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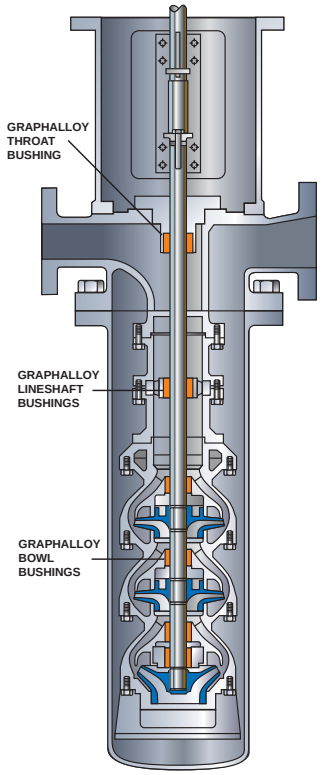
GRAPHITE ♦ METALLIZING CORPORATION ISO 9001:2000 CERTIFIED

How Does GRAPHALLOY® Improve Pump Operation?

GRAPHALLOY Permits Dry Starts

Deep setting vertical turbine well pumps require pre-lubrication of the standard bronze or rubber bearings between the low water level and the discharge surface. Environmental concerns have now restricted the use of oil and grease. The alternate of water from a local source for start-up requires a complicated auxiliary system. The solution is to use GRAPHALLOY lineshaft bushings which eliminate the need for any pre-lubrication by running dry until pump discharge flow is established. At one installation, the engineer estimated that it would take more than five minutes for the pumpage to reach the surface discharge from the water level. GRAPHALLOY survived this duration with margin to spare.

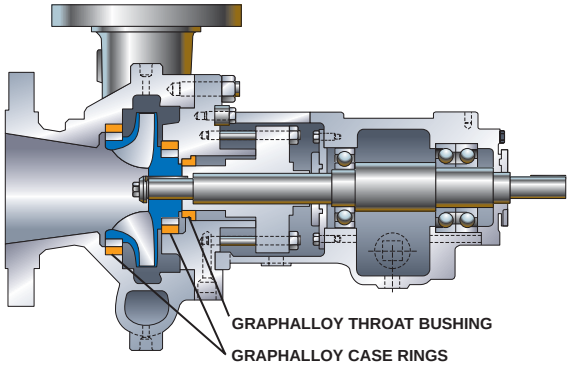


GRAPHALLOY Survives Frequent Loss of Suction

Boiler Feed pumps for industrial steam generators are frequently subjected to loss of suction flow during transient switch over. Pumps fitted with metal and plastic wear parts fail in a few minutes of dry running, while those fitted with GRAPHALLOY have survived and resume pumping when flow returns without wear parts damage. At a chemical plant, three pumps experienced 25 failures in eight years at a cost of $15,000 per failure. Following a GRAPHALLOY retrofit of all pumps, failures were reduced by 68% and the average repair cost by over 90% during the next five years.

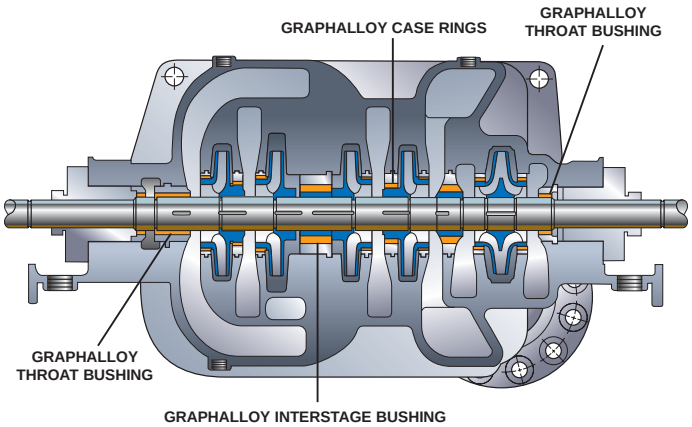
GRAPHALLOY Extends Life for Continuous Service

Self-lubricating GRAPHALLOY has long been the standard bearing in vertical “can” pumps in the refinery tank farm area. The typical light hydrocarbon products have poor lubricity and tendency to “flash”. This, combined with recurring “run dry” operation when the tanks emptied, motivated designers and operators to search for a replacement of the bronze bearing material. GRAPHALLOY is now the overwhelming choice (recognized by the API 610 Eighth Edition) for lower wear rates and “run dry” survival.



GRAPHALLOY Reduces Vibration

Pumps with mechanical seals have frequent failures due to excessive shaft vibration. Upgrades using GRAPHALLOY case rings and close clearance throat bushings provide reduced vibration levels-in one specific case from 1.2 to less than .05 IPS. The result is fewer seal and bearing failures and increased MTBF. This upgrade is recognized in the current API 682 standard. GRAPHALLOY more than meets this specification.



What Makes GRAPHALLOY® Upgraded Pumps Better?

What is GRAPHALLOY ?

Originally developed over 90 years ago for electrical brushes and contacts, GRAPHALLOY, a graphite-metal alloy, was found to possess outstanding mechanical properties. Today this self-lubricating bearing material is widely used by designers and maintenance engineers for bushings, wear rings, thrust washers, friction discs and seals. It is particularly useful where petroleum lubricants cannot be used, for example, at high temperatures and in submerged applications.

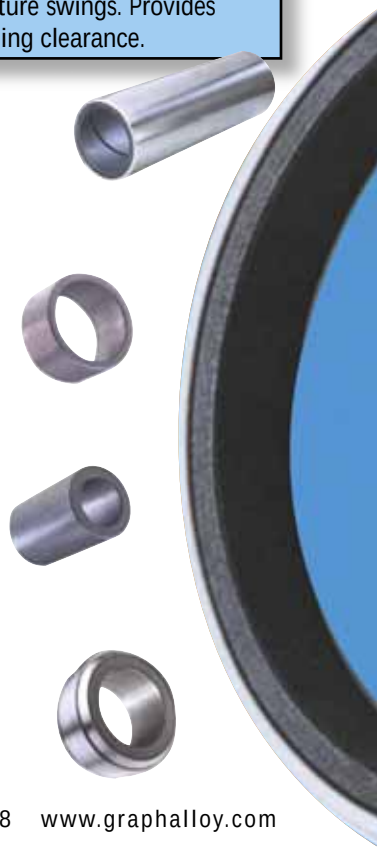
GRAPHALLOY materials are formed by forcing molten metal into the pores of solid graphite. The self-lubricating properties of GRAPHALLOY depend on the combined properties of graphite and the impregnated metal. The metal increases the graphite's strength, and rapidly removes the heat generated at the contact surface...reducing wear. GRAPHALLOY bushings deposit a thin metal-graphite film on the shaft which provides a low friction surface.

GRAPHALLOY is dimensionally stable and is normally supplied in finished form so that it can be installed without additional machining.

The GRAPHALLOY trademark refers to a family of products manufactured by Graphite Metallizing Corporation of Yonkers, New York.

FEATURES	BENEFITS
Self-Lubricating	Handles low lubricity fluids such as light hydrocarbons, liquefied gases and hot water in which metallic bearings wear excessively.
High Temperatures	Runs at temperatures well above the limit of plastic (even in molten metals above 1000°F). Survives thermal shock.
Cold Temperatures	Performs in cryogenic temperatures to -450°F where other materials become brittle or seize.
Dry Running	Survives dry starts, flashing and loss of pumpage for prolonged periods without damage. Allows immediate restarts.
Wet	No lubricant to wash away. Resists attack by most corrosive liquids including sulfuric acid, hydrochloric acid, chlorine water and caustics.
Non-Galling	Survives high speed contact that would gall metal parts. Permits closer running clearances between rotating parts resulting in lower shaft vibration.
Improved Efficiencies	Allows closer running clearances which can provide higher pump efficiencies.
Dimensionally Stable	Maintains dimensional stability when submerged under load and over wide temperature swings. Provides constant running clearance.

GRAPHALLOY GRADE – APPLICATION CHART	
BABBITT GRAPHALLOY	Potable water, water, sea water, hydrocarbons, liquid methane, propane, butane, xylene, liquors, acids, sulfuric acid (to 50%), gasoline, kerosene, JP-4 & JP-5 fuels, sodium hydroxide (caustic soda), pharmaceuticals, dry clean fluids, solvents bleaches and more.
BRONZE GRAPHALLOY	Water, hydrocarbons, dyes, lacquers.
IRON GRAPHALLOY	Propane, butane, geothermal, hydrocarbons, paper & pulp mill liquors, molten sulfur.
Nickel GRAPHALLOY	Hydrocarbons, demineralized water (750°F atomic applications), tanning baths, alkalies, acids (sulphuric, nitric & HF), paper & paper mill liquors.
SILVER GRAPHALLOY	Hydrochloric acid, JP-4 & JP-5 fuels, alkalies, hydrocarbons, foods, pharmaceuticals.
COPPER GRAPHALLOY	Acetic acid, liquid oxygen, liquid nitrogen, industrial solvents, hydrocarbons, dow therm.
GRAPHLON	Demineralized water, most acids, alkalies & solvents, atomic applications, fuels, hydrazine, paper & pulp mill liquors, hydraulic fluids.
GRAPHALLAST	Water, sea water, silt laden water, sewage, dyes, bleaches, paper & pulp mill liquors, tanning baths, food stuffs, diluted acids, alkalies or solvents.



