MAGNETICALLY DRIVEN CENTRIFUGAL PUMPS— ELIMINATING SEAL PROBLEMS IN REFINERY AND CHEMICAL PROCESSING PLANT EQUIPMENT

by

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ABSTRACT AND INTRODUCTION

Centrifugal pump design plays an essential role in the safe operation of any refinery or chemical processing plant. In analyzing the performance of centrifugal pumps, pump operating time to failure is almost always limited to that of the shaft mechanical seal. Mechanical seals and their sophisticated supporting systems have become more complicated as the pumping industry perseveres in its efforts to produce satisfactory seal life. Numerous research projects have proceeded, many papers demonstrating seal leakage have been presented, but the overall progress in extending seal life has not been to everyone's satisfaction.

A viable and important option, therefore, is a centrifugal pump that does not require mechanical seals. A magnetically driven sealless pump is such a machine. It conveys liquid safely with no dynamic seal between the motor shaft and the impeller(s). There is no potential leakage path, since prime mover energy is transmitted magnetically through the pressure casing wall.

Magnet drive pumps are capable of producing flow rates to 5000 gpm and heads to 1000 ft. Temperatures ranging from − 100°F to + 850°F, and system pressure to 5000 psi can be accommodated without the need for any ancillary services or supporting systems. Likewise, the magnet drive pump is excellent for high vacuum services where sealing mechanically may prove extremely difficult. Sealless pumps generally are thought to be intolerant of solids in pumpage. However, magnet drive pump designs are now available with substantially improved performance in abrasive services.

The magnet drive centrifugal pump is simply a conventional centrifugal pump with an integral magnetic coupling imposed between the driver and the liquid end. This magnetic coupling replaces the seal chamber or stuffing box in such a way that the liquid end is made hermetic. The mechanical seal or packing is eliminated and the only seal is a stationary gasket or O-ring.

The mechanical design features are outlined for the sealless magnet drive centrifugal pump along with the advantages and occasional limitations of this type of machine compared with mechanically sealed pumps. Particular reference is made to proven applications and to the significant increase in recent years in the efficiency of and power available in magnetic drives.

CASE HISTORIES OF MAGNET DRIVE PUMPS

The magnet drive pump was developed to protect the life and health of people involved in chemical processing, nuclear power generation, national defense and others because mechanical seals are often not judged safe and reliable enough for certain fluids and some systems. In the mid 1960s through mid 1970s, economics favored the use of magnet drive pumps only in such drastic circumstances. Since then, continuous development, responsible application, and marketing of the magnet drive pump, and progress in the development of new and more powerful magnets have taken place. Today, economic considerations often favor use of the magnet drive simply as a matter of securing reduced maintenance. When a total evaluation tends to favor this conclusion, one might say that a revolution in the application and maintenance of centrifugal pumps is not far away.

CHEMICAL PROCESS

In the late summer of 1988, the engineering manager of a large Gulf Coast chemical plant reported that a recently installed standard magnet drive pump was saving maintenance dollars for mechanical seal replacements at the rate of $100,000 per year. In addition, the product being produced, acrylonitrile, was acclaimed by their customers to be of the highest purity that these customers had ever experienced. Elimination of the double mechanical seal not only reduced seal maintenance significantly, but also led to the discovery of a leaking heat exchanger which had contributed additional product dilution along with that of the double seal buffer water. The pump is a horizontal centrifugal magnet drive pump rated for 160 gpm at 120 ft total head. The specific gravity is 0.79. Pumping temperature is 106°F. The driver is 15 hp, 3600 rpm. The pump is protected from dry running by a thermocouple arrangement as described later.

A metals company in Utah has been using magnet drive sealless pumps to handle liquid anhydrous chlorine, a hazardous chemical and a very poor lubricant, for over ten years. Typical service is 20 gpm at 40 ft total head, with a specific gravity of 1.57 and pumping temperature of − 70°F.

The change in configuration of these pumps is generally described in Figure 1 as a result of replacing conventional pumps with magnet drive pumps. The packing box or seal chamber behind the impeller has been replaced by the Number 5 containment shell creating a hermetic pumping chamber. Part numbers 6 and 7 represent the other parts of the magnetic coupling. In
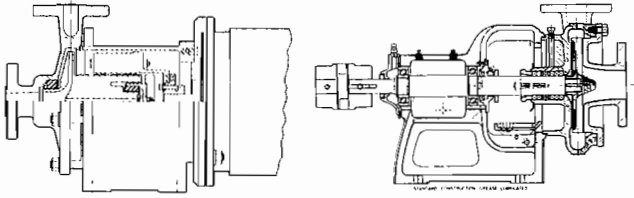
Figure 1. A Magnet Drive Pump (Top) Replaced a Sealed Pump Similar to the One on the Bottom, in Liquid Chlorine Service (Courtesy Worthington Div., Dresser Industries).

this instance part number 7, impeller assembly, contains the inner magnet ring or torque ring.

The success of these units led to applications in the Pacific Northwest, where remote paper manufacturers receive their anhydrous liquid chlorine by barge. Typical unloading pumps on these barges and on shore are rated 120 gpm at 200 ft total head, handling chlorine at 70°F pumping temperature.

Similarly, the safety, reliability, and low maintenance expense of magnet drive pumps has resulted in their supplanting mechanical seal fitted pumps in the chemical processing industries in other applications where extremely hazardous liquids must be handled, liquids such as hydrogen cyanide and liquid phosgene.

