Mechanical Seals
Technical Manual

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The mechanical seal

Mechanical seals have the purpose of preventing leakage of a fluid (liquid or gaseous) through the clearance between a shaft and the fluid container. (Fig.1)

The main components of a mechanical seal are the seal rings on which a mechanical force is acting, generated by springs or bellows, and an hydraulic force, generated by the process fluid pressure.

The seal ring which rotates with the shaft is called the "rotary ring"; the seal ring fixed on the casing of the machinery is called the "stationary ring".

Secondary seals are required to perform static sealing between rotary rings and shafts and also between stationary rings and the casing of the machinery.

Elastomeric O-Rings are usually used as secondary seals but alternative systems can be used, as described in the following sections. (Fig.2)
Typically mechanical seals are installed on **pumps** and **mixers**. (Fig.3 & 4)

On both of the above set-ups, the installation of a suitable device is required to seal the fluid contained in the casing.
The liquid film

In order to minimize the amount of friction between the seal rings an efficient lubrication is required.

Seal faces can be lubricated by the process fluid or, with double mechanical seals, by a proper auxiliary fluid (see chapter relevant to configurations).

An stable and complete layer of lubrication greatly affects the performance and the life of a mechanical seal. (Fig.5)
In order to insure good lubrication and sufficient cooling of the seal rings, the correct selection of a mechanical seal shall take into consideration the following parameters:

**Process fluid temperature**

**Vaporisation pressure** at operating temperature

**Process fluid characteristics**

**Shaft speed**

(see also chapter relevant to selection)

Concepts and principles above discussed are valid for all mechanical seal operating with a liquid fluid. Dry-running seals and gas-seals operate on different principles and shall be considered further on.

**Leakage**

**All mechanical seals produce leakage.**

The reason lies in the previously discussed theory of lubrication; it is obvious that a stable lubrication layer means a certain amount of leakage.

Leakage can be calculated and depends on several factors as rotational speed, fluid pressure and characteristics, and balancing ratio. But the equipment on which the mechanical seal is installed can have some influence on it too. **Often leakage is so reduced that it cannot be detected (vaporisation).**

**Degree of freedom**

The elastic components of a mechanical seal (spring or bellow, gaskets) are of paramount importance for good performance.

The gasket mounted on the seal ring pushed by the spring or bellow (usually the rotary ring) has to follow the movement of the ring induced by
unavoidable phenomena like vibrations, misalignment and shaft run-out and for this reason it's called "dynamic" (Fig.6)

It follows that such parameters as **working length**, **gasket compatibility** with the process fluid, **dimension** and **finishing** of the shaft have to be carefully considered for good application of a mechanical seal.

**Balancing ratio**

If we consider a piston on which a constant pressure is applied we know that the force produced shall be proportional to the area of the piston itself.

In mechanical seals, in addition to the closing force generated by the springs or bellow, an hydrostatic force generated by the fluid pressure acts on the seal ring.

As previously discussed the fluid pressure also penetrates between the seal faces, producing a lubrication film and generating an opening force.

The ratio between the forces which are closing the seal ring and the ones which are opening the seal ring is called the "balancing ratio".
When the balancing ratio is greater than one, we have an unbalanced seal.

In the other cases we have a balanced seal.

The dimensions needed for a balanced seal are obtainable thanks to a small notch placed on the sleeve or on the body of the seal itself.

**Unbalanced seals**

Generally unbalanced seals have good performance when subjected to vibrations, misalignments or cavitation; they are cheaper and their application does not require shaft or sleeve notching.

The main limitation in the application of unbalanced mechanical seals is the operating pressure.

High pressures produce an excessive closing force which affects the stability of the liquid film between the seal faces, inducing overheating and premature wearing. (Fig.7)

Fig. 7

\[ K = \frac{Ah}{Af} \rightarrow Ah > Af \rightarrow K > 1 \]

\[ Ah = (d_2^2-d_1^2)\cdot\pi/4 \quad Ah = \text{Anular area on which the pressure is acting} \]

\[ Af = (d_3^2-d_2^2)\cdot\pi/4 \quad Af = \text{Sliding faces area} \]
**Balanced seals**

High pressure and high speed obviously generate proportionally high values of friction heating.

Balanced seals address this problem with a reduced closing force, as previously discussed.

Also in cases where a high value of vapour pressure has to be considered, a balanced mechanical seal is the right choice.

API standard defines as "**flashing**" all hydrocarbons that have a vapour pressure higher that 1 barg and for these fluids a double or tandem balanced seal has to be provided. (Fig.7a)

---

**Fig. 7a**

\[ K = \frac{Ah}{Af} \rightarrow Ah < Af \rightarrow K < 1 \]

\[ Ah = (d_2^2-d_1^2)\frac{\pi}{4} \quad Ah = \text{Annular area on which the pressure is acting} \]

\[ Af = (d_2^2-d_3^2)\frac{\pi}{4} \quad Af = \text{Sliding faces area} \]
THE CONFIGURATIONS
Single internal seal

This is the most popular and efficient configuration for the most applications. It is called internal because of its being completely submerged in the product. The balancing ratio is designed for pressure acting outside the seal, therefore usually, if installed as an external seal, the fluid pressure will cause translation of the stationary ring and excessive separation of the seal faces. (Fig.8)

Single external seal

In this execution the sealed product is inside the seal and the outside part of the rotary ring is exposed to the atmosphere. (Fig.9)

It is employed with aggressive fluids which can chemically attack materials commonly used for internal seals or when the use of special materials is considered too expensive.