Frequently-Asked Questions

Hardness

Q. *Hard carbon materials are available; will they perform better?*

A. Carbon materials can be made over a wide range of hardnesses – from soft brush materials to nearly ceramic hard mechanical seal face materials. Hard carbons can be made much harder than usual shaft materials. These hard carbons can score shafts and have been known to cut-off shafts. Bushings for pumps are intended to be expendable wear parts, absorbing the shocks, rubbing and abrasion of normal use without damaging the shafting. GRAPHALLOY is chosen for pumps to provide non-galling, self-lubricating bearings. GRAPHALLOY with a moderate hardness is used in most pump applications to insure that expensive shaft materials will be protected.

Surface Finish

Q. *Mirror finishes are available on GRAPHALLOY seals; will these finishes improve bearing life?*

A. The short answer is no. Bearings and seals perform very different functions. Seals require "light band" quality surfaces to do their jobs against equally perfect mating parts. Normally, GRAPHALLOY bushings are not performing a sealing function. A rougher surface is both permissible and desirable as an aid in maintaining a layer of lubricating pumpage. The self-lapping qualities of GRAPHALLOY will quickly coat the shaft surface and smooth out any surface irregularities in the bushing. A high polish finish on a pump bearing is only a cosmetic touch and is generally quickly destroyed in actual use. The ideal shaft surface finish is 8 to 16 microinches.

Resiliency

Q. *GRAPHALLOY bearings can be pressed in with much greater press fits than hard carbon materials; how does this help?*

A. Generally, the harder the carbon material, the lower its elastic modulus. GRAPHALLOY has a higher modulus of elasticity and tolerates greater press fits. This same property means that GRAPHALLOY withstands the shock of shop handling, pump installation and most importantly, pump operation. The hard carbon bushing, that chips easily when dropped, is at a disadvantage when encountering similar shocks in use.

Run-Dry

Q. *Is GRAPHALLOY a true "Run-Dry" material?*

A. GRAPHALLOY is an alloy of carbon graphite and metal. The graphite provides continuous lubrication, without the need for grease, oil or other forms of lubrication. GRAPHALLOY deposits a thin film of graphite on the shaft to reduce friction. The metal impregnation helps to transfer heat from the rubbing surface to the housing. GRAPHALLOY has much higher temperature limits than many thermoplastics available today. Run-Dry transients will not melt the GRAPHALLOY as it may do to other materials. Normally the pumps can be put back in service immediately after dry running transients while thermoplastics may require replacement.

Grade Type Selection

Q. *How do I choose the correct grade of GRAPHALLOY ?*

A. There are many grades to choose from. The GRAPHALLOY grade selection for pumps is primarily a function of operating conditions of the application. The key questions are temperature, pumpage and whether run dry or flashing is expected. Our engineers are available to assist with your application. (See the grade chart in this guide for more details)

Plastics/Thermoplastics

Q. *How do thermoplastics compare to GRAPHALLOY?*

A. There are several advantages in selecting GRAPHALLOY compared to thermoplastics:

- Plastics have lower temperature limits: GRAPHALLOY performs in temperatures of more than 1000°F. It does not melt.
- Plastics can seize or deform during dry run: GRAPHALLOY survives dry starts, transient upsets and flashing while continuing to run. It does not melt and adhere to pump surfaces.
- Many plastics swell when submerged: GRAPHALLOY is dimensionally stable.
- Plastics expand rapidly and non-linearly when friction generates heat: Stable GRAPHALLOY expands more slowly and conducts heat away more effectively. Plastic bushing expansion can lead to seizure while GRAPHALLOY keeps on running.

Thermal Expansion

Q. *What does GRAPHALLOY do when the housing and the shaft expand due to temperature?*

A. Correctly installed, the thermal expansion of GRAPHALLOY will follow the housing it is pressed into. The expansion of the housing and the shaft must be considered when calculating the press fit and running clearance during pump operations. GRAPHALLOY's unique properties enable the designer to maintain a nearly constant clearance over a wide temperature range.

Thermal Conductivity

Q. *Does GRAPHALLOY run cooler than thermoplastics?*

A. GRAPHALLOY material conducts heat better than thermoplastic bearing materials. This provides for cooler operating temperatures during dry run starts, flashing and transient upsets.

When Should GRAPHALLOY® be Used?

GRAPHALLOY is used in applications where there is a possibility of metal-to-metal contact. The unique non-galling and self-lubricating properties of GRAPHALLOY enable a pump to handle fluids and survive upsets that would seize a metal fitted pump.

GRAPHALLOY can also be used to convert a metal fitted pump to reduce vibration and produce a higher efficiency. These performance improvements have been recorded in retrofitted pumps in the field and corroborated under controlled test conditions.

GRAPHALLOY Material Reccomendation

GRAPHALLOY is not one material but rather a family of materials formulated for specific applications. Babbitt, Nickel–Chrome and Bronze are the grades most frequently used in pumps. The physical and chemical properties of GRAPHALLOY can be varied within broad limits by adjusting formulation, material and processing procedures. Through continuing research, Graphite Metallizing Corporation develops additional grades of GRAPHALLOY to meet the needs of today's industries.

GRAPHALLOY is Used for These Tough Situations:

- Frequent upsets & loss of suction
- Dry run conditions
- For higher pump efficiency
- Condensate pumps
- Corrosive liquids
- High temperature pumpage
- Low specific gravity fluids
- To improve reliability and availability
- HF acid and other acidic fluids
- Deep well, potable water pumps

Typical Physical Characteristics of Some of the More Commonly Used GRAPHALLOY Grades

GRAPHALLOY MATERIAL	Max Ambient Temp in Air	In Non-Oxidizing Atmospheres or Submerged	Typical Coefficient of Thermal Expansion X10^{-6}in/in/°F	Maximum Static Load (pounds)
BABBITT	300°F/125°C	300°F/125°C	3.0	5000
COPPER	750°F/400°C	1700°F/725°C	3.1	5000
BRONZE	750°F/400°C	1600°F/685°C	3.1	5000
NICKEL	750°F/400°C	1700°F/725°C	3.7	5000
SILVER	750°F/400°C	1500°F/640°C	3.7	5000
GRAPHALLAST	150°F/65°C	150°F/65°C	N/A	2000
ANTIMONY	550°F/235°C	550°F/235°C	3.2	5000

Notes:

1. Coefficient of Friction: When a GRAPHALLOY bushing runs dry in contact with a well polished shaft, the friction coefficient varies from .1 to .4 depending on the grade. The coefficient is quite constant for varying speeds. When submerged in water, gasoline, hydrocarbons and most liquids the coefficient of friction drops to about 1/10 that of the dry coefficients given above.
2. Hardness: The Scleroscope Hardness is within the range of 30 to 100, depending on the grade.
3. Tensile strength: 4000 to 6000 PSI, depending on the grade.
4. Compressive Strength: 15,000 to 25,000 PSI, depending on the grade.
5. Density: The density of GRAPHALLOY varies from 1.7 to 3.5 depending on the grade.
6. Pumpage must be considered when selecting grade.

Bearing Design for Pumps

Design Notes and General Information

The successful use of GRAPHALLOY for pump bushings and wear rings involves the application of basic engineering principles coupled with an understanding of the unique properties of the material itself. This guide provides a design overview. Our engineers are available to discuss your application in more detail.

Load Handling

In pump applications, load is not normally a design consideration for bushings. The PV factors, used for continuously loaded applications, do not provide meaningful acceptance criteria due to the minimal loading and the self-centering of the rotating element.

When bushings are subjected to transient dry running, the design must consider the PV values as a guide. For continuously loaded dry running applications, good results have been obtained with the following formula:

$$\frac{R \times W}{L} < 46{,}000$$

where
L = Minimum Bushing Length, Inches
W= Total Shaft Load, Pounds
R = Shaft Speed, RPM

This formula is based on a conventional dry PV value of approximately 12,000, where P is the PSI on the projected bearing area and V is the shaft surface speed in FPM. If the bushing is continuously loaded and operating wet, the values can be increased by a factor of 7 or more.

In many combinations of speed and load for pumps, the values given by the above formula can be exceeded. In such cases, contact our engineers for specific recommendations.

Pressure Differentials

GRAPHALLOY bushings have successfully served as throttle bushings and center stage bushings where pressure differentials of 1000 PSI and more are routinely experienced. High pressure differentials may require special GRAPHALLOY grades. Wire drawing (erosion) has not been found to be a serious problem in the applications encountered.

Pressure differentials across GRAPHALLOY must be minimized, however, where abrasive materials are being pumped.

Recommended Wall Thicknesses

Wall thickness requirements depend, in part, on how the bushing will be installed. The table below provides guidance for pressed in bushings. Requirements for thinner walls can be accommodated by machining the bushing, after installation, in a metal housing.

Where the bushing will be supporting loads of greater than 500 PSI, the wall thickness should be 3/8" minimum and normally 1⁄2" to 5/8". Bushings subject to these relatively high loads are normally found with slower moving shafts in equipment other than centrifugal pumps.

