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HOW TO SPECIFY, DESIGN AND INSTALL CANNED MOTOR PUMPS IN A REFINERY

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ABSTRACT

This tutorial will guide the end user through the process of specifying and installing canned motor pumps in refinery services. Specific examples will be shown of both successes and failures and lessons learned will be discussed.

INTRODUCTION

Canned motor pumps have been around for a long time. They have been used successfully by the chemical industry since the early 1950's. But they haven't yet gained widespread acceptance in the U. S. refining market.

In 2011, BP's Whiting Refinery built a new Naphtha Splitter Unit. One of the pumping services involved procuring and installing a pair of pumps in a high Benzene stream. The engineering firm doing the project suggested a canned motor pump. We had no experience with them. Long story short, those pumps have now been running, continuously, for 8 years. Recently the refinery commissioned an 85MBPD Naphtha Hydrotreater. All 19 process pumps are canned motor pumps, including the three, 650 hp feed pumps.

The benefits of canned motor pumps are many - no seals, no oil or grease lubrication, no coupling/alignment and no leaks – but care should be taken as to where and how they are installed.

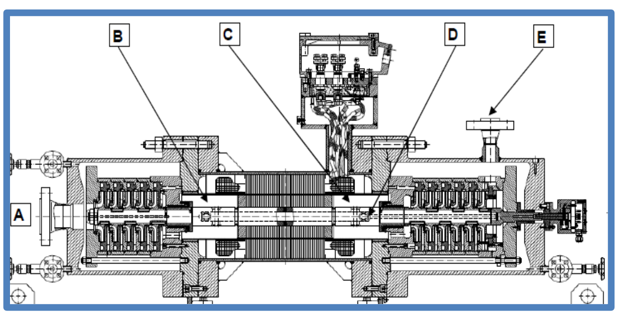
WHERE AND WHERE NOT TO USE A CANNED MOTOR PUMP

Canned motor pumps are traditionally used in "light ends" services in a refinery. That would include most everything at an Alkylation Unit, a Vapor Recovery Unit, an Isomerization Unit, a Hydrotreater, etc., but we have found uses for them in sour water, caustic, acid and hot water services as well. Basically, anything that's "clean and thin". We would not attempt to use them in crude oil or dirty water services (I would guess Mississippi River water would not be a good candidate, nor would, I'm sure, Lake Michigan water with its Zebra Mussels). Remember, a typical canned motor pump may only have a clearance between the stator can and the rotor can of about 0.03-0.04".

Also, be careful of installing a canned motor pump in an intermittent service. The fluid circulating thru the motor is used to cool the motor, so the pump must continue to run for a prescribed amount of time after it is started.

WHATS GOING ON INSIDE A CANNED MOTOR PUMP

The most important thing to remember when installing a canned motor pump is that the product being pumped must be kept a liquid everywhere inside the pump because the pump relies on the liquid for cooling, “lubrication” and thrust balancing. As the liquid travels through the different parts of the pump/motor, the pressures and temperatures of the liquid change. It is imperative that it remains a liquid. API685 is the guidance document for sealless pumps in refinery service. It requires pump manufacturers to furnish the expected temperature and pressure profiles of the liquid in the various parts of the pump (see figures 1 and 2 below).



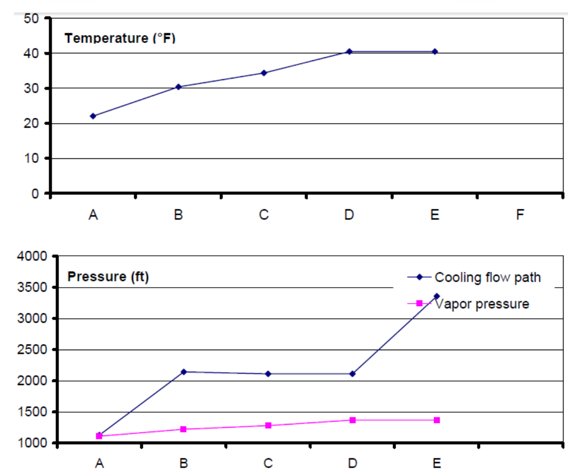


Figure 1 – Multi-stage canned motor pump

Figure 2 – Temperature and Pressure profile

To create the curves in figure 2, the end user must provide the supplier, accurate liquid properties. Net Positive Suction Head Available (NPSHa), temperature/vapor pressure curve, accurate suction temperature and pressure, viscosity and specific heat are all necessary for the manufacturer to design the pump properly.