In this type of seal often there are no metallic parts in contact with the product or, if there are any, special materials such as Hastelloy or Titanium are used.

The rotary ring and the stationary ring (in contact with process fluid) can be made of graphite, ceramic or silicon carbide.

Gaskets can be in fluoroelastomer, PTFE or perfluoroelastomer.
The application of external seals is often employed in top entry mixers because of an easy installation and the possibility to carry out an efficient cooling of the stationary ring, required for dry running applications.

**Back-to-back double seal**

This configuration is recommended with critical products (i.e. gaseous, abrasive, toxic or lethal) and generally when no emissions in the atmosphere are permitted.

The back-to-back lay-out, so called because the two seals are placed literally back to back, gives the possibility to create a barrier made of a pressurised auxiliary fluid not harmful to the environment.

The lubrication of the seal faces is carried out by the auxiliary fluid which should be compatible with the process fluid. (Fig. 10)

In a back-to-back configuration an internal pressurisation having a value greater than the process fluid (at least 1 bar or 10% more) is required in order to avoid opening of the seal (as explained in chapter relevant to internal single seals) and to provide an efficient barrier against leakage of process fluid into the atmosphere.
**Tandem double seal**

In this configuration the two seals are assembled with the same orientation.

The auxiliary fluid often is at a lower pressure than the process fluid but also pressurised systems can be implemented with suitable seal rings (see dual seals). (Fig.11)

In an unpressurised configuration there is the advantage of avoiding relatively costly pressurisation systems obtaining a performance equivalent to the one of the back-to-back lay-out, which consists of:

- No leakage of the process fluid into the atmosphere
- Good lubrication and cooling of the seal rings

This configuration however is not suitable with toxic, abrasive or highly viscous process fluids, prone to create sticking of seal rings; in these cases the back-to-back configuration should be used.

Tandem double seals are usually employed in petrochemical and refinery plants, where service with high vapour pressure and low specific weight on centrifugal pumps is required.
Dual seal

This is a new configuration foreseen by API 682 standard (American Petroleum Institute), where the two seals are assembled in a tandem lay-out.

A special design of the seal rings gives the possibility to operate both in an unpressurised system and in a pressurised system (as with the back-to-back configuration), obtaining the advantages of the two previous configurations.

Only a **cartridge** assembly is allowed by API 682 in this configuration. (Fig.12)

Face-to-face seal

This last double seal configuration is composed by a unique central stationary ring and two opposite rotary rings.

It can work in the same way as a **dual seal** (pressurised and unpressurised system).
Less used than some of the previous configurations, it has some interesting features like:

Reduced overall length

Spring not in contact with the process fluid (Fig.13)
Cooling system and API planes

The great importance of efficient lubrication of the seal rings for good importance has been previously underlined. It follows that a suitable cooling system should be implemented to limit the operating temperature of the seal. Many different lay-outs can be used, depending on the configuration and the required service. (Fig.14)

A good seal selection must include criteria for a safe and durable installation. API standard has supplied an exhaustive collection of flushing and pressurisation lay-outs, each intended for a specific service. The various connection lay-outs are identified by a specific number which gives the possibility to simply define all possible configurations (See API plans at pag.20)

Selection of mechanical seals

The API 682 standard is a powerful tool to carry out mechanical seal selection for intended use in refinery plants.

In chemical plants the variety of applications and process fluids makes the selection of the seal a challenging job.

Many parameters should be considered as characteristics of the fluids, configuration of the machinery on which the seal have to be installed, specific requirements in terms of compatibility with some restrictive standards (i.e. FDA rules for food industry).

In the next sections the most diffuse products and relevant recommended configurations are grouped into families and defined with the intent of explaining the logic of the API plans.

More details about specific products can be found in our catalogue, in the selection section.
**PLAN 01**
Internal recirculation from pump discharge to seal.

**PLAN 02**
Dead-ended seal chamber with no circulation of flushed fluid; water-cooled stuffing box jacket and throat bushing required when specified.

**PLAN 11**
Recirculation from pump case through orifice to seal.

**PLAN 12**
Recirculation from pump case through strainer and orifice to seal.

**PLAN 13**
Recirculation from seal chamber through orifice and back to pump suction.

**PLAN 21**
Recirculation from pump case through orifice and heat exchanger to seal.

**PLAN 22**
Recirculation from pump case through strainer, orifice and heat exchanger to seal.

**PLAN 23**
Recirculation from seal with pumping ring through heat exchanger and back to seal.

**PLAN 31**
Recirculation from pump case through cyclone separator delivering clean fluid to seal and fluid with solids back to pump suction.

**PLAN 32**
Recirculation from pump case through cyclone separator delivering clean fluid through heat exchanger to seal and fluid with solids back to pump suction.

**PLAN 51**
Dead-ended blanket (usually methanol - see note 3); typically used with auxiliary sealing device (single or double seal arrangement).

**PLAN 52**
Non pressurized external fluid reservoir (see note 3) with forced circulation; typically used with tandem seal arrangement.

**PLAN 53**
Pressurized external fluid reservoir (see note 3) with forced circulation; typically used with double seal arrangement.

