"Analysis of the requirements of all seals on a household dishwasher and design of a test bench to verify the seals"

Borja Pérez de Ciriza García

Index

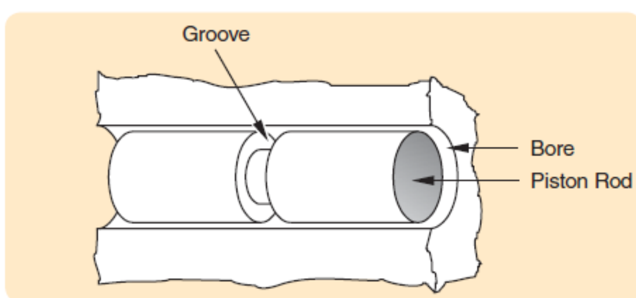
1. Introduction to O-Rings and seals

1.1 What is an O-Ring?

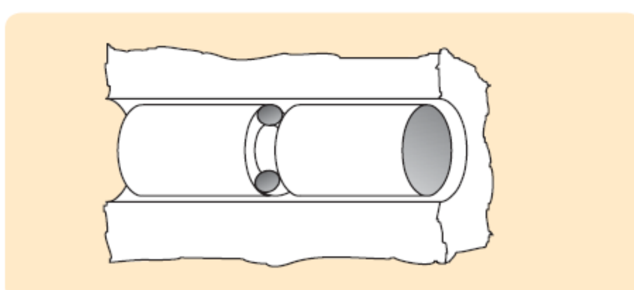
An O-ring is a torus, or doughnut-shaped ring, generally molded from an elastomer, although O-rings are also made from PTFE and other thermoplastic materials, as well as metals, both hollow and solid. O-rings are used primarily for sealing...” O-rings are also used as light-duty, mechanical drive belts.

1.2 What is an O-Ring Seal?

An O-ring seal is used to prevent the loss of a fluid or gas. The seal assembly consists of an elastomer O-ring and a gland. An O-ring is a circular cross-section ring molded from rubber. The gland usually cut into metal or another rigid material contains and supports the O-ring. The combination of these two elements; O-ring and gland constitute the classic O-ring seal assembly.



Basic Gland



Gland and O-Ring Seal

Types of Squeeze:

As shown, o-ring squeeze may occur in two possible ways:

1. Axial Squeeze "A": Where the squeeze occurs on both the top and bottom surfaces of the o-ring.

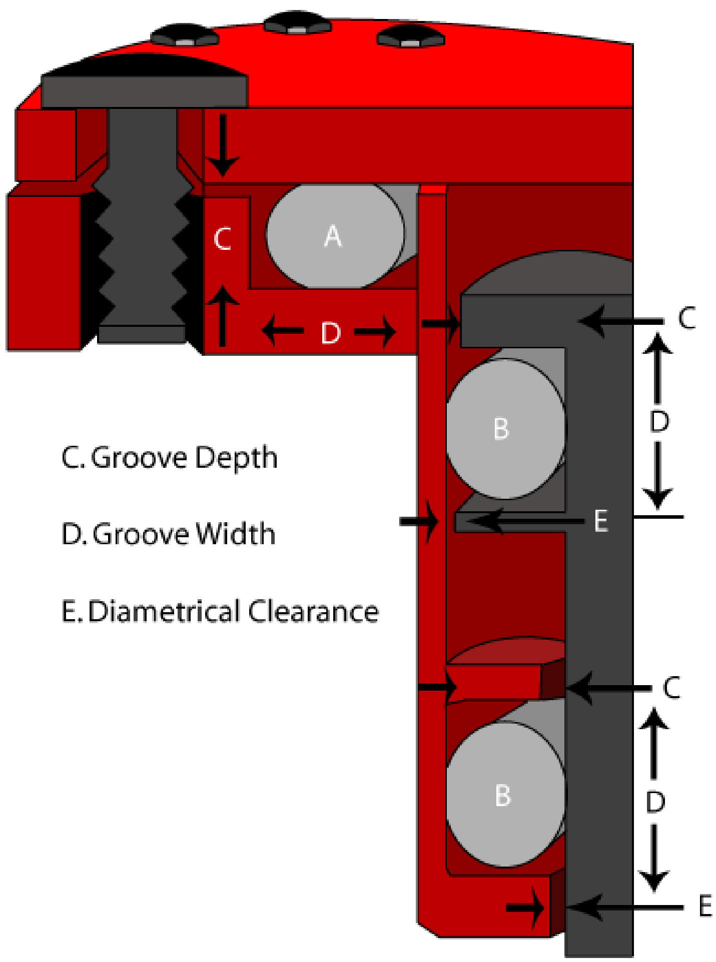
2. Radial Squeeze "B": Where the squeeze occurs on the inner and outer surfaces of the o-ring.

Basic Applications

Two basic o-ring applications:

1. Static Applications "A": O-ring is contained within two non-moving parts.

2. Dynamic Applications "B": O-ring is contained within moving gland walls.



1.3 Advantages of O-Rings

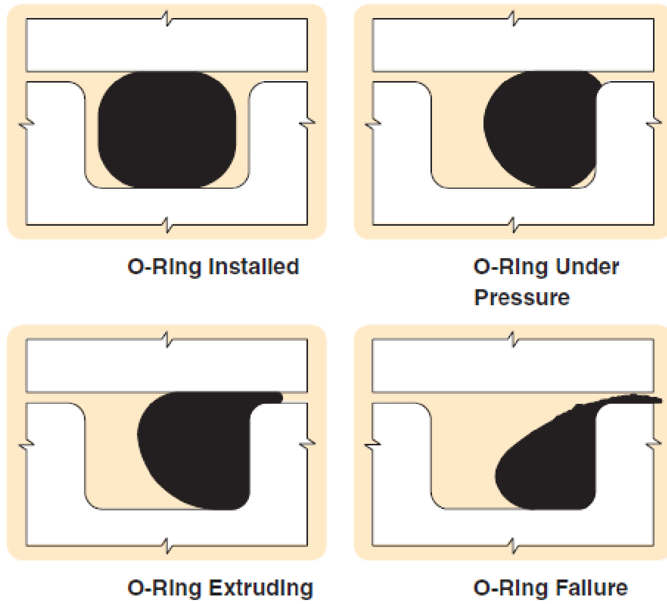
• They seal over a wide range of pressure, temperature and tolerance.
• Ease of service, no smearing or retightening.
• No critical torque on tightening, therefore unlikely to cause structural damage.
• O-rings normally require very little room and are light in weight.
• In many cases an O-ring can be reused, an advantage over non-elastic flat seals and crush-type gaskets.
• The duration of life in the correct application corresponds to the normal aging period of the O-ring material.
• O-ring failure is normally gradual and easily identified.
• Where differing amounts of compression effect the seal function (as with flat gaskets), an O-ring is not affected because metal to metal contact is generally allowed for.
• They are cost-effective.

1.4 Operation

All robust seals are characterized by the absence of any pathway by which fluid or gas might escape. Detail differences exist in the manner by which zero clearance is obtained

— Welding, brazing, soldering, ground fits or lapped finishes
— Or the yielding of a softer material wholly or partially confined between two harder and stiffer members of the assembly. The O-ring seal falls in the latter class.

The rubber seal should be considered as essentially an incompressible, viscous fluid having a very high surface tension. Whether by mechanical pressure from the surrounding structure or by pressure transmitted through hydraulic fluid, this extremely viscous fluid is forced to flow within the gland to produce “zero clearance” or block to the flow of the less viscous fluid being sealed. The rubber absorbs the stack-up of tolerances of the unit and its internal memory maintains the sealed condition. The first figure illustrates the O-ring as installed, before the application of pressure. Note that the O-ring is mechanically squeezed out of round between the outer and inner members to close the fluid passage. The seal material under mechanical pressure extrudes into the microfine grooves of the gland. The second figure illustrates the application of fluid pressure on the O-ring. Note that the O-ring has been forced to flow up to, but not into, the narrow *gap* between the mating surfaces and in so doing, has gained greater area and force of sealing contact. The third figure shows the O-ring at its pressure limit with a small portion of the seal material entering the narrow gap between inner and outer members of the gland. The last figure illustrates the result of further increasing pressure and the resulting extrusion failure. The surface tension of the elastomer is no longer sufficient to resist flow and the material extrudes (flows) into the open passage or clearance gap.



1.5 O-Ring Characteristics

A very early and historically prominent user of O-rings cites a number of characteristics of O-ring seals which are still of interest to seal designers. Extracts of the more general characteristics are listed as follows:

A. The seals can be made perfectly leak-proof for cases of static pistons and cylinders for fluid pressures up to 5000 psi. (Limit of test pressure). The pressure may be constant or variable.

B. The seals can be made to seal satisfactorily between reciprocating pistons and cylinders at any fluid pressure up to 5000 psi. There may be slight running leakage (a few drops per hundred strokes) depending on the filmforming ability of the hydraulic medium. O-rings can be used between rotating members with similar results but in all cases the surface rubbing speed must be kept low.

C. A single O-ring will seal with pressure applied alternately on one side and then on the other, but in cases of severe loading or usage under necessarily unfavorable conditions, seal life can be extended by designing the mechanism so that each seal is subjected to pressure in one direction only. Seals may be arranged in series as a safety measure but the first seal exposed to pressure will take the full load.

D. O-ring seals must be radially compressed between the bottom of the seal groove and the cylinder wall for proper sealing action. This compression may cause the seal to roll slightly in its groove under certain conditions of piston motion, but the rolling action is not necessary for normal operation of the seals.

E. In either static or dynamic O-ring seals under high pressure the primary cause of seal failure is extrusion of the seal material into the piston-cylinder clearance. The major factors effecting extrusion are fluid pressure, seal hardness and strength, and piston-cylinder clearance.

F. Dynamic seals may fail by abrasion against the cylinder or piston walls. Therefore, the contacting surfaces should be polished for long seal life. Moving seals that pass over ports or surface irregularities while under hydraulic pressure are very quickly cut or worn to failure.

G. The shape of the seal groove is unimportant as long as it results in proper compression of the seal between the bottom of the groove and the cylinder wall, and provides room for the compressed material to flow so that the seal is not solidly confined between metal surfaces.

H. The seal may be housed in a groove cut in the cylinder wall instead of on the piston surface without any change in design limitations or seal performance.

I. Friction of moving O-ring seals depends primarily on seal compression, fluid pressure, and projected seal area exposed to pressure. The effects of materials, surfaces, fluids, and speeds of motion are normally of secondary importance, although these variables have not been completely investigated. Friction of O-ring seals under low pressures may exceed the friction of properly designed lip type seals, but at higher pressures, developed friction compares favorably with, and is often less than, the friction of equivalent lip type seals.

J. The effects of temperature changes from +18°C to +121°C (-65°F to +250°F) on the performance of O-ring seals depends upon the seal material used. Synthetic rubber can be made for continual use at high or low temperatures, or for occasional short exposure to wide variations in temperature. At extremely low temperature the seals may become brittle but will resume their normal flexibility without harm when warmed. Prolonged exposure to excessive heat causes permanent hardening and usually destroys the usefulness of the seal. The coefficient of thermal expansion of synthetic rubber is usually low enough so that temperature changes present no design difficulties. (Note: This may not be true for all elastomer compounds, especially FFKM.)

K. Chemical interaction between the seal and the hydraulic medium may influence seal life favorably or unfavorably, depending upon the combination of seal material and fluid. Excessive hardening, softening, swelling, and shrinkage must be avoided.

L. O-ring seals are extremely dependable because of their simplicity and ruggedness. Static seals will seal at high pressure in spite of slightly irregular sealing surfaces and slight cuts or chips in the seals. Even when broken or worn excessively, seals may offer some measure of flow restriction for emergency operation and approaching failure becomes evident through gradual leakage.

M. The cost of O-ring seals and the machining expense necessary to incorporate them into hydraulic mechanism designs are at least as low as for any other reliable type of seal. O-ring seals may be stretched over large diameters for installation and no special assembly tools are necessary.

N. Irregular chambers can be sealed, both as fixed or moving- parts installations.

1.6 Limitations of O-Ring Use

Again citing Mr. D. R. Pearl's paper, limitations of O-ring use are given as:

"Although it has been stated that O-rings offer a reasonable approach to the ideal hydraulic seal, they should not be considered the immediate solution to all sealing problems. It has been brought out in the foregoing discussion that there are certain definite limitations on their use, i.e., high temperature, high rubbing speeds, cylinder ports over which seals must pass and large shaft clearances. Disregard for these limitations will result in poor seal performance. Piston rings, lip type seals, lapped fits, flat gaskets and pipe fittings all have their special places in hydraulic design, but where the design specifications permit the proper use of O-ring seals, they will be found to give long and dependable service."

While no claim is made that an O-ring will serve best in all conditions, the O-ring merits consideration for most seal applications except:

A. Rotary speeds exceeding 1500 feet per minute contact speed.

B. An environment completely incompatible with any elastomeric material.

C. Insufficient structure to support anything but a flat gasket.

Note: These points are general statements and there are, of course, numerous exceptions.

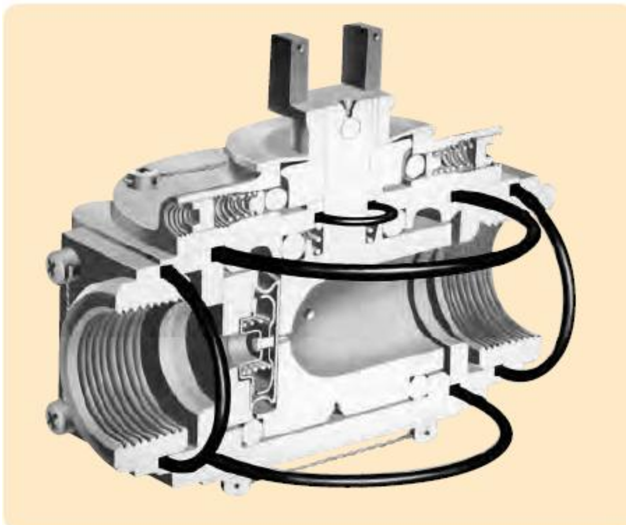
1.7 Scope of O-Ring Use

Further discussion is based on specific types of O-ring seals and special applications. These terms are common to the sealing industry.

1.7.1 Static Seals

In a truly static seal, the mating gland parts are not subject to relative movement (except for small thermal expansion or separation by fluid pressure), as contrasted from seals in which one of the gland parts has movement relative to the other. Examples of static seals are: a seal under a bolt head or rivet, a seal at a pipe or tubing connection, a seal under a cover plate, plug or similar arrangement or, in general, the equivalent of a flat gasket.

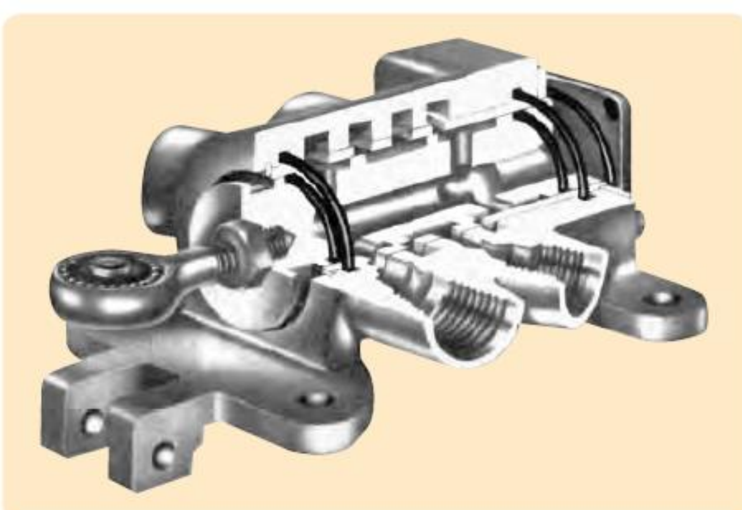
Note: True static seals are generally quite rare. Vibrational movement is present in virtually all static applications.



1.7.2 Reciprocating Seals

In a reciprocating seal, there is relative reciprocating motion (along the shaft axis) between the inner and outer elements. This motion tends to slide or roll the O-ring, or sealing surface at the O-ring, back and forth with the reciprocal motion. Examples of a reciprocating seal would be a piston in a cylinder, a plunger entering a chamber, and a hydraulic actuator with the piston rod anchored.

Note: O-ring seals are generally not recommended for reciprocating installations in which the speed is less than one foot per minute.

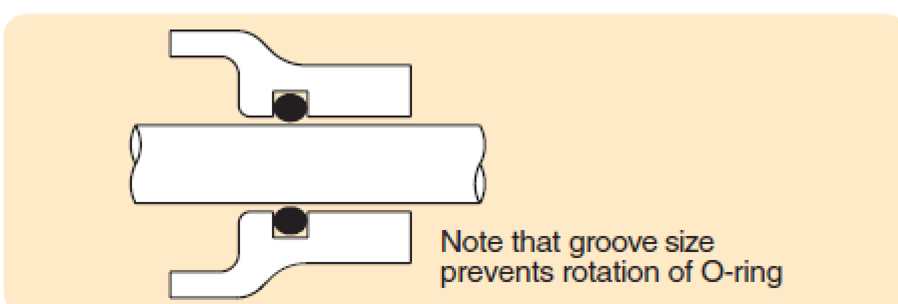


1.7.3 Oscillating Seals

In an oscillating seal, the inner or outer member of the seal assembly moves in an arc (around the shaft axis) relative to the other member. This motion tends to rotate one or the other member in relation to the O-ring. Where the arc of motion exceeds 360°, as in multiple turns to operate a valve handle, the return arc in the opposite direction distinguishes the oscillating seal from a rotary seal. Except for very special cases, any longitudinal motion (as caused by a spiral thread) involved in what is classed as an oscillating seal is not important. An example of an oscillating seal is an O-ring seal for a faucet valve stem.

