Abstract

THE ECONOMIC BENEFITS OF PLASTIC LINED MAGNETIC DRIVE PUMPS

by Anthony E. Stavale and Guenter Naasner

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The continual development of sealless pumps over the past several years has resulted in improvements in operational safety and increased reliability. Further areas of application are in use due to the economic availability of new materials and improvements in manufacturing processes. Increasing use is being made of plastic lined magnetic drive pumps for the pumping of highly toxic, corrosive, and other dangerous liquids in the chemical and pharmaceutical markets. These pumps offer significant advantages in first cost, particularly when compared to sealless pumps with metallurgy more noble than 316 ss and for conventional sealed pumps, constructed for similar leak free emission, in metallurgy higher than Alloy 20. The eddy current-free containment shell design, inherent to plastic lined pumps, has the advantages of lower operating costs and the virtual elimination of heat input to the process liquid, critical when pumping saturated liquids or liquids with steep vapor pressure-temperature curves. The nonconductive containment shell in a plastic lined pump is of paramount importance if the unit is to survive under dry run conditions.

Of the various liner materials available, PFA/PTFE offers the highest degree of temperature and corrosion resistance. High performance PFA lined pumps are particularly well suited for transfer and tank car unloading services, where a variety of corrosive liquids can be transferred by a single pump.

Although sensitivity to dry running has long been considered to be a weakness of sealless pumps, recent advancements in dry run technology utilizing Safeglide™ coated silicon carbide bearings permit short term dry running and provide valuable time to identify

and correct process conditions before damage can occur. Prior experience of this coating by a manufacturer has shown rather dramatic improvements in repair frequency during user audits.

INTRODUCTION

Pumping of highly corrosive liquids requires careful material selection and robust pump design to prevent leakage and contamination of the environment and to optimize mean time between planned maintenance. Conventional metal pumps manufactured of Hastelloy C and other more noble alloys can be an expensive proposition and can require 14 weeks and longer for the delivery of special non-stock metallurgies. In addition, spare parts inventory, a virtual necessity for minimizing downtime, can represent a significant investment to the user and tie up vital resources that can be applied elsewhere.

Plastic lined magnetic drive pumps are becoming an increasingly popular choice for many severe service applications where leakage to the environment cannot be tolerated (1). The selection of liner materials depends on several important considerations in order to maintain reliability. Since the plastic liner is exposed to the process liquid, the key properties that must be considered in the application are: degree of corrosion resistance, temperature capability, resistance to permeation, and abrasion resistance (1, 2). Although, there are a variety of liner materials available to suit specific applications as shown in Table 1 (1, 2). PFA/PTFE offers the highest degree of confidence in a fluoroplastic liner material from the standpoint of corrosion resistance and temperature capability. High performance PFA/PTFE lining materials are virtually inert to chemical attack and have the flexibility of allowing the pump to be used in a wide variety of services while maintaining reliability. For applications requiring lower corrosion and temperature resistance the partially fluorinated PVDF and ETFE have been used successfully. UHMW-PE is a material that is particularly well suited for the pumping of abrasive solids in suspension, provided temperature and corrosion resistance is satisfactory (2).

PLASTIC LINED MAGNETIC DRIVE PUMPS

Certain features of heavy duty plastic lined magnetic drive pumps are key to realizing economic benefits, not only during the initial cost and installation of the unit, but also in lowering operating costs and reducing costs associated with maintenance, cleanup, and downtime.