BUSHINGS

DIA	Wall Thickness
To 1/4"	1/8"
3/4"	3/16"
1 1/2"	1/4"
2"	3/8"
6"	1/2"

CASE RINGS

DIA	Wall Thickness
To 4 1/2"	1/4"
5"	5/16"
6"	3/8"
9"	7/16"
11"	1/2"

Recommended Press Fits

A press fit is the primary means used to hold a GRAPHALLOY bushing into its housing. The press fit must be sufficient to hold the bushing securely at the operating temperature.

A shoulder is recommended on the low pressure side of the housing so that the bushing cannot be pressed out by differential pressure.

The different thermal coefficients of expansion of the bushing, housing and shaft must be considered when determining the bushing press fit. Typical press fits range from .004" for small bushings at ambient temperatures to .025" for large bushings at elevated temperatures in stainless steel housings. Factory applications engineers will give you specific recommendations.

PRESS FIT FACTOR (Multiply Housing ID by the Following Factor to Arrive at the Minimum Bushing OD)

Material (Housing)	Design Temperature [a]			
	Up to 300°F/140°C [b]	300°F/140°C to 500°F/260°C	500°F/260°C to 700°F/370°C	700°F/370°C & Higher
400SS	1.002	1.002	1.003	Discuss with Yonkers Engineering
Carbon Steel or Cast Iron	1.002	1.003	1.004	
300SS	1.003	1.004	1.005	

Notes:

a) Must include safety factors for dry running, start/stop rubbing or any other conditions that could increase bushing temperature.

b) Can be reduced to 1.001 for cryogenic applications, provided the pump will not be operated or tested at higher temperatures.

c) Minimum running clearance should be based on the pump manufacturer or designers recommendations for GRAPHALLOY bushings. Since GRAPHALLOY bushings will not gall and are self lapping, running clearances can be 1/2 to 1/3 of normal metal on metal clearances. Alternatively a minimum of .004 can be used up to 2" shaft or sleeve, plus .0005 in/in for larger sizes, provided potential assembly alignment difficulties are considered.

d) Running clearances under operating conditions can be estimated by comparing the shaft OD and Housing ID expansion or contraction only, since a GRAPHALLOY bushing has a lower expansion co-efficient and its OD will follow the ID of the housing.

Bushing I.D. Close-in

After the GRAPHALLOY bushing is pressed into the housing, the ID will close-in an amount approximately equal to the press fit. Ninety percent of this close-in will take place almost immediately, while it may take up to 24 hours to reach final size.

If the housing wall is thin or weak, it may deform, reducing the amount of close-in. Also tolerance build up (housing ID, bushing OD, bushing ID and shaft OD) may make precise control of clearance impossible to achieve, except by machining after installation. For precise control of clearance, press the bushing in and machine after 24 hours.

Running Clearance

GRAPHALLOY material does not gall, thereby allowing closer running clearances than are normally established by pump manufacturers for metal bushings or rings. Since GRAPHALLOY is self-lubricating, the rotating parts of the pump may contact the GRAPHALLOY ring or bushing during start up without significant effect. During operation, GRAPHALLOY will self-lap to conform to the rotating part, increasing the bearing area and slowing long term wear.

The following diametrical running clearances are typical at the operating temperature:

VERTICAL PUMPS

DIA	Clearance
To 3/4"	.003"
1"	.004"
1 1/2"	.005"
2"	.005"
3"	.006"
4"	.007"

HORIZONTAL PUMPS

DIA	Clearance
To 3"	.004"
4"	.004"
5"	.005"
6"	.006"
9"	.009"
15"	.015"

Notes:

Unusual conditions, such as viscous liquids, etc., may require additional clearance. For improved efficiency, even tighter clearances may be used. Contact our application engineers for specific recommendations.

Bearing Design for Pumps (continued)

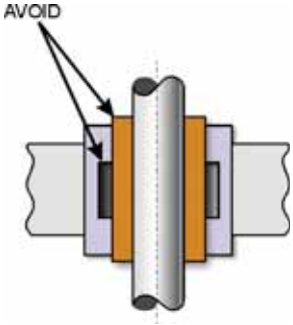
Spiral I.D. Groove

A spiral groove is recommended for pump bushings that have equal pressure at both ends, such as column bushings. The spiral groove will produce a pumping or washing action through the bushing. Grooves are also specified when the pumpage contains an occasional gritty particle, or when the bushing is used in a low lubricity fluid. The standard spiral groove is .12" wide x .06" deep x 4" right hand pitch.

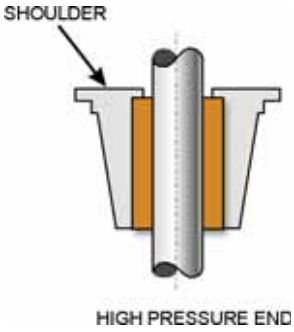
Housing Design

1. In almost all installations, the GRAPHALLOY part will be the stationary (non-rotating) member of the assembly.

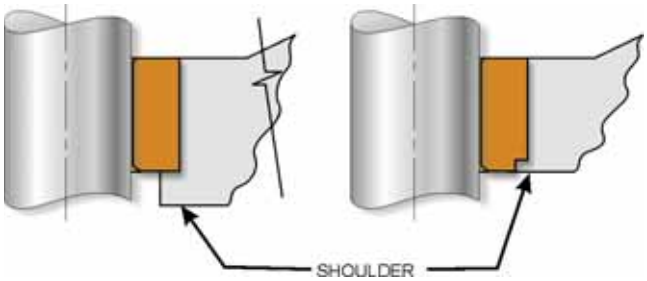
2. The bushing outside diameter must be supported throughout its full length. Designs where the housing bore is relieved in the center, or where the bushing extends beyond the housing should be avoided. These configurations place a shearing stress across the bushing which can crack the bushing. (In some sealing applications, floating, unsupported GRAPHALLOY rings are used.)



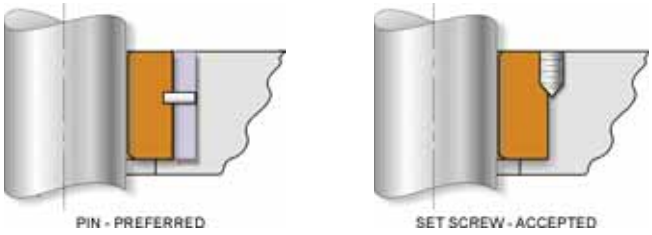
3. When using a bushing to breakdown pressure, provide a shoulder on the low pressure side of the housing, so that the bushing will not be pushed out. When the bushing has equal pressure on both sides, a shoulder is not required as long as the minimum press fit is maintained at operating temperature.



4. In most horizontal pumps, GRAPHALLOY case wearing rings are sufficiently locked in the housing by the combination of the interference press fit and the hydraulic force against the shoulder.



Anti-rotation devices are recommended where severe vibration may occur (perhaps due to cavitation or loss of pumpage) and in high energy applications (surface speeds greater than 3,000 ft/min.). The two acceptable methods are shown. Pinning is preferred. When using set screws, form the holes with an end mill (not a drill) to avoid drifting over into the GRAPHALLOY material. Ensure that more than half the set screw is in the metal.



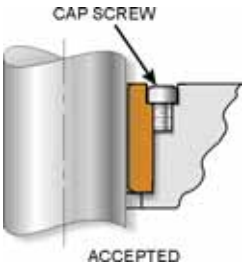
5. For axially split pumps, all case wearing rings are installed in separate metal housings. The housing protects the GRAPHALLOY ring during pump assembly. Existing metal wear rings and bushings may be over-bored and used as housings for the GRAPHALLOY rings. The metal housings should be notched or keyed to the case to prevent rotation of the assembly.

6. For most radially split pump designs, case wearing rings are made in one piece and are installed directly into the pump case. Extremely large diameter rings are furnished in metal housings.

7. Split rings should be retained by a stop on both sides. An anti-rotational pin should be used on each half of the ring allowing a reduction of interference fit to facilitate assembly. Contact our Applications Engineering department with the specifics of your design.

8. Stationary case wear rings on ring-section or other stacked channel ring/diffuser designs are normally solid GRAPHALLOY and are pressed into the channel ring/diffuser assembly.

9. Applications where a reversal of pressure is anticipated, snap rings or cap screws should be used to assist retention.



Material for Shafts and Rotating Rings

GRAPHALLOY bushings can be used with standard smooth cold-rolled pump quality shafting. However, for maximum life, a hardened shaft ground to a finish between 8 and 16 RMS is recommended. A hardness of Rc 45 or greater is suggested, when possible. The 300 series stainless is not rated on the Rc scale. For longest life the journal area should also be hardened.

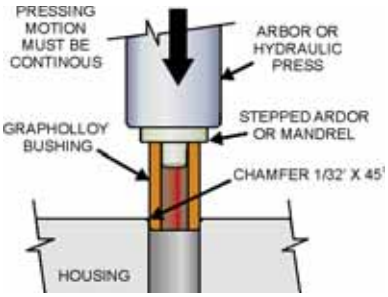
For potentially dry-running applications in horizontal pumps, hard materials are required for wear rings and sleeves running against GRAPHALLOY throttle and center bushings. The material of the wear rings and sleeves must not fracture when subjected to thermal shock. GRAPHALLOY materials have survived substantial thermal shocks in field applications and laboratory tests.

