Circulation Systems for Single and Multiple Seal Arrangements-Part Three

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Conclusion of our series covering applications in which they are used, why they are used, how they fail, and things operators can check/do to maintain the performance of the seal flush plan.

Plan 52

Plan 52 uses an external reservoir to provide buffer fluid for the outer seal of an unpressurized dual seal arrangement. During normal operation, circulation is maintained by an internal pumping ring. The reservoir is usually continuously vented to a vapor recovery system and is maintained at a pressure that is usually at or near atmospheric pressure. The inner process seal of the dual unpressurized arrangement usually has its own flush plan.

For example, Plan 11 might be used on the inner seal along with Plan 52 for the outer seal. In such cases, the complete flush plan might be described as Plan 11/52. The reservoir size can range from 2 gallons to 5+ gallons of liquid capacity and has an internal coil of tubing which is used to remove heat.

Unlike heat exchangers, in the reservoir the cooling water flows through the coils while the buffer fluid flows over the exterior of the coils. In some cases the cooling coils are replaced by an external heat exchanger or even finned tubing if the heat load is very small.

The circulation rate within a Plan 52 depends on the performance of the pumping ring within the particular closed loop system. The reservoir size is selected based on the size of the seal and the pump shaft speed. Small ANSI pumps typically have the smaller 2-gal reservoir. Larger pumps may require larger reservoirs, especially at elevated pumping temperatures. Heat soak, seal generation heat, along with turbulence energy within the outer seal chamber must be considered in determining the desired circulation rate.

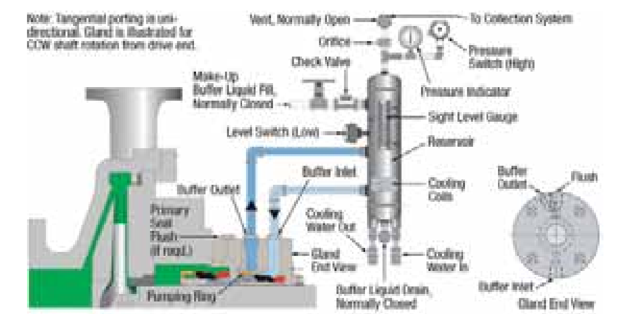

Figure 1. Seal Flush Plan 52

The general rule of thumb is that the reservoir should be located within a plot plan radius of about 3-ft, with the bottom of the reservoir 18-in to 30-in above the centerline of the pump. Many customers require that the liquid level provide at least 3-ft of static head to the outer seal.

Piping should be large in diameter and minimum length with long radius bends to minimize the pressure drop within the system to maximize flow. To prevent vapor locking, the piping should slope up from the gland plate to the reservoir.

In the event that the process, or inner, seal fails, there will be a pressure and/or level increase in the reservoir to set off an alarm. When this occurs, the reservoir should be blocked in by closing the valve near the top of the reservoir. As the process seal continues to leak, pressure and fluid level in the reservoir continues to increase. The reservoir can potentially reach the same pressure as the process seal chamber.

For all practical purposes, the outer seal takes over as the primary seal. For this reason, the recommended operating procedure is to begin planning an orderly shutdown for seal replacement as soon as possible after failure of the process seal.

In the past, most reservoirs for Plan 52 were vented to atmosphere, but due to environmental concern most systems are piped to a vapor recovery system. Plan 52 is used for both non-volatile and volatile process services. Although the leakage rate across the inboard seal is roughly the same as for a single seal, the leakage is directed into the reservoir of the dual unpressurized seal system.

In non-volatile services the leakage from the process seal increases the liquid level in the reservoir. In volatile services, the leakage from the process seal vaporizes and rises to the top air space inside the reservoir. When the reservoir is connected to a vapor recovery system, the actual emission rate can be very low.