For hot services, an external cooler may be supplied to help cool the product. This is done when the motor winding temperature would be exceeded (for example in a hot, heat transfer fluid application). This provides a thermal barrier between the fluid and the motor section of the pump. An auxiliary impeller is used to circulate the liquid through the motor section, to the cooler and back. The heat exchanger is used to remove the heat created by the motor. This not only provides a margin of protection against flashing the liquid, it helps the motor run cooler, which improves the life of the motor. Note that API685 does not specify the construction features of the cooler like API682 (or API614) does. I believe this is a shortcoming of the specification that should be addressed. The end user should review the details of the cooler construction prior to purchasing. We require heat exchanger datasheets be filled out by the pump supplier.

Canned motor pumps have “circulation plans”, like API610/682 have “flush plans”. There is a Plan 1-S that circulates fluid inside the pump through the motor and back to the suction via a rifle drilled hole in the shaft (see figure 3). There is a Plan 1-SD, that is similar to 1-S, except that it adds a small additional impeller to help keep the pressure up in the motor end for very low specific gravity services (see figure 4). The flush plan we use with the cooler mentioned above is a 23-S (see figure 5). There are also flush plans that are vendor specific such as those used for multistage pumps, which aren’t specifically addressed in API685.

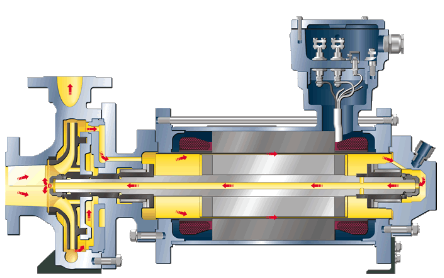


Figure 3 Plan 1-S

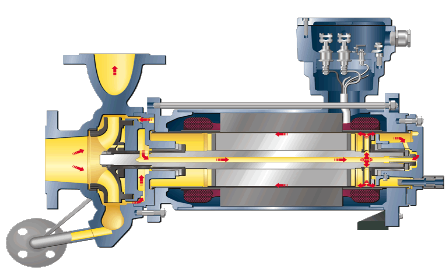


Figure 4 Plan 1-SD

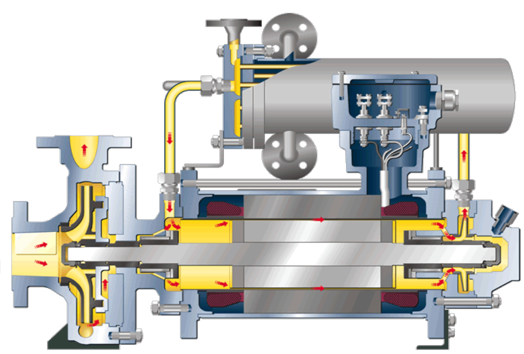


Figure 5 Plan 23-S

So, what happens inside a canned motor that is stopped (intentionally or otherwise) after weeks/months/years of service? Remember, the fluid being pumped is used to cool the motor. What happens to the heat in the motor when the fluid is no longer being pumped? That heat is transferred to the fluid that is left in the motor when the pump was stopped. That heat may be enough to cause the fluid to flash due to the fluid being at a lower pressure because the pump is no longer running. Although most pumps are self-venting, if an operator runs out to restart the pump without checking, he could, depending on the fluid properties, be starting it up without it being fully liquid filled. We address this in 3 ways. We have a fluid detection instrument that is known colloquially as a “tuning fork” (see photo figure 11) in the suction line that is wired to the starter permissive, we have a bypass around each check valve that allows flow from the spare pump to run backwards through the pump that is in standby and we have a timer that controls the time between starts. The timer allows the motor to cool off and allows time for the process fluid to condense back to a liquid before restarting. Dry running is the most frequent cause of canned motor pump failures. Note also, that in applications requiring a cooler, we install a “tuning fork” right above the cooler inlet to make sure the cooler is completely full of process fluid prior to starting.

