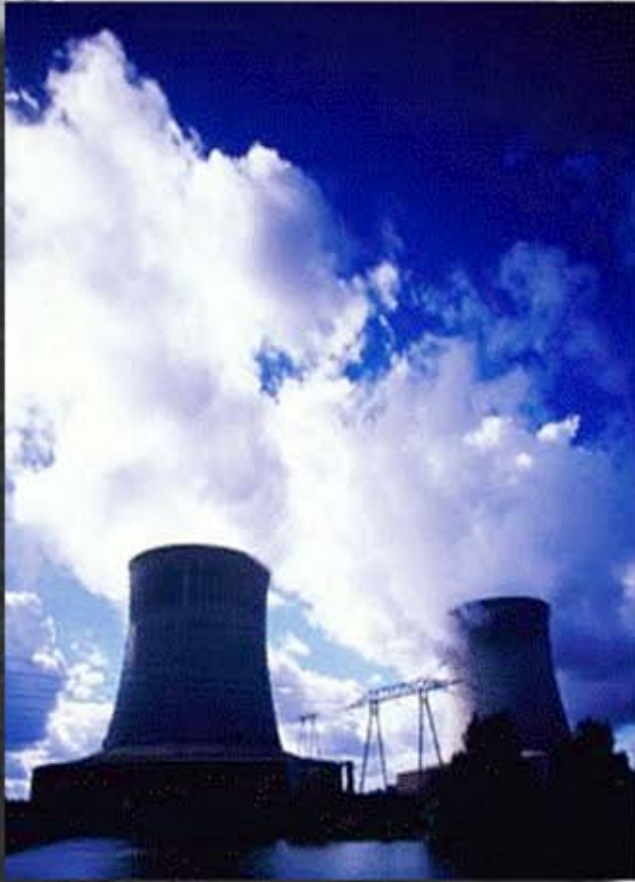


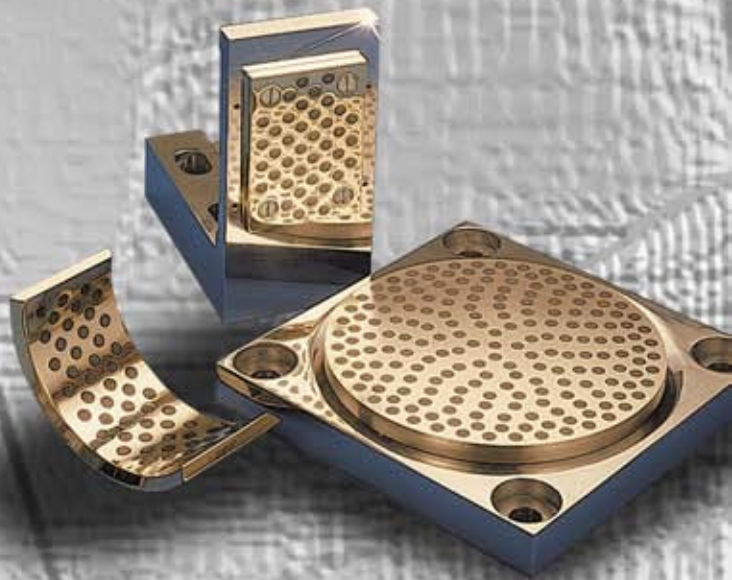
Nuclear Power



Lubron®

AE

**Self-Lubricating
Bearings**

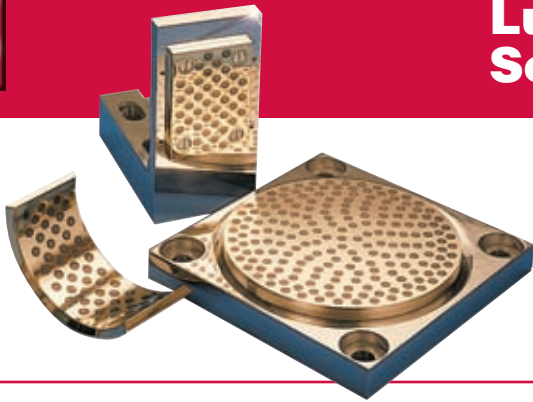


Lubron Bearing Systems

Bearings to move the world.



