ASIA TURBOMACHINERY & PUMP SYMPOSIUM
SINGAPORE | 22 – 25 FEBRUARY 2016
MARINA BAY SANDS

The Development of API 682 4th Edition

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ABSTRACT

API 682 was first published in 1994 and it became established as the industry leading document for mechanical seals. It promoted proven, high reliability seal solutions across refining markets.

As new sealing technologies were developed, the standard was developed further and opened out to chemical, petrochemical and other industries.

Published in 2014 the 4th Edition of API 682 continues to promote proven sealing solutions but has been updated to be less prescriptive. This tutorial will discuss changes to the standard for 4th Edition and will provide an insight into the decision making process used by the Task Force.

THE INTRODUCTION OF API 682

The American Petroleum Institute (API; Washington, D.C.) has been publishing standards and recommended practices for the oil and gas industries since 1924. In the 1950's, API produced the first edition of a standard for centrifugal pumps, API 610. At this time mechanical seals were in use on refineries and other process plants but generally sealing defaulted to soft packed pumps and it wasn't until 1981, when the 6th Edition of API 610 was published, that seals became first choice for pumps. However, seal standards generally remained buried in other standards such as DIN 24960, ANSI B73 and API 610.

In the 1980's a group of refinery equipment engineers and managers, led by V. R. Dodd of Chevron, proposed creation of a stand-alone standard for mechanical seals and API agreed to establish this standard, designated API 682.

The first meeting of the API 682 Task Force was held in January 1991. This Task Force comprised members from the refining industry along with seal and pump manufacturers. The 1st Edition of API 682 was published in October 1994 (Figure 1). Although intended as a stand-alone document some seal related details were retained in API 610 and it wasn't until publication of the 2nd Edition in 2002 that full separation was finally achieved.

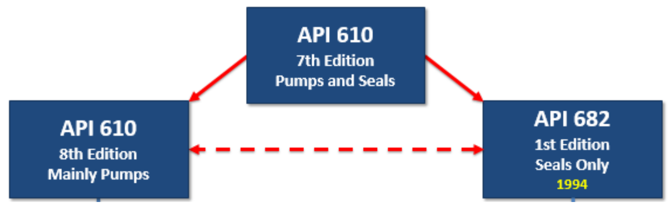


Figure 1 Separation of Mechanical Seals from the API 610 Standard

API 682 1ST EDITION – AN OVERVIEW

At the heart of the 1st Edition was the mission statement *This standard is designed to default to the equipment types most commonly supplied that have a high probability of meeting the objective of at least three years of uninterrupted service while complying with emissions regulations.*

While no longer included in the standard, this philosophy is fundamental to the work of all API 682 Task Forces and it is key to continuing development of the standard.

Even at this early stage in its history it was recognised that it was not practical to attempt to cover all refinery pumps, so the Task Force developed the standard around an aim that it would address 90% of the applications on a typical refinery. This meant that the standard could be based on a restricted range of shaft sizes and operating conditions.

As part of the process in developing the API 682 standard, definitions were created for concepts such as seal types and arrangements. These were backed by introduction of qualification tests.

Three seal types, A, B, and C were created to represent pusher seals (A), general purpose bellows seals (B) and high temperature seals (C).

Before API 682 was developed, multiple seals were normally designated as being either "tandem" or "double" but developments in seal design meant that these definitions could not always be used to describe a seal. The Task Force introduced a more descriptive system for dual seal arrangements. Where two seals were used in the same seal chamber the arrangement was described as a dual seal; the fluid between these two seals could be either pressurised or unpressurised. This resulted in the descriptions of dual pressurised (generally for seals that had previously been designated as 'double seals') and dual unpressurised (previously 'tandem').

Three standard arrangements were defined: Arrangement 1 described a single seal, Arrangement 2 a dual unpressurised seal and Arrangement 3 a dual pressurised seal.

The 1st Edition also provided a seal selection guide covering typical refinery applications. To do this, it was necessary to categorise refinery applications into a number of services: non-hydrocarbon, non-flashing hydrocarbon and flashing hydrocarbon.

Inherent in API 682 was the target that mechanical seals should '*have a high probability of meeting the objective of at least three years of uninterrupted service.*' To demonstrate this capability the Task Force introduced the need for seal Qualification Testing. This required seals to be performance tested on representative process fluids at typical operating conditions. The test simulated both steady state operation and running under 'upset conditions'. Five fluids were selected to represent process fluids that would be normally encountered on a refinery; water, propane, cold oil, hot oil and 20% NaOH.

While API 682 contained technical data and information normally found in a standard, the published edition went one step further. The first review copy of the standard contained notes and comments explaining the reasoning behind many of the requirements and reviewers asked that they be kept in the finished document so that users of the standard could understand this reasoning. This idea was further developed and some comments were expanded to become tutorials and included in the document appendix.

Although the value of API 682 was recognised across the refining industry, some users did have concerns about the extra cost of API 682 compliant seals. The result of this was that seals 'in the spirit of API 682' started to appear. These were products which contained key design benefits from the standard but did not always come with the same level of documentation.

API 682 2ND & 3RD EDITIONS – AN OVERVIEW

While API 682 1st Edition was used throughout the world, it was not recognised as a true international standard. At the start of work on the 2nd Edition of the standard it was decided to open up the development process to global input from the International Organisation for Standardisation (ISO). The aim was to co-brand the 2nd Edition as an API/ ISO standard.

In addition to this the 2nd Edition was also subject to extensive expansion, both in the markets it addressed and in the seal designs it incorporated. Seal categories were introduced to allow easier transference of the standard across more processes, with 'chemical industries' added to the scope of the document. The years since publication of the 1st Edition of the standard had also seen establishment of 'new technologies' such as gas and containment seals and these, in turn, required creation of new piping plans and further development of seal selection process and qualification testing.

The base consideration for the 1st Edition was refinery pumps and seals. However the standard was being applied to other industries and the Task Force decided to expand the standard to a wider market and incorporate alternative levels of seal solutions. This was achieved by the introduction of three seal categories 1, 2 and 3. Category 3 seals were introduced to cover the original API 682 1st Edition seals i.e. seals with full documentation and qualification test and typically applied to API 610 pumps. Category 2 was introduced to meet a market demand for less costly seals as users were concerned about the cost of 1st Edition seals. Category 2 seals were of the same design and construction as Category 3 but had reduced documentation and less prescriptive qualification demands. Category 1 seals were introduced to cover chemical and other markets which normally used non-API-610 pumps.

In the years following publication of API 682 1st Edition, gas seals and dry running containment seals became more common in many industries and these were added to the standard. Along with these new seal types came the requirement for new piping plans and qualification tests.

The 1st Edition had also defaulted to a Face to Back (FB) arrangement. Recognising that this arrangement was not the best for every application the task Force introduced two further arrangements, Back to Back (BB) and Face to Face (FF).

While the goal had been to publish 2nd Edition as an international (ISO) standard, the technicalities of completing this within API's update window proved too large an obstacle and the standard was solely issued as API 682 2nd Ed in 2002. The goal remained active however, which meant that the 2nd Edition was followed by the 3rd Edition in 2004.

ISO 21049 was published in 2004. This standard was very similar to API 682 2nd Edition but did contain some editorial changes and correction of a small number of technical errors. To completely align API 682 and ISO 21049, API 682 was updated to 3rd Edition and re-issued in 2004 (Figure 2).

Figure 2 Transition from API 682 to ISO 21049

API 682 4TH EDITION – AN OVERVIEW

The fundamental building blocks of API 682 2nd / 3rd Editions, seal types, arrangements and configurations, remain effectively unchanged for the 4th Edition There are minor changes in the seal categories e.g.