**PLAN 54**
Circulation of clean fluid from external system (see note 3); typically used with double seal arrangement.

**PLAN 55**
External fluid quench (steam, gas, water, etc. see note 3); typically used with throttle bushing or auxiliary sealing device (single or double arrangement).

**NOTE:**
1) These plans represent commonly used systems. Other variations and systems are available and should be specified in details by the purchaser on mutually agreed upon by the purchaser and the vendor.

3) When supplemental seal fluid is provided, the purchaser will specify the fluid characteristics. The vendor shall specify the volume, pressure, and temperature required, where these are factors.

**LEGENDA SIMBOLI:**
- Heat exchanger
- Pressure gauge
- Temperature gauge
- Pressure switch
- Cyclone separator
- Flow indicator
- Flow regulating valve
- Block valve
- Check valve
- Orifice
Clean, not harmful, neutral, not flammable products

Example: Water, Vegetal oil, Glycol

**API Plan 11 or 01** is the recommended lay-out, in order to dissipate the heating produced by the seal rings and to carry out a proper venting of the stuffing box.

In the case of a conical stuffing box also **API Plan 02** can be used.

**Fluids crystallizing when in contact with atmosphere**

Example: Sulphates, fosfates, saline solutions, alcaline solutions

A single configuration is recommended, combined with **API Plan 11 or 01** in order to dissipate the heating produced by the seal rings and to carry out a proper venting of the stuffing box.

Implementing an additional **API Plan 62** with water or steam at low pressure (max 0.3 barg), an efficient removal of crystallization deposits can be insured, preventing locking of the rotary ring (see also degree of freedom at pag.4).

**PLAN 62:**
It consist in washing the seal on atmospheric side with a proper fluid, an auxiliary seal (packing, lip seal, floating bush) avoid the leakage on atmosphere.

**PLAN 61:**
The same connection for plan 62 are closed available for the end-user.
Acid products

A single internal seal is recommended, **API Plan 11/61** or **01/61** is in theory the proper connection.

In case of conical stuffing box use **API Plan 02/61**.

With these products an external seal is suitable too; in this case protection should be provided to prevent possible spraying of product.

Hot liquids

Example: Heavy hydrocarbons, diathermic oils

Temperatures over 200°C up to 400°C are typical applications in refinery plants or pumps for diathermic oil.

It is important to evaluate the effective operating temperature in the stuffing box.

Many pumps come with a cooling system which reduces the temperature in the stuffing box, in order to avoid very expensive configurations of the mechanical seals.
The selection of the materials and the configuration will mainly depend on the operating temperature.

The recommended configuration is a single internal seal, with **API Plan 02**. A complete venting of the stuffing box is required and then the installation of a suitable system has to be verified.

Implementing an additional **API Plan 62** with water or steam at low pressure (max 0.3 barg), an efficient removal of crystallization deposits can be insured, preventing locking of the rotary ring (see also degree of freedom at pag.4).

For a more accurate analysis, make reference to API 682 specifications.

**Aqueous solutions prone to solidify or produce sediments**

Example: lime, paper pulp, slurry

A single internal seal recommended, installed with the **API Plan 32** flushing system in order to supply a clean fluid, compatible with the process fluid for a good lubrication and cooling of the seal faces (auxiliary fluid should have a pressure higher than the process fluid).

A throat bushing, properly dimensioned, provides a barrier flushing equivalent to a pressurised system.

A valid alternative, if solid particles are in low percentage, is an **API Plan 02/62** in a conical stuffing box.

A quench with water provides an efficient washing of the seal rings and cools them as well.
Toxic, poisonous or highly viscous fluids

Example: Solvent based varnishes, inks, creams, glues, lattice

The back-to-back configuration is recommended with a pressurised API Plan 53.

The lubrication of the seal faces is provided by the auxiliary fluid. Suitable instruments (i.e. level switch) installed on the pressurisation system can detect an eventual leakage.

Abrasive fluids

Example: Water mixed with sand, slurries

A double configuration is recommended with a pressurised API Plan 54.

The best lay-out is a stationary seal with the product outside the seal rings.
Less used but sometimes suitable is a single internal seal with **API Plan 31**, where the pumped liquid is passed through a cyclone separator and then injected into the stuffing box.

![API Plan 31](image)

**Flammable fluids**

Example: Hydrocarbons, solvents

A tandem configuration is recommended with an unpressurised **API Plan 52**.

An auxiliary tank, complete with level and/or pressure switch can provide an efficient flushing of the seal and prevent emissions into the atmosphere.

For a more accurate analysis make reference to API 682 specifications.

![Buffer fluid at pressure < than product pressure](image)

**Buffer fluid at pressure < than product pressure**

![API Plan 52](image)
Hot water

Example: boiled feed water, condensate recovery

These kinds of applications are more difficult than expected at an initial evaluation. Viscosity of water consistently decreases at high temperatures, supplying a poor lubrication of seal faces.

At temperatures over 90°C the consistency of the lubrication film is so reduced that a progressive and fast wearing of seal faces can be expected.

The recommended choice is a single internal seal with API plan 23.

The hot water is cooled while it follows the path of a closed loop around a heat exchanger, all with the help of a suitable pumping device, typically a pumping ring. With correct dimensioning of the flushing system, operating temperatures lower than 90°C can be obtained, insuring good performance of the mechanical seal.