A chemical plant in the U.S. Northeast experienced problems with canned motor pumps on a 320°F diamene service. It was rated 20 gpm at 265 ft. Every time the process was shut down, the pump was removed and returned to the manufacturer to be rebuilt. This was necessary, because it was impossible to melt the solid diamene in the interstices of the canned motor pump at startup. In 1985, a jacketed magnet drive pump was installed. Since then, the plant has been operating with no problems and with only routine maintenance of the pumping unit required. The jacketed magnet drive is shown in Figure 2. The simplicity and greater internal clearances of the magnet drive pump made this improvement possible.
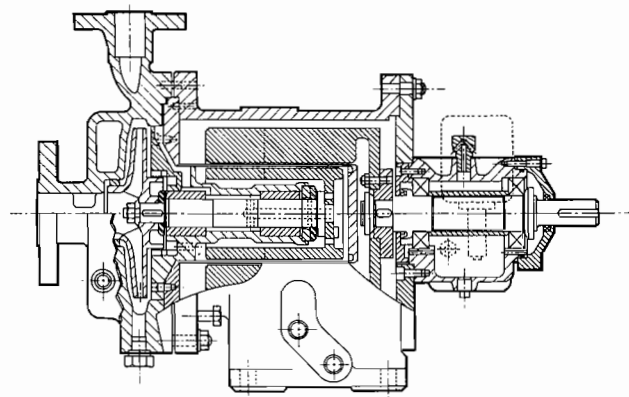

Figure 2. Cross Section of Jacketed Magnet Drive Pump.

Typical of the ability of magnet drive pumps to handle high suction pressure and high temperature is a pump installed in 1980 which continues to handle a nonlubricating reactive ethylene compound at temperatures in excess of 400°F 24 hr/ day within a 2200 psi system. This pump ran continuously without any preventive maintenance for over five years, when it reached end of bearing life. It was severely damaged, but did not leak. It was rebuilt, returned to service and continuous full time operation. This pump had not been instrumented to pro-

tect it from end of bushing life failure. It should have been at least inspected within that five year period, to establish the rate of bushing wear, but it was not.

Magnet drive pump use in chemical processing plants has been steadily increasing over the use of canned motor pumps. Two acknowledged reasons for this are:

• Greater acceptance at the plant site because magnet drive pumps can be overhauled onsite, therefore do not have to be decontaminated to ship outside the plant.

• The tendency to be more forgiving of abuse.

POWER GENERATION

Other high suction pressure applications of note include those at a laboratory of a supplier of nuclear power plants for the U.S. Navy. Ten smaller pumps have been in operation since 1978, handling water at 650°F and 2500 psi suction pressure. The pure carbon bushings in these pumps have averaged over 12,000 hrs life, one unit having operated over 20,000 hrs. This is interesting considering the zero lubricity of water above 600°F and the fact that ANSI B73 calls for a minimum bearing life of 17,500 hr.

Probably the service best performed, certainly the most common single application for magnet drive pumps, has been heat transfer fluids, ranging from − 100°F to 750°F. While average mechanical seal life at higher temperatures in such service is generally considered to be about six months, magnet drive pumps have proven themselves capable of many years of operation, the only maintenance being normal lubrication of external bearings of the pump and motor driver. They have also proven to be superior to mechanical seals where rapid temperature cycling is required in a process. The development of the unique eddy current type magnetic coupling, described later, made this possible.

A recent outstanding example of pump life is the magnet drive pump, which in 1987 received its first carbon bushing replacement after operating in a New Hampshire plastics plant over a period of fourteen years, pumping Dowtherm A at 638°F to 642°F.

Experience gained with magnet drive pumps in heat transfer fluids prompted one company to convert three polystyrene plants to magnet drive pumps and commission one of the world's largest magnet drive pumps for their affiliated company in Venezuela (Figure 3). This pump is rated 3000 gpm at 36 ft total head. Two similar magnet drive pumps rated 2100 gpm have
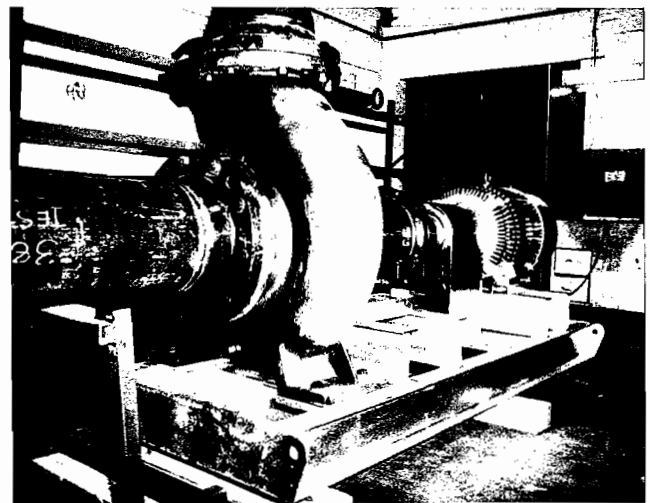

Figure 3. Largest Heat Transfer Oil Service Magnet Drive Pump, Rated at 3000 GPM at 36 FT Total Head.

been in operation in Massachusetts since 1983, with only routine maintenance. One pump, the only one operated, was inspected in 1989. Bushing wear was found to be negligible and the pump was returned to service with its original bushings.

One of the first magnet drive pumps to be placed in service was recently retired after 34 years. This unit was within the containment shell of the UK Atomic Energy Authority reactor "Pluto," circulating heavy water. The pump was inspected every five years and bushings replaced, regardless of amount of wear. The only spares utilized over these 34 years were these bushings.

MARINE

On modern ocean going vessels, there are few maintenance engineers. ship owners are looking for long life, reliable low maintenance pumps. In analyzing pump problems, the primary reason for stoppage is premature failure of, or excessive leakage from, dynamic seals.

A French company in St. Nazare is fitting each of three luxury cruise liners with six vertical inline magnet drive pumps (Figure 4) to recirculate chilled water through the air conditioning system. Each pump is rated at 3500 gpm at 80 ft head and is driven by a 175 HP motor. The decision to install sealless pumps was an economic decision based on the high cost of maintenance aboard ship. The possible considerations involved in such a decision are displayed in Table 1.

Figure 4. Largest Vertical Inline Magnet Drive Pump, Rated 3500 GPM at 115 FT Total Head.

