Secondary Dry Containment Seals

Considerations in their use and application

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EXPERIENCE THE EXCEPTIONAL

Introduction

In March 2015 AESSEAL® published an article on the use and limitations of secondary dry containment seals[i], further consideration of this topic was given at the 2016 International Rotating Equipment Conference in Dusseldorf Germany[ii].

This article will use a case study as an example of one of the many cases seen in the field with a range of different manufacturer's seals, to illustrate the points made by these two technical papers and provide a check list of considerations for applications where product containment is essential.

Background

Legislation surrounding leakages from rotating equipment sealing devices has led to the introduction of more stringent regulations particularly relating to emissions and health and safety issues. Upgrading single seals to more compliant technology for mature assets has evolved from being a reliability issue, into a requirement to provide effective containment, or prevention of the process fluid leaking to atmosphere. In addition to selecting more modern sealing devices there is often a need to introduce, or upgrade a seal auxiliary system to further manage the risk of process fluids from reaching the atmosphere. One such instance is where wet or dry secondary containment seals have been incorporated in addition to the primary seal faces that seal the process fluid. Dry Containment seals[1] have gained popularity over the past two decades. Specifically the refinery sector has used this technology for limiting emissions without incurring the cost of more traditional liquid dual mechanical seal auxiliary systems, however there is little written about monitoring of the condition of Dry Containment seals during operation, or how they behave in the event of high levels of leakage from a primary seal. Kalfrin and Gonzalez[iii] state '*there are specific concerns regarding reliability and integrity of dry containment seals when compared to wet buffer outer seals'*.

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[1] For the purpose of clarity we have used the American Petroleum Industry standard API 682 4th Edition definition of a containment seal i.e. '**Containment Seal** – Special version of an outer seal used in Arrangement 2 and that normally operates in a vapor (gas buffer or no buffer) but will seal the process fluid for a limited time in the event of an inner seal failure'[1]

Case History

The Application

A petrochemical plant had installed a containment seal on a process pump that contained Butadiene as the process fluid. No seal support system was applied; however a pressure gauge was fitted to the containment seal cavity. The seal operated at a temperature of 44°C, a seal chamber pressure of almost 8.2 Barg and a speed of 2920 rpm. After approximately four years of operation the seal catastrophically failed and it was reported that there was a fire on the pump in question.

The Investigation

Figure 1 illustrates a typical containment seal design and will be used to indicate the key points discussed below

