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PROTECTIVE WISDOM: HF RELEASES AND ASSOCIATED PUMPS

Better Pumps and Seals for HF Service

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Heinz P. Bloch resides in Montgomery, Texas. His engineering career commenced in 1962 and included long-term assignments as Exxon Chemical's Regional Machinery Specialist for the United States. After retirement he concentrated on consulting assignments and course presentations on all six Continents. He has authored or co-written over 700 publications, among them 20 widely used books--issued in 46 Editions--on practical machinery management, failure analysis, failure avoidance, compressors, steam turbines, pumps, oil mist lubrication and practical lubrication for industry. Some of these books have been translated into Russian, Spanish, Portuguese and other languages. Mr. Bloch holds B.S. and M.S. degrees (cum laude) in Mechanical Engineering. He is an ASME Life Fellow and, in 1984, became a founding member of TAMU's International Pump Users Symposium. Heinz Bloch was awarded life-time registration as a Professional Engineer in New Jersey.

ABSTRACT

Exposure to HF is often fatal; hence, specific safety measures are needed to enter the process unit. With lives at stake, the reliability of alkylation units and other plant locations with hydrofluoric acid is of utmost importance to reliability engineers at safety-conscious plants.

To date, some of the relevant issues have been addressed as fragmented efforts, but some have turned into costly and undesirable trial-and-error. Because there is an obvious need for consolidation and clarity, this tutorial is structured to teach how, what and why pump and seal selection deserve diligence and forethought. Pump styles that are presently in service and yet have only recently developed troublesome failure histories are examined. The impressive positives and relatively few negatives of properly engineered canned motor pumps are highlighted, as are flush plans and mechanical seal configurations.

INTRODUCTION

Tutorials are a highly effective method of transferring knowledge and may be used as an important means of imparting learning. That said, tutorial styles vary greatly. The focus of this tutorial are examinations on how successful installations differ from unsuccessful, safety-compromising installations. Accordingly, readers and tutorial attendees should keep in mind that only a fraction of HF-related incidents are ultimately reported. It was not yet known, as of this writing in early May, how a 970 lbs (440 kg) HF escape from a Texas refinery will be viewed. A resulting fire and explosion in April 2018 is certainly at odds with boastful claims heard by the author in 2017. At that time, speakers at two technical conferences attended by the author stated: "We have the problem under control." Let the record show that there were also clear refutations from several employees who knew the facts, and whose consciences compelled them to alert the author "from the side lines", so to speak.

Pump and seal distress often have seemingly elusive origins and excessive shaft deflection is among these. This tutorial will briefly explain why high deflection values are affecting some seal configurations more and others less. The risk associated with choosing the wrong seal configuration for shafts with pronounced deflection in HF services must be explained to mechanical work forces that may not have been made aware of the details. Space and time limitations preclude dwelling on seals and/or systems that have failed to perform well in HF and similar acid services. Instead, the tutorial concentrates on

suitable mechanical seals and systems with demonstrated life spans exceeding five years. The author is readily pointing out that such seals are available from more than one vendor-manufacturer. Regrettably, though, not every seal provider was forthcoming or cooperative in the author's quest to obtain relevant data and illustrations.

Both ANSI (American National Standards Institute) and pumps complying with API (American Petroleum Institute) can be found in HF and similar acid services. Pump type and routing of flush fluids ("Flush Plan") variants are examined for alkylation unit applications and similar acid services. However, the author leaves it to readers to retrieve, from virtually any seal manufacturer they choose, illustrations of API flush plans that were tried at an oil refinery in the United States and found wanting in HF services. As will be shown, these services include deisobutanizer bottoms and depropanizer charge pumps operating in that United States facility. It is widely acknowledged that many pumps in an alkylation unit could have their mechanical seals exposed to hydrofluoric acid. Such services call for dual seals; single mechanical seals no longer represent best available technology. The primary metallic parts of mechanical seals in HF service must be supplied in Alloy 400 (Monel®) metallurgy; secondary (elastomeric) parts must be perfluoro-elastomers (Kalrez) throughout.

HOW INFORMAL CONSULTING PRESENTED A TEACHING OPPORTUNITY

Important corroborating information regarding problems with seals in HF service was received, in mid-2017, from a young reliability engineer employed by a U.S. refinery. The author's communications with this bright young professional represented a highly relevant frame of reference. It allowed the author to fold a recent case history into this tutorial and, hopefully, highlight what many in industry seek to know. These communications led to a unique teaching opportunity---in a sense a true tutorial---which the author wanted to share with his wider reading and listening audiences. However, readers are urged to completely read and fully absorb this tutorial material before reaching premature conclusions. Moreover, it should be noted that the advice given here for an existing plant would not usually apply to a new plant. The reasoning that led to this decision will be explained in the narrative that follows.