Table 1. Magnet Drive Pumps in Refinery Applications.

REF NO.	APPLICATION	PUMP TYPE	SERVICE LIQUID	GPM	TDH-FT	TEMP. °F
1	ACID RERUN	1S2HCL	HYDROFLUORIC ACID	16.5	172.2	93 2
2	CAUSTIC SUPPLY	P1DCH	CAUSTIC & HEROXSOLIN	32.56	111.52	95
	" "	P1DCH	CAUSTIC SOLUTION	33	82	86
	" "	11S2/A2H	CAUSTIC SOLUTION 20% WT	92.4	66.912	113
	" "	HSOH	CAUSTIC SOLUTION	2.816	50.184	104
	" "	CT1DSH	CAUSTIC SOLUTION 20%	10.56	114.80	86
3	COMPRESSOR SUCTION DRUM	P1DSH	PENTANES	11	32.8	39.2-150.8
4	OFFSHORE and/or PIPELINE	HC1L/HSP	CRUDE OIL + WATER TRACES	24.64	29.59	195
	"	P4FSX2	CRUDE OIL	189.20	885.6	255.2
	"	P1DSH	CONDENSATE	44	172.2	86
	"	P2DSH2	WATER	25.52	334.56	80.6
	"	P2DSH	CONDENSATE/WATER	74.8	36.08	122
	"	P2DSL	CRUDE OIL	220	68.88	716
	"	11P1CCH-105	CRUDE	13.2	16.4	
	"	11P1CCH-105	CRUDE	.396	16.4	
	"	11C1L/HSP	SOUR CRUDE OIL	44	16.4	86/194
5	DETERGENT ALKYLATION PLANT	P4FSL	BENZENE/ALKY 11F ACID	1188	66.25	104
	"	PAL1KSH	ACID SOL	20.24	98.4	150.8
	"	CS1DSL	5% NAOH SOL	40.04	56.41	150.8
	"	AL2EXGD 112CH	BENZENE 11F ACID	85.448	265.35	86
	"	AL2DSH	CRUDE ALKYLATE TRACES 11F	35.64	195.81	383
	"	AL2DCH	11F ACID TRACE 1120 11YDROCARD	13.904	189.91	86
	"	CS2DCH	BENZENE	11.88	13.77	86
	"	AL1DCH	AQUEOUS CAUSTIC SODA + 11F	44	82	86
	"	CT1DCH	CAUSTIC SOLUTION	44	114.8	86
6	DEWAX	CSJ2ECH	WAX SOLVENT MIXTURE	120.12	574	-4/122
	"	CSJ2ECH	WAX/SOLVENT	120.12	239.44	-4/122
	"	CSJ3ECH	SLACK WAX	220	177.12	140
7	FLARE DRUM RECIRCULATION	P1DSH	CONDENSATE	66	65.6	-4to608
8	GENERAL REFINERY	AL1DSH (SP)	SOUR WATER (WATER +112S)	5.72	120.38	122
	" "	P2DSH-11P	LPG	59.84	152.52	104
	" "	CT1DSH	WATER + 112S	11	131.2	122
9	LUBE OIL PLANT	PJ4F3112	KUWAIT SHORT RESIDUE	182.16	459.2	698
	" " "	PJ2ESH	RC 7811 + 35% TOLUENE	110	100.04	104
	" " "	P4F3112	EXTRACT MIX & FURFURAL	215.6	349.65	343.4
	" " "	CS1DCH	FURFURAL	17.6	62.32	104
	" " "	CSJ3ECH	SLACK WAX	220	177.12	140
10	PP TREATER	AL1CSH	WATER+112S+CO2 HERCAPTONS	8.228	54.45	95
	" "	CS1DCH	DI-ACETONE ALCOHOL	8.8	119.49	242.6
	" "	CS2ECH	SOUR WATER	198	98.4	194
	" "	CS3GFSL	DEHON WATER	871.2	59.04	77
	" "	CS1CSH	SOUR WATER	6.688	118.08	59-104
	" "	CS2DCH	SOUR WATER	55.44	132.84	59-104
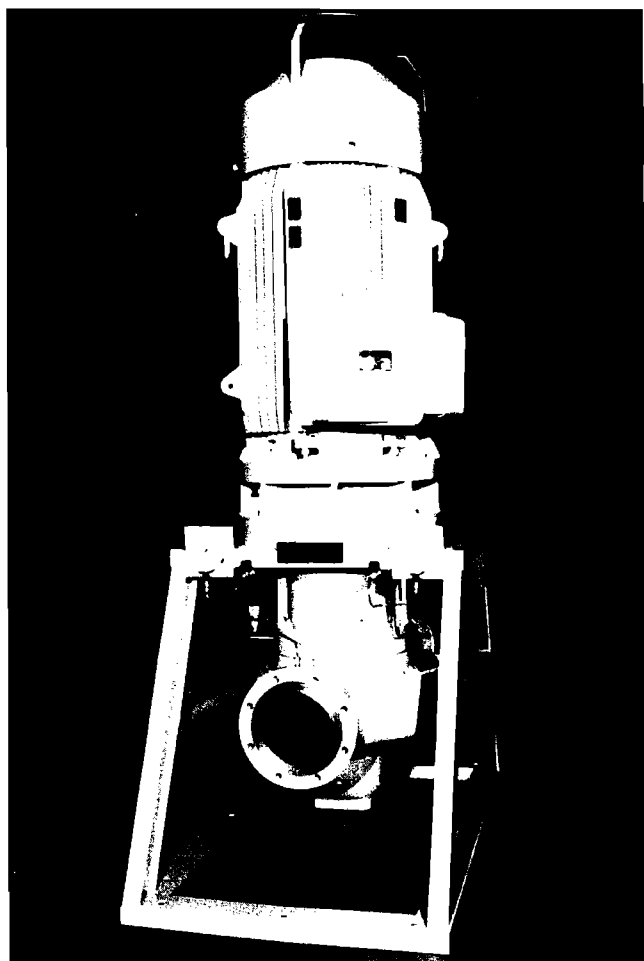
One of the most demanding applications of the magnet drive pump in recent years is in raw unscreened seawater service aboard British Royal Navy nuclear submarines [1]. (The desirability of having a pump that cannot leak in submarine service is most obvious). In addition, naval machinery must have high reliability, low maintenance, durability, low first cost, and must be shock resistant and essentially silent. In eliminating mechanical seals, the magnet drive was selected over the canned motor pump, (Figure 5) because of 1) the tendency for sand and silt to build up in the fine clearances of the motor cooling circuits of the canned motor pump, and 2) the fact that the "can" which separates the seawater from the electrical windings of the motor
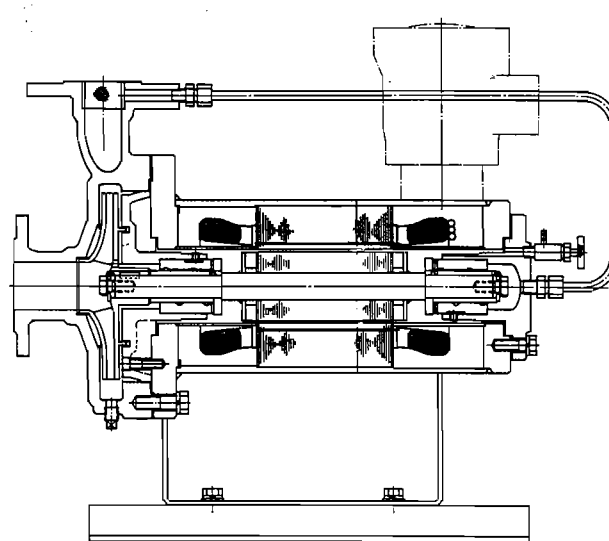