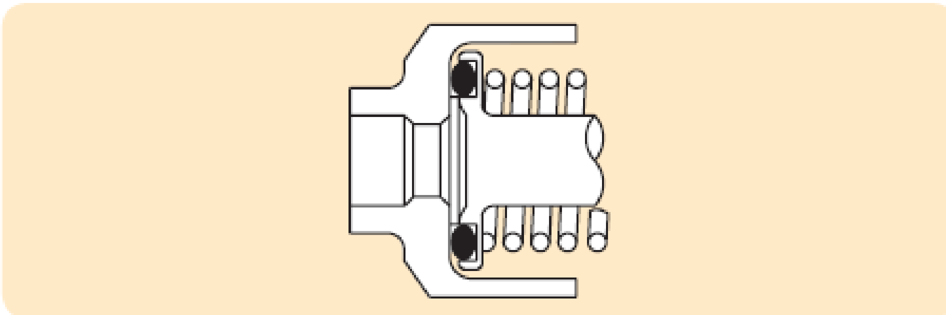
1.7.4 Rotary Seals

In a rotary seal, either the inner or outer member of the sealing elements turn (around the shaft axis) in one direction only. This applies when rotation is reversible, but does not allow for starting and stopping after brief arcs of motion, which is classed as an oscillating seal. Examples of a rotary seal include sealing a motor or engine shaft, or a wheel on a fixed axle.



1.7.5 Seat Seals

In a seat seal, the O-ring serves to close a flow passage as one of the contact members. The motion of closing the passage distorts the O-ring mechanically to create the seal, in contrast to conditions of sealing in previously defined types. A sub-classification is closure with impact as compared with non-impact closure. Examples of a seat-seal include O-ring as a "washer" on the face of a spiral threaded valve, a seal on the cone of a floating check valve, and a seal on the end of a solenoid plunger.



1.7.6 Pneumatic Seals

A pneumatic seal may be any of the previously described types of O-ring seals but is given a different classification because of the use of a gas or vapor rather than a liquid. This has a vital affect on the lubrication of the O-ring and thus influences all moving (or dynamic) seal installations. A further point is that pneumatic seals may be affected by the increase in gas temperature with compression. Note that the seal should be defined as "pneumatic-rotary" etc. for complete identification.

1.7.7 Vacuum Sealing

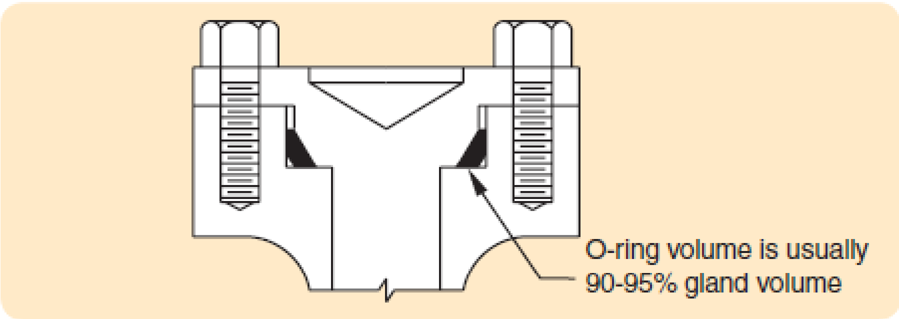
A vacuum seal confines or contains a vacuum environment or chamber. The vacuum seal may be any of the previously defined types (except a pneumatic seal) and as in the case of "pneumatic seals", both terms applicable to the seal should be given for complete identification. This classification is given primarily because, in most cases, the leakage tolerance is less than for pressure seals. In addition, the problem of pressure trapped between multiple O-rings, which increases the load on a single O-ring, does not apply. Multiple O-rings are useful in a vacuum seal to reduce permeation.

1.7.8 Cushion Installation

Such an application requires that the O-ring absorb the force of impact or shock by deformation of the ring. Thus, forcible, sudden contact between moving metal parts is prevented. It is essentially a mechanical device. An example is the use of an O-ring to prevent metal-to-metal bottoming of a piston in a cylinder. The O-ring must be properly held in place as otherwise it might shift and interfere with proper operation of the mechanism.

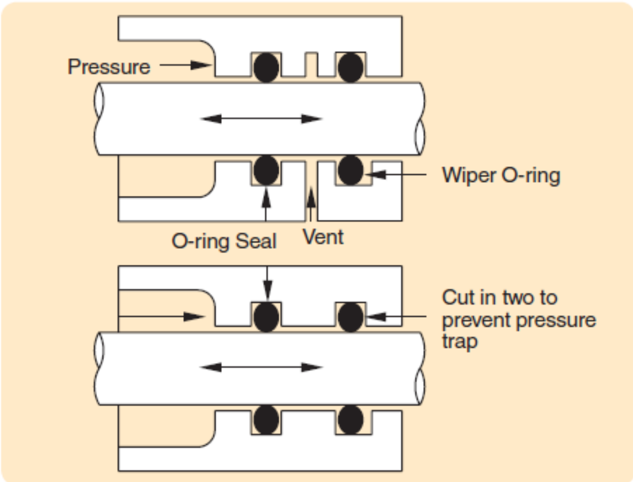
1.7.9 Crush Installation

This use of an O-ring is a variation of the static seal. The O-ring is crushed into a space having a cross-section different from that of a standard gland — for example, triangular. While it is an effective seal, the O-ring is permanently deformed and therefore generally considered non-reusable.



1.7.10 Rod Wiper Installation

In this case, the O-ring is used to keep a reciprocating shaft or rod clean to prevent damaging an O-ring seal located inboard from the wiper. The wiper O-ring does not necessarily seal. If there is a possibility of trapping liquid between the wiper and sealing O-rings, the space between the two must be vented. This installation is effective on actuating cylinders of machinery used in dirty, dusty areas.



1.8 Tolerances

Since O-rings can not be made exactly to their dimensions every time, manufactures are allowed to make them within range of their original dimensions. Variations in the rubber compound and in the manufacturing process cause slight variations in the shrink of the material and affect the finished size of the O-rings. Note that O-rings are made larger because they shrink in the mold and during the post curing stage. These variations make it difficult to mass produce O-rings to their exact dimensions so the need for tolerances comes in. Tolerances can be expressed in several different ways. The most common is a "±" figure like 1.239 ± .011. Others state a range that is acceptable for a dimension, like 1.228-1.250 inches. Therefore 1.239± .011 is the same as 1.228-1.250. Tolerances play an important part in seal design.

1.9 Type of Elastomers

O-ring seals are commonly made of rubber but they can also be made with plastic or metal. 36 different types of rubber compounds exist on the market today because of the different temperatures, chemical exposures and environments that O-rings are subjected too. For instance, Nitrile, also called Buna, resists oils and greases very well but will not last when exposed to sunlight or ozone. On the other hand ethylene propylene has good resistance to sunlight and ozone but is not good with hydrocarbon based oils and greases. Temperature range also plays a major role in material selection. Some applications require a material with a low temperature range. An air conditioning unit may see temperature as low as -40°F or more, some Nitrile works to -55°F, while other applications may go as high as 600°F or more. In this case silicone may be a good choice.

1.10 Rubber Hardness

Now that are described the types of elastomers and temperature ranges there is one more property of the rubber to consider when choosing an O-ring -- the hardness of the rubber. Rubber material can be made very soft, a low durometer reading, to very hard, a high durometer reading. The hardness is usually called out in increments of 5 durometer points, for example 60, 65, 70 and so on. The hardness of rubber also has a tolerance of ±5 points. This is due to the fact the hardness is hard to control because of all the variables involved in the compounding and the manufacturing process. Thus, each of the ingredients of the rubber compound vary slightly from batch to batch not to mention the when you mix all the ingredients together to make the rubber compound will also vary from batch to batch. Adding this to the variables in manufacturing like temperature of the mold and ovens, time in press and oven and so on can cause the hardness to vary. Therefore manufactures ask for a tolerance of ±5.

Durometer gauge with conveloader stand. The conveloader helps to make the durometer readings more consistent by controlling the force and rate which is applied to the gauge as well as keeping it perpendicular to the sample being tested.

Rubber is made in different hardnesses for several reasons. Some sealing surfaces may not be totally smooth. The little voids, pits and scratches allow a pathway for fluid or air to escape through. Softer materials tend to flow better into these voids and imperfections on the sealing surface creating a better seal. On the other hand, harder rubbers will not do this as well but they do resist extrusion cause by high pressures. Softer rubbers tend to extrude into the clearance between the two parts being sealed when exposed to high pressure causing a failure of the O-ring seal.

Coefficient of friction, either static, breakout or running friction is also effected by the hardness of the rubber. Softer rubber has a higher coefficient of friction, meaning if you take a piece of rubber and try to slide it across the surface of your desk. The higher the friction more force is needed to make it move and keep it moving. Coefficient of friction plays a factor when the O-rings are sealing a part that moves.

Hardness of rubber is measured with a durometer gauge. There are many scales of durometer gauges like type A, B, C, D, O, OO, M. Durometer is simply the measure of how far an indenter penetrates a rubber sample. The softer the rubber the more the indenter penetrates the rubber shows low durometer reading. The harder the rubber the less the indenter penetrates the rubber causing a higher durometer reading. The durometer scales are from 1-100. Glass would give a reading of 100. Scale A is the durometer used for rubber. Small O-rings can not accurately be tested using the type A gauge because of the small size and curvature of the O-ring. So there is Type M durometer gauge. This durometer gauge has a smaller indenter and is more accurate for checking the hardness of the actual O-ring. Unfortunately you can not convert one scale reading to another. There is no correlation between these scales.

There are many factors that effect durometer readings. Temperature, humidity, how much force is applied to the gauge, how fast the gauge is pushed down and when the reading is taken all play a part in what type of reading you will get. Many durometer gauge manufactures have a conveloader to reduce some of the variations by controlling the force and rate at which is applied to the gauge. But note that it is not uncommon for two people to get two different reading from the same rubber sample and gauge. Durometer reading are only accurate to around ±2.

O-rings come in many sizes, hardness, elastomers and colors to suite the particular application.

1.11 Elastomer Characteristics Chart

	Nitrile	EP	FKM	Silicone
Common Name	Buna, Nitrile, NBR	EPR,EPT,EPDM	FKM, Viton®	Silicone, MVP
Chemical Definition	Butadiene Acrylonitrile	Ethylene Propylene	Fluorocarbon	Polysiloxane
General Characteristics				
Durometer Range (Shore A)	30-95	30-90	60-90	30-90
Tensile Range (P.S.I.)	200-3000	500-2500	500-2000	200-1500
Elongation (Max %)	600	600	300	700
Compression Set	Good	Good	Good	Good
Resilience-Rebound	Good	Good	Fair	Good
Abrasion Resistance	Excellent	Good	Good	Fair to Poor
Tear Resistance	Good	Fair	Good	Poor
Solvent Resistance	Good to Excellent	Poor	Excellent	Poor
Oil Resistance	Good to Excellent	Poor	Excellent	Fair to Poor
Low Temperature	-40°F	-60°F	-10°F	-60°F to -150°F
High Temperature	to 250°F	to 350°F	400°F to 600°F[1]	to 450°F
Aging Weather-Sunlight	Poor	Excellent	Excellent	Excellent

Advantages	• Has good solvent, oil, water, hydraulic fluid resistance.	• exceptionally god weather aging and ozone resistance.	• Resistant to a wide range of oils and solvents, specially all aliphatic, aromatic and halogenated hydrocarbons, acids, animal and vegetable oils	• Low compression set and good resilience
	• Good compression set, abrasion resistance tensile strength.	• Excellent water and chemical resistance.		• Moderate solvent resistance.
		• Excellent resistance to gas permeability and aging due to exposure to steam.		• Excellent heat resistance.
		• Good in keytones and alcohol's.		• Good release characteristics.
		• Excellent water and chemical resistance.		• Highly resistant to oxidation and ozone.
Disadvantages	• Not recommended for use in highly polar solvents such as acetone and MEK, ozone, chlorinated hydrocarbons and nitro hydrocarbons.	• Not recommended for food applications or exposure to aromatic hydrocarbons	• Not recommended for keytones, low molecular weight esters and nitro containing compounds.	• Not recommended for most concentrated solvents, oils, concentrated acids and dilute sodium hydroxide.

	Neoprene	SBR	Natural	Butyl
Common Name	Neoprene, CR	SBR	Natural Rubber	Butyl
Chemical Definition	Polychloroprene	Styrnen Butadiene	Polyisoprene	Isobutylene Isoprene
General Characteristics				
Durometer Range (Shore A)	50-90	30-90	20-90	40-90
Tensile Range (P.S.I.)	500-3000	500-3000	500-3500	500-3000
Elongation (Max %)	600	600	700	850
Compression Set	Good	Good	Excellent	Fair to Good
Resilience-Rebound	Excellent	Good	Excellent	Fair
Abrasion Resistance	Excellent	Excellent	Excellent	Fair
Tear Resistance	Good	Fair	Excellent	Good
Solvent Resistance	Fair	Poor	Poor	Poor
Oil Resistance	Fair	Poor	Poor	Poor
Low Temperature	+10°F to -50°F	0°F to 50°F	-20°F to -60° F	-10°F to -60°F
High Temperature	to 250°F	to 225° F	to 175°F	to 250°F
Aging Weather-Sunlight	Good	Poor	Poor	Excellent

Advantages	• High resilience with low compression set.	• Low cost non-oil resistant material.	• High resilience and good compression set.	Impermeable to most gasses.
	• Flame resistance.	• Good water resistance and resilience up to 60 durometer.	• High tear strength.	• Good resistance to sunlight and ozone.
	• Animal and Vegetable oil resistance.	• Satisfactory for most moderate chemical and wet or dry organic acids.	• Good low temperature.	• Normally it's satisfactory when exposed to animal and vegetable oils and oxidizing chemicals.
	• Not affected by moderate chemicals, fats, greases and many oils and solvents.		• Usable for keytones and alcohol.	
			• Good low temperature properties.	
Disadvantages	• Not recommended for strong oxidizing acids, esters, keytones, chlorinated aromatic and nitro hydrocarbons.	• Not recommended for ozone, strong acids, oils greases, fats and most hydrocarbons.	Not recommended for oils and solvent resistance and ozone attacks it.	• Not recommended for use with petroleum solvent, coal tar and aromatic hydrocarbons.

1.12 O-ring failure.

O-rings typically fail in their applications because of the combined adverse effects of several environmental factors. Experience has shown the most common causes of O-ring failure are:

* Improper gland design; allowing for too much or too little compression, not enough room for displacement under compression, or tolerance stack-up.

* Incorrect O-ring size.

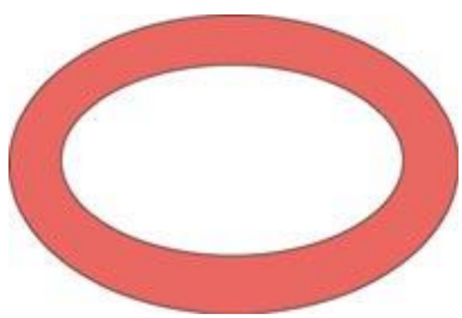
* Incompatibility between the O-ring elastomer and environmental elements it must contact.

* Improper O-ring installation.

* Inadequate O-ring lubrication.

The combination of stresses that act on O-rings can be complex and difficult to evaluate. Therefore, it is very important that both the O-ring compound and size be tested in the real environment of its service. The following examples picture and classify the common types of O-ring failure that can occur.

Failure without visible evidence on seal

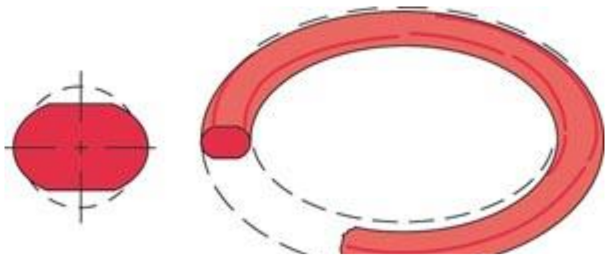


Failure pattern: Of the various types of seal failure, this is among the hardest to diagnose because the result of the problem is not visible on the O-ring. There are no visual clues.

Problem sources: Insufficient compression . . . Tolerance stack-up . . . Eccentric-shaped components . . . Parting lines and/or flash left on the O-ring from the molding process. . . Improper volume relationship between the seal and its gland.

Suggested solutions: Maintain recommended compression range for the application . . . Identify the amount of stretch as it reduces the O-ring cross section with increased stretch . . . Determine the component tolerance stack-up as it directly affects the seal cross section . . . Consider maximum component shift in design to ensure that compression is still contained within recommended compression range . . . Avoid parting lines in O-ring grooves as they tend to be areas of flash and mismatch. . . Ensure that the O-ring gland volume surpasses the O-ring volume to allow for seal expansion without seal detriment.

Compression set

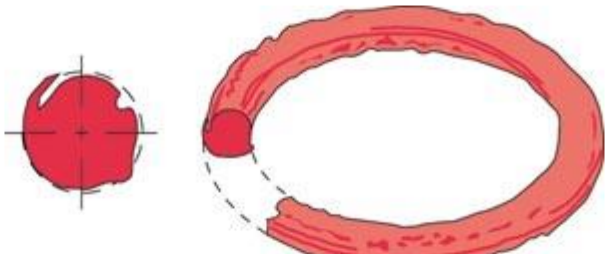


Failure pattern: Common to both static and dynamic sealing applications, compression set failure produces flat surfaces on both sides of the O-ring's cross section.

