Sundyne

White Paper

HMD Kontro

The Application Of Sealless Magnetic Drive Pumps

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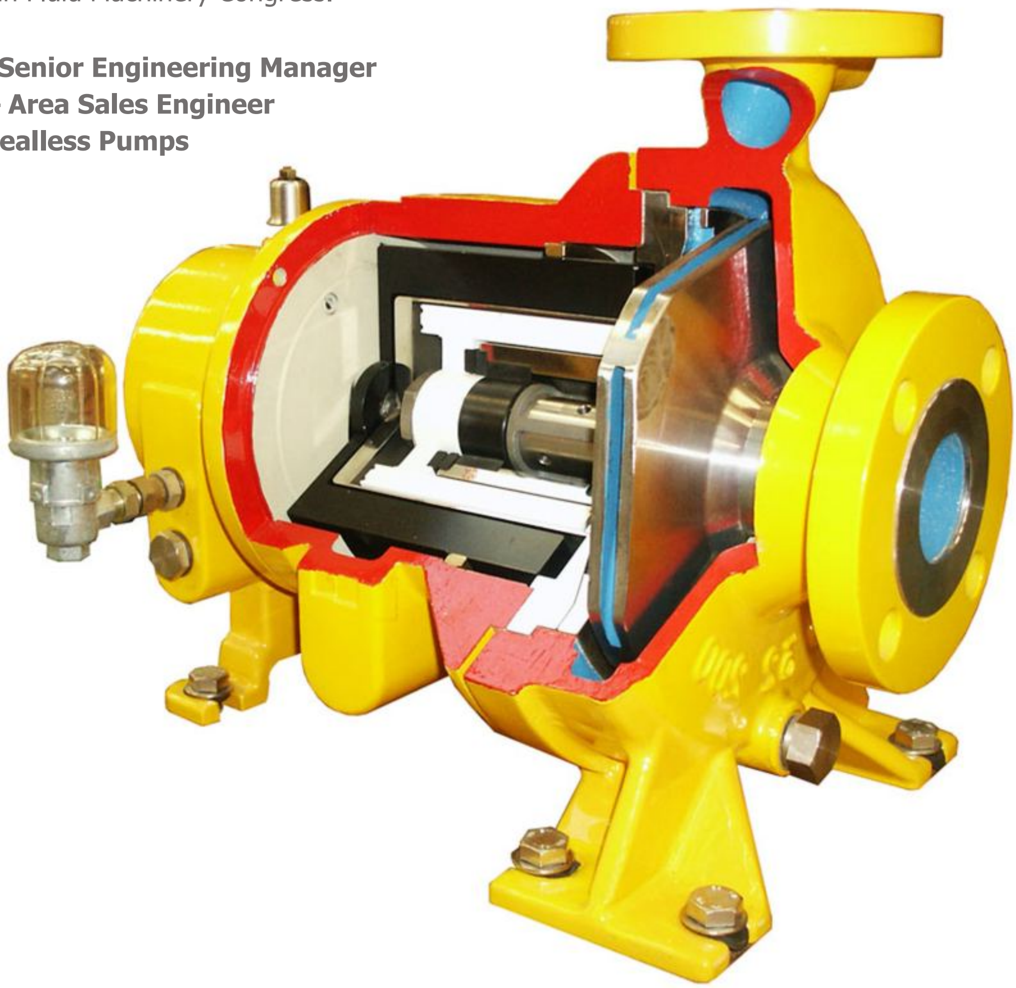


Abstract

Sealless magnetic drive pumps give total containment of the pumped process liquid, which in an industry where there are tightening environmental constraints on plant operation and increasing health and safety requirements, offer real advantages of reliability and safety to users.

This paper, using the API 685 standard as a basis describes the key design features of magnetic drive pumps as well as the potential failure modes and the protective systems and design features that can be put in place to monitor and protect the pumps in a petrochemical plant environment.

As with any piece of machinery, magnetic drive pumps have an operating envelope where their use is to be recommended. The factors which determine efficient and reliable magnetic drive pump application are described (such as power, head, flow, fluid cleanliness, NPSH available, fluid properties etc.) and the data presented upon which the criteria were determined.

Some case studies are then presented showing successful applications illustrating reliability and safety.