Lubron AE Self-Lubricating Bearings



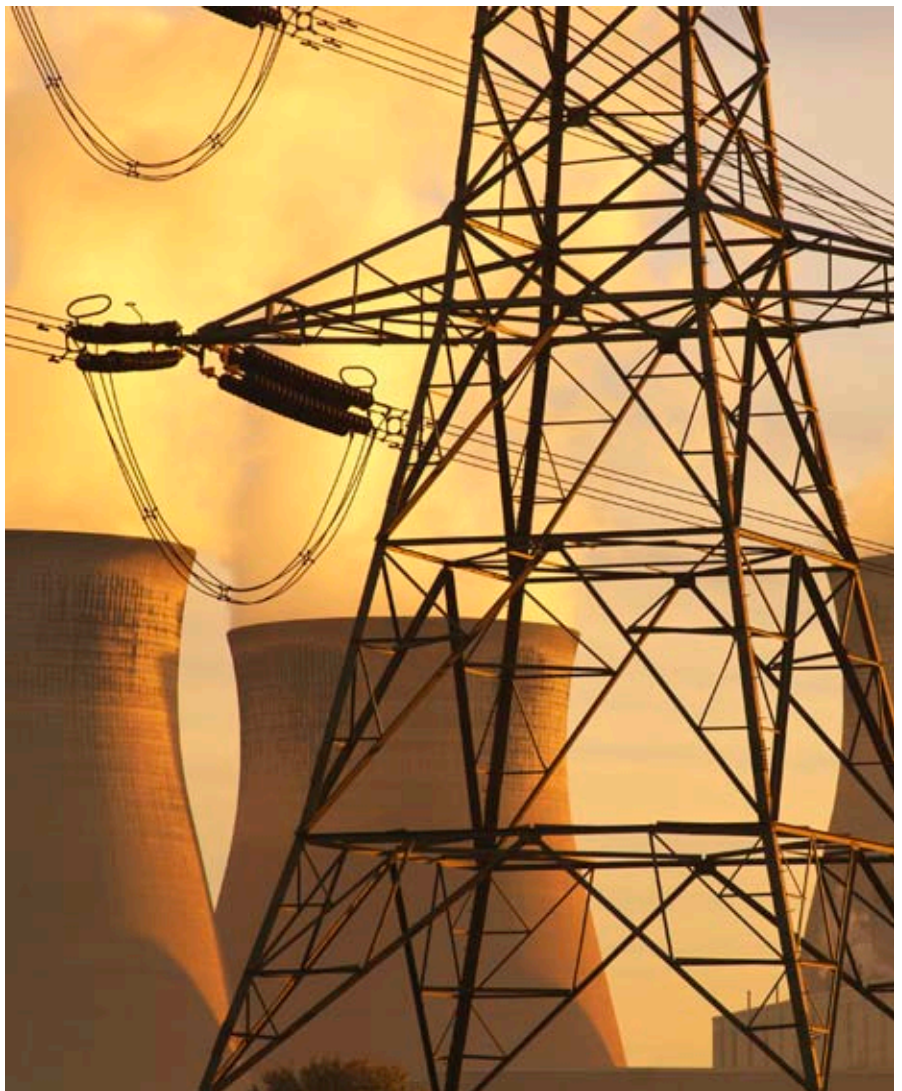
LUBRON® AE self-lubricating bearings are used in a variety of nuclear applications subject to medium-to-heavy loads and slow-to-medium speeds. LUBRON AE bearings are designed to minimize stresses resulting from differential thermal expansion and seismic activity, and have the capacity to resist high temperatures and exposure to irradiation. LUBRON AE's versatile properties provide maximum bearing life and maintenance-free operation in both dry and immersed environments.

LUBRON AE self-lubricating bearings have been widely used in nuclear applications for more than 30 years. Designed to provide low coefficient of friction and maintenance-free operation, LUBRON AE bearings offer maximum safety and long service life. LUBRON AE bearings are ideal for heavy loads, slow speeds and inaccessible locations, and are capable of withstanding high temperatures and irradiation without degradation in performance.

CONSTRUCTION

Adequate lubrication is the single most important factor for successful operation of a bearing, especially for high strength bearing alloys that require continuous lubrication to prevent seizing, scoring and galling. LUBRON AE self-lubricating bearings are effective in applications where relative motion is not sufficient to promote circulation of grease or oil, and operating conditions exist where auxiliary lubrication is not possible or practical.

LUBRON AE bearings feature nuclear grade purified graphite lubricants embedded in cast bronze or Meehanite® alloys. The near-isotropic graphite lubricants are compressed into trepanned or circular recesses provided for containment of the solid lubricant. The recesses cover 30% to 40% of the bearing surface in uniform, geometric and overlapping patterns to assure optimum lubricating coverage. The recesses securely anchor the solid lubricant and provide permanent reservoirs for continuous lubrication of the bearing surface.





Lubron AE Self-Lubricating Bearings

BEARING ALLOYS

A wide selection of bearing alloys is available for nuclear applications. Manganese bronzes are used extensively, especially where toughness and shock resistance are desirable. Aluminum bronzes offer excellent wear and corrosion resistance. Tin and leaded tin bronzes provide good embedability and tolerate some misalignment, but are generally limited to low and moderate bearing loads and temperatures. Meehanite® metals combine good strength, wear resistance and high temperature capabilities.

In selecting a suitable alloy for a specific application, Table 1 provides our recommended design loads, comparative specifications and performance characteristics for bearing alloys most often used in nuclear applications. Other alloys are also available to satisfy special requirements.

Proper selection of a suitable alloy depends on a variety of factors, which include bearing load, velocity, type of movement, temperature, environment, shear strength, fatigue strength, deformability, compatibility, hardness differential, corrosion resistance, wear resistance and cost. These factors should be evaluated in conjunction with the other bearing components to insure long bearing life and trouble-free operation.