Initial Bushing Break in Wear

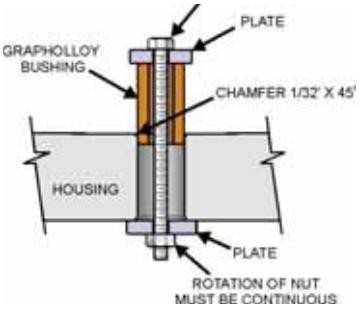
When the shaft rotates in the GRAPHALLOY bushing, a thin GRAPHALLOY film is transferred from the bushing to the shaft surface. This thin film provides a friction and corrosion inhibiting surface that results in low wear for extended periods of operation.

Installation

Install GRAPHALLOY bushings and wear rings in accordance with the following installation instructions. Special care should be taken to insure that no square or rough corners remain in the housing bore. A sharp edge will shave the bushing OD during installation. All edges must be rounded or chamfered.



Normal Method of Pressing GRAPHALLOY Bushing into Housing using an Arbor or Hydraulic Press



Bolt-and Nut Method of Pressing GRAPHALLOY Bushing into Housing

Each GRAPHALLOY bushing is normally pressed into its housing by means of an arbor press or hydraulic press. (Figure 1) The housing ID should have a chamfer of 1/32" X 45° to facilitate entry of the bushing. A stepped mandrel or arbor should be used to insure the bushing will be positioned straight with the hole before installation. The small OD of the arbor should be 1/16" smaller than the ID of the bushing, and the large OD of the arbor should be larger than the OD of the bushing. The pressing motion must be continuous with no interruption until the bushing is completely in place.

Where more practicable, the bushing may be pressed into the housing by the bolt and nut method: that is, with a plate against the upper end of the bushing. (Figure 2) The nut must be continuously drawn up!

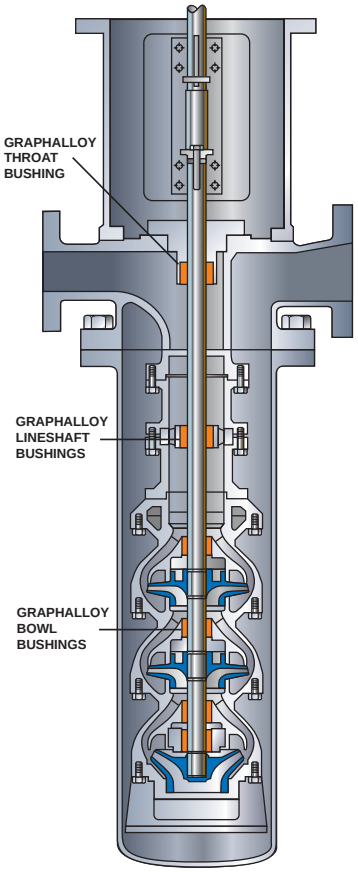
CONDENSATE PUMP

These pumps are installed in a Texas steam generating power plant.

Material: **BABBITT GRAPHALLOY**

Operating History -
These condensate pumps were originally furnished with plain carbon bearings. When these did not wear well, they were replaced with bronze bushings. A recent change in water chemistry made the bronze unacceptable. Maintenance was reluctant to use carbon again, and ran material comparison tests of metal-impregnated GRAPHALLOY vs. the original plain carbon.

GRAPHALLOY material proved best and all eight pumps were converted. Subsequently three more smaller twelve-stage condensate return pumps were also retrofitted. After two years of service, the bearings showed no measurable wear. A subsequent inspection confirmed no wear and the utility has been able to extend its maintenance cycle to five years.



LIGHT HYDROCARBON TRANSFER SERVICE

These pumps are on light hydrocarbon transfer service at a Gulf coast refinery.

Material: **BABBITT GRAPHALLOY**

Operating History -
The pumps were originally furnished with bronze bushings. Because of the poor lubricity of the pumpage and the occasional flashing at the first stage, there was excessive wear. The bronze bushings were replaced with Babbitt GRAPHALLOY ten years ago and an excellent service life has been reported since that date.

Vertical Condensate Type	
Pumpage	Condensate Water pH 9.4
Temperature	100°F to 120°F
Number of Stages	Five
Capacity	4900 GPM
Discharge Head	1040 Ft.
Speed	1750 RPM
GRAPHALLOY Bushing Dimensions	
Lower	3 1/16” x 2 17/32” x 6 1/8”
Bowl	4 7/16” x 4” x 5 3/4”
Line Shaft	4 7/16” x 4” x 5 3/4”
Stuffing Box Flange	4 1/2” x 4” x 10”

Vertical Multi-Stage Can Type	
Pumpage	Butadiene Sp.Gr. 0.61
Temperature	100°F
Number of Stages	Three
Capacity	335 USGPM
Discharge Head	455 Ft.
Speed	3560 RPM
GRAPHALLOY Bushing Dimensions	
Bowl	1 3/4” x 1” x 1”
Column	1 3/8” x 1” x 1”

DEEP SETTING MULTI-STAGE TURBINE BOWL

Material: **BABBITT GRAPHALLOY**

Operating History -
These pumps were installed in a Saudi Arabian fossil lake for which there is no aquifer. After three years of operation the water table had dropped 500 ft. The pumps were pulled to add an additional 200 ft. of column. The badly corroded stainless steel bowls had to be replaced. After three years of service, the GRAPHALLOY bushings were only slightly polished and were not replaced.

Multi-stage Vertical Turbine Bowl	
Pumpage	Very corrosive underground water
Temperature	167°F
Horsepower	450
Capacity	900 GPM
Speed	1750 RPM
Pump Setting	800 ft.

DEEP SETTING 1000´ POTABLE WATER PUMP

Material: **FDA ACCEPTED BABBITT GRAPHALLOY**

Operating History -
Two pumps are being used by this water utility, one for peak usage another for non-peak. Each pump was started and stopped daily. The pumps had been operating with bearings that were lubricated with lightweight turbine oil that was dripped into the top of the enclosing tube. This was an effective method of lubrication, but was becoming a concern due to water quality and environmental issues. A solution was to convert to a food-grade oil. These are expensive and have such poor lubricating properties that seize-ups are frequent in the applications where it is employed. Water lubrication was the solution. Dry run conditions in deep wells caused failures in pumps using rubber line shaft bearings. GRAPHALLOY FDA accepted grade material was selected to retrofit the pump. During start up some of the bushings experience up to 5 minutes of dry run condition. The pumps have run, without failure for more than 6 years.

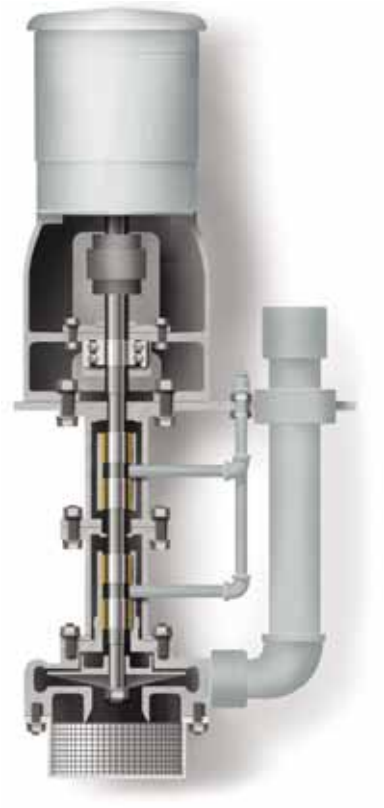
Layne & Bowler 11DWH-19	
Pumpage	Potable Water
Temperature	Ambient
Horsepower	300
Setting	1028 feet
Speed	1770 RPM
Number of Stages	19
Capacity	800 GPM

SEA WATER SUMP PUMPS

These sump pumps are operating at a New England utility steam generating station.

Material: **BABBITT GRAPHALLOY**

Operating History -
The pumps were originally furnished with glass filled PTFE bushings. Normally they were lubricated by clean city water but when this flow was reduced or temporarily shut off, the bushing wore excessively. The GRAPHALLOY bushing replacements have been in service for more than 4 years and have extended the pump operating life significantly.



Vertical Single Stage Sump Type	
Pumpage	Sea Water containing Chemical Waste Products
Temperature	95°F Maximum
Capacity	600 GPM
Discharge Head	75 Ft.
Speed	1750 RPM
GRAPHALLOY Bushing Dimensions	
Column	2" x 1 1/2" x 5"

PHOSPHATE SLIME SLURRY PUMPS

These pumps are installed in a clay-settling pond at a Florida potash processing facility.

Material: **BABBITT GRAPHALLOY**

Operating History -
These pumps were originally furnished with metal backed rubber bearings. The rubber bearings were averaging only 30-90 days life because of inconsistent external lubricating water flow. Bearings were changed to self-lubricating GRAPHALLOY bushings. Bearing life increased by several times since the upgrade to GRAPHALLOY.

