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Extending Pump Life by Changing the Environment of Mechanical Seal Operation

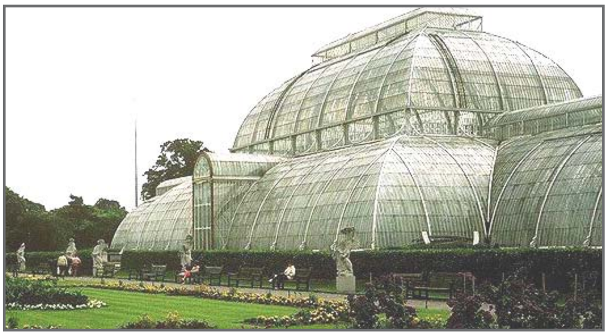
Application of Bi-directional Seal Circulating Devices for API plan 23

Author Richard Smith

Introduction

API Plan 23 is one of the seal piping flush plans detailed in the API 682 standards. The plan effectively changes the environment in which the seal operates. An analogy of how the plan works can be made with a greenhouse or glass house. A greenhouse creates a micro climate that will enable delicate plants to thrive in a cosseted environment regardless of the harsh, cold conditions that would exist in the outside world. Tropical species can be grown in high northern latitudes where they would have no chance of existence. In a centrifugal pump, Plan 23 uses a throat bushing to effectively isolate the seal chamber from the pump media. The small volume of liquid in the seal chamber is circulated through a local cooler or heat exchanger. Mechanical seals are potentially fragile components and their reliability significantly reflects the life of a pump asset. By placing the mechanical seal in its own micro climate and maintaining the temperatures in this area to temperatures where a seal can comfortably exist, extended life and reliable service are possible even on some of the most hostile high temperature duties.

Microclimate
Lat 51° 29' North



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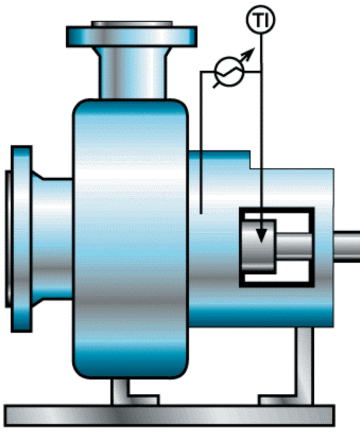
API Plan 23 Description

In API Plan 23, liquid is circulated by a pumping ring in the seal chamber through a cooler and back to the seal chamber. The plan is used on hot applications and minimises the load on the cooler by cooling only the small volume of liquid in the seal chamber that is recirculated. The only load is the heat generated by the seal faces and heat soak through the seal chamber casing. At the very heart of a Plan 23 is the seal chamber pumping ring or circulating device.



API 682 Plan 23

Recirculation from a pumping ring in the seal chamber through a cooler and back into the seal chamber.

API 682 Comments on Plan 23

API 682 is the international standard for mechanical seals used in the petroleum and associated industries. The document has been written by gathering knowledge from both user groups and seal manufacturers alike. Many guidance notes included in the document assist users in making the optimum selection for providing safe, reliable services. These are some of the statements made in the standard with regard to Plan 23 and seal cooling.

- *Annex A 4.8....* — *Plan 23 .is the plan of choice for all hot water services, particularly boiler feed water,*
- *Annex A 4.8....* — *Plan 23 ..is also desirable in many hydrocarbon services where it is necessary to cool the fluid to establish the required margin between fluid vapour pressure and seal chamber pressure.*
- *6.1. 2.14 (note) ...* — *Maintaining an adequate vapour pressure margin helps protect the seal faces against localised boiling of the process fluid at the seal faces. This can cause loss of seal-face lubrication and subsequent seal failure.*
- *6.1. 2.14 (note) ..* — *Lowering the flush fluid temperature is always preferable to pressurising the seal chamber.*