Communications were initiated when the author received a well-written request from the engineer alluded to above. The author opted to call him "YRE" -- young reliability engineer. YRE expressed concern over the seriousness of HF (hydrofluoric acid) releases and had collected much relevant data. Chances are that he was not inclined to become just another trial-and-error person. The author sees in YRE a person of integrity; his observations -- as related here -- are important. Neither he nor the author had an agenda other than wanting to uncover facts. No photos were supplied and neither pump nor seal vendors were ever mentioned in our information exchange. This then allows the correspondents to show or replicate initial e-mail content together with follow-up replies and the author's recommendations.

Because YRE works for an existing plant and within certain constraints, the author recommended against a canned motor pump. However, new plants should favor a high-quality canned motor pump; accordingly, responsible reliability-technical employees are encouraged to read a comprehensive paper that emphasizes pump metallurgy in HF services, Ref. 2. The recommended write-up was presented in tutorial format at a TPS (Texas A&M Pump Users Symposium) in Houston/TX in mid-December 2017. It first came to the author's attention in mid-February 2018.

Back to YRE, who had initiated the following discourse by writing to the author. YRE wrote:

> "I have a particular sealing challenge and was hoping to explore your expertise on the matter. It deals with a situation that I recently inherited here at my oil refinery, (which the author chose to call "MOR.") "Actually, sealing challenges in volatile and toxic HF services have been a topic at MOR for quite a few years."
>
> "We have an HF Alkylation Unit in our refinery and the Depropanizer Charge Pumps are a bit of a nightmare, to put it mildly. They are moving 75 gpm of 165 psi propane with up to 25 percent HF acid (SG 0.534) to a discharge pressure of 365 psi (865 ft TDH, total dynamic head). The current pumps are two-stage overhung centerline-mounted API-610 compliant pumps by legacy manufacturer "P", with their BEP (Best Efficiency Point) at 230 gpm. These pumps have been upgraded with power ends (shafts, bearing frames, and back covers) from manufacturer "P's" successor provider "F" in 2008. My predecessor colleagues at MOR also changed the seals from seal Vendor "A's" Flush Plan 32/54 (alkylate/isobutane flush) to mechanical seals from seal Vendor "B" with a composite Flush Plan 11/72/76 ---obviously including an inert gas sweep."

"The charge pumps are made of Monel® (a nickel-copper alloy) to resist hydrofluoric acid attack. In the last three years we have had many issues with these pumps; distress events included case gasket crush, shaft bushing materials, and seal failures, to name but a few. We have resolved most of the problems with valuable help from "F", who are both the process pump's successor company and primary upgrade provider. However, we continue to spend lots of money on mechanical seals. In fact, we have recently had really bad luck with our seals. Vendor quality seems to have gone down and repair times are never fast enough."

"My questions are two-pronged. First, what would you consider the best pumps for this application? Please note that the current pumps' hydraulics have been quite satisfactory. They have been in service since the 1960s and have done well, even while running relatively far from BEP. Next, we would like to find a seal that is more reliable than the one using nitrogen backup, but API Plans 52/53A/53B and 54 all have their own disadvantages. Ideally, we would like to find a seal-less option."

"For now, we want to stay in compliance with API 610, 675, and 685. I am looking at positive displacement pumps, mag-drives, canned motor pumps, but most vendors seem unable to come up with an API option and, at best, are suggesting ANSI pumps. I have been led to believe that chemical plants processing HF are primarily using ANSI-dimensioned magnetic drive pumps. Thank you for your time; any advice would be greatly appreciated."

UNDERSTANDING A USER'S DILEMMA

As will be seen, the author's pump recommendation differed from what YRE had probably expected. The author's opening reply relating to mechanical seals was accurate and quickly endorsed by seal manufacturer "C", a company that freely shared its seal experience data. In both the pump and seal-related questions posed by YRE, his dilemma was easy to see. Weighing lots of pros and cons, it was recommended that he should consider staying with an API pump and not select an ANSI pump for this potentially hazardous service. It was assumed that, if he did not select best available technology, he would risk losing his reputation over it.

CONSIDERING SEAL-LESS PUMPS

Overall, there are relatively few issues with properly designed and carefully manufactured seal-less process pumps (canned motor pumps). Thousands of these are successfully operating in oil refineries world-wide. However, few of these refineries are eager to publish their experiences, nor are they likely to allow being quoted. An oil refinery's legal advisors often block the release of meaningful application and/or repair data for a host of reasons, be they fact-justified or contrived. Except for one cooperative responder, the author's attempts to secure data from mechanical seal manufacturers were unsuccessful.