A specific datasheet is available to specify all parameters required for proper selection.
THE TYPES
Single seal with single spring

Its essential design make it easy to install and cheaper than any other type of seal.

A conical spring has the double function of giving axial positioning engaging in a proper shoulder on the shaft and of driving the rotary ring self locking on the shaft during rotation. Not very clear so i don't know how to correct

**Main advantages are**: low cost, large misalignments allowed, good efficiency even with viscous or dirty products.

**Disadvantages are**: mono-directional, need of a shoulder on the shaft, not suitable for sticking products.

Fluiten proposes seal types S (SA,SC,SPB)

**Solution according DIN 24960 K**

**SA type**

*Unbalanced mechanical seal with stationary ring with slot for antirotation pin.*

**SC type**

*Unbalanced mechanical seal with "short" stationary ring without slot for antirotation pin.*

**SPB type**

*Balanced mechanical seal with stationary ring with slot for antirotation pin.*
**Bi-directional seals**

By all means the most popular type of seal.

A suitable seal body, carrying springs, secondary seal and rotary ring can be installed on the shaft and locked by means of set screws.

**Main advantages are:** low cost, robust construction suitable to withstand sticking of seal faces, cavitations and misalignments.

**Disadvantages are:** a certain level of skill is required for proper installation. Shaft dimensions and finishing must be accurate, in particular for balanced seals.

Fluiten proposal is seals type "U", "N", "B" (US3A, UM3A, N3X, BS3A, BM3A, BL3X).

**Solution according DIN 24960 K**

**UM3A type**

Unbalanced mechanical seal multiple springs.

Over 100 mm: **N3X**.

**BM3A type**

Balanced mechanical seal multiple springs. Over 100 mm: **BL3X**.

**US3A type**

Unbalanced mechanical seal single spring.

**BS3A type**

Balanced mechanical seal single spring.

For UM3/US3/BM3/BS3 is foreseen a solution with "short" stationary ring without slot for antirotation pin. (UM3C/US3C/BM3C/BS3C)

For N3X/BL3X is foreseen a solution with clamped stationary seat. (N3W/BL3W)
Seals with protected springs

A suitable designed body has the double function of providing a locking system on the shaft and of working as a sleeve on which the rotary ring is installed. Springs are inside the seal body, protected by the rotary ring gasket.

**Main advantages are:** suitability of operation with highly viscous fluids or with fluids containing solid particles. The incorporated sleeve makes it a balanced seal without requiring notching of the shaft.

**Disadvantages are:** costs more than other seals, not suitable for a back-to-back configuration.

Fluiten proposes seal types "TB" & "TZKA".

**TB type**
Balanced mechanical seal single spring external product - according DIN 24960.

**TZKA type**
Balanced mechanical seal with multiple springs available up to 200 mm
Elastomeric bellow seals

The rotating seal face is incorporated in an elastomeric bellow and a spring supplies the mechanical load.

**Main advantages are**: low cost, no secondary seal required since the bellow is sealing onto the shaft.

This solution is suitable for critical fluids as crystallizing or solidifying products, preventing eventual sticking of the seal on the shaft.

**Disadvantages are**: limited pressure ratings allowed, in the case that bellows fail, will bring consistent leakage of product.

Fluiten proposes seal types PC4A.

*PC4A type*

*Rubber bellows mechanical seal according DIN 24960.*
PTFE bellow seal

Constituted of an external seal where the product is in contact with a PTFE bellow. Driving set screws are replaced by a split ring nut, in order to provide a safe locking on any kind of material shafts.

Main advantages are: excellent performance with extremely aggressive products. Simple construction with no metallic parts in contact with the product, preventing chemical attacks or sticking.

Disadvantages are: limited pressure ratings allowed, failure of the bellows brings consistent leakage of product. Possibility of product being trapped inside the bellows.

Fluiten proposes seal types ES

In case of high pressure/temperature provide a locking nut or a shoulder on shaft.
Metal bellow seals

A metal bellow has double functioning as a secondary dynamic seal and as a spring. A secondary static seal is mounted in the carrier of the bellow.

**Main advantages are:** The absence of a secondary dynamic seal makes this seal particularly suitable to operate with critical fluids such as crystallizing or solidifying products, preventing eventual sticking or fretting of the seal on the shaft. Good performance with very hot or very cold fluids too, providing secondary static gaskets in Grafoil.

**Disadvantages are:** Relatively expensive in comparison to conventional seals. Low capability to operate with large misalignments. The metal bellow makes it impossible to carry out reconditioning.

Fluiten proposes seal types TSMA, TSHA.

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**TSMA type**

Metal bellows solution available on stationary execution - according DIN 24960.

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**TSHA type**

Metal bellow solution provide of wedge grafoil gasket for high temperature. Available on stationary execution.
External seals

They have performance equivalent to a PTFE bellow external seal; the PTFE bellow is replaced by a O-Ring gasket. The rotary ring, usually made of silicon carbide or reinforced PTFE, is carried by a metallic body by means of driving pins. The stationary ring needs axial locking to prevent pressure-induced displacement.

For heavy service types EFC and EF1C feature a special design.

**Main advantages are**: suitability to operate with extremely aggressive fluids. Parts in contact with product are not metallic or made of Hastelloy or Titanium, depending on the configuration. Simple design makes the installation easy. Suitable in particular for top-entry mixers.