Advantages

- Plan 52 is a necessity for dual unpressurized seals using a liquid buffer fluid. In comparison to single seals, the dual unpressurized seal can provide reduced net leakage rates as well as redundancy in the event of a main seal failure.
- The buffer fluid should not enter the process stream and contaminate the process fluid, because it is unpressurized.
- The buffer fluid can serve as a quench for the process seal.
- The pressure rating for a dual unpressurized seal is usually greater than that of a single seal.

Disadvantages

- Plan 52 is more complex and expensive than any single seal and the associated piping system.
- There will always be some leakage from the process seal into the buffer system where the buffer fluid is contaminated by the process fluid. Thus, buffer fluids must be selected with great care. It is possible over time that heavier process fluids will displace the buffer fluid resulting in the outer seal to be sealing the process fluid, thereby losing a buffer between the product and atmosphere.
- If the process fluid has a low vapor pressure margin, the heat from the outer seal can further reduce the margin causing the inboard seal to run with partial to full vapor between the sealing faces so an alternate system with dry running containment seals would be the recommendation.
- Venting is essential for Plan 52 to prevent vapor locking should vapor bubbles collect near the pumping ring.
- Selection, design and location of the pumping ring along with inlet and outlet ports is crucial to the successful operation of Plan 52.

Pressurized Dual Seal Plans

In the past there was only one Plan 53, but with the 2nd Edition of API 682 and the 1st Edition of ISO 21049 other variations of Plan 53s were created.

Plan 53A is the former Plan 53. Plan 53B is what had been in the past denoted as Plan 53 Modified; this is especially popular in European and Middle Eastern countries. Plan 53C is a variation of this that has also been used in the past and is now formally recognized.

The major difference in the plans is that Plan 53A uses an external reservoir, while Plans 53B and 53C run within a closed loop system with a make-up system piped to it for replenishment of the barrier fluid.

In dual pressurized sealing arrangements the inner process seal can have its own flush plan; in such applications the complete flush plan system designation should include both plans. For example, Plan 11/53A means that the inner seal has its own flush plan, Plan 11. The API/ISO default is for no separate flush plan when using any of the Plan 53s, but this can vary with the application conditions.

With the older traditional back-to-back seal arrangement the inboard seal usually does not require a separate flush. In applications like hydrofluoric acid, where it is both extremely hazardous and corrosive, a Plan 32 can be used in conjunction with a Plan 53. The dual pressurized face-to-back seal arrangement eliminates some of the potential problems associated with the back-to-back design. This face-to-back seal arrangement sometimes incorporates a reverse pressure capability that is not a default with the back-to-back design.

Also, face-to-back arrangements do not have a dead zone underneath the inboard seal that can become clogged by dirty process fluid and lead to seal hang-up. However, the face-to-back arrangement is not a cure-all. With the product on the seal O.D. and with it being used on API pumps that still incorporate throat bushings, it is advantageous to provide a flush for the inboard seal on a number of applications.

Abrasives can accumulate in the more closed API type seal chambers compared to the newer generation chemical duty pumps with large cylindrical bore or tapered bore chambers. The use of a Plan 11 or similar bypass type flush for the inner seal has advantages. It can help keep the seal chamber clean. It also has an improved overall heat transfer setup versus just using a Plan 53 system alone.

In comparison to a Plan 54, Plans 53A/B/C are usually less complex and less expensive. With Plans 53A/B/C, both the inner and the outer seals are lubricated by the barrier fluid, which can be selected for optimum seal performance. Plans 53A/B/C are usually selected for dirty, abrasive, or polymerizing process services which might be difficult to seal directly with single seals or with dual unpressurized seals using a Plan 52. There will always be some leakage of the barrier fluid into the process with any pressurized system.

With some of the Plan 53 systems the volume of barrier fluid is limited, especially compared to a Plan 54 system. Venting of the seal chamber is essential for all Plan 53's where vapor locking can if vapor bubbles collect near the pumping ring or in the piping.