- Silicon carbide face materials should be selected based on chemical compatibility rather than using any default selection for each seal category.
- Floating bushes are now specified for Category 2 seals.
- The pressure range for Category 2 and 3 seals has changed from 42 bar absolute to 40 bar gauge aligning API 682 with the API 610 pump standard. The pressure range for Category 1 seals has changed from 22 bar absolute to 20 bar gauge.

A key objective for the 4th Edition Task Force was to reduce misinterpretation of the standard which, in some instances, resulted in its recommendations being misunderstood and applied too rigidly. This was also borne out by the need to address over 300 comments which had been received on ISO 21049. In earlier editions some design features were stated as ‘required’ and the Task Force recognised that such a description was over restrictive. As a result, equally effective design features could be identified as ‘out of scope’ and rarely used. For these reasons the 4th Edition has moved from defining “standard” designs (which imply a requirement) to “default” designs (which signify that alternative designs are available). Hence, many of the changes in the 4th Edition are detail enhancements, particularly with auxiliary systems and piping plans.

It is important to recognise that API 682 is not a specification but recommended good practice. Many operating companies will produce their own purchasing specifications based around API 682 but replace some clauses with alternatives of their own. A feature of 1st Edition which has been maintained throughout the history of the standard is the inclusion of ‘bullets’ within the standard which indicate ‘decision points’.

The primary objectives of 25,000 running hours and emission containment remain unchanged from previous editions but the Task Force wanted to highlight that this was not a guarantee of performance (as no standard can cover all application possibilities) but an assurance that seals covered by the standard had been design and manufactured with the aim of achieving long, reliable service life.

During work on the updated standard, API and ISO ceased collaboration and API decided to issue its standards independently of ISO. Hence the current edition of API 682 was only issued as API 682 4th Edition and not as ISO 21049.

API 682 4TH EDITION – REVIEW

The 4th Edition of API 682 contains 11 sections and 9 annexes. Some of these have changed little and the detail in this tutorial will reflect that. It is important to recognise that this tutorial contains far less detail than the 250+ page standard and should not be considered an alternative purchasing a full copy from API.

Section 1 - Scope

The scope of API 682 has not changed with the 4th Edition although much of the detail included in the 2nd Edition has been moved to other sections of the standard. In summary

- The standard still specifies requirements and gives recommendations for sealing systems for centrifugal and rotary pumps used in the petroleum, natural gas and chemical industries.
- It remains applicable mainly for hazardous, flammable and/or toxic services
- It continues to cover seals for shaft sizes from 20mm to 110mm.

Some discussion was held by the Task Force on a proposal to extend the scope of the standard to cover larger shaft sizes. While the merit of the suggestion was recognised it was considered that the need to do this was limited (using the 90% guide) and it was agreed to defer this change to future issues of the standard.

API 682 does get referenced by other machinery standards and within the scope of 4th Edition it is made clear that the “standard is not specifically written to address all the potential applications that a purchaser may specify. This is especially true for the size envelope specified for API 682 seals”. The Task Force were keen to highlight that while some design features may be transferable across standards the purchaser and vendor need to discuss and agree when these cannot be accommodated in equipment outside the scope of API 682.

Section 2 – Normative References

This section lists “referenced documents indispensable for the application” of API 682. The list has changed from previous editions but these changes will not be covered by this tutorial.

Section 3 – Terms, Definitions and Symbols

Many definitions have been improved for greater clarity with more concise and descriptive wording. A number of new definitions have also been added while some of the more involved definitions have been moved to other sections of the standard. An example of change for the 4th Edition can be found in definition 3.1.67. In this the definition of pressure casing clearly identifies seal parts that are included and excluded from being part of the pressure casing. In previous editions the same exclusions existed but were buried in the text of the standard and could be missed by the user.

Definitions in the 4th Edition have also been revised to be more consistent with terminology generally used elsewhere in the sealing industry. This included working with the Fluid Sealing Association (FSA) and European Sealing Association (ESA) to harmonise descriptions.

Section 4 – Sealing Systems

Seal Type describes the basic design features of a seal, API 682 identifies three seal types, A, B & C and the definitions of these have not changed from the 3rd Edition

- Type A - are balanced, cartridge seals using elastomeric secondary seals
- Type B - are cartridge, metal bellows seals using elastomeric secondary seals.
- Type C - are cartridge, high temperature bellows seals using flexible graphite secondary seals.

The 4th Edition has however adapted the definition of seal types to be less prescriptive. API 682 has always allowed a purchaser to specify either a rotating or stationary flexible element for the seal cartridge. However, historically it has been assumed that the defaults shown in the standard will always provide the best solution. This has meant that Type A & B seals have been supplied with rotating flexible elements while Type C have been supplied with stationary flexible elements. The 4th Edition now clarifies that both rotating and stationary flexible elements are considered 'technically equivalent' and the relevant clauses have been modified.

The 4th Edition has also updated the definition of an Engineered Seal (ES) which is now clearly defined as a mechanical seal for applications with service conditions outside the scope of the standard. Note that an Engineered Seal is not a seal Type but rather identification that special design features may be required to meet the application conditions. An Engineered Seal is not covered by the requirements of the standard and is not required to be qualification tested.

The 4th Edition now clarifies that dual seals can be of mixed types. For example, mixing a type C (flexible graphite mounted bellows) inner seal with a type A (multi-spring pusher) outer seal could provide flexibility to the manufacturer or user. Such an assembly would be described as a type C/A (Figure 3).

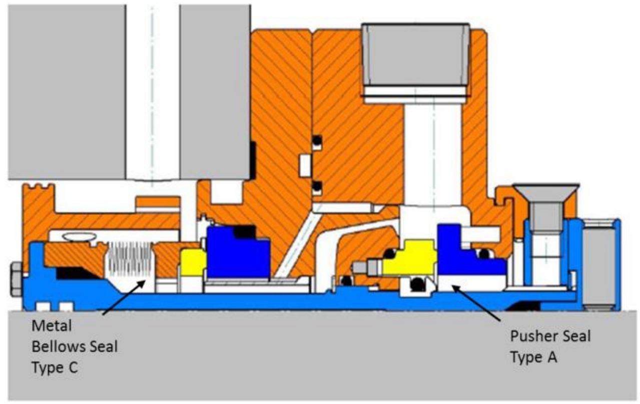


Figure 3 Dual Seal Comprising Mixed Types (Source: AESSEAL plc, Rotherham, UK)

Seal Configuration refers to how seals are orientated in a dual seal assembly. Three orientations (Figures 4, 5 & 6) are described in 4th Edition, Face to Back, Back to Back and Face to Face (as in previous editions).