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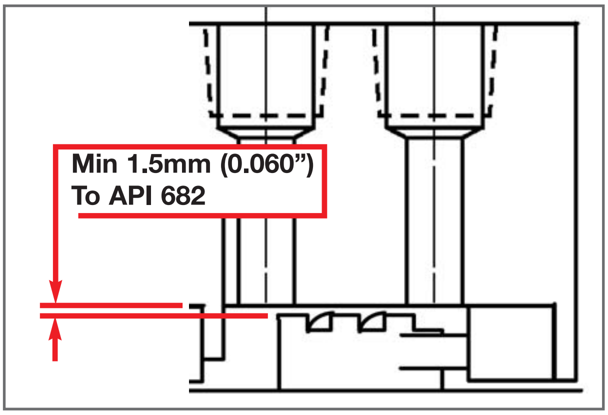
Seal chamber pumping ring (circulating device) technologies

Traditional flow devices normally fall into two categories,

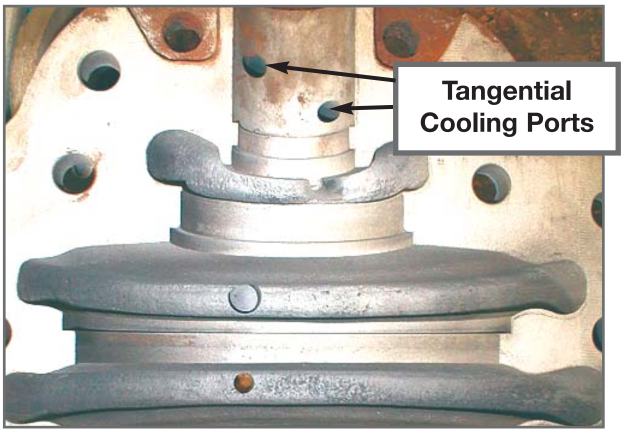
[i] Uni-directional helical scroll type
[ii] Straight vane radial flow inducer type

These scroll type flow devices have been used in mechanical seals now for many years. The principle is similar to that of an Archimedian screw. This type has two distinct disadvantages. Helical scrolls are reliant on working on close clearance. This contradicts the requirements of API 682; seal pumping rings should have a minimum radial clearance of 1.5mm (0.060") between the rotating component and its associate stationary part.(see API 682 8.6.2.3 & 6.1.2.6). With a clearance in excess of 0.5mm (0.020") the efficiency of these devices dramatically drops off and effectively make the helical scroll arrangement unusable. The other disadvantage with pumping scrolls is that they are uni-directional, meaning a left handed and right handed scroll would need to be provided for between bearings pumps. With any unidirectional device there is opportunity for human error, both with the mechanic who is assembling the device to the pump in the field and the manufacturer marking up the device for the wrong end of the pump.

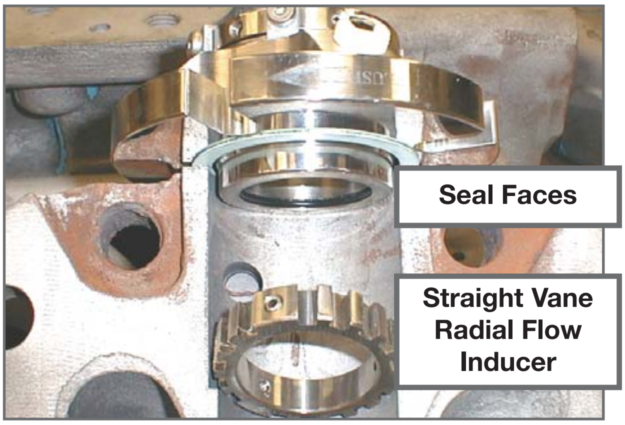
Straight vane (axial paddle type) alternatives to the pumping scroll are commonly used. These devices will need to operate with tangential porting. Whilst they are bi-directional, devices of this type will only promote flow in the plane where they are operating (see API 682 7.2.4.2 note). In many instances, the flow will not be across the seal faces, the seal faces may not therefore be operating in the cooled liquid flow, cooling is not optimised.



Seal with uni-directional pumping scroll



Traditional Plan 23 arrangement.



Horizontal split case pump.

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Example of the application of Plan 23 (previous page). The picture demonstrates a conversion to an old machine that typically used a soft packed gland. The mechanical seal upgrade from the soft packed gland was to provide increased reliability, reduced leakage and maintenance costs. A cartridge seal was mounted on the seal chambers (stuffing box) face and inside the seal chamber was mounted a separate, axial straight vane pumping ring and throat bushing. Additional holes were required to be drilled in the pump casing to accommodate the flush circulation. Although this conversion was effective, cooling flow was not directed over the seal faces and the overall package was not particularly elegant.

