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# ADVANCED SEALING SOLUTIONS FOR NON-CRUDE HYDROCARBON SERVICES

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**ABSTRACT**
Two-thirds of the pipelines in North America are transporting non-crude hydrocarbon products such as NGL, diesel, avaiation fuel,

propane, ethane, etc. This industry and the number of miles of pipeline is growing as the need for these products are increasing to record levels. Industry regulations and environmental concerns are becoming more stringent and demanding for the pipeline operators. Operators are looking for reliable and proven technologies to meet these growing demands. A pipeline is made up of a series of pumping stations to maintain process flows. Typically they are separated by 50-70 miles depending on the product being transported and the terrain. Usually one pumping station will have between two to three pumps in series with one pump at maximum line pressure. Operators are looking for increased reliability and better control of leakage, or lost product, during normal and catastrophic seal failures. Many end-users have in-house requirements on product containment and preferences on seal arrangement. These preferences are designed to enhance pump reliability, reduce maintenance costs, and improve run time, while providing the level of product containment required to meet environmental regulations. Two years ago, an innovative Non-Pusher Secondary Sealing technology was introduced to the industry to improve seal performance on crude services. This now proven technology has been utilized in services throughout North America. That same technology has now been developed into a seal capable of handling non-crude hydrocarbon applications. In this paper we look at the development, testing, and field deployment of a primary seal and a non-contacting, bi-directional secondary containment seal for non-crude hydrocarbon services.

## BACKGROUND

Three years ago, the Non-Pushing Secondary Seal (NPSS) technology was introduced to the pipeline industry and since then it has successfully addressed challenging pipeline services. Over 300 seals have been installed utilizing the NPSS technology on crude services across North America. The use of Non-Pusher Sealing Technology represents a novel approach to the pipeline industry and has proven to enhance the reliability of crude oil pipeline applications. The NPSS technology has been meeting the stringent environmental regulations and the demands of the operators for safe, reliable, performance. This unique Non-Pusher Secondary Seal elastomeric element stretches and compresses to take up shaft/axial movement experienced by the seal in certain pipeline services. The sealing faces of the non-pusher seal tracks each other while in operation while providing class leading emission containment. In pipeline services shaft shuttling can occur due to the unstable axial loading conditions during hydraulic upsets [1]. Hydraulic shaft shuttling would quickly wear an O-ring and fret the stub sleeve resulting in increased leakage and premature seal failure. Coatings under the dynamic O-ring have been used in the past to help reduce the fretting of the O-ring, but they do not hold up over the expected life of the seal. Even the hardest of coatings have shown not to last more than a year under shuttling conditions. When using the NPSS, hard coating of the stub sleeve is no longer required because there is no movement of the secondary seal under shuttling conditions. This saves time and cost during seal refurbishment. Figure 1.0 illustrates the Non-Pusher Secondary Seal (NPSS) used on a high duty single seal utilizing a dual bushing [2] as the containment device (API Plan 66A).

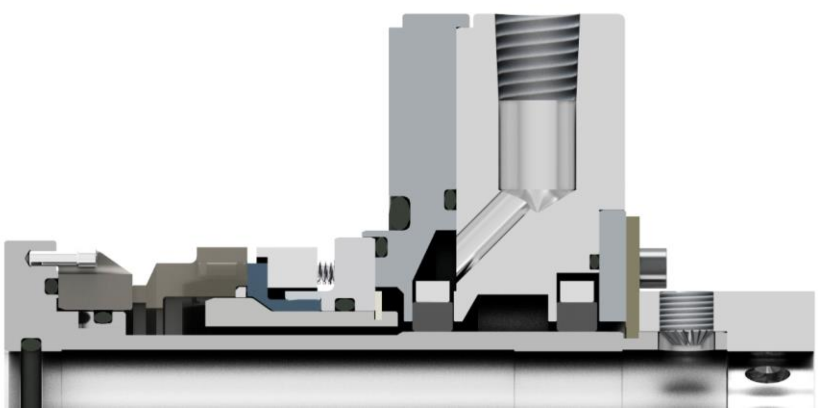


Figure 1. Non-Pusher Secondary Seal (NPSS) used on a high duty single seal utilizing dual bushing containment device.

## INTRODUCTION

There are few applications that place such a significant demand on mechanical seals as those associated with the handling of various fluids through pipelines. Pipeline applications are unique in that they typically encompass variable fluid properties, along with fluctuations in pressure, temperature, and speed, sometimes through the same pumping equipment. The movement of the chosen fluid is just one of the challenges associated with midstream pumping, additional challenges are associated with the remote nature of the installations and limited accessibility. Equipment monitoring and logistics of preventative maintenance support place an increased emphasis on the criticality of selecting a robust mechanical seal design and associated support equipment.

Increasing demand for products places additional demand on the rotating equipment charged with moving product along pipeline networks, this manifests in increased demand on the mechanical seals incorporated in the equipment within these networks. Many midstream pipelines handle multiple products with variable fluid properties and varying operating conditions and expect to accomplish this with the same rotating equipmnet and importantly the same mechanical seal. Pressure and temperature fluctuations along with variable fluid properties warrant special consideration into aspects of the mechanical seal design in order to achieve satisfactory performance, achieving accpetable levels of compliance in terms of safety, reliability, and environmental performance. Fluids encountered being considered in midstream pipeline facilities range from, refined products (gasoline / diesel), flashing hydrocarbons (propane, butane, NGL, Y grade), supercritical fluids (ethylene, ethane, and EP mix), and even Carbon Dioxide.

To be effective and acceptable pipeline sealing solutions must have:

- A solution that delivers extended reliability in all products
- Ability to resist hang up and wear of the secondary seal
- Ability to work with marginal interface lubrication
- Ability to withstand contaminates and abrasives
- The secondary containment device should be suitable to effectively divert leakage to drain at full dynamic pressure and ensure there is limited leakage to atmosphere
- While the leakage definition / acceptability will vary by customer, province, region or state, a typical large pipeline operator specifies "failure" criteria as approximately 10 drops per minute as reason to shut down equipment. Therefore, design criteria needs to reflect this as a typical shut down requirements, and be flexible enough to deal with individual requirements or circumstances.

This paper will discuss how a technology developed for crude duties has become a best in class technology that can be used in all liquid hydrocarbon duties as primary and secondary sealing technology.

The Non-crude hydrocarbon pipeline network is expansive and continues to grow as old lines are upgraded and new capacity is added [3]. Figure 2.0 illustrates the market split of pipelines globally.