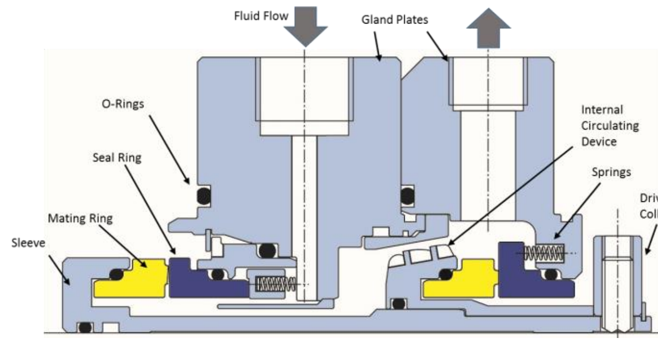


Figure 4 Face to Back Seal (Source: AESSEAL plc, Rotherham, UK)

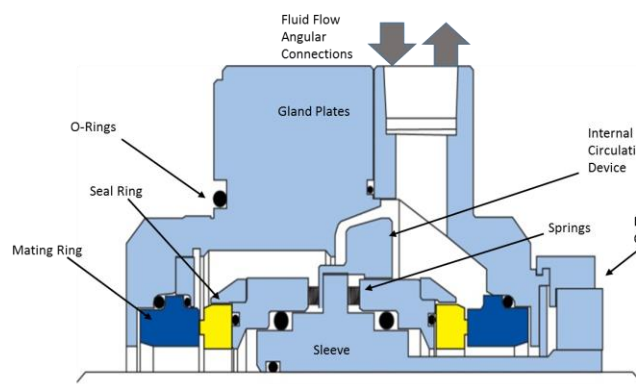


Figure 5 Back to Back Seal (Source: AESSEAL plc, Rotherham, UK)

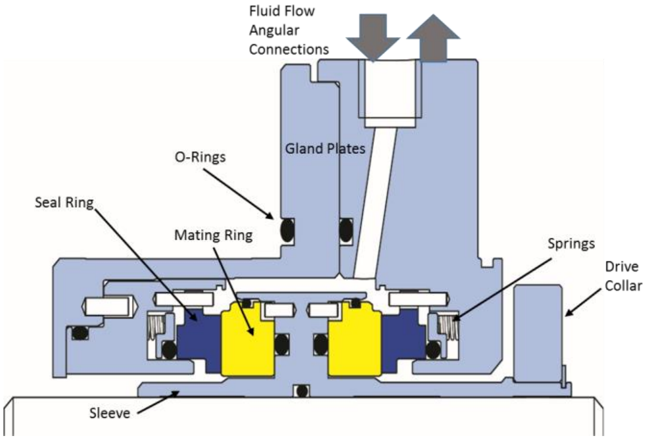
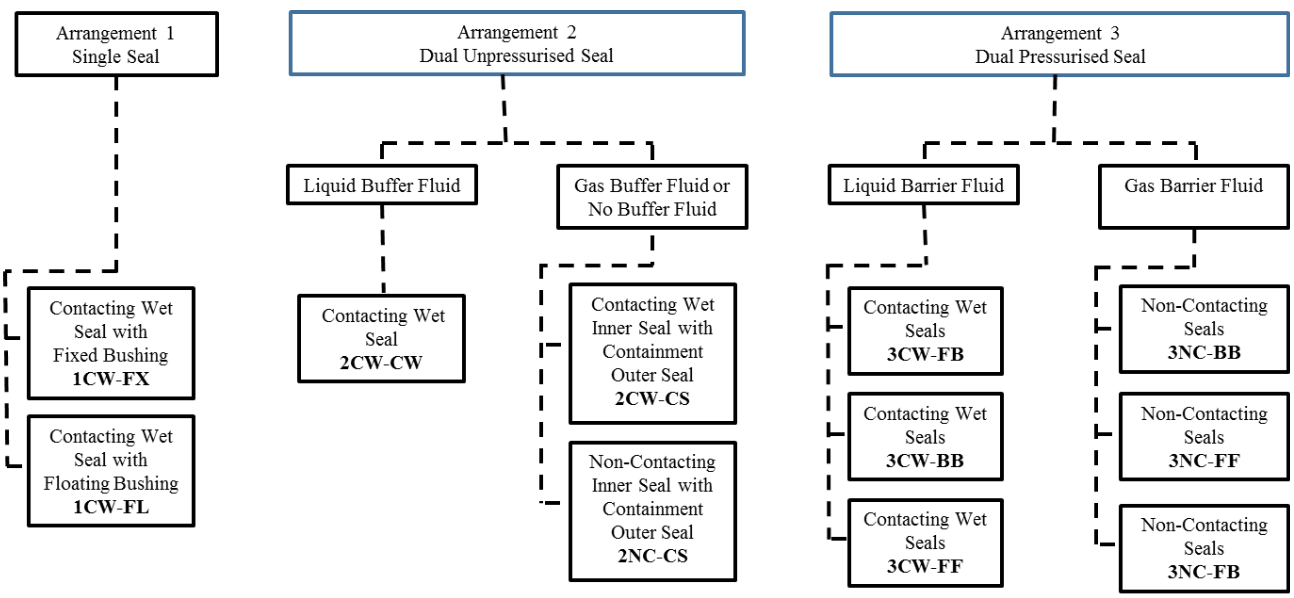


Figure 6 Face to Face Seal (Source: AESSEAL plc, Rotherham, UK)

with others. For the 4th Edition, while still referring to 'defaults' in the text, the standard states that configurations are 'technically equivalent' and should be selected on merit for any specific application. Figure 7 shows seal arrangement and configuration options.

Seal Categories have not changed from earlier editions but some of the seal design details within categories has been amended. For Category 1 seals the pressure range has been changed from 22 bar absolute (a figure that was included in 3rd Edition in error) back to 20 bar gauge. Reference to the ISO 3069 standard has also been removed as the dimension of these chambers did not always accommodate API 682 seal designs. Category 2 & 3 pressure ranges have similarly been adjusted to 40 bar gauge.

Design requirements for Category 2 seals have been increased. Floating bushes are now specified for Category 2 seals rather than fixed bushes and they must now utilise



CW = Contacting Wet
CS = Containment Seal
NC = Non Contacting

FX = Fixed Bushing
FL = Floating Bushing

BB = Back to Back
FB = Face to Back
FF = Face to Face

Figure 7 Seal Arrangements and Configurations

Earlier editions of API 682 led to some users thinking that certain orientations were 'preferred' by the standard. In practice this 'preference' was just recognition that Task force members had more experience with some configurations compared

Maximum pressure	20 barg	40 barg	
Temperature range	– 40 °C to 260 °C – 40 °F to 500 °F	– 40 °C to 400 °C – 40 °F to 750 °F	
Seal faces	Premium, blister resistant carbon v Silicon carbide		
Seal flush	Single Distributed option	Distributed	
Bushing	Fixed carbon Floating option	Floating carbon Segmented option	
Qualification test	Cat. 1 test unless core components qualified as Cat. 2 or 3	Cat. 2 test unless core components qualified as Cat. 3	Cat. 3 test as complete cartridge assembly
Seal data requirements	Minimal		Extensive

Table 1 Comparison of Features by Seal Category

distributed flush. There is also an option to specify a segmented carbon bushing in Category 2 and 3 seals. Category requirements are summarised in Table 1.

Section 5 – General

This section is unchanged and identifies responsibility for the seal system dependant on how it is purchased. It also states that the purchaser has responsibility as to whether drawings etc are in SI units or US units

Section 6 – Design Requirements

While API 682 has certainly had a big impact on mechanical seal design it was never meant to offer guidance on how to design seals for specific applications. The variety of seals, applications and operational requirements found in the refining, petrochemical, chemical and other related industries means that one standard cannot attempt to cover all scenarios. The 1st Edition and all subsequent editions of API 682, identified good design practice but that was strongly influenced by operating experience. So, for example, the default rotating flexible elements for Type A & B seals and stationary flexible elements for Type C seals became the 'assumed best solution' because that was where the end users had most experience. Similarly, the selection of Face to Back seals in the 1st Edition was based on operating experience and was not a statement that this configuration was technically better.

The 4th Edition Task Force recognised that the identification of 'standard designs' could be limiting use of other equally effective seal arrangements or design features. For these reasons, the 4th Edition has moved from defining "standard" designs (implying a requirement) to "default" designs (recognising that other options are available). The Task Force wished to ensure that the best seal arrangement and orientation was selected for every application and that those selections were not unduly influenced by a general description contained in the standard. So, within 4th Edition users will see comments of the type "Within the scope of this standard, rotating and stationary flexible elements are considered to be technically equivalent"

The API Standard has always allowed a purchaser to specify either a rotating or stationary flexible elements in the seal cartridge. The 4th Edition now clarifies that both rotating and stationary flexible elements are considered technically equivalent.