High performance plastic lined magnetic drive pumps consist of a pressure containing metal outer shell covered internally by a 1/8 to 3/16 inch plastic coating of internal wetted parts. The metal outer shell, normally ductile iron,

TABLE 1.
COMPARISON OF TYPICAL PLASTIC LINING MATERIALS

Material	Corrosion Resistance	Temp. Limit (°F)	Therm. Shock Resistance	Impact Resistance	Abrasion Resistance
PTFE (Polytetrafluoroethylene)	Nearly Universal	360	Good	Good	Limited
PFA (Perfluoroalkoxy)	Nearly Universal	360	Good	Good	Limited
PVDF (Polyvinylidene fluoride)	Good	250	Good	Good	Relatively Good
ETFE (Ethylene Tetrafluoroethylene)	Good	250	Good	Good	Relatively Good
PE-UHMW (Polyethylene - Ultra High Molecular Weight)	Fair	195	Good	Good	Very Good

provides the structural rigidity to handle the pump internal pressure and external nozzle loads, while the liner material provides the corrosion resistance. All wetted components are either covered by a plastic liner, manufactured of solid plastic, usually fiber reinforced, or made of engineered ceramics, such as silicon carbide for the product lubricated bearings. Several key features of heavy duty plastic lined magnetic drive pumps, shown in Figure 1, are distinguished from other lighter duty designs:

- Higher working pressure - Full 150 pound flange rating to 275 psig
- Superior corrosion resistance - PFA/PTFE plastic linings provide near universal corrosion resistance
- Higher temperature capability - PFA/PTFE plastic linings have a maximum temperature limit of 360°F (180°C)
- Short term dry running silicon carbide bearings - Silicon carbide is chemically inert, highly wear resistant, and has excellent load carrying ability. Dry run capability is essential protection for surviving system upsets and occasional operator error.
- Heavy duty bearing carrier - The carrier supports all wet end bearing loads with no additional loads and vibration on the containment shell.
- Large clearances - The pump provides increased reliability and allows internal growth of rotating parts and solids passage.