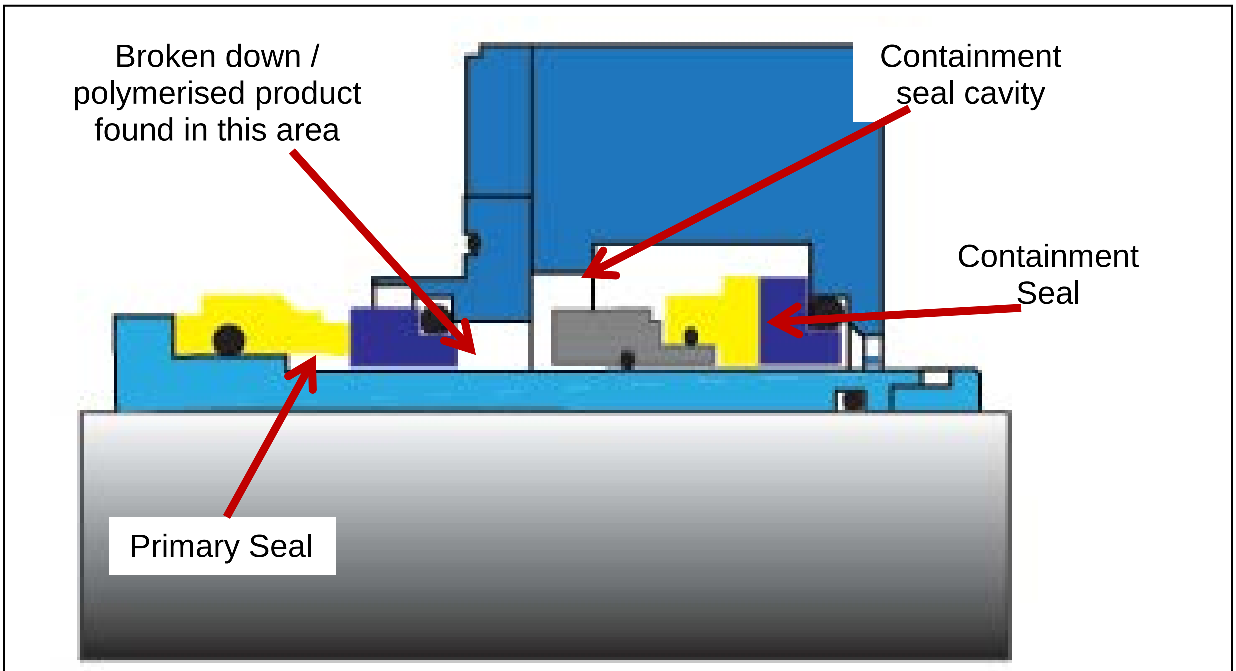

Figure 1: A Typical Containment or API 682 Arrangement 2 seal[iii]

The seal was returned for investigation where the following was discovered:

- The primary (inboard) seal faces although appearing scored and phono grooved were intact, suggesting that the primary seal did not catastrophically fail, although heavy leakage cannot be ruled out.
- Abraded damage to the primary seal faces mean that flatness was barely measurable. The abraded damage to the seal faces could have been as a consequence of heavily contaminated process leakage, or the degraded product build-up within the containment seal cavity.

- The containment (outboard) seal faces were totally destroyed suggesting a catastrophic failure of the containment seal. Heavy build-up of what appeared to be degraded process fluid was found within the containment seal cavity and around the outside diameter of the sleeve. It is suspected that this build up is a consequence of years of 'normal' process fluid leakage over the primary seal faces into the containment seal cavity. The process fluid has then broken down (polymerised) once subject to atmospheric pressure and ambient temperature within the cavity.

The seal had been operating without any auxiliary system support for the secondary containment seal. A pressure gauge was used to monitor any increase in pressure within the containment cavity should the primary seal suffer from high leakage. Had the primary seal suffered excessive leakage this would lead to either excessive vapour leakage to atmosphere and/or a back pressure within the containment seal cavity (dependant of the quality of the leaked process). If the containment seal was still in good condition to contain the process leakage from the primary seal, the pressure gauge should indicate a pressure increase providing the reference line to the gauge was not blocked. There were no reports from site of a pressure increase on the pressure gauge. This therefore indicates that either the primary seal was still operating satisfactory or that the pressure reference line was blocked.

Note: If high primary seal leakage does occur and as a result of no auxiliary piping plans being in place, the gas lift grooves within the containment seal will fill with process fluid. If the process fluid has polymerised/broken down these grooves will be ineffective and not produce any dynamic lift, leading to seal face contact, overheating and eventual seal face failure.

Containment Seals

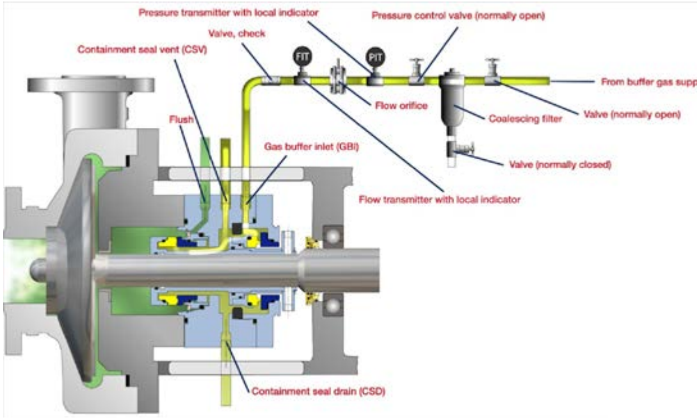

Figure 2 – API 682 Plan 72. [Ref iii]

In 2002, dry containment seals were recognized in the 2nd edition of *API 682.* A series of piping plans offered to take leakage to a safe collection point. The basis for a containment seal is an arrangement 2 seal with an API plan 71 seal support system as a minimum requirement (i.e. without buffer gas feed). The introduction of a buffer gas is covered with API plan 72 (Fig. 2) and the collection/disposal of process leakage is covered by API plan 75 (Fig. 3) and API plan76 (Fig 4).