It should be noted that MOR is an existing oil refinery, one with a long-term stable work force. Existing facilities are---conceivably---set in their ways of doing things. Being set in one's ways of doing things can be good if sound procedures are consistently being followed; but it can also be bad if procedures are incorrect, or if making changes is frowned upon, or if procedures do not exist in the first place. Because the author-presenter knew nothing about the local situation at MOR, it was decided to err on the safe side. Therefore, unless no other reasonable options existed, a seal-less pump would probably not be the most ideal solution for MOR.

Every seal-less pump has its own issues and obtaining adequate lubricity from a liquid with a specific gravity of 0.534 will not allow wide latitude in sleeve bearing quality and design. The rotor-to-can clearances are small and if the pump is subjected to excessive pipe stress, there will be internal rubbing. Internal rubbing contact can have serious and often near-instantaneous consequences. Nevertheless, there is pump manufacturer "X," a company that has for many decades produced high quality API-compliant canned motor pumps. YRE might contact "X," but should be prepared to pay for the kind of quality which is in "X's" DNA. The company was founded over 150 years ago and has been in the canned motor pump business for almost half of its existence.

An update on seal-less pumps is a desirable part of this tutorial because the company which is here identified with "X" presently has over 250 pumps in HF services. The majority have been provided in alloy steel or generic stainless steel, also some in Hastelloy and some in Monel®. The physical properties of HF or HF solutions are in a range that does not present a challenge to properly engineered canned motor pump or their components. As a general observation, the viscosity is always high enough for a competent vendor to advocate standard horizontal canned motor pumps. Multistage canned motor pumps

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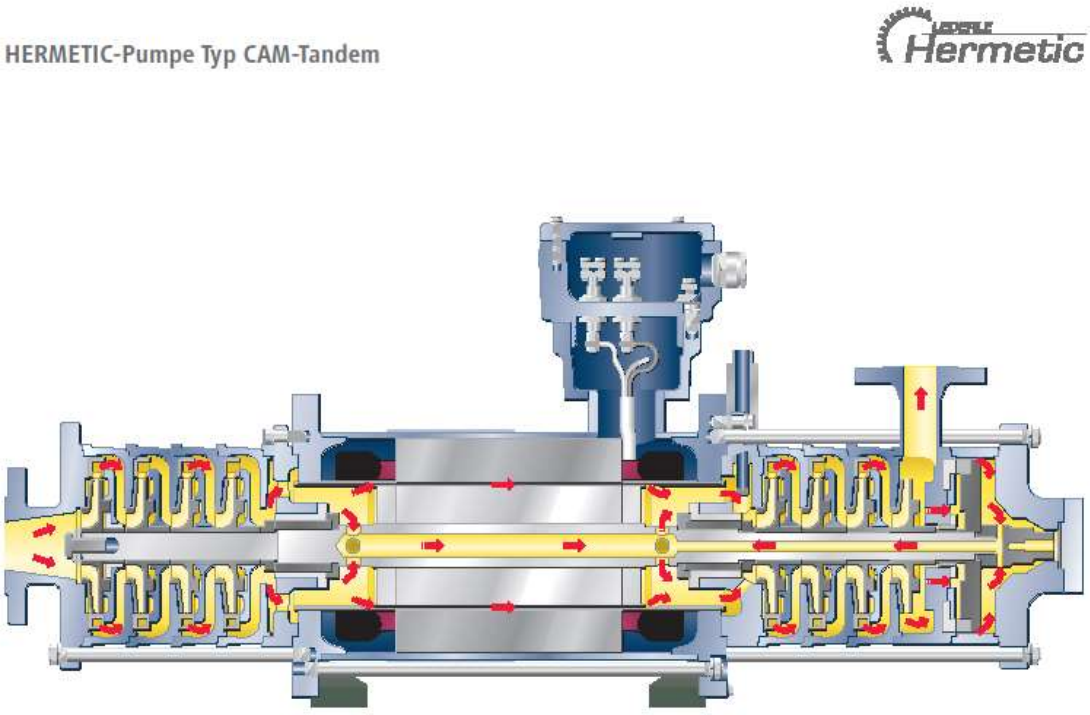

Figure 1: An eight-stage canned motor pump (Courtesy of Hermetic Pumpen)

But, in the interest of full disclosure: One might find it a bit frustrating to obtain reference data from technically outstanding vendor "X." A few years back, the company wrote a great article for publication in a premier trade journal. It involved one of their customers, a refinery with a large population of canned motor pumps that were performing quite successfully. However, days before publication, the refinery's lawyers withdrew the article. Likewise, while the author appreciated the good update obtained (in early 2018) from one of this company's longtime and well-informed staffers, the mutually beneficial information exchange was later halted for unknown reasons.