Problem sources: The selected elastomer has poor compression-set properties . . . Low heat resistance of material . . . Excessive swelling of O-ring material in system fluid . . . Too much squeeze to achieve seal . . . Incomplete curing (vulcanization) of the O-ring material during production.

Suggested solutions: Use a low set elastomer . . . Specify an O-ring material that resists both operating and friction-generated heat . . . Re-check O-ring material compatibility with system chemicals . . . Reduce O-ring squeeze if possible . . . Inspect incoming O-rings for correct physical properties.

Extrusion and nibbling

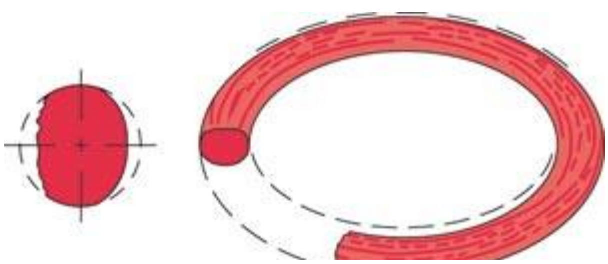


Failure pattern: Typical of high-pressure systems, this pattern can be identified by the many small bites or nibbles taken out of the O-ring on the low-pressure (downstream) side.

Problem sources: Excessive gland clearances . . . Excessive system pressure . . . O-ring material too soft . . . Degradation of O-ring by system fluid . . . Irregular clearance gaps caused by eccentricity . . . Improper machining of O-ring gland (leaving sharp edges) . . . O-ring size too large for gland.

Suggested solutions: Decrease gland clearances by machining . . . Use back-up rings to prevent extrusion . . . Use harder O-ring material . . . Re-check elastomer compatibility with system chemicals . . . Increase rigidity and improve concentricity of metal components . . . Break sharp edges of gland to a minimum radius of 0.005 in. . . . Install proper size O-ring . . . Consider substituting a reinforced composite seal, such as rubber bonded to metal.

Abrasion

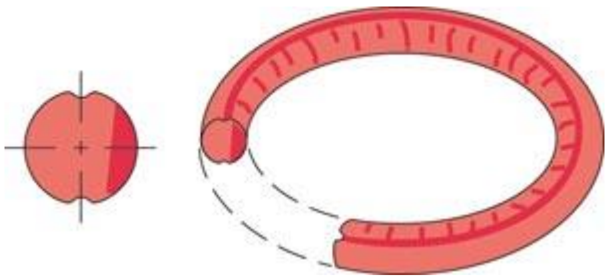


Failure pattern: Occurring primarily in dynamic seals involving reciprocating, oscillating, or rotary motion, this failure pattern can be identified by a flattened surface on one side of the O-ring's cross section.

Problem sources: Metal surfaces of gland are too rough and act as an abrasive . . . Metal surfaces are too smooth causing inadequate lubrication . . . Poor lubrication . . . Excessive temperatures . . . System fluid contaminated with abrasive particles.

Suggested solutions: Use recommended metal finishes . . . Provide adequate lubrication (consider internally lubricated O-rings) . . .Check material compatibility with system temperature . . . Eliminate abrasive contamination with filters and/or wiper seals . . . Consider changing to a more abrasion-resistant O-ring material, such as carboxilated nitrile or urethane.

Heat hardening and oxidation



Failure pattern: Seen in both static and dynamic seals, the surface of the O-ring appears pitted and/or cracked, often accompanied by the flatness of high compression set.

Problem sources: Excessive temperature causing elastomer hardening, evaporation of plasticizers, and cracking from oxidation.

Suggested solutions: Specify high temperature O-ring materials with antioxidants . . . Lower operating temperature of hydraulic system.

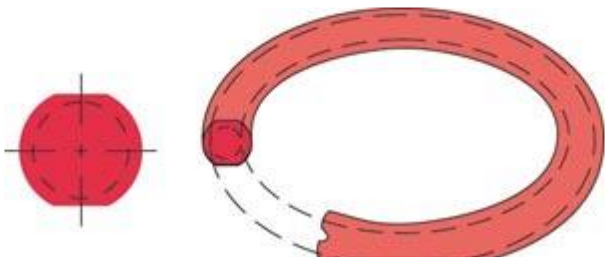
Damage during installation

Failure pattern: Occurring in both static and dynamic seals, this failure mode is marked by short cuts or notches, or a skinned or peripherally peeled surface.

Problem sources: Sharp edges on mating components of the O-ring gland . . . Sharp threads over which the O-ring must pass during assembly . . . Insufficient lead-in chamfer . . . Oversized O-ring ID on piston . . . Undersized O-ring ID on rod . . . O-ring was twisted or pinched during installation . . . O-ring was not lubricated during installation . . . O-ring elastomer has low tear resistance (typical of silicone).

Suggested solutions: Break all sharp edges . . . Cover threads with tubes or tape during O-ring installation . . . Provide a 15° to 20° lead-in chamfer . . . Install correctly sized O-rings . . . Use lubrication during assembly.

Excessive swell



Failure pattern: Easily identified by a marked increase in seal dimensions; can occur in both static and dynamic applications. Results in reduction of physical properties and can result in improper sizing between seal and gland. Dynamic applications are especially prone to this problem because friction accelerates seal failure.

Problem sources: Like a sponge, the seal absorbs the surrounding fluids and swells to the point of malfunction because of incompatibility between seal compound and system environment (i.e. chemical incompatibility, high humidity, etc.).

Suggested solutions: Select an O-ring material that is chemically compatible with the fluid it will contact.

Spiral failure

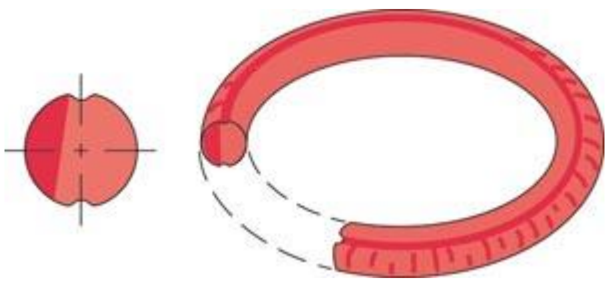
Failure pattern: Generally found on long stroke, hydraulic piston seals, the surface of the O-ring exhibits a series of deep, spiral 45°-angle cuts.

Problem sources: Caused when some segments of the O-ring slide while other segments simultaneously roll. At a single point on its periphery, the O-ring gets caught on an eccentric component or against the cylinder wall, causing twisting and development of 45° angle surface cuts.

Contributing conditions include: Eccentric components . . . Wide clearance combined with side loads . . . Uneven surface finishes . . . Inadequate lubrication . . . O-ring material is too soft . . . Stroke speeds are too slow.

Suggested solutions: Check the cylinder bore; it may be out of round . . . Decrease the clearance gap . . . Machine metal surfaces to a 10 to 20 µin. finish . . . Improve lubrication (consider substituting internally lubricated O-rings) . . . Increase O-ring material hardness and/or cross-sectional area . . . Add anti-extrusion back-up rings.

Weather or ozone cracking

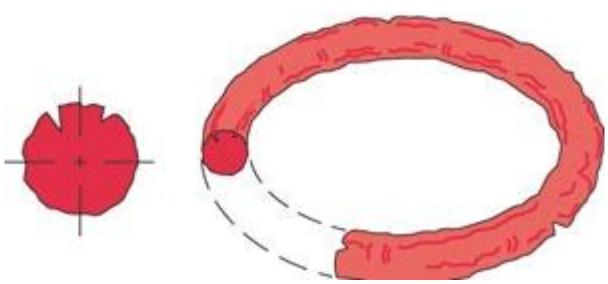


Failure pattern: Occurring in both static and dynamic seals exposed to atmospheres containing ozone and other air pollutants, this failure mode is marked by the appearance of many small surface cracks perpendicular to the direction of stress.

Problem sources: Ozone attacks the polymer chains, causing O-ring material to crack.

Suggested solutions: Substitute O-ring elastomers that are resistant to ozone attack.

Explosive decompression



Failure pattern: Marked by random short splits or ruptures going deep into the O-ring's cross section. When the O-ring is first removed, the surface may also be covered with small blisters.

Problem sources: Absorption of gas by O-ring while operating in high pressure conditions. Subsequent rapid decrease in system pressure traps gas within the O-ring's micro pores, causing surface blisters and ruptures as the gas escapes.

Suggested solutions: Increase the time for decompression . . . Change to a material that has a hardness in the 80 to 95 durometer range . . . Reduce the O-ring's cross-sectional size.

1.13 Tool identifies O-ring material

Almost by definition, all O-ring seals look pretty much alike. With some basic measuring devices, a mixed bag of O-rings can be sorted by size, but how can you identify their material for chemical compatibility - and do it without destroying the O-ring? One way: use the ORID 70-C O-ring identifier, built by Bachus Instrument Co., Nashville.

Just holding this simple tool - which is about the size of a pencil - in a vertical orientation with its bottom end against an O-ring of unknown material that is lying flat on a table or desk. Slide the tool's internal weight to the top of its slot and release it. The straight edge at the bottom of the weight should drop directly on the O-ring cross-section so that the edge strikes and bounces off that cross-section's arc. Watch the height of the first bounce when the weight rebounds off the O-ring. Marks inscribed along the slot identify Viton, Kalrex, nitrile or Buna-N, and ethylene propylene. Because minor differences in operator technique may produce variations in bounce, it's best to take multiple readings.

The stainless-steel ORID 70-C will accurately read 100, 200, 300, and 400 Series (0.103 to 0.275 in.) cross-section O-rings with durometer hardness of 60, 70, or 80. Note that the surface supporting the O-ring should be hard and rigid. The ORID 70-C tool should not be used with damaged or failed O-rings, or O-rings older than their indicated shelf life, and it cannot identify material correctly that is not in an O-ring configuration.

2. Analysis and specifications of a household dishwasher seals.

Once the properties, assembly and possible failures of o-rings have been seen and analyzed, a specific analysis of every dishwasher seal can be made because in most cases, all of this can be applied to the different shaped seals.

Forward, in this point, the sealing will be presented with descriptive pictures, his profile and some interesting characteristics and specifications such as:

- Shore Hardness (A)
- Lubricant
- Torque
- Material
- Water/Air *
- Temperature
- Type
- Weight

* → This means if the sealing is normally in contact with water, with air or both.

Finally, a CAD design will be added to have an idea of the pressure points and interferences of the seal in order to know from where the seal is deformed. Some explanatory and curious comments are made to finish this detailed analysis.

In this case, the total amount of seals to analyze is 31 (which are almost from the hydraulic side of a household dishwasher) and can be very different and have very varied functions.

An important thing to keep on mind is that all this data come from CAD designs, test benches and workers´ experience so some of this data and information are possible estimations which can be a little bit different from reality. Moreover, the materials and designs are subject to big and continuous changes due to the researching, so these data can be obsolete later.

Thus, the analyzed parts and seals are:

2.1 Door seal

Function description:

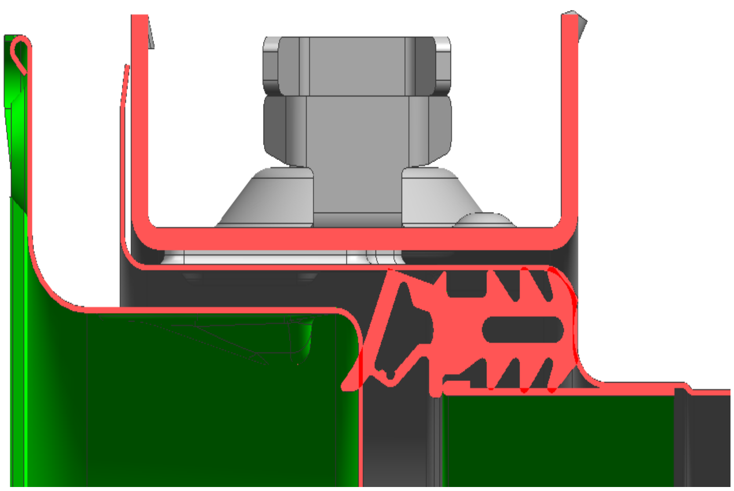
The door seal goes on the tub´s edge and his aim is to produce a sealing with the dishwasher´s door. In this manner, there is not a leakage while the dishwasher is running. An other target is to do not let the steam escape because it is very heated and also can expand the kitchen´s wood.

Section view:

Specifications:

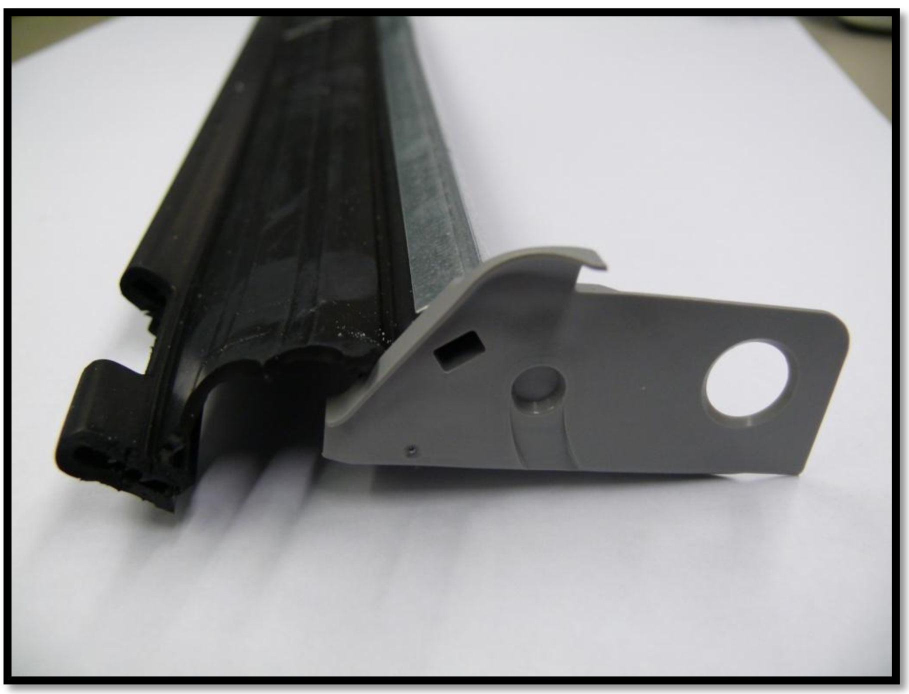
Door seal	
Shore Hardness A	61 (real) / 60 ±5 (theoretical)
Lubricant	Promol (1l promol/2´5l water)
Torque	………………………………………..
Material	EPDM GTE 57
Water/Air	Both
Temperature(°C)	Test DVR → 100°C max.
Type	Axial
Weight	168´8g

Observations:



To have an estimated idea of the pressure of the door seal, there is a table who measures the force of the door and the the way of the seal. This diagram shows the range of values accepted for this sealing. (N-mm)

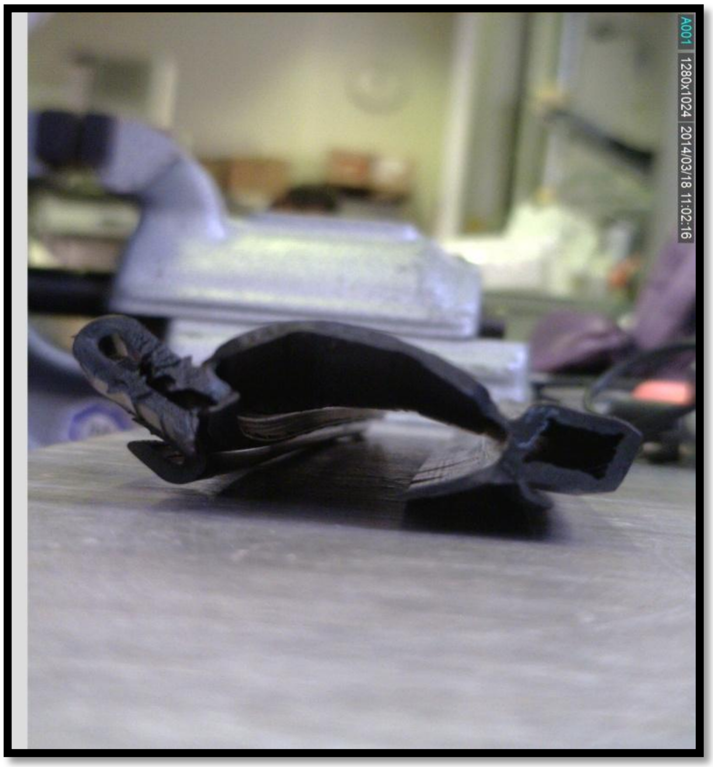
2.2 Lower door seal

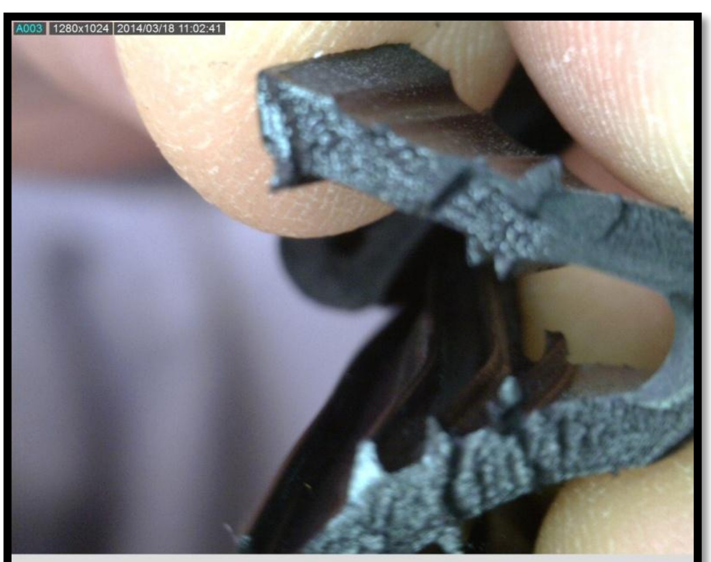


Function description:

The principal performance of the lower door seal is to not produce water and steam leakages but in the same time it can be a security ally by the fact we have, in Zeolith ones, little holes in the sides to canalize the water to the security water switch. In those who are not Zeolith, there are not little holes but little apertures in the sides because there is not a necessity of a so fast action as in Zeolith.
This water switch is the second security system of the dishwasher after the reed switch flow meter. The lower door seal is fixed to the door with screws.