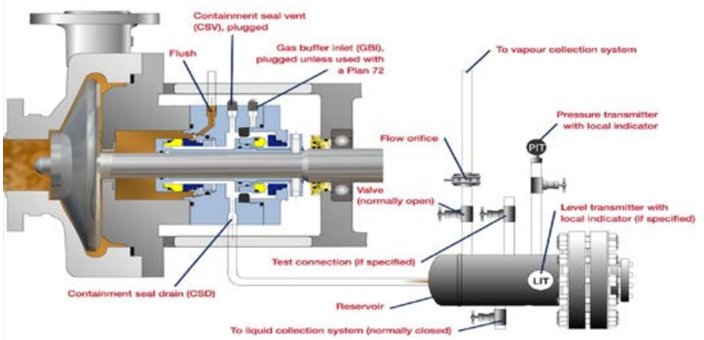

Figure 3 – API 682 Plan 75. [Ref iii]

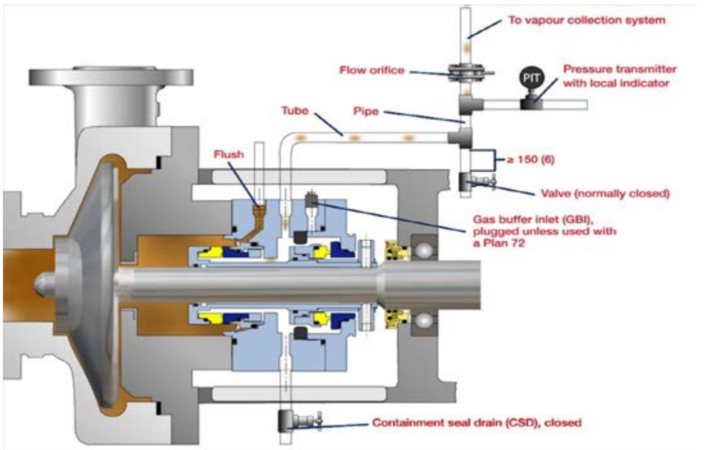

Figure 4 – API 682 Plan 76. [Ref iii]

Plan 75 is used for pumped fluids where 'normal' leakage would be condensing or mixed-phase fluid at ambient conditions. Plan 76 is used where the 'normal' pump fluid leakage would vaporize in ambient conditions. Additionally, Plan 72 with N_2 quench can be used to assist by sweeping the normal leakage to the collection location.

Note: API 682 4th Edition does not specify the buffer media

Containment Seals: Items for Consideration

- Contacting containment seals should be used with caution when no buffer gas is available.
- Non-contacting containment seals should not be used when no buffer gas is available.
- Plan 72 buffer gas systems provide a suitable means of preventing emissions.
- Plan 72 buffer gas systems provide a suitable means of reducing debris and subsequent damage to secondary seal faces whilst at the same time provide cooling.
- Periodic testing of secondary seals is advisable to ensure containment integrity is provided in the event of a primary seal failure.
- Dual seals with pressurised seal support systems are the only true means of preventing process leakage to atmosphere.
- With correct instrumentation dual seals with pressurised seal support systems can allow seal integrity to be continuously monitored.

When this is combined with the different requirements concerning emissions during normal and failure service (for both primary and secondary seals) plus integrity checks and monitoring it can be realised why containment seals are not readily understood by most operators.

Other options

Other sealing options can also be adopted that potentially provide the same level of sealing integrity as dry containment seals.