Plan 53A

Plan 53A uses an external reservoir to provide barrier fluid for a pressurized dual seal arrangement. Reservoir pressure is produced by a gas, usually nitrogen, at a pressure greater than the maximum process pressure being sealed. The gas pressure is regulated by a system that is outside the schematic of the piping plan. Circulation of the barrier fluid is maintained by an internal pumping ring.

Like Plan 52 reservoirs, cooling is accomplished internal coil of tubing to remove the heat. Also like Plan 52 reservoirs, the volume of barrier liquid can vary from 2 gallons to 5+ gallons, where API and ISO standards specify 3-gal and 5-gal, depending upon the shaft diameter.

For non-API specifications, smaller reservoirs – typically 2-gal – are often used, especially at ambient pumping temperatures. Pressure alarms, pressure gauges and level switches are typically standard equipment and are required by API 682/ ISO 21049.

The circulation rate in a Plan 53A system is like a Plan 52 system described earlier. The piping to and from the seal chamber and location of the reservoir is also the same as a Plan 52 system. Unlike Plan 52, the elevation of the reservoir does not contribute to the pressure in the sealing cavity.

The usual guideline for Plan 53 barrier pressures is that they be a minimum of 20-psi to 50-psi above the maximum process pressure seen by the seal. Barrier pressure is normally supplied by a plant wide distribution system. Nitrogen bottles should not be used as they require a lot of attention and maintenance.

API 682/ISO 21049 recommends that the system be limited to 150-psig due to gas entrainment into the barrier fluid. Field experience has shown that with the proper barrier fluid, Plan 53A systems can be used up to 300-psig if the temperature is controlled to less than 250-deg F. A variation to this would be to use an accumulator to eliminate gas entrainment.

Advantages (vs. other Plan 53 systems)

- Least expensive of the various Plan 53 systems.
- Should the loop be contaminated for any reason, the contamination is isolated to a single installation.
- Wear particles that are heavier than the barrier fluid will settle to the bottom of the reservoir away from the reservoir outlet to the seal chamber.
- The volume of barrier fluid is dependent upon the size of the reservoir. Larger flow rates should use larger reservoir sizes so that retention time in the reservoir is maximized for longer fluid life.

Disadvantages (vs. other Plan 53 systems)

- The barrier fluid in Plan 53A is subject to gas entrainment due to direct exposure to the pressurizing gas. Different barrier fluids have varying levels of gas entrainment.
- Heat dissipation capacity is limited to the coiling coils, unlike Plan 53B/C, which have separate and potentially larger capacity.
- Installation should be limited to a single seal installation even on between bearing pumps. Therefore, for a large number of installations, Plan 53A can be more expensive than Plan 53B or 53C.

Plan 53B

Unlike a Plan 53A that incorporates a pressurized reservoir within the circulation loop, Plan 53B incorporates a bladder type accumulator along with the piping and an air or water cooled heat exchanger to provide for barrier fluid capacity.

Some installations use finned tubing as the heat exchanger, but these should be used with caution as the heat removal depends upon a positive air flow across the tubing to be effective. Gas entrainment is not a problem with this plan since it incorporates bladder accumulator to maintain the barrier pressure within the closed loop circuit.

The accumulator should be pre-pressurized to between 80 percent and 90 percent of the barrier pressure. This creates a problem in that it limits the volume of fluid within the Plan 53B circuit. The majority of the accumulator volume is gas.