Section view:

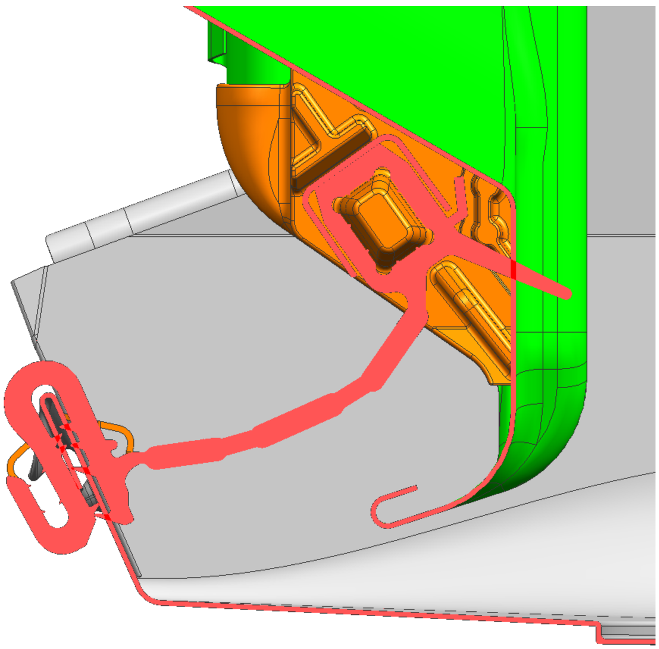




Specifications:

Lower door seal	
Shore Hardness A	Hard part: 95±5 / Soft part: 57±5
Lubricant	…………………………………………..
Torque	…………………………………………..
Material	GV640: EPDM (GV440 : PP and TPE)
Water/Air	Both
Temperature(°C)	70°C max
Type	…………………………………………..
Weight	136´2g

Observations:



It is a profile made by extrusion. It is composed by two parts one time manufactured: Hard part and soft part. The GV440 is made by two differentiated parts, which make the assembly easier. It is a compromise between a safety system and a sealing.

2.3 Zeolith tap seal

Function description:

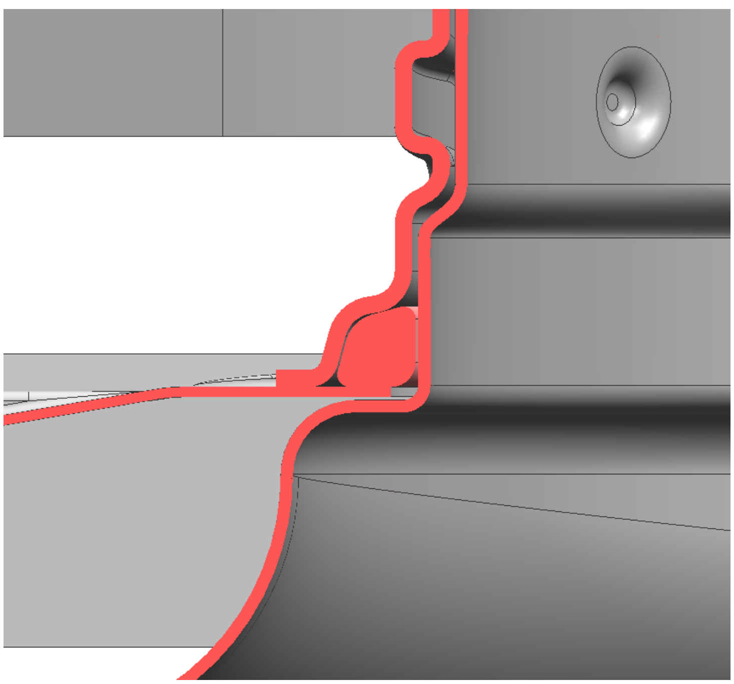
The object of the Zeolith tap seal is to prevent a water leakage into the Zeolith box and the damage to the Zeolith heat system and to the mineral, which can not absorb such a big quantity of moisture. If the water comes into the box, the mineral must be refilled.

Section view:

Specifications:

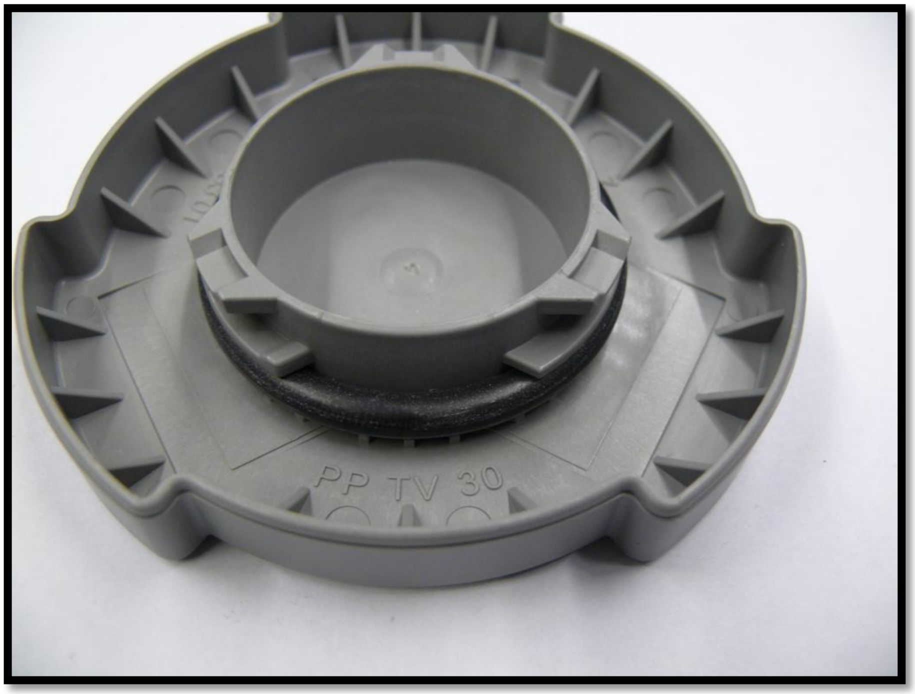
Zeolith tap seal	
Shore Hardness A	30±5
Lubricant	Promol
Torque	………………………………………..
Material	Liquid silicone
Water/Air	Water
Temperature(°C)	70°C
Type	Axial and radial combined
Weight	2´3g

Observations:



The ideal pressure is around 25%. This seal needs to be resistant against chemicals and detergents. In tests, it is possible to see an exothermal reaction of the Zeolith mineral with a box temperature of 150/160°C and a mineral temperature of 220°C. The torque depends on the dimensions and tolerances of each piece.

2.4 Water softener tap seal



Function description:

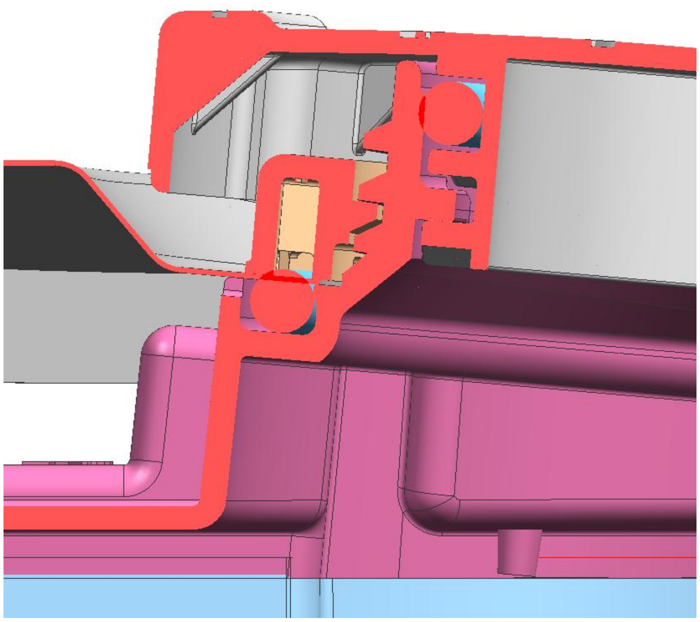
The aim of the water softener tap seal is to not allow to the salt to go out of the water softener and avoid that the dirty water comes into the water softener.
This sealing uses talcum instead of Promol because it is better for the handgrip and also it is more long-lived in the water´s presence.

Section view:

Specifications:

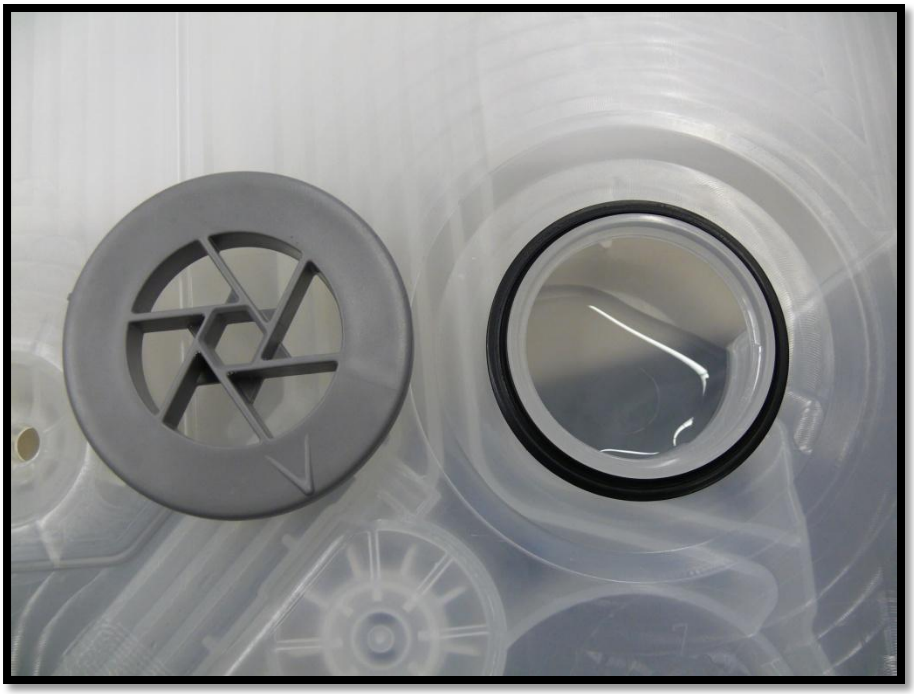
Water softener tap seal	
Shore Hardness A	50±5
Lubricant	Talcum
Torque	………………………………………
Material	EPDM
Water/Air	Salty water
Temperature(°C)	70°C max
Type	Radial
Weight	3 g

Observations:



The ideal pressure is around 15-30%. The seal´s hardenss is very important. It does not have to be very hard. Resistant to the salty water´s aggression. It is used talcum for the first time and after always is wet due to the water.

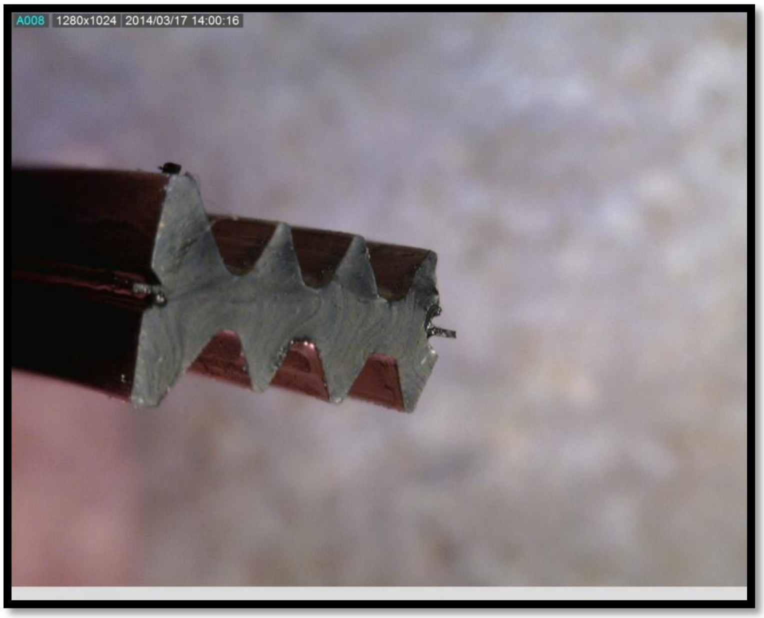
2.5 Seal steam vent



Function description:

The target of the steam vent seal is to seal the expansion system to the tub such that it is not possible a steam leakage. It is also prepared to seal the water that comes from the spray arms. It is very important that on the assembly line, a torque of 11 Nm is done to the piece for a correct behavior.

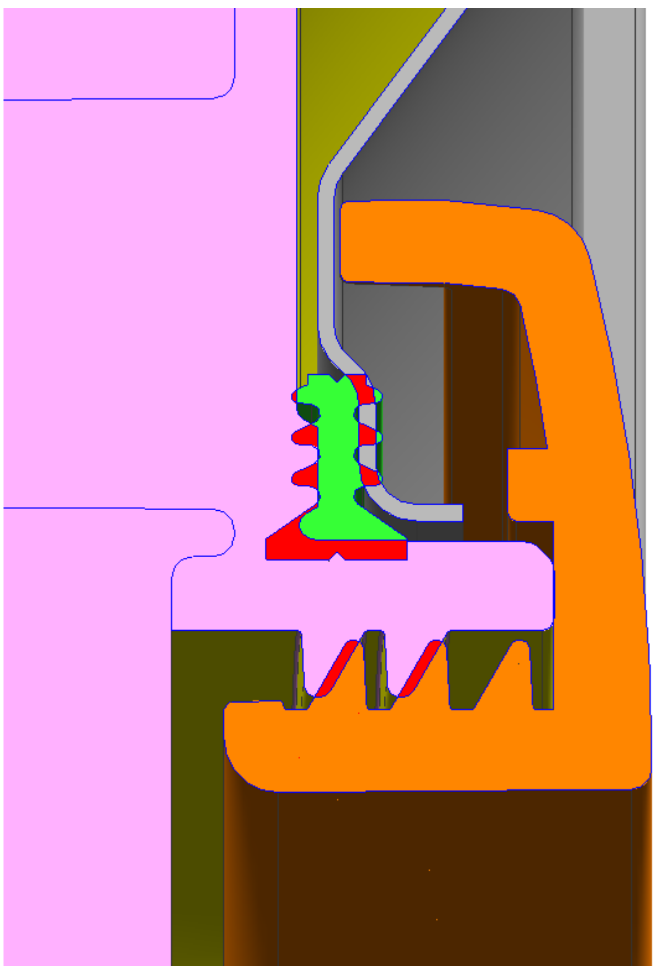
Section view:



Specifications:

Seal steam vent	
Shore Hardness A	50±5
Lubricant	Promol
Torque	11 Nm
Material	EPDM
Water/Air	Both
Temperature(°C)	80 °C max
Type	Axial
Weight	1,3g

Observations:



2.6 Seal water inflow

Function description:

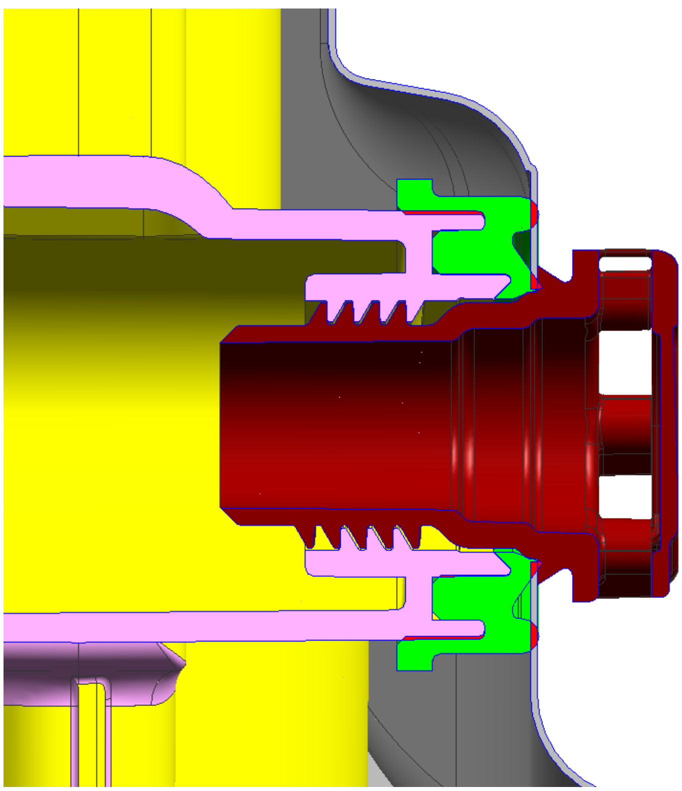
The performance of the water inflow seal is to permit the water to pass from the heat exchanger to the tub without producing water leakages.
It is very important that on the assembly line, a torque of 150 Ncm is done to the piece for a correct behavior.