THRUST BALANCING

Canned motor pumps don’t have thrust bearings like API610 pump (although some have thrust disks that support startup and other short-term transients). The axial forces inside the pump are controlled/balanced by the pressures acting on discs of different diameter (Pressure =Force/Area) and the clearances between them. As with any pump it is critical to let the manufacturer know what minimum and maximum flows will be required or anticipated. Likewise, the manufacturer must let you know what the minimum and maximum flows are for stable operations. Pumps should not be operated below the minimum flow specified by the manufacturer. We have min. flow spillbacks on all our canned motor pumps to keep the flows as close to rated conditions as possible.

REPLACING AN EXISTING PUMP WITH A CANNED MOTOR PUMP

Net Positive Suction Head Available (NPSHa) is critical. And, of course, to know how much NPSHa you have, you must know the properties of the liquid being pumped. So, if you are going to replace a pump that has a seal that keeps failing because of low NPSH margin, installing a canned motor pump will solve the seal leakage issues but the pump may still cavitate – which isn’t good for any type of pump. Remember, a canned motor pump must be liquid filled everywhere inside of it for it to run reliably. The temperature/pressure profile through the canned motor must be kept above the liquid’s vapor temperature/pressure.

We have a Sulfuric Acid Alkylation Unit. It had some pumps in alkylate service (specific gravity of 0.5) that were very unreliable due to insufficient NPSHa. One of the 6 was always being worked on. We replaced them with vertical canned motor pumps, below grade, to get more NPSHa to the pumps which solved the problem (see figure 5). Notice in the photo the pump and the motor are both in the pit, so the shaft is short, unlike an API610 vertical where the motor would be above the pit. Due to electrical area classification of below grade installations, we submerge the pumps in glycol so there can't be an explosive environment around the pumps (even though the pumps are rated for Class 1, Group C/D, Div. I areas).

Figure 5 Vertical canned motor pump submerged in Glycol

As I mentioned, you need to know everything about the fluid being pumped. That includes fluids that you didn't anticipate being pumped! The alkylate pumps mentioned above have seen, from time to time, sulfuric acid carryover from the reactor. That acid gets into the pumps. The specific gravity of the acid is double what the pumps were designed to pump. In hindsight we should have made the motors larger. These are the types of things you need to keep in mind – off design conditions. This became a real problem with the standby pumps that were left with their suction block valves open. Over time, acid accumulated in the bottoms of the pumps, and we were unable to start them due to the motor overamping. We now leave the suction and discharge block valves closed and we have an elaborate flushing procedure to remove any acid.

Even if you have adequate NPSHa, if the product is very light, you may still want to use a vertical pump (see Figure 6). This is because vertical pumps have reduced bearing loads. Remember, the liquid must provide the film stiffness between the shaft and the bearing that supports the rotor when the pump is in service. Low specific gravity fluids are not as viscous as heavier hydrocarbons and can't provide as thick a barrier between the shaft and the bearing. By putting the shaft vertical, the radial load on the bearing is reduced so you don't need as stiff a liquid barrier.