REMEMBER THE PART PLAYED BY PROCESS PUMP PIPING

Returning to user company MOR and considering vendor "X", MOR could spend less money for someone else's canned motor products but might not get the same built-in strength. Field personnel might not get away with using excessive force on "average" canned motor or magnetic-drive pumps. Of course, we are not even remotely impugning the craftsmanship and diligence of MOR's field personnel and installation contractors. But, in general, the user-purchasers of canned motor and magnetically-driven process pumps must ask if they are willing to do battle with the occasional millwrights who make it their practice to risk pump distress by pulling piping into place.

While excessive pipe load can cause big problems for all manner of alignments (shafts, seals, bearing components, etc.), properly designed and duly selected canned motor pumps are neither more nor any less vulnerable than other process pumps. Unavoidably high pipe stress can be addressed by selecting a higher casing pressure design or with a pressure barrel for multistage pumps---all within the boundaries of common sense. Piping designs can be modified for thermal expansion away from pump nozzles; also, a thoughtful craftsperson will respond in the spirit of cooperation and use proper work procedures throughout.

As on all process pumps (irrespective of size and configuration), reliability engineers at Best Practices or Best-of-Class companies have insisted on pipe installation practices whereby prefabricated piping is laid *towards* the pump. This piping terminates at least 3 ft (0.9 m), but no more than 10 ft (3 m), from the pump's nozzles. Next, the remaining (and relatively short) piping is installed from the pump nozzles in the direction *away* from the pump. A final weld is then made where the very long and the relatively short pipe sections meet. One should be prepared to hear outcries over the additional time and money which these and other sound piping procedures consume. YRE was encouraged to defend his position as it relates to piping. Indeed, pump users benefit from doing their homework in all matters relating to piping. Realize, for instance, that a two-layer Teflon®-plate sandwich is needed under pipe slippers to ensure low-friction (Teflon®-on-Teflon®) thermal

expansion-and-contraction movement. This movement must be away from the pump nozzles. YRE and the user community must understand and insist on proper piping practices before worrying about what pumps to select. Ethical and truly reliability-focused engineers and technicians always find it rewarding to take their stand as professionals. They allow no deviations from best available practices and are reluctant to grant access to vendors that use the customer's plant as an experimental test bed.

TWO-STAGE PUMPS AND SHAFT DEFLECTION

Although the MOR facility was asked to continue using the present pumps until they had fully implemented the best-available mechanical seal option, it is worth noting that two-stage overhung pumps are no longer used by experienced Best-of-Class user companies. Therefore, YRE's backup plan might be a two-stage between bearing pump. An axially-split two-stage pump is shown in Figure 2, although a pump with barrel-style ("vertically split") casing would be much preferred for HF service. In either case one would choose a pump with flows at BEP much closer to the pump's normal process demand, apparently 75 gpm in this instance. If YRE were to find one with the right material in the used equipment market, MOR should buy it. With the right seals, between-bearing pumps will outlast all other pumps. YRE stated that the HF pumps at MOR were made from the correct material and were hydraulically OK--as one would expect from the original legacy brand manufacturer "P." All things considered, YRE thus had good reasons to stay with these pumps.

Figure 2: Axially split two-stage between-bearing process pump (Courtesy of HydroInc)

CONCENTRATING ON MECHANICAL SEAL DETAILS

Two-stage overhung pumps often have excessive shaft deflection. This deflection is caused by unequal hydraulic forces surrounding pump impellers. Shaft deflection also becomes greater as flow is moved away from BEP and closer to shutoff. Whenever these two negatives combine, it will be very important to select seals of the type and style where the axially flexible face is part of the non-rotating assembly (Figure 3). If the back-and-forth flexing seal faces are part of the rotating assembly, the seal will not represent the best-available technology demanded by YRE's HF pumps. Flexing rotating faces have their springs continually moving back-and-forth. In contrast, seals where the stationary face is spring-loaded will experience only momentary spring compression while the shaft (with its clamped-on rotating face) deflects initially. The greater-than-average shaft deflection found in twin-overhung impeller pump styles is further amplified if these pumps operate closer to shutoff.