**Disadvantages are**: locking of the stationary ring introduces some additional work on the machinery. Dirty fluids can penetrate between the seal faces.

Fluiten proposes seals types E, EFC, EF1C.

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**EFC type**
Mechanical seal with PVDF body and locking nut for shaft in plastics material.

**E type**
External balanced mechanical seal with clamped stationari ring.

**EF1C type**
Solution with body in titanium for metal shaft.
Cartridge seals

In principle they are made up of a conventional seal assembled with a cartridge and a flange, in order to ease the installation on the machinery. Many configurations are available as: stationary or rotating seal, multiple or single spring, balanced or unbalanced. Cartridge seals type C, produced by Fluiten, feature a complete series of versions, each one designed for a specific application as pumps, mixers or other machinery.

Main advantages are: low cost, suitability for most applications, versatility. Monolithic balanced seal rings.

Disadvantages are: initial cost higher than that of spare components of traditional seals. Not recommended when PTFE gaskets are required.

Fluiten proposes seal types “C”

C2S type
Single balanced execution.

C2K type
Single unbalanced execution.

C2KC type
Single unbalanced execution with connections for flushing (Plan 11 - 32)

C2D type
Double balanced execution.

C4D type
Double dry-running

C3K/C3KC type
Solution with reinforced sleeve.

C2DQ/C2SQ/C4DQ type
Solution with auxiliary V-Ring for Plan API 62.

C3S/C3D/C3DQ/C3SQ type
Solution with reinforced sleeve.
Stationary seals

Usually featuring special design for specific applications.

Springs are stationary and not in contact with the product.

These seals are recommended for high rotational speed and for operation with viscous or dirty fluids, even lattices if assembled in a pressurised double set.

The robust design makes these seals, in TC and HD version, a good solution for heavy services.

**Main advantages are:** Suitable for the higher operating parameters.

**Disadvantages are:** Relatively high cost. Larger overall dimensions compared to conventional seals.

Fluiten proposes seal types TC and HD
THE MATERIALS
Seal face materials

A good sealing function requires perfect planarity of the seal faces, even under consistent gradients of temperature.

Moreover the high relative speed and pressure at which seal faces have to operate require an optimised lubrication and cooling.

The combination of the above factors brings to the selection of suitable materials conveniently designed and machined (lapping).

The choice of a proper seal face material is the first and most important step for long wear and favorable results.

The most reliable combination of materials is that of one seal face in graphite and the counterface in silicon carbide, tungsten carbide or ceramic. The main advantage of a graphite seal ring is its capacity to perfectly complement the counterface after a short time of operation.

When the fluid to be sealed is abrasive it is recommended to install two hard faces such as silicon carbide or tungsten carbide. In this latter case particular care should be taken to prevent the possibility of transitory dry running which can lead to permanent damage of the seal.

Graphite

The self-lubricating properties of this material make it the first choice as seal face. Many varieties are available on the market, all of them produced by means of the sintering of carbon and graphite powder, bonded with proper resins or metals.

Bonding is required to seal the microporosity generated by the high temperature (over 1000°C) which is required for the sintering process.

The more common types of graphite are:

Resin impregnated graphite, with high chemical resistance and then suitable for most chemical application.
Metal impregnated graphite (typically antimony or bronze), suitable for higher operating temperatures and pressures.

Electrographite, sintered at a very high temperature (2500°C). Suitable for high temperatures and very aggressive fluids.

Main advantages of graphite are: capacity to wear off small initial defects of planarity in a short time. Good self-lubricating properties which permit transitory dry running.

PTFE

This material has properties similar to graphite, except for the mechanical strength which is relatively low. Various bonding materials are used to increase the wearing resistance, glass is the more commonly used.

PTFE is in practice completely inert and then suitable for any kind of aggressive fluid when mating a silicon carbide or ceramic counterface. Not suitable for mating with Chromium steel and Stellite.

Stellite

This alloy is composed of Cobalt, Tungsten and Chromium which give high superficial hardness. Usually employed as coating on stainless steel rings to provide a hard sliding surface. Poor capability to take thermal dilatation.

Chromium steel

It is a stainless steel with high percentage of Chromium, which gives an excellent combination of hardness resistance to corrosion. Seal rings made of this material do not have the disadvantages of Stellite in respect to thermal dilatation. Chromium steel is generally combined with graphite counterfaces.

Ceramic

This material is an Aluminium Oxide (Al2O3) and it is produced by sinterization of powders and machined by grounding.
Different types are available on the market, identified by the level of purity of the material. Fluiten is using a 99.7% pure Al2O3, with high chemical and wearing resistance. Ceramic has great hardness, so suitable for abrasive products. Main disadvantage is a poor resistance to thermal shocks.

Generally it is mated with counterfaces in resin impregnated graphite or reinforced PTFE.

**Tungsten carbide**

This material has great mechanical resistance, so it is suitable to operate with abrasive fluids and has a limited but very useful capability to withstand short transitory conditions of poor lubrication. The alloy can be constituted of Tungsten bonded with Cobalt or Nickel. The bonding materials give different properties.

Cobalt provides high mechanical strength and it is commonly used for machining tools. Nickel gives a slightly lower mechanical resistance but it improves the chemical resistance and it is preferred for the production of seal faces.