API 682 has previously specified very generous lead-ins for ease of assembly of O-rings within the seal. However, seal designers have often used different values internally within the seal cartridge. The 4th Edition now clarifies what has become accepted practice, chamfers for O-rings are now only specified for the seal/pump interface and those internal to the seal cartridge are left to the seal OEM.

One issue debated at length, as some members felt this to be a safety concern, was the internal clearance between rotating and stationary components within the cartridge seal assembly (Figure 8).

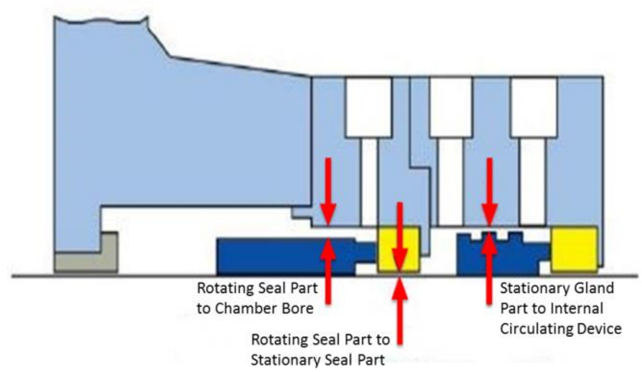


Figure 8 Seal Clearances (Source: AESSEAL plc, Rotherham, UK)

Previous editions of the standard only specified internal clearances for bushes and circulating devices (pumping rings). For the 4th Edition, the Task Force re-evaluated the requirements of the radial clearances and combined the results into a single table, as shown in Table 2. Pumping ring clearance, previously 3mm [0.118"], was reduced to fall in line with these values.

Inside diameter (ID)	**Outside diameter**		**Minimum diametral clearance**
ID seal chamber bore & gland plate	OD rotating seal part	CW seal type NC seal type	6 mm (0.25 in) 3 mm (0.125 in)
ID stationary seal part	OD rotating seal part	shaft ≤ 60 mm shaft > 60 mm	1 mm (0.039 in) 2 mm (0.079 in)
ID stationary gland part	OD internal circulation device	shaft ≤ 60 mm shaft > 60 mm	1 mm (0.039 in) 2 mm (0.079 in)
ID containment fixed bushing (2CW-CS, 2NC-CS)	OD rotating seal part	shaft ≤ 60 mm shaft > 60 mm	1 mm (0.039 in) 2 mm (0.079 in)

Table 2 Seal Clearances

Most clearances had never been included in API 682 (or API 610 before it) so proposed clearances were based on the current practice of many seal manufacturers. Some reviewers were critical of the clearances proposed, believing them to be too small since contact between rotating and stationary components could be a safety issue. A ballot was held by the end user representatives on the Task Force, manufacturers were excluded to ensure no commercial bias. Unanimous agreement could not be reached between the end users so the clearances included in API 682 were a majority decision.

The Task Force end users felt that the clearances specified in 4th Edition were proven to be acceptable in service on equipment built and maintained to the standards required by API 682/ API 610. It is understood however that the clearances quoted in API 682 are minimal values and the standard recognises that they are not necessarily appropriate in every design or application. The seal OEM is responsible for ensuring that the seal design clearances are correct for the application. In particular, certain conditions are identified where minimal clearances may be inadequate, these include.

- Pumps not maintained to the correct levels
- Older or non-API 610 equipment
- Pump types not covered by the scope of the standard
- Machinery subject to pipe strain or bedplate distortion
- Some severe services.

A 4th Edition seal is visibly very similar to earlier edition seals. One key discernible feature that will identify a 4th Edition seal is the plugs in the gland plate. Traditionally, stainless steel plugs have been used during transportation, plugs remain in the seal gland plate during installation, or are removed for connection of pipework for piping plans. The purpose of this requirement was to ensure that the ports would not be inadvertently left unplugged after the seal was installed into the pump.

Some users had concerns that the anaerobic sealant used on the plugs could cause issues when the plugs were removed with sealant debris falling into the seal or that threads may become damaged during plug removal. After considerable discussion within the Task Force, it was decided that red plastic plugs with a centre tab should be used with a yellow label stating they should be removed and replaced with steel plugs or pipework during assembly. (Figure 9)

Figure 9 Plugs and Warning Labels (Source: AESSEAL plc, Rotherham, UK)

Metal plugs are supplied with the seal in a separate plastic bag, which also contains a copy of the seal drawing and an additional warning label.

Vapour pressure margin is the difference between the seal chamber pressure and the vapour pressure of the fluid. This is an important consideration since contacting wet (CW) mechanical seals require liquid for generation of a fluid film at the seal faces, for cooling and lubrication. In the 1st Edition, it was simply stated that the seal must have a minimum 3.5 bar [50 psi] or 10% vapour pressure margin. The 2nd & 3rd Editions required a seal chamber vapour pressure margin (for single and unpressurised dual seals) of 30%, or a product temperature margin of 20ºC [68ºF]

A user on the Task Force stated that there was confusion with this requirement, *is the vapour pressure multiplied by 1.3 or the seal chamber pressure multiplied by 0.7*? The curve for the 20ºC margin was very different for the curve for a 30% margin.

The Task Force agreed to revert back to the 1st Edition (3.5 bar) margin but pump manufacturers highlighted that this could not be achieved on many low differential, pressure-pumping applications. The final position was a minimum margin of 3.5 bar be applied and, when this cannot be achieved, a minimum fixed ratio (at least 1.3) between the seal chamber pressure and maximum fluid vapour pressure is required.

API 682 requires that seal faces which can be exposed to reverse pressure in operation or a vacuum under static conditions must have their faces retained so they will not dislodge under these conditions. This has traditionally been achieved by use of snap rings or similar features and, due to this being illustrated in earlier editions of the standard, thought by some to be a required feature. An alternative method is to retain faces by balancing axial thrust forces hydraulically. The resulting designs offer resilient mounting of seal face mating rings, preventing metal contact with the brittle face material, and ease of assembly. API 682 4th Edition recognises both methods. (see Figure 10)

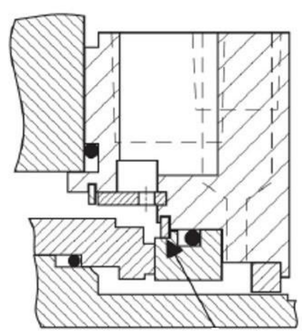
Seal face materials are critical to seal performance and have been a focus of attention in all editions of API 682. In previous editions the defaults for the silicon carbide face were based on the expected market usage. So

- Category 1 had a default of premium grade, blister resistant carbon versus self-sintered silicon carbide (SSSiC) - selected for the superior chemical compatibility characteristics of this material.

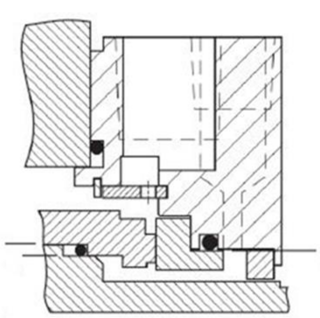
Category 2 & 3 had a default of premium grade, blister resistant carbon versus reaction bonded silicon carbide (RBSiC) - selected due to its long record of excellent performance in refinery services.

In the same way that seal arrangements cannot be generically identified, the selection of face materials is more complex than identification of seal category and seal OEM may recommend materials other than the defaults.

The 4th Edition states that "For all seal categories the material for one of the rings shall be reaction bonded silicon carbide (RBSiC) or self-sintered silicon carbide (SSSiC)." Thus allowing selection of the right material for the sealing duty.