Alternative Solution: Bi-directional, large clearance, taper cavity pumping ring

A more elegant and efficient method of providing a plan 23 seal was sought by AESSEAL®. The design requirements were for a cartridge seal of stationary spring design that incorporated a bi-directional pumping ring that could be applied to a pump with no modifications to the pump hardware.

AESSEAL® had already produced a bi-directional pumping ring for use in their dual seal plan 53 operation. This device was first produced by AESSEAL® in 1999 and is subject to several global patents. This pumping ring consists of a series of helical vanes, these are cut in both directions at an approximate angle of 45°. The ring also forms a shallow taper and is partnered by a taper bored cavity. The device provides for excellent pumping flow and head even for the large radial clearance of 1.5mm as prescribed by API 682. The curves demonstrate the ability for the pumping ring to provide flow and head, in either direction of rotation, in both oil and water. The device had been bench-marked against two competitors straight vane devices and had demonstrated a considerable improvement over these traditional designs.

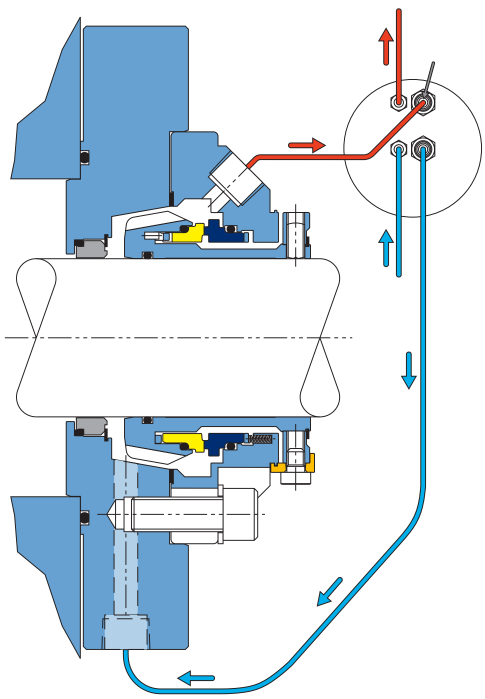
Flow Inducing Devices

AESSEAL® "Pumping" Design

The patented pumping ring has been applied to the AESSEAL® standard SMSS™ single cartridge mechanical seals. In the SMSS23™ design, the seal uses standard component parts, apart from the seal sleeve. The seal sleeve is extended and on the nose of the sleeve, the bi-directional pumping contours are sculptured into the metal work. Although this looks a particularly complex machining operation, with the advent of multi axis CNC machine tools, designers have been able to effectively employ such features in cartridge mechanical seals at economic cost.

SMSS23™

Single Mechanical Seal For Hot Applications



The seal is mounted to its associated gland plate, which provides the taper cavity, the secondary port and the throat bushing. The seal and gland plate are effectively a self-contained unit of very compact design that can be applied to existing machines frequently with no modification or changes to the design of the existing machine hardware.

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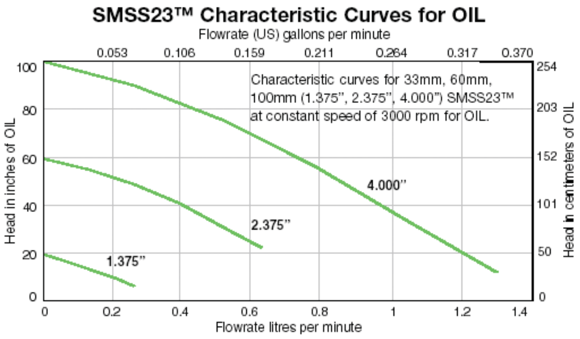