Figure 5. Canned Motor Pump Cross Section (Courtesy Goulds, Inc.).

must necessarily be thin and may be breached easily. It can be said that generally the thickness of containment of a magnet drive pump is four to five times that of a canned motor pump. The minimum clearances are generally at least twice those of a canned motor pump.

This magnet drive pump design incorporates silicon carbide on silicon carbide bearings because of its excellent wearing characteristics. It has the ability to grind solids passing through the bearing into fine particulates which can pass harmlessly through the rest of the pump. While silicon carbide cannot survive even minimal dry running, a frequent occurrence in commercial application, the danger in submarine service is minimal. The major design considerations are accommodating its low coefficient of thermal expansion to its metallic counterparts, and nondestructive testing of the material itself to obviate flaws which tend to be common in the material.

In excess of eighty units from five kW to 22 kW have been produced for the Royal Navy (Figure 6). Much of the technical information is classified. The production units are designed for flow rates to 1300 gpm at 1750 rpm. Testing has been done on units over 6000 gpm in capacity.

Figure 6. Magnet Drive Seawater Pump after Two Years of Service in a Royal Navy Submarine.

REFINING

With thousands of magnet drive pumps operating satisfactorily for many years in the chemical processing industries, it is interesting that only a few hundred have been placed in refinery applications around the world. Eleven different existing applications are listed in Table 2 of magnet drive pumps from one manufacturer. Many of these have been operating satisfactorily for six to seven years.

The largest number of magnet drive pumps operating in one refinery are at a large Western Australia refinery. There, products such as caustic soda solution, HF acid, and benzene have

Table 2. Magnet Drive Pumps at an Australian Refinery.

PUMP TYPE	SPEED	SERVICE	LIQUID	GPM	FT	°F
PJ4F3HZ	2900	LUBE OIL PLANT	KUWAIT SHORT RESIDUE	182.16	459.2	698
P1DCH	2900	CAUSTIC SUPPLY	CAUSTIC & MEROXSOLIN	32.56	111.52	95
P4FSL	2900	DETERGENT ALKYLATION PLANT	BENZENE/ALKY HF ACID	1188	66.256	104
P4F3HZ	2900	CHARGE PUMP - LUBE OIL PLANT	EXTRACT MIX & FURFURAL	215.60	349.65	343.4
CSJ2ECH	2900	DEWAX PUMPS	WAX SOLVENT MIXTURE	120.12	574	-4 122
SP1DCH	1450	GEN. REFINERY	OIL SLOPS	462	28.86	104
CS1DCH	2900	LUBE OIL PLANT	FURFURAL	17.6	62.32	104
AL2EX20 H2CH	2900	DETERGENT ALKYLATION PLANT	BENZENE HF ACID	85.45	265.35	86
AL2DSH	2900	DETERGENT ALKYLATION PLANT	CRUDE ALKYLATE TRACES HF ACID	35.64	130.22	383
AL2DCH	2900	DETERGENT ALKYLATION PLANT	HF ACID TRACE H20 HYDROCARBON	13.904	189.91	86
CS2DCH	2900	DETERGENT ALKYLATION PLANT	BENZENE	11.88	13.776	86
AL1DCH	2900	DETERGENT ALKYLATION PLANT	AQUEOUS CAUSTIC SODA & HF	44	82	86
CT1DCH	2900	DETERGENT ALKYLATION PLANT	CAUSTIC SOLUTION	44	114.8	86
CSJ2ECH	2900		WAX/SOLVENT	120.12	239.44	-4/122
CSJ3ECH	2900	LUBE OIL PLANT WAX TRANSFER	SLACK WAX	220	177.12	140

been pumped by magnet drive pumps since 1982. In 1981, this refinery made an extensive study of operating experience in both the chemical processing and refining industries in Australia and the U.K. before embarking upon a program to develop experience in this type of sealless pumping. The refinery's investigations showed some initial problems caused by process upsets, incorrect specification of process conditions, or improper operation, but after resolution of those problems, the magnet drive pumps have either not been touched at all for maintenance or have achieved three to four years of operations without maintenance. (Some units have recorded runs of five, six, and seven years). This study resulted in decisions to install the pumps described in Table 3.

