surface velocity – V

Standard DX bearings can be used up to 50 fpm (0.25 m/s). When speeds exceed this value and approach 100 fpm (0.5 m/s) then... to accommodate the thermal expansion caused by surface heat generation. Refer to Table 5-2 for velocity calculations.

PV factor

PV factor is used as a guide to the useful operating life of a DX bearing and the relubrication interval. PV is the product of the bearing pressure \( P \) and the surface velocity \( V \). PV is expressed as psi-fpm (N/mm\(^2\)-m/s). At extreme values, each parameter must be considered individually as well as together.

PV factors of up to 80,000 psi-fpm (2.8 N/mm\(^2\)-m/s) can be accommodated at speeds up to 5 fpm (0.025 m/s), while for speeds between 5 to 100 fpm (0.025 to 0.5 m/s), PV factors up to 20,000 psi-fpm (0.7 N/mm\(^2\)-m/s) can be used.

Effective PV – EPV factor

The EPV factor takes into account the effect of high load and is used to estimate DX bearing life. Table 5-1 shows the maximum bearing pressure, \( U \), for various operating conditions. If referring to Figure 5-3 for a \( U \) value, choose a corresponding \( U \) value based upon the desired bearing cycles life, \( L_0 \).

Once the value for \( U \) is selected, the EPV can be calculated as follows:

\[
\text{EPV} = \frac{U \times P \times V}{U-P}
\]

Refer to pages 5-6 to 5-9 for the method of estimating DX bearing life and regreasing interval.

Table 5-1: Maximum Pressure – U

<table>
<thead>
<tr>
<th>Load Condition</th>
<th>Operation</th>
<th>Lubrication</th>
<th>Maximum Pressure, U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steady</td>
<td>Little or very slow continuous motion</td>
<td>Grease</td>
<td>20,000 psi (140 N/mm(^2))</td>
</tr>
<tr>
<td>Steady</td>
<td>Continuous rotation</td>
<td>Grease</td>
<td>10,000 psi (80 N/mm(^2))</td>
</tr>
<tr>
<td>Steady</td>
<td>Oscillating motion</td>
<td>Grease</td>
<td>Refer to Figure 5-3</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Continuous rotation</td>
<td>Grease</td>
<td>Refer to Figure 5-3</td>
</tr>
</tbody>
</table>

Table 5-2: DX Design Factors

<table>
<thead>
<tr>
<th>KEY</th>
</tr>
</thead>
<tbody>
<tr>
<td>( d ) = bearing/thrust washer ID</td>
</tr>
<tr>
<td>( D ) = thrust washer OD</td>
</tr>
<tr>
<td>( L ) = bearing/slide pad length</td>
</tr>
<tr>
<td>( W ) = slide pad width</td>
</tr>
<tr>
<td>( S ) = bearing/slide pad stroke</td>
</tr>
<tr>
<td>( P ) = calculated bearing pressure in psi (Newtons/mm(^2))</td>
</tr>
<tr>
<td>( F_r ) = radial load in pounds (Newton)</td>
</tr>
<tr>
<td>( F_t ) = thrust load in pounds (Newton)</td>
</tr>
<tr>
<td>( F_s ) = slideway load in pounds (Newton)</td>
</tr>
<tr>
<td>( V ) = relative surface velocity in feet per minute (fpm) or meters per second (m/s)</td>
</tr>
<tr>
<td>( n ) = rotation speed, revs per minute</td>
</tr>
<tr>
<td>( c ) = cycling rate, cycles per minute</td>
</tr>
<tr>
<td>( \alpha ) = angle of oscillation, degrees</td>
</tr>
</tbody>
</table>

Refer to Figure 5-2 for Oscillation Angle

Figure 5-2. Oscillation Angle

Figure 5-3. DX Maximum Pressure for Cyclic Applications

Refer to pages 5-6 to 5-9 for the method of estimating DX bearing life and regreasing interval.
Calculating DX™ bearing life

A useful approximation of actual performance in a specific application can be made by making allowance for the effect of the most important variables including speed, mating surface, operating temperature, and bearing size proportions. This section covers the method of estimating DX bearing life and regreasing interval.

Figure 5-4 shows the basic service life, Lb, in hours assuming normal room temperature conditions, normal running clearances, and good heat dissipation of a well-proportioned bearing operating against low carbon steel with a surface finish of 16 micrometers (0.4 micrometers). The following graphs and tables describe major factors affecting DX bearing life.

