Diaphragm seals and diaphragm seal systems
Application - Functionality - Design

Definition

Diaphragm seals are used for pressure measurements when the process medium should not come into contact with the pressurised parts of the measuring instrument.
A diaphragm seal has two primary tasks:
1. Separation of the measuring instrument from the process medium
2. Transfer of the pressure to the measuring instrument

Functionality of a diaphragm seal

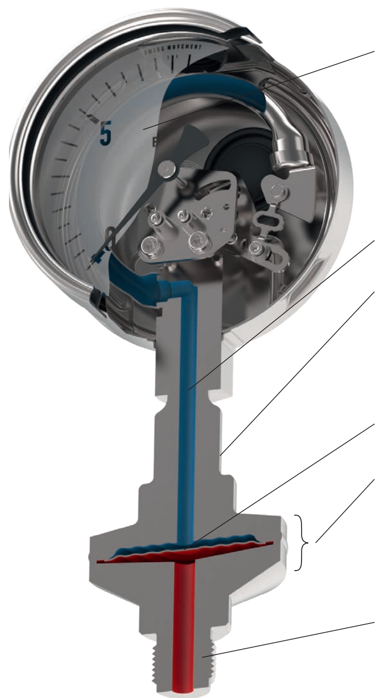
The functionality of a diaphragm seal is illustrated in the figure on the right.

Principle
The process side of the seal is isolated by a flexible diaphragm. The internal space between this diaphragm and the pressure measuring instrument is completely filled with a system fill fluid. The process pressure is transmitted by the elastic diaphragm into the fluid and from there to the measuring element of the pressure measuring instrument.

In many cases, between the diaphragm seal and pressure measuring instrument, a capillary is connected in order (for example) to eliminate or to minimise temperature effects from the hot fluid to the measuring instrument. The capillary affects the response time of the overall system.

Diaphragm seal, capillary and measuring instrument form a closed system. The sealed filling screws on the diaphragm seal and the measuring instrument must therefore never be opened, since the function of the system is affected following any escape of fill fluid!

The diaphragm and the process connection are the elements of the system which come into contact with the medium. Therefore, the material from which they are made must meet the relevant requirements in terms of temperature and corrosion resistance.



Installation example of a diaphragm seal system

If the diaphragm is leaking, the system fill fluid can enter the medium. For applications in the food industry, it must be approved for contact with food. In selecting the fill fluid, the factors of compatibility, temperature and pressure conditions in the medium are of crucial importance. Customer-specific solutions can be realised for the different operating conditions of the applications.
Diaphragm seal systems are capable of withstanding extreme temperatures of -130 ... +450 °C [-202 ... + 842 °F] and pressures of 35 mbar ... 3,600 bar [0.5 ... 52,200 psi].

Fields of application

The use of diaphragm seals enables the user to employ a large number of pressure measuring instruments for the most difficult process conditions.

Examples

- The medium is corrosive and the pressure measuring instrument itself (e.g. the interior of a Bourdon tube) cannot be sufficiently protected against it.
- The medium is highly viscous and fibrous, thus causing measuring problems due to dead spaces and constrictions in the bores of the pressure measuring instrument (pressure ports, Bourdon tubes).
- The medium has a tendency towards crystallisation or polymerisation.
- The medium has a very high temperature. As a result, the pressure measuring instrument is strongly heated. This heating leads to a large temperature error in the measurement on the pressure measuring instrument. The increased temperature can also lead to the upper limits for the thermal loading of the measuring instrument components being exceeded.
- The measuring location is not favourably located. For reasons of space, the pressure measuring instrument can either not be mounted or cannot be read or can only be read with difficulty. By installing a diaphragm seal and using a longer capillary, the pressure measuring instrument can be installed in a location where it can be easily viewed.
- In the manufacture of the product, and in the production plant, hygienic requirements must be followed. For this reason, dead spaces and undercuts in the wetted parts must be avoided.
- The medium is toxic or harmful to the environment. It cannot be allowed to escape into the atmosphere or environment through leakage. On the grounds of safety and environmental protection, the appropriate protective measures must therefore be taken.

