"GRAFOIL" GRAPHITE TAPE - ITS MANUFACTURE, PROPERTIES AND USES

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SUMMARY

This paper will describe a new form of graphite - GRAFOIL graphite tape, paper-like in structure and having unusual properties including a high degree of flexibility and compressibility. The paper will discuss briefly the manufacture of GRAFOIL tape products, their properties and their uses in research and development and in chemical and other industrial applications.

MANUFACTURE

GRAFOIL is Union Carbide's trade mark for graphite tape which is made up of interlocking and self-adhering graphite particles. The tape contains no bonding agents such as adhesives, resins or rubber compounds. The particles and the layers which give the tape a laminar structure through its thickness are held together by Van der Waal forces. GRAFOIL graphite tape is manufactured by a patented process in which graphite particles are rolled into sheets .005 or .010 inches in thickness. These 5 and 10 mil thick tapes are flexible as can be seen by the spiral in Figure 1. The normal density of the tape is 70-75 pounds per cubic foot, and by varying the rolling pressure, the density of the tape can be controlled down to 12 pounds per cubic foot.

From these basic graphite tape forms, GRAFOIL laminates (Figure I) are made by cementing layers of tape together with a resin cement which is then carbonized while the laminate is held under pressure. As the thickness of these laminates increase, the flexibility characteristic of the GRAFOIL tape decreases. However, they are still flexible compared to solid graphite and they are still compressible.

Two other forms of GRAFOIL tape illustrated in Figure I are foam and molded forms, made by compressing graphite particles in a mold under pressure. Again the bond is strictly a particle surface phenomenom, no bonding agents being used. Foam materials are light, having a density in the range of 3 to 6 pounds per cubic foot, whereas the molded materials have densities in the range of 70 to 100 pounds per cubic foot, depending on their configuration and end use.

PROPERTIES

The physical properties of GRAFOIL tape are shown in Table I. As can be seen from the data, GRAFOIL tape has a relatively high tensile strength for graphite material. Compressive strength is more than adequate for most applications. The low permeability of GRAFOIL tape is shown by its helium admittance of 2×10^{-4} sq. cm./sec., which is comparable to that of cast brass. (Conventional extruded graphites have admittances of 10^{2} to 10^{3} sq. cm./sec., while premium graphites have helium admittances in the range of 10^{-2} sq. cm./sec.)

TABLE I

PROPERTIES OF "GRAFOIL" TAPE

Property	Approximate Value
Bulk Density (lb./cu.ft.)	60-80
Ash Content (Weight %)	0.1
Melting Point	Does not melt; sublimes at 6600°F
Tensile strength (surface plane or "a" direction) (lb./sq/in.)	1500-2500
Elastic Modulus, Tensile (10^6 lb./sq.in.)	0.2
Ultimate Compressive Strength (lb./sq.in.)	15,000
Helium Admittance: 0.005 in. thick foil (sq. cm./sec.)	2×10^{-4}
laminated bodies (sq. cm./sec.)	5×10^{-5}
Coefficient of Friction (against stainless steel @ 8 lb/sq.in.)	0.05

The material is very anisotropic and this is shown by the directional nature of the electrical resistances, which are given in Table II. In this respect, GRAFOIL material is similar to pyrolytic graphite.

Table II

ELECTRICAL RESISTANCE OF "GRAFOIL" TAPE

Form	Surface Plane or "a" Direction	Across Surface Plane or "c" Direction	Ratio "c" to "a" Direction
Tape	.00046 ohm-cm	70 ohm-cm	150,000
Laminate	.0008 "	0.4 "	500

The thermal conductivity of GRAFOIL graphite tape in the surface plane or "a" direction is similar to that of most graphite materials in that it decreases with increasing temperature. Table III shows thermal conductivities at various temperatures for a GRAFOIL graphite tape laminate with a density of 70 lbs/cu.ft.