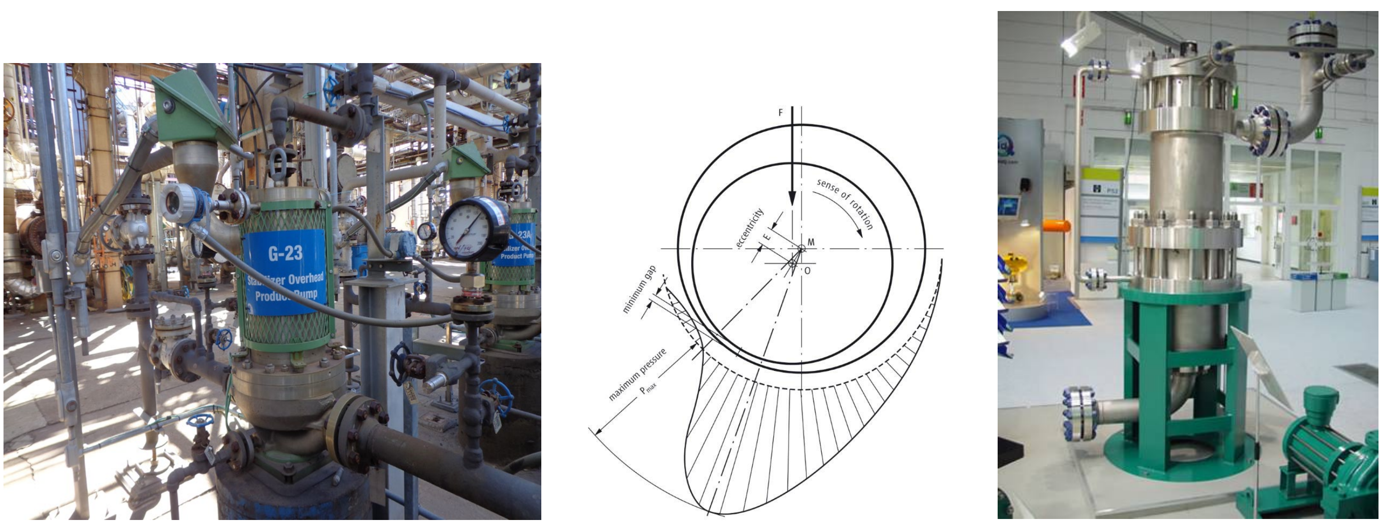


Figure 6 Vertical canned motor pumps to reduced radial load of rotor

Another important consideration when replacing existing pumps, is that not all canned motor pump manufacturers offer both 480 and 4160 volt motors. So be aware, when trying to replace larger 4160 volt powered pumps, that you may also need a step-down transformer. Canned motor pumps can require more current than a conventional API610 pump motor for the same flow and pressure. This lower efficiency is because there is a larger clearance between the rotor and the stator than in a conventional motor. That additional clearance is to accommodate the liquid that needs to flow in that annular space to provide cooling for the motor. If you are retrofitting an existing service, you need to know the ramifications of the additional load on existing starter and wire sizes. When supplying 480 volt power to high horsepower pumps, the current gets very large. Therefore, the cables can get very large. To reduce cable size, we have had to supply 6 leads to a motor in some cases instead of 3 to keep the cable sizes manageable. This requires oversized electrical boxes from the pump manufacturer (see figure 7).

We also separate the high voltage (480/4160) from the low voltage instrumentation by asking the manufacturer to wire all the instruments to a separate junction box. That way we can troubleshoot an instrument issue without having to lock out the whole pump.

Figure 7 Oversized electrical boxes to accommodate larger wires

Another thing to know about canned motor pumps, is that they are not certified to all U.S. electrical standards. For example, all conventional motors in a refinery would typically meet NFPA (National Electric Code), FM and UL requirements. Most would meet the requirements of IEEE 841 and API 541. This is generally not true of canned motor pump motors. This does not mean the pumps are less well designed, it means they are not certified by the manufacturers to those standards. They are instead, certified to other global standards that are equivalent in their intent but different than the ones your electrical group is familiar with. The key is to get them involved early in the discussions.

PROTECTION PHILOSOPHY - WHAT INSTRUMENTATION IS REQUIRED

API685, requires a.) power (or flow) monitoring, b.) leakage monitoring in the secondary containment area of the pump and c.) temperature monitoring of the containment shell or max. liquid temperature in the rotor chamber. We comply with these requirements by installing a power monitor in the switchgear (see figure 8), a pressure switch-or preferably a pressure transmitter-especially for oil filled motors-(see figure 9 below) to detect a breach of the can, and a liquid temperature transmitter in a thermowell in the back end of the pump. API also says “if specified” to add radial and/or wear monitoring. We monitor the axial position of the shaft (see figure 10 below).