Wet Dual Seal with Unpressurised Seal Auxiliary System

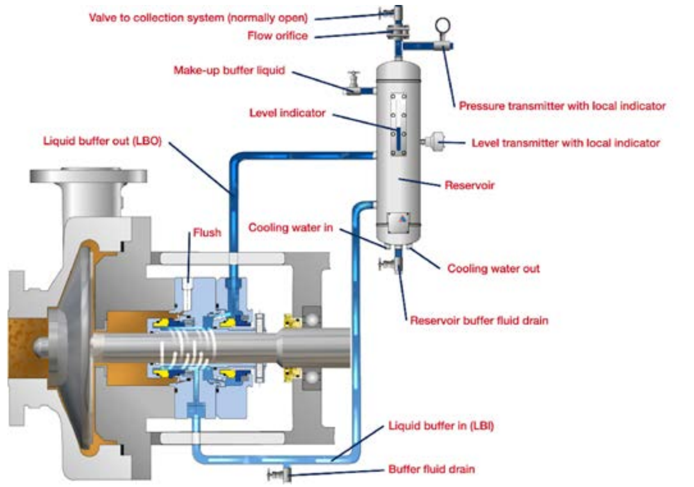

Figure 5 – API 682 Plan 52. [Ref iii]

Plan 52 (Fig. 5) is a wet dual unpressurised seal (Arrangement 2) where the buffer fluid (liquid) fills the space between the primary seal and the outer seal. Plan 52 is intended to be connected to a flare system so that the gaseous emissions that separate from the buffer fluid in the collection vessel can be vented. The 4th Edition of API 682[iv] specifies transmitters for both pressure and level, thereby offering a means of condition monitoring the primary and the secondary containment seal simultaneously. Any increase in liquid level in the tank, or an increase in pressure above flare would indicate high leakage from the primary seal. A reduction in liquid level would indicate a high leakage from the secondary containment seal. Plan 52 if operated and designed correctly is limited to the same application group as Plan 76 and is unsuited for process fluids which condense at ambient conditions. API 682 3rd edition and subsequent 4th edition specifically addressed the suitability (or otherwise) of plan 52 systems. *'Plan 52 works best with clean, non-polymerizing, pure products that have a vapour pressure higher than the buffer system pressure. Leakage of higher vapour pressure process liquids into the buffer system will flash in the seal pot and the vapour can escape to the vent system. Inner seal process liquid leakage will normally mix with the buffer fluid and contaminate the buffer liquid over time. Maintenance associated with seal repairs, filling, draining and flushing a contaminated buffer system can be considerable'*

Dual Seals with Pressurised Seal Auxiliary System

The principal difference between a dual seal with a pressurised and unpressurised containment seal auxiliary system is that with a pressurised system, both the primary and secondary seals will be sealing a clean, non-hazardous barrier fluid, whereas with an unpressurised containment seal, the system is managing the hazardous (and or contaminated) leakage from the primary seal.

A benefit of this type of system is that in the event of a pump being accidently dry run (not an uncommon occurrence in tank farm product transfer, or off-loading), both seals (primary and secondary) remain lubricated and therefore will survive.

Pressurised Dual Seals are becoming increasingly commonly found within industry. The cost of the supporting systems of pressurised dual seals has become more comparative with unpressurised containment seals, especially when considering the cost of utility connections. The barrier fluid of the system can be either a non-compressible liquid (Plan 53 A, B or C) or compressible gas (Plan 74).

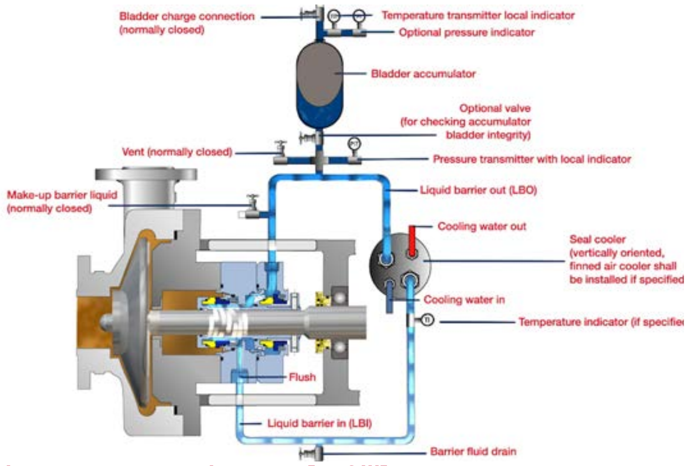

Figure 6- API 682 Plan 53B. [Ref iii]