Accounting for all the variables in a specific application is difficult, but the following recommended approach will provide a useful guide for the designer.

The calculated EPV factor, as described on page 5-4, is used to determine the basic DX bearing service life Lb. The estimated bearing life, LZ, is calculated by applying various service factors to the basic service life Lb. Refer to Figure 5-4 and read the basic service life based on the calculated EPV.

Garlock Bearings offers a computer program that will assist in calculating DX bearing life. Contact our Applications Engineering Department for a copy of this program.

The formula for DX bearing life is:

$$L_{DX} = L_b \times r \times s \times t \times b$$

The formula for DX regreasing interval is:

$$R_{DX} = \frac{L_{DX}}{2}$$

Where:

- L_{DX} = DX bearing life, hours
- R_{DX} = regreasing interval, hours
- L_b = DX basic service life, hours, see Figure 5-4
- r = surface speed factor, Table 5-3
- s = mating surface factor, Figure 5-5
- t = operating temperature factor, Figure 5-6
- b = bearing size factor, Figure 5-7

For linear sleeve bearings or slideway (see page 5-5), the above equation is modified as follows:

$$L_{DX} = \frac{L}{L+S} \times L_b \times r \times s \times t \times b$$

Where:

- L_b = sleeve bearing basic service life, Figure 5-4
- L = bearing length, inches (mm)
- S = bearing stroke, inches (mm)

Oscillating, cyclical, and linear motion/fluctuating loads

These conditions require special consideration when calculating bearing life. The maximum bearing pressure, U, is a function of the desired bearing life, LQ, expressed in cycles. Figure 5-3, page 5-4, shows the U factor as a function of cycles. Bearing life, LQ, in hours, can be estimated by using the previously described method. Bearing life is converted into equivalent cycles by the equation:

$$L_{Q} = 60 \times L_{DX} \times c$$

Where:

- LQ = desired bearing life in cycles
- LD = DX bearing life in cycles
- LD = DX bearing life, hours
- c = cycling rate in cycles per minute

Table 5-3: Surface Speed Factor – r

<table>
<thead>
<tr>
<th>Surface Speed</th>
<th>Surface Speed Factor – r</th>
</tr>
</thead>
<tbody>
<tr>
<td>fpm</td>
<td>Surface Speed</td>
</tr>
<tr>
<td>m/s</td>
<td>N/mm²-m/s</td>
</tr>
<tr>
<td>up to 0.025</td>
<td>0.025 to 0.25</td>
</tr>
<tr>
<td>80,000</td>
<td>20,000</td>
</tr>
<tr>
<td>Maximum permissible PV factor for grease lubrication</td>
<td>2.8</td>
</tr>
<tr>
<td>DX bearings – steady load vertically downwards (lubricant draining towards load area)</td>
<td>un machined</td>
</tr>
<tr>
<td></td>
<td>machined</td>
</tr>
<tr>
<td>DX bearings – steady load not downwards (lubricant draining away from load area or dynamic load)</td>
<td>un machined</td>
</tr>
<tr>
<td></td>
<td>machined</td>
</tr>
<tr>
<td>DX bearings</td>
<td>rotating load</td>
</tr>
<tr>
<td></td>
<td>machined</td>
</tr>
<tr>
<td>DX thrust washer</td>
<td></td>
</tr>
</tbody>
</table>
Mating surfaces – s
DX bearings may be used with all conventional shaft materials. A ground finish of better than 16 microinches (0.4 micrometers) is recommended. Hardening of steel shafts is not essential unless abrasive dirt is present, in which case a shaft hardness of at least Rc40 is recommended. Figure 5-5 shows the relationship of application factor s, for various surface finishes.

Operating temperature – t
The effect of environmental temperature and basic type of grease lubricant is shown by application factor t, as shown in Figure 5-6. The heat dissipating properties of the housing, especially if the bearing is mounted in an area close to an engine or other heat generating unit, affect bearing surface temperature and are particularly important at high PV values. When the temperature approaches the top limit of 260°F (125°C), consult our Application Engineering Department.

Bearing size factor – b
Frictional heat is generated at the bearing surface during operation and is dissipated through the shaft and housing. The heat generated depends both on the operating conditions (i.e., PV factor) and the bearing size. For a given PV condition, a large bearing will run hotter than a smaller bearing due to a proportionately smaller contact area.