1) Introduction

1.1 A brief history

The first magnetically driven pumps (MDP's) were manufactured in 1947 by HMD Sealless Pumps Ltd, Eastbourne, UK. The 60 year evolution of magnetics and associated drive technology has led to the availability of high quality, high integrity, economical zero leakage pumps that comply with ISO, ANSI and API design standards and offer significant advantages over equivalent mechanically sealed designs.

The hydraulic coverage of such designs is comparable to sealed pumps, and currently powers of up to 300kw can be transmitted using this technology.

Magnetic drive sealless pumps are widely used in the chemical and pharmaceutical industries for a wide variety of liquids, they are particularly suited to liquids that are toxic, pungent, hot or corrosive as the complexity usually associated with a sealing system for such liquids is completely eliminated. Magnetic drive pumps are also now quickly gaining acceptance in the hydrocarbon processing industry where absolute safety, integrity and reliability are key factors behind rotating machinery selection.

1.2 Key design features

Basic design

The magnetic drive pump can be viewed as three parts. The hydraulic (casing and impeller), the supporting shaft and bearing system and the magnetic drive.

The hydraulic end is fundamentally the same as a traditional centrifugal pump and as such invokes energy into the pumped liquid.

At the rear of the casing, a non-magnetic containment shell is used to completely contain the liquid being pumped. This shell is rated for the same design conditions as the pump casing and is part of the pressure boundary. Inside the containment shell, the impeller is mounted to a shaft that is supported on journal bearings which are lubricated by the pumped fluid.

Attached to the shaft is an inner rotor which usually consists of a ring of permanent magnets or in some cases a torque ring, similar to that of an electric motor rotor. Correspondingly around the outside of the containment shell is an outer magnetic ring. This ring of magnets is either directly mounted on a motor shaft or is supported by some form of external bearing assembly.

The outer magnet ring is rotated by a standard electric motor. The principle of operation is that as the outer magnetic ring is rotated by the electric motor, magnetic flux is transferred through the non-magnetic containment shell to the inner magnet ring or torque ring, thus causing the shaft and impeller to rotate. [Fig. 1]

Simplicity

One of the key features of this design of pump is that it completely eliminates the need for any form of dynamic sealing device. This in turn reduces the number of potential leak paths and also removes the need for any ancillary support systems that are associated with more complex dynamic sealing systems.

Because there are no mechanical seals, there are fewer potential leak paths, no complex seal systems are necessary, they have fewer working parts and maintenance is simple.

Zero leakage

No fugitive emissions, no odours and no monitoring is required with such a system. No loss of product to atmosphere means inherent safety when pumping hazardous liquids. Usually a single, fully trapped controlled compression gasket forms the static seal between the casing and the containment shell and is designed in such a way that blow out is not possible.

Extended mean time between failure (MTBF)

Magnetically drive pumps, because of their robust design and the fact that they have no mechanical seals (the principal cause of pump failure), will generally operate for long periods without maintenance. This means that costs of maintenance and lost production are kept to a minimum and that overall life costs are reduced significantly.

Internal bearings (silicon carbide bearings)

Silicon Carbide became the standard magnetic drive pump bearing material in the 1980's. This material is one of the hardest materials available, has high thermal conductivity and a very low coefficient of thermal expansion. It is chemically inert and extremely abrasion resistant. These factors make SIC the first choice material for the internal bearing system, although in some cases carbon and other materials are utilised.

Typically pumps are fitted with two journal bearing bushes and corresponding shaft sleeves positioned behind the impeller to support radial loads. Axial loads are catered for with the use of thrust bearings designed to adequately carry the imposed hydraulic loads across the complete design flow range.

Magnetic Coupling

The introduction of high energy magnetic materials in the early 1980's has considerably increased the amount of power transmitted by the magnetic coupling. Current magnetic couplings usually feature one of two types of magnetic material – Neodymium iron boron or Rare earth samarium cobalt. Neodymium has the higher energy product but has a lower operational temperature threshold and therefore tends to be used on pumps featuring plastic construction. Samarium Cobalt, whilst having a lower energy product is able to cope with higher operational temperatures and features in metallic magnetic drive pumps which have the ability to operate with process temperatures up to 315 C. Both materials are capable of operation at sub-zero temperatures.