API Plan 53B (Fig. 6) has been widely adopted by many users / operators as it requires no connections to any external utilities (if an air cooled system is adopted). The barrier fluid is pressurised in a bladder accumulator with a nitrogen pre-charge. The bladder accumulator feeds the barrier fluid to the seal cooling circuit and the barrier fluid is pumped around the cooling circuit via a pumping ring within the seal assembly. During normal operation, 'normal' leakage of barrier fluid will enter the process across the primary seal and to atmosphere across the secondary seal. Pressure is measured and as the pressure decays over time, barrier fluid will be recharged either manually or by an automated top up system. The frequency of top up required provides owner / operators with a with a very clear indication of the condition of seal condition. Increasing refill frequency would provide an early warning of seal condition deteriorating.

With a properly designed dual seal in the event of major leakage from either the inner or the outer seal, the process will be contained. With excessive leakage from the primary seal, the barrier fluid circuit pressure would become equal to the seal chamber pressure. The pressure would alarm but if alarm was ignored for an extended period of time, the outer seal would contain process. If the alarm was further ignored the barrier fluid cooling circuit would become contaminated with process fluid over time. In the event of excessive leakage from the secondary containment seal, providing the inner seal is hydraulically double balanced, the inner seal will contain and seal the process fluid. 53B is perhaps the safest of all the dual seal plans with the highest degree of fault tolerance providing the operators understand the alarm and trip philosophy and have these levels set correctly in relation to the seal chamber pressure under normal operating and fault conditions.

Sealing System Fault Tolerance Comparison

Table 1 compares typical containment seals against other typical dual seal arrangements. Various typical scenarios are presented along with the alarm strategy that would be used and the effect of the condition. The traffic light colour coding illustrates areas of concern. In particular the table focuses on a major event where the seal leakage is high (so called catastrophic). Generally of equal importance is the prolonged integrity of the secondary sealing device since this ultimately prevents or restricts the leakage of large amounts of process fluid into the atmosphere.

In the case of containment seals the condition of the secondary seal at the time of primary seals failure along with monitoring devices will dictate how long containment is likely to last (if at all) and hence whether process leakage will be prevented prior to shut down and isolation of the equipment.

Kalfrin and Gonzalez[iii] recommend protocols: testing of containment seal integrity to detect a potential hidden failure of the outer seal. It is recommended to establish and adjust testing frequencies.

Fone, Bowden[v] recommended containment seal integrity testing to be conducted on a weekly basis – Such frequency would probably be impractical however as with any spot check testing the condition of the containment seal is only known at the point of testing.