Section view:

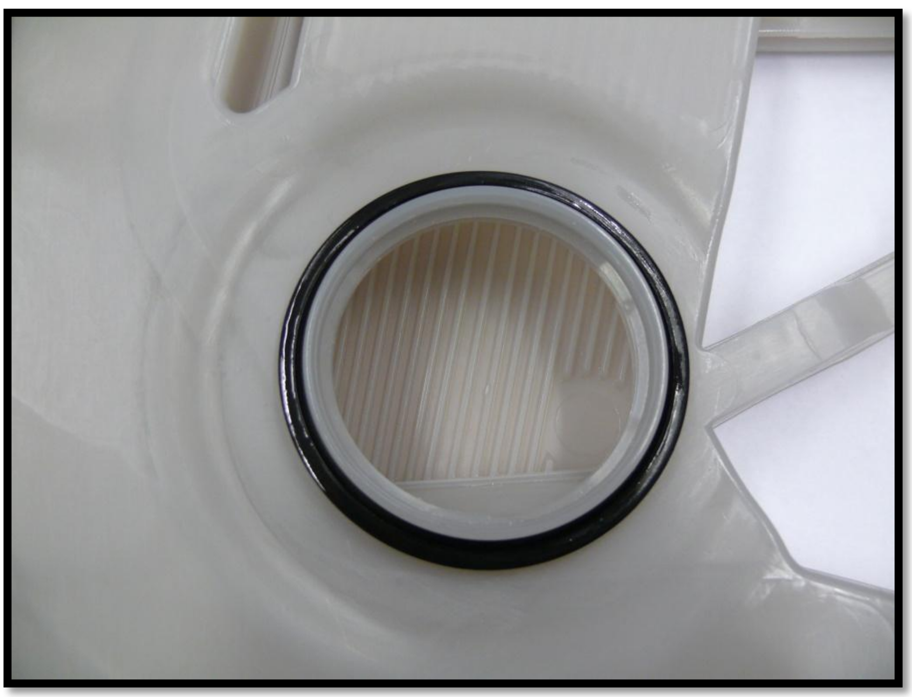
Specifications:

Seal water inflow	
Shore Hardness A	60±5
Lubricant	Promol
Torque	150 Ncm
Material	EPDM
Water/Air	Water
Temperature(°C)	80°C max
Type	Axial
Weight	2´1g

Observations:



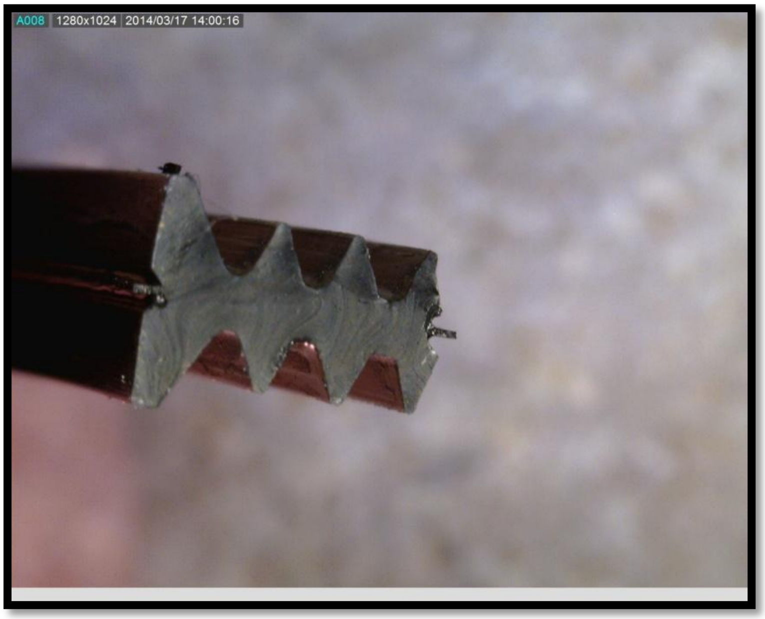
2.7 Zeolith system seal



Function description:

It is the same seal as the steam vent seal and it is needed the same torque. As the channel goes up, the water can not get into the Zeolith fan. So the seal has to stand up for water and steam leakages. The Zeolith system´s cover cap is now different from the steam vent´s cover cap because little fins have been added to avoid that the air entrance can be totally covered by dishes.

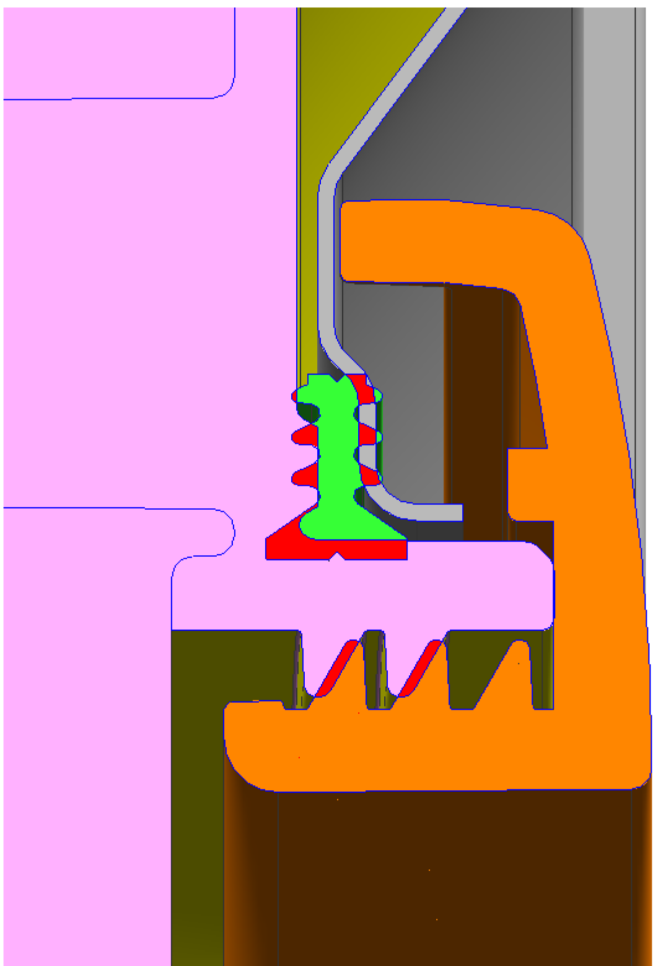
Section view:



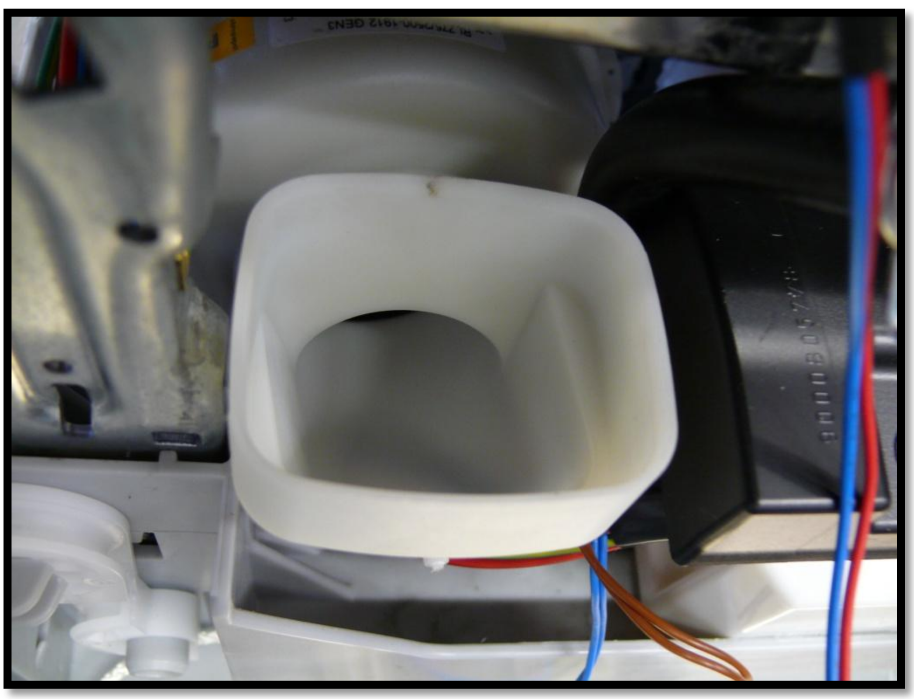
Specifications:

Zeolith system seal	
Shore Hardness A	50±5
Lubricant	Promol
Torque	11 Nm
Material	EPDM
Water/Air	Both
Temperature(°C)	80 °C max
Type	Axial
Weight	1´3g

Observations:



2.8 Zeolith fan seal



Function description:

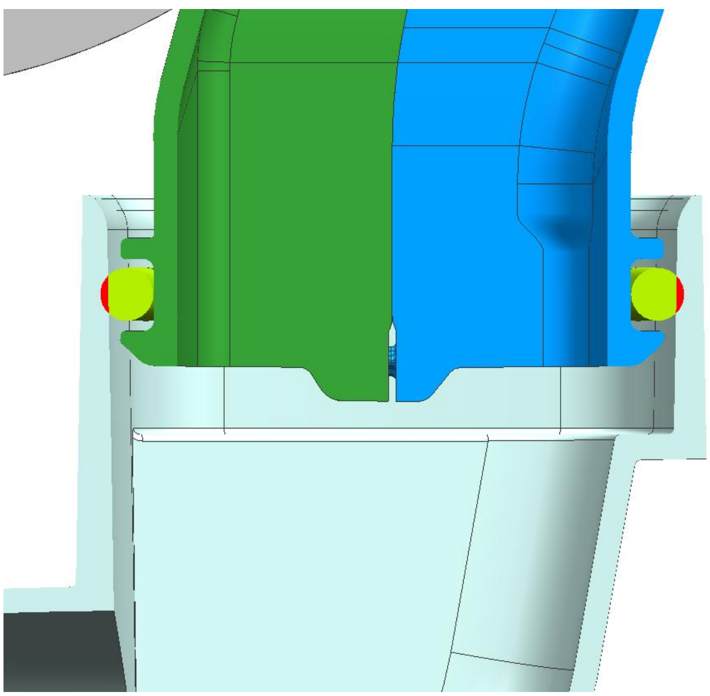
The object of the Zeolith fan system seal is to avoid the income of cold air from the environment into the Zeolith pipe because it is wanted, with the heat system and a chemical reaction with the mineral, hot and dry air to go up into the tub for the drying step. The cycle is repeated.

Section view:

Specifications:

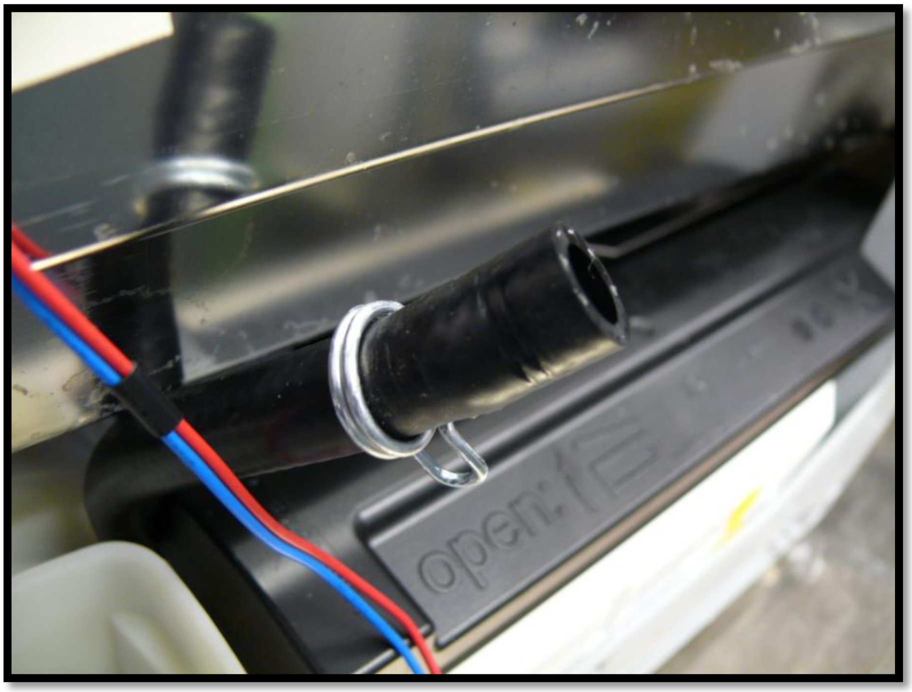
Zeolith fan seal	
Shore Hardness A	60±5
Lubricant	Promol
Torque	…………………………………………
Material	EPDM
Water/Air	Air
Temperature(°C)	70°C max
Type	Radial
Weight	3g

Observations:



The ideal pressure is around 20%. The serial seal has caused an assembly problem so there is a new one, which is only an o-ring whose weight is 2,1g and improves this trouble.

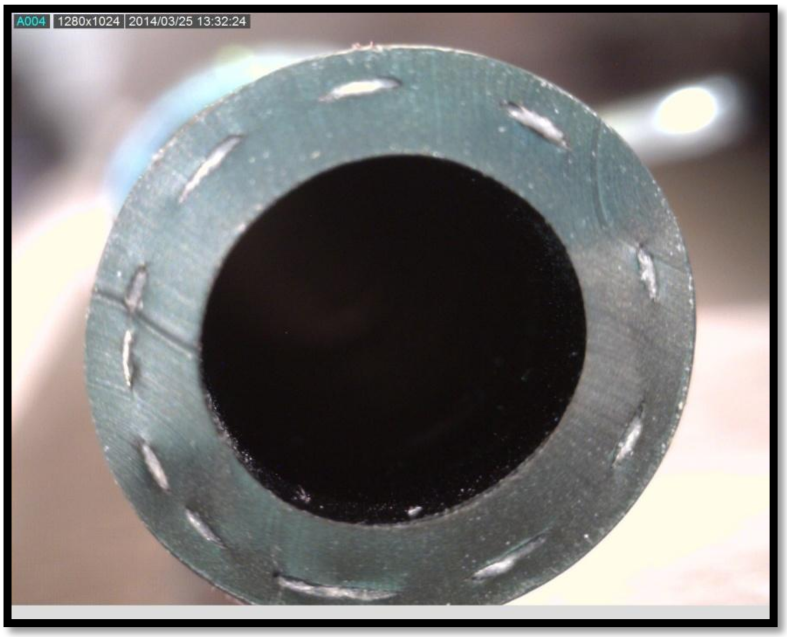
2.9 Water storage hose seal

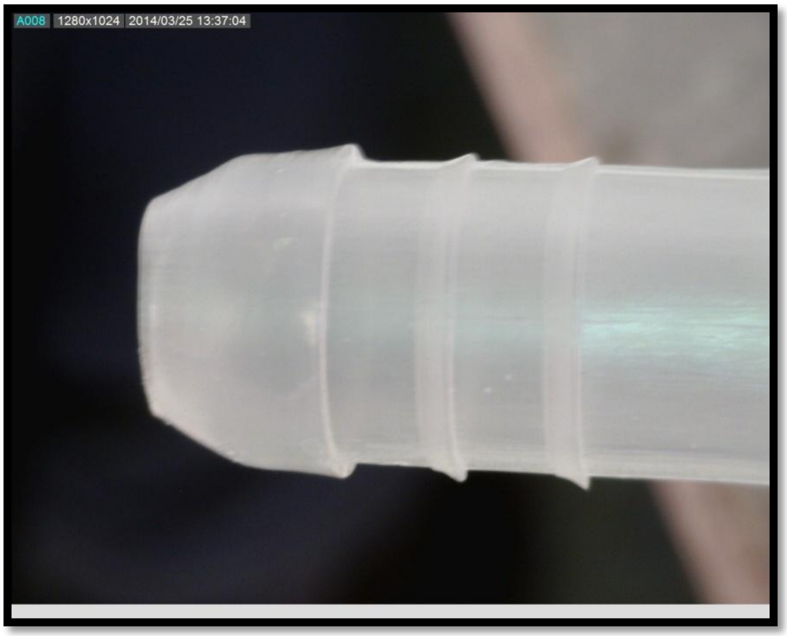


Function description:

It is the sealing between the water storage hose and the water storage tank. They are fixed with the aid of a hose clamp. This hose comes from the water switch and it is composed by a nylon net who gives it stability, pressure and temperature resistance.
The water storage tank is used to the first pre-wash of the next program.