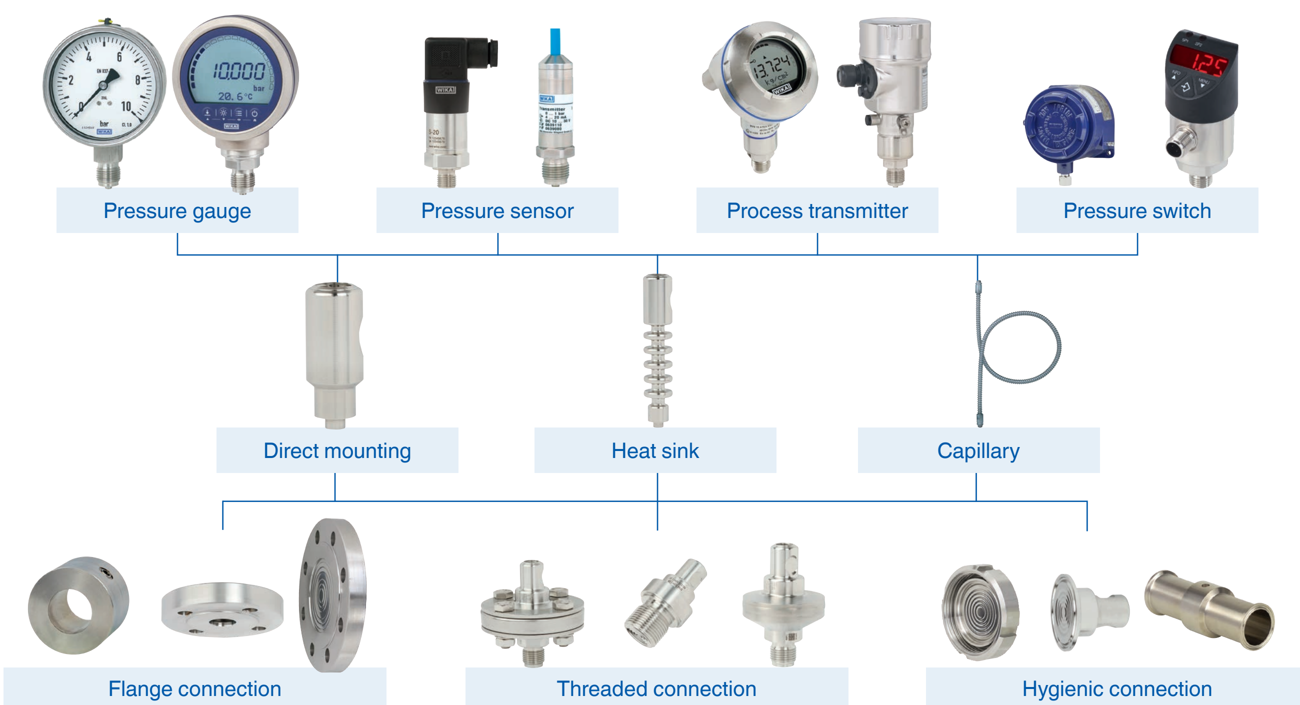
Thanks to its many years of experience, WIKA is able to turn challenging tasks into solutions with a technological edge.

Advantages from using diaphragm seals

- Long service life of the measuring assembly
- Reduced installation effort
- Elimination of maintenance

Combinations for diaphragm seal systems

A diaphragm seal system is defined with the pressure measuring instrument, the mounting type and the diaphragm seal with process connection.
The optimal diaphragm seal designs, materials, system fill fluids and accessories are available for each application.



Mounting types

The required mounting type for pressure measuring instruments with diaphragm seals depends, among other things, on the operating conditions of the diaphragm seal system. The choice is between direct mounting, flexible capillary or heat sink. This makes the diaphragm seal system adaptable to customer-specific conditions. When selecting the mounting type, influences on the measuring capability of the diaphragm seal system must be taken into account. Mounting via a capillary or a heat sink results in a longer response time than direct mounting, for example.

Direct mounting
Direct mounting is achieved by welding the measuring instrument directly to the diaphragm seal via a connection adapter.

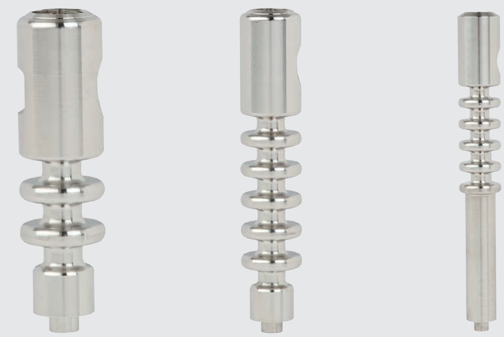
Direct mounting via axial connection adapter

Capillary
The capillary is a flexible connecting piece between the measuring instrument and the diaphragm seal, which typically consists of a tube, a capillary protection hose and, optionally, a further jacket. Capillaries are used where the process media are at high temperatures, as these are cooled down through the connecting line. Furthermore, this mounting type is suitable for decoupling strong vibrations, or if the measuring instrument cannot be mounted at the measuring location or is easier to read at another location.