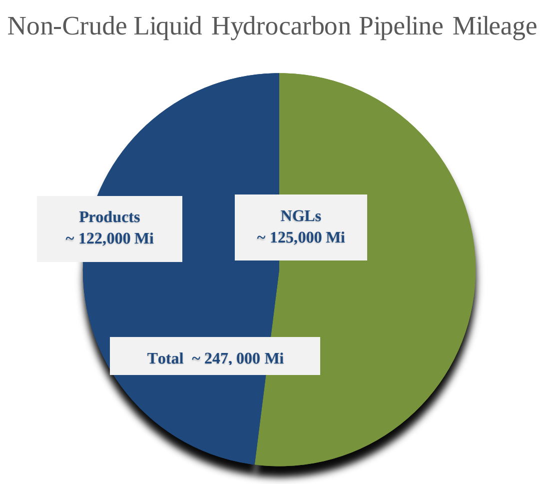



Figure 2. Global Market Split of Non-Crude Liquid Hydrocarbon Pipeline Mileage. [3]

Similar to crude pipelines, non-crude pipeline operators are demanding reliable sealing for flashing and non-flashing hydrocarbon services, such as NGL (Natural Gas Liquids). NGL applications offer challenges to the operators and the seal designer because of the nature of the fluids. Proven, reliable sealing solutions are required since pumping stations are normally located in remote locations. Containment of the process fluid and increased MTBR (Mean Time Between Repair) drives the selection of the sealing arrangement and support system.

Mechanical seals must have the ability to remain flexible and continue to perform without variation and ideally without failure. To meet the design requirements of the pipeline mechanical seals must be capable of operating up to 1500 psig (100 barg) dynamic and 2200 psig (152 barg) static across a range of pump sizes. The static duration can vary depending on shut down characteristics of the equipment and shut down procedures, while the characterization of leakage and the acceptable performance range varies by operating company. A typical large pipeline customer specifies "failure" criteria as leakage exceeding 1.5 standard cubic feet per minute at normal operation and 4 standard cubic feet per minute at process containment as reason to shut down equipment. These definitions and references are central to the seal design philosophy as well as the performance expectations assigned to a given design. [4]

This paper will discuss the proven Non-Pusher Secondary Seal technology for non-crude hydrocarbon services. For this paper, non-flashing hydrocarbon services will refer to fluids with a specific gravity greater than 0.65 and flashing hydrocarbons fluids with a specific gravity less than 0.65. "NGL" will be used to refer to services involving flashing and non-flashing hydrocarbons.

## CURRENT TECHNOLOGIES FOR NON-CRUDE HYDROCARBON APPLICATIONS

NGL pipeline conditions vary greatly, but typical operating conditions of NGL pipeline applications located in North America are:

- Fluid: NGL
- Temperature vs. viscosities
    - -2.5 C @ 3169Cst
    - 15C @ 650Cst
    - 30C @ 215Cst
- Temperature: -4 to 400 F (-20 to 204 C)
- Size (shaft) range: 2.625" to 6.130" (67-156mm)
- Speed: Up to 5000 fpm (25.4 m/s)
- Pump: Double-ended between bearings configuration
- Seal chamber pressure: Up to 1175 psig (81 barg) dynamic / 2200 psig (150 barg) static

## TYPICAL EQUIPMENT USED ON LIQUID HYDROCARBON PIPELINES

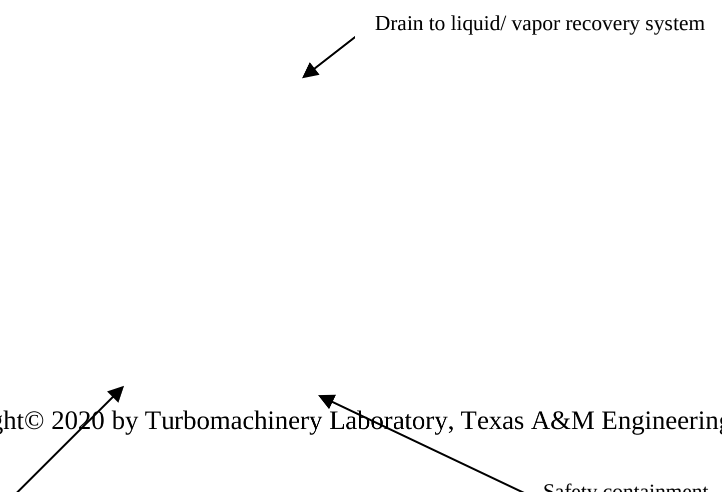
Pumps used in crude oil pipeline service are almost always described and defined by the API 610 pump standard [5]. API 610 groups pump types using a designation code. The following pump types are typically used in liquid hydrocarbon pipeline service:

- OH2 is one horizontal overhung impeller, centerline mounted and very common in refineries and offshore; sometimes called the "API 610 pump" or "process pump"
- OH3 is one vertical impeller, in-line mounted, very common in refineries and offshore
- BB1 is one impeller between bearings, axially split case, used in refineries and pipelines
- BB3 is multi-stage, impeller between bearings, axially split case, used in pipeline service
- BB5 is multi-stage, impeller between bearings, used offshore, called a "barrel pump"
- VS1 is a vertical, multi-stage pump, sometimes called a vertical turbine pump
- VS6 are used for booster pumps

Types BB1, BB3, and BB5 are the most common pumps used in NGL pipelines across North America.

## TYPICAL SEAL ARRANGEMENTS FOR NON-CRUDE HYDROCARBON SERVICES

Single seals with a secondary containment close clearance throttle bushing have been used successfully for many years. This arrangement is intended to provide for liquid leakage containment of the primary seal. Any leakage past the primary seal will be directed to a drain or vapor recovery system. The containment bushing arrangement can be a single bushing (API Plan 65A/B) or a dual arrangement (API 66A/B). This arrangement should not be used if the level of H2S exceeds 1000 PPM (Parts Per Million). Safety concerns demand the use of a dual unpressurized or pressurized arrangement with full product containment. The seal shown in Figure 3 uses an O-ring as the secondary seal. This O-ring can become compromised if the pump experiences hydraulic shuttling, which is common on pipeline equipment. Once the O-ring is compromised, it greatly reduces its ability to maintain a proper function. Installation records and failure reports on seals installed on shuttling pumps indicate this as the leading cause of reduced MTBR. Figure 3.0 illustrates a typical single pusher seal with secondary O-ring and with a safety containment bushing (API plan 65A or 65B).



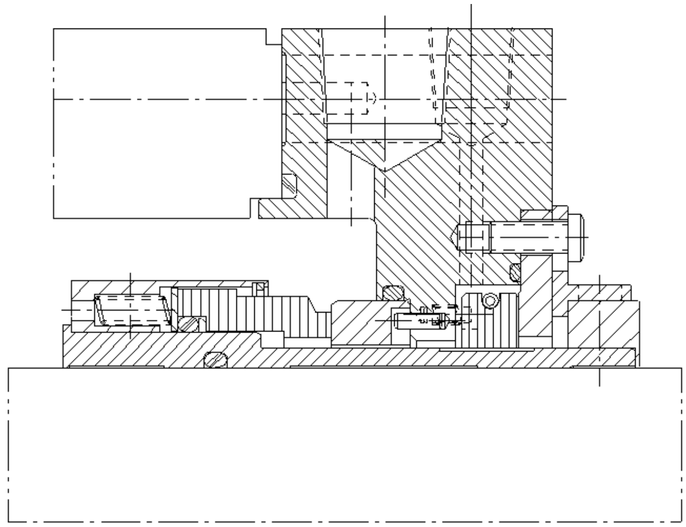


Figure 3. A Typical single pusher seal with a segmented bushing.