The production is obtained by sinterization in vacuum atmosphere, then machining by grounding. A very low level of porosity makes it an ideal material for seal faces. The typical mating material is resin or antimony impregnated graphite but, when operating with highly abrasive products, it is common practice to install a counterface in Tungsten Carbide or Silicon Carbide, taking care to always provide efficient lubrication.

**Silicon carbide**

This material is produced by the sinterization of powders of silicon carbide, and, in some cases, with the addition of pure Silicon.

Depending on the method of production two different types of Silicon carbide are available on the market.
Sinthered alpha (SiC)

It does not contain free Silicon and it shows a high chemical resistance, even against caustic solutions and oxidating acids.

Reaction bonded (SiSiC)

It contains free Silicon.

The mechanical properties are better than the ones of SiC but the chemical resistance is lower. Friction coefficient is the best among hard materials. Not recommended for alkaline solutions where Sic is the primary selection and Tungsten Carbide the alternative material. Silicon carbide usually mates resin impregnated with graphite or antimony (at high temperature). The relatively low friction coefficient makes it suitable for mating with parent material.

**TAB. I - FLUITEN code seal face materials**

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th>Constructive shape</th>
<th>Fluiten code</th>
</tr>
</thead>
<tbody>
<tr>
<td>METALS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AISI 316 + stellite</td>
<td>Massive</td>
<td>S</td>
</tr>
<tr>
<td>Cast chrome - molybdenum steel</td>
<td>Massive</td>
<td>Y1</td>
</tr>
<tr>
<td>CARBIDES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silicon carbide infiltrated</td>
<td>Massive</td>
<td>U41</td>
</tr>
<tr>
<td>Silicon carbide infiltrated</td>
<td>Insert</td>
<td>U42</td>
</tr>
<tr>
<td>Silicon carbide sinterized</td>
<td>Massive</td>
<td>U31</td>
</tr>
<tr>
<td>Silicon carbide sinterized</td>
<td>Insert</td>
<td>U32</td>
</tr>
<tr>
<td>Tungsten carbide - nickel binder</td>
<td>Massive</td>
<td>K21</td>
</tr>
<tr>
<td>Tungsten carbide - nickel binder</td>
<td>Insert</td>
<td>K22</td>
</tr>
<tr>
<td>METALLIC OXIDES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceramic</td>
<td>Massive</td>
<td>C</td>
</tr>
<tr>
<td>GRAPHITES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graphite antimony impregnated</td>
<td>Massive</td>
<td>Z11</td>
</tr>
<tr>
<td>Graphite antimony impregnated</td>
<td>Insert</td>
<td>Z12</td>
</tr>
<tr>
<td>Graphite resins impregnated</td>
<td>Massive</td>
<td>Z31</td>
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<tr>
<td>Graphite resins impregnated</td>
<td>Insert</td>
<td>Z32</td>
</tr>
<tr>
<td>Graphite resins impregnated - dry-running</td>
<td>Massive</td>
<td>ZD71</td>
</tr>
<tr>
<td>Graphite resins impregnated - dry-running</td>
<td>Insert</td>
<td>ZD72</td>
</tr>
<tr>
<td>Graphite resins impregnated - dry-running - F.D.A. approved</td>
<td>Massive</td>
<td>ZD51</td>
</tr>
<tr>
<td>Graphite - food industrie - F.D.A. approved</td>
<td>Massive</td>
<td>Z51</td>
</tr>
<tr>
<td>Graphite - food industrie - F.D.A. approved</td>
<td>Insert</td>
<td>Z52</td>
</tr>
<tr>
<td>NON METALS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PTFE + glass</td>
<td>Massive</td>
<td>T1</td>
</tr>
<tr>
<td>PTFE + glass</td>
<td>Massive</td>
<td>T11</td>
</tr>
<tr>
<td>PTFE + glass</td>
<td>Insert</td>
<td>T12</td>
</tr>
<tr>
<td>MATERIAL</td>
<td>GRAPHITE</td>
<td>PTFE</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------</td>
<td>------</td>
</tr>
<tr>
<td>Lubricating properties</td>
<td>Good</td>
<td>Good</td>
</tr>
</tbody>
</table>
| Chemical resistance      | Good (1) | Very good | Sufficient | Very good (2) | Limited | Very good | Good (2) | 1) Some oxidizing products can generate unpredictable chemical reactions  
2) Unsuitable for basic environments (caustic)                                           |
| Resistance to high       | Good (1) | Poor (2) | Good     | Good, if constant (3) | Good       | Very good | Very good | 1) Up to 150°C Resin impregnated.  
2) Up to 350°C Metal impregnated.  
3) Up to 450°C Electrogaphite.  
3) Up to 250°C in static applications  
3) Up to 80°C when used as seal face  
3) Fragile with thermal shock. |
<p>| temperature              | Wear resistance (suitable to operate with abrasive or crystallizing products) | Poor | Poor | Limited | Good | Very good | Very good | Very good |
| Deformation at high      | YES      | YES  | NO       | NO      | NO               | NO            | NO                     | At high pressure monolithic seal rings are recommended |
| pressure                 | Suitable for food &amp; pharmaceutical applications | NO (1) | Si Se FDA approved | YES | YES | YES | 1) In some cases there is not an actual problem of contamination but release of graphite powder can change the color of the product |
| Thermal conductivity     | Poor     | Very poor | Poor | Poor | High | High | High |</p>
<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>RESIN IMPREGNATED GRAPHITE</th>
<th>ANTIMONY IMPREGNATED GRAPHITE</th>
<th>PTFE 25% GLASS REINFORCED</th>
<th>STELLITE (GRADE 1)</th>
<th>CERAMIC Al_2O_3 99.5%</th>
<th>TUNG. CARB. COBALT BINDER</th>
<th>TUNG. CARB. NICKEL BINDER</th>
<th>SILICON CARBIDE &quot;REACTION BONDED&quot; SSIC</th>
<th>SILICON CARBIDE &quot;SINTERED ALPHA&quot; SiC</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPECIFIC WEIGHT (Kg/m³)</td>
<td>1800</td>
<td>2500</td>
<td>2250</td>
<td>8690</td>
<td>3870</td>
<td>14700</td>
<td>14700</td>
<td>3100</td>
<td>3100</td>
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<tr>
<td>BENDING STRENGTH (N / mm²)</td>
<td>65</td>
<td>50</td>
<td>-</td>
<td>-</td>
<td>320</td>
<td>1750</td>
<td>1700</td>
<td>500</td>
<td>450</td>
</tr>
<tr>
<td>TENSILE STRENGTH (N / mm²)</td>
<td>41</td>
<td>48</td>
<td>12-20</td>
<td>610 (UTS)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>THERMAL CONDUCTIVITY (W / mK)</td>
<td>9</td>
<td>20</td>
<td>0.4</td>
<td>15</td>
<td>30</td>
<td>80</td>
<td>70</td>
<td>120</td>
<td>70</td>
</tr>
<tr>
<td>HARDNESS</td>
<td>90-100 SHORE A</td>
<td>85-95 SHORE A</td>
<td>70-75 SHORE D</td>
<td>600 HV</td>
<td>1800 HV</td>
<td>155-1600 HV</td>
<td>1300-1500 HV</td>
<td>1200-2700 HV</td>
<td>2400 HV</td>
</tr>
<tr>
<td>THERMAL EXPANSION COEFFICIENT (x 10^-6/°K)</td>
<td>3.0</td>
<td>3.5</td>
<td>44-92</td>
<td>11.3</td>
<td>6.9</td>
<td>5.1</td>
<td>4.8</td>
<td>3.4</td>
<td>4.0</td>
</tr>
</tbody>
</table>