Taking a closer look at Figure 3, one also notes a highly effective device (a pumping impeller) for barrier fluid pump-around. It's beneficial to become familiar with the merits of this bi-directional tapered pumping device. Whenever pumping screws or

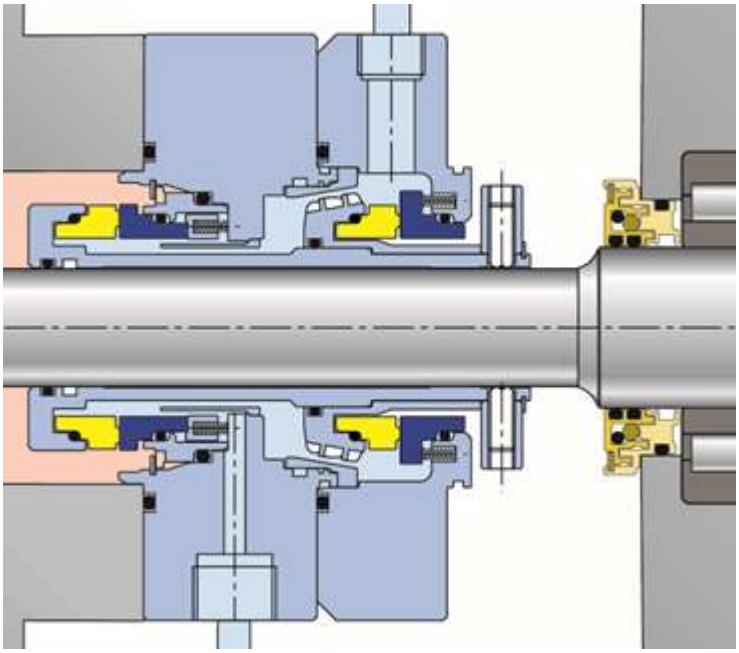

Figure 3 (above): Cross-section view of a cartridge style dual seal suitable for HF Service (Courtesy of AESSEAL)

Figure 4 (above): External view of the cartridge seal in Figure 3 (Courtesy of AESSEAL)

pumping impellers are involved in dual seals, compare the respective efficiencies of different offers. The published efficiency and head-flow characteristics of bi-directional tapered pumping devices (see external view, Figure 4) often surpass the pumping rings traditionally offered by some seal manufacturers.

ELIMINATE MONEL VS. MONEL WEAR RING COMBINATIONS

Today's knowledgeable users apply a PFA/CF (perfluoro-alkoxy carbon-filled polymer) composite from the PTFE (Teflon®) family--but superior to Teflon®-- as an advantageous wear ring material in pumps that handle HF acid. The first use of this high-performance polymeric material in HF services dates back to about 2003. PFA/CF does not suffer from chemical degradation and, in HF services, is installed with *standard* API-610 clearances. It is worth noting that this installation practice is prompted by the risk of encountering a buildup of crystalline fluorides in certain HF pumps (Ref. 2). In most other pumping services, PFA/CF materials generally allow clearances to be reduced to half of those needed for metal wear rings. Tighter clearances tend to stabilize pump rotors and often add as much as 5% to the pump's efficiency (Ref. 3). Nevertheless, upgrading to PFA/CF case rings, *with standard clearances* in this instance, is known to substantially improve HF pump reliability.

Whenever HF acid pumps have carbon steel casings with Monel® case rings, crystalline fluoride build-up (possibly a form of galvanic or crevice corrosion) seems possible between casing and case rings. Over time, the Monel case rings can deform and close-in the clearances. At startup, galling will occur. In efforts to prevent the buildup of crystalline fluoride, attempts have been made to coat the casing locations where Monel rings are fitted. The results seem to be mixed, at best. Fortunately, the issue is rather academic since PFA/CF will cure the seizing and/or galling problems reported with Monel wear rings.

PICK THE RIGHT SEAL AND FLUSH PLAN

The author-presenter sees no merit in explaining the various flawed flush plans to which YRE had alluded in his e-mails. None of these flush plans are recommended and the reasons are thought to be obvious. A good seal manufacturer will assist in sorting things out and will impress customers with candor and honesty. Such a mechanical seal manufacturer may be fair-minded to the point of explaining to its client-customers where the competition might excel. So, YRE should work with a seal manufacturer who is loath to do experiments with MOR "holding the bag," so to speak. YRE could (and should) verify that

other refineries also have the depropanizer charge pump service (flow, pressure, product properties) found in MOR's alkylation unit (Ref. 3).

The author identified at least two refineries, one in the U.S. and one in South Africa, where manufacturer "C" has applied many pressurized dual seals. In old legacy pumps with restricted seal chamber dimensions, seals of the type generally known as pressurized tandem 3CW-FB (Contact Wet, Face-to-Back) were used. For pumps manufactured after 1994, face-to-face designs (3CW-FF) were provided; both types used stationary-mounted flexing parts. These installations generally incorporated a flush plan that varied slightly from Plan 53B; no nitrogen connection was used. Essential features of Plan 53B are those of a dual seal assembly with pressurized buffer fluid circulation. The fluid circulation loop includes a bladder-type accumulator (Figures 5 and 6).