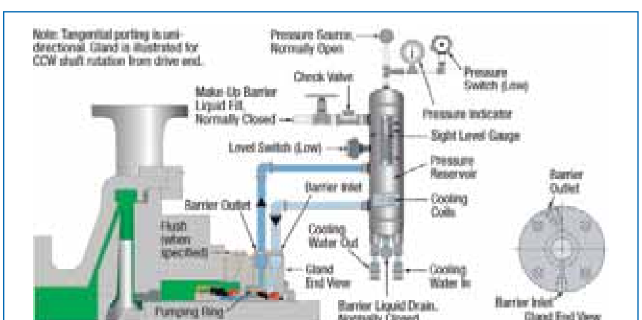

Figure 2. Seal Flush Plan 53A

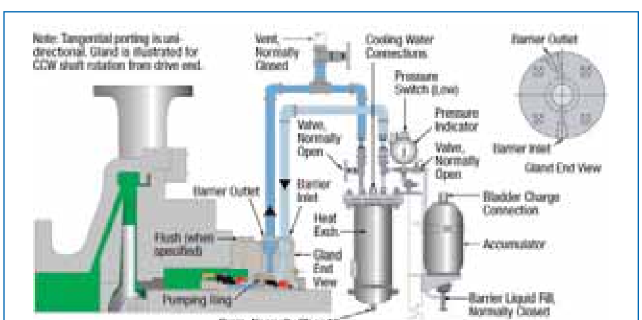

Figure 3. Seal Flush Plan 53B

The basic setup is comprised of two parts; the closed loop circulating system made up of the piping and heat exchanger and the make up system.

Flow in the circulating system is usually induced by an internal pumping device. The make up system can be configured a number of ways based upon the customer's preference, ranging from a simple hand pump to an elaborate pumping system feeding multiple pumps/seals.

Like Plan 53A, the flow rate of the Plan 53B circuit is controlled by the pumping ring design, peripheral speed, barrier fluid viscosity, and resistance of the piping circuit; the piping circuit of 53B includes a heat exchanger. The sizing of the heat exchanger depends upon the heat load of the system. The heat exchanger should be designed to contribute minimum resistance.

API 682, 3rd edition does not provide guidelines for sizing the accumulator of Plan 53B, but the total fluid volume of the system should be about the same as the volume of a 53A system.

Advantages (vs. other Plan 53 systems)

- The contamination within the loop, if any, is contained within the closed circuit.
- The make up system can supply pressurized barrier fluid to multiple dual pressurized sealing systems with either like or unlike pressure conditions.
- The barrier fluid is not subject to nitrogen or air entrainment as with a Plan 53A.

Disadvantages (vs. other Plan 53 systems)

- The volume of fluid within the closed loop circuit is very limited, as little as one-half gallon in some instances.
- With the limited fluid volume the barrier fluid gets thermally cycled on a much more frequent basis than a Plan 53A, so the service life of the fluid is reduced.
- The finite volume of the accumulator requires a designed pressure operating range between refills (in excess of that required for a Plan 53A) and this must be built into the pressure rating of the seals.
- A change in the system temperature affects the Plan 53B pressure.
- The separate heat exchanger introduces additional flow resistance to the piping system and will have a lower flow rate than an otherwise identical Plan 53A.
- Wear debris has nowhere to settle as in a Plan 53A system so it is continually circulated.

Plan 53C

Plan 53C is a variation of Plan 53B that uses a piston accumulator to track the pressure of the seal chamber. In Plan 53C, the piston accumulator has a reference line from the seal chamber to the bottom of the accumulator. There are differences in diameter of the internal piston so that a higher pressure is generated on the top half, which in turn is piped to the circuit loop

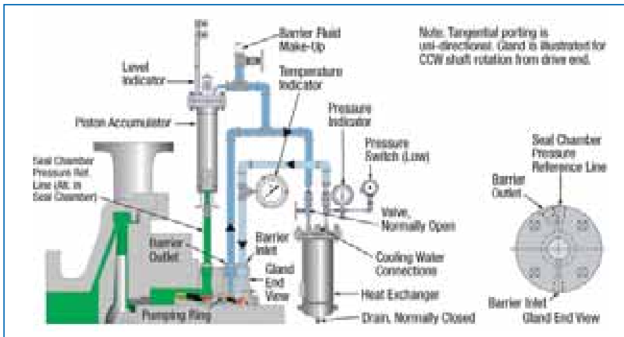

Figure 4. Seal Flush Plan 53C

into and out of the seal chamber.