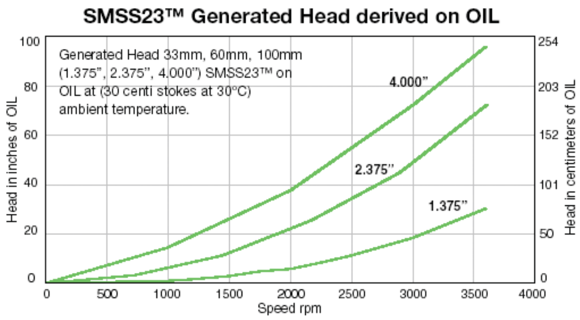

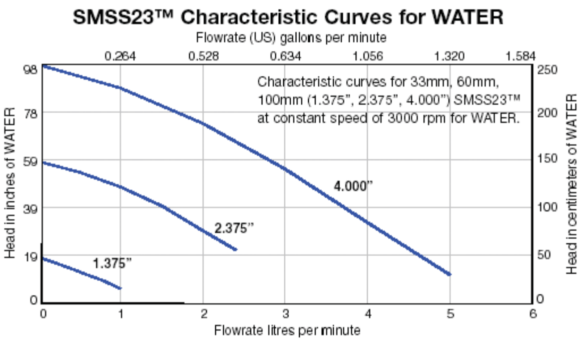

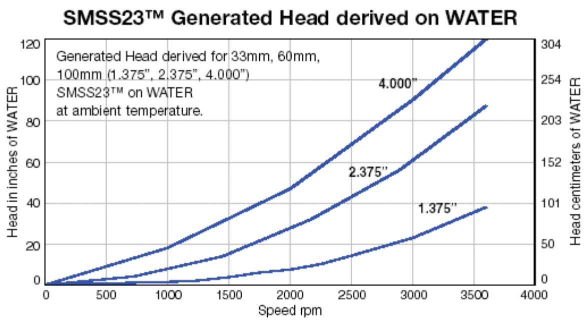

The SMSS23™ is a stationary mounted cartridge seal that utilises monolithic faces. Monolithic faces provide for exceptional stability of faces during a wide range of operating conditions Stationary springs provide for self-aligning capability that will accommodate seal chamber face angular misalignment or runout. Loss of perpendicular alignment of seal chamber face to shaft axis is a concern with pumps that run at high temperature. The effects of potential asymmetric thermal expansion of the complex geometry of a pump casing can cause this phenomenon. Additionally, on high temperature duties there is the danger of thermal expansion from associated pipe work loading on the pump nozzles and distorting the casing. (see API 682 6.1.1.5 note on consideration for stationary seals) Plan 23 will normally be applied to high temperature duties.

The SMSS23™ is a self contained design and will, in conjunction with a cooler, provide a low temperature seal environment for the mechanical seal faces irrespective of the harsh operating conditions that may be endured within the pump.

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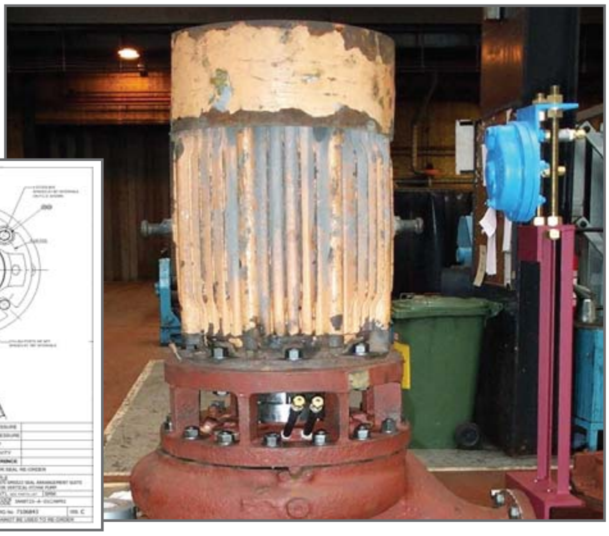
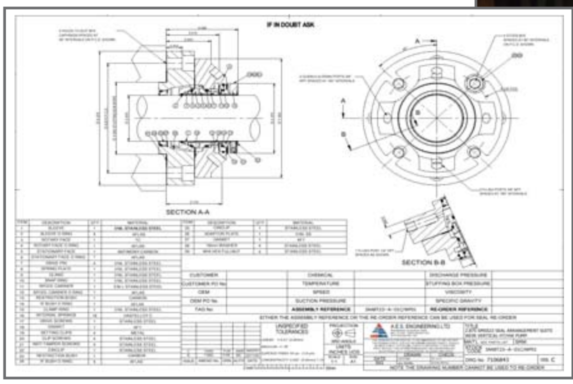
Case Histories