Retention by Device e.g. Snap Ring



Retention by Hydraulic Balance

Figure 10 Examples of Face Retention Methodologies

Seal Category defines features, materials, operating windows and intended equipment. While there are no hard and fast rules about application of seal categories it is generally expected that Category 1 seals will be used on chemical duty pumps and Category 2 & 3 on heavier duty pumps found in the refining industry. Changes to category specific design in the 4th Edition are relatively minor and include

- The pressure range for Category 1 seals has changed from 22 bar absolute to 20 bar gauge.
- The pressure range for Category 2 and 3 seals has changed from 42 bar absolute to 40 bar gauge aligning API 682 with the API 610 pump standard.
- Floating bushes are now specified for Category 2 seals.
- Distributed flush is now specified for Category 2 seals

The introduction of Category 2 seals was to address concerns expressed by operating companies over the cost of fully documented and compliant seals in the 1st Edition Category 2 reduced documentation requirements and was less rigid on testing requirements. With the upgrading of seal design features for Category 2 seals the only effective differences between Category 2 & 3 are now the strictness of seal qualification and documentation requirements.

Section 7 – Specific Seal Configurations

Changes for the 4th Edition are relatively minor.

For Arrangement 1 seals, segmented carbon bushings are now identified as options for Category 2 & 3.

Comments on bushings for new piping plans 66A/B have been added

Provision of an external quench is required if specified or required by the seal OEM.

For Category 3 seals the seal OEM is required to provide pumping ring performance curves based on qualification test results. Note, this means that curves are based on two qualification test sizes, not that every size of seal requires testing!

Section 8 – Accessories

Seal accessories can be defined as hardware which is required to support the mechanical seal or seal piping plan, e.g. orifices, seal coolers or seal fluid reservoirs. API 682 4th Edition maintains most of the requirements identified in earlier editions but has added some new accessories.

For the 4th Edition the point of reference for piping system materials has been moved to the pressure casing (i.e. seal gland), in previous editions this reference point was the pump casing. This section of the standard requires that piping, components and appurtenances used in piping plans, buffer and barrier systems shall have a pressure-temperature rating at least equal to the maximum allowable working pressure and temperature of the pressure casing and not less than 20 barg for Category 1 and 40 barg for Category 2 & 3. The relevant clause in the standard does however recognise that "For high discharge pressure pumps, where the seal chamber pressure can get higher than the MAWP of the seal" (e.g. multi-stage (BB5) pumps) installation of a pressure relief valve may be considered as an alternative to building a system to meet the MAWP (8.1.4).

All cooler sizing is based on application conditions and not the pump shaft size as was done in previous editions.

Table 4 "Minimum Requirements for Auxiliary Piping" has been updated and now includes reference to applicable piping plans.

The total length of pipework between the mechanical seal and the seal auxiliary system shall not exceed 5 metres [16.4 ft]

Air Coolers.

Over the last decade, air cooling has increasingly been used in auxiliary piping plans, such as Plan 53B and Plan 23. Cooler fouling and the quality and availability of cooling water have been the principal drivers for this trend. Air cooling is now included in the 4th Edition with natural draft being the default using either stainless steel or aluminium fins.

Strainers

Strainers are supported in defined piping plans and are limited to minimum mesh size 125µm.

Reservoirs

Most requirements for reservoirs have been carried over from previous editions, including materials of construction, location of connections, instrumentation, dimensions and capacities. In the 4th Edition a minimum of 28 days of operation without the need to add additional barrier or buffer fluid is required.

Bladder Accumulators

Bladder accumulators are used to pressurise barrier fluid in Plan 53B systems. As with reservoirs 4th Edition requires a minimum of 28 days of operation without operator intervention. To achieve this standard sizes of 20 litres [5 gal] and 35 litres [9 gal] have been selected.

Plan 53B pressures can vary significantly with ambient temperature, this affects both operation and re-pressurisation under maintenance. For this reason a pressure alarm with a temperature bias is recommended.

4th Edition also requires an extensive nameplate detailing pressure/temperature relationships be supplied with the accumulator.

It should be noted that bladder accumulators are different to other seal accessories in that the default material for the accumulator shell is carbon steel. The reasoning behind this decision is that the accumulator is not directly in the cooling circuit but is located in a 'dead-ended' line. For the same reason the temperature rating of the bladder itself may be below the pump maximum allowable working temperature (provided failure of the bladder does not result in loss of containment).

A tutorial describing how to size, pre-charge, and operate a Plan 53B system is included in Annex F of 4th Edition.

Piston Accumulator

A piston accumulator is used to provide barrier fluid pressurisation in Plan 53C systems. The piston accumulator uses a piston with different hydraulically loaded areas to provide a pressurised barrier fluid referenced to pressure in the pump. Two sizes are defined in 4th Edition

- 2.8 litres [0.7 gal] maximum for shaft sizes 60mm or less
- 5.1 litres [1.28 gal] maximum for larger shaft sizes.

Accumulator materials are to be the same as the seal gland and the O-rings to ensure suitability for both process and barrier fluid.

Collection Reservoir for Liquid Leakage

Although Plan 65 has been defined and used in some industries, the Plan 65 detection vessel has not been defined in API 682. The 4th Edition states that Plan 65 and Plan 75 systems are considered part of the pressure boundary and are subject to the pressure requirements of the rest of the seal support system. For a Plan 65 the reservoir shall have a capacity of at least 3 litres [0.75 gal] and be equipped with a locally indicating level transmitter. For a Plan 75 the reservoir capacity shall be at least 12 litres [3 gal] and include a pressure transmitter with HLA and restriction orifice to detect primary seal leakage.

Section 9 – Instrumentation

A number of the API piping plans utilise instrumentation for sensing pressure, level, or temperature. Historically, switches were specified within the Standard. However, the Task Force recognised the growing trend within the industry for a preference for transmitters. Transmitters now form the default selection, with switches being an allowable alternative option.

Section 10 – Inspection, Testing and Preparation for Shipment

In earlier editions section 10 contained information on the seal qualification test. For the 4th Edition, as this section is primarily written for manufacturers, the testing section was removed from the main body of the text to Annex I.

Air Integrity Test

The API 682 Standard has always had a requirement that all seal assemblies should be air tested prior to shipment. Historically, the air test was devised as a simple check of correct seal assembly, to perform a quality check on the assembly and identify face distortion, gross damage or missing gaskets. The representative of a major European user within the 4th Edition Task Force raised the question as to why the integrity test was not aligned to the qualification test and requested that this air test be made more rigorous and considered as a performance verification test. Some studies have indicated that a seal with a small hole could pass the integrity test.

The question of using the air integrity test as an acceptance test was subject to considerable discussion. While the merits of making this an acceptance test are very valid, as the scope of the standard has increased, it has made it difficult to apply the same test criteria to all seals. Some seals (e.g. gas seals or containment seals) may be designed to operate on a slight leakage, dual pressurised seals may have such a small volume between the seals that the tests are very sensitive. Also, while the original test was intended to test face pairs used in dual seals individually (possible with Face to Back designs), this is not practical in Back to Back or Face to Face arrangements without dismantling the seal (and so defeating the object of the test)

Seal				Design Options				Size		Plans
Category	Arrangement	Type		Containment Device	Gasket Material	Face Material		Shaft mm		Piping Plan
2	**1**	**A**		**L**	**F**	**N**		**XXX**		**11/62**

Table 3 Example of Seal Coding

After lengthy discussions, the Task Force decided not to change the acceptance criteria from the previous editions and this remains that when testing at 1.7 bar [25 psi] the pressure drop cannot exceed 0.14 bar [2 psi] in five minutes.