Capillary (example)

Heat sink
With hot media, the heat sink ensures that the system fill fluid cools down sufficiently to guarantee precise measurement.

Heat sink (examples)



Process connection and design

Diaphragm seal systems are used in demanding applications in a wide range of industries. The optimal process connections and designs are available for each application.

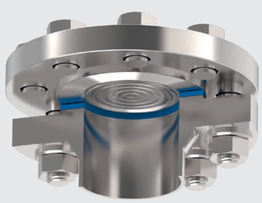
The decision for the right diaphragm seal depends on both the specifications as well as the installation options and requirements of each specific measuring task.

Classification of the process connections
- Flange connection
- Threaded connection
- Hygienic connection

Flange connection

Diaphragm seals with flange connection can be used for processes with aggressive, adhesive, corrosive, highly viscous, environmentally hazardous or toxic media. Diaphragm seals with flange connections are available with dimensions for all common standard flanges. The sealing face is flush and the diaphragm is designed to be either flush or internal.

Flush diaphragm



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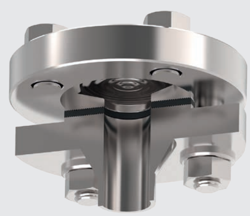
Internal diaphragm



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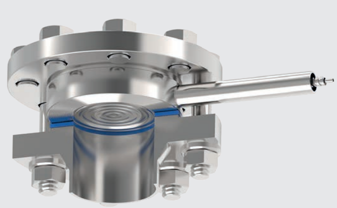
Cell-type
The cell-type is a specific variant of diaphragm seal with flange connection. It consists of a cylindrical plate, whose diameter is matched to the sealing face area of corresponding standard flanges. The diaphragm is flush and matched to the nominal width.
A blind flange is used to mount the cell-type, available for all common flange standards.

Cell-type



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Extended-diaphragm version
Diaphragm seals with extended diaphragm are used, among other things, on thick-walled and/or insulated product lines, vessel walls, etc. The version with extended diaphragm is available for flange- and cell-type designs.

Extended-diaphragm version

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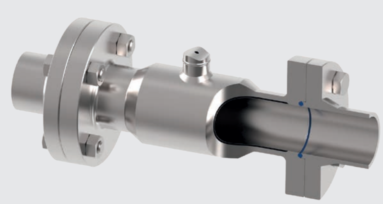
In-line diaphragm seal with flange connection
These diaphragm seals are exceptionally suitable for the measurement of flowing media. The in-line diaphragm seal is clamped directly into the pipeline using flanges at both ends. This integration into the process line prevents disturbing turbulences, as this design has no corners, dead spaces or other obstructions in the flow direction. Different nominal widths allow the in-line diaphragm seals to be adapted to any pipeline cross-section. The in-line diaphragm seals are also available in a cell-type design.

In-line diaphragm seal with flange connection



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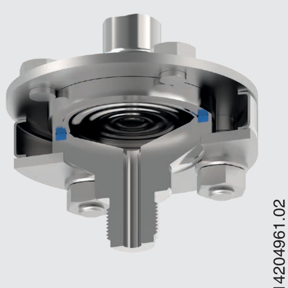
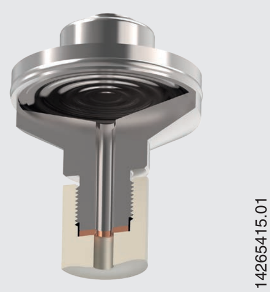
Threaded connection

Diaphragm seals with threaded connection can be used for processes with aggressive, adhesive, corrosive, highly viscous, environmentally hazardous or toxic media. The connection of the upper and lower bodies of the diaphragm seal is available in either a threaded or a welded design. These diaphragm seals are available with female or male thread in their basic design. The wide variety of available process connections enables many different adaptations without any problems. The material of the upper body of the diaphragm seal and the lower body of the diaphragm seal can be the same or be different.

Threaded design



Welded design



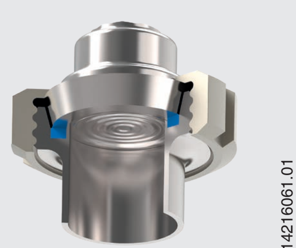
Hygienic connection

Diaphragm seals in hygienic design can be used for processes with gases, compressed air or vapour and also with liquid, pasty, powdery and crystallising media. The diaphragm seals resist the temperatures that occur and meet the requirements for sterile connections. The flush diaphragm can be integrated hygienically into all applications thanks to the various process connections.