On NGL services, dual unpressurised seals are often installed, with either a liquid lubricated, dry running or non-contacting containment seal outboard. Many pipeline operators prefer one of these offering as standard, [6] because of the increased safety and leakage containment. Dual unpressurized seal arrangements utilize a primary seal inboard running on the process fluid, normally on an API Plan 11. This arrangement combines the use of a full containment seal along with the primary seal. This arrangement has proven to be effective in providing an added level of safety containment in the event of a primary seal failure. In dual unpressurized arrangements, as shown in Figure 4, any leakage from the primary seal will mix with the buffer fluid used to provide lubrication for the outboard (containment) seal. These arrangements typically uses an API Plan 11/52. This arrangement has been used successfully, but they do require added cost and maintenance due to the support system. Also, most use O-rings as the secondary sealing element in the containment and safety seal.

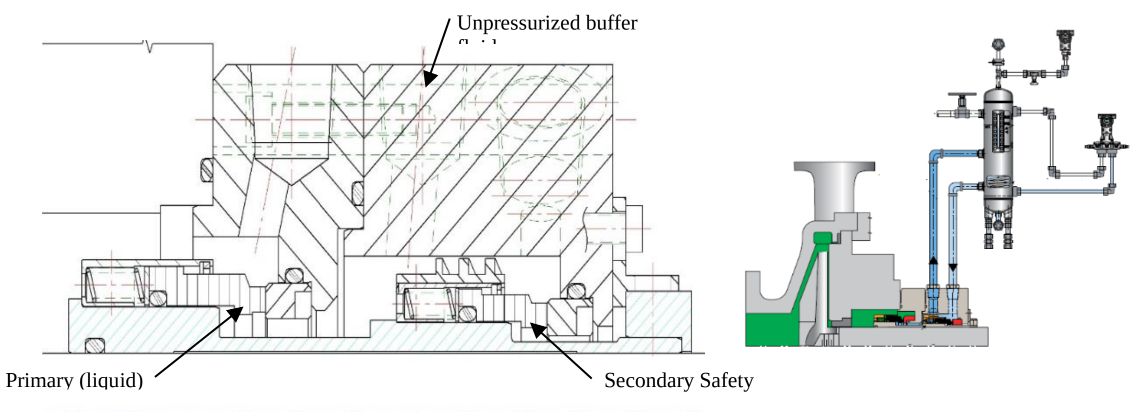



Figure 4. Typical dual unpressurized pusher seal arrangement using a liquid safety containment seal outboard with API plan 11/52

Figure 5.0 illustrates a typical dual unpressurized seals with a dry running, contacting containment seal. This runs on a seal support system that requires lower maintenance as the containment seal is running dry. Dry running contacting seals are designed to run in a dry environment (no buffer fluid) due to lightly loaded faces and special materials that can handle the lack of lubrication. The contact between the faces result in material transfer of the carbon graphite to the silicon carbide, resulting in a reduction in the coefficient of friction, thus lowering the heat generation and face wear. Some designs use specially designed hardware to reduce the temperature of the hardware as well, resulting in improved heat transfer. All secondary containment seals must be designed to run five years and handle full process pressure containment in the event of an inboard seal failure. They must also meet the API requirement of being capable of continuous running at back pressures (flare pressure) up to 40 psig (2.75 barg). Generally, dry running contacting seals run below 5 psig (0.34 bag). Dry running contacting seals typically use an O-Ring as the secondary sealing element to allow the seal to remain flexible. This arrangement has been used in crude services, but hang-up around the O-ring can occur when the crude does not drain out of the buffer chamber, thus hanging the seal open. These arrangements utilize an API Plan 11/75 or 76 as shown in Figure 5.

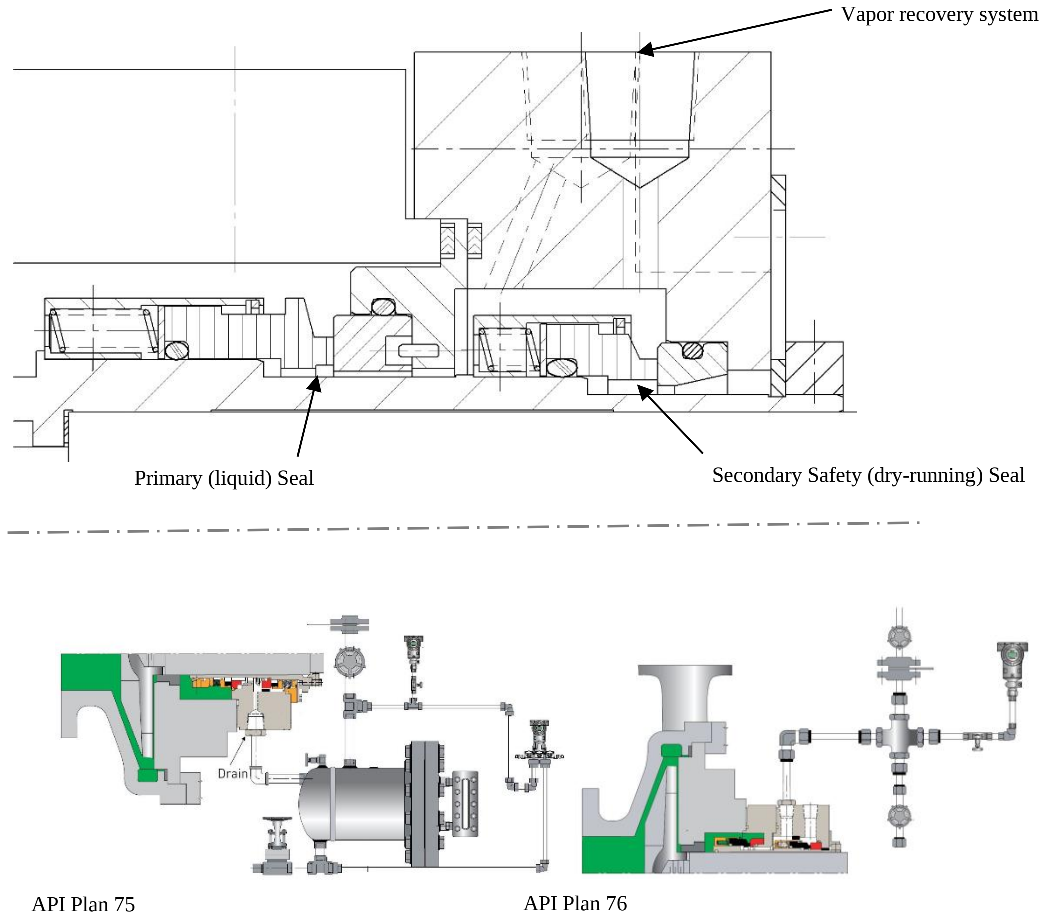



Figure 5. Typical dual unpressurized pusher seal arrangement using a dry-running safety containment seal outboard API plan 11/ 75 or 76