Section view:

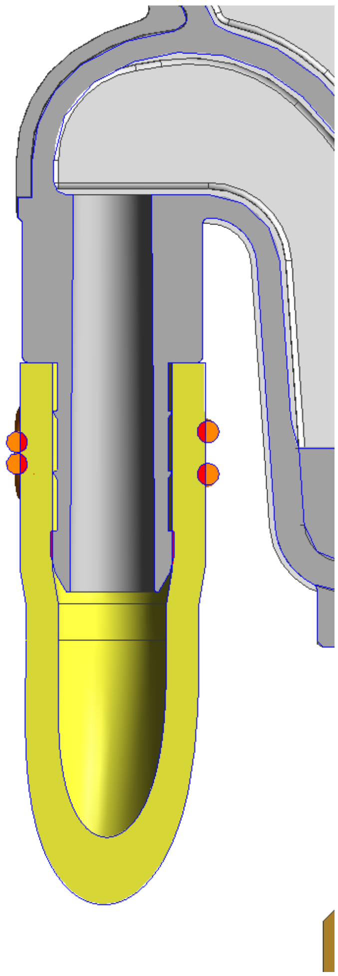




Specifications:

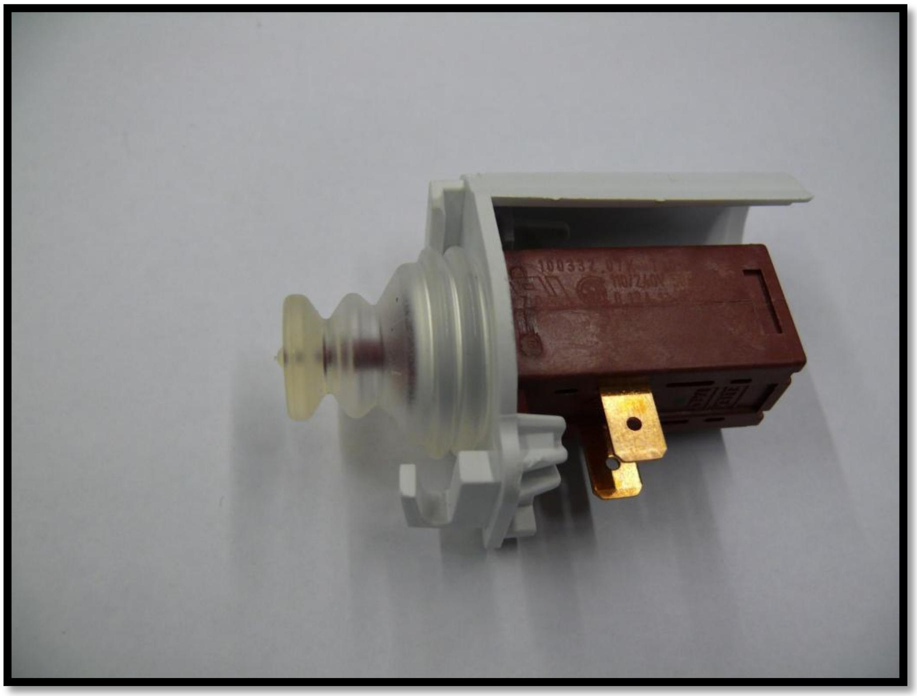
Water storage hose seal	
Shore Hardness A	80 Shore
Lubricant	Promol
Torque	………………………………………
Material	PVC to PP
Water/Air	Water (Dirty)
Temperature(°C)	70°C max
Type	Radial
Weight	71´6g

Observations:



The ideal pressure is around 500mbar with peaks of 800mbar (estimated value). The PVC has a density of 1´33g/cm³.

2.10 Storage valve seal



Function description:

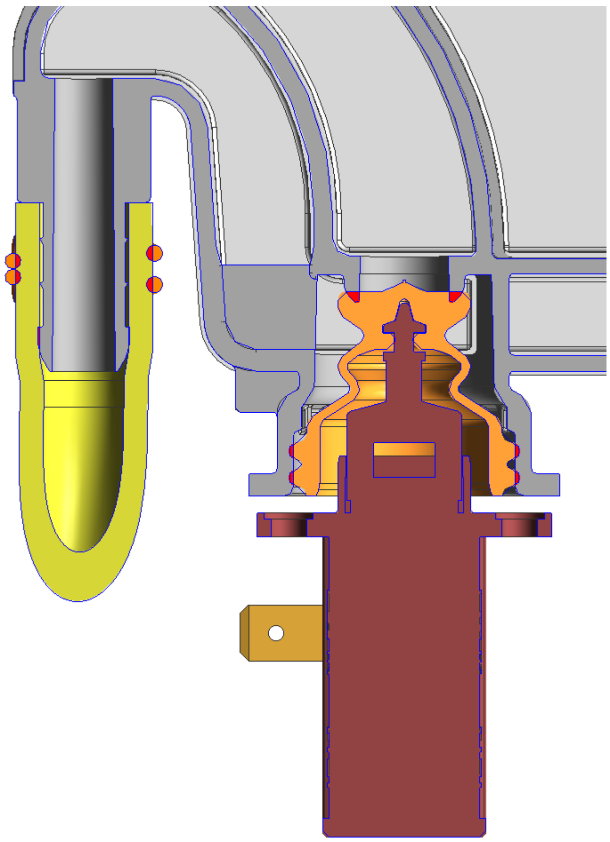
It is the sealing from the water storage valve. It closed the water´s passage depending on the position of the water switch.
This valve is a wax valve, which is stronger than a magnetic one (30N against 0´5N) and slower. It expands with the current´s passage.

Section view:

Specifications:

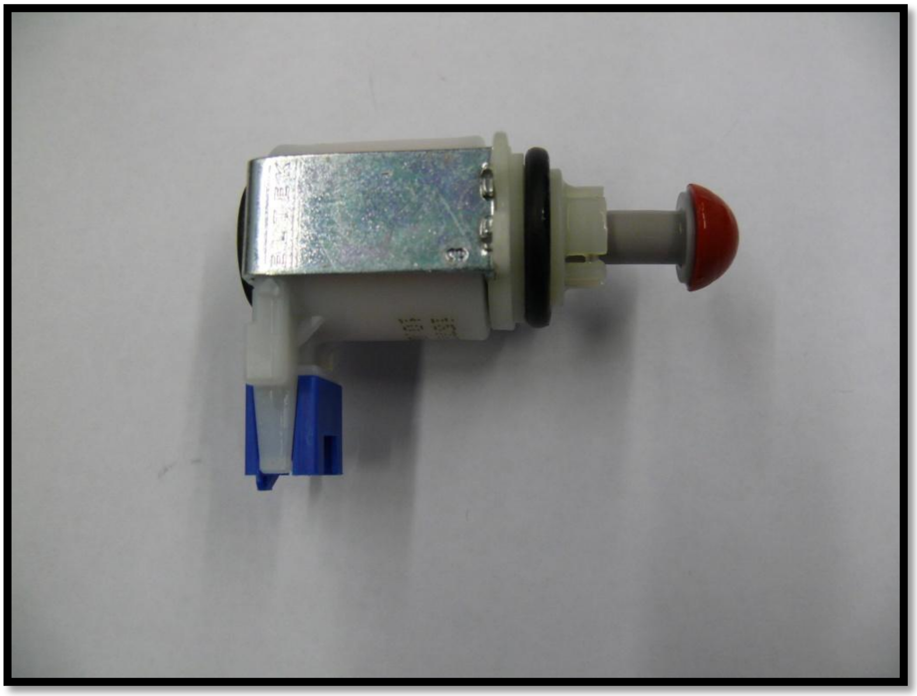
Storage valve seal	
Shore Hardness A	50±5
Lubricant	Promol
Torque	………………………………………..
Material	LSR
Water/Air	Water (Dirty)
Temperature(°C)	70°C max
Type	Axial and radial combined
Weight	3´3g

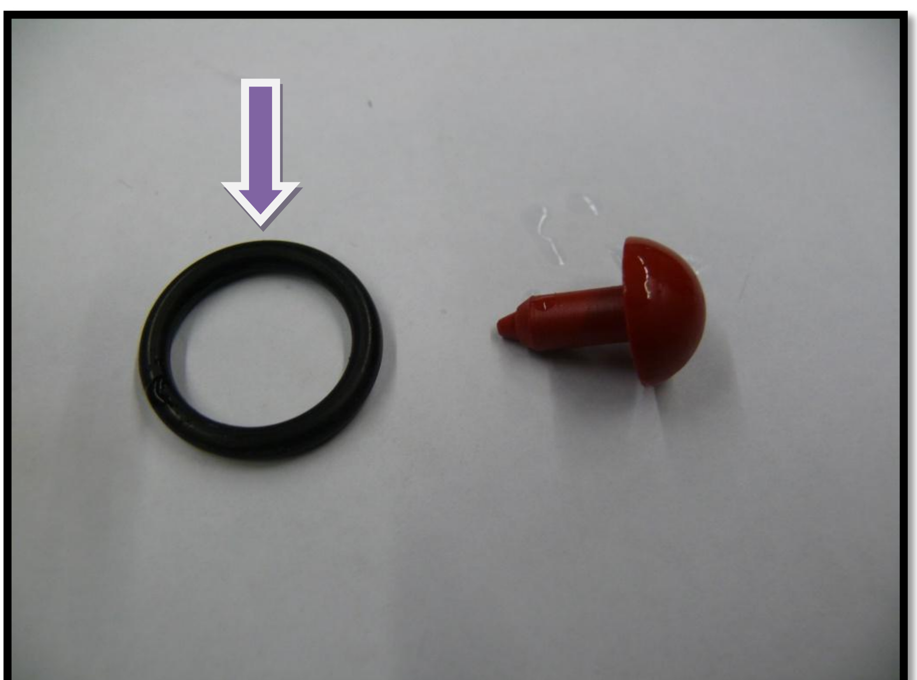
Observations:



There is a torque but it is not defined. The valve works under a pressure of 0´3bar (estimated value) around it due to the passage of water during the washing cycle.

2.11 Heat exchanger valve seal n°1 (outlet valve)





Function description:

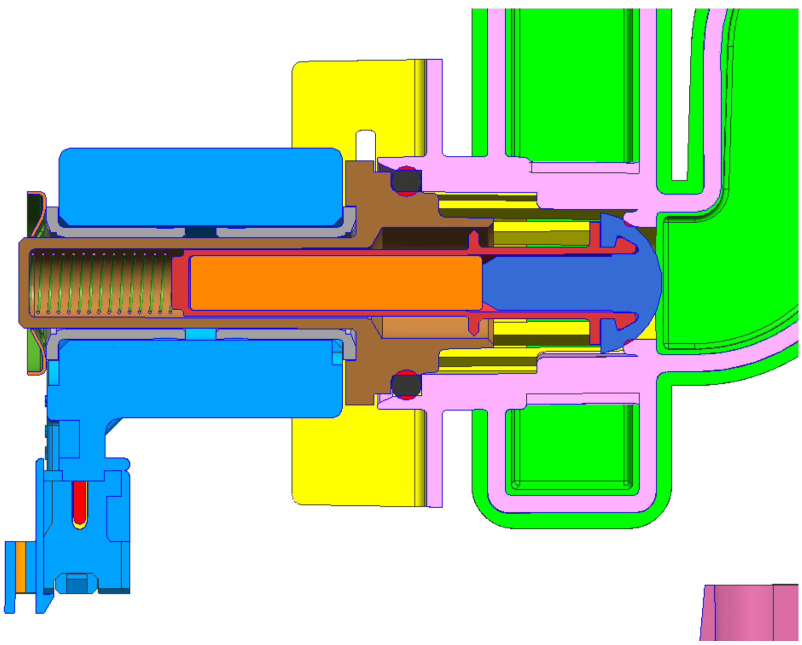
The aim of the first seal of the outlet valve is to cut off the water into the outside of the heat exchanger. This valve is a magnetic one.

Section view:

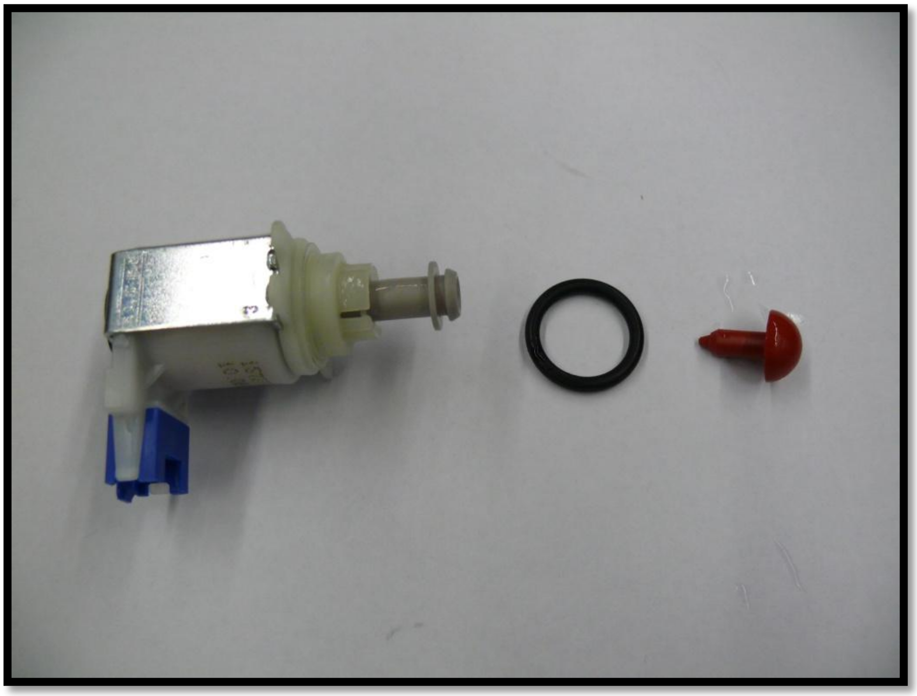
Specifications:

Heat exchanger valve seal n°1	
Shore Hardness A	60-70 (±5)
Lubricant	Promol
Torque	…………………………………………
Material	EPDM
Water/Air	Water
Temperature(°C)	70°C max
Type	Radial
Weight	0´6g

Observations:



2.12 Heat exchanger valve seal n°2 (outlet valve)



Function description:

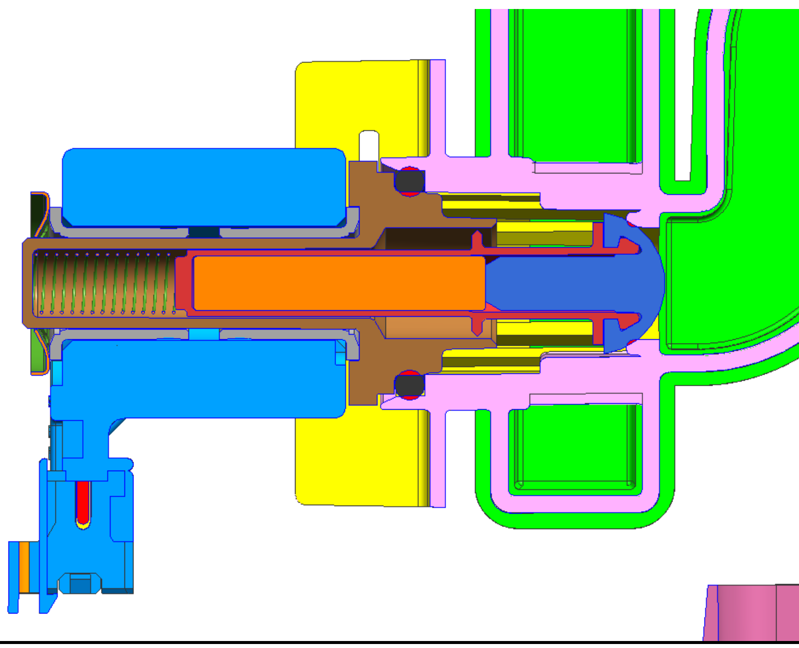
The target of the second seal of the outlet valve is to regulate the amount of water that pass to the water inflow. The surface in touch with this valve has to be polished for a correct performance.