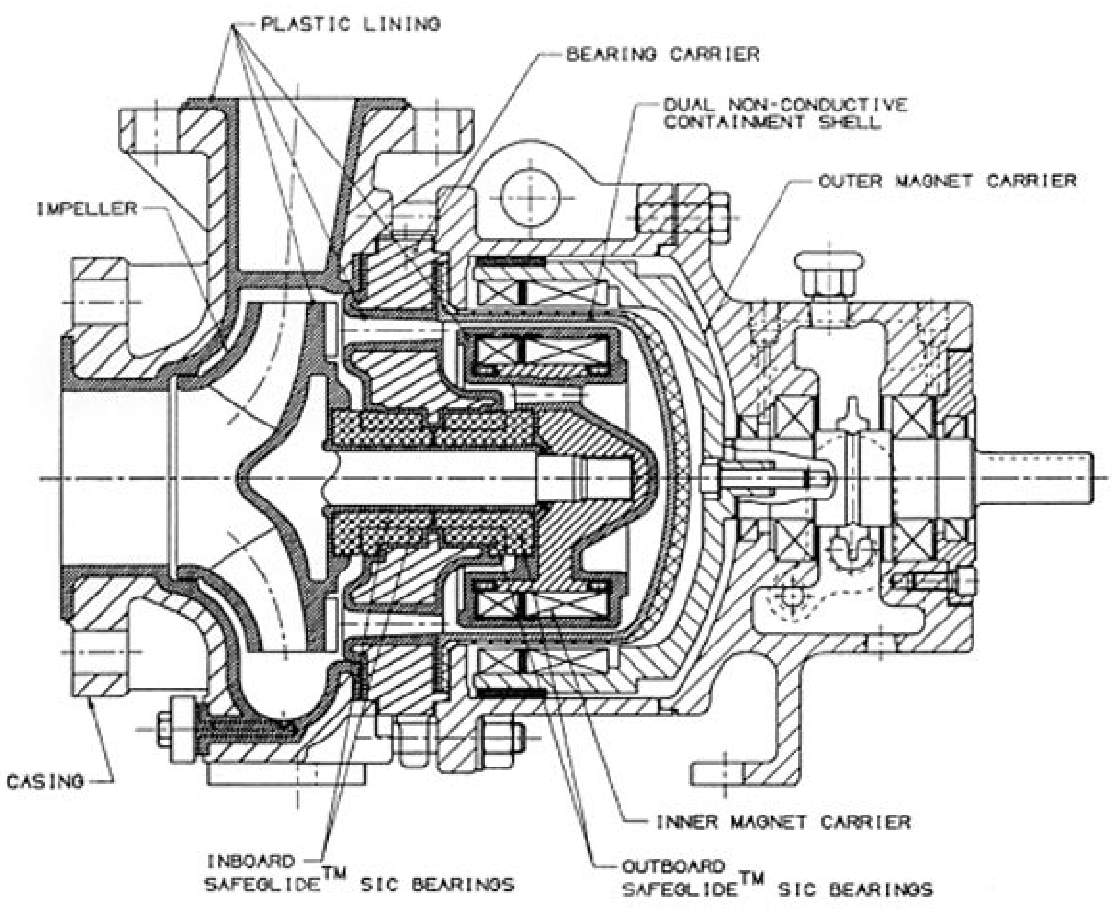

Fig. 1. Plastic Lined ANSI Magnetic Drive Pump

ECONOMIC BENEFITS

Lower First Cost

Heavy Duty PFA/PTFE plastic lined magnetic drive pumps become economically important when comparing their costs to pumps with metallurgies more noble than 316 ss. These pumps can become highly favorable when comparing their cost to the Hastelloys and more exotic alloys such as Titanium and Tantalum (1). The relative cost for a 1.5 x 1 x 8 ANSI magnetic drive pump with PFA liner is compared to a similar size pump of several different metallurgies in Figure 2. As shown, savings can begin to be realized when comparing PFA lined pumps to similar pumps of Alloy 20 metallurgy. These types of pumps can become highly economical and an inexpensive alternative to metallurgies such as Hastelloy B and C. A favorable cost comparison can also be made for a PFA lined pump against conventional sealed pumps of Hastelloy C construction with double liquid lubricated mechanical seals or gas lubricated barrier seals as shown in Figure 3.

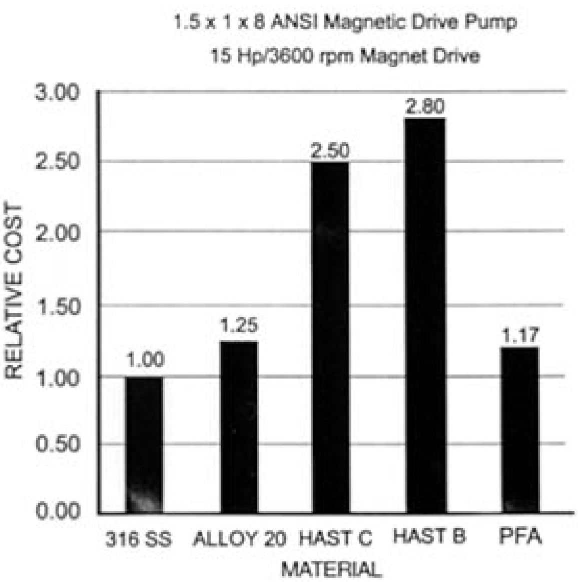

Fig. 2. Relative First Cost of PFA Lined Versus Metal Pumps of Various Metallurgies

Since many unloading and transfer services require the pumping of a wide range of corrosive liquids, these services can be accommodated both easily and cost-effectively by the use of a single pump with a PFA/PTFE liner without risk of failure.