Section 11 – Data Transfer

Transfer of data remains the joint responsibility of purchaser and vendor, data requirement forms have been moved to Annex E.
Datasheets have been updated and are in Annex C

Annexes

Over 2/3 of API 682 4th Edition is contained in the Annexes which come in two formats. A Normative annex is one that is important to implementation of API 682 and is therefore considered a requirement of the standard. An Informative annex is one intended to inform or educate.

Annex A (Informative) Recommended Seal Selection Procedure

Seal selection is a complex process and every seal OEM will have differing procedures based on their own products and market experience. API 682 therefore only provides guidance on selecting mechanical seals for specific applications as an informative annex and is not a requirement of the standard.

The procedure is a series of steps used to select the seal category, type, arrangement, and piping plan. The 4th Edition retains the selection procedure from previous editions but also adds an alternative selection process.

The historical procedure utilises a series of simple questions to make the selection of seal Type, Category and Flush plan, however it does not easily answer questions about which Seal Arrangement is required when leakage is considered hazardous and increased levels of sealing are required. In 4th Edition, an alternative method to select the Seal Arrangement was presented based on methodology proposed by the French Oil Company Total.

This method looks at seal selection using Material Safety Data Sheet information which takes into account the toxicity and flammability of a process fluid as well as its physical properties. The selection is based on the fluid hazard code according to the United Nations Globally Harmonized System of Classification and Labelling of Chemicals (GHS). The substances are categorized in “H” statements and tables place them into a one of four groups. A Seal Arrangement Selection Logic is then provided based on these groups. This seal selection takes into account concentrations of each substance within the mixture as well as exposure limits for hazardous or toxic substances and mixtures of these chemicals, and is thus a benefit to a broader audience, not just petroleum refining based processes.

It is important to note that a hazard assessment is only one criterion which must be considered. Other considerations such as the fluid properties, dry running of the equipment, seal leakage detection strategies, leakage disposal options and process contamination must also be considered before making a final selection and these are made using the updated 4th Edition selection procedures for Type, Category and Piping plan.

Annex B (Informative) Typical Materials and Material

Specifications for Seal Chamber and Mechanical Seal Components

This annex includes data on materials specifications. It is informative and should only be used for guidance. This annex has expanded considerably for the 4th Edition, of particular interest is the inclusion of reference data for graphite loaded silicon carbide which has increased in use considerably.

Annex C (Informative) Mechanical Seals Datasheets

Datasheets have evolved with every edition of API 682 in response to user feedback. The 4th Edition contains a two page datasheet.

Annex D (Informative) Seal Codes

API Seal Codes are commonly used by EPC in the procurement process of major projects. They are normally found on the datasheets and provide the purchaser with the simple methodology of obtaining comparative pricing for identical, generic types of mechanical seals from competing seal vendors. The 3rd Edition coding covered seal category, type, arrangement and piping plan. However, some regions still preferred to use the old API 610 coding dating back to the 1990s, which included materials of construction. The new 4th Edition code incorporates both 3rd Edition and historic API 610 coding. The new code also includes the shaft size. (Table 3)

In the example shown the seal is defined as

- Category - 2
- Arrangement - 1
- Seal Type - A
- Containment device – L (floating throttle bushing)
- Secondary sealing elements – F (FFKM)
- Face materials = N (Carbon v Reaction bonded silicon carbide)
- Seal size - XXX – Not defined. (use of ‘X’ represents an unknown value, this is common at the project stage where pump vendors may use differing shaft sizes)
- Piping plans 11 & 62

Annex E (Normative) Mechanical Seals Data Requirement Forms

Annex E contains forms describing all the information that needs to be transferred at proposal and contract stages of a project.

Annex F(Informative) Technical Tutorials and Illustrative Calculations

As indicated by the title of the annex, this is a guidance section showing typical calculations and covering topics such as seal leakage, vapour pressure, product temperature margins and piping plans. As with seal selection, seal OEM will have their own calculations and those in the standard do not necessarily reflect these. Readers wishing to know more about this section should refer to the T. Arnold/ C.J. Fone paper “Mechanical Seal Performance and Related Calculations”

Annex G (Normative) Standard Piping Plans and Auxiliary Hardware

Note, 4th Edition refers to piping plans not flush plans. It includes a legend and symbol library for the first time in the history of the standard. Seal piping plans are designed to improve performance and reliability of the seal, they range from simple systems to complex ones which provide pressurisation, cooling and circulation for support fluids and gases. API 682 defines the basic operation of the piping plan, the requirements for instrumentation and the design of seal support equipment. It should be noted that drawings are ‘typical’ or ‘generic’, API 682 does not attempt to define the exact construction of a piping plan. Minor changes to suit application are permitted, major changes to piping plans should be designated as an engineered plan (Plan 99).

Similarly, annex G states that pump, seal chamber and seal designs are intended to illustrate principles and design features, seals are intended to show generic location. Seal designs in API 682 may have a different appearance to those used in the figures and the seals illustrated are not an endorsement of a specific design or configuration.

In earlier editions of the standard, Plan 53B bladder accumulator and Plan 53C appeared as schematic designs with no specification provided as to the materials of construction and sizing. The 4th Edition now defines sizing for these piping plans and the materials of construction. It also indicates that these devices need to be sized to allow for at least 28 days between refilling.

Plan 03

In Piping Plan 03 circulation between the seal chamber and pump is created by seal chamber design (see Figure 11). The mechanical seal is cooled by product flow created by seal chamber design and which also provides improved venting of air or vapours

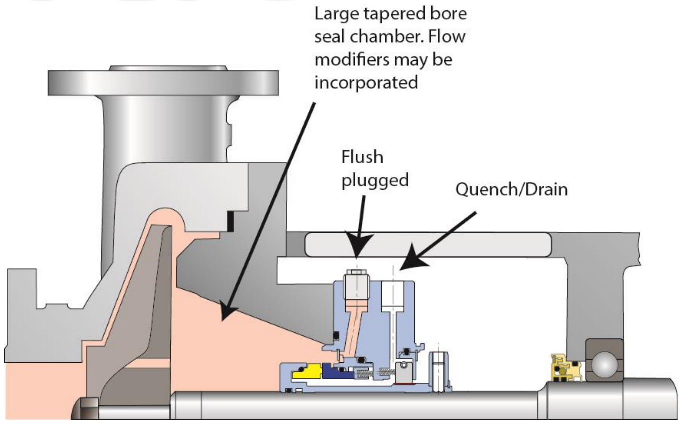


Figure 11 Plan 03 (Source: AESSEAL plc, Rotherham, UK)

Plan 55

Piping Plan 55 is an unpressurised external barrier fluid circulation from a central pressure source or from a stand-alone pumping unit (see Figure 12). It provides higher flow rate, better heat dissipation and positive circulation of buffer fluid. It also increases cooler efficiency due to higher flow rate to the heat exchanger.