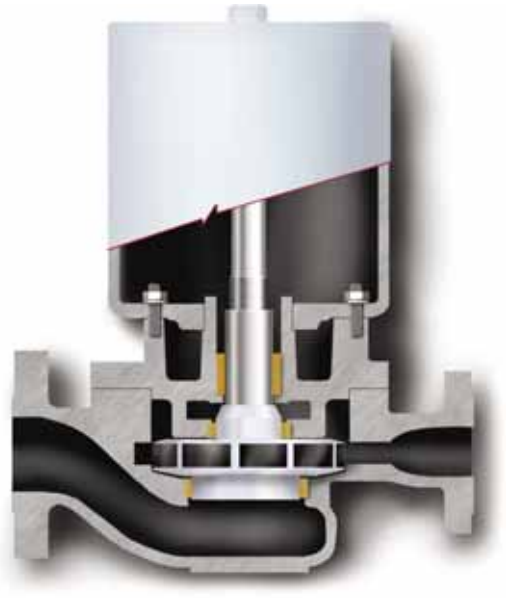
Single Stage Vertical, Double Suction Slurry Pump	
Pumpage	Phosphate Slimes - pH 2
Temperature	100°F
Horsepower	400
Number of Stages	One
Capacity	15,000 GPM
Discharge Head	84 Ft.
Pump Speed	840 RPM
GRAPHALLOY Bushing Dimensions	
	5 1/4" x 4 1/4" x 6 1/2"

OFF SHORE PLATFORM PUMP

This In-Line double volute pump is in service on a California off shore platform.

Material: **NICKEL GRAPHALLOY**

Operating History -
The pump was originally designed with chrome wear parts and large running clearances. Poor shaft run out caused coupling alignment problems and short seal life. Pump was converted to GRAPHALLOY in 1992 and diametrical running clearance was reduced from .024" to .010". Since then the unit has performed except for some wear on the softer AISI 316 impeller wear rings.



Vertical Single Stage Type	
Pumpage	Heat transfer fluid
Temperature	340°F Normal to 500°F Maximum
Specific Gravity	.75 to .86
Capacity	1650 GPM
Discharge Head	382 Ft.
Suction Pressure	136 Ft. to 253 Ft.
Speed	3560 RPM
Pressure Differential	140 PSI
GRAPHALLOY Bushing Dimensions	
Case Wear Ring (Eye Side)	7 5/8" x 6 3/4" x 7/8"
Case Wear Ring (Hub Side)	7 1/8" x 6 3/8" x 1/2"
Throat	2 3/8" x 1 5/8" x 1 3/4"

MULTI-STAGE VERTICAL QUAD VOLUTE

Material: **NICKEL GRAPHALLOY**

Operating History -
Pump was originally furnished with GRAPHALLOY bowl bushings. However, a metal throttle bushing was furnished due to high differential pressure. The metal bushing galled and after several failures, it was changed over to GRAPHALLOY. The pump has operated successfully more than 10 years.

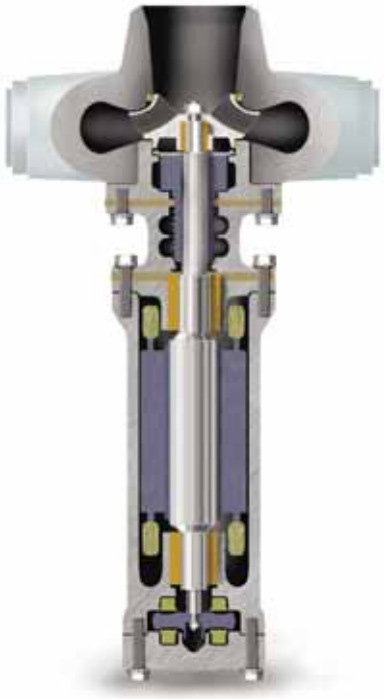
Multi-stage Vertical Quad-Volute 15" Dia. Bowl	
Pumpage	HC Solvent (Reactor Wash)
Temperature	Ambient to 550°F
Horsepower	250
Number of Stages	Eight
Capacity	254 GPM
Discharge Head	2509 Ft.
Speed	3560 RPM
Pressure Differential	
Across Throttle Bushing	900 PSI Maximum
Across Bowl Bushing	112.5 PSI Maximum
GRAPHALLOY Bushing Dimensions	
Throttle	2 3/4" x 2" x 3"
Bowl	2 3/4" x 2" x 1 1/4"

VERTICAL WET MOTOR BOILER CIRCULATING PUMP

Utility High Pressure, High Temperature Boiler Circulation

Material: **NICKEL GRAPHALLOY**

Operating History -
Two GRAPHALLOY bushings, one above and one below the motor, support the assembly. The pump impeller is at the top of the assembly. This circulating assembly has a totally sealed pump motor in water at the same pressure as the boiler water, thus eliminating the necessity for sealing high pressures between the pump and the motor. The radial load is taken by two GRAPHALLOY bushings in each motor-pump assembly.



This pumping unit consists of three main sections: the pump at 650°F 3100 PSI; thermal barrier; and submerged motor. The thermal barrier minimizes heat flow to the motor by cooling water. The motor is held at 140°F at 3100 PSI with an external heat exchanger.

Single Stage Vertical Pump	
Pumpage	Boiler water
Temperature	650°F (boiler water)
Horsepower	1750
Capacity	2800 GPM
Speed	1800 RPM
Shaft	7" dia.
Motor & Pump Assembly	Height 15 Ft.
GRAPHALLOY Bushing Dimensions	
	8 1/4" x 7" x 9 1/4"

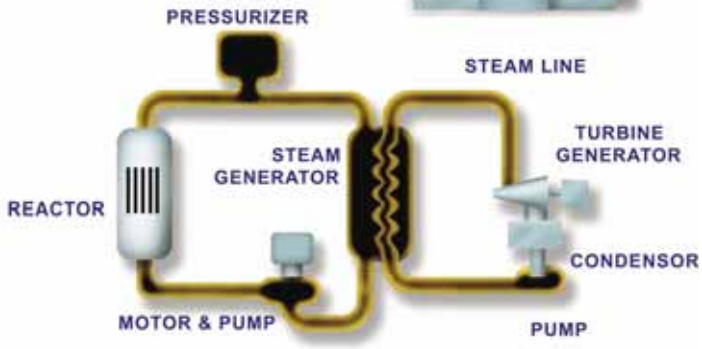
VERTICAL NUCLEAR REACTOR CIRCULATING PUMP

These pumps are operating on a Nuclear Reactor Primary Circuit pressurized water system.

Material: **GRAPHALLOY GMK703**

Operating History -
These pumps are in a radioactive, totally inaccessible location for two to three years at a time. Shutdown is required only for scheduled maintenance. A flywheel is added to the large squirrel cage induction motor to keep the pump turning in the event of power failure. The flywheel forces the pump to continue pumping coolant through the reactor. The motor insulation has been designed to withstand gamma particle radiation.

After 5 years of service at a nuclear station no measurable wear was found.



POWER REACTOR COOLANT PUMP CIRCUIT

Single Stage Vertical Pump	
Pumpage	Demineralized water at 95 PSI
Temperature	550°F
Horsepower	9000
Capacity	88,000 GPM
Speed	1200 RPM
Motor & Pump	
Height	65 feet
Weight	100 tons
Shaft OD	8"

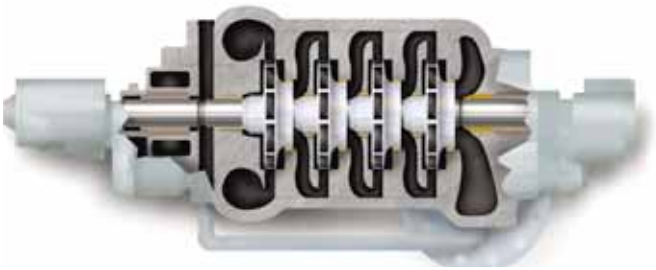
AXIALLY SPLIT DIFFUSER PUMPS

BOILER FEED WATER

This axially split diffuser type pump is in service at an oil refinery in the Pacific Northwest.

Material: **NICKEL GRAPHALLOY**

Operating History -
This pump is one of three units in parallel. When one was started with the adjacent two pumps running, one of the three would cavitate due to suction flow starvation causing damage and seizure. The installation of GRAPHALLOY has minimized the wear caused by this transient condition. The associated repair costs have been reduced by 75% per failure and the mean time between failures extended from six months to two years.



Horizontal Multi-Stage Type	
Pumpage	Boiler feed water
Number of Stages	Six
Temperature	250°F
Horsepower	350
Capacity	450 GPM
Total Head	2140 FT.
Speed	3570 RPM
Pressure Differential	
Across Case Wearing Ring	145 PSI
Across Balancing Drum	900 PSI
GRAPHALLOY Bushing Dimensions	
Case Wearing Ring	6 5/8” x 5 7/8” x 7/8”
Throttle	3 5/8” x 2 7/8” x 1”
Balance Drum	6 3/8” x 5 5/8” x 3 1/8”

BOILER FEED WATER

This axially split diffuser type pump is in service at an oil refinery in the Central Midwest.