Similar to Plan 53B, there is no gas pressurizing the barrier fluid so there is no chance of gas entrainment. Also, like Plan 53B, flow is generated by a pumping ring through a heat exchanger. The heat exchanger can be water cooled, air cooled or can be finned tubing if the heat load is small enough. This system should be used with caution, as the reference line to the accumulator is subject to the process fluid. The process fluid may be corrosive, abrasive, or a slurry that could potentially clog the pressure reference line, threatening the tracking ability of the system.

Advantages & Disadvantages (vs. other Plan 53 systems)

- The advantages and disadvantages are the same as the Plan 53B system. Additionally, the disadvantage of this system is that pressure spikes or pressure drops in the process pressure will vary the pressure on the outer seal that may create a temporary leakage condition. Also, tracking pressures can always be subject to delays that can cause a temporary loss of positive pressure differential across the inboard seal.

Plan 54

Plan 54 utilizes an external source to provide a clean pressurized barrier fluid to a dual pressurized seal. Strictly speaking, there is no "Plan 54 System" specified by API. That is, the details of the external lubrication system are not included by simply specifying Plan 54.

The external lubrication system for Plan 54 can be as simple as a basic reservoir, pump/motor, heat exchanger and relief valves to a complex system per API Standard 614 system. Plan 54 can even be pressurized from a process stream (the so-called "Process Plan 54").

The more complex systems can be supplied with redundant systems for uninterrupted service, accumulators to maintain pressure in the case of a power outage, and any number of alarms to detect operational problems. The complexity of the external lubrication system should be in line with the severity of the service or importance of the equipment operation it is supplying barrier fluid to.

The flush rate for a Plan 54 system must take into account not only energy from the mechanical seal (heat soak, seal gen-

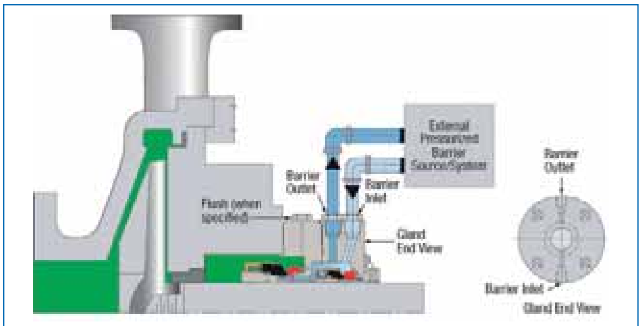

Figure 5. Seal Flush Plan 54

erated heat, and turbulence), but also the heat added to the barrier fluid from the pump supplying the barrier fluid. On low pressure/flow systems this is minimal, but can become significant on larger systems operating at high pressures and flows.

The system reservoir should be sized for a retention time of 5 minutes, so if the flow rate is 4-gpm the reservoir size should be a minimum of 20-gal. The flow rate is usually controlled by the size of the pump on the system. In applications where one system is supplying barrier fluid to multiple seal chambers, flow can be controlled with simple manually adjustable needle or globe valves to control valves utilizing a variety of mechanical or pneumatic systems.

Like other pressurized systems, the barrier pressure should be above the maximum pressure that the inboard seal will be subject to. This differential can range from a minimum of 25-psi to large differentials to account for possible upset conditions.

Advantages

- The barrier fluid is typically one that has good to exceptional lubricating properties, that when applied properly can result in extended MTBPM for the seal.
- When properly instrumented, the system can safeguard the seal against process pump upset conditions as well as power outages.
- The mechanical seal is exposed to a neutral fluid, with the exception of parts of the inboard seal, so that corrosion and other chemical related problems are eliminated.
- Positively eliminates leakage of harmful and fugitive emissions to the atmosphere.
- Can provide pressurized flow to multiple seal installations with one system to reduce costs.
- Is not constrained by nitrogen ingress into the barrier fluid as in a Plan 53A.