Choice of lubricants for DX™ bearings
The choice of lubricant will depend primarily upon three factors: the maximum temperature expected; the stability of the lubricant in the environmental conditions; and the degree of contamination. When the lubricant is applied on the initial assembly only, a grease is recommended. For temperatures between 160°F and 210°F (70°C and 100°C), the grease, or in some cases oil, should contain an antioxidant, while for temperatures between 210°F (100°C) and the maximum permissible temperature of 260°F (125°C), a silicone grease is preferred. DX bearings are only suitable for operation in water when the load and speed conditions permit a hydrodynamic film to be established, or alternatively when the PV factor is less than 1,000 psi-fpm (0.04 N/mm²). The degree of contamination is a very important factor. In contaminated applications, with or without seals, a grease should be used rather than any type of oil to purge the bearing clean.

Table 5-4: Greases

<table>
<thead>
<tr>
<th>TYPE OF GREASE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premium Quality</td>
<td>Stabilized, Antioxidant Lithium Base*</td>
</tr>
<tr>
<td>Multi-Purpose</td>
<td>Lithium Base with 3% Molybdenum Disulfide, High Drop Point*</td>
</tr>
<tr>
<td>Multi-Purpose</td>
<td>Calcium Based, for General Automotive and Industrial Use</td>
</tr>
<tr>
<td>Anti-Friction Bearing</td>
<td>Calcium Based with EP Additives</td>
</tr>
<tr>
<td>Extreme Pressure (EP)</td>
<td>Calcium Based with EP Additives</td>
</tr>
<tr>
<td>High Temperature</td>
<td>Modified Sodium Based, High Drop Point*</td>
</tr>
<tr>
<td>Transmission</td>
<td>Semi-Fluid, Calcium Based</td>
</tr>
<tr>
<td>Molybdenum Filled</td>
<td>Lithium Based with 2% Molybdenum Disulfide*</td>
</tr>
<tr>
<td>Graphite Filled</td>
<td>Sodium Based with 2% Graphite</td>
</tr>
<tr>
<td>Block Grease</td>
<td>Sodium Based Solid Grease</td>
</tr>
<tr>
<td>White Grease</td>
<td>Aluminum Complex Based with Antioxidant &amp; Rust Inhibitors &amp; Zinc Oxide Additives</td>
</tr>
<tr>
<td>Silicone</td>
<td>Lithium Based with Silicone Oil Lubricant</td>
</tr>
</tbody>
</table>

*Especially recommended

GREASES NOT RECOMMENDED

<table>
<thead>
<tr>
<th>TYPE OF GREASE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cup Grease</td>
<td>Light Service Calcium or Sodium Based Grease</td>
</tr>
<tr>
<td>Graphite Filled</td>
<td>Greases with More than 10% Graphite</td>
</tr>
<tr>
<td>Molybdenum Filled</td>
<td>Greases with More than 10% Molybdenum Disulfide</td>
</tr>
<tr>
<td>Fluorocarbon</td>
<td>Low Molecular Weight Chlorofluorocarbon Polymer with Inert Thickeners</td>
</tr>
<tr>
<td>White Grease</td>
<td>Calcium Based, Zinc Oxide Filled</td>
</tr>
</tbody>
</table>
**Installation and Fabrication**

**Self-Lubricating Bearings, Prelubricated Bearings**

**Installation Guidelines**

The success of a DU® or DX™ application depends, in part, on the proper installation of the bearing or thrust washer. The following pages show how to best install and modify DU and DX bearings.

### Sizing DU and DX bearings

DU bearings do not require sizing in the bore and, except in unusual circumstances, should not be roller burnished, broached, or machined. DU bearings can be sized by burnishing, although this may lead to reduced bearing life depending upon the amount of burnishing. Refer to Figure 6-3 for burnishing tool recommendations and Table 6-2 for DU bearing life modification factor.

DX bearings have a nominal 0.010 inch (0.25 mm) acetal layer and can be sized at assembly by boring, broaching, or reaming the bore. If DU or DX bearings are not to be sized at assembly, it is important that both the shaft diameter and housing bore are finished to the sizes listed in the standard bearing tables. Any increase in clearance may result in a reduction in performance.

Assembly in a rigid steel or cast-iron housing will produce the calculated close-in and proper running clearances. With thin-walled housings or housings made from less rigid materials, such as aluminum or plastic, the clearances will be increased. In these circumstances, the housing should be bored slightly undersize or the shaft diameter increased—the correct size being determined by experiment.