Section view:

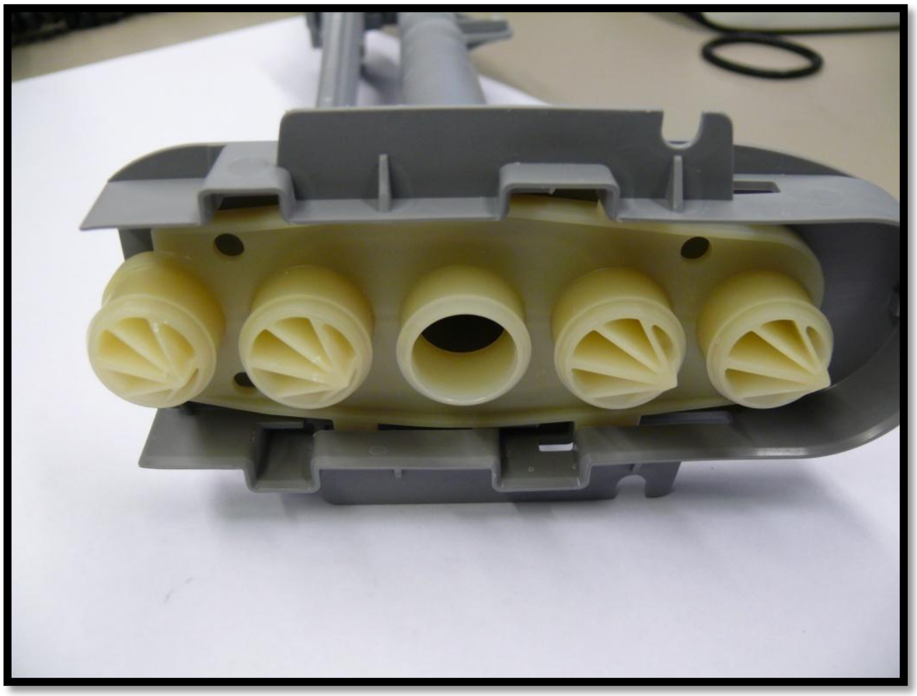
Specifications:

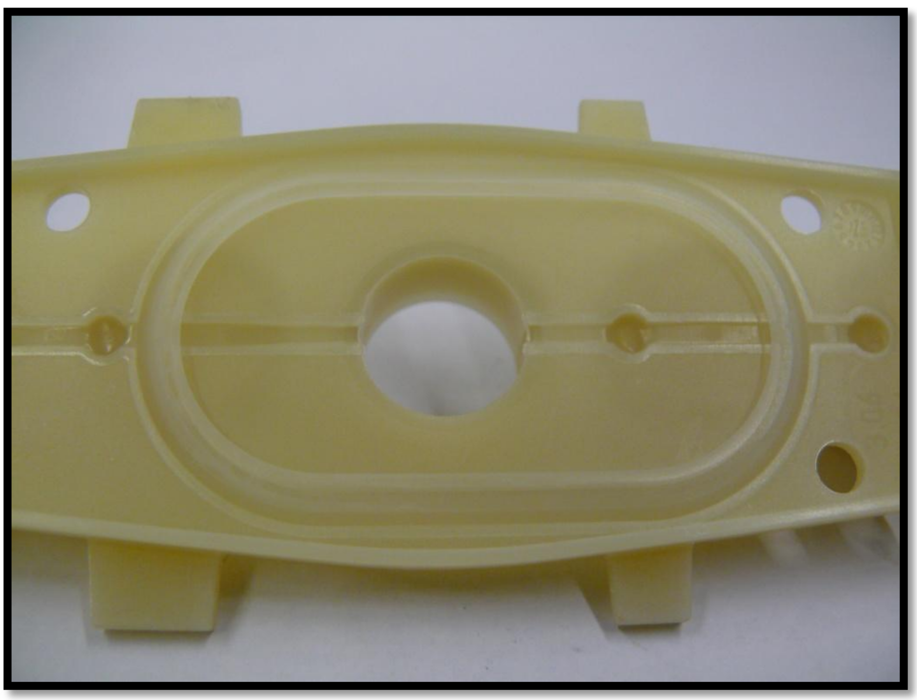
Heat exchanger valve seal n°2	
Shore Hardness A	30±5
Lubricant	Promol
Torque	………………………………………
Material	Fluid silicone
Water/Air	Water
Temperature(°C)	70°C max
Type	Axial
Weight	0´8g

Observations:



2.13 Inlet pipe seals

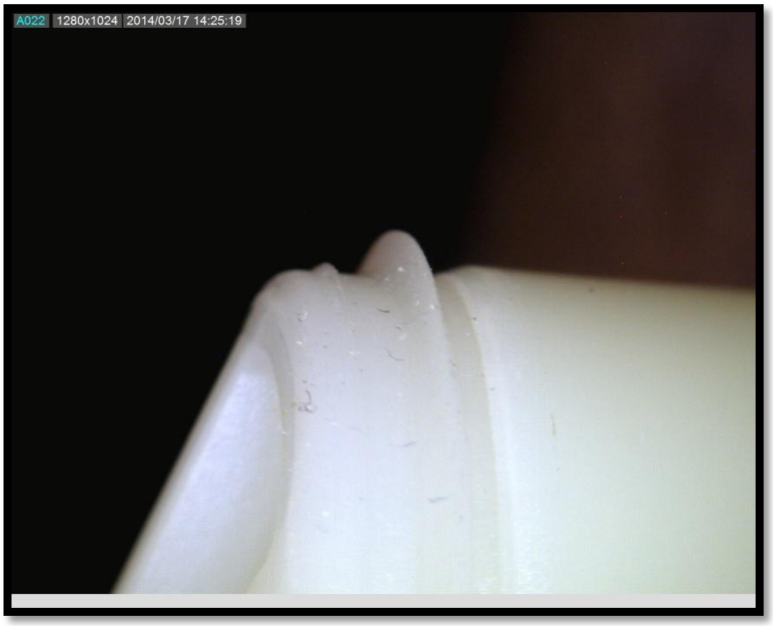




Function description:

The inlet pipe seals are molded at the same time than the plastic parts. This sealing allow to have little leakages because the movement´s diversity of the basket (3 positions up/down and different inclinations). It is designed to not lose a big quantity of pressure.

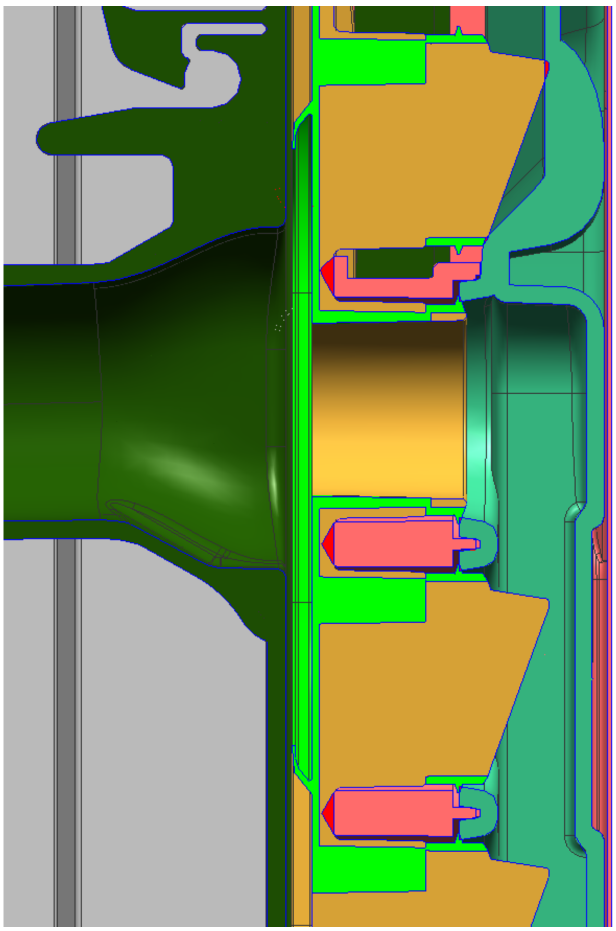
Section view:



Specifications:

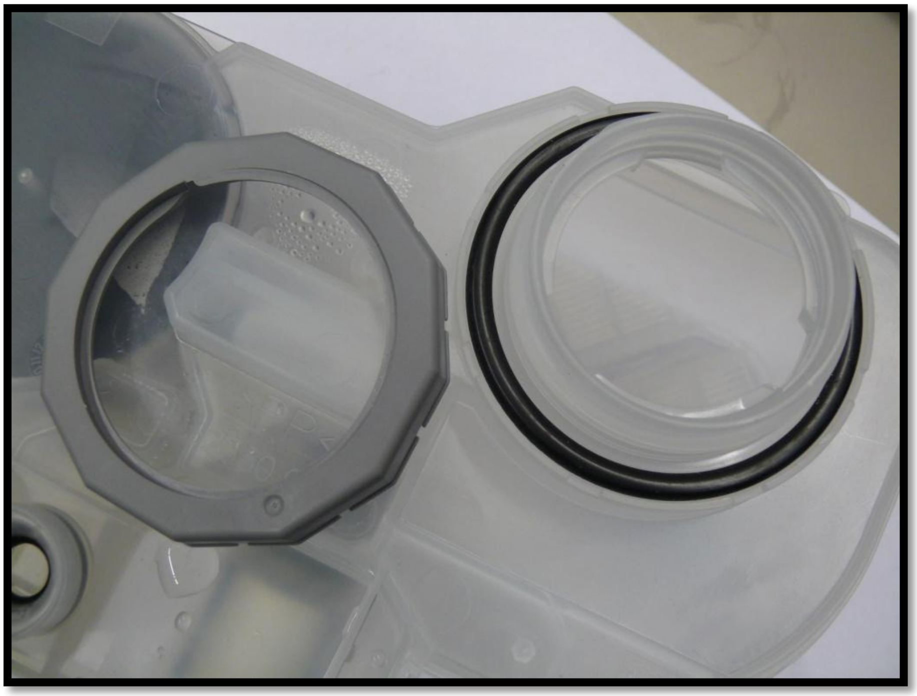
Inlet pipe seals	
Shore Hardness A	50±5
Lubricant	……………………………………….
Torque	……………………………………….
Material	Silicon Wacker Elastosil
Water/Air	Water
Temperature(°C)	80°C max
Type	Radial and Axial
Weight	2´6g

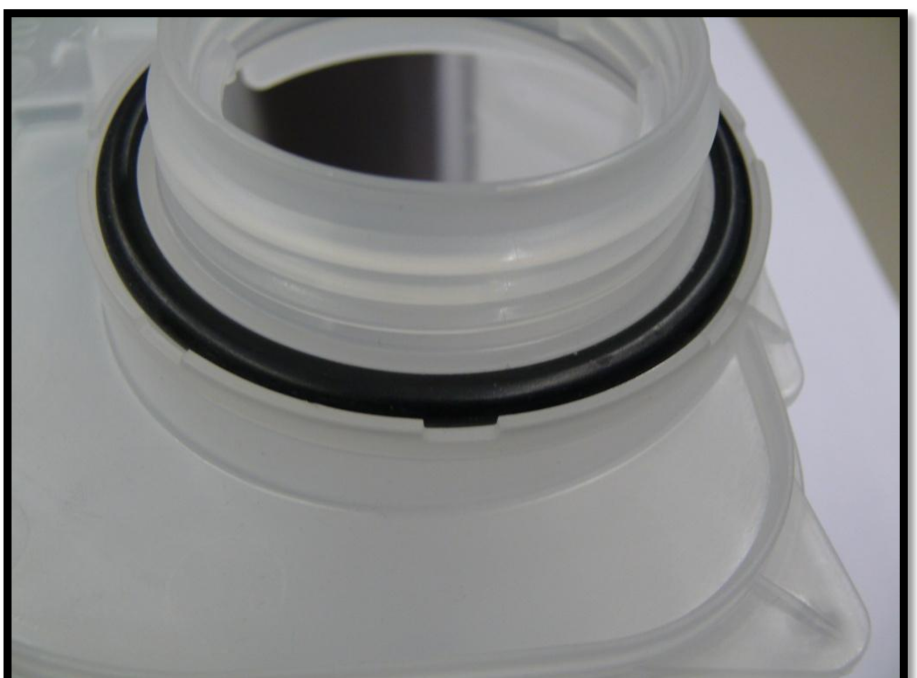
Observations:



The Silicon parts are approximately the 10% from weight of the whole part.

2.14 Water softener and tub seal





Function description:

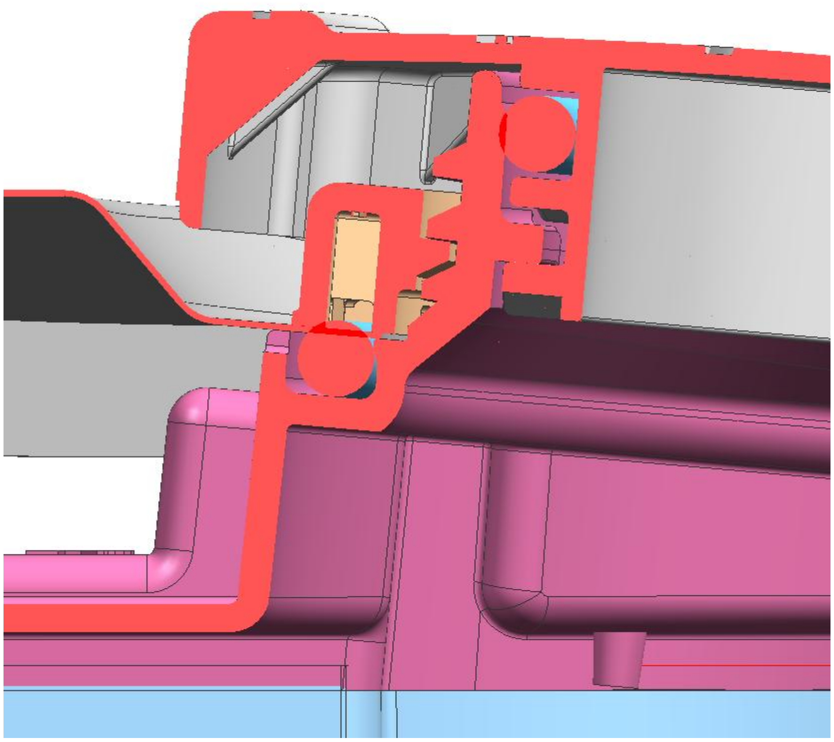
This sealing between the water softener and the tub has been designed to not permit water leakages to the basic carrier. It is because of this why the seal has to have a torque of 28Nm.

Section view:

Specifications:

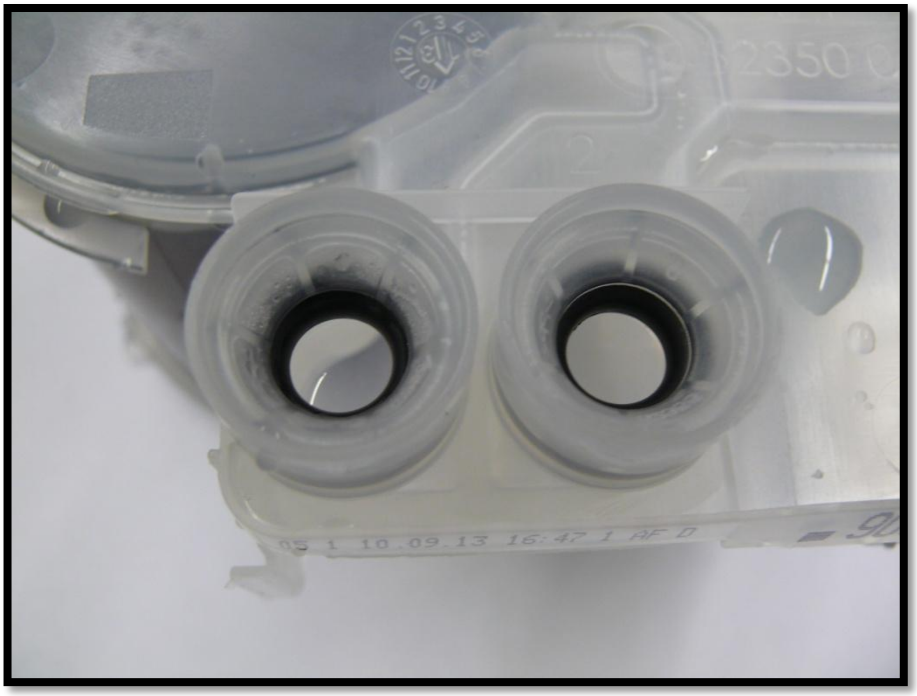
Water softener and tub seal	
Shore Hardness A	50±5
Lubricant	Talcum from supplier/ Promol for assembly
Torque	28Nm
Material	EPDM
Water/Air	Water (Dirty)
Temperature(°C)	70°C max
Type	Axial
Weight	4´8g

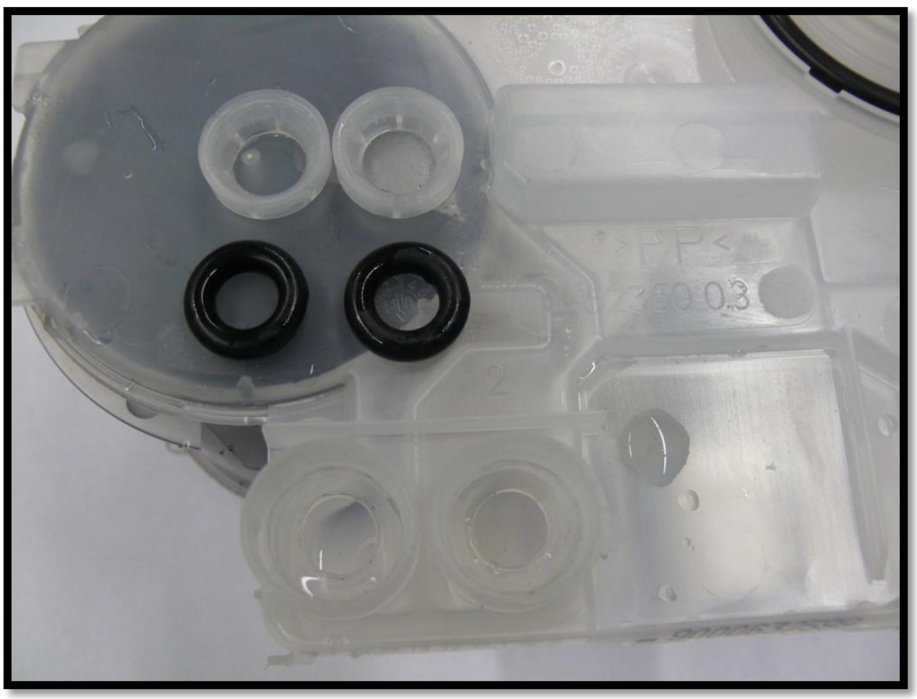
Observations:



The ideal pressure is around 20%. (The radio is 5mm and the step is 4 mm so the seal is pressed for 1mm)

2.15 <u>Water softener inlet and outlet seals (support ring)</u>





Function description:

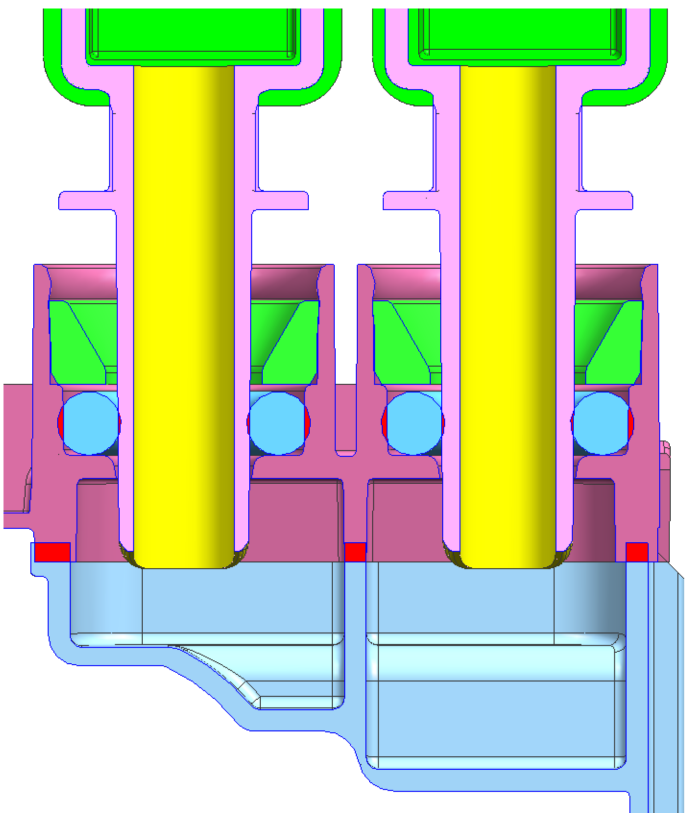
The principal performance of this seals is to seal the plastic pipes of the heat exchanger with the water softener such that water can not escape and produce leakages.
The left one corresponds to the hard water and in the right one the water is already treated and converted into soft water.