Figure 5 (above): Plan 53B seal support system incl. bladder-type accumulator (Courtesy of AESSEAL)

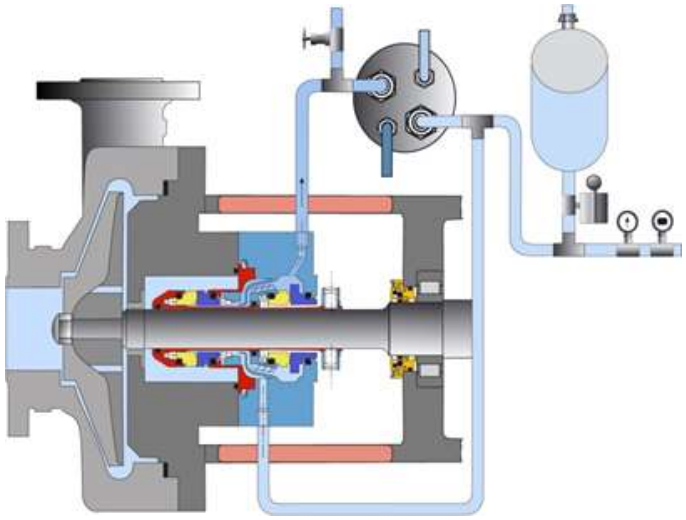

Figure 6 (above): Schematic view of Figure 5, a typical system with successful service in HF processes (Courtesy of AESSEAL)

An experienced colleague pointed out that Plan 53B systems have been viewed as an "engineering challenge" around the world, often with long lead times. However, at least one manufacturer's innovative modular concept permits application of a dozen modular options to create an API Plan 53B system for any application. This modular design approach facilitates efficient stock control which in turn allows modular API Plan 53B systems to achieve rapid delivery times. Quite possibly the YRE can solve long seal delivery times by working with vendors that excel in modular designs. Modularity eases the compilation and production of documentation for each Plan 53B product. Modularity also makes it easier to determine the correct solution for a particular sealing application.

THE RIGHT PLAN FOR HF SERVICE: DESCRIPTION OF API FLUSH PLAN 53B

Pressurized barrier fluid circulates in the outboard seal of dual seal configurations. Circulation is maintained by using a pumping ring in running condition and with thermosiphon effect in stand-still condition. The pressure is maintained in the seal circuit by a bladder-type accumulator. The operating principles of Plan 53B are as follows:

- Keeps barrier fluid and pressurized gas (inert gas) separate by using a bladder
- Heat is removed from the circulation system by an air-cooled or water-cooled heat exchanger
- Being a stand-alone system, it does not rely upon a central pressure source. Hence, it is considered more reliable than a Flush Plan 53A
- In no case will media leak to atmosphere
- Clean fluid film formation between the inboard seal faces gives better seal life
- Suitable for applications where no leakage to atmosphere can be tolerated, e.g. hazardous, toxic, and flammable media
- For dirty, abrasive or polymerizing products where the pumped fluid is unsuitable as a lubricant for inboard seal faces

There are some cautionary words, however. A user should realize there will always be some leakage of barrier fluid into the product. Hence, the compatibility of a barrier fluid with product should be reviewed and ascertained. The volume of barrier fluid in the system is relatively low and heat dissipation is largely dependent on cooler efficiency. Bladder pressures need to be maintained; one always recharges the bladder to 0.9 times working pressure and the system must be properly vented before startup. Finally, product quality can deteriorate due to barrier fluid contamination.

VALUE A SEAL MANUFACTURERS' EXPERTISE

As mentioned earlier, a seal manufacturer's expertise deserves to be highly valued. But should one of the seals in the dual arrangement have its inside or its outside diameter contacted by the buffer fluid? Or should both of the dual-face pairs be contacted by the buffer fluid on their respective insides or outsides? An inexperienced seal salesperson may not be able to say and to explain; so, rule out the inexperienced. Seal specialists whose only intent and motivation is making a sale may hesitate to tell clients that their offer is less than ideal; accordingly, YRE and other reliability-focused engineers would rule them out.

At the risk of offending by being repetitious: Please learn. More specifically, YRE was asked to recognize a highly principled and experienced seal person: He/she is the one desiring to divulge all the pluses and minuses of the many different available configurations and styles; so, user-purchasers should pick that person with great care. Oftentimes a vendor's application engineering expertise rapidly adds real value. It's impossible to overstate the importance of carefully choosing one's information sources. Facts will forever trump opinions, and forever is a very long time.