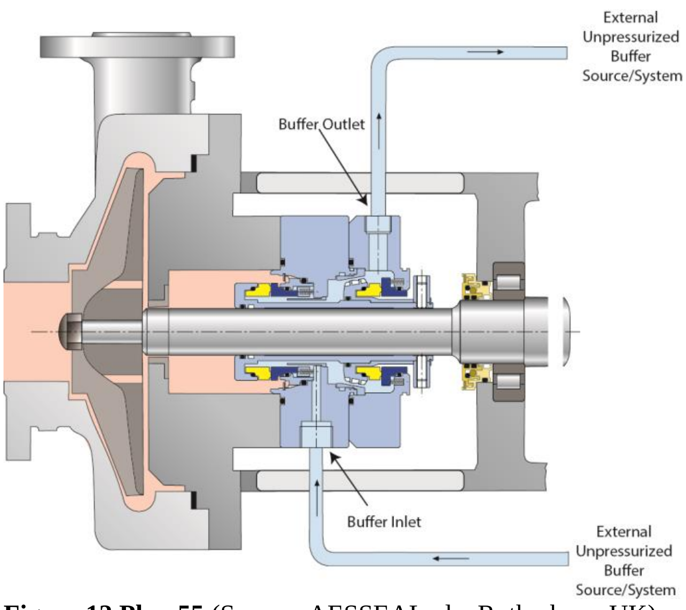


Figure 12 Plan 55 (Source: AESSEAL plc, Rotherham, UK)

Plan 65A

In Piping Plan 65A leakage from seal faces is directed to a liquid collection system. A vessel with a high level alarm is provided for detection of excess leakage (see Figure 13). It is normally used with single seals where the leakage is expected to be mostly liquid, piping is connected to the drain connection of the gland plate. Excessive flowrates are restricted by the orifice downstream of the vessel causing leakage to accumulate in the vessel activating the level alarm.

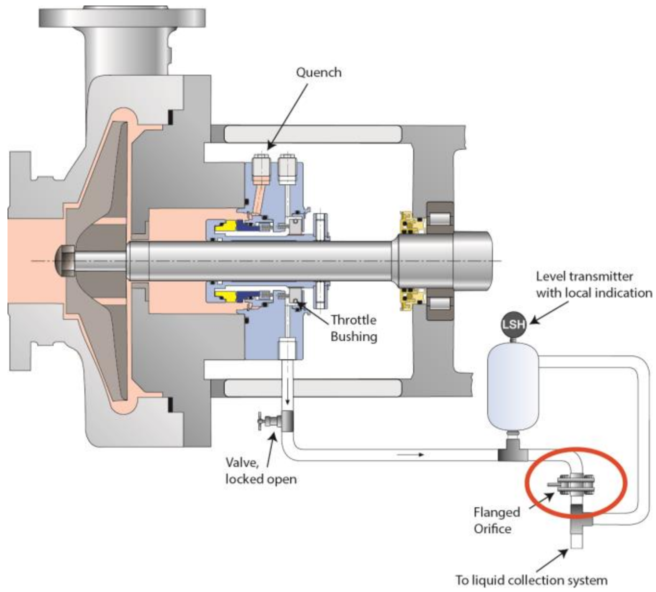


Figure 13 Plan 65A (Source: AESSEAL plc, Rotherham, UK)

Plan 65B

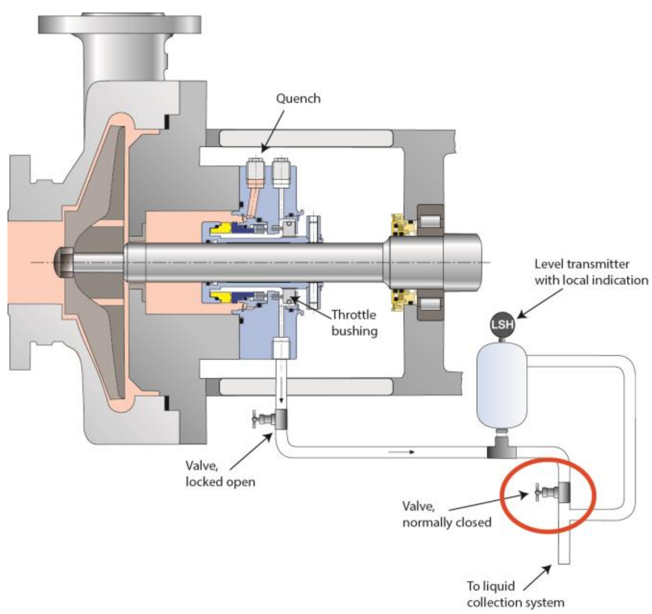


Figure 14 Plan 65B (Source: AESSEAL plc, Rotherham, UK)

In Piping Plan 65B leakage from seal faces is directed to a liquid collection system (see Figure 14). A vessel with a high level alarm is provided for detection of cumulative leakage.

It is normally used with single seals where the leakage is expected to be mostly liquid, piping is connected to the drain connection of the gland plate. Leakage is collected in the vessel until the high level alarm is reached. Excessive fill rate indicates seal failure.

Plan 66A

In Piping Plan 66A a throttle bushing in the seal gland restricts leakage in event of seal failure (see Figure 15). Pressure increase is detected by a pressure transmitter.

Normal leakage passes the inner restriction bush to drain. Excess leakage is restricted by the inner bush from leaving seal gland, causing a pressure increase which is sensed by the pressure transmitter. Leakage is directed to a liquid recovery system or sump

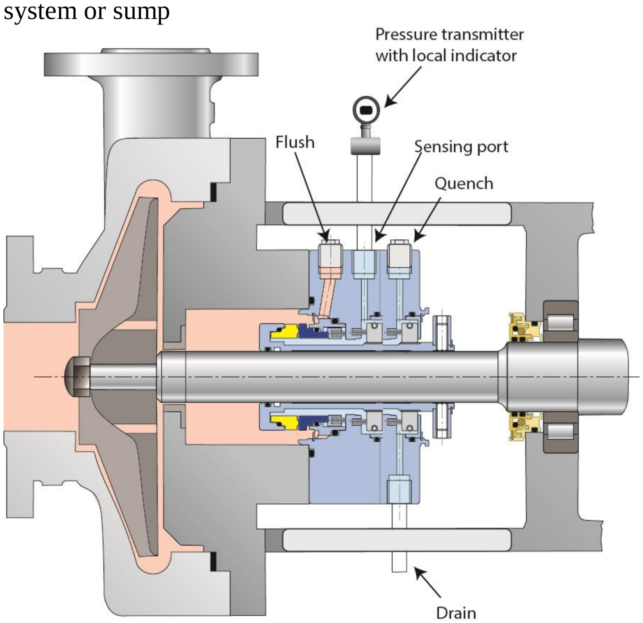


Figure 15 Plan 66A (Source: AESSEAL plc, Rotherham, UK)

Plan 66B

In Piping Plan 66B an orifice plug in the drain port restricts seal leakage in event of seal failure. Pressure increase is detected by a pressure transmitter (see Figure 16).

Normal leakage passes the orifice plug to drain. Excess leakage is restricted by the orifice plug from leaving the seal gland, causing a pressure increase which is sensed by the pressure transmitter. Leakage is directed to a liquid recovery system or sump.

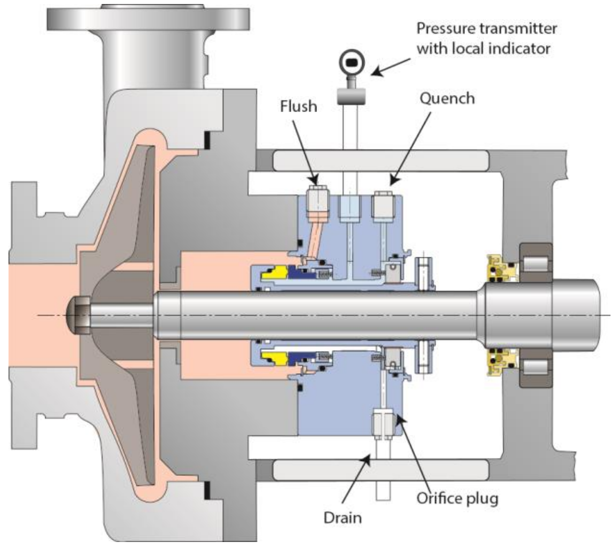


Figure 16 Plan 66B (Source: AESSEAL plc, Rotherham, UK)

Plan 99

Piping Plan 99 is an engineered piping plan not defined by other existing plans. It is an engineered system to suit the specific requirements of the customer and can be applicable to any seal arrangement, see schematic in Figure 17. Detailed engineering and customer input are required for effective solution.