Section view:

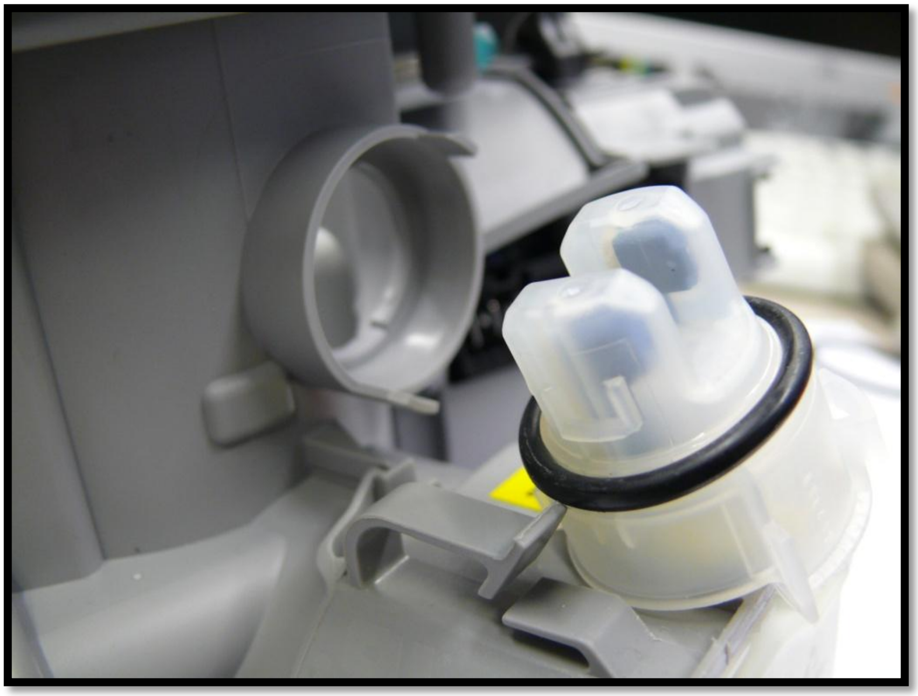
Specifications:

Water softener inlet/outlet seals	
Shore Hardness A	50±5
Lubricant	Promol/Water
Torque	………………………………………
Material	EPDM
Water/Air	Water
Temperature(°C)	It depends on the customer
Type	Radial
Weight	1´3g

Observations:



2.16 Aquasensor seal



Function description:

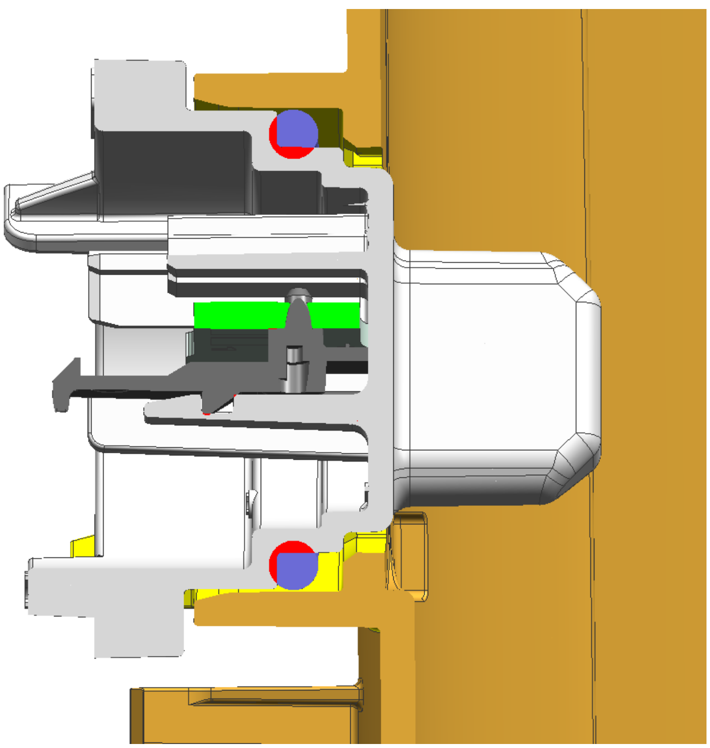
The task of the aquasensor seal is to not have water leakages from the sump. Principally it is conceived for the AUTO programs. If there is a lot of dirty, the program is larger and the heat is higher. On the contrary, if there is not a lot of dirty, the program is quicker and the heat lower.

Section view:

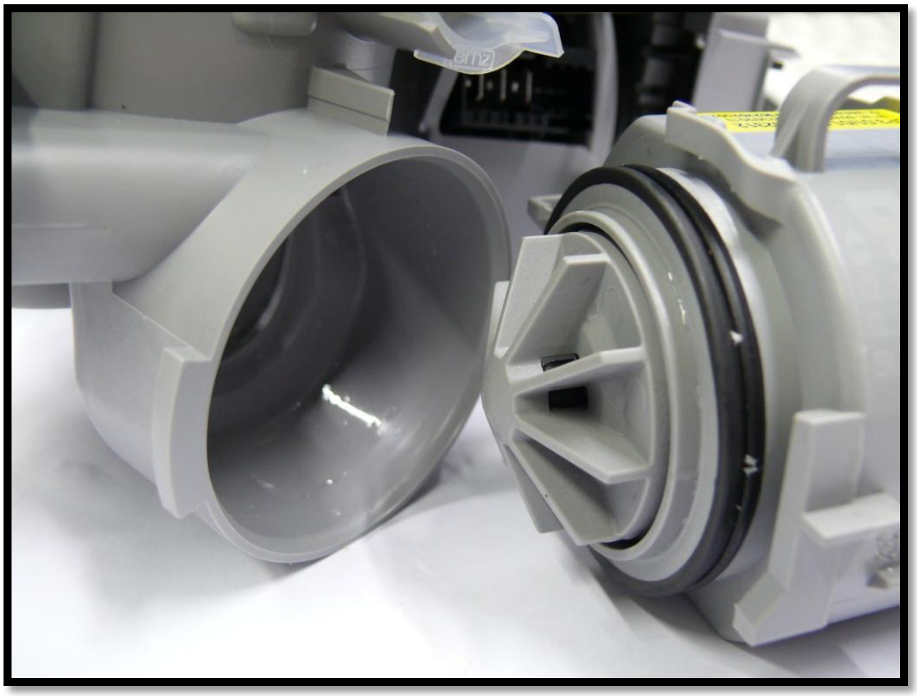
Specifications:

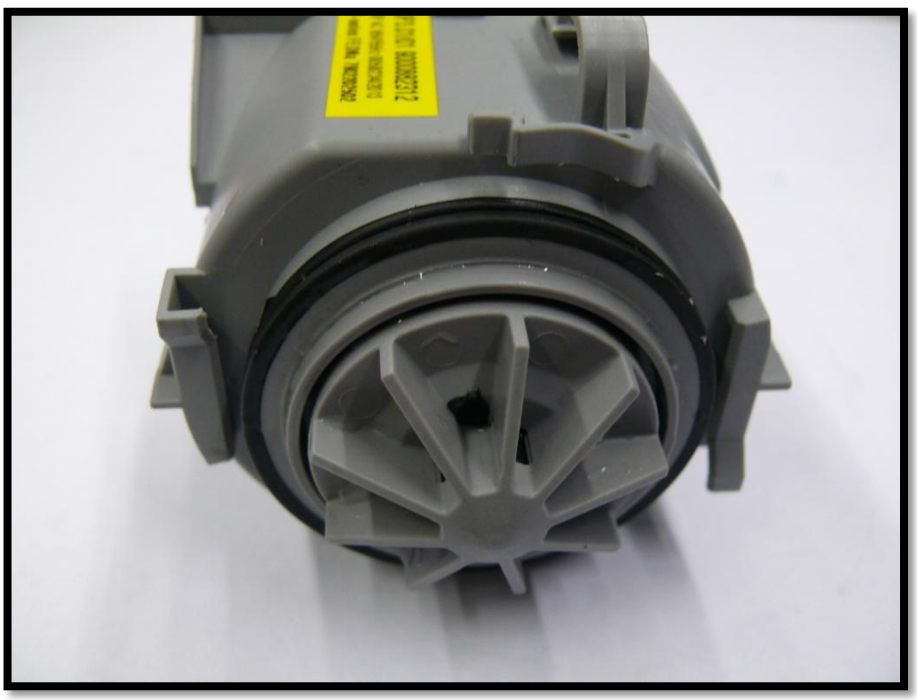
Aquasensor seal	
Shore Hardness A	70±5
Lubricant	Promol
Torque	…………………………………………
Material	NB
Water/Air	Water (Dirty)
Temperature(°C)	80°C max
Type	Radial
Weight	0´7g

Observations:



2.17 Drain pump seal

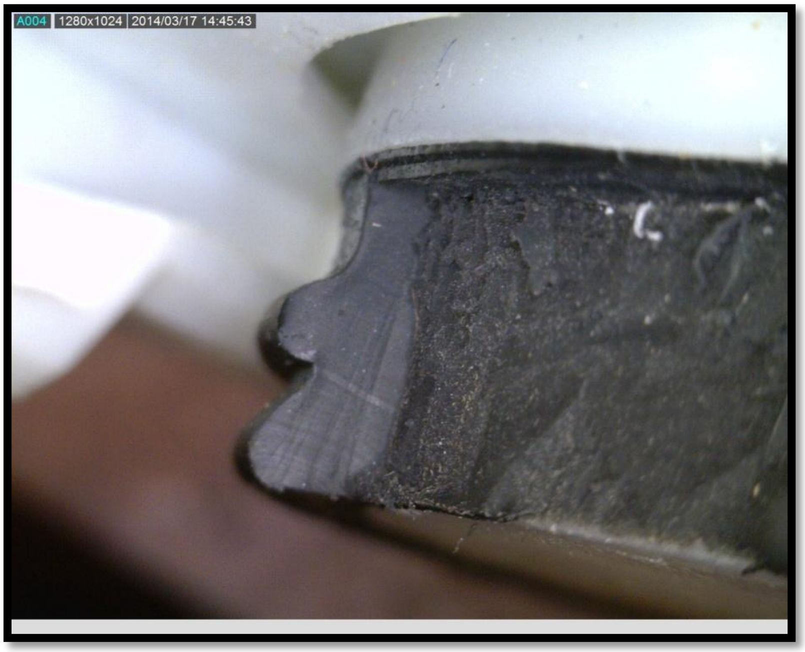


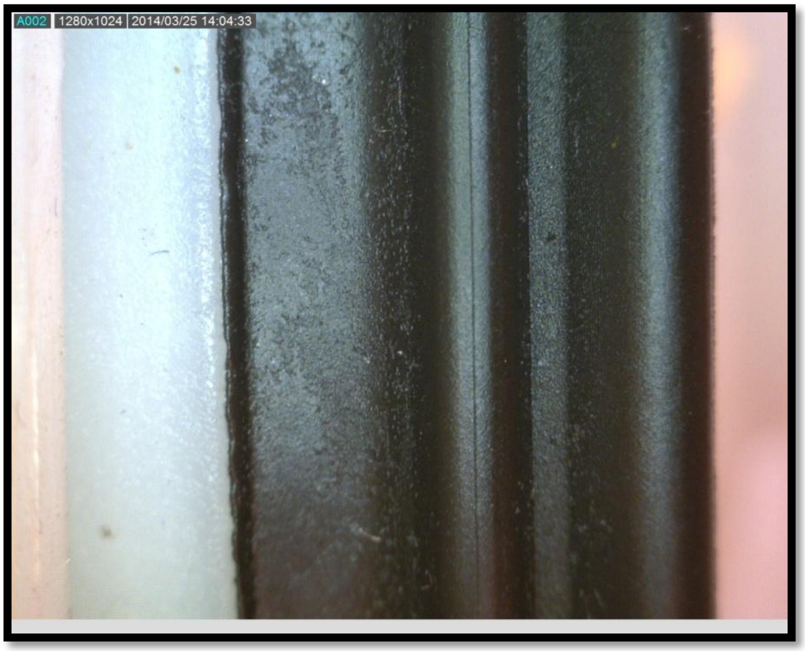


Function description:

The drain pump has to be sealed with the sump in order to do not let the water escape. The drain pump crush the big dirty from the huge filter of the sump and if it can not, the drain pump blocks.

Section view:

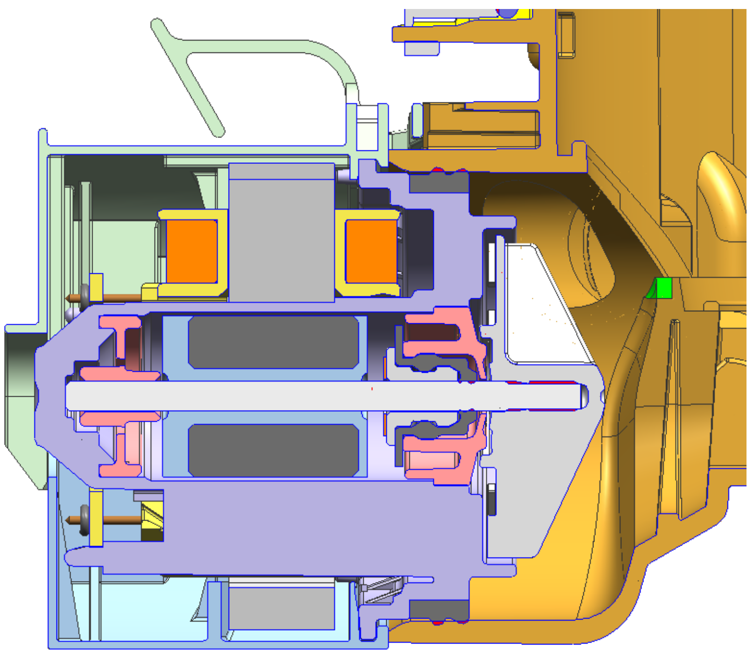




Specifications:

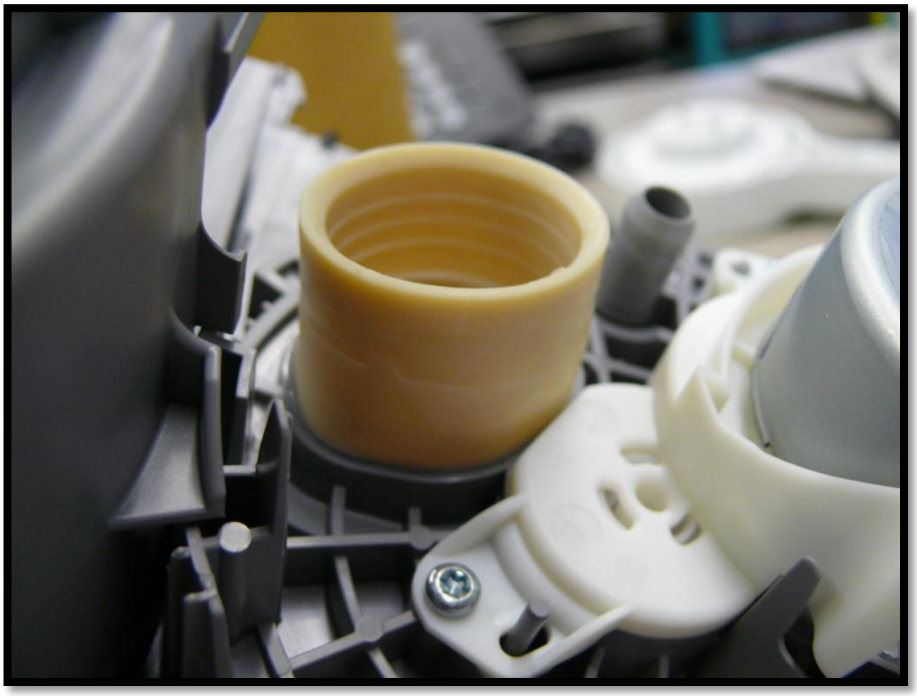
Drain pumps seal	
Shore Hardness A	59±5
Lubricant	Silicon oil
Torque	…………………………………………..
Material	TPE
Water/Air	Water
Temperature(°C)	70°C max
Type	Radial
Weight	Not specified → Directly molded

