important advantages in fields where other bearing materials are unsatisfactory. Carbon-graphite bearings are used where contamination by oil or grease is undesirable, as in textile machinery, food handling machinery, and pharmaceutical processing equipment. They are used as bearings in and around ovens, furnaces, boilers and jet engines where temperatures are too high for conventional lubricants. They are also used with low-viscosity and corrosive liquids in such applications as metering devices or pumps for gasoline, kerosene, hot and cold water, sea water, chemical process streams, acids, alkalis, and solvents.

The composition and processing used with carbon bearings can be varied to provide characteristics required for particular applications. Carbon-graphite has from 5% to 20% porosity. These pores can be filled with a phenolic or epoxy resin for improved strength and hardness, or with oil or metals (such as silver, copper, bronze, cadmium, or babbitt) to improve compatibility properties.

3.3 Load Carrying Ability of Plastic Bearings

In **Section 2.2** of sintered metal bearings, the meaning and formulas for calculation of PV factor was dealt with.

For different plastic materials, the following values of PV and load capacities apply:

Table 3-2

Bearing Material	Load Capacity (psi)	Max. Temp. (°F)	Max. Speed (fpm)	PV Limit (Unlubricated)
Phenolics	6000	200	2500	15000
Nylon	2000	200	600	3000
PTFE	500	500	50	1000
Filled PTFE	2500	500	1000	10000
PTFE fabric	60000	500	150	25000
Polycarbonate	1000	220	1000	3000
Acetal	2000	200	600	3000
Carbon-graphite	600	750	2500	15000
Rubber	50	150	4000	——
Wood	2000	160	2000	12000

A PV limit of 15000 ordinarily can be used for dry operation of carbon bearings. This should be reduced for continuous running with a steady load over a long period of time to avoid excessive wear. When operating with liquids which permit the development of a supporting fluid film, much higher PV values can be used.

A hard, rust-resistant shaft with at least a 10 μin finish should be used. Hardened tool steel or chrome plate is recommended for heavy loads and high-speed applications. Steel having a hardness over Rockwell C50, bronzes, 18-8 stainless steels, and various carbides and ceramics also can be used.

Certain precautions should be observed in applying carbon-graphite. Since this material is brittle, it is chipped or cracked easily if struck on an edge or a corner, or if subjected to high thermal, tensile, or bending stresses. Edges should be relieved with a chamfer. Sharp corners, thin sections, keyways and blind holes should be avoided wherever possible. Because of brittleness and low coefficient of expansion (about 1/4 that of steel), carbon-graphite bearings are often shrunk into a steel sleeve. This minimizes changes in shaft clearance with temperature variations and provides mechanical support for the carbon-graphite elements.

The PV factor, used as a load-speed limit also provides a basis for estimating relative wear rates. The total volume of material worn away is approximately proportional to the total normal load multiplied by the distance traveled in a length of time.

Thus,

$$R = K(PV)\ T$$

where:

R = radial wear in a sleeve bearing (in)
K = wear factor (in^3•min/ft•lb•hr)
P = load (psi)
V = surface velocity (fpm)
T = time (hrs)

This equation does not always provide accurate absolute values for wear rate, but it is useful for estimating relative wear rates for alternative materials. In general, K wear values with fillers are lower than unfilled materials. If wear values are important for specific components, life tests should be made. These might employ moderately accelerated load and speed conditions to obtain a K value representative of the plastic, the shaft and its finish, and the application conditions.

K values should be increased by 50% for cast iron and bronze shafts, and more than 5 times with soft stainless steel or aluminum alloys. Increased surface hardness can markedly reduce wear, while surface roughness of the shaft often has an optimum value in the 4 to 14 μin rms range. Lubrication also has a pronounced influence on wear. With oil impregnation, wear rates commonly drop to negligible values with plastics, wood, and porous metals.

The wear factor K values are shown as follows:

Table 3-3

Material	Wear Factor K (in^3 min/ft lb hr)	
	Filled*	No Filler
Nylon	16×10^{-10}	200×10^{-10}
Polyester	20×10^{-10}	——
Polycarbonate	30×10^{-10}	2500×10^{-10}
Polyurethane	35×10^{-10}	——
Polypropylene	36×10^{-10}	——
Styrene Acrylonitrile	65×10^{-10}	——
Polysulfone	70×10^{-10}	——
Acetal	200×10^{-10}	65×10^{-10}

For 40 psi load at 2000 PV operating against carbon steel of hardness 20 Rc with a 6–12 μm finish.
*Filled with 30% (by weight) glass fiber, 15% (by weight) PTFE.

Comparative values for plastics often used as bearing materials are given in the following table:

Table 3-4

Property	Graphitar (Carbon-Graphite)	Oilon PV® 80 (TFE)	Rulon® (TFE)
Coefficient of friction	0.04 to 0.25	0.05 to 0.10	0.15 to 0.20
Temperature range	Cryogenic to 1000°F in some grades	–40°F to +250°F	–400°F to +550°F
Approx. max PV (unlubricated)	15000	18000	10000 (sleeve bearing)
Max. P	*	3000 psi	1000 psi
Max. V	*	1700 ft/min	400 ft/min
Recommended shaft surface finish	≤ 30 rms	*	8 to 32 rms
Recommended shaft clearance	0.003 in/in for most unlubricated applications	$(tw)10^{-4}$ + 0.004" t = temp. °F w= bearing wall thickness (in)	*
Typical elastic modulus	(0.5 to 3.5) x 10^6 psi	(3.5 – 3.8) x 10^6 psi	*
Tensile strength	1000 – 9500 psi, depending on grade	7200 psi	*

*Consult manufacturer

Data reprinted with the permission of the following manufacturers:

(i) "Graphitar" Wickes, 1621 Holland Ave., Saginaw, MI 48601;

(ii) "Oilon PV®" 80 Design Guide", TFE Industries, 148 Parkway Kalamazoo, MI 49006

(iii) "Rulon® Standard Stock Bearings, Engineering Manual, Cat. 75", Dixon Corp., Div. of Dixon Industries, Bristol, RI 02809.