TABLE 1

Alloy No.	Generic Description	ASTM Specification	Maximum Recommended Bearing Load	Maximum Recommended PV	Maximum Operating Temperature
GA50	Meehanite	A48(50)	8000 psi 55 N/mm ²	72,000 psi-ft/min 150 N/mm ² -m/min	1100°F 593°C
614	Aluminum Bronze	B169-C61400	5000 psi 35 N/mm ²	60,000 psi-ft/min 130 N/mm ² -m/min	800°F 427°C
863	Manganese Bronze	B22-C86300	8000 psi 55 N/mm ²	72,000 psi-ft/min 150 N/mm ² -m/min	750°F 399°C
905	Tin Bronze	B22-C90500	2000 psi 14 N/mm ²	30,000 psi-ft/min 65 N/mm ² -m/min	500°F 260°C
932	High Lead Tin Bronze	B584-C93200	1500 psi 10 N/mm ²	24,000 psi-ft/min 50 N/mm ² -m/min	450°F 232°C
954	Aluminum Bronze	B148-C95400	4000 psi 27.5 N/mm ²	48,000 psi-ft/min 100 N/mm ² -m/min	600°F 315°C
955	Nickel Aluminum Bronze	B148-C95500	6000 psi 41 N/mm ²	72,000 psi-ft/min 150 N/mm ² -m/min	600°F 315°C



Lubron AE Self-Lubricating Bearings

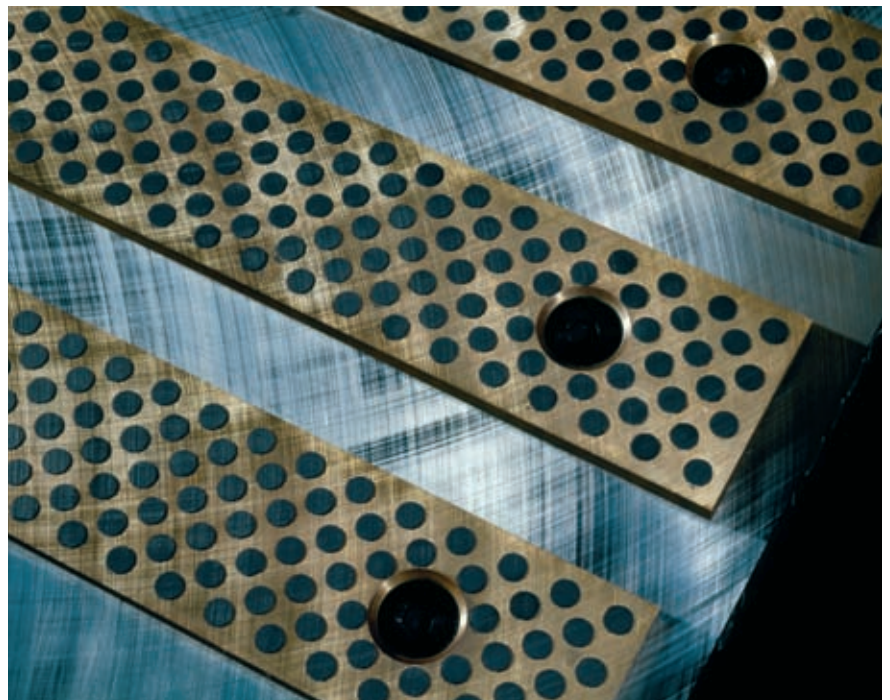
PERMANENT LUBRICATION

LUBRON AE lubricants consist of near-isotropic nuclear grade graphites with impurity contents less than 100 ppm. Near-isotropic graphites provide the greatest resistance to fast neutron and thermal fluences. Depending on the intended use, operating temperatures, size and configuration of the bearing, LUBRON AE30 and LUBRON AE40 solid lubricants are suitable for most nuclear power plant applications.

LUBRON AE30 lubricants consist of purified graphite powders compounded with radiation resistant epoxy resins and hardeners, specially formulated to achieve optimum bearing performance. The natural lubricity and high concentration of the graphite powders result in low coefficient of friction, while the epoxy resins combine to provide excellent wear and chemical resistance. LUBRON AE30 lubricants are recommended for operating temperatures up to 500°F (260°C).

LUBRON AE40 lubricants consist of purified solid graphite plugs compressed into circular recesses. LUBRON AE40 graphite lubricants are capable of resisting high temperatures up to 2000°F (1093°C), and exhibit excellent dimensional stability under neutron irradiation. In tests performed for General Electric Company, LUBRON AE40 bearings were irradiated to a minimum total neutron fluence of 1×10^{18} n/m² and a minimum total integrated gamma dose of 1×10^7 rads.

LUBRON AE lubricants have been thoroughly analyzed for ash, including all major neutron absorbing burnable and non-burnable impurities except oxygen and nitrogen. Impurity contents of LUBRON AE lubricants are less than 100 ppm.