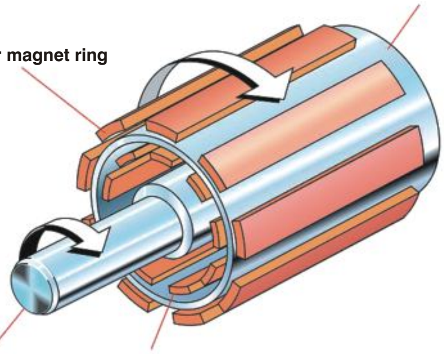


Fig. 1

By replacing the inner magnetic ring with a torque ring (similar to the squirrel cage rotor of an induction motor) the operating temperature of the coupling can be further increased to 450C without the need for any form of ancillary cooling system.

Another significant point relating to these magnetic materials and in the increase in power they provide has enabled magnetic drive Sealless pumps to be manufactured to ANSI and DIN dimensional standards.

Magnetic couplings are now available that are capable of transmitting powers in excess of 300kw (50 Hz) and 400kw (60 Hz). As a consequence the hydraulic range is now comparable to most manufacturers' ranges of ANSI and API pumps.

High pressure capability

As there are no dynamic sealing devices in the Magnetic Drive pump, high system pressures can be easily catered for. High Pressure designs suitable for system pressures in excess of 185 Bar have been manufactured and successfully applied. Typical duties in this area include Crude Oil Jet Mixing, Sampling and Hydrocarbon Condensate applications.

Temperature capability

Low temperature to minus 100°C and high to 450°C pumps are available.

2) Environmental Considerations

We live in a world where stringent environmental legislation is increasing and where "green" issues are having an impact on us all.

In the UK the Environment Agency is responsible for pollution prevention and control. It promotes "Best Available Techniques" to prevent leakage and emissions. The Key issues for pumping machinery are:

- Fugitive Volatile Organic Compounds (VOC's) emissions to Air
- Point Source emissions of VOC's to air (process release points)
- Emissions to water
- Odour
- Energy Efficiency
- Chemical analysis & monitoring of emissions

The Environment Agency has basic rules for the oil, gas, chemical and pharmaceutical industries which include minimising fugitive releases of liquid and gaseous materials at the design stage with a priority on environmental protection and a formal leak detection and repair program. Monitoring in the UK has been variable in the chemical industry and according to the environmental agency it is imperative that more consistency should be applied. There is interim guidance available and further guidance is currently being developed. [(1)]

It is calculated that 10% of fugitive emissions in refineries and chemical installations are from sealed pumps. [(2)] MDP's completely eliminate fugitive emissions and odours by their zero leakage design. Because there are no emissions there is no requirement to monitor them.

It is argued that MDP's are less efficient than their mechanically sealed equivalents because of eddy current losses in the metallic containment shell (though remember mechanical seals also use energy, high pressure seals can run at high temperatures). This means that more energy is required to power a magnetic drive pump than its mechanically sealed equivalent. The level of losses experienced in a metallic containment shell is a function of the electrical resistivity of the shell material, the thickness of the shell, the flux density of the magnetic coupling and speed the coupling is operated at. Typically high strength, high chemical resistant materials are used such as Hastelloy®. Losses can range from 5 to 15% for typical applications.

Plastic lined, non metallic magnetic drive pumps feature non-metallic containment shells and thus the eddy currents associated with a metallic containment shell are reduced to zero and therefore efficiencies are comparable to a mechanically sealed pump. The restriction with using a non-metallic containment shell is that temperature and pressure capability is reduced when compared to a metallic shell. High performance polymers and other materials are slowly gaining acceptance and it is likely that these will, in time, provide higher pressure and temperature capabilities.

3) Health and Safety Considerations

According to HSE report in October 2000 [(3)] "To handle hazardous liquids and gases safely, particularly where the plant operates under pressure, the whole of the containment system needs to be built to a high standard. There are detailed codes for pipework and pressure vessels, but there is less information about mechanical seals, although these are widely regarded as the weakest link in many containment systems."

Magnetic Drive pumps by design are leak free and therefore odour free meaning operators have less exposure to the process liquids. Liquids are contained within the pump which has a design pressure rating equal to or in excess of the pipework, pressure vessels and other ancillary equipment.

The extended mean time between failures (MTBF) means fewer repairs, therefore less handling and decontamination and disposal requirements.

MDP's therefore can contribute to a cleaner, safer working environment.