Table 3. Factors in Overall Cost Comparisons—Pump.

INITIAL COSTS	OPERATING COSTS	CONSEQUENTIAL COSTS
System Design	Maintenance	Production
Purchase Price	Replacement Parts	Standby Units (Capital & Interest)
Installation	Power Consumed	Damage
Start-Up	Loss of Fluid	Health
	Training Personnel	Pollution
	Interest of Value of Spares Stocked	Penalties
	Monitoring	Admin. Costs (Reports of Spillage) Public Relations

WHY USE MAGNET DRIVE PUMPS

Early development of the magnet drive pump was pioneered by Geoffrey Howard of H.M.D. Pumps, Limited, in the U.K. in the late 1940s, and a few years later by Franz Klaus in West Germany. This development was in response to a need for 100 percent containment of diphyl heating fluids, since at that time, development of mechanical seals had barely started, and all dynamic seals were prone to leakage, especially at elevated temperatures. Two companies pioneered the use of magnet-drive pumps: Imperial Chemical Industries in the U.K. and Bayer in West Germany.

Mechanical face seals require lubrication if they are to have a useful working life. Two lubrication modes are inherent in most

contact seals; 1) hydrodynamic, when the seal is running normally at speed, and 2) boundary lubrication when starting or stopping. Hydrodynamic lubrication requires a one to three micron fluid film between the stationary and rotating faces. This explains why seals are so sensitive to slight distortions resulting from hydraulic forces, temperature gradients, or external forces. In addition, the mechanism is dependent upon the proper selection of materials compatible with the fluid and able to withstand the mechanical stresses and corrosive conditions to which its precision parts are necessarily exposed.

Fragility of mechanical seals is one concern. Another is the fact that a mechanical seal must leak in order to function. As the hydrodynamic fluid vaporizes, cooling the seal faces, there is a continuous vapor emission into the environment. Referring to single mechanical seals, a study of vapor emissions from rotary seals reported by the British Hydro mechanical Research Association in 1980 [2] states, "seal emission levels were found to be considerable, even when the pump was stationary. On occasion, a fivefold increase was observed as the pump came to rest." In this study, 69 seals were examined and all were leaking a measurable quantity of vapor. The overall range of measured vapor emission values was 0.3 to 70 grams/hour. The average would be 11.6 drops per minute, considerably more than one might casually visualize.

This inherent face leakage leads to utilization of the concept of seal environmental control. This means controlling (1) the thermal environment of the seal, (2) the pressure differential across the seal, (3) the lubricant availability or (4) the concentration of solid contaminants. These measures require auxiliary piping and ancillary equipment such as control valves, pressure vessels, filters, coolers, flowmeters, and on and on. The system provides for emission free pumping, but only if the seal does not fail and the system is properly maintained and operated. This complication exacts a substantial price both in cost and reliability.

Both the magnet drive pump and the canned motor pump have provided an answer, a means of absolutely preventing leakage. Over most of the past 30 years, their application was limited essentially to pumping life threatening or extremely hazardous fluids. Because of the higher cost of the equipment and possibly the stigma of some unsuccessful or unreliable products that came on the market, sealless pumps tended to be considered categorically by many as the solution of the last resort. However, by the 1970s, enough experience had been gained in the chemical processing industries to bring some engineers to the conclusion that the magnet drive pump had been developed to the point that it had become the most economical solution in many process systems.

The increased concerns of management over safety and the environment has led to a broader analysis of pumping costs (Table 1) which favors the magnet drive pump in many systems. While initial costs of magnet drives pumps are usually higher, projected operating costs and evaluated consequential risks frequently outweigh this initial cost difference where.

• Site conditions dictate the use of double or tandem mechanical seals.

• Seal support systems are expensive or unreliable.

• Fluid is toxic or radioactive.

• Mechanical seals are unreliable because of very low temperature or very high temperature ($-100°F$ to $850°F$) or temperature transients are extreme.

• Mechanical seals are unreliable because of the subatmospheric or extremely high pressures.

• Explosive or volatile liquids, which vaporize at mechanical seal face, are pumped.

• Liquids pumped solidify on contact with air.

• Pure fluids must not be contaminated bacteriologically.

• Products are so valuable that even minor spillage is cost prohibitive.

The adoption of scheduled preventative maintenance and the use of the magnet drive pump makes possible continuous, reliable pumping without leakage. Mechanical seals generally give no prior warning of impending failure. Planned maintenance, providing for replacement of internal bushings before end-of-life on a routine basis, enables a magnet drive pump to operate continuously without leakage. The cost of replacement bushings roughly approximates the cost of a replacement double mechanical seal in most cases. The frequency of bushing replacement is normally less, since bushing adequacy to its task is measured in mills instead of light bands, as is a mechanical seal's.

DESIGN CONCEPT

General

A magnet drive centrifugal pump closely resembles a conventional centrifugal pump with an integral magnetic coupling imposed between the driver and the pumping unit. The pumping unit is hermetic. Power to drive the impeller is transmitted through the containment shell, located behind the impeller, by a magnetic field which turns a driven inner magnet ring or torque ring within the pumping unit. It is in turn connected to the impeller or its shaft (Figure 7).
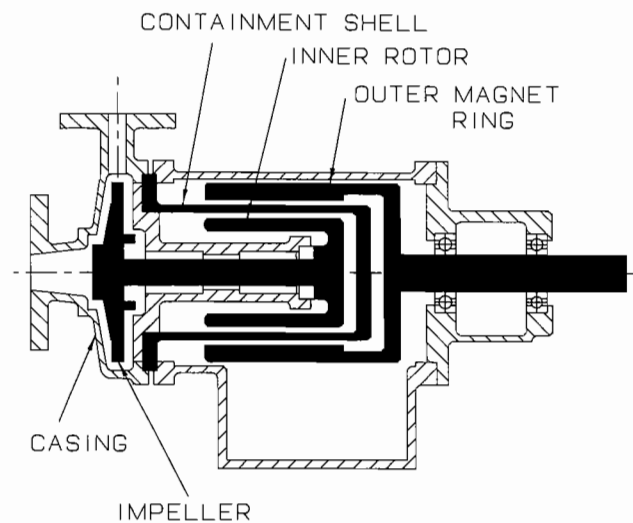

Figure 7. Magnet Drive Pump Components.