Figure 8 Power monitor

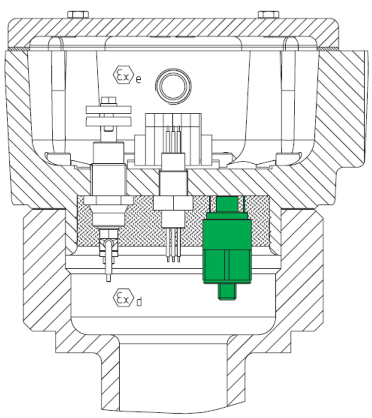


Figure 9 Pressure switch

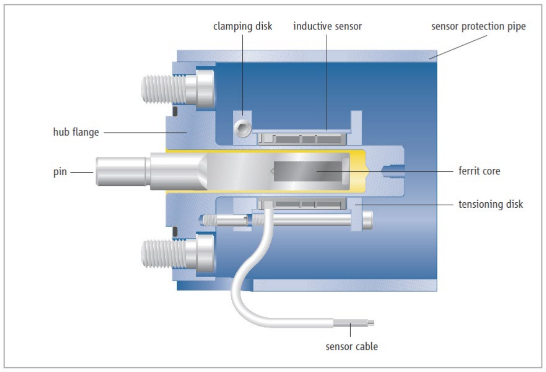


Figure 10 Axial monitor

We also add a "tuning fork" liquid level detector mounted horizontally in the suction piping downstream of the block valve and suction strainer (see figure 11) and RTD's or thermocouples for motor winding temperature monitoring.

Figure 11 Liquid level detection

API685 also requires a rotation sensor. Figure 12 shows 2 types. One is hard wired and the other is hand held. Use the hand held to verify the wired one. Remember, there is no part of the shaft that can be seen from the outside, so you won't know if the pump is running in the right direction without one. I have heard stories about pumps that have run backwards for years without the end user knowing it until the pump is finally sent out for repair. The pump comes back, gets reinstalled and by chance, turning the right direction and the end user complained about the repair shop putting a larger impeller in it!

Figure12 Rotation sensors

Obviously, all the instruments should be alarms, but which should be trips? Each site probably has a different philosophy but here's what we do. We trip on loss of level in the suction piping, high motor winding temperatures (2 out of 3 voting) and fluid recirculation temperature. We also don't let the pump run backwards! We don't trip on breach of the containment shell (pressure transmitter) which gives us time to switch pumps.

FACTORY TESTING OF CANNED MOTOR PUMPS

Because a canned motor pump is a pump and a motor combined, the pump is tested with its motor, not with a separate shop motor like most API610 pump tests. If the pump being tested is designed for a light hydrocarbon, sometimes the factory test, using water as the fluid, has to be performed at a slower speed and/or a reduced flow than the pump was designed for to keep from overloading the motor. The test results then need to be corrected for the speed and SG of the fluid that the pump was purchased for.

CONSIDERATIONS WHEN INSTALLING CANNED MOTOR PUMPS

Installing a traditional API610 pump is an expensive endeavor. First there is the excavation for a foundation, which must be formed and poured, and then the top is chipped off in preparation for the grout. The baseplate (which is also expensive) must be cleaned and prepped for grout. Then there is the leveling of the baseplate, the forming around the foundation for the grout, the building of the grout tent, the heating of the grout tent, the mixing and pouring of the grout, the curing and testing of the grout samples, the stripping of the forms. With canned motor pumps, you pour a pad (36" frost line in Whiting) and bolt the pump base to it. Period. We do not grout in canned motor pumps. We do shim under the base to get the pumps "level". And, we do still adhere to the API 686 piping guidelines to minimize the flange loads on the pumps, but again, not as critical because the rotating assembly floats inside the pump. Also remember there is no coupling or alignment required.

COLD WEATHER CONSIDERATIONS

If you are in a cold climate like we are, then you need to consider how you are going to keep the spare pump from freezing in the winter. We use electric heat tracing, but care must be taken not to trace or insulate the motor end of the pump. The motor must not be insulated because it must be able to dissipate the heat it generates under normal operation. To keep the liquid in the motor from freezing when the pump is down, we have a bypass around the check valves in all pump discharge lines (also used to cool the motor – see page 3) and we leave them cracked open so there is always some flow backwards through the standby pump. It is important to size the bypass line around the discharge check valve large enough to heat the entire pump but not large enough to let the pump spin backwards while in standby. It is particularly important to keep hot pumps at a uniform temperature. You do not want one part of the pump hot and another part of the pump cold. This will cause the pump to seize up upon starting.

CONCLUSIONS

Canned motor pumps can improve the safety, reliability and environmental performance of any plant if they are specified, designed and installed correctly. Special considerations need to be given to where and how they are applied in a refinery. They have unique electrical issues because of the instrumentation requirements and potential voltage considerations. It is imperative you fully understand the properties of all the fluids being pumped (true for all pumps but especially true with canned motor pumps). The service life of canned motor pumps is longer than that of conventional pumps because there are no stationary parts in contact with rotating parts. They can easily run continuously for 10-15 years or longer if they have been specified and installed properly.

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