4) Overview of Api 685 Standards[(5 & 6)]

4.1 Background

The petrochemical, oil & gas industries have always tended to wait for technology to be proven before adoption of the product and this has been especially true of magnetic drive pumps.

The first magnetic drive pumps based on the widely specified API 610 standard were introduced in the 1980's. Recognizing the need for a sealless pump specification for heavy duty services in refineries and related industries the American Petroleum Institute introduced the API 685 standard in 2000 – some fifty years after its invention.

This provided further credibility for the technology and resulted in acceptance of MDP's by some of the world's largest oil companies who now see the opportunity to reduce maintenance and monitoring and to protect both their employees and the environment.

4.2 Parameters

API 685 (2000) recommends the use of the standard for sealless services that exceed the following limits:

- Discharge pressures greater than 275 psig (1900kPa)
- Suction pressures greater than 75 psig (500kPa)
- Pumping temperature greater than 300°F (150°C)
- Rotational speed greater than 3600 rpm
- Rated total head greater than 400 ft (120m)
- Maximum impeller greater than 13 inches (300mm)

API recognizes that below these limits purchasers may wish to consider sealless pumps that may not comply with API 685 for process services.

API does not give guidelines on when a sealless pump should be considered but they are especially suited for applications with the following characteristics:

- Carcinogenic
- Flammable
- Lethal
- Expensive Fluids
- Fluids containing dissolved solids (i.e. Caustic)
- Fluids containing H2S (Sour Water)
- Heat Transfer Fluids (Cold and Hot)
- High Vapour Pressure Liquids
- Toxic
- Fluids presenting sealing difficulties
- Liquids that have emissions regulated

4.3 Examples

A few examples of some of the typical liquids that API 685 pumps have been used for are:

- Hydrocarbons
- Sour Water
- Aromatics (Benzene, Xylene, Toluene)
- Anhydrous Hydrofluoric Acid
- Hydrofluoric acid
- Caustic
- Alkylate
- Methyl Mercaptan
- Aromatics (Benzene, xylene, toluene)
- Methanol
- Olefins
- Naptha
- Sulphuric Acid
- Amines
- Isobutane

4.4 API 685 Standard – some of the key points

- Minimum Service Life 20 years
- 3 years uninterrupted operation
- NPSH Margin over whole operation portion of the performance curve
- Designed for rapid maintenance
- Corrosion Resistance of liquid contact components
- Fully closed impellers
- Ability to withstand the API 610 forces & moments on the pump nozzles
- Centerline Mounted Casing
- External bearing L10 life 50,000 hours
- No lip seals allowed
- Balancing to G1.0 (ISO 1940), many manufacturers offer G2.5 as standard
- API 610 baseplates
- Mandatory Pressure v Temperature evaluation (Heat balance calculation)
- Impeller and pump case wear rings
- Secondary Control and containment options
- Drive End and pump driver removable without disturbing pressure casing
- Pump design to protect the outer magnet ring from contacting containment shell if a shaft or a bearing fails.

Whilst most of the above points are self explanatory the one pertaining to Pressure v Temperature evaluation requires further explanation:

A heat balance calculation is a means of establishing the temperature rise of the pumped liquid as it travels from the point at which it enters the pump, to the point at which it exits the pump.

The calculation establishes the bulk rise in temperature (overall temperature rise from Suction to Discharge) and the rise in temperature of the magnetic coupling cooling and lubrication flow as it travels over the Inner Magnet Ring (IMR) through the internal bearing feed system. [Fig. 2]

Why carry out the calculation?
Liquids that are pumped that are close to their boiling point need to be checked to ensure that the temperature rise in the pumped liquid is not sufficient to allow the liquid to change its state to a gas.

For such a calculation to be carried out the user needs to supply the following information:

VP Curve for the pumped liquid
The Suction Pressure (or range of suction pressures) the pump will be operate
The Specific Heat of the liquid.
The Specific Gravity of the liquid.

It should be noted that API685 mandates the need for a heat balance calculation to be carried out at the proposal stage to ensure the pump is correctly selected for the application.