Material: **NICKEL GRAPHALLOY**

Operating History -
There are six units in this refinery power house. Prior to the installation of GRAPHALLOY material, the pump rotors were frequently seizing. The first unit was converted to GRAPHALLOY in April 1992. Four more have been converted since. There have been no seizing of these pumps and recently one was run dry for several hours with no damage to the rotating parts.

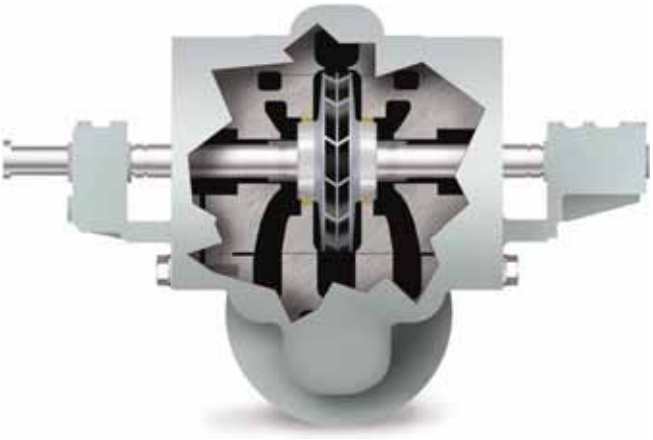
Horizontal Multi-Stage Type	
Pumpage	Boiler feed water
Number of Stages	Eight
Temperature	212°F
Horsepower	200
Capacity	250 GPM
Total Head	1830 FT.
Speed	3570 RPM
Pressure Differential	
Across Case Wearing Ring	100 PSI
GRAPHALLOY Bushing Dimensions	
Case Wearing Ring	5 1/4” x 4 1/2” x 7/8”
Throttle	3 7/16” x 2 1/2” x 2 5/8”
Channel Ring	3 1/2” x 2 3/4” x 2 5/8”

CO_2 PIPELINE PUMP

This radially split horizontal pump is installed in the CO_2 pipeline that runs from Southwest Colorado to West Texas.

Material: **BRONZE GRAPHALLOY**

Operating History -
This Pipeline Pump is carrying CO_2 for oil field injection. The pump ran for six hours with the suction shut-off. No damage to the GRAPHALLOY bushings resulted.



Horizontal Radially Split Volute Type	
Pumpage	Liquid CO_2 at 70°F to 180°F Max.
Horsepower	3000
Number of Stages	One
Capacity	16000 GPM
Discharge Head	600 FT.
Suction Pressure	1800 PSIG
Pump Speed	1780 RPM
Pressure Differential	
Across Case Wearing Ring	195 PSI
GRAPHALLOY Bushing Dimensions	
Case Ring	15” x 13 5/8” x 1 5/8” Lg.
Housing	16 5/8” x 15” x 1 5/8” Lg.

SINGLE STAGE VOLUTE

This single stage, volute pump is in service at a major oil refinery in Southern California.

Material: **NICKEL GRAPHALLOY**

Operating History -
The pump, originally furnished with chrome casing rings and throttle bushing, could not be remotely started from cold standby because thermal distortion would cause rotor seizure. Increasing the ring clearance to .060” eliminated the rubbing but the resulting decreased efficiency tripped the motor at full load. GRAPHALLOY bushings were installed with the clearance returned to the original value to .020”. GRAPHALLOY’s non-galling capability has since allowed rubbing at start-ups without detrimental effects.

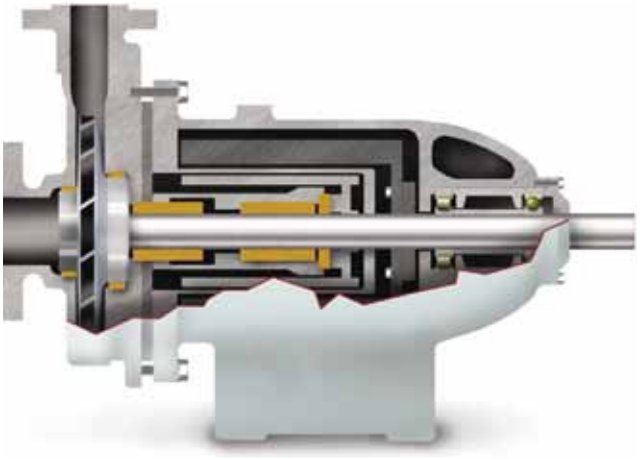
Horizontal Single Stage, Between Bearings	
Pumpage	Boiler Feed Water at Sp.Gr. 0.786
HP	40
Temperature	500°F
Capacity	925 GPM
Discharge Pressure	732 PSIG
Suction Pressure	685 PSIG
Pump Speed	1760 RPM
Pressure Differential	
Across Case Wearing Ring	47 PSI
Across Throttle Bushing	47 PSI
GRAPHALLOY Bushing Dimensions	
Case	8 1/2” x 8” x 1 1/8”
Throttle	3 1/4” x 2 5/8” x 1 1/4”

MAG-DRIVE PUMP

This single stage mag-drive pump is in service at a Louisiana chemical plant.

Material: **NICKEL GRAPHALLOY**

Operational History -
The plain carbon bushings furnished by the pump OEM were not satisfactory. Initially a thrust pad of GRAPHALLOY was installed. After it ran successfully for six months the user converted the neck rings and bushings to GRAPHALLOY material.



Horizontal, Single Stage, Overhung	
Pumpage	Phosgene
Temperature	100°F normally 300°F Max.
Horsepower	15
Speed	3500 RPM
Capacity	150 GPM
Suction Pressure	70 PSIG
Discharge Pressure	180 PSIG
GRAPHALLOY Bushing Dimensions	
Thrust Pad	2 1/2" x 1 3/8" x 3/8"
Front Ring	3 1/8" x 2 5/8" x 1"
Back Ring	3 3/4" x 3 1/8" x 3/4"
Bushings	2" x 1 1/4" x 1 3/4"

POSITIVE DISPLACEMENT ASPHALT GEAR PUMP -GRAPHALLOY BUSHING

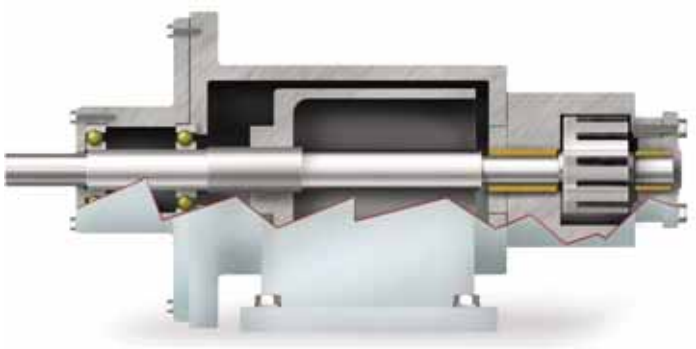
This positive displacement gear pump is in service in a West Virginia asphalt plant.

Material: **COPPER GRAPHALLOY**

Operating History -
Brass, plain carbon, and tungsten carbide bushings were tried with unsatisfactory results. The service life was between 100 and 180 hours and often both the bushing and the metal idler pin were destroyed.

The use of GRAPHALLOY material for this idler bushing has increased the service life to over 400 hours. When it was finally replaced the metal parts showed no wear.

Since the initial application, the customer has used GRAPHALLOY Bushings on his gear pumps of other sizes and submersibles.



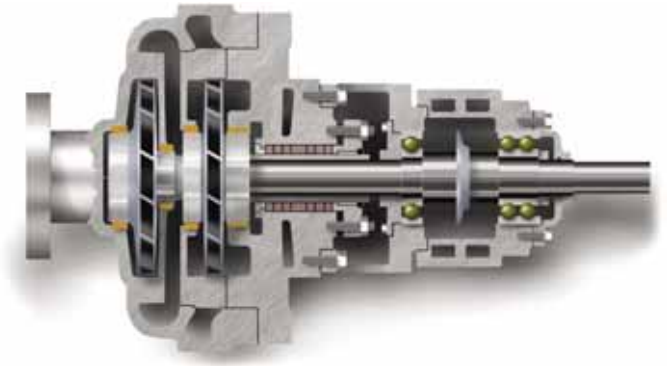
Horizontal, Radially Split, End Suction Type	
Pumpage	Tar Still Distillate at 300°F containing abrasives
Service	Tank car cleaning
Number of Stages	One
Capacity	400 USGPM
Suction Pressure	0 PSIG
Discharge Pressure	50 PSIG
Speed	300 RPM
GRAPHALLOY Bushing Dimensions	
	3" x 2 1/2" x 5" (with ID Spiral Groove)

PROPANE / BUTANE PUMP

These two-stage overhung horizontal pumps are in service at an Ontario, Canada, oil refinery.

Material: **BABBIT GRAPHALLOY**

Operating History -
The pump with metal rings had a vibration level in excess of 0.5 IPS due to running clearances opening up to .025" and higher. GRAPHALLOY stationary rings were installed with clearances of .015". The vibration level was lowered to 0.15 IPS and the product output returned to specification. After seven months of operation the customer was so pleased that GRAPHALLOY parts were installed in three larger pumps of the same type. The improvements were similar with the vibration levels reduced from 0.25 IPS to less than 0.15 IPS.