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Lubron AE Self-Lubricating Bearings

DESIGN CRITERIA

The overall performance of LUBRON AE bearings is directly influenced by a variety of factors which in particular include bearing load, speed, PV and type of movement. The following section describes the design criteria needed to specify a LUBRON AE bearing. While specific criteria are not provided for every application, essential design considerations and guidelines are discussed in some detail.

The following guidelines are recommended for both LUBRON AE30 and LUBRON AE40 self-lubricating bearings and are suitable for either dry operation or immersion in demineralized water.

Normal operating load: 2 to 8 ksi

One time shock load: 80 ksi

Maximum total fast neutron dose: 10^{21} nvt

Maximum total integrated gamma dose: 10^{10} rads

Maximum static coefficient of friction: 15%

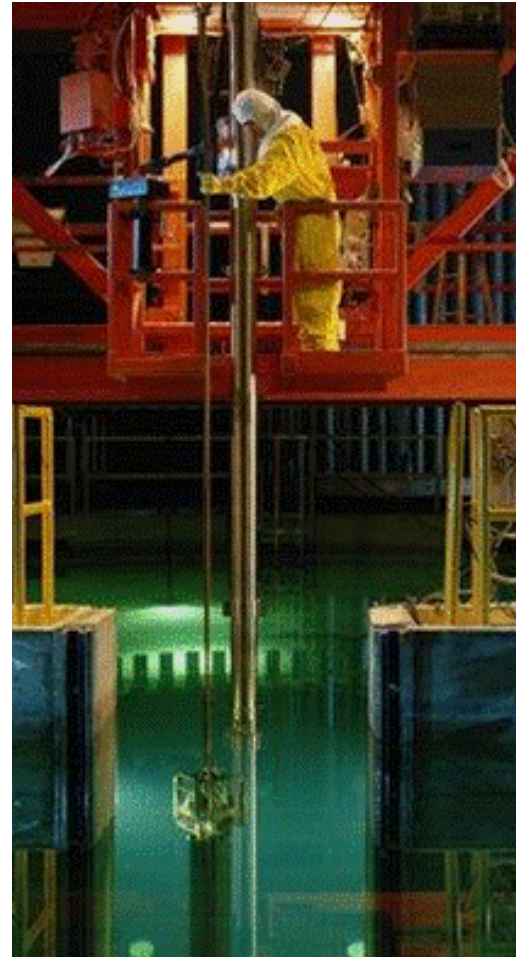
The operating load and temperature range is dependent on the bearing alloy selected. For specific recommendations, please consult a LUBRON engineer.

Coefficient of Friction

LUBRON AE self-lubricating bearings typically have a coefficient of friction between 0.10 and 0.15, depending on a variety of factors effecting performance. The bearing load, velocity, temperature, type of environment, finish and hardness of the mating surface all influence coefficient of friction. Friction, defined as the resistance to sliding motion between two surfaces, is largely determined by the resistance to shear of the lubricant. LUBRON AE's low coefficient of friction and shear strength are derived from its high graphite content. During startup, LUBRON AE lubricants deposit a cohesive, molecule-thick film of graphite on the mating surface, filling asperities and sealing the mating surface. Both surfaces burnish quickly under pressure, and result in a highly polished bearing surface capable of withstanding heavy loads.

Bearing Pressure

Bearings should be sized to accommodate the total applied load without exceeding the maximum design load. Recommended maximum design loads are shown in Table 1, having been determined by dividing the yield strength of each alloy by an appropriate safety factor. In most cases, the safety factor is extremely high, and actual loads may occasional exceed the design load with no detrimental effect on bearing life.





Lubron AE Self-Lubricating Bearings

Bearing pressure is defined as the total load applied on the supporting or projected area of the bearing, and is generally expressed in psi, ksi, kg/cm², or N/mm². For uniformly loaded bearings, bearing pressure can be calculated as follows:

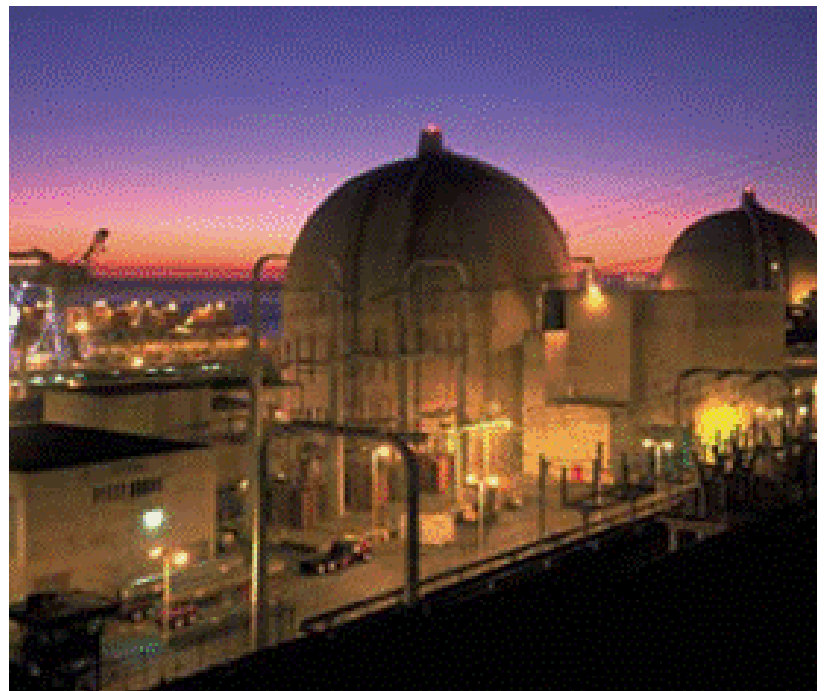
$$\begin{aligned} P &= \frac{\text{LOAD}}{\text{PROJECTED AREA}} = \frac{\text{LOAD}}{\text{ID X LENGTH}} \quad (\text{Bushings}) \\ &= \frac{\text{LOAD}}{.0785 \times (\text{OD}^2 - \text{ID}^2)} \quad (\text{Thrust washers \& flange thrust surfaces}) \\ &= \frac{\text{LOAD}}{\text{WIDTH X LENGTH}} \quad (\text{Plates}) \end{aligned}$$