Figure 6.0 illustrates the typical unpressurized dual pusher seal with a dry running non-contacting safety containment pusher seal. The outboard seal utilizes a spiral groove faces pattern to provide hydrodynamic lift-off to separate the faces while running at low pressure operation. The faces run on a gas film generated by the vicious shearing of the gas at the interface (between the sealing faces). This increase in pressure is enough to separate the faces, resulting in a non-contacting condition. This technology was first introduced to mechanical seals over fifty years ago for turbo gas compressors and then to the pump industry 25 years ago [7]. Being non-contacting offers many advantages, such as, long life and less expensive and low maintenance support systems. Typically they are pusher seals using an O-ring as the secondary sealing element. Designs can be uni-directional or bi-directional. Like the dry running contacting secondary seal, the non-contacting arrangement using an API 11/75 or 76.

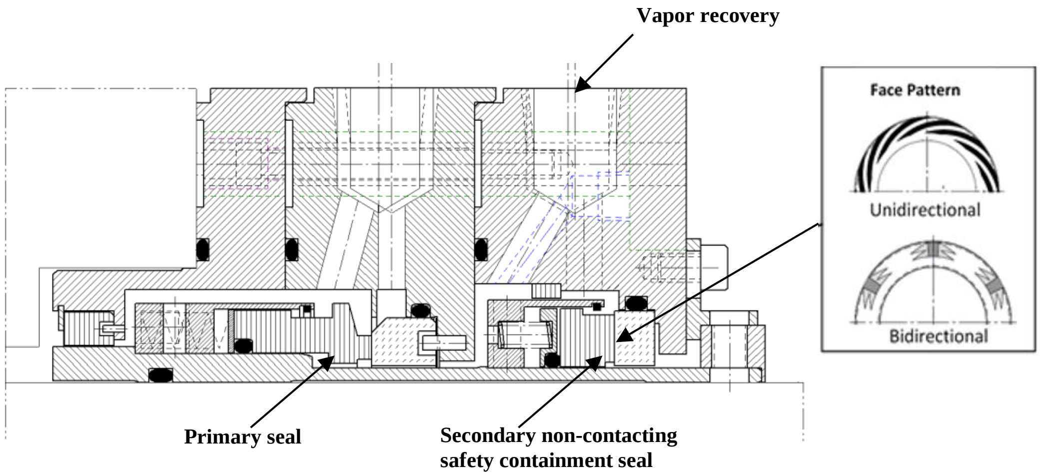



Figure 6. Dual unpressurized pusher seal with a non-contacting safety containment seal with API plan 11/ 75 or 76

Dual pressurized seals are often considered the ultimate in leakage containment and used where high concentrations of H2S (above 10,000 PPM) are present. Both the inboard the outboard seals run on a clean lubricating pressurized barrier fluid at a higher pressure than the process. This level of added safety and containment provides zero product emissions. Typically the barrier fluid pressure is set at 30-50 psi (2-3 bar) above the process pressure. A small amount of barrier fluid will leak into the process and across the outboard seal. Dual pressurized seals are deployed with intricate support systems as per API piping Plan 53 A/B/C or Plan 54 [8]. These support systems require more space, regular maintenance and often manual monitoring. Most dual pressurized seals for non-crude pipeline applications still utilize O-rings as the secondary seal which can result in O-ring wear and sleeve fretting due to pump shuttling. Figure 7.0 illustrates a typical dual pressurized pusher seal with an API Plan 11/53A.

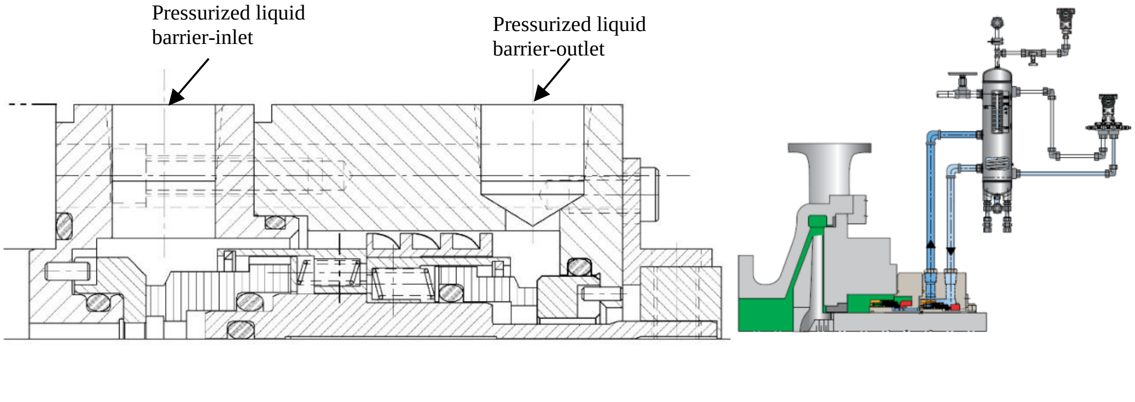



Figure 7. Typical dual pressurized pusher seal arrangement with API plan 11/ 53A

## CHALLENGES OF NON-CRUDE LIQUID HYDROCARBON PIPELINE APPLICATIONS

Pumping stations are often in remote locations, limiting their access and limiting the ability to incorporate support systems that require regular maintenance, such as the recharging of barrier or buffer systems. These logistical and maintenance concerns have dictated that most of the seal arrangements used in North America are single seals with a bushing or dual unpressurized seals, incorporating a wet seal or a dry running secondary containment seal as the containment/safety seal. These arrangements greatly reduce the complexity of the seal support systems required. Typically operators use the same BB style pumps for lighter and heavier products and in some cases experiences similar issues of O-ring wear and sleeve fretting as a result of pump shuttling.

## NON-CRUDE LIQUID HYDROCARBON APPLICATIONS

Based on the successful application of Non-Pusher Secondary Sealing technology on crude oil services, now the NPSS technology is extended to non-crude hydrocarbon services. Components of NGL's have varying states during production, some will exist as a liquid or vapor, and some will be a mixture of the two depending on temperature and pressure. The NGL's can be classified into non-flashing and flashing hydrocarbons. As per API 682, non-flashing hydrocarbons has a vapor pressure at any specified operating temperature which is less than an absolute pressure of 0.1 MPa [1 bar] [14.7 psi], or a fluid that will not readily boil at ambient conditions. Non-flashing hydrocarbons provides a stable fluid film (Specific gravity of the fluid is greater than 0.65). The recommended seal face design is a plain face that runs on the fluid film with contacting faces. API 682 defines that flashing hydrocarbons have an absolute vapor pressure greater than 0.1 MPa [1 bar] [14.7 psi] at the pumping temperature. A flashing fluid will readily boil at ambient conditions. (Specific gravity of the fluid is less than 0.65). The recommended seal design for these duties is a grooved face that runs as a non-contacting seal on a stable hydrodynamic vapor film lifting off the faces.