Horizontal End Suction, Back Pullout Type	
Pumpage	Propane and Iso-Butane Sp.Gr. 0.57 at 100°F
Number of Stages	Two
Speed	3600 RPM
Capacity	435 GPM
Discharge Pressure	220 PSIG
Suction Pressure	15 PSIG
GRAPHALLOY Bushing Dimensions	
Eye	6 3/8" X 5 7/8" X 1"
1st Stg hub	6 3/4" X 3 1/4" X 11/16"
2nd Stg hub	6 3/4" X 5 7/8" X 1 3/8"

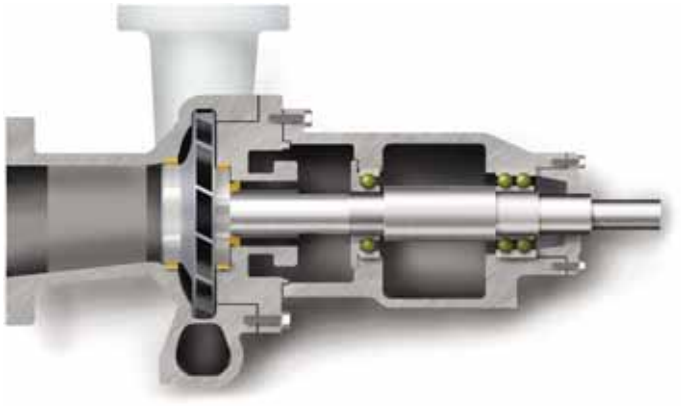
REFINERY SINGLE STAGE OVERHUNG PUMP

These single stage overhung pumps are in service in Southern California.

Material: **NICKEL GRAPHALLOY**

Operating History -
GRAPHALLOY rings were installed with a .012" diametrical running clearance. Resulting pump efficiency is 2% higher than similar pump with metal rings. The pump vibration readings are approximately one half of the metal ringed pump.

(A similar pump fitted with GRAPHALLOY Case Rings and Throttle bushings has been used successfully in 97% HF Acid. The pump was pulled for a mechanical seal change after over 4 years and no wear was detected on the GRAPHALLOY. For more details see DS 2090-171A.)



Horizontal Overhung	
Pumpage	Therma "C" at 450°F to 550°F Max.
Number of Stages	One
Capacity	2335 GPM
Discharge Head	390 FT.
Discharge Pressure	165 PSIG (Max)
Suction Pressure	0 PSIG
Speed	3560 RPM
Pressure Differential	
Across Case Wear Rings	125 PSI
GRAPHALLOY Bushing Dimensions	
Case Ring	8 1/8" X 7 7/16" X 7/8"
Housing	8 5/8" X 8 1/8" X 7/8"

AXIALLY SPLIT VOLUTE PUMPS

GRAPHALLOY CASE WEARING RINGS

These axially split volute pumps are operating in a West Coast oil refinery.

Material: **IRON GRAPHALLOY**

Operating History -
This pump is one of three parallel pumps with a history of cavitation caused failures. This is a pump of a different design in the same installation as shown on the left side of page 15. Over a 4,000 hour period, the GRAPHALLOY wearing rings measured less than 0.001" wear.

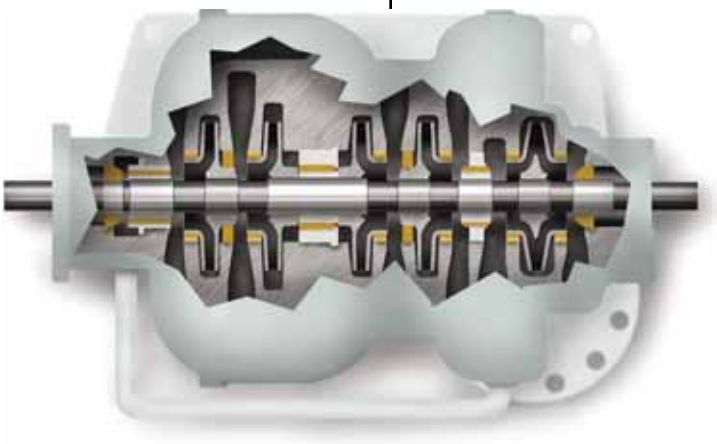
Horizontal Multi-Stage Type	
Pumpage	Boiler feed water
Number of Stages	Seven
Temperature	250°F
Horsepower	350
Capacity	450 GPM
Total Head	2140 FT.
Speed	3570 RPM
Pressure Differential	
Across Series Stage Ring	125 PSI
Across Center Stage Bushing	500 PSI
GRAPHALLOY Bushing Dimensions	
Series Stage Ring	4 3/4" x 4" x 1/2"
Center Stage	4 5/8" x 3 3/4" x 2 3/8"
Throttle	3 3/8" x 2 7/8" x 2 1/2"

GRAPHALLOY CASE RINGS & STAGE PIECES

This axially split volute pump is in service at a fiberboard plant in northern California.

Material: **NICKEL GRAPHALLOY**

Operating History -
The pump was originally fitted with metal stationary parts. When there was suction flashing in the start-up mode, these rings would gall, often causing shutdown. The retrofit to GRAPHALLOY parts not only eliminated this problem but also increased the pump capacity and the power output from the boiler.



Horizontal Multi-Stage Type	
Pumpage	Boiler feed water
Temperature	275°F
Number of Stages	Seven
Capacity	1100 GPM
Total Head	3750 FT.
Speed	3570 RPM
Pressure Differential	
Across Case Wear Ring	115 PSI
Across Center Stage Bushing	585 PSI
GRAPHALLOY Nominal Dimensions	
Hub Stage Piece	5 1/4" X 4 5/8" X 5/8"
Center Stage Piece	5" X 4 1/8" X 2 3/4"
Series Stage Piece	4 7/8" X 4 1/8" X 1 3/8"
Throat Bushing	3 7/8" X 3" X 3/8"
Throttle Bushing	4 3/4" X 4" X 2 3/8"

LIGHT HYDROCARBON SINGLE STAGE PUMP

These single stage horizontal pumps are in service at a Texas refinery.

Material: **BRONZE GRAPHALLOY**

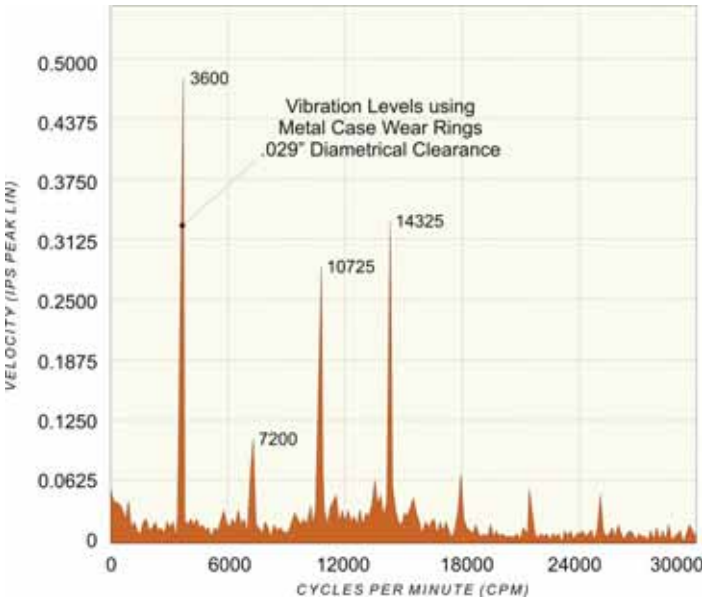
Operating History -
The refinery opened the clearances to .029" to avoid the metal to metal contact on the wear parts. This created a new problem – higher vibration levels and premature failure of the ball bearing. The high vibration levels and the ball bearing failures necessitated a change. Bronze GRAPHALLOY wear rings were installed with .010 clearances.

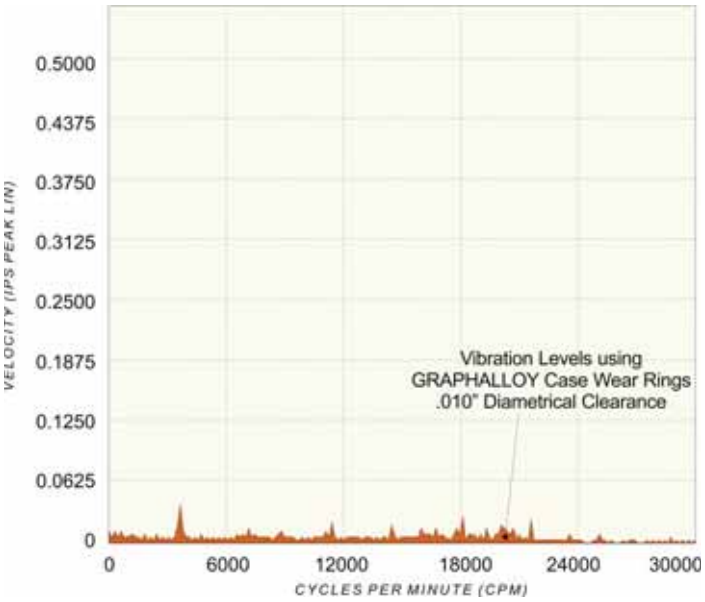
Graph #1 shows the results using the metal wear rings. Three vibration spikes exceeded .25 IPS with the highest more than .4 IPS occurring at 3600 cps, the operating speed of the pump.