When free-running is essential, or where lighter loads prevail (less than 15 psi [0.1 N/mm²]) and the available torque is low, increased clearance is required, and it is recommended that the shaft diameter shown in the standard product tables be reduced by 0.001 inch (0.025 mm).

### Tolerance for minimum clearance

When it is necessary to keep the variation of assembled clearance to a minimum, closer tolerances can be specified at the lower end of the housing tolerance and/or at the upper end of the shaft tolerance. It is not possible to reduce the lower housing limit or the upper shaft limit without running the risk of the shaft interference in the assembled bearing.

Normally, it is recommended that the housing and shaft be finished to the limits given in the standard product tables. With these sizes, the following are examples of the diametral clearance range created on assembly:

- **DU Bearings**
  - 0.002 to 0.0034 inch for a 0.5 inch bore
  - 0.002 to 0.0068 inch for a 2.0 inch bore

- **DX Bearings**
  - 0.0007 to 0.0048 inch for a 0.5 inch bore
  - 0.0015 to 0.0097 inch for a 2.0 inch bore

### Alignment

Accurate alignment is a primary design consideration in all bearing applications but is particularly important with DU bearings because there are no lubricants to spread the load. To maximize bearing life of DU bearings, misalignment over the length of a bearing (or pair of bearings in tandem), or over the diameter of a thrust washer should not exceed 0.002 inch (0.05 mm) for DX bearings, misalignment should not exceed 0.002 inch (0.05 mm).

### Axial location

Where axial location is necessary, it is advisable to use DU or DX thrust washers in conjunction with DU or DX bearings, even when the axial loads are light. Alternatively, for DU applications, flanged DU bearings should also be considered. Experience has indicated that fretting debris from mating thrust surfaces without a thrust bearing between them can enter an adjacent bearing and adversely affect the bearing life and performance.

### Allowance for high temperature

When a DU or DX bearing is subjected to elevated temperatures, the diameter of the shaft should be reduced by 0.0002 inch per 100°F (0.010 mm per 100°C) for a DU bearing or 0.0005 inch per 100°F (0.025 mm per 100°C) for a DX bearing above normal room temperature. If the housing is a bronze-, zinc-, or aluminum-based alloy, its bore should be reduced by the amount shown in Table 6-1 to give an increased interference fit to the bearing. The shaft diameter should be reduced by this same amount in addition to previously mentioned shaft diameter reduction.

**Table 6-1: High Temperature Allowance**

<table>
<thead>
<tr>
<th>Housing Material</th>
<th>Reduction in Housing and Shaft Diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel and Cast Iron</td>
<td>Nil</td>
</tr>
<tr>
<td>Brass or other</td>
<td>0.025% per 100°F (0.05% per 100°C)</td>
</tr>
<tr>
<td>Copper Alloys</td>
<td>0.05% per 100°F (0.10% per 100°C)</td>
</tr>
<tr>
<td>Aluminum Alloys</td>
<td>0.05% per 100°F (0.10% per 100°C)</td>
</tr>
<tr>
<td>Zinc Base Alloys</td>
<td>0.08% per 100°F (0.15% per 100°C)</td>
</tr>
</tbody>
</table>
Bearing installation

As illustrated by Figure 6-1, the bearing is inserted into its housing with the aid of a conventional stepped mandrel, preferably made from case-hardened mild steel and free of burrs and sharp edges.

Care must be taken to insert the bearing squarely into the housing to avoid damage to the lining material. A slight lead-in chamfer should be machined in the housing and a smear of oil may be applied to the housing bore to assist the fitting operation. Installation can be further improved by using an installation ring as shown on Figure 6-1. This approach is helpful for installing large diameter bearings. Figure 6-1 shows the recommended housing bore chamfer for flanged DU bearings. Recommended arbor and chamfer dimensions are given in the accompanying illustrations. Housing and shaft sizes are given in the standard product tables.

When the use of a mandrel for large bearings becomes impractical, other methods can be used, provided care is taken to protect the edge of the bearing from being damaged. Steps must be taken to maintain the alignment of the bearing split during assembly.

Note: Even though bearing surfaces of DU and DX materials are extremely durable when rubbing against a suitable shaft or thrust face, care must be taken to ensure that the bearing material is not scratched or otherwise damaged by sharp projections before or during installation.