Once any changes are made to an API Flush Plan, it becomes a Plan 99. A modified Plan 53B is the system most likely to provide the highest level of integrity while continuously monitoring both primary and secondary seal condition. In any event, establish access to a solid, smart, customer-oriented seal manufacturer who has provided the appropriately modified Plan 53B--now Plan 99—on previous occasions. Establish for yourself that a hypothetical manufacturer "C" has refinery customers that have exceeded a five-year seal life on their less-than-perfect depropanizer pumps. Prove to yourself that this Vendor "C" can explain and provide a pressurized Flush Plan 99 dual seal for this very critical service. Whenever Vendor "C's" Plan 99 offer is verifiably duplicating the geometry, dimensions, and operating conditions in satisfactory, safe, identical HF-services elsewhere, a run length of 10 years is not out-of-reach with better-than-average or fully API-610-compliant process pumps.

THE BEST SEAL IS WORTH PAYING FOR

Because YRE and his employer MOR will want high reliability with HF, they should strongly discourage experimentation. YRE should be prepared for opposition from staffers who, conceivably, will cite partnership agreements MOR might have with seal vendors "A", "B", or "D". The author's recommendation was for YRE to tactfully prove to his managers that even the most expensive experience-backed mechanical seal is truly inexpensive when compared to the many risk-prone potential scenarios with cheap and/or experimental seals. The record shows that these risky scenarios can range from highly unpleasant to absolutely devastating. Working exclusively with "A", "B" or "D" can be fraught with compromises. The experience related to the author by YRE confirmed and reaffirmed that view. Moreover, there is consensus among experts that no oil refinery has ever reached true "Best-of-Class" performance, safety and profitability by single-sourcing mechanical seals. MOR was asked to consider adding Vendor "C" to its list of technology providers. Management at MOR should endorse and encourage YRE to engage in discourse with this potential provider.

Yet even here, as one deals with a principled and experienced vendor, configurational and instrument-related details need to be fully confirmed by the user. Operator skills and diligence obviously influence these choices and selections.

MECHANICAL SEAL VARIANTS

The list provided by the cooperating manufacturer contained several seal type variants applied in different applications. One service of particular interest is a deisobutanizer bottoms pump on the alkylation unit of a refinery in Texas. Being on the alkylation unit will mean the seal could be subject to hydrofluoric acid which calls for the seal to be supplied in Alloy 400 (Monel, except for Vespel parts) and high-performance perfluoroelastomers (Kalrez) in mechanical seals. Recall that exposure to HF in process plants will be restricted. Remember that full compliance with specific safety measures is needed to enter, or even approach, the HF unit. Therefore, seal reliability on these units will no doubt be of the utmost importance to YRE and other reliability engineers in modern refineries.

Most seal manufacturers place considerable emphasis on the advantages of cartridge-style dual seals that are collectively identified as cartridge-API Style. Reliability-focused users ask questions on how fluid motion is promoted in dual mechanical seals. Close-clearance pumping devices may be vulnerable to galling when contact is made with stationary parts. Plain cog-type pumping rings are rather inefficient; some produce only low flows and low head rise. In contrast, tapered pumping rings may cost more but are designed with relatively wide-open clearances.

Overall, there are many different variants of cartridge seal used in oil refineries and petrochemical plants. At least four of these are often considered by the author and other reliability-focused engineers:

- A pusher seal that is available in single and dual format. It is generally applied per API 682 guidance in service conditions up to temperatures of 350°F (176°C). The dual seal version is used in HF services. If possible, these seals incorporate a bi-directional tapered pumping ring (Figure 7) for greater cooling efficiency.
- Seal variants intended for mature assets, meaning legacy pumps with smaller cross-sectional stuffing box dimensions. Pressurized tandem 3CW-FB (Contact Wet, Face-to-Back) seals are often used in HF services with limited size stuffing boxes
- Dual seals with metal bellows. These seals incorporate full graphite secondary sealing for temperatures up to 750°F (400°C)
- Variants specific to API Flush Plan 23 and commonly used on boiler feed water services. These seals also incorporate a bi-directional tapered pumping ring (Figure 7) for greater cooling efficiency.