**FLASHING AND NON-FLASHING HYDROCARBON SEALING SOLUTIONS**

Sealing flashing and non-flashing hydrocarbons has its challenges, mostly in selecting the proper materials, face features, and secondary seal. If one was to use a standard low emissions seal in a flashing or non-flashing service, the seal would not perform at the level required to provide low emission sealing. Materials needs to be selected that will provide the strength needed to resist pressure distortion while still providing the lubrication at the interface. Antimony carbon is the material of choice for the primary ring running against a silicon carbide mating ring. Silicon carbide offers high strength and excellent wear resistance and heat transfer. A properly designed seal for these services needs to have a seal balance (force opening vs force closing) that will provide enough closing force to control leakage, while still allowing a stiff fluid film across the sealing interface. This is a challenge when the fluid has the tendency to flash across the face due to the drop in pressure and being subjected to the heat generated at the seal interface. If the fluid flashes across the face, the fluid film will collapse causing the faces to have a high contact pressure. This condition results in very high face wear, increased leakage, and reduced seal life. Face patterns are used to enhance the fluid film when sealing flashing hydrocarbons. The face pattern shown in Figure 8 is laser etched into the silicon carbide mating ring. The feature is made up of shallow grooves (2-3 micrometers) that are bi-directional, meaning the pattern can be rotated clockwise or counter-clockwise. The grooves allow more process fluid to enter the interface and the shape and the rotation of the grooves create a slight hydrodynamic lift. This helps to separate the faces just enough to reduce the contact load on the faces. A reduced contact load allows the fluid film to remain across the entire sealing interface. This results in reduced heat generation, reduced wear, and less leakage because the faces remain in good condition.

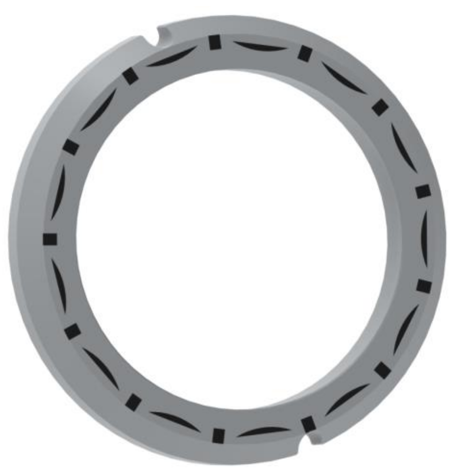


Figure 8. Laser Groove Face

The seal shown in Figure 9.0 is a dual unpressurized seal that can be used for flashing and non-flashing hydrocarbon services. It incorporates the NPSS (Non-Pusher Secondary Seal) technology on both the inboard and outboard seals. The inboard seal can be designed with plain faces inboard for non-flashing hydrocarbons or with laser grooves if sealing flashing hydrocarbons. The seal is a rotating seal design and has a robust drive to handle high startup torque and shaft misalignment. The seal has been designed using many of the features of the crude seal that has been running successfully for nearly three years. The proven NPSS is used to allow the seal to handle pump shuttling and provide stable face loading during changes in axial position or changes in hydraulic pressure. When process pressure varies, the percent of closing force does not change which allows the seal to maintain a fluid film when sealing flashing and non-flashing fluids. This is important because the seal can handle a range of pressures, from low to high, based on the extremes of line pressure. Seals that are designed to specifically handle very high pressures do not typically run well at very low pressures. Those seals tend to leak far more than a seal properly designed for high and low pressures. The stub sleeve under the NPSS is made of a high stress metal to hold up to the very high line pressures. No hard coatings are required because the secondary seal does not move during shaft misalignment.

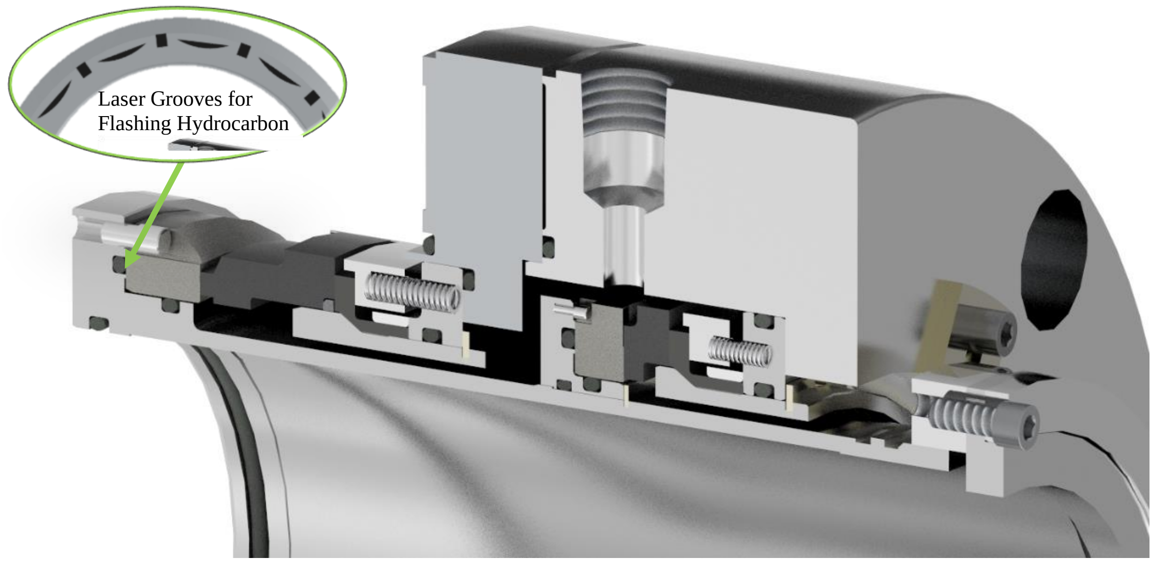
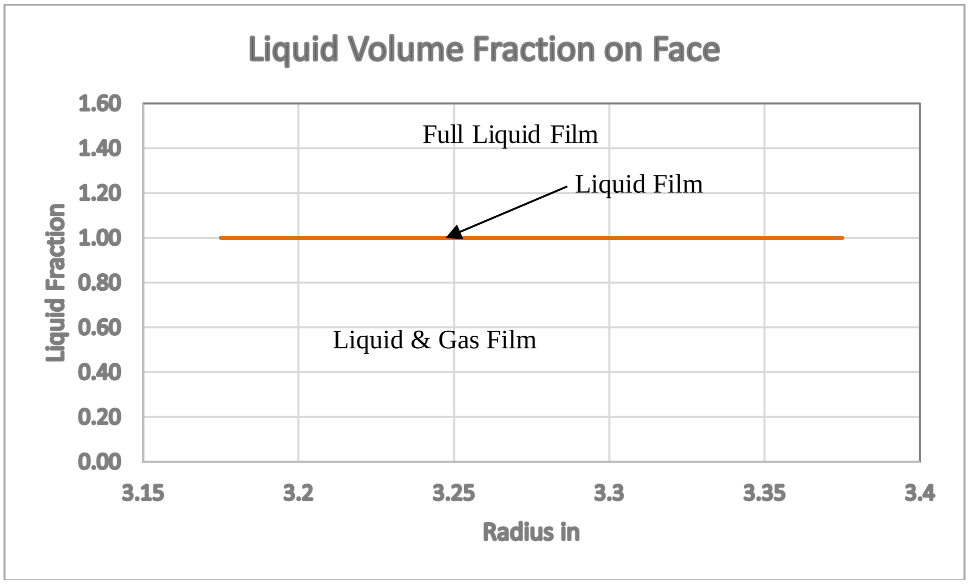