NOTE: Data here in specified are orientative. Materials manufacturers can supply more detailed and accurate data.
Secondary seal materials

Selection of secondary seals depends on process fluid and operating temperature. Chemical incompatibility can lead to swelling of the gaskets and subsequent failure of the mechanical seal.

Elastomers

Elastomers take their denomination from the excellent elastic memory they have. This is the reason why elastomers are the primary choice as secondary seals.

Their properties are: capacity to operate in a satisfactory way even when the mating surface is not accurately finished.

Capacity to tolerate small misalignments between the shaft and the rotary ring.

Capacity to absorb shaft vibrations.

Easy installation in any kind of seat or shaft, even with key or sharp corners.

The cost is generally low, with the exception of perfluoroelastomers (Kalrez or equivalent).

Main composites are:

**Nitrilic rubber**

*Composed* of acrylonitrile polymer and butadiene.

*Temperature range*: -40 a 100°C (120° max for a short time).

*Availability*: easy in all sizes.

*Chemical compatibility*: Very good with mineral oils.

Good with water, greases and aliphatic hydrocarbons.

Poor with concentrated acids, aromatic hydrocarbons, ketones.
**Fluoroelastomer**

**Composed** by copolymer of hexafluoropropylene (HFP) and vinylidene fluoride (VDF or VF2).

**Temperature range**: -20 to 200°C

**Availability**: easy in all sizes

**Chemical compatibility**: Very good with mineral oils and hydrocarbons
Good with most acids
Poor with hot water and steam
Very poor with concentrated alkaline solutions and ketons.

**Ethylene Propylene**

**Composed** of Co-polimer of ethylene e propylene

**Temperature range**: -55 to 150°C

**Availability**: easy in all sizes

**Chemical compatibility**: Very good with hot water, steam, acids, alkaline solutions, ketons, hydraulic fluids. Very poor with petrol based fluids which cause consistent swelling

**Perfluoroelastomers**

**Temperature range**: -12 to 260°C

**Availability**: not easy, depends on size

**Chemical compatibility**: Very good with most aggressive fluids. Excellent resistance to high temperature.

**Silicone**

**Temperature range**: -115 to 232°C

**Chemical compatibility**: medium

**Neoprene**

**Temperature range**: -20° to 90°C

**Chemical compatibility**: Very good with Freon
**Aflas**

**Temperature range**: -10° to 200°C  
**Chemical compatibility**: Very good with hot water and steam. Good with acids

**Non elastomeric materials**

For the most demanding applications elastomeric materials cannot give a satisfactory answer. Very high or very low temperatures, below 100°C and over 300°C, cannot be withstood by any kind of elastomer. PTFE for chemical compatibility and Grafoil for high and low temperature are the standard option in severe applications.

It is worth underlining that these materials require a more accurate and specific design.

Mating surfaces must be finished within Ra 0.4 - 0.2.

No misalignments are allowed.