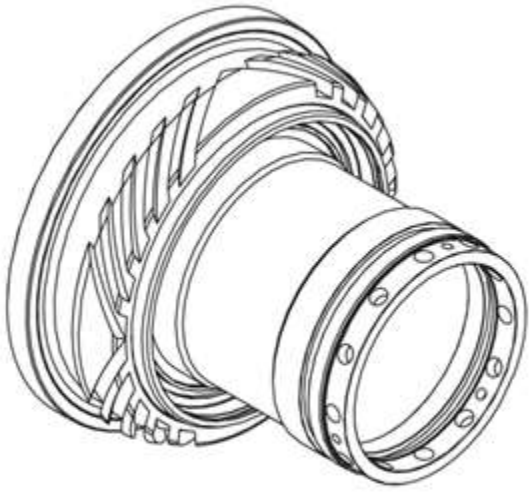

Figure 7: Bi-directional tapered pumping ring often used in dual seals for HF service (Courtesy of AESSEAL)

A PROCESS-RELATED NOTE: USING CONVERSIONS TO AVOID HF ALKYLATION

The major alkylation technologies at oil refineries use either sulfuric acid or hydrofluoric acid to catalyze the needed reaction. It's different with grassroots (greenfield) construction where the much less dangerous sulfuric acid alkylation process has almost

exclusively been used in the past two decades. However, as of 2018, a large number of aging HF-based units are still in operation. Their owners should give serious consideration to today's well-proven conversion technologies. These can offer the enhanced safety of sulfuric acid (H_2SO_4) over hydrofluoric acid (HF). Recently published conversions have achieved capacity increases at relatively attractive cost. While of primary interest to long-range planners, H_2SO_4 conversions deserve the attention of reliability-focused owner-operators (Ref. 4).

SUMMARY

As one fully analyzes YRE's experience, it is clear that both MOR and the author know several seal vendor-manufacturers that produce and provide mechanical seals for HF services. Still, YRE should disallow "re-inventing the wheel" where such re-inventing is simply not needed. MOR should join other user companies that value reliability focus over all other considerations. Reliability focus starts by specifying and purchasing products that are backed by verifiable operating experience. The long-term safety and reliability record of these user companies is proof that paying for the right products and engaging in relevant pre-procurement experience checks is the best available selection strategy.

PUMPS

View the system. It includes (but is not limited to) pump, pump characteristics, seal, seal characteristics, and seal support system. Pumps must also be viewed with local installation and maintenance practices in mind. Avoid sets of Monel wear rings. Instead, consider using a special polymer material (such as a PFA/CF composite, consisting of 20% mass fraction x-y oriented carbon fibers) in pump upgrading efforts (Ref. 2). The PFA/CF material is formulated to provide heat resistance, lubricity, dimensional stability, and both chemical and creep resistance. PFA/CF constitutes a superior wear ring material and, in the case of HF, should be used with the clearance values stipulated for metallic wear rings per API-610, latest Edition. (It should again be noted that tighter clearances are recommended for PFA/CF materials in virtually all other services).

MECHANICAL SEALS

Look for experience. Never allow experimentation. Teach operators and mechanical workforce members what the support system does and explain in great detail how and why it must be part of operator surveillance and maintenance diligence. Save time by having access to the vendor-manufacturer's application engineers, not just the regular sales force.
Give credit to modular design concepts and understand the merits of cartridge-style seals.

One particular seal manufacturer clearly impressed the author with a list of seals with a lifespan of 5-years-plus. This manufacturer provided a tabulation listing a total of 61 applications, 49 of which were still operating when last checked. The manufacturer also provided photos of its cartridge-style single and dual seals. Regrettably, the author was faulted for not giving enough publicity to other competent seal manufacturers. Let the record show that the author tried. Efforts were made to obtain illustrations and reference lists from other seal manufacturers that have not produced the desired results. And never forget the experience of YRE at MOR. Recall that he has struggled with this issue for years.

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The author would like to thank AESSEAL's Richard Smith for support in the development of this tutorial. An anonymous reviewer deserves praise for opining that the author's recent observations and writeups have shifted towards opinion rather than balanced data from field installations. It prompted the author to ascertain that this tutorial contains facts only. Regrettably, none of the reviewers provided data from their own field installations.

The author also expresses gratitude to the one (or, hopefully, several) unnamed supporter(s) who presently serve on Texas A&M's International Pump Users Symposium Advisory Board. Their courageous vote in favor of both presentation and dissemination of a fact-filled tutorial evidently overcame the unidentified objections or concerns of those who seemingly place vendor self-interest ahead of the interests of pump users. Aside from clinging to the personal belief that the need for professionalism and candor is factual and adds real value, this tutorial text reflects facts and events that are easy to verify. If, as was suggested by an anonymous reviewer, it reads like a sales presentation, so be it. To those who only read, hear and produce sales presentations, every narrative will sound like sales talk. But unless professionalism and candor prevail, the seekers and practitioners of reliability thinking are in danger of being outflanked by determined opposers. For now, no worry. The author is much encouraged by a few bright and principled people; they resist counterproductive trends and choose to pursue the sound ethical imperative of fighting the good fight (Ref. 5).