Figure 9. Dual unpressurized seals with laser face technology for flashing hydrocarbon services and a dry running non-contacting seal outboard.

**TESTING AND DEVELOPMENT**

The seal shown in Figure 9 has been developed using computer-aided FEA design software. Graph 1.0 shows the output of the modeling. It shows the liquid fraction at the interface is 1.00, which indicates full fluid film. Figure 10 shows the distortion of the faces under maximum pressure. The FEA results were validated through thousands of hours of testing. Two sizes were tested: 3.760" (95.5mm) and 5.510" (140mm) shaft sizes. Both sides were tested in propane and diesel at low pressure 200 psig (14 barg) and maximum pressure of 1175 psig (81 barg) and at 1800 and 3600 rpm. Throughout the test the leakage did not exceed 300 PPM for Propane and 20 ml/hr for Diesel for largest size at the highest speed and pressure. Operating conditions were determined by establishing actual operating conditions collected from several pipeline operators. Face heights were recorded pre and post-test. After each test, the data showed excellent performance and great correlation to the FEA model. Figure 11 shows the post-test faces from propane and diesel testing. The pictures show a desirable wear pattern on the inboard seals and no damage caused by a collapsed fluid film. See Figure 12 for the test rig setup.




Graph 1. FEA analysis at maximum pressure showing a full fluid film across the faces

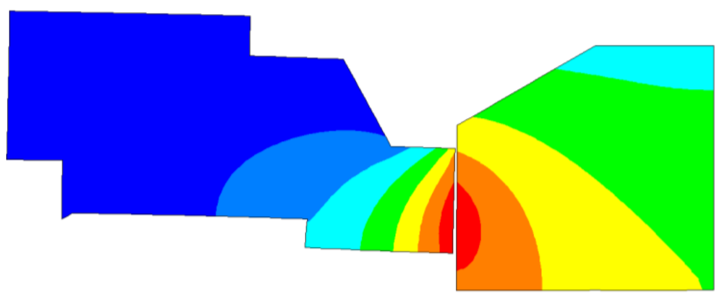


Figure 10. Face distortions from FEA analysis showing minimum distortion of the faces at maximum line pressure