Grafoil can work only as a static seal.

**PTFE (Polytetrafluoroethylene)**

**Temperature range**: -180° to 250°C  
**Availability**: easy in all shapes and sizes  
**Chemical compatibility**: Excellent with any kind of product. The only disadvantage of PTFE is a non-elastomeric behaviour which makes it not suitable for dynamic applications. To overcome this great limitation, Fluiten has developed a special gasket, Fluigam, which can be employed in dynamic applications. The operating principle of Fluigam is simple; since PTFE does not have good elastic properties, a spring-shaped stainless steel core is built in, lending the required elasticity to the gasket. Fluigam is generally used as dynamic gasket for a rotary ring. Another way to enrich the elasticity of PTFE is to insert an elastomeric gasket inside a PTFE gasket that is, in a more realistic way, to coat an elastomeric gasket, usually of Viton or Silicon with a PTFE layer.
FEP (Fluoruro of ethylene e propylene)

Actually, a specific material called FEP (having characteristics similar to PTFE), is used for the coating. FEP is slightly porous and this has to be considered during selection. Very aggressive products can penetrate the coating and attack the elastomeric gasket inside. Availability of FEP coated gasket is limited.

Grafoil and asbestos free

Grafoil is generally used for temperatures over 300°C and up to 500°C.

Since graphite has in practice no elasticity, any dynamic application is almost impossible.

In the past, when the choice between gasket materials was limited, graphite wedges were used with good results but nowadays such an application does not make any sense.

Asbestos free gaskets are generally suitable for all static applications.

---

**TAB. IV - FLUITEN code secondary seals**

<table>
<thead>
<tr>
<th>MATERIALE</th>
<th>Codice FLUITEN</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ELASTOMERI</strong></td>
<td></td>
</tr>
<tr>
<td>Etilene propilene</td>
<td>D</td>
</tr>
<tr>
<td>Gomma al silicone</td>
<td>O</td>
</tr>
<tr>
<td>Gomma al silicone rivestito FEP</td>
<td>O2</td>
</tr>
<tr>
<td>Gomma Nitrile</td>
<td>G</td>
</tr>
<tr>
<td>Neoprene</td>
<td>N</td>
</tr>
<tr>
<td>Perfluoroelastomero</td>
<td>G711</td>
</tr>
<tr>
<td>Perfluoroelastomero</td>
<td>G741</td>
</tr>
<tr>
<td>Perfluoroelastomero</td>
<td>G771</td>
</tr>
<tr>
<td>Tetrafluoroetilene e propilene - Aflas</td>
<td>G4</td>
</tr>
<tr>
<td>Viton</td>
<td>V</td>
</tr>
<tr>
<td>Viton rivestito FEP</td>
<td>V2</td>
</tr>
<tr>
<td><strong>NON ELASTOMERI</strong></td>
<td></td>
</tr>
<tr>
<td>ASBESTOS FREE universale</td>
<td>A</td>
</tr>
<tr>
<td>Grafoil</td>
<td>G5</td>
</tr>
<tr>
<td>PTFE</td>
<td>T</td>
</tr>
<tr>
<td>PTFE + molla in AISI 316</td>
<td>T3</td>
</tr>
</tbody>
</table>
Metallic parts

Ancillary parts of a mechanical seal such as body, springs, sleeves, and flanges are, as a standard option, made of AISI 316.

For aggressive products there are valid alternatives such as Hastelloy, Titanium or Monel.

Many other less diffuse materials are available on the market for specific applications.

**TAB. V - FLUITEN code metallic parts**

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>Fluiten code</th>
</tr>
</thead>
<tbody>
<tr>
<td>AISI 301</td>
<td>J</td>
</tr>
<tr>
<td>AISI 304</td>
<td>Q</td>
</tr>
<tr>
<td>AISI 316</td>
<td>E</td>
</tr>
<tr>
<td>AISI 904L</td>
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<tr>
<td>Duplex (SAF 2205)</td>
<td>E3</td>
</tr>
<tr>
<td>Duplex (SAF 2507)</td>
<td>E9</td>
</tr>
<tr>
<td>Hastelloy B2</td>
<td>H</td>
</tr>
<tr>
<td>Hastelloy B3</td>
<td>H3</td>
</tr>
<tr>
<td>Hastelloy C22</td>
<td>I2</td>
</tr>
<tr>
<td>Hastelloy C276</td>
<td>I</td>
</tr>
<tr>
<td>Inconel 718</td>
<td>I3</td>
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<tr>
<td>Monel 400</td>
<td>M</td>
</tr>
<tr>
<td>PVDF</td>
<td>T5</td>
</tr>
<tr>
<td>Titanium</td>
<td>L</td>
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<tr>
<td>Hast. C (Bellow) + Carpenter 20</td>
<td>xE</td>
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<td>AM350 (Bellow) + AISI 316</td>
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<tr>
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</tr>
<tr>
<td>Hast. C (Bellow) + AISI 316</td>
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<tr>
<td>AM350 (Bellow) + AISI 316 + Carpenter 42</td>
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<tr>
<td>Inconel 718 HT (Bellow) + Carpenter 42 + AISI 316</td>
<td>xL</td>
</tr>
<tr>
<td>Carpenter 20 (Bellow) + Carpenter 20</td>
<td>xZ</td>
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</tbody>
</table>