Case History 1

The first case history is for a coal fired power station. The previous sealing device was a double seal. There had been instances in the past of boiler feed water being contaminated with (barrier fluid) cooling water. The pump duty is a hot condensate heater drains, operating at a temperature 180° C (356° F). The pump is a Weir Lynavane, inline vertical overhung unit. The pressure on the seal was 16 bar and the operating speed was 1500 rpm at a seal diameter of 2.875 (73mm). The SMSS23™ seal was designed to fit the pump without any requirement to modify the pump parts or hardware. Site measurements demonstrated that the flush water from the seal to the cooler temperature measured a mere 65° C (150° F). This is a very comfortable operating condition for a single mechanical seal in water.





Case History 2

Again this is at a power house, this time at a Paper Mill in Washington State. The pump is an 11 stage, Bingham centre discharge between bearings pump. Operating conditions were 18 bar pressure (265 psi) within the seal chamber at 180° C (356° F). The speed of the pump unit was 3,600 rpm shaft size 3.260 (82.8mm). SMSS23™ seals were applied to replace single component seals and now operate with the seal chamber temperature of below 60°C (140° F).

Case History 3

Comparison between API Plan 21 and API Plan 23

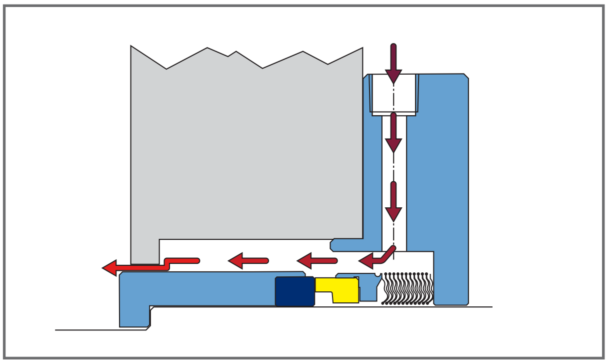
The third case history serves to demonstrate the significant advantage of Plan 23 seal flush plans compared to that of Plan 21. In a Plan 21 flush plan, process fluid is circulated from the discharge of the pump through orifice plates, and then once through the heat exchanger into the seal flush and thereby back into the process stream. API flush plan 21 would be considered a one pass cooler as opposed to Plan 23 which is a multiple pass of the liquid through the cooler. The application in question was on a VLCC crude oil tanker of 300,000 tonnes. The pumps were the exhaust gas economiser circulation pumps that were operating at 180°C (356° F), 21 bar pressure (308 psi). The pumps were manufactured in Japan and furnished with a stationary bellows mechanical seal of 35mm diameter.

The bellows were welded to the gland plate and the rotary face of the seal formed part of the 'hooked' sleeve. The seal was furnished with a flush plan operating in an API Plan 21 configuration. Service life of the seals was less than 12 months, frequently as low as 8 months. With sea water being applied as the cooling medium on the shell side of the cooler. The parameters of this application were inputted into a software package provided by AESSEAL® specifically to work out cooler heat loads for both Plan 21 and Plan 23 operation. From the differential pressure between the pump discharge and the seal chamber, and applying a 3mm orifice, a flush flow rate of 7 litres per minute was calculated. Cooling water to the cooler was specified at 20 litres per minute, 30° C (86° F).

Exhaust Gas Economiser

Seal flush Plan No.21

Original Arrangement



API Plan No.21 Product recirculation from discharge through orifice and heat exchanger.