API Plan	Technology	Scenario					
		VOC Emissions	Condition monitoring leakage detection		Catastrophic Failure Consequence		No liquid in seal chamber
			Primary Seal	Secondary Seal	Primary Seal	Secondary Seal	
Historic Practice Pressure Switch on Drain Line	Contacting Containment	Good	Leakage would need to exceed 15L/ min to alarm	Manual air test (pump offline[5])	**Pressure alarm**[1] Process leakage to Atmos > 0.1cc /min[6]	No way of detecting failure	Inner seal fails potentially catastrophically
	Non Contacting Gas Lift	Acceptable[2]	Leakage would need to exceed 15L/ min to alarm	Manual air test (pump offline[5])	**Pressure alarm**[1] Process leakage to Atmos > 45cc / min[6]	No way of detecting failure	Inner seal fails potentially catastrophically
75 Condensing Leakage	Contacting	Good	Leakage detection[4] visual unless optional Level Transmitter API 682 4th is specified	Manual Air test (pump offline[5])	**Level alarm**[1 2] Process leakage[6] to Atmos >0.1 cc/min	No way of detecting failure	Inner seal fails potentially catastrophically
	Non Contacting Gas Lift	Acceptable[2]	Leakage detection[4] visual unless optional Level Transmitter API 682 4th is specified	Manual Air test (pump offline[5])	**Level alarm**[1 2] Process leakage[6] to Atmos >45cc/min	No way of detecting failure	Inner seal fails potentially catastrophically
76 Vaporising Leakage	Contacting	Good	Leakage detection[5] via pressure transmitter - Flow rate~50L/min (90gr/min)	Manual Air test (pump offline[5])	**Level alarm** [1 2] Process leakage to Atmos >0.1cc/min	No way of detecting failure	Inner seal fails potentially catastrophically
	Non Contacting Gas Lift	Acceptable[2]	Leakage detection[5] via pressure transmitter - Flow rate~50L/min (90gr/min)	Manual Air test (pump offline[5])	**Level alarm** [1 2] Process leakage to Atmos >45cc/min	No way of detecting failure	Inner seal fails potentially catastrophically
53B	Pressurised Dual Wet 53B	Zero	Pressure Transmitter	Pressure Transmitter	**Pressure alarm** Process fluid will contaminate Barrier fluid over time.	**Pressure Alarm** Inner seal will contain Process[7]	Seal faces lubricated by Barrier Liquid Fluid - Barrier fluid temperature will increase
74	Pressurised Dual Gas 74	Zero	N2 Flow Transmitter	N2 Flow Transmitter	**High Flow Alarm** If insufficient N_2 flow available process fluid will not be contained by outer seal	**High Flow Alarm** Inner seal will not contain Process	Seal faces lubricated by Gas Barrier Fluid

Notes

1	Assumes a containment seal will contain; No guarantee if regular period static tests of the containment system are not performed
2	Figures Form API 682 4th edition Annex F.1.3 Predicted leakage rates
3	Assume API 682 4th edition philosophy and use of transmitter 3rd edition would rely on trending frequency of the level switch
4	Assumes fluid is primarily condensing (>C5) Level transmitter optional (API 682 4th) - A switch is optional in earlier editions of API 682
5	Assumptions C3 Propane Seal chamber 18 Barg. Orifice 3mm (as specified by API 682) Note: Reducing the orifice size will increase alarm sensitivity at the risk of blockage
6	Assumes 50mm seal / Seal Chamber Pressure 2.75 Bar
7	Assumes inner seal has reverse pressure capability

Table 1: Summary of Secondary Seal Buffer and Barrier Seal Piping Plan Monitoring[ii]

Conclusion

Secondary Containment seals should be operated with particular attention being paid to control the 'normal' primary seal process leakage collection. Operating them with an appropriate API plan as stated in API 682 is always key to ensure safe collection or disposal of the primary seal process leakage. In the example case study shown, the ideal solution would be to upgrade the seal and seal support system to a dual seal with a pressurised seal support system which would ensure the integrity of both the primary and secondary seal.

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[i] Contain 'normal' leakage from primary seals. R. Smith and S. Shaw, AESSEAL. Published in Hydrocarbon Processing March 2015

[ii] Secondary Dry Containment Seals: Their Use and limitations. Dr C. Carmody, and R. Smith AESSEAL Session 7-2 International Rotating Equipment Conference 2016. Dusseldorf Germany

[iii] API 682 Arrangement 2 Configurations – Considerations for Outer Seal and Support System Design. B. Kalfrin and L. Gonzalez Presented at 45th Turbomachinery & 32nd Pump Symposia. Houston, Texas, USA Sept 2016

[iv] API 682 4th Edition

[v] Bowden, P. E. Fone, C. J. Containment Seals for API 682 ISO 21049 Proceedings Of The 19th International Pump Users Symposium. 2002, Turbomachinery Laboratory pp 67-84