TABLE III

THERMAL CONDUCTIVITY OF "GRAFOIL" LAMINATE

Temperature	Surface Plane or "a" Direction	Across Surface Plane or "c" Direction
70°F	100 BTU/hr./sq/ft/°F/ft.	3.0 BTU/hr./sq.ft./°F/ft.
900°F	50 "	1.8 "
1800°F	25 "	1.7 "
4000°F	11 "	2.0 "
4500°F	11 "	

Table IV shows data on compressive load deflection characteristics of GRAFOIL laminates as a function of starting density. The data were taken at a load of 250 lbs./sq.in. With a density of 43 pounds/cu.ft., a load of 250 lbs./sq.in. produced a 22.8% deflection of which 13.6% was permanent set. The resiliency was 7.4% and there was no hysteresis. At densities of 73 and 90 pounds per cubic foot, deflections were 5.5% and the resiliencies were 2.6%. The permanent sets were 2.7% and 2.2%, respectively. These data show the ability of the GRAFOIL material to be cold worked to a higher density at relatively low loads. The material retains resiliency at the higher densities. With the range of densities available, material can be fabricated to a specified low deflection characteristic over a wide range. In one instance, GRAFOIL laminates were made to a specification of 67% deflection at 11 psi load.

TABLE IV

COMPRESSIVE LOAD DEFLECTION OF "GRAFOIL" LAMINATE

Starting Density - lbs/cu.ft.	Deflection-% of Original Thickness	Permanent Set-% of Original Thickness	Resilience-% of Final Thickness
44	22.8	13.6	7.4
73	5.5	2.7	2.6
90	5.5	2.2	2.6

As GRAFOIL graphite tape is all graphite without any binders, its corrosion and temperature resistance are those of graphite. It can be used at temperatures from those of cryogenic liquids, such as liquid oxygen, to those of molten metals, such as molten aluminum and steel. It can be used in any chemical environments other than those of a highly oxidizing nature, such as air above 740°F, hot concentrated nitric acid and hot wet chlorine. In neutral and reducing atmospheres, the material has been used at temperatures up to 3000°C. Table V is a brief list of corrosives to which GRAFOIL materials are resistant. The corrosion resistance at higher temperatures is illustrated by the references to molten caustic, high pressure steam and molten aluminum.

TABLE V

CORROSION RESISTANCE OF "GRAFOIL" MATERIAL

	Conc.	Temp.
Hydrochloric Acid	All	All
Sulfuric Acid	To 95%	300°F
Phosphoric Acid	All	All
Hydrofluoric Acid	All	All
Nitric Acid	To 60%	70°F
Caustic Soda	All	750°F
Aluminum	-	1350°F
Steam	-	1000°F
Chlorinated Organics	All	All
Organic Alcohols	All	All
Organic Esters	All	All
Benzene	All	All
Air	-	740°F

APPLICATIONS

Corrosion and temperature resistance combined with their resilience and compressibility make GRAFOIL materials outstanding as gaskets for flange joints and as packings for seals in rotating and reciprocating equipment. Typical gaskets and packings are shown in Figure II. GRAFOIL tape's sealing characteristics are similar to those of rubber-like materials. Neither cold flow nor creep are experienced with the material and no special flange face conditions are required. Table VI shows applications in which GRAFOIL gaskets give excellent service.

TABLE VI

"GRAFOIL" GASKET APPLICATIONS

Chemical Environment	Temperature-°F	Pressure-Lbs/Sq.In.
Molten Aluminum	1350	5000
Molten Polyester Resins	600	6000
Dowtherm	660	80
Anhydrous Hydrogen Fluoride	660	50
Molten Caustic	650	25
Anhydrous Hydrogen Chloride	1000	Atmospheric
Steam	490	600
Hydrogen Chloride;Chlorine;Organics	100	25
Chlorine plus Organics	650	10
Titanium Tetrachloride	1800	10
Chlorinated Hydrocarbons	212	200