Magnetic Couplings

The driving unit of a magnetic coupling (outer magnet ring or OMR) employs banks of high strength permanent magnets, magnetized and stabilized before use. There is no demagnetizing from aging, and under proper operation, the magnets will never lose power. The only cause of degradation is extreme temperature.

The driven unit of the magnetic coupling within the hermetic enclosure incorporates either, 1) corresponding banks of similar magnets which cause it to rotate in synchronization with the driving or outer magnet ring, or 2) a squirrel cage arrangement of copper bars, which causes it to follow the outer magnet ring at a slightly lower speed. The former is called a "synchronous coupling," the latter an "eddy current coupling," or "torque ring coupling." Slip in the eddy current coupling is proportional to

the liquid end power requirements, normally 1.5 to three percent. Interestingly, power loss varies directly with the power transmitted.

The advantages of the eddy current coupling are:

• Excellent abuse factor with no magnet damage, even when fully stalled. It cannot decouple.

• High starting torque characteristics with couplings selected, so that they cannot overload the prime mover.

• For liquids such as heat transfer fluid with "cold start" viscosity, the eddy current drive will slip on startup and then speed up with temperature. A synchronous coupling sized for cold viscosity would be inefficient when running at "hot" reduced load condition.

• Similarly for low specific gravity liquids, a standard pump with synchronous drive would have excessive power loss since pumps are sized to test on water. Eddy current drive power loss is proportional to transmitted power and reduces with lower specific gravity.

• For pumping liquids with a high percentage of ferrite particles, there are no magnets in the product area and, therefore, no buildup in the coupling. One large New Jersey pharmaceutical plant has banned the use of synchronous drive pumps after experiencing such a buildup of particles of iron from tower packing.

• Perhaps most significant is the higher temperature capability, since there are no temperature limited magnets subject to process temperature.

The advantages of the synchronous coupling are:

• Where performance must be obtained from certain dimensional constraints, and slip would not be compatible with this performance.

• At low input speeds where slip of an eddy current coupling would represent a significant reduction in performance.

• For high specific gravity liquids, where maximum power is required for minimum dimensional configuration.

• For maximum efficiency at design flow. For lower flows, efficiency may not be optimum because synchronous coupling loss is constant, while eddy current coupling loss varies with power transmitted.

The synchronous coupling utilizing rare earth magnets is slightly more efficient overall than the torque ring coupling. However, since synchronous coupling loss is constant, this advantage is somewhat limited by sizing problems, matching the rating of the coupling to the driven load or the motor size and, in addition, the over sizing required to overcome the starting torque of the standard electric motor. The use of clutches or soft-start electrical equipment will permit higher magnet drive pump efficiency, but add to cost and complexity of the system.

Efficiencies of modern magnetic couplings generally range from 85 to 95 percent. This results, in many applications, in the motor driver being one size larger for the magnet drive pump than it would be for a conventionally sealed pump. (A canned motor pump motor would similarly be large.) For example, a magnet drive or canned motor pump will often require a 25 hp driver where a conventional pump requires 20 hp sizing.

Containment Shell

The containment shell of a magnet drive pump is constructed from a material having high electrical resistivity properties for good coupling efficiency. Hastelloy C is normal for all but the smallest couplings, which may be of austenitic stainless steel. Other alloys can be used if liquid characteristics require. They are usually designed and manufactured to ASME Section VIII Standards. Typical wall thickness is 0.060 in for pumps rated at 300 psi, and it can be up to 0.120 in for system pressures of 5000

psi. Running clearances between the containment shell and inner magnet or torque ring are generous, being radially 0.030 in minimum with an increase for large pump sizes.

The area of the metal containment shell that lies between the outer magnet ring and the driven ring is subject to temperature rise when the coupling is in operation. This area experiences the highest temperature that occurs in a magnetic coupling, including the bushings. This heat must be continually removed while the pump is in operation, by flushing the inside surface with a small amount of pumpage, normally two to three percent of the pump design flow. This flow maintains a temperature rise in the containment shell ranging from 3°F to 5°F on water/water based liquids and 8°F to 15°F on hydrocarbons of low specific heat. Failure to provide this flow will ultimately result in demagnetizing the rare earth magnets in a synchronous coupling and ultimately seizure of parts due to thermal expansion of the inner magnet ring or torque ring. It is, therefore, necessary to protect against dry running, wherever the potential for it exists.

This can be done in a number of ways; for example, a tip sensitive thermocouple is often used to sense the external temperature of the containment shell and provide a signal to a controller for shutdown of the driver. Other devices used are differential pressure switches and power sensing devices which function with power upsets.

CONFIGURATION

Today magnet drive process pumps are available for flows from five to 5000 gpm and heads normally consistent with conventional single stage process pumps. In lower flows, two stage and three stage pumps make heads up to 1000 ft possible. One of the largest units built, shown in Figure 3, is a 3000 gpm, 65 ft total head magnet drive pump for heat transfer service in Venezuela.