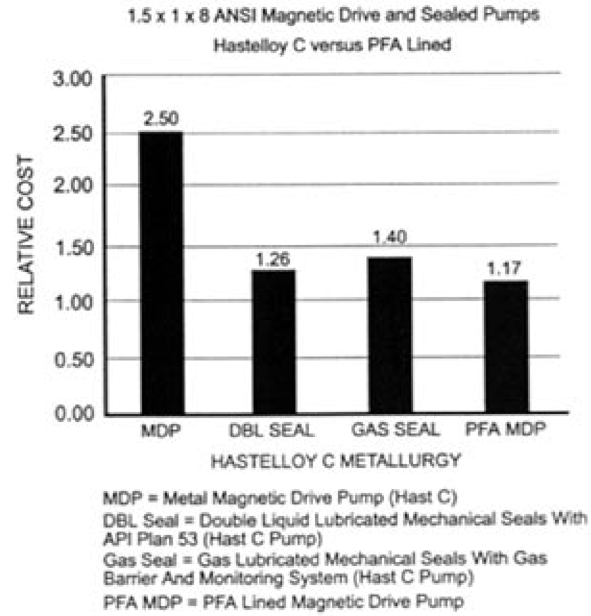

Fig. 3. Relative First Cost of PFA Lined Versus Sealed and Sealless Hastelloy C Pumps

Lined magnetic drive pumps can also be furnished in a close-coupled arrangement whereby the outer magnet carrier is mounted directly onto the motor shaft and a separate pump bearing frame is eliminated from the design. This has several advantages (1, 2):

- There is no coupling or coupling alignment. This helps to reduce installation time and cost.
- A close-coupled configuration is shorter than a separately coupled unit and saves space.
- Since there is no coupling, coupling guard, or bearing frame, the first cost is lowered (typically by 10%) and there are fewer parts to inventory.
- C-face motors have a more favorable bearing span than long coupled pump bearings that conform to ASME B73.1 dimensions. Since wet end radial and axial thrust loads are absorbed by the product lubricated bearings the only loads transmitted to the motor bearings are the outer magnet carrier weight, residual dynamic unbalance, and any magnetic unbalance.

Lower Operating Costs

Inherent to the design of a plastic lined magnetic drive pump is a nonconductive containment shell. Typically, the containment shell consists of a corrosion resistant liner material with a fiber reinforced backing. Dual containment shells are available that can be monitored for leakage between inner and outer shells, thereby providing secondary containment and an early warning in the unlikely event leakage occurs. Since the shell is nonmetallic, it is not electrically conductive and isn't subject to eddy current losses, as are metal containment shells. Eddy currents are generated when rotating lines of magnetic flux cut through a stationary can conductor. These eddy currents are influenced by the geometry of the containment shell, shell material, and pump operating speed. In metal shells, a material of high electrical resistivity, such as Hastelloy C, is normally selected to keep eddy currents to a minimum. As shown in Table 2, a shell of 316 ss has approximately one-half the electrical resistivity and nearly double the eddy current losses compared to a Hastelloy C shell (3).

Other containment shell metallurgies, such as Titanium and Monel, have 2.5 to 3 times the losses of a Hastelloy C shell and are best limited to lower speed operation to avoid excessive power losses and heat input to the process liquid. Depending on the containment shell geometry and material, eddy current losses in metallic containment shells can range from 10% to 20% of the magnetic drive rating at 3,550 rpm. For example, a magnet drive rated for 50 hp at 3,600 rpm can have up to 10 hp in losses due to eddy currents. Typical eddy current loss versus speed curves for one manufacturer are shown in Figure 4. These eddy currents represent lost power that produces heat in the shell due to its electrical resistance. This heat is transferred to the pump liquid which serves to cool the containment shell and prevent overheating. Often, heat added to the pumped liquid can become highly undesirable, especially when pumping saturated liquids, liquids with steep vapor pressure curves, or liquids that can polymerize locally at increased temperature (4). The higher temperature complicates the selection process and must be given careful attention in order to avoid the risk of failure. This is not an issue for nonconductive shells in plastic lined pumps, since there are no eddy currents generated and a much simpler pump selection process can be used. Magnetic drive pumps with nonconductive shells can operate as efficiently as conventional pumps with double mechanical seals and provide potential annual savings of thousands of kilowatt-hours in operating costs over metal containment shells. For example, a 50 hp pump with a nonconductive shell in continuous service will have an annual cost saving of $5,200 based on a kw-hr cost of $0.08. It should be noted that some manufacturers offer nonmetallic containment shells in their metal magnetic drive pumps.