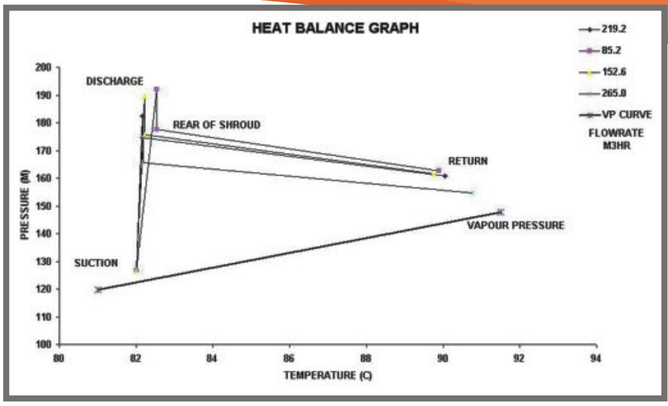


Fig. 2

5) Why Pumps Fail

5.1 Pumps fitted with mechanical seals

It is estimated that 80% of pump break downs are due to mechanical seal failure resulting in pumped liquid escaping to atmosphere or to the sealing system in the case of double seals. The remainder are due to bearing failure or gasket leaks.

Mechanical seal failures can be caused by:

- Running Dry
- Loss of seal flush/cooling or barrier fluid on double seals
- Shaft misalignment or bent shaft
- Shaft deflection caused by operating at low or high flow
- Wear of seal faces
- Failure of elastomers – due to heat or incompatibility with fluid
- Gasket failure
- Faulty installation of seals
- Bearing failure
- Excessive vibration, low NPSH
- Hang up caused by crystallisation

5.2 Magnetic drive pumps

The failure modes of MDP's are somewhat different from their mechanically sealed equivalent. Gasket failure is virtually unknown, and drive bearing failure is not usually catastrophic as it is with sealed pumps. In many cases a non-spark phosphor bronze "bump ring" is fitted so that in the event of bearing failure the outer magnet ring runs against this and not the thin walled containment shell hence limiting the damage.

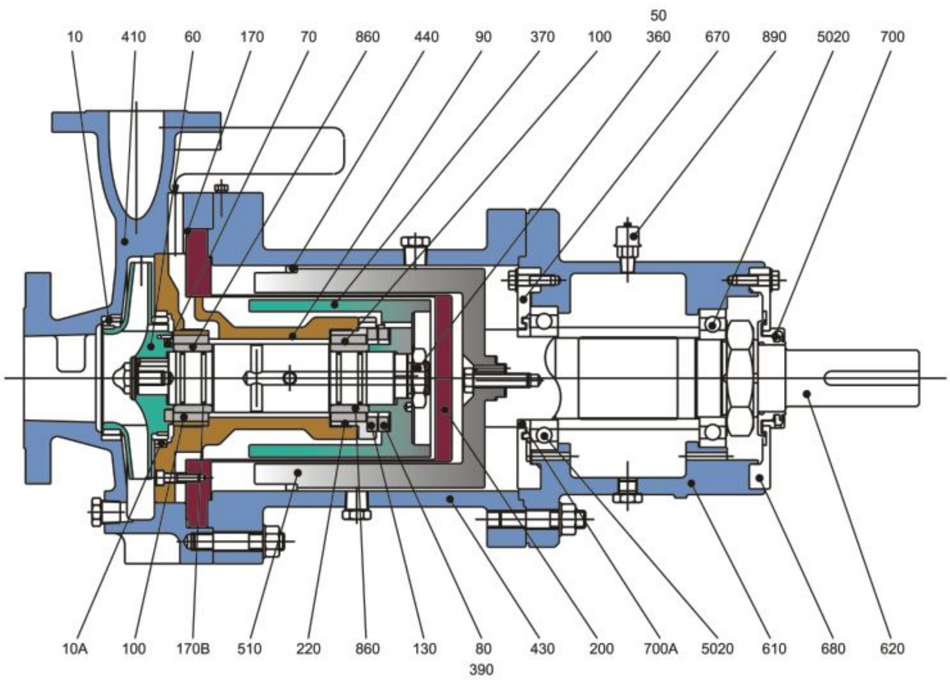
Shaft deflection is not usually an issue with MDP's, as the overhang from the closest bearing is very short – unlike mechanically sealed pumps. Consequently there is little deflection and little damage to the impeller and renewable rings.