The pump and driver arrangement most often consists of a horizontal end suction pump with close coupled D-flange or C-face motor driver (Figure 8). Second in popularity and prevalent above 20HP is the conventional frame mounted arrangement on a baseplate with a flexible coupling and foot mounted motor (Figure 9). In addition, vertical inline (Figure 5) and vertically extended shaft pumps are offered.
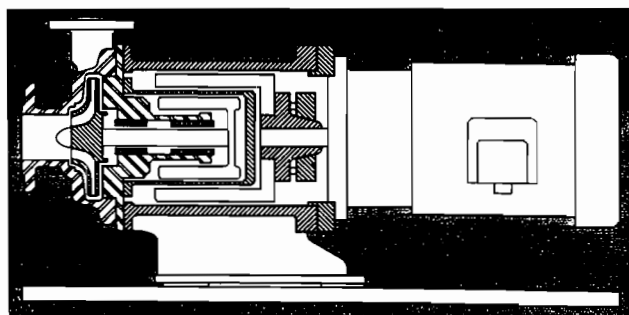

Figure 8. Close Coupled Magnet Drive Arrangement.

Functional arrangements include, in addition to the conventional magnet drive centrifugal:

• Self priming pumps designed for unloading services from the tops of vessels where bottom opening is prohibited.

• Jacketed pumps to provide flexibility in shutting down and starting up processes in which fluid is a solid at ambient temperatures.
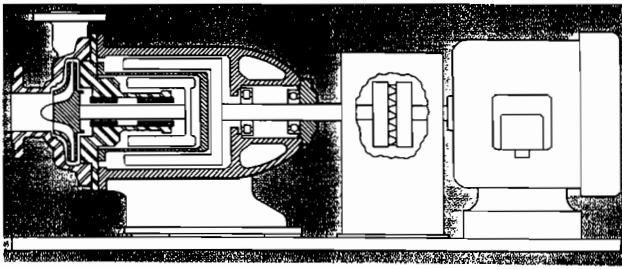
• API-610 pumps for refinery service.

Figure 9. Frame Mounted Magnet Drive Arrangement.

• High suction pressure pumps to circulate fluid in a high pressure system (to 5000 psig).

• Small regenerative turbine pumps for low flow, high head service.

Materials of Construction

Materials of construction are similar to those of conventional pumps. Note that the containment shell must be a non-ferric material with high electrical resistivity. Common pump liquid end construction materials are 316 SS, carbon steel, Alloy 20, Hastelloy C, Hastelloy B. Nimonic 90 and Inconel 718 are used in high pressure, high temperature units. A range of plastic materials are available from certain manufacturers for corrosive services, including PTFE, Kynar and others. These are often accepted for the most aggressive services where suitable metallurgy is nonexistent or where the cost of suitable alloys makes the physical limitations of plastics a secondary consideration.

APPLICATION AND OPERATION
General

Operation of a magnet drive pump is normally maintenance free for periods of years if the pump is not run dry and is properly operated on its curve with adequate NPSH. General application parameters are 1) − 100°F to 850°F, 2) viscosity limit up to 100 to 200 cp, and (3) solids limited to 1.5 percent (weight), 100 microns and smaller.

What You Should Not Do

As pointed out before, dry running will damage a magnet drive pump in a short time.

The inherently rugged design and bearing support make it possible to operate most magnet drive pumps continuously at only 10 percent of the best efficiency point (BEP), as opposed to 20 to 30 percent for most mechanically sealed volute centrifugal pumps. (This may be limited by temperature considerations with some heat sensitive liquids). On the other hand, running a magnet drive pump well beyond BEP can result in accelerated thrust bearing wear and in some cases overheating if pumping temperature sensitive fluids.

Services and process upsets that tend to slam and bang a pump back and forth across its performance curve will shorten the bearing and seal life of conventional sealed pumps. In a magnet drive pump, it will cause premature thrust bearing wear and is never recommended.

It is important to note that while the above describes three ways to seriously damage any pump, none of these should cause a magnet drive pump to leak unless the pump is driven to total destruction. Conventional mechanical seal fitted pumps would be most likely to leak under all of these stressed situations.

IMPROVEMENT IN MAGNETS

The magnet drive pump has been under development for over thirty years. Until 1978, all development work in the field of process magnet drive pumps was carried out with metal (Alnico) magnets and substantial improvements were made up to that time (Figure 10). After 1978, rare earth materials with reasonable prices appeared on the market for the electronics and hifidelity industry. These materials enabled engineers to greatly advance the state of magnet drive technology. Utilization of these materials has enabled a threefold to fourfold improvement in the amount of power that can be transmitted within the space envelope of a magnet-drive.
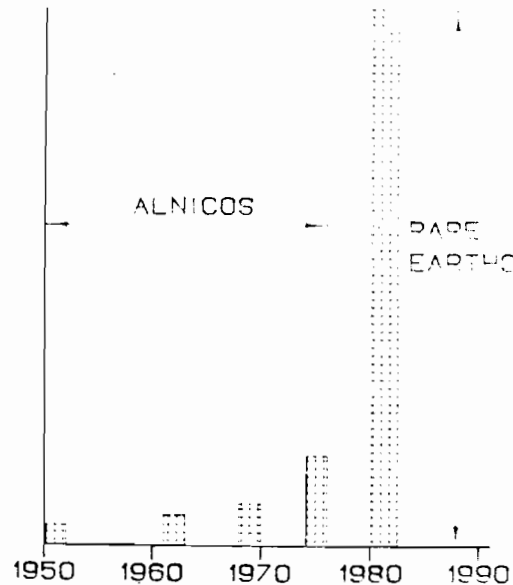

Figure 10. Increase in Magnetic Coupling Performance.

The difference in the material can be seen by inspecting the BH curves (Figure 9). Alnicos possess high flux potential (B) and should therefore exert a high pull. However, their low coercivity (H) which is their resistance to demagnetization means that in practice they operate at very low flux levels. When subjected to high demagnetizing force such as "pulling out-of-step" in a synchronous coupling, they can lose magnetism. This makes them generally less suitable for synchronous couplings.