Velocity

Surface velocity of a bearing is expressed in surface feet per minute (SFM) or meters per minute (m/mm). The maximum allowable surface velocity for LUBRON AE bearings depends on the applied load and other operating and environmental variables. In general, surface velocity should not exceed 35 SFM for intermittent operation and 10 SFM for continuous operation.

PV Limit

PV is defined as the product of bearing pressure (P) and the surface velocity (V), and is used as a means of measuring bearing performance. Values for pressure and velocity must be considered individually, as well as their combined product. Temperature is the most important factor in determining a bearing's PV limit. For most cases, the PV limit reflects the point where surface temperatures are at a maximum, but still stable. Anything effecting temperature, including coefficient of friction, running clearance, hardness and surface finish, will also affect the PV limit. Bearings which operate at lower PV values will generally have longer service lives. LUBRON AE bearings will perform best when the bearing assembly is designed for maximum heat dissipation and the recommended mating materials are used.





Lubron AE Self-Lubricating Bearings

Type of Movement

The recommended PV limits shown in Table 1 are based on rotating motion and intermittent operation. For oscillating and reciprocating motion, or for continuous operation, up to 50% of the PV limit should be used, depending on the service life required.

LUBRON AE bearings are especially effective for intermittent oscillating and reciprocating motion where conventional lubricants are inadequate. By providing a tough solid lubricant film over the sliding surface, LUBRON AE bearings offer maximum resistance to wear and seizure under the harshest operating conditions.

SHAPES

LUBRON AE bearings are available in many different configurations depending on the application, direction of load, and type of movement. The most common shapes are listed below.

Bushings

One-piece sleeve bushings are used to accommodate all types of rotary and linear motion. Sleeve or journal bushings are employed when the shaft load is essentially perpendicular to the axis of the shaft (radial loads). Either of both the inside or outside diameters of the bushing can be lubricated. Depending on the bearing size and application, the lubricating recesses may extend completely through the bearing wall, or for larger bushings or bushings subject to heavier loads, the lubricating recesses will only extend partially through the bearing wall.

Where split housings or a need for disassembly and reassembly make split bushings advantageous, LUBRON AE bearings are available either matched (split before final machining providing 180° perfect halves), or unmatched (split after final machining varying slightly from perfect 180° halves). Perfect halves are match-marked for proper assembly to assure maintenance of concentricity.

Washers

Washers are used to accommodate rotational end thrust when the shaft load is in the direction of the shaft axis. Used alone in conjunction with sleeve bushings, LUBRON AE washers can be lubricated on one or both sides.

Flange Bushings

Flange bushings combine the features of sleeve bushings and washers into one unit. Available with flanges on one or both ends, flange bushings are used when the shaft load has an axial and perpendicular component. The flanges may be lubricated for thrust load applications, or provided without lubrication when required to act only as a spacer.



Lubron AE Self-Lubricating Bearings

Spherical Self-Aligning Bearings

Self-aligning spherical bearings and bearing assemblies are designed primarily to accommodate radial loads and some misalignment. Misalignment may be caused by articulation, rotation, or structural deflections under load. LUBRON AE spherical bearing assemblies consist of an inner component (gimbal) and an outer two-piece component (housing). Either the gimbal outside spherical surface or the housing inside spherical surface can be lubricated.

Plates

Flat bearing plates are used to accommodate longitudinal and transverse movement under compressive loads. LUBRON AE bearing plates can be fastened with machine screws or restrained in place with welded steel nesting bars.

Radial bearing plates have both a curved radial surface and a flat surface. Either or both surfaces can be lubricated. Radial surfaces can be either concave or convex. The radial surface, installed with a matching curved mating plate, is designed to permit deflection and rotation. The flat surface will accommodate linear expansion and contraction.

Spherical bearing plates have lubricated concave or convex spherical surfaces to allow rotation in any direction. Spherical bearings plates are available to accommodate sliding, rotation, and severe angular misalignment. Mating spherical components, sole plates, base plates and anchorage are also available.