Although MDP's have an extended MTBF, they do fail occasionally and experience shows that this is usually due to process upsets such as running dry, running with a closed suction or discharge valve, cavitation/vapour in the pump or high flow overload. The extent of damage can vary from internal bearing failure to damage of magnet rings and potential breach of containment shell.

5.3 Pump protection

In most cases the pump can be protected using an inexpensive power control monitor. This simple device monitors the actual power absorbed and will cut out the pump if it falls below a predetermined value or above its upper set limit. Soft start devices and inverter drives often have this feature.

This method has eliminated most of the catastrophic failures experienced by some users in past years. An alternative or additional method of pump protection that can applied to metallic MDP's is to use a temperature measuring device located on the outside of the containment shell. A rise in temperature indicates a reduced cooling effect of the magnetic drive cooling and bearing feed stream thus signalling a potential issue with operation. [Fig 3]



10	Neck Ring [Front]
10A	Neck Ring [Back]
50	Coupling Washer
60	Impeller
70	Front Thrust Washer
80	Back Thrust Washer
90	Bush Holder
100	Bush
130	Thrust Pad
170	Casing Gasket
170B	'O' Ring
200	Containment Shroud
220	Rear Bush Housing
360	Coupling Nut
370	Inner Magnet Ring
390	Support Gasket
410	Casing
430	Coupling Housing
440	Bump Ring
510	Outer Magnet Ring
610	Bearing Housing
620	Drive Shaft
670	Front Cap
680	Back Cap
700	Labyrinth Seal [Kit]
700A	Sec. Containment Seal
860	Shaft Sleeve
890	Breather
5020	Race
********	Fixings [Kit]

Typical construction of magnetic drive pump

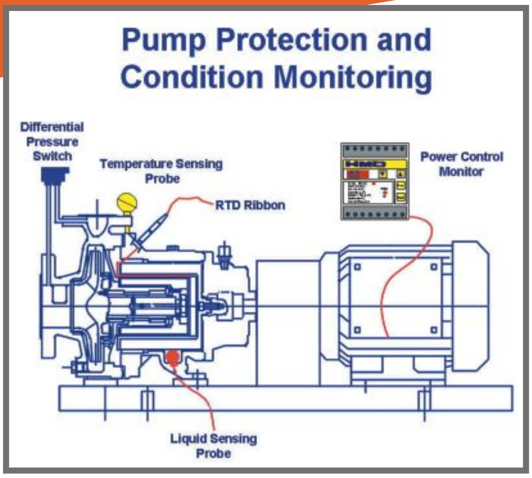


Fig. 3

6) Reliability

It is reasonable to assume that if a pump does not have mechanical seals, then it will be more reliable and magnetic drive pumps certainly have an extended MTBF – estimated at 2 to 3 times that of an equivalent mechanical seal pump.

It is very difficult to get consistent reliability data for pumps – each site has differing experiences for both types of pump. Available seal data from internet research and customer feedback suggests MTBF of approximately 2 years for an unbalanced seal on ANSI or ISO Chemical service pump and up to 4 to 5 years for an API specified pump with balanced seals.

API 682 states that mechanical seals should "have a high probability of meeting the objective of at least three years of uninterrupted service while complying with emission regulations" [(2)]

MTBF varies widely depending upon the nature of the product being pumped.

Theoretical Mean Time Between Failure can be calculated for magnetic drive pumps. The methodology [(4)] used is to statistically examine the historic life of the major components within the pump whose failure can cause major pump problems/pump failure. The various historic lives are then fed into the following equation to give an overall pump MTBF:

$$1/MTBF = [(1/L1)^2 + (1/L2)^2 + (1/L3)^2 + (1/L4)^2]^{0.5}$$

Where
L1 = Internal Bearings (SiC estimated at 25 years)
L2 = Anti Friction Bearings (estimated at 15 years)
L3 = Wear rings (estimated at 25 years)
L4 = Shaft (estimated at 30 years)

On a clean liquid the impeller is not considered to be a wearing part and the magnetic coupling if correctly applied should never fail. This is based on a correctly applied, installed & maintained pump.

Actual customer feedback from MDP users suggests MTBF of 8 to 10 years for both ANSI and API pumps *without preventative maintenance.*

This extended MTBF means that when Life Cycle Costs are considered the enhanced reliability will in many cases give a lower cost for the MDP, together with increased production, less maintenance and downtime.