The rare earths, however, start off with a lower flux potential (BN), but have extreme resistance to demagnetization. They, therefore, retain their original level under the condition of desynchronization described above.

The disadvantages of rare earth magnets lie in their fragility as compared with metal magnets, their relatively high assembly cost and the fact that most must be limited in operating temperature to 392/482°F whereas Alnicos can be used up to 842°F. The Curie point of the Alnico magnet is 1562°F, but standard pump design is limited to 842°F. The Curie point is the temperature at which the magnet starts to loose magnetism as the result of heat.

Continued development has allowed the efficiencies of magnet drives to be increased from typically 60 percent in the early 1960s to the current 80 to 90 percent. This allows them to compete much more effectively with mechanical seal systems (Table 1).

EXPERIENCE WITH BEARINGS IN
MAGNET DRIVE PUMPS

Possibly one of the reasons that magnet drive pumps have not been more fully utilized is the concern of some engineers over
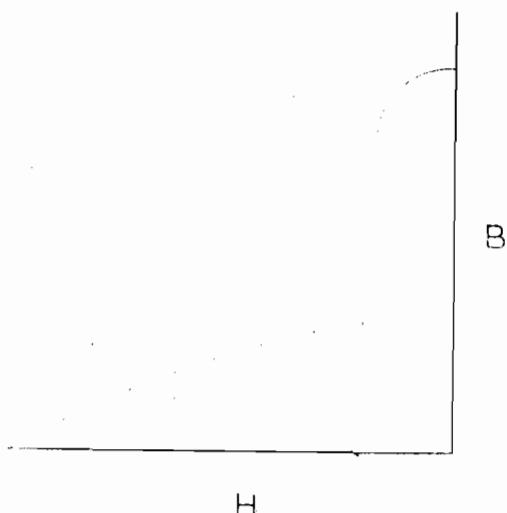
Figure 11. Magnet B/H Curves.

having bearings (bushings) in the process fluid. Recognizing that the application of these pumps is presently on relatively clean liquids of low viscosity, a category into which the majority of pumping applications fall, it may be reasonable to make comparisons between "bushing and shaft life" in a magnet drive pump and "shaft, mechanical seal and antifriction bearing life" in conventional sealed pumps in order to quantify this concern. This would seem to be a functionally correct way to make one comparison between sealed and sealless pumps.

With no actual test data to be offered, conclusions can only be drawn from the experience of the reader. However, the following facts are believed to be generally accepted by those knowledgeable in process pumping. The two major causes of process pump failures have been 1) mechanical seals and 2) bearings [3]. It is well recognized that these failures are interrelated in many cases, one precipitating the other. The minimum rated life of ANSI B73.1 pump bearings is 17,500 hrs at maximum load. Mechanical seal life varies widely, but two to three years of life would generally be considered excellent. The writers' feedback from many maintenance engineers has painted a picture of the combination of bearings and seals seldom approaching two to three years of life in the real world.

Compare this experience with the operating experience of magnet drive pumps. Spare parts order records of one manufacturer and field reports support the conclusion that average bushing life is three to five years in typical magnet drive pump service. Ten years operation with original bushings has been achieved in a number of instances. Perhaps some of the concern over internal bushing life in the U.S. comes from over 25 years of experience with canned motor pumps where inherent close clearances cannot provide the longer term wearing capability which is common in magnet drive pumps.

By far the most common bushing material in use in magnet drive pumps today is special plain carbon. Bushings are sometimes pressed but most often are an interference fit to handle higher temperatures, pinned for the highest temperature services. Carbon is consistent in performance with a fluid and has good lubricating qualities that will normally enable a pump to survive a period of dry running, provided it is short enough so that the pump itself is not damaged. (Dry running is a fact of life with most pumps at one time or another). With essentially no binder to be attacked, carbon is suitable for all but a few services throughout the range of magnet drive pumps. Bushings are provided with spiral grooves of about⅛ in diameter on the ID to permit solids to pass through the bushings. They are combined

with hardened shaft journals, except where bushings are lightly loaded and the hardening is not required to obtain satisfactory shaft life.

Acids such as sulfuric acid and nitric acid do not attack plain carbon, but electrolytic damage makes many carbons unsuitable. Filled PTFE versus 316 SS has proven to be satisfactory in these services, although not as consistent as carbon, with a tendency to cold flow and to swell in the presence of certain chemicals. This bushing material, like plain carbon, has good lubricating properties and will survive short duration dry running. Shorter maintenance intervals must be planned when this material is initiated because of the inconsistency cited. PTFE bushings may be carbon filled, glass filled or mica filled, each having different chemical compatibility. The temperature range of PTFE as a bushing bearing is limited to 250°F, whereas carbon is suitable for the full range of magnet drive service, − 100 to 850°F.

For abrasive service, unusually high bearing loads, and corrosive services where PTFE is inadequate, silicon carbide *vs* silicon carbide bushings and journals are recommended. They have the advantages of extremely high load capacity compared with carbon or PTFE, and they are more tolerant of solids and abrasive material. The negative aspects of their use are, 1) higher cost, 2) complexity of detail design, because of the need to provide for different coefficients of thermal expansion with this very brittle material, and most significantly, 3) the inability to tolerate even a short period of dry running, which makes it much less abuse resistant than other materials described. Fragments of a failed silicon carbide bushing can cause extensive damage in a pump.

Other bearing materials that have been tested with magnet drive pumps, such as asbestos filled phenolic and other ceramics, have not found wide usage and have not proved to be equal in most applications to those described.

THE FUTURE

It appears that development of magnets has leveled off, but only for the immediate future. Progress will lie in continued development of the magnet drive pump as it exists today. Economic advantages to the user will increase with the users' increased awareness of the benefits of sealless pumps and the resulting economies of scale.

The magnet drive pump has been developed to the point where its qualities, both technical and economic, should cause it to be perceived as the pump of choice for most processes and systems where leakage of product is undesirable.

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