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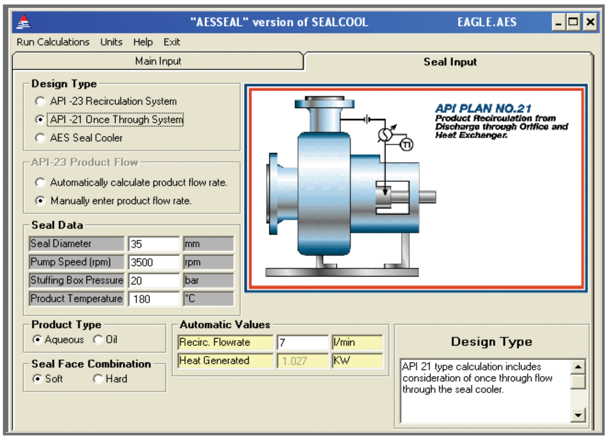
The resultant output for this particular set of parameters demonstrated that the seal would be operating in excess of 118° C (244° F). More concern however should be expressed as the cooler is working with a heat load in excess of 30 KW (40 HP) to provide this level of cooling. The same parameters were input into the software for the Plan 23 operation seal. This time, however, the flush flow rate was calculated at 1.2 litres per minute from the performance curves published for the SMSS23™.

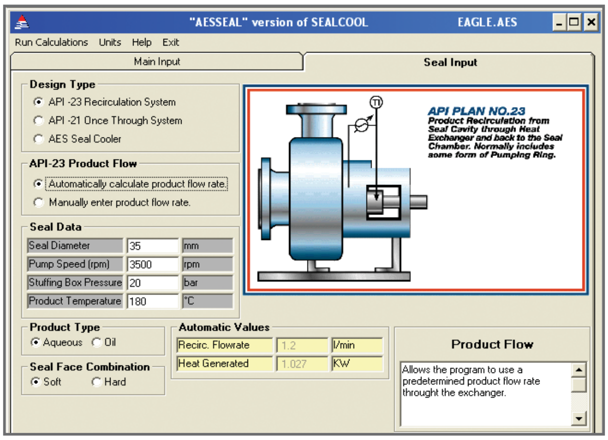
The resultant output demonstrated the significant efficiency improvement gained from using Plan 23. Seal faces were now operating in a seal chamber temperature of 57° C (134° F), which is a very comfortable condition for a set of single seal faces. Heat load on the seal cooler was now 1.3 KW (1.7 HP), a mere 1/20th of the heat load of the Plan 21 condition.

The findings of this study are also endorsed with comments from the API 682 standard in comparison between these two piping plans:



- *Annex A 4.8....* *In a Plan 23, the cooler only removes seal face-generated heat plus heat soak from the process.*
- *Annex A 4.8....* *This duty is usually much less than that in a Plan 21. Lessening the duty is very desirable because it extends the life of the cooler.*
- *Annex A 4.8....* *The industry has considerable negative experience with Plan 21 because of cooler plugging.*

An SMSS23™ Plan 23 mechanical seal was produced. Again, the design was such that no adaptations to the existing pump were required to enable the fitment of the cartridge seal package. The seal was fitted in August 2001 and at the time of writing, June 2005, the seal is still operating today. Exchanger life has improved with no maintenance being required to the exchanger during this period. The cost of the original OEM seal is the region of $4,000 US dollars, with the purchase direct from Japan.



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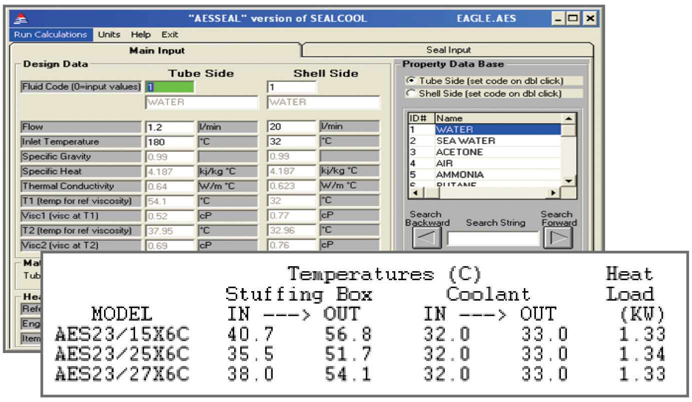
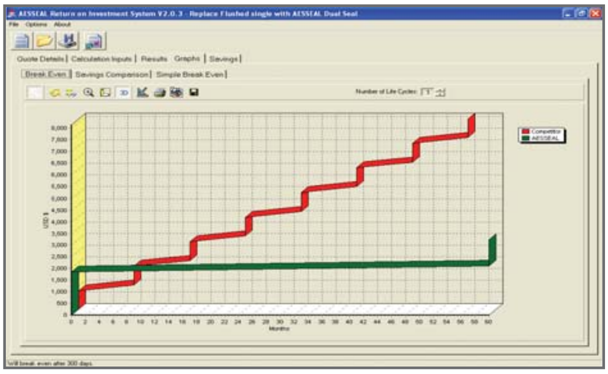
Alternative patent, part mechanical seals are available from other sources and the cost of these has been found to less than $1,000. The SMSS23™ seal cost is $1,800. These figures have been input into a return on investment software, with a few hundred dollars for every rebuild included for bearings and other components. The lower cost figure for the existing mechanical seal was used. Disregarding all costs for labour and all costs for the heat exchanger over a five year period, huge savings are calculated for the new SMSS23™. The customer has already enjoyed savings of over $4,000 and a predicted $6,000 over 5 years. This is on one simple 35mm 1 3/8" mechanical seal hot water service.