Propane Post Test Faces

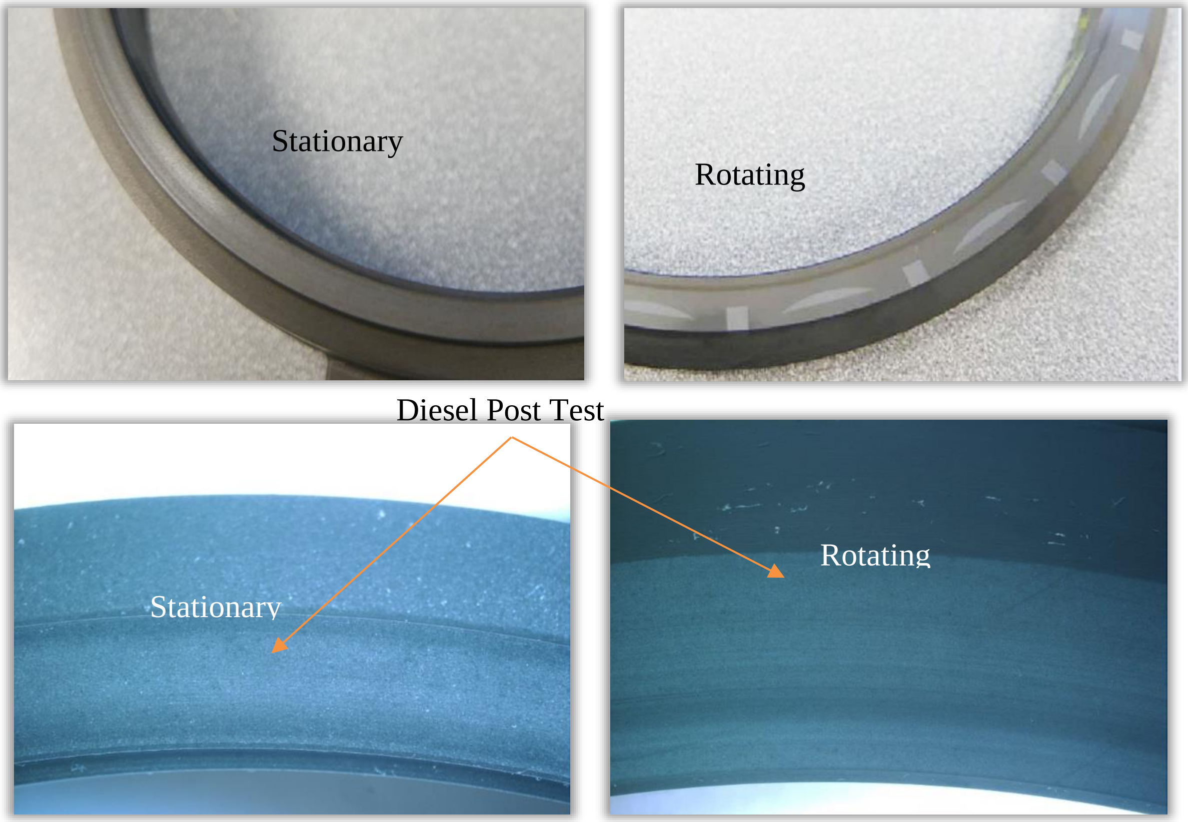



Figure 11. Propane and Diesel post-test faces of primary inboard seal

Figure 12. Test rigs for testing Diesel and propane

**DUAL UNPRESSURIZED SEAL WITH A DRY RUNNING NON-CONTACT SECONDARY CONTAINMENT SEAL**

Flashing hydrocarbons are liquids under high process pressure, but change to vapor due to a reduction in pressure or an increase in heat. Along with the Non-Pusher Secondary Sealing technology, face patterns provide hydrodynamic lift-off to the seal faces and minimize the frictional heat during the liquid phase change. In the dual unpressurized arrangement, a primary seal utilizing Non-Pusher Secondary Sealing technology is paired with a specially designed dry running non-contacting secondary containment seal. The outboard seal runs unpressurized during normal operation, but is designed to handle full line pressure in the event of an inboard seal failure. It also keeps the vast majority of seal leakage from exiting the pump while directing it to drain/vapor recovery system using an API plan 75/76 arrangement. The secondary containment seal has the capacity to operate at the same conditions as the primary seal for a short duration while equipment shut down and maintenance commences. This secondary containment seal offers extended safety and reliable seal performance. A dual unpressurized seal with a non-contacting dry running secondary containment seal utilizing Non-Pusher Secondary Sealing technology for NGL services is illustrated in Figure 13. The faces incorporate bi-directional spiral grooves. This feature allows the seal to be run clockwise or counter-clockwise., thus preventing the seals from being installed incorrectly, compensating for any reverse rotation and reducing spare part inventories.

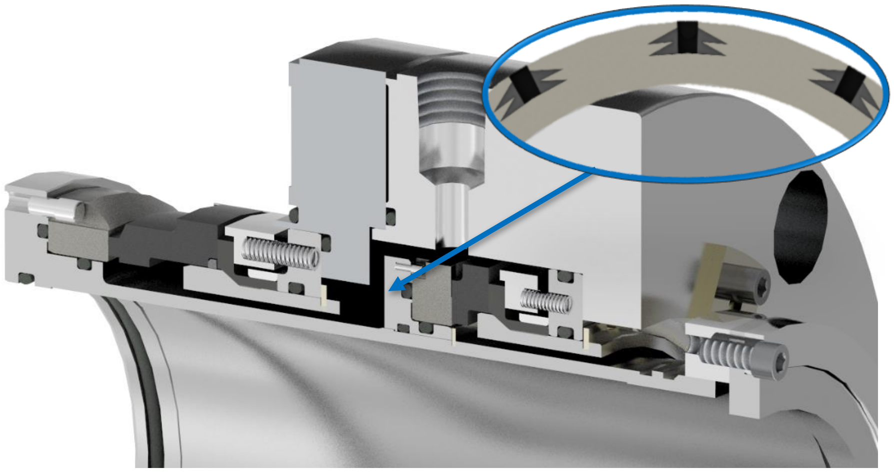


Figure 13. Dual unpressurized seals with non-contacting dry running secondary containment seal utilizing Non-Pusher Secondary Sealing technology for NGL services

**TESTING AND DEVELOPMENT OF DRY RUNNING NON-CONTACTING SECONDARY CONTAINMENT SEAL**

With the focus on secondary containment seal design for flashing NGL services, the test parameters were established with direct input from key pipeline operators which they based on their operating conditions at their pumping stations. Testing was performed on two shaft sizes 5.510" (140mm) and 3.760" (95.5mm), see Figure 14 for test setup. The seals were run in air to evaluate the seal performance at normal operating conditions and tested in water to validate the seal integrity during a containment condition. During testing, pressure, shaft speed, temperatures and air leakage were electronically monitored and digitally recorded.

The range of test Parameters:
Dry Dynamic normal operating pressure: 5 to 75 psig (0.34 to 5.2 barg)
Wet Static containment pressure: 0 to 1450 psig (0 to 100 barg)
Speed: 1450 to 3600 rpm
Starts / stops: 1100 at 5 psig (0.34 barg) pressure at highest speed and coast down to full stop over 30 seconds.

Figure 14. Test rigs used to test the dry running non-contacting containment seal.

Seals ran successfully up to the maximum dynamic pressure of 75 psig (5.2 barg) with stable and consistent performance. Generally, the seals would be subjected to around 5 psig (0.34 bag), having the capability to run at high pressures allowing the users to set alarms at a point that would not give false alerts. Maximum leakage of 0.2 SCFH was observed along with a low temperature rise. Temperature is a good indicator that the faces are running in a non-contacting state. An acoustic monitoring system was used during testing to detect asperity contact. The system cancels the noise from the rig and singles out the seal acoustics. If face contact occurs, the system will record an increase in noise levels. The system was used to determine the exact point at which the faces lifted off and closed during the start and stop testing. The faces showed no-contact. Graph 1 shows the test data at 3600 rpm speed and 75 psig (5.2 barg) pressure. To evaluate the seal performance in common pipeline stop start conditions, a cycle of 1100 rapid starts with a 30 second coast shutdown and an one minute hold between cycles was performed to simulate a typical 3 year life simulation in an overly aggressive test regime. In operation, pumps could have slow coasting shaft speeds for approximately 30 seconds may result in reduced dynamic lift-off. The seals shown in Figure 13 have been designed with increased hydrostatic lift to accommodate the slower speeds. The seal ran through the 1100 starts and stops with stable repetitive performance and no contact. Figure 15.0 shows the condition of the post-test faces after normal operation.

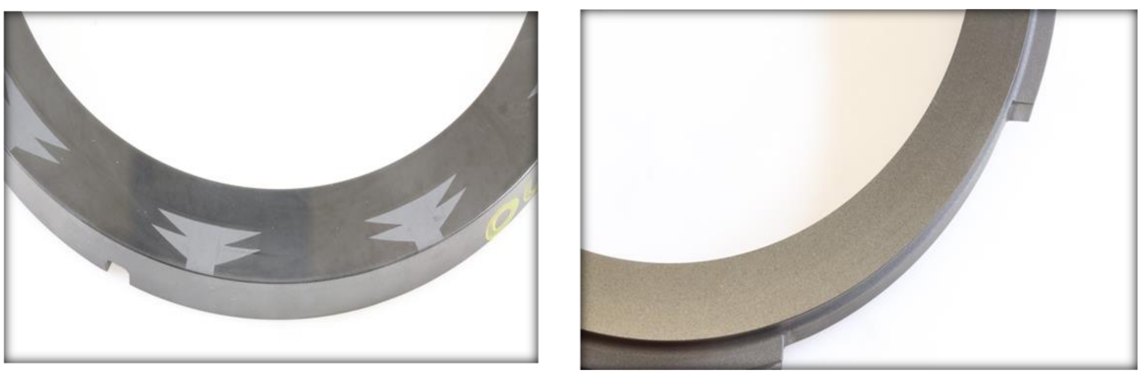


Figure 15. Post-test faces of secondary containment seal after normal operation.