Of even greater importance to the Chemical Process Industries is the use of GRAFOIL packings in pumps, valves, mixers, etc. To take advantage of the material's directional thermal conductivity, the packing is fabricated with the high 'a" direction thermal conductivity perpendicular to the shaft so that frictional heat developed in the stuffing box is transmitted rapidly away from the shaft, preventing overheating and possible impairment of the strength and corrosion resistance of the shaft. Conversely if the stuffing box must be heated, GRAFOIL packing will rapidly conduct the heat throughout the box. As there are no binders or additives in GRAFOIL packing, thermal breakdown, chemical attack, leaching or squeezing out of additives commonly used in other types of packings can not degrade performance. GRAFOIL packing is self-lubricating, has a low coefficient of friction and prevents shaft, stem or plunger scoring.

Figure III illustrates equipment in which GRAFOIL packing is giving extened packing life without shaft damage in a wide variety of corrosive environments. Table VII lists some of the results obtained in commercial installations of GRAFOIL packing.

TABLE VII

"GRAFOIL" PACKING APPLICATIONS

Equipment	Corrosive	Temp.-°F	Pressure-lb/sq.in.	Comments
Plunger Pump	Acid Water	200	1,500	Life up 50 times. No scoring.
Plunger Pump	Organics	70	2,500	Life up 10 times. No lubrication required.
Centrifugal Pump	Organics	100	80	Out-performed mechanical seal; leak-free operation
Centrifugal Pump	Pitch	340	50	Life up 12 times. No scoring.

TABLE VII (Continued)

"GRAFOIL" PACKING APPLICATIONS

Equipment	Corrosive	Temp.-°F	Pressure-lb/sq.in.	Comments
Centrifugal Pump	Mobiltherm-600	400	50	No leakage after 6 months.
Control Valve	Chlorinated Organics	350	100	Life up 9 times. No scoring.
Control Valve	Dowtherm	660	80	Life up 4 times.
Pressure Control Valve	Steam	490	600	Life up 3 times.

Other uses of GRAFOIL tape take advantage of its flexibility together with its electrical conductivity, its chemical inertness and its low thermal conductivity in the "c" direction at extremely high temperatures. Thin film batteries designed for high power outputs use GRAFOIL tape as internal conductors and anodes. GRAFOIL is an excellent separator in multiple hot pressing of refractory metal compounds and ceramic items since its laminar construction allows easy separation of adjacent pressed parts.

The low "c" direction thermal conductivity and dimensional stability at extremely high temperatures of GRAFOIL materials are being put to use in insulating barriers used in missiles, nuclear reactors, and high temperature vacuum furnaces. GRAFOIL tapes cut into narrow strips are used as electric resistance heating elements. Research and development laboratories throughout the country stock GRAFOIL tape for use in high temperature experimental work.

In conclusion, GRAFOIL tape is a unique form of graphite. Properties such as directional thermal and electrical conductivities, excellent corrosion resistance, low permeability and temperature stability are available in a thin, flexible, compressible, easily fabricated form for a wide range of demanding chemical, metallurgical, nuclear and aerospace uses.