Thrust washer installation

As illustrated in Figure 6-2, thrust washers should be located on the outside diameter in a recess. The inside diameter must be clear of the shaft to prevent the steel backing from rubbing on the journal surface. The recess diameters should be 0.005 inch (0.13 mm) larger than the washer diameter.

A dowel or countersunk screw should be used to prevent rotation, but the head must be recessed at least 0.010 inch (0.25 mm) below the bearing surface. The size and position of the dowel hole provided for this purpose can also be found in the tables of standard sizes. Where a housing recess cannot be provided, two dowels or screws or a suitable adhesive may be used. When the use of screws or dowels is not convenient, solder or a synthetic resin adhesive may be used. Care must be taken not to heat the bearing above the maximum recommended operating temperature to avoid damage to the bearing material. Advice on the use of an adhesive should be obtained from the adhesive manufacturer.

Electroplating

The back and edges of DU can be electroplated with most conventional metals. With light deposits of materials such as tin, no special precautions are necessary. Since harder materials such as chromium or heavier deposits may bond to or etch through the surface layer, it is advisable to use an appropriate method of masking the bearing surface. Refer to Corrosion Protection on page 4-2.

Typically, DX bearings do not require plating since they are subsequently lubricated with grease or oil.

Length shortening, drilling

The modification of DU and DX bearing components requires no special procedures. In general, it is more satisfactory to perform machining or drilling operations from the bearing surface side in order to avoid burns. When cutting is done from the steel side, minimum cutting pressure should be used. Remove all burns and steel or bronze particles protruding into the remaining bearing material.
Burnishing DU® bearings

DU bearings can be sized at assembly by burnishing the bearing I.D. using tools as shown in Figure 6-3. This method of sizing DU is used to help control the assembled bearing clearance. However, burnishing will reduce dry bearing life. Table 6-2 lists a factor, based on the degree of burnishing, to be used when estimating DU bearing life. Multiply the bearing size factor by the factor in Table 6-2. For full hydrodynamic applications, burnishing will not affect bearing life except during starting and stopping. Roller burnishing is not recommended since the bronze innerstructure may be damaged.

<table>
<thead>
<tr>
<th>Table 6-2: Burnishing Factor</th>
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<tbody>
<tr>
<td>Excess of burnishing tool diameter, ( d_s ), over mean installed bearing I.D.</td>
</tr>
<tr>
<td>0.001 inch (0.025 mm)</td>
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<tr>
<td>0.0015 inch (0.038 mm)</td>
</tr>
<tr>
<td>0.002 inch (0.05 mm)</td>
</tr>
</tbody>
</table>

Figure 6-3. Burnishing Tools

Boring DX™ bearings

Acetal resin has good general machining characteristics and can be treated as a free cutting brass in most respects. The pattern of indents applied to DX bearings makes certain machining procedures necessary. To obtain good results, we suggest use of a tool made from high speed steel or tungsten carbide.

Cutting speed should be high, the optimum lying between 400 and 900 fpm (2.0 to 4.5 m/s). The feed should be low, in the range of 0.002/0.001 inch (0.05/0.03 mm). For cuts of 0.005 inch (0.13 mm), the lower feeds should be used with the higher speed value.

Care should be taken with the final cut to make sure that the acetal bearing material does not smear into the indentations. Also, machining may lead to the formation of burrs or whiskers due to the resilience of the DX lining. This can be avoided by using machining methods which remove the lining in a broad ribbon, rather than a narrow thread. Satisfactory finishes can usually be obtained machining dry, but should difficulty be met, a coolant can be used.

It is recommended that not more than 0.005 inch (0.13 mm) cut should be removed from the thickness of the DX lining, in order to ensure that the lubricant capability of the indent remaining after machining is not seriously reduced.

Reaming DX bearings

DX bearings can be reamed satisfactorily by hand with a straight-fluted expanding reamer. For best results, the reamer should be sharp, the cut 0.001 to 0.002 inch (0.03 to 0.05 mm), and the feed slow.

Where hand reaming is not desired, machining speeds of about 10 fpm (0.05 m/s) are recommended with the cuts and feed as for boring.

Broaching DX bearings

Broaches are suitable for finishing grooved or indented DX bearings. The broach should be used dry, at a speed of 20 fpm (0.1 m/s).

A single-tooth broach should be used where the bearing is less than 1 inch (25 mm) long, and a multiple tooth broach, for longer bearings or for bearings mounted in tandem.