SIP and CIP criteria, which are an essential requirement for sanitary applications, are met by using WIKA diaphragm seals.

Clamp connection

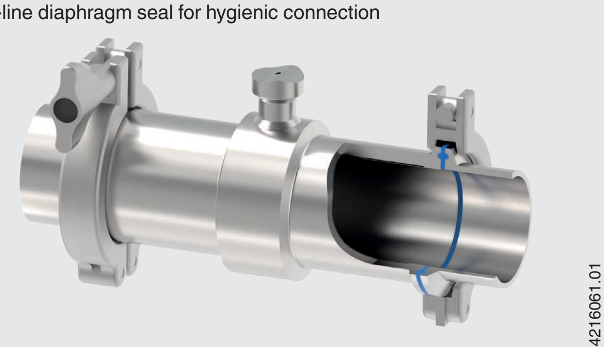
Grooved union nut



In-line diaphragm seal for hygienic connection

The in-line diaphragm seal is perfectly suited for use with flowing media. With the seal being completely integrated into the process line, measurements do not cause any disturbing turbulences, corners, dead spaces or other obstructions in the flow direction. The in-line diaphragm seal is clamped directly into the pipeline. With in-line diaphragm seals, the medium flows through unhindered and effects the self-cleaning of the measuring chamber. Different nominal widths allow the in-line diaphragm seals to be adapted to any pipeline cross-section.

In-line diaphragm seal for hygienic connection



Materials and coatings

The predominant material for diaphragm seals is stainless steel 316L. For the wetted parts, a wide range of special materials and coatings are available for specific areas of application. WIKA offers this variety of different materials in order to be able to find the best possible solution for the demands of the measuring location.

The material selection for diaphragm seals is strongly dependent upon the operating conditions. In addition to the pressure load, the requirements for the temperature and also the resistance against the medium must be known. Then the material selection for the diaphragm seal can be made. The selection can be designed with different materials for the base body, the sealing face and the diaphragm, as these are not equally wetted in every design.

Material combinations and coatings
Especially when using special materials, high costs and long delivery times can occur.
Such circumstance can be resolved by intelligent selection of material combinations or coatings. A cost-effective base material is used for the load-bearing parts, for example, and only the wetted parts are made of a special material or have a coating. The joining and connection technology play an important role here, as different materials cannot always be welded. Regardless of the type of connection technology, these diaphragm seals can withstand extreme operating conditions.

Material	Unified numbering system (UNS)
Stainless steel 316L (1.4404 or 1.4435)	S31603
Stainless steel 904L (1.4539)	N08904
Stainless steel 321 (1.4541)	S32100
Stainless steel 316Ti (1.4571)	S31635
Stainless steel 1.4466 (urea grade)	S31050
Duplex 2205 (1.4462)	S31803
Superduplex 1.4410	S32750
Tantalum (also lining)	R05200
Hastelloy C276 (2.4819)	N01276
Hastelloy C22 (2.4602)	N06022
Inconel 600 (2.4816)	N06600
Incoloy 825 (2.4858)	N08825
Inconel 625 (2.485)	N06625
Monel 400 (2.4360)	N04400
Nickel 200 (2.4066)	N02200
Nickel 201 (2.4068)	N02201
Titanium 3.7035 (class 2)	R50400
Titanium 3.7235 (class 7)	R52400
Zirconium GR702	R60702

The maximum permissible process temperature is limited by the joining method and the system fill fluid. The maximum process temperature can be found in the data sheet for the diaphragm seal.

Coatings
Stainless steel with ECTFE coating
Stainless steel with PFA (FDA; 21 CFR 177.1550 and 21 CFR 177.2440)
Stainless steel with PFA, anti-static (suitable for Ex applications)
Stainless steel with gold plating
Stainless steel with gold-rhodium
Stainless steel with Wikaramic®

System fill fluids

When selecting the system fill fluid for diaphragm seals, factors such as medium compatibility as well as temperature and pressure conditions at the measuring location are of critical importance in order to avoid endangering the process. Depending on the system fill fluid, the appropriate minimum and maximum operating temperature range must be observed. In addition, the change in volume of the system fill fluid at extreme application temperatures must be taken into account.

Highly flammable applications, such as oxygen and chlorine applications, and the high demands within both sanitary applications and the semiconductor industry are also crucial in choosing the right fluid.