Disadvantages

- Systems can be costly compared to other flush plans, depending upon the number and type of redundant and safeguard systems utilized.
- The system is dependent upon a separate pumping system (pump and motor) that can cause seal failure if power to the "system" is lost.
- Damage to the inboard seal can result in contamination of the process from barrier fluid leakage.
- If used on multiple seal installations, the failure of one can have an effect on all of the other installations unless proper precautions are taken to isolate the failed seal.
- Dependent upon a reliable electrical supply.

Plan 72

Plan 72 uses an external low pressure buffer gas, usually nitrogen, which is regulated by a control panel before it is injected into the outer seal cavity of a dual unpressurized seal arrangement. It is almost always used in conjunction with either a Plan 75 or Plan 76 to lead inboard seal leakage to a collection system.

The control panel should contain a pressure control valve to limit buffer gas pressure in order to prevent reverse pressure on the inboard seal and/or limit pressure applied to the secondary containment seal. This is followed by either an orifice or needle valve to control the gas flow rate. The control panel should also have a coalescing filter to prevent solids and/or liquids within the buffer gas from contaminating the secondary containment seal.

A very important feature of this plan is that the gas purge is introduced close to the seal faces, whereas the vent and drain are located away from the seal faces. In API 682/ISO 21049 a bushing is required to physically separate the buffer inlet and the vent/drain. Plan 72/75 is used for primary seal leakage that is condensing (returning to liquid form). Plan 72/76 is used for non-condensing (vapor) leakage. This helps to minimize process fluid from affecting the containment seal faces and aids in diluting leakage to the atmosphere.

It is recommended that a Plan 72 not be used in a dead-ended containment chamber. The gas pressure regulator should control the pressure upstream of the flow control system to slightly less than the Plan 75 or 76 alarm setting to ensure buffer flow over the complete system operational range.

The minimum gas flow rate for dry containment seals should be in the 3-scfh to 6-scfh range, which will provide adequate product leakage dilution at normal inboard leak rates. Gas flow rates at this level can only be controlled by a needle valve. If dilution is still required at Plan 75 or 76 alarm points

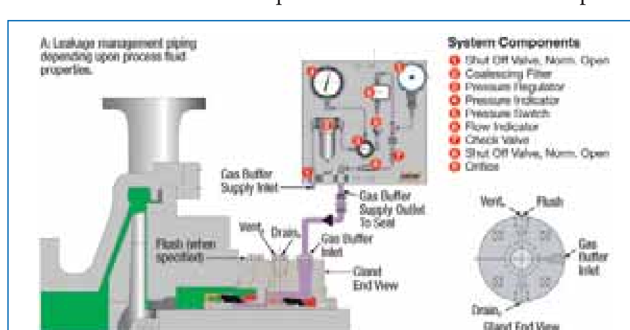

Figure 6. Seal Flush Plan 72

and/or a flow control orifice is specified by the purchaser, buffer gas flow rates are likely to be in excess of 20-scfh.

Advantages

- Protects the outer containment seal.
- Reduces fugitive emissions.
- Prevents icing in cryogenic services.
- Introduction of nitrogen keeps the outer seal chamber cooler. This is an advantage where the process fluid has a low vapor pressure margin.
- Temporary loss of nitrogen should not affect the performance of the containment seal.
- Lower maintenance and operating costs than a Plan 52 system.

Disadvantages

- Temporary loss of nitrogen can result in temporary increase in fugitive emissions.
- Contacting containment seals run better with the moisture from the process vapor leakage. A dry nitrogen purge reduces the moisture in the containment seal chamber and can decrease the operating life of the containment seal.

Plan 74

Plan 74 is a pressurized plan for dual gas seals that utilizes an inert gas, typically nitrogen, as the barrier fluid. As with all pressurized dual seal arrangements, the barrier fluid is at a pressure greater than the process pressure being sealed.

Dual gas seals differ from other pressurized dual seal arrangements in that they do not require circulation of a fluid between the seals since the seal generated heat is minimal. The flow of inert gas is the result of leakage past the outboard seal faces and, to a lesser extent, the inboard seal faces due to the low differential between the barrier pressure and process pressure.