SIZING

While many factors affect bearing design, the following is applicable for most LUBRON AE bearings. Available in both inch and metric sizes, LUBRON AE bearings are furnished finish machined to meet the exacting requirements of each application.

Inside Diameter

The nominal inside diameter of a bushing is dependent on the shaft diameter. To obtain the lowest frictional resistance and power loss, the shaft strength and rigidity should be as high as practical to permit the smallest possible shaft diameter.

When bushing sizes need to be increased to accommodate larger loads, increasing the bearing length rather than enlarging the bushing inside diameter is recommended. As the inside diameter is increased, there is a relatively larger running clearance which results in a proportionately smaller contact surface area. This reduction in contact area has the same effect as increasing the bearing load.



Lubron AE Self-Lubricating Bearings

Outside Diameter

The outside diameter of a bushing is dependent on the required wall thickness and size of the housing bore. To determine the outside diameter, add twice the recommended wall thickness of the inside diameter of the bushing. Tables 2 and 3 provide the recommended wall thickness for LUBRON AE bushings. The minimum and maximum values shown are suitable for most applications, and are based on the permissible shaft load, bushing diameter and yield strength of the bearing material. In general, lower strength bearing alloys should require the maximum wall thickness, while higher strength alloys can utilize the minimum wall thickness.

Length

Bearing length is usually determined by the amount of projected area necessary to accommodate the radial load, and can be calculated by dividing the shaft load by the desired bearing pressure times the inside diameter. In general, the length-to-diameter (L/D) ratio should be between 1.0 and 2.0 for best performance. Shorter lengths may cause the bearings to become over stressed, while longer lengths may induce edge loading. Bearings designed within the recommended L/D ratio will usually tolerate shaft misalignment and shock load without excessive wear.

Flange and Washer Thickness

The thickness for a bushing flange or thrust washer is generally the same as the corresponding wall thickness shown for a bushing in Tables 2 and 3.

Plate Thickness

Plate thickness should be consistent with the overall plate size. A minimum 1/2" (12.7 mm) thickness is recommended for most flat plates. A minimum 1" (25.4 mm) is desirable for radial and spherical plates where one or both bearing surfaces are lubricated.

Running Clearance

Proper running clearance for LUBRON AE bushings is dependent on several factors, including load, speed, size, temperature and type of application. Running or diametrical clearance is the amount the bearing inside diameter exceeds the shaft diameter after press fit closure allowance. Diametrical clearances recommended for LUBRON AE bushings are shown in Tables 2 and 3 for sizes ranging from 1" (30 mm) to 30" (765 mm).

The clearance limits must be adjusted for any closure due to press fit by adding the maximum interference to the limits of clearance. These adjusted values will normally permit adequate clearance for proper bearing performance. Consult a LUBRON engineer for severe or special conditions.



Lubron AE Self-Lubricating Bearings

LUBRON AE BUSHINGS

CLEARANCE & INTERFERENCE LIMITS BEFORE PRESS FIT

TABLE 2 (INCHES)

NOMINAL SIZE RANGE OVER TO	SHAFT DIA. (f7)	BEARING I.D.	LIMITS OF CLEARANCE	BEARING O.D. (r7)	HOUSING I.D. (H7)	LIMITS OF INTERFERENCE	RECOMMENDED WALL THICKNESS
1.00 - 2.00	-.001 -.002	+.008 +.007	.008 .010	+.003 +.002	+.001 -.000	.001 .003	.125 .375
2.00 - 3.00	-.0010 -.0025	+.0100 +.0095	.0105 .0125	+.003 +.002	+.001 -.000	.001 .003	.250 .500
3.00 - 5.00	-.001 -.0030	+.0130 +.0115	.013 .016	+.0035 +.0025	+.0015 -.0000	.0010 .0035	.375 .625
5.00 - 7.00	-.0015 -.0030	+.016 +.014	.0155 .0190	+.0040 +.0025	+.0015 -.0000	.001 .004	.500 .750
7.00 - 10.00	-.002 -.004	+.021 +.017	.019 .023	+.005 +.003	+.002 -.000	.001 .005	.625 .875
10.00 - 12.00	-.0025 -.0045	+.0215 +.0195	.022 .026	+.0055 +.0035	+.002 -.000	.0015 .0055	0.750 1.000
12.00 - 16.00	-.003 -.005	+.0245 +.0220	.0250 .0295	+.0065 +.0045	+.0025 -.0000	.0020 .0065	0.875 1.125
16.00 - 20.00	-.0040 -.0065	+.0275 +.0250	.029 .034	+.0075 +.0050	+.0025 -.0000	.0025 .0075	1.000 1.250
20.00 - 30.00	-.005 -.008	+.033 +.028	.033 .038	+.010 +.008	+.003 -.000	.005 .010	1.000 1.500

TABLE 3 (MM)