The properties of the system fill fluids affect the permissible operating temperature of the diaphragm seal system. Since the parameters of the individual system fill fluids vary, WIKA offers a wide range to cover different applications.

FDA approval

The FDA ("Food and Drug Administration") is a US authority under the Department of Health. It is responsible for the monitoring of foodstuffs and pharmaceuticals and serves to protect public health in the United States.
Liquids that could find their way into the end product in the event of a failure must be FDA-compliant.

Designation	Identification number	Solidification point	Boiling/ degradation point	Density at 25 °C	Kin. Viscosity at 25 °C	Remark
	KN	°C	°C	g/cm³	cSt	
Silicone oil	2	-45	+300	0.96	54.5	Universal application
Glycerine	7	-35	+240	1.26	759.6	FDA 21 CFR 182.1320
Silicone oil	17	-90	+200	0.92	4.4	Low temperatures
Halocarbon	21	-60	+175	1.89	10.6	Oxygen [1] and chlorine
Methylcyclopentane	30	-130	+60	0.74	0.7	For very low temperatures
High-temperature silicone oil	32	-25	+400	1.06	47.1	For high temperatures
Neobee® M-20	59	-35	+260	0.92	10.0	FDA 21 CFR 172.856, 21 CFR 174.5
DI water	64	+4	+85	1.00	0.9	For ultrapure media
Silicone oil	68	-75	+250	0.93	10.3	
DI water/propanol mixture	75	-30	+60	0.92	3.6	For ultrapure media
Medicinal white mineral oil	92	-15	+260	0.85	45.3	FDA 21 CFR 172.878, 21 CFR 178.3620(a); USP, EP, SP

Other system fill fluids on request

Note:

- The stated lower temperature limit is a purely physical characteristic of the system fill fluid. The resulting response time has to be calculated and evaluated separately.
- The upper temperature limit for a diaphragm seal system is further restricted by the operating pressure and the diaphragm. To determine the upper temperature limit for the individual diaphragm seal system, a calculation is required.

1) For oxygen applications the following values per BAM test (Federal Institute for Materials Research and Testing) apply:

Maximum temperature	Maximum oxygen pressure
to 60 °C	50 bar
> 60 °C to 100 °C	30 bar
> 100 °C to 175 °C	25 bar

Influencing factors on the measurement

Response time

A combination of the individual components generally causes a delay in the output of the measured value. This delay is referred to as the response time and varies depending on the assembly.
Factors such as the control volume of the measuring instrument as well as the capillary length and its associated cross-section are included in the calculation. It can therefore be concluded that the response time increases with a large control volume or a long capillary. This effect can be counteracted by selecting a measuring instrument with a smaller control volume, a shorter capillary or a capillary with a larger cross-section.

In addition to the geometric variables of the diaphragm seal system, the viscosity of the fill fluid, among other things, must also be taken into account. The higher the viscosity value, the more viscous the medium. An optimisation of the response time can thus be realised through the selection of a fill fluid with a lower viscosity.
Furthermore, the temperatures applied influence the physical properties of the system fill fluid. If the temperature increases, then the medium becomes less viscous and the response time shortens. Conversely, the response time of the measuring instrument increases as the temperature drops due to the increasing viscosity.

Temperature effect

Diaphragm seal systems are generally filled at room temperature. If there are now temperature changes in the environment or in the process, these have a negative effect on the output values of the measuring instrument. The reason is due to the change in the physical properties of the system fill fluid. If the measuring system experiences an increase in temperature, there is an increase in volume which leads to a deflection of the diaphragm in the direction of the process. The restoring force of the diaphragm simultaneously ensures a positive zero point offset on the measuring instrument.

To counteract this error, large diaphragm diameters should be chosen due to their low rigidity. Other factors that counteract the zero point offset are a lower dead volume of the entire system and a lower thermal expansion coefficient of the fill fluid.

The opposite effect is seen when the temperature drops. The decrease in volume now causes the diaphragm to deflect in the direction of the diaphragm bed. The temperature reduction causes a negative zero point offset due to the restoring force of the diaphragm.

Height difference

Any height difference between the pressure measuring instrument and the diaphragm seal (this applies especially when using capillaries) affects the measurement. This is due to the hydrostatic pressure of the liquid column in the capillary. The display is reduced when the pressure measuring instrument is positioned higher than the diaphragm seal.
It is increased when the pressure measuring instrument is positioned lower. This height difference must be known when designing the entire system at the factory so that it can be taken into account accordingly.

Note: After mounting, a zero point test and, if necessary, a zero point correction is recommended.

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