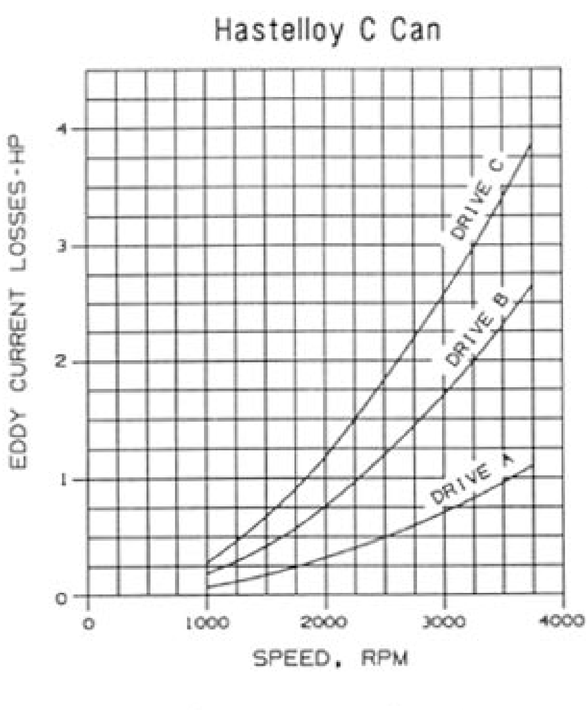

Fig. 4. Eddy Current Losses Versus Speed

TABLE 2. ELECTRICAL RESISTIVITY AND EDDY CURRENT MULTIPLIER FOR VARIOUS CONTAINMENT SHELL MATERIALS

Material	Electrical Resistivity (micro-ohm cm.)	Eddy Current Multiplier Over Hastelloy C
410 ss	23	5.8
Monel	48	2.8
Titanium	53	2.5
316 ss	74	1.8
Alloy 20	75	1.8
Hastelloy C	133	1.0
Non-Metallic	Infinite	0

Reduced Life Cycle Costs

Life cycle costs include not only first cost, but the total cost of ownership. In addition to energy costs, these include parts and labor for overhauling the pump, lost productivity due to downtime, and any costs associated with environmental cleanup and disposal of contaminants (1). These life cycle costs are influenced by material compatibility, robustness, simplicity of design, and the ability of the unit to tolerate system upsets or occasional operator error. The design should be simple enough to allow the user to quickly repair the pump at the plant while offering little risk of improper assembly by unskilled workers.

For clean liquids, with little or no abrasive solids, there can be longer periods between planned maintenance since no corrosion occurs in PFA components. Additionally, the impeller operating clearance or ring clearance will not be changed and affect pump performance as often occurs in metal pumps (5).

Dry running has long been considered to be a major weakness of sealless pumps and a leading reason for users not to purchase these types of pumps (6). Product lubricated bearings of sintered silicon carbide (SSiC) offer important advantages in chemical inertness, wear resistance, temperature stability, and load carrying ability. However, these bearings are particularly sensitive to dry running that occurs frequently in transfer and unloading services (2, 7). Tests at 3,600 rpm by one manufacturer confirm that silicon carbide will be destroyed in a matter of seconds if allowed to run bone dry (6).

Some manufacturers provide carbon bearings to attain short term dry running capability, but these bearings have shortcomings in chemical compatibility, load carrying capability, increased wear rate, and an intolerance for handling solids. This is particularly important since process liquids are seldom pure.

The elimination of a conductive containment shell from the design, as mentioned in the preceding section, eliminates the high temperature increase attributed to eddy currents that can cause shell temperatures to reach 1,000°F in a matter of seconds during dry running (8).