NOMINAL SIZE RANGE OVER TO	SHAFT DIA. (f7)	BEARING I.D.	LIMITS OF CLEARANCE	BEARING O.D. (r7)	HOUSING I.D. (H7)	LIMITS OF INTERFERENCE	RECOMMENDED WALL THICKNESS
30 - 50	-.025 -.051	+.209 +.185	.210 .260	+.076 +.051	+.025 -.000	.025 .076	3.2 9.5
50 - 80	-.025 -.063	+.264 +.242	.267 .327	+.076 +.051	+.025 -.000	.025 .076	6.3 12.7
80 - 120	-.038 -.076	+.326 +.294	.332 .402	+.089 +.063	+.038 -.000	.025 .089	9.5 15.9
120 - 180	-.038 -.076	+.404 +.362	.400 .480	+.102 +.063	+.038 -.000	.025 .102	12.7 19.1
180 - 250	-.051 -.102	+.472 +.431	.482 .574	+.127 +.076	+.051 -.000	.025 .127	15.9 22.2
250 - 315	-.063 -.114	+.551 +.498	.561 .665	+.140 +.089	+.051 -.000	.038 .140	19.1 25.4
315 - 400	-.076 -.127	+.629 +.566	.642 .756	+.165 +.114	+.063 -.000	.051 .165	22.2 28.6
400 - 500	-.102 -.165	+.696 +.633	.735 .861	+.190 +.127	+.063 -.000	.063 .190	25.4 31.8
500 - 765	-.127 -.203	+.763 +.701	.828 .966	+.254 +.203	+.076 -.000	.127 .254	25.4 38.1



Lubron AE Self-Lubricating Bearings

Press Fit

LUBRON AE bushings are usually press fit into their housings. The bushing outside diameter is slightly larger than the housing bore, resulting in a press or interference fit. Press fitting will cause the inside diameter of the bushing to close-in, usually in direct ratio of the magnitude to the interference fit. This closure must be compensated for in the bearing design to achieve proper running clearance after press fit.

Tolerances

Machining tolerances for most LUBRON AE bushings range from $\pm .001$ " (.025 mm) to $\pm .002$ " (.050 mm) for the inside diameters, and $\pm .0005$ " (.012 mm) to $\pm .001$ " (.025 mm) for outside diameters. Surface finishes will generally not exceed 63 microinch (1.6 micrometer) for most applications.

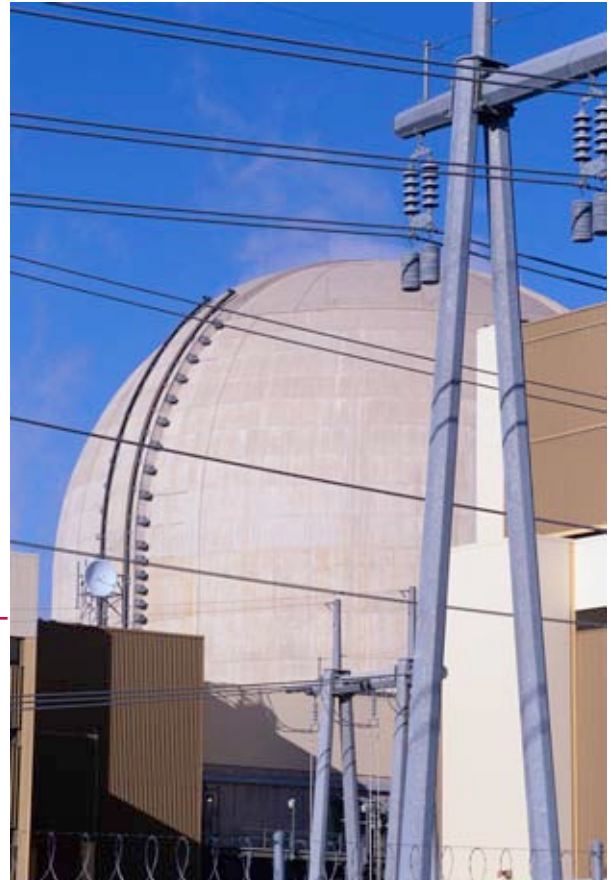
MATING SURFACES

LUBRON AE bearings will operate against most metals, but best performance is achieved with the hardest possible mating surface. A minimum hardness of Rc 20 (BHN 228) is desirable, although softer materials will generally provide satisfactory performance. Smoother finishes are normally required for harder materials, higher loads and higher surface speeds. For maximum wear resistance, mating materials should be machined and polished to a surface finish between 16 to 63 microinch (0.4 to 1.6 micrometer). Mating materials should be selected that will most effectively resist corrosion.

LUBRON AE100 supplemental dry film lubricant is available for application on the mating surface in the event that additional corrosion protection is desired. LUBRON AE100 resists corrosion and compliments the performance of the self-lubricating bearing. LUBRON AE100 is a dispersion of colloidal nuclear grade graphite in thermoplastic resin and isopropanol, and is generally applied to the mating surface with a clean brush. LUBRON AE100 is available in pint, quart and gallon containers.