As with the Plan 53A system, the inert gas normally is supplied by a plant wide distribution system. In some very special cases the nitrogen source can be a bank of nitrogen bottles. However, this can be an expensive, unreliable system, and the maintenance is high to ensure that the bottles have sufficient pressurized gas at all times.

Plan 74 includes a control panel to regulate the pressure going to the dual gas seals and API 682 includes some details of the panel. The panel also acts to remove moisture and filter the inert gas. The panel should contain a low pressure alarm along with flow meters. Flow alarms warn against problems with the gas supply and are optional.

The nitrogen source in a typical plant has pressure on the order of 100-psig. If the dual gas seal is sealing product pressures in excess of 75-psig, then the typical plant nitrogen gas source alone may be inadequate. In these applications a pressure amplifier (piston pump) can be utilized to boost system pressure.

The high pressure gas from the booster should be fed

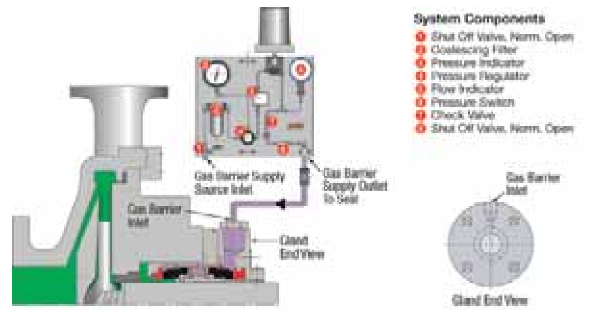

Figure 7. Seal Flush Plan 74

into a receiver of suitable capacity, as piston pumps are not designed for continuous operation. For this reason it is advisable to oversize the piston pump to minimize its operation and prolong maintenance cycles. It is not recommended to just hook the inert gas line directly to the seal cartridge. This is very unreliable, prevents regulation of pressure, and can allow for contamination of the seal faces that results in seal performance problems.

The schematic for Plan 74 shows two connections, a gas barrier inlet and outlet. The outlet is normally plugged, as flow beyond makeup for seal leakage is typically not a requirement for these seals.

Advantages

- Lower system cost than liquid dual pressurized systems, especially for between bearing pumps.
- Lower maintenance requirements and associated cost compared to dual liquid systems that utilize a pressurized reservoir (Plan 53).
- Leakage from the inboard seal into the process is an inert gas and is easily separated from the process downstream.
- Barrier fluid leakage to atmosphere is an inert gas. Drainage and cleanup is not an issue as with dual liquid systems.

Disadvantages

- Entrained gas from seal leakage can cause pump problems, especially on closed loop systems.
- Gas entrainment problems can cause pump performance problems on some installations with both low suction head and low flow conditions.
- Entrained gas under certain conditions can influence net positive suction head testing at the pump OEM level.
- Not recommended for services where dehydration of the pumpage causes solids buildup.

Plan 75

Plan 75 is designed for use with a dual unpressurized seal utilizing a dry running containment seal, where primary seal leakage is collected into a reservoir. It is intended to be used when the process sealed by the primary seal will condense to a liquid at

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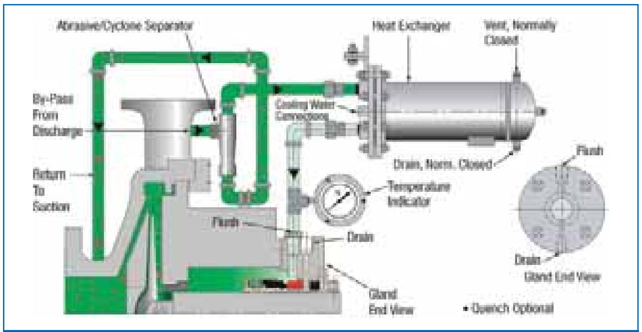