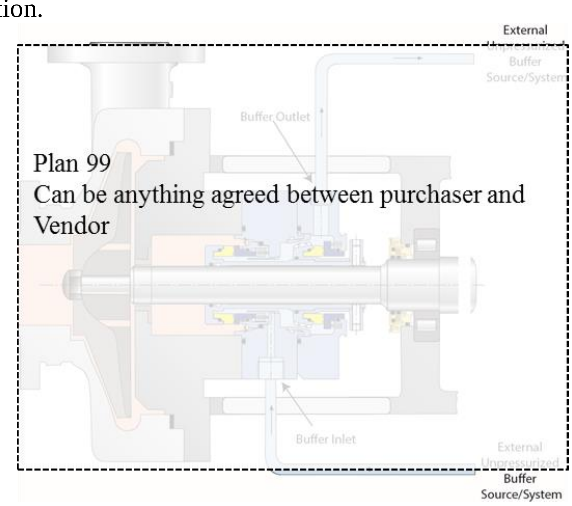


Figure 17 Plan 99 (Source: AESSEAL plc, Rotherham, UK)

Annex H (Informative) Inspectors Checklist for all Seals

A simple checklist suffices.

Annex I (Normative) Seal Qualification Testing Protocol

Introduced by users on the 1st Edition Task Force, qualification testing remains a cornerstone of the Standard. The qualification testing program was expanded in later editions to include gas seal and containment seal technologies. The 4th Edition retains this testing and has introduced an additional test for dual pressurised seals that are orientated in a Back to Back or Face to Face format.

Annex I also introduces the concept of core seal components and how these can be shared across differing designs and categories. This is to prevent the unnecessary duplication of qualification testing.

Seal qualification testing was introduced to demonstrate that mechanical seals covered by the standard offered a reasonable assurance that they can meet the performance and life expectations in the standard. However, testing all seals in all possible combinations raised the possibility of seal OEM having to complete thousands of qualification tests.

For this reason, API 682 4th Edition has introduced a common sense approach to testing. One way this has been achieved is by the definition of "core seal components" which may be used across different designs without additional qualification testing.

By introducing a hierarchy of seal parts

- Core components (seal ring and mating rings)
- Adaptive hardware (sleeves, glands and circulating devices)

and using seal Categories, Types and Configurations to complete the description of the seal cartridge, the definitions can be used to describe how core seal components can be shared across qualification tests.

In the 1st Edition, testing of dual seals required that the inner seal be tested as an individual test followed by an evaluation of the complete dual seal assembly. These requirements continued in the 2nd & 3rd Editions even though the standard added additional options for BB and FF orientations. There were some serious technical difficulties with applying the test requirements to these orientations since the seal would be exposed to operation with high ID pressurisation and this severely restricted seal OEM from offering these designs.

For the 4th Edition a new procedure was developed to demonstrate the performance of dual liquid seals in BB & FF orientations. The complete seal assembly must be tested and be accepted according to the existing dual liquid seal test criteria. In addition to this test, the seal must demonstrate its ability to survive reverse pressurisation and upset conditions which might be experienced in service.

The 4th Edition includes a new table (Table 4) showing how qualification testing for different seal configurations has generally been organised by seal manufacturers. It should be remembered that to be considered qualified for API 682 a seal does not have to be tested in every combination shown, e.g. seals need only be qualified in process fluids appropriate to the services they are being supplied into.

Design Parameters						Test Parameters		
Cat	Balance diameter	Face Materials	Seal Type	Flexible Element	Config	Scope	Procedure	Test Fluid
1	38 to 75 >75 to <127	C v /SSiC C v RBSiC SSiC v SSiC RBSiC v RBSiC	A B C	Rotary Stat'ry	1CW-FX	Inner seal	Dynamic, static, cyclic phases App. 100 hr	Water Cold oil Hot oil Propane NaOH
					1CW-FL			
					2CW-CW	Inner seal and arrang't		
					2CW-CS			
					2NC-CS			
					3CW-FB			
					3CW-BB	Arrang't		
					3CW-FF			
2 3	50 to 75 100 to 127				3NC-BB			
					3NC-FB			
					3NC-FF			
					2CW-CS	Contain't seal only	Dynamic, static App. 200 hr	Water, oil, diesel & nitrogen, steam, propane
					2NC-CS			
					3NC-BB	Arrang't	Variable barrier gas pressure App. 1 hr	Nitrogen
					3NC-FB			
					3NC-FF			

Table 4 Qualification Test Matrix

The 4th Edition Task force also addressed the ongoing requirement for seal OEM to qualify new seal face materials.

In earlier editions this would require completion of a full qualification test on two sizes of seal. To reduce testing requirements 4th Edition allows face material combinations to be qualified as a mating pair and used across multiple seals with a single test. If a seal is qualified with a specific mating pair on a specific fluid, any other qualified seal may use the same mating pair on the same fluid without additional testing. Additionally, new face pairings may be qualified by a single test (of the largest test size) provided only one face material is changed. This is most easily illustrated in a diagram, see Figure 18.

- Seal ring SR1 and Mating ring MR1 are qualified by the full test (2 sizes)
- A single test may be used to qualify SR2 as a pair with MR1
- A single test may be used to qualify MR2 as a pair with SR1
- SR2 and MR2 are not a qualified face pair unless tested

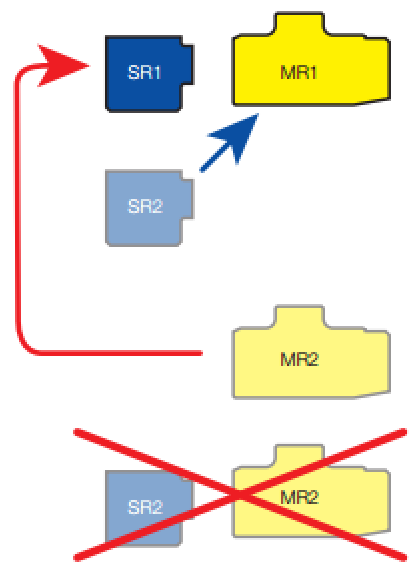


Figure 18 Face material qualification

CONCLUSIONS

With the publication of the 4th Edition of API 682 the American Petroleum Institute continues to drive reliability and good sealing practice across the process industries. The standard continues to address advances in sealing technology but with the 4th Edition has also sought to address issues with the implementation of the standard across user communities. A key objective for the 4th Edition Task Force was to reduce misinterpretation of the standard which, in some instances, resulted in the recommendations in it being misunderstood and applied too rigidly. For these reasons the 4th Edition has moved from defining "standard" designs (which imply a requirement) to "default" designs (which signify that alternative designs are available).

API 682 will continue to serve as the most significant standard for mechanical sealing systems in centrifugal pumps.

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ACKNOWLEDGMENTS

The author would like to express his gratitude to the American Petroleum Institute and all members of the API 682 Task Force whose dedication made publication of the standard, and therefore this paper, possible. Special recognition goes to the API 682 Task Force Chairman, Mr. Rick Eickhoff.

The author would also like to express his sincere gratitude to his sponsors, AESSEAL UK, for recognising the importance of bringing knowledge and understanding of API 682 to everyone and enabling me to attend the 2016 Asia Symposium and present this tutorial. In particular I would like to thank Richard Smith and Stephen Shaw for their support and invaluable contributions.

The author would also like to thank Mike Goodrich (retired CFR Total) and Henri Azibert (Fluid Sealing Association) for providing materials in support of this tutorial.