INSTALLATION

LUBRON AE bearings are furnished fully machined and ready for installation. Even though LUBRON AE bearings are very durable, care must be exercised to ensure that the lubricated bearing surfaces are not damaged before or during installation. LUBRON AE bushings are usually press fit into their housings. The sizes recommended in Tables 2 and 3 provide the proper interference fits for assembly.





Lubron AE Self-Lubricating Bearings

The bushings must be inserted squarely into the housings. Accurate alignment is particularly important for self-lubricating bearings. Misalignment over the length of the bushing or over the diameter of a thrust washer should not exceed .0008 inches per inch (.02 mm per mm). Chamfers are provided on the outside diameter of the bushings to facilitate proper alignment. Shouldered arbor plugs should be used to install smaller bushings. For larger sizes, LUBRON AE bushings can be shrunk fit by refrigerating or packing the bushings in dry ice prior to installation. LUBRON AE bushings should be wiped clean and free of all debris prior to installation. The shaft ends should be burr-free and have a minimum .060" (1.5 mm) radius or 15° chamfer. LUBRON AE bushings are normally furnished with a 30° chamfer. Application of LUBRON AE100 dry film lubricant prior to assembly will permit easier installation and provide better initial performance. Most LUBRON AE bearings are lubricated with a coating of LUBRON AE100 lubricant prior to shipment.



QUALITY ASSURANCE

Every LUBRON AE bearing is guaranteed to meet or exceed the quality requirements for each job. From procurement and fabrication to final inspection, every phase of manufacturing is monitored by our quality control personnel. Every step is planned, performed, checked and certified in writing. All LUBRON AE bearings are manufactured and inspected in strict accordance with the quality requirements of ISO 9002, 10CFR50 Appendix B, ANSI N45.2, and ASME Section III NCA 3800. Non-destructive testing, including radiograph, ultrasonic, magnetic particle and liquid penetrant examination, are performed to comply with the specifications of ASTM and ASME by certified independent testing laboratories.

ENGINEERING SERVICES

We offer a variety of engineering services from the selection of bearing materials to in-house testing of bearing assemblies to simulate load, movement, velocity and temperature present during the actual operation of LUBRON AE bearings. Bearing design, AutoCAD® drawing preparation, testing, consulting and on-site engineering services are available upon request.



Lubron AE Self-Lubricating Bearings

STANDARD SPECIFICATION FOR LUBRON AE40 SELF-LUBRICATING BEARING PLATES

The following specification is recommended for nuclear power plant applications. Specifications for other applications and bearing configurations are available upon request.

Self-lubricating bearing plates shall be equal to "LUBRON AE40" as manufactured by Lubron Bearing Systems, Huntington Beach, California, USA. The bearing plates shall be composed of a supporting metal and a solid lubricant suitable for nuclear power plant applications. The bearing manufacturer shall have proven capabilities of producing the bearings in exact compliance with the Project drawings and specifications within its own facilities, and have an acceptable Quality Assurance System meeting the requirements of ISO 9002, ANSI N45.2, 10CFR50 Appendix B, and ASTM Boiler and Pressure Vessel Code, Section III, Division 1, NCA 3800.

The supporting metal shall be high strength manganese bronze, Copper Alloy UNS C86300, manufactured in strict accordance with ASTM B22-C86300. Circular recesses shall be machined perpendicular to the bearing surface to properly contain the solid lubricant, and arranged in a uniform, overlapping geometric pattern in the direction of movement. The recesses shall be at least .25 inches (6.3 mm) deep, and shall have a net cross-sectional area of at least 40% of the total bearing surface.

The solid lubricant shall consist of near-isotropic nuclear grade solid graphite capable of long-term exposure to radiation. The lubricant shall not employ binders, and shall not contain sulfur, halogens or ash impurities in total amounts greater than 100 ppm. The solid lubricant shall have non-deteriorating characteristics under neutron irradiation, and shall be capable of a minimum integrated gamma dosage of 1×10^7 rads and a minimum total neutron fluence of 1×10^{18} n/m². An additional coating of LUBRON AE100 dry film lubricant shall be applied to 100% of the bearing surface prior to packaging.

The self-lubricating bearing plates shall be furnished completely finish machined to the sizes and tolerances as specified on the drawings. The surface finish of the bearing plates shall not exceed 125 microinches (3.2 micrometers) as measured in accordance with ANSI Standard B46.1. All machined surfaces shall be flat within .0008 inch per inch (.02 mm per mm) and parallel within .0008 inch per inch (.02 mm per mm) of length and width. For curved surfaces, the concave radius shall have a positive tolerance not exceeding .010 inch (.254 mm) and the convex radius shall have a negative tolerance not exceeding .010 inch (.254 mm). The self-lubricating bearing plates shall have a design load capacity of at least 8 ksi (55 MPa). The static and dynamic coefficients of friction shall not exceed 0.15 when subjected to loads up to 8 ksi.

Lubron Bearing Systems

17211 Metzler Lane
Huntington Beach, CA 92647
USA

Phone: 714-841-3007
Fax: 714-841-3507

Email: sales@lubron.com
www.lubron.com