Case History 4

Plan 23 technologies have also been supplied to non industry applications. Plan 23 offers advantages for heating pumps in the heating of large buildings. The plan has successfully been applied to some very prestigious addresses. Seals used within the London residence of Her Majesty the Queen, Buckingham Palace, employed this type of technology and have replaced single seals with recirculation plan 11. These units are providing leak free service and to date, have been installed for just over 3 years. Previous sealing devices were providing less than 1 year's service. The cooling arrangement in this particular example had limitations, as no cooling water service was available for a heat exchanger system. A simple piping loop with high surface area (finned pipe) was applied. The cooling efficiency of Plan 23 was sufficient to enable this simple solution to be used.

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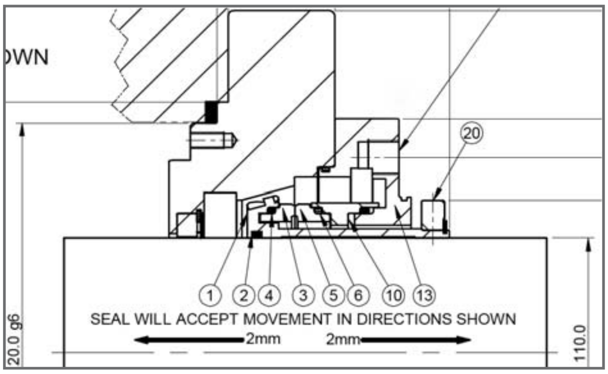
Hydrocarbon Service

SMSS23™ technologies have been used in a number of hydrocarbon services across the world. Users have enjoyed the compact design that is easily applied to existing machines, normally with no modifications. The benefit of improved vapour pressure margin in seal chamber has extended seal reliability. In other examples the reduced working temperature of the seal from Plan 23 operation has prevented coking on the atmospheric side of the mechanical seal, again, enhancing seal life and seal reliability. Conversion from other piping plans to Plan 23 has also proven to extend cooler life.



End float designs SMSS23™ - AX

This is a variant of the SMSS23™ and has been designed specifically for larger machines where there is known to be end float during the machines operation. Such examples are common in multi stage machines where the thrust of the rotating element is taken by a balance disc or balance piston. On start up transients, end float can occur, axial movement will also take place due to balance disc wear. On other multi stage machines, end float can exist due to differential thermal expansion between pump casing and pump shaft during start up or shut down of operation. The SMSS23™ CAPI AX™ design again is a stationary design but with long axial springs designed to accommodate up to 4mm movement. The shallow taper of the pumping device prevents any major changes in pumping ring clearances and thus not dramatically affecting the circulation performance.

Conclusion

There are significant benefits to applying a Plan 23 flush plan to high temperature mechanical seal applications. Historically, this plan has not received wide acceptance due to the complications of applying seal circulating devices or pumping rings. With the advent of new manufacturing technologies, this has paved the way to efficient, simple Plan 23 cartridge seals. These are now available in a compact format that is simply applied to both new and old machines. The sheltered environment provided by the Plan 23 configuration will allow single conventional mechanical seals to enjoy a significant life improvement over other arrangements and impacting positively on plant reliability, MTBF and heat exchanger life.

Further Information

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