7) Factors Determining The Correct Selection Of Magnetic Drive Pumps

As described earlier, magnetic drive pumps are suitable for many services, but there are still many misconceptions regarding their use. Apart from the toxic duties already suggested they are also suitable for many other liquids and from experience we give the following parameters:

- Liquid Cleanliness – up to 5% solids, 150 micron in size. By installing a self cleaning discharge flange mounted filter this can be increased to 250 micron. This is similar to the limits of other closed impeller pumps. External filtration and clean sacrificial flush can be considered for some applications. However, consideration should be given to the abrasive nature of the solids – for example no more than 0.5% silt/sand should be pumped with a standard closed impeller pump, but the higher limits would apply to softer crystalline solids of the type regularly encountered in the pharmaceutical industry.
- NPSH Available – this is critical to any pumping application and care should be taken to ensure that there is an adequate margin between this and the NPSH requirement of the pump. This will ensure cavitation will not damage the pump, or interfere with the flow of liquid to the pump internal bearings. There are no hard and fast rules for defining this margin, but it is good practice to ensure a minimum of 0.5m for non critical duties and of 1.0m for critical services.
- Safe Minimum and Maximum flow rate – Manufacturers all have different guidelines for this and again there is no industry standard. Guidelines are therefore generally based on practical experience, testing and independent research. Two energy dependant factors determine a pumps safe minimum flow. First, the mechanical effects of increased vibration levels at a low flow. Second, on larger pumps as flow through the pump decreases other hydraulic factors become more dominant, such as suction and discharge recirculation, which can cause high vibration and shorten pump life.

On volatile and low specific heat liquids the mechanical safe flow should be adjusted to achieve the safe thermal minimum flow, to ensure the liquid does not change state to gas.

Pump protection options should also be considered when selecting MDPs as previously indicated. The prime recommendation is for a power control monitor to be incorporated into the pump controller as described above. Consideration should also be given to Temperature probe which can measure the temperature at the containment shell – an increase in usual temperature can indicate partial blockage which would not be detected by the monitor.

Secondary Control or Containment

Some form of Secondary control or Containment should also be considered when pumping particularly hazardous liquids. By secondary, we refer the unlikely situation that the primary containment shell is breached, and the liquid then comes into contact with the secondary system. The basis of this 'secondary system' of liquid retention is achieved by fitting the external drive bearing housing with some form of sealing device. Different manufactures offer different options ranging from lip seals to dry running gas seals.

The purpose of a Secondary Control system is to control any leakage that may occur in the event of the primary pressure Containment Shell failure. This is done by controlling the leakage in such a way that it can be diverted away from the pump in a controlled and safe manner whereby it can be dealt with appropriately.

A Secondary Containment system is able to contain any leakage that may occur. Once contained safely, the leaked product should have a means of being drained away from the Secondary Containment area in a safe and controlled manner.

Case Studies

8.1 BP Grangemouth

Sixteen sealless pumps based on API 610 installed in 1994 pumping propane and butane. Each pump runs 4 months in rotation. There have been no mechanical failures to date. Inspection carried out in 2006 showed little wear with the pump bearings still within tolerance.

8.2 Huntsman Group

The Huntsman Corporation have now used magnetic drive pumps since the mid 1990's when they were installed during a major investment programme. The Huntsman production facility at Wilton in the UK, now use sealless pumps, as their preferred unit, to pump a whole range of potentially toxic and explosive liquids.

Included within these are Aniline, Benzene, Nitro Benzene, Amine Water and Phenols. For all of these applications, the magnetic drive ensures that the pumps contain liquids within the process, ensuring safety and stability of the operation at all times.

8.3 Shell UK

Original Equipment Manufacturers, Jiskoot Auto Control (United Kingdom), build and supply Densitometer Skids to the Oil Supply Industry. Their customers include many of the worlds largest Oil corporations such as Shell UK.

Primarily, Densitometer Skids provide information on the quality and characteristics of the crude oil being extracted. This information provides details for the relevant taxation authorities. Sealless magnetic drive pumps extract oil from the pipeline and pump through the densitometer and back to the pipeline. Working pressure in these applications can be up to 185 bar.