Recently, major advances have been made in dry run technology for silicon carbide bearings that will allow dry running for extended periods of time, even when bone dry. Safeglide™ coatings have been applied to silicon carbide bearings and tested successfully under bone dry laboratory conditions for five hours without damage. Safeglide™ is a very hard, chemically inert friction-reducing coating that has a dry coefficient of friction as low as 0.05. As shown in Figure 5, this is a reduction in friction of 85% to 90% over uncoated silicon carbide (2, 6).

A test was conducted with Safeglide™ coated SSiC bearings in a 7.5 hp ANSI magnetic drive pump of 316 ss construction and fitted with a nonconductive containment shell. As shown in Figure 6, the test pump was successfully operated bone dry for five hours prior to opening the suction valve and admitting 45°F water into the pump. Once primed, normal pumping continued for 20 minutes prior to shutdown and inspection of

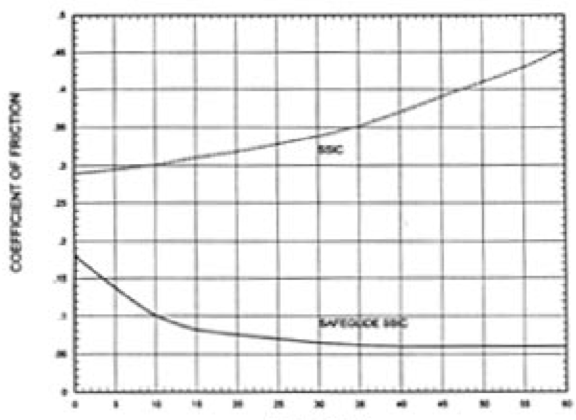

Fig. 5. Dry Coefficient of Friction Versus Time

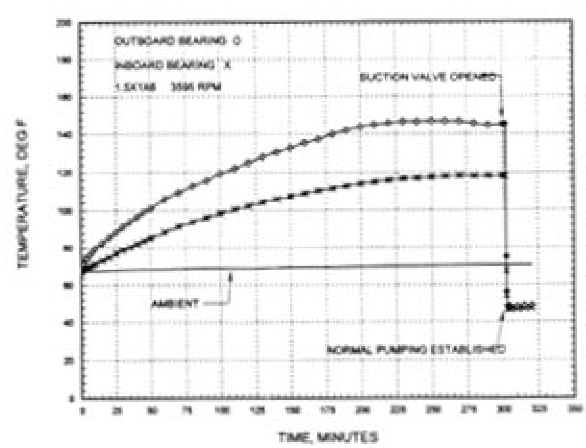

Fig. 6. Bone Dry Run Test

the unit. It was found that no damage or scoring had occurred to the silicon carbide bearings. The 80°F temperature rise of the product lubricated bearings was low enough, even after five hours of bone dry run operation, to eliminate any risk of thermal shock.

Similar capabilities have been obtained in plastic lined pumps. However, due to the insulating properties of the plastic lining that covers the bearing carrier and shaft, the transfer of heat away from the silicon carbide bearings is substantially diminished. For this reason Safeglide™ coatings were developed that significantly reduce the coefficient of friction of the silicon carbide bearings and allow the pump to become more resistant to dry running over a limited period of time (approximately 30 minutes at 3,600 rpm) (2). These dry run silicon carbide bearings provide valuable time to identify and rectify process interruptions before damage can occur. One added benefit for plastic lined pumps on transfer and unloading services is that the risk of mechanical shock due to slamming of the rotor, that can occur as prime is lost and re-established as the liquid level is drawn down, is greatly minimized by the cushioning effect of the plastic lining.