To simulate in-service conditions, a test was designed subjecting the seal to normal running conditions between 5 to 75 psig (0.34 to 5.2 barg) and at 1800-3600 rpm for several hours. At the conclusion of the normal running condition, the same seal was subjected to 1100 starts and stops with a 30 second coast down, then the seal was subjected to 1450 psig (100 barg) water. Maximum water leakage past the containment seal was 120 ml/min over 30 minutes. When the shaft was stopped, the leakage stopped. This test was repeated successfully several times over the two tested sizes. This test proved the seal's integrity is maintained throughout its life, Figure 16.0 shows the post-test faces that have ran through 1100 starts & stops and 1450 psig (100 barg) in water. One advantage of having non-contacting faces on the outboard seal is, in the event of an inboard seal failure, the faces of the outboard seal will seal off the process fluid quickly being that the faces will be in like-new conditions.

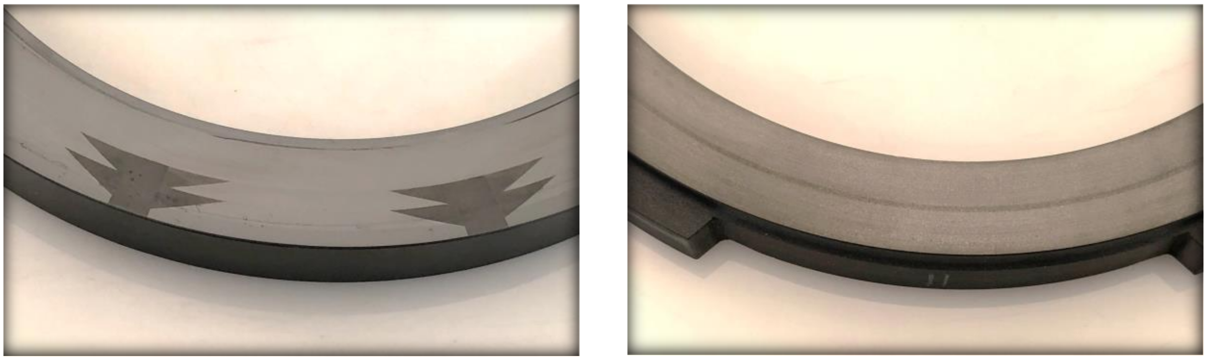
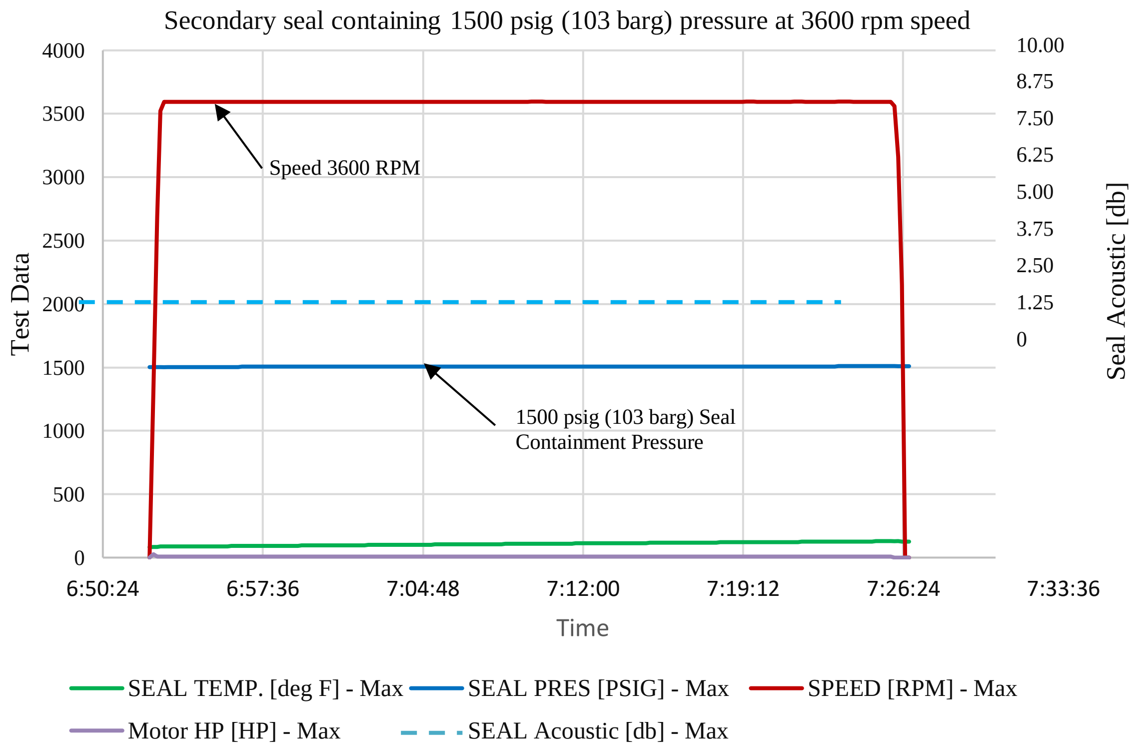


Figure 16. Post-test faces that ran through 1100 starts & stops cycles in air and was subjected to 1450 psig (100 barg) dynamic & static in water

In Graph 2.0 the test data illustrates the stable seal performance at maximum containment pressure of 1500 psig.




Graph 2. Uniform seal data at maximum containment pressure while running at 3600 RPM

**CONCLUSION**

Non pusher secondary seal technology has been available for crude oil duties for several years and has proven to greatly aid seal reliability in crude oil duties. The use of this proven Sealing Technology to enhance the reliability of NGL or light hydrocarbon pipeline applications represents a new and novel approach to the pipeline industry to enhance on going reliability and safety performance in these duties. The design philosophy replaces the single dynamic O-ring sealing device used in both the primary and back up seals with a novel semi-static, but non dynamic non-pusher secondary sealing device. The dynamic challenges faced by the single secondary O-ring especially in unique pipeline duties is managed far better with a Non-Pusher Secondary Seal. The NPSS compensates for the movement experienced in the rotating equipment within the elastomer itself rather than requiring dynamic movement along the shaft or sleeve. This enhances the ability of the seal to maintain a high integrity through all operating conditions, especially those encountered during an upset. Ultimately the reliability of the sealing system is enhanced many folds as a result of these design changes.

The successful use of Non-Pusher Secondary Sealing technology on dry running non-contacting safety containment seals in pipeline services demonstrates the ability to meet the functional requirements of the typical NGL service. It can provide the primary elements of safety and containment when used to support a single primary mechanical seal. While it demonstrates exceptional sensitivity to pressure containment it should not be expected to provide exclusively an early warning to primary seal failure. However the design successfully demonstrates the capability to provide a reliable warning signal in the form of a detectable pressure increase between the primary and secondary seals for triggering operator derived pump shut down and isolation activities when the primary seal is compromised or failing. By safely containing the process during operational upsets, up to full pipeline pressure, and during shut down and pump isolation, the design offers high levels of security, and can effectively reduce environmental impact and enables simplified remote monitoring with the right instrumentation associated with API plan 75/76.

**NOMENCLATURE**
API = American Petroleum Institute
NGL = Natural Gas Liquids

**FIGURES**



**GRAPHS**



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