FIGURE I

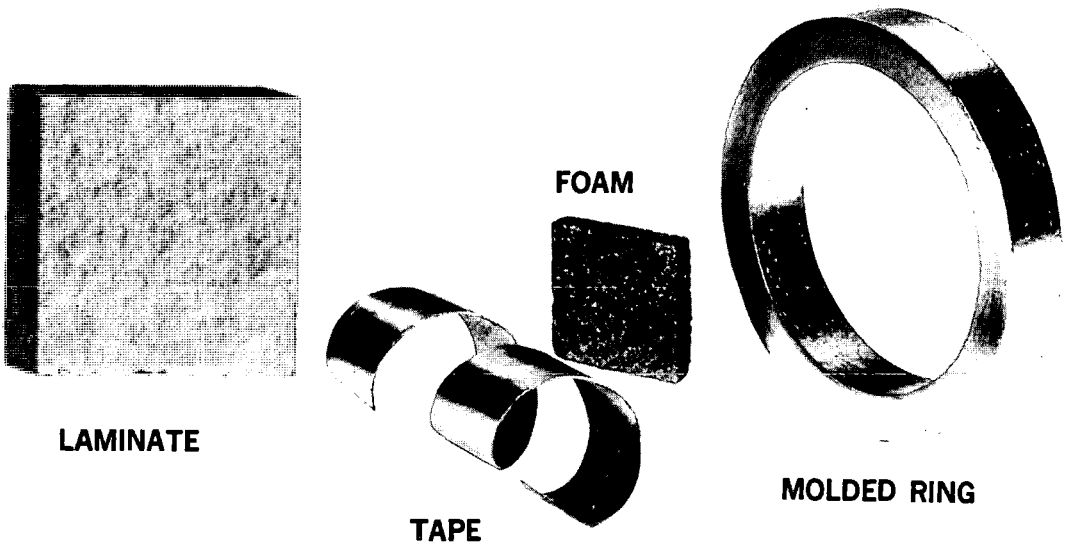


FIGURE II

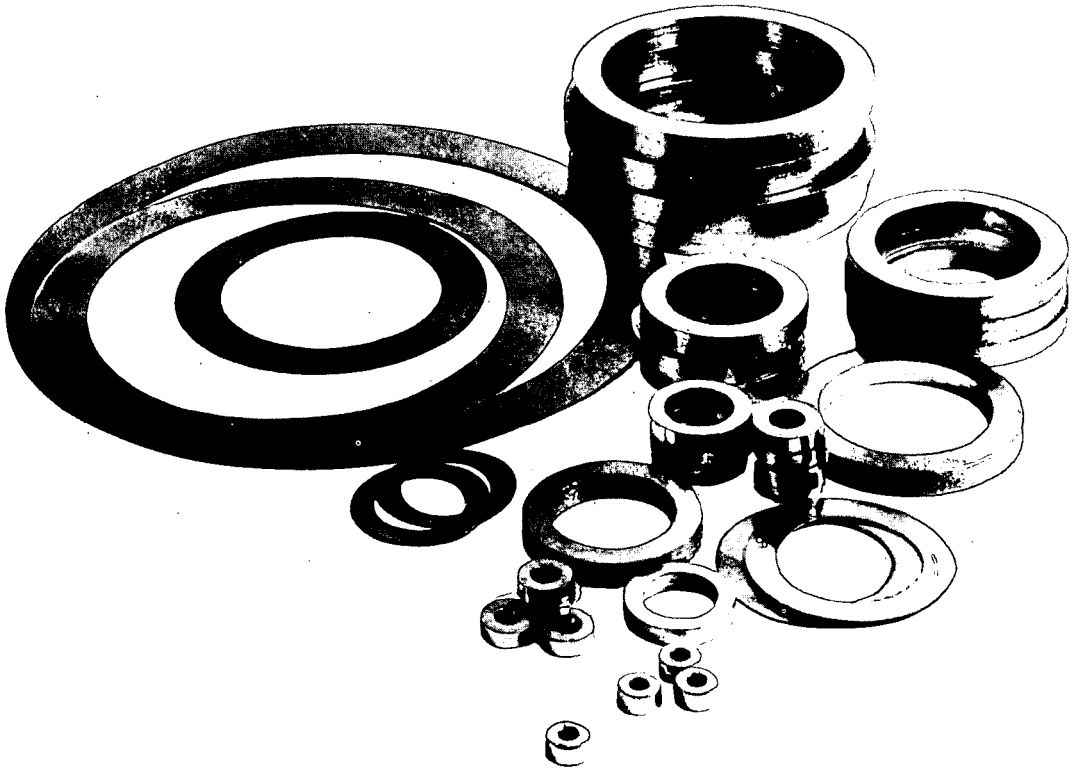
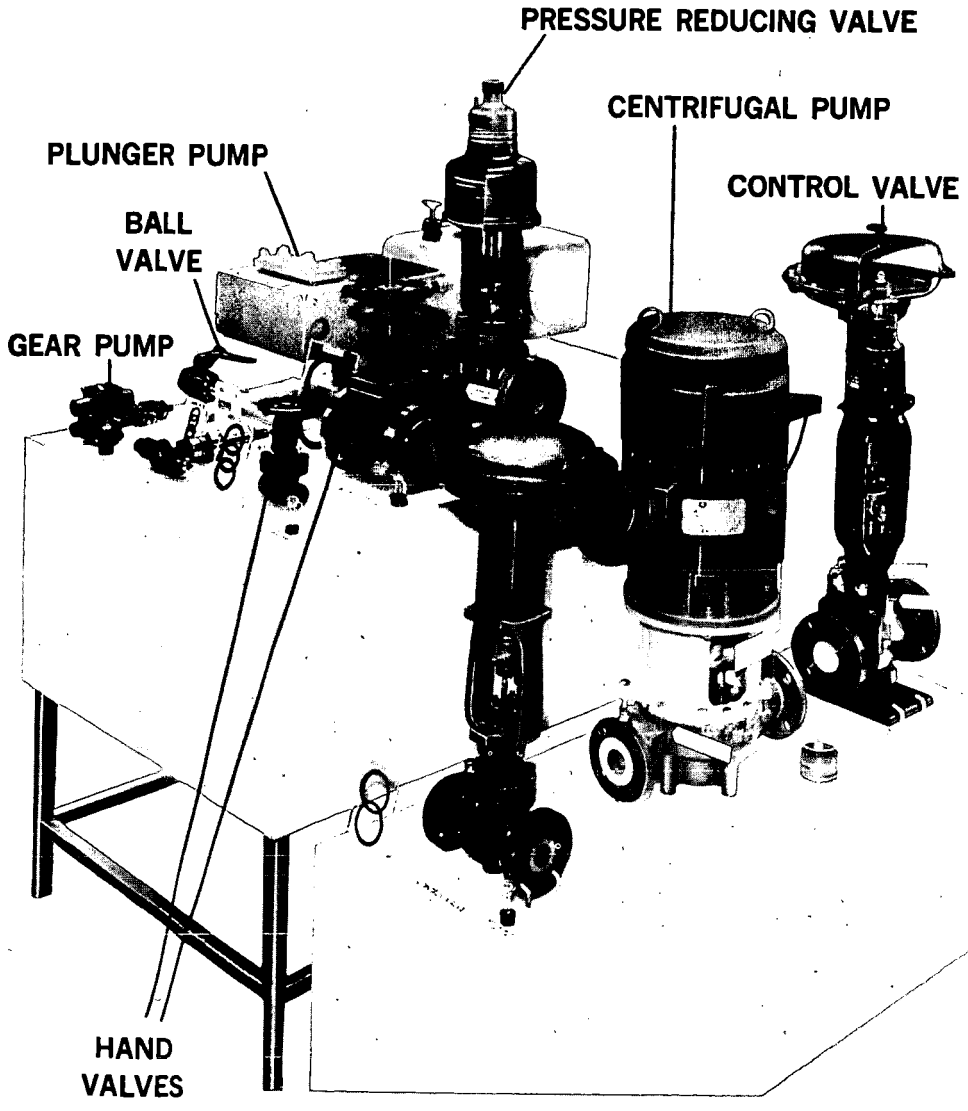


FIGURE III


PRESSURE REDUCING VALVE
CENTRIFUGAL PUMP
PLUNGER PUMP
CONTROL VALVE
BALL VALVE
GEAR PUMP
HAND VALVES