Figure 8. Seal Flush Plan 75

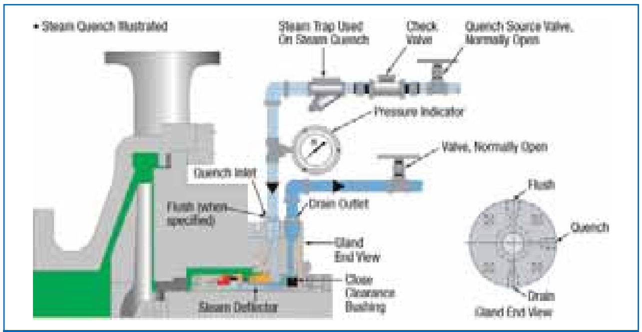

Figure 9. Seal Flush Plan 76

lower temperatures or is always in a liquid form.

In this arrangement, the drain is located at the bottom of the outer seal gland and is routed to the reservoir. Liquid leakage is collected in the reservoir and the gaseous portion is further routed through an orifice to a flare or vapor recovery system.

The reservoir does contain a pressure gauge and a high pressure switch to indicate a buildup in pressure in the reservoir from excessive primary seal gaseous leakage or a primary seal failure of some magnitude. Some users prefer to isolate the secondary containment device with valves to the reservoir in the event of a primary seal failure. A level switch to warn of excessive liquid leakage is optional on the reservoir.

The secondary containment seal can be subject to clogging in this arrangement. Some sort of baffle or close clearance bushing between the seal and gland should be used to isolate the containment seal from the leakage of the primary seal per API 682/ISO 21049. As noted earlier, Plan 75 can be used in conjunction with a gas purge from Plan 72. Typically, contacting secondary containment seals are used with this plan.

Plan 76

Plan 76 is designed for use with a dual unpressurized seal utilizing a dry running containment seal, where primary seal leakage is piped to a flare or vapor recovery system. It is intended to be used when the process sealed by the primary seal will not condense to a liquid at lower temperatures or pressures.

In this arrangement, the vent connection is located at the top of the outer seal gland for routing the vapors through an orifice that would create a back pressure to exist in the event of high inboard seal leakage. A pressure gauge and a high pressure alarm indicates this condition. API requires a minimum orifice diameter of .125-in, but smaller sizes may be necessary to provide a realistic leakage alarm point. It is recommended that the high pressure alarm switch be set at 7-psi above the mean operating condition in the flare or vapor recovery system.

The piping should continuously rise from the vent to the piping/instrument harness and should be properly supported so as not to impart strain to the gland. A drain connection in the piping is advisable in order to safely dispose of process fractions that may have condensed. A block valve is standard on this arrangement, to isolate the containment seal in the event of a primary seal failure.

While the secondary containment seal is less subject to clogging in this arrangement, the leakage from the primary seal may be a combination of a condensing and non-condensing fluid. When this is the case, the addition of a Plan 72/76 is highly recommended.

Advantages of Plans 75 and 76

- Lower initial cost alternative to liquid dual unpressurized seals using a Plan 52.
- Lower maintenance requirements and associated costs compared to liquid dual unpressurized seals that utilize reservoirs (Plan 52).
- Heat generated by secondary containment seals is small compared to contacting wet seals so minimal heat is added to the inboard seal. This is important in applications where the vapor pressure margin for the inboard seal is critical.

Disadvantages of Plans 75 and 76

- The secondary containment seal may not be capable of running for extended periods of time in the event of a primary seal failure.
- The secondary containment seal can become clogged with debris if the primary seal leakage contains a heavy fluid that can coke or crystallize upon exposure to air. This can be improved upon through the use of Plan 72 and a bushing that directs the fluid away from the seal and seal faces.
- Should some of the primary seal leakage condense and accumulate in the seal chamber, the containment seal will generate more heat that can potentially cause coking of the product and shorten seal life.
- All of the primary seal leakage will not go to the disposal system and can leak past the secondary containment seal faces to atmosphere.

P & S

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