8.4 Spallation

The Spallation Neutron Source project in the USA needs to keep careful control on the temperatures within the neutron beam facility. Ultra-clean De-Ionised water, in cooling loops, is the medium used but this becomes activated during operation necessitating pumps of high safety and integrity. Magnetic drive pumps were chosen because of zero leakage and enhanced reliability.

8.5 Statoil

Statoil in Norway use fifteen API 685 sealless pumps on its Onshore Rich MEG Feed system. The units are used to pump reflux water and mono ethylene glycol. Further high system pressure pumps are used on the Troll A platform on methane condensate applications. One pump on the platform was recently inspected and showed little or no wear. A recommendation was made to inspect every four years.

9) Summary

Following 60 years of evolution magnetic drive pumps can now be treated as mature technology. Because of zero leakage they are environmentally sound and inherent safety benefits are excellent.

Their selection and application is very well understood by the manufacturers and the experience gained over many years is considerable. They can be very cost effective due to their long, uninterrupted service life and now provide a real alternative to double sealed pumps.

References:

(1) Guidance Notes - Environment Agency, UK.
(2) European Sealing Association – Sealing Technology BAT guidance notes
(3) HSE Report TD5/021 "Mechanical Seals On Process Plant" – A. Tyldesley
(4) "Downtime Prompts Upgrading of Centrifugal Pumps" – Article from "The Chemical Engineer" by Heinz P. Bloch – Exxon Chemicals.
(5) API Standard 685 2000, "Sealless Centrifugal Pumps for Petroleum, Heavy Duty Chemical, and Gas Industry Services", First Edition, American Petroleum Institute, Washington DC, USA.
(6) API 685 Tutorial – Shawn L. Bennett, Sundyne Corporation, Arvada and Jim Bryant, KBR, Houston, Texas.

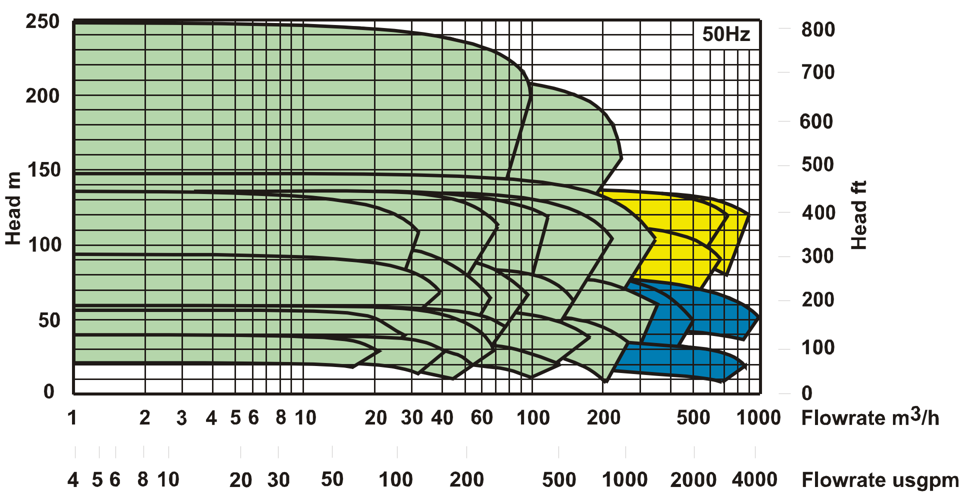
Sundyne HMD Kontro Sealless Pumps

Pump Parameters

- Temperatures - Down to minus 100°C
- Up to 450°C / 840°F Torque Ring Design
- Up to 315°C / 600°F Synchronous Design
- Flow - 1500m^3 / Hour 6600 USGPM
- Heads - 350m / 1140' Differential
- Viscosity - Maximum 200cps
- Power - 315kW 50hz / 400kW 60hz
- System Pressures Up To 185Bar / 2600 PSI
- Compliance to API 685 / ANSI B73.3 / DIN EN 22858

Options

- Close Coupled - Flange Mounted on Sub-Base Design
- Separate Mounted - Foot Mounted on Baseplate Design
- Solids Handling - Various filtration options available
- Secondary Containment - Via Gas Seal
- Casing Heating Jackets
- Coupling Housing Heating Jackets
- Secondary Control - Via, Magnetic Seal / Flanged Drain Valve



For the Know-How about HMD Kontro sealless pumps, please request a copy of our free guide by contacting us using the details opposite.

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