Graph #2 illustrates the resulting vibration levels after the retrofit with GRAPHALLOY. At all speeds the vibration levels of the GRAPHALLOY fitted pump was less than .05 IPS.

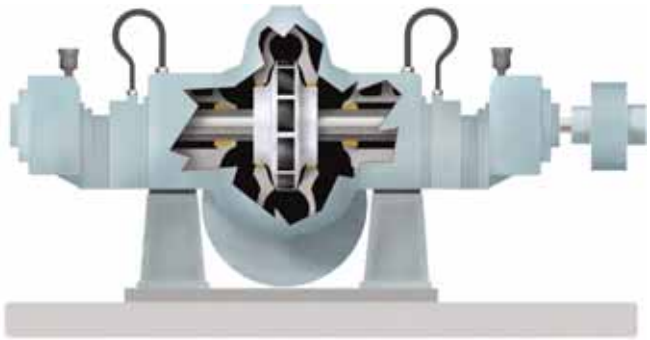
The vibration levels of the metal wear rings were at least eight times higher than the vibration levels of the pump with the GRAPHALLOY upgrade.

As a result the refinery retrofit the other pumps in this application with Bronze GRAPHALLOY wear rings at a clearance of .008"–.010". The vibration was reduced to the point that the pump has been operating successfully since.





Horizontally Split Single Volute Double Suction Type	
Pumpage	Light hydrocarbons (naphtha) 0.70 S.G.
Temperature	250°F to 450°F
Suction Pressure	25 PSIG
Discharge Pressure	250 PSIG
Speed	3550 RPM
GRAPHALLOY Nominal Dimensions	
Casing Rings	8" X 7 1/2" X 1 1/8"
Throttle Bushings	3 3/8" X 2 3/4" X 1 1/4"



BARREL CASE DIFFUSER PUMP

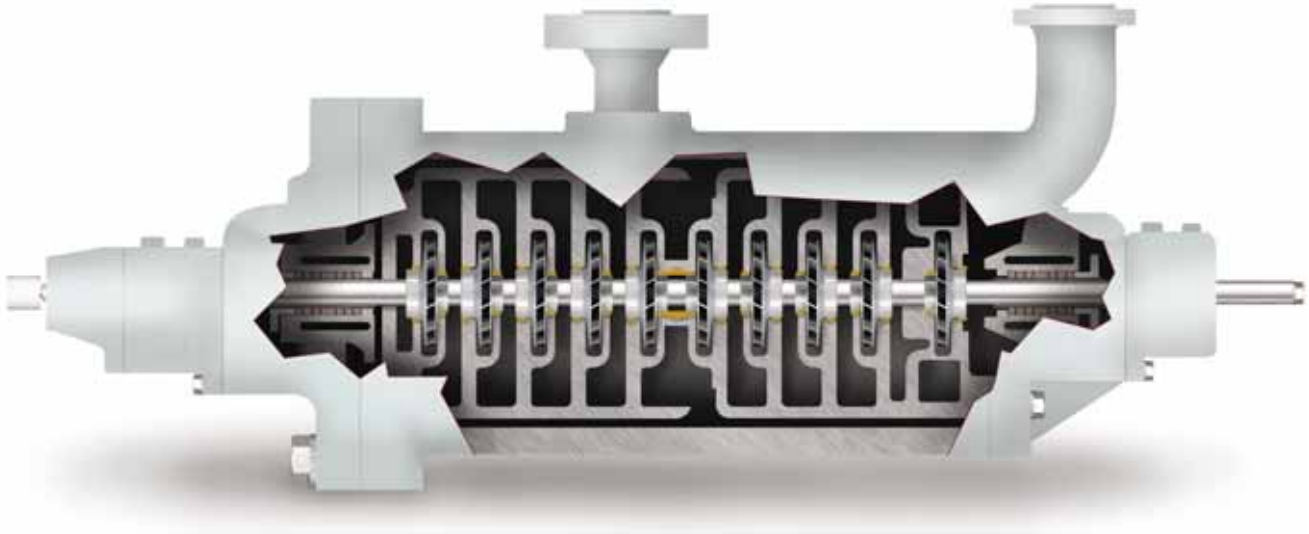
This barrel case diffuser type pump is in service as a main boiler feed pump in a Midwest steam generating station.

Material: **NICKEL GRAPHALLOY**

Operating History –
This pump is one of eight units of this station. With standard metal-to-metal rings there were three to four seizures per year due to transient dry running during boiler load shift demands. Each failure resulted in a $60,000 overall repair cost.

One pump was retrofit with GRAPHALLOY wear parts. Nine months later another was retrofit and two more after another nine months. The pumps have operated without seizure for many years.

Horizontal Multi-Stage Type	
Pumpage	Boiler feed water
Number of Stages	Eleven
Temperature	370°F
Horsepower	2500
Capacity	1300 GPM
Total Head	5600 FT.
Speed	3570 RPM
Pressure Differential	
Across Interstage Bushing	1100 PSI
Across Case Wear Rings	255 PSI
Across Throat Bushing	510 PSI
GRAPHALLOY Bushing Dimensions	
Interstage	6 1/4” x 5 1/2” x 3 5/8”
Case Wear Ring	7 1/8” x 6 3/4” x 1”
Throat	4 1/2” x 4” x 5 3/8”



Test Results Support the Use of GRAPHALLOY®

Independent labs, pump OEMs, and pump users have extensively tested GRAPHALLOY for use in pump applications.

Symposium presentations, case histories and numerous articles attest to GRAPHALLOY performance under the most demanding circumstances and to the increased life and reduced maintenence achieved.

These are some examples:

Test program at a major pump manufacturer in a full scale pump on their test loop
- Run Dry
- Vibration Testing
- Stop & Start
- Thermal Transients

Rensselaer Polytechnic Institute test program GRAPHALLOY vs PEEK
- Load to Failure
- Time to Failure

Test Program of European Pump Manufacturer
- GRAPHALLOY out performs PEEK in severe run dry tests

Test Program of a US pump manufacturer
- Dry running for vertical pumps

Deep well potable water application
- Surviving daily dry starts

Data Sheets and additional details of these tests and more are available from your local GRAPHALLOY Engineering Sales Representative or by contacting our corporate engineering group.

With tens of thousands of pumps using GRAPHALLOY we have probably already tested your application.

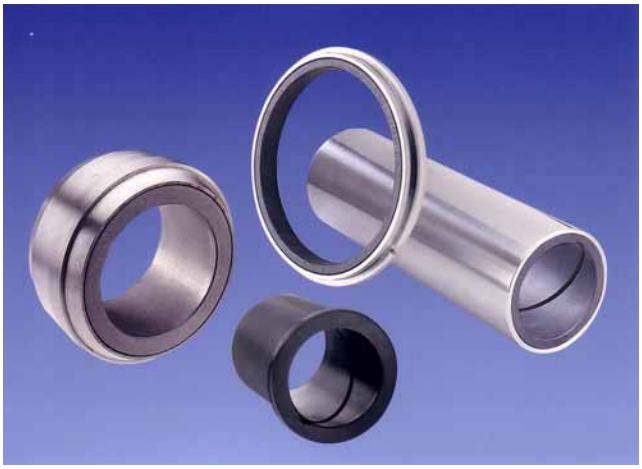
Pump Installations of GRAPHALLOY®

GRAPHALLOY is a graphite/metal alloy used extensively for pump bushings and wear rings. Two key advantages for pumping applications:

1. **GRAPHALLOY** enables pumps – that run dry, flash, or handle extremely low viscosity fluids – to survive without damage. Numerous case histories and pump manufacturer test results confirm that GRAPHALLOY performs where plastics are unable to stand up and metal parts seize disastrously.

2. **GRAPHALLOY** enables rings and bushings to be designed with tighter clearances which can improve efficiency, increase output, reduce vibration. In addition the stuffing box bushing will also reduce leakage of external seal flush into the process fluid. GRAPHALLOY can also be used in the gland as a back up or disaster bushing reducing process fluid leakage in the event of a seal failure. GRAPHALLOY's non-galling, dimensionally stable, toughness enables the pump to operate at these tight fits without the risk of metal-on-metal rubs or seizure.

While plastics might survive less demanding applications – specify GRAPHALLOY where you know it has to work.



Pump Manufacturers and Pump Lines

FLOWSERVE
INGERSOLL-DRESSER
JOHNSTON
BYRON JACKSON
PACIFIC
WORTHINGTON
WMD
GOULDS
MARLEY
RHURPUMPEN
DAVID BROWN
UNION
SULZER
BINGHAM
CPC
HAYWARD TYLER
HAZELTON
KSB
VIKING

Major Pump Users:
Refineries and petrochemical

SHELL
PHILLIPS
TOSCO
HESS
MOTIVA
ARAMCO
EXXON/MOBIL
CHEVRON
BP/AMOCO
SUN
CONOCO
VALERO
IMPERIAL
PETRO CANADA
EASTMAN
TOTAL
MARATHON

Electric Power Plants
Chemical Plants
Pipelines
Pulp and Paper Mills

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