- **Introduction**

Carbon, the sixth element in the atomic series, is the 19 th most abundant on the surface of the earth. It has four valence electrons, all of which can enter into s -type or covalent bonds. The valence electrons of carbon can also form less energetic p-type or resonant bonds. This arrangement of valence electrons gives carbon the ability to form compounds with many other elements, compounds which vary widely in properties. Indeed, the variety of carbon compounds is so vast that an entire field of science, organic chemistry, has arisen from their study

- **Carbon As a Self-Lubricating Solid**

The key to the value of carbon as a self-lubricating solid lies in its laminar crystal structure, its ability to form strong chemical bonds with gasses such as water vapor, and the fact that absorbed gas weakens the interlayer bonding forces. An understanding of these factors is important when selecting carbon grades for applications in mechanical devices.

- **Properties of Manufactured Carbon**

Manufactured carbon is a polycrystalline material whose structure contain many more defects and a wider range of crystallite sizes than naturally occurring graphite.

Resin-Bonded Carbon
The first material is a resin-bonded carbon typical of those used for light-duty seals and valve seats. The resin is a phenol formaldehyde, and the filler is finely ground flake graphite. Specific applications for this type of “carbon” include automobile water pump seals, seals for washing machines and other household appliances, and valve seats on gasoline metering pumps.

Metal-Bonded Carbon
The second manufactured carbon is a silver-bonded graphite typical of those used for dry running bearings. This class of materials is noteworthy because it is unusually strong and yields and deforms significantly before failing in tension or flexure. It has been used with some success in slow-moving bearings which carry heavy loads and where misalignments in the system require a deformable bearing. Copper, like silver, does not react chemically with graphite at sintering temperatures; hence, it can be used as a metal binder.

Low Modulus Carbon
The third carbon material was developed for piston and wear rings on large, nonlubricated air compressor. It is made from relatively coarse synthetic graphite lubricating particles bonded with carbonized pitch. The high

permeability of this type of carbon permits forming and baking large shapes without cracks or laminations caused by escaping gas when the binder is pyrolyzed.

Low Permeability, Machinable Carbon

The fourth carbon grade shown, a low permeability, machinable carbon-graphite, was developed for sleeve bearings in submerged pumps. It is similar to the previous carbon except that a finely ground natural graphite is used, and the pitch to graphite ratio I higher.

High Strength Carbon

The fifth carbon was developed for applications where strength, stiffness, and abrasion resistance were the prime requirements. Finely divided calcined petroleum coke is used in the filler to achieve these properties. A typical application would be vanes for dry air pumps.

High Thermal Conductivity Carbon

Seal face rubbing speeds to 30,000 ft/min (150 m/sec) are encountered in aircraft jet engines. Frictional heat generated at the interface must be conducted away, and this requires a high thermal conductivity carbon. High strength, abrasion resistance, and oxidation resistance are also needed to give long operating life under the severe conditions encountered. The sixth type of carbon was developed for these conditions. The finest available filler carbon, together with high pitch loadings, was used to obtain strength and abrasion resistance. Thermal conductivity was increased by graphitizing (heat treating) the carbon at temperatures above 2760 C (5000 F).