Prior experience of the Safeglide™ coating by a plastic lined magnetic drive pump manufacturer is reflected in the 1990 and 1992 repair trends at a large German chemical plant. Manufacturer F, a plastic lined pump manufacturer, began to introduce the Safeglide™ coating on SSiC bearings during late 1990. As shown in Figures 7 and 8, during 1992 this manufacturer experienced a 62% drop in repair frequency (29% to 11%) at this plant (2, 6). Although it is uncertain exactly what percent of this drop can be attributed to the Safeglide™ coating and/or improvements in operating procedures and maintenance practices by plant personnel, it is clear that Manufacturer F had the largest improvement in repair frequency among all suppliers at this plant. It should be noted that the time period that was studied correlates exactly with the introductory phase of the Safeglide™ coated SSiC bearings. Similar trends have been confirmed at other plants by this manufacturer.

CONCLUSIONS

Plastic lined magnetic drive pumps can represent an economic alternative to metal magnetic drive pumps with metallurgies more noble than 316 ss. These pumps can become highly attractive when compared to pumps of Hastelloy C construction where savings of more than 50% can be realized. These plastic lined sealless pumps have also been found to have a cost advantage of 10% to 20% over conventional ANSI B73.1 mechanical seal pumps of Hastelloy C construction with liquid lubricated double seals and gas lubricated barrier seals. Additional savings can be realized due to lower cost spare parts inventory.

Typical delivery cycles of three to six weeks, or less, can routinely be accommodated with plastic lined pumps compared to 14 weeks or longer for special nonstock metallurgies. Close coupled pumps can provide further savings in both lower cost and reduced space requirements since the pump bearing frame, coupling, and coupling guard are eliminated. Heavy duty PFA lined pumps provide near universal corrosion resistance and high temperature capability (to 360°F) which permits application flexibility for pumping a wide range of corrosive liquids while maintaining process integrity.

Nonconductive containment shells result in lower operating cost when compared to metallic shells, where power losses of up to 20% can be experienced due to eddy currents. This results in plastic lined pumps operating as efficiently as conventional pumps with double mechanical seals. The consequence of undesirable heat input to the process liquid, attributed to eddy currents, is also eliminated when nonconductive shells are used. This is of paramount importance when pumping liquids with steep vapor pressure curves.

Recent advancements in dry run technology, utilizing Safeglide™ coatings permit short term dry running of silicon carbide bearings without damage, even when operated bone dry. During a frequency-of-repair audit by a large German chemical plant, it was shown that the use of Safeglide™ coated

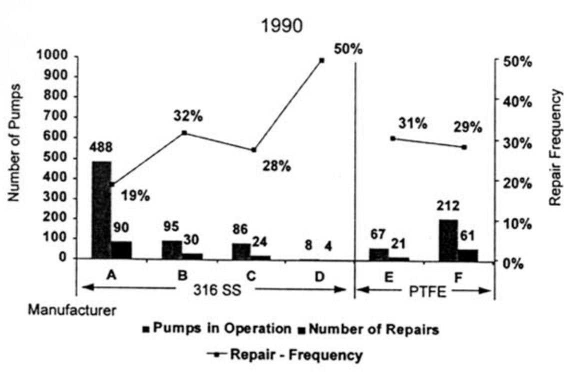

Fig. 7. Repair Trends of Magnetic Drive Pumps at a Large German Chemical Plant in 1990

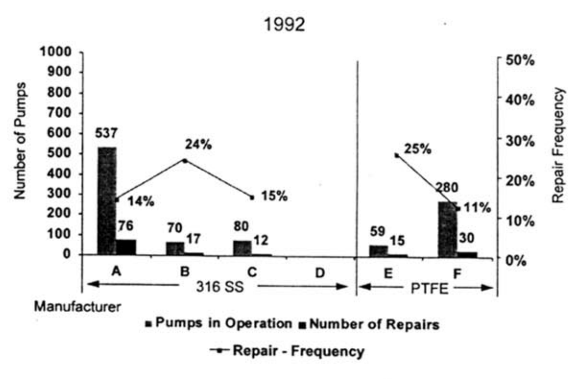

Fig. 8. Repair Trends of Magnetic Drive Pumps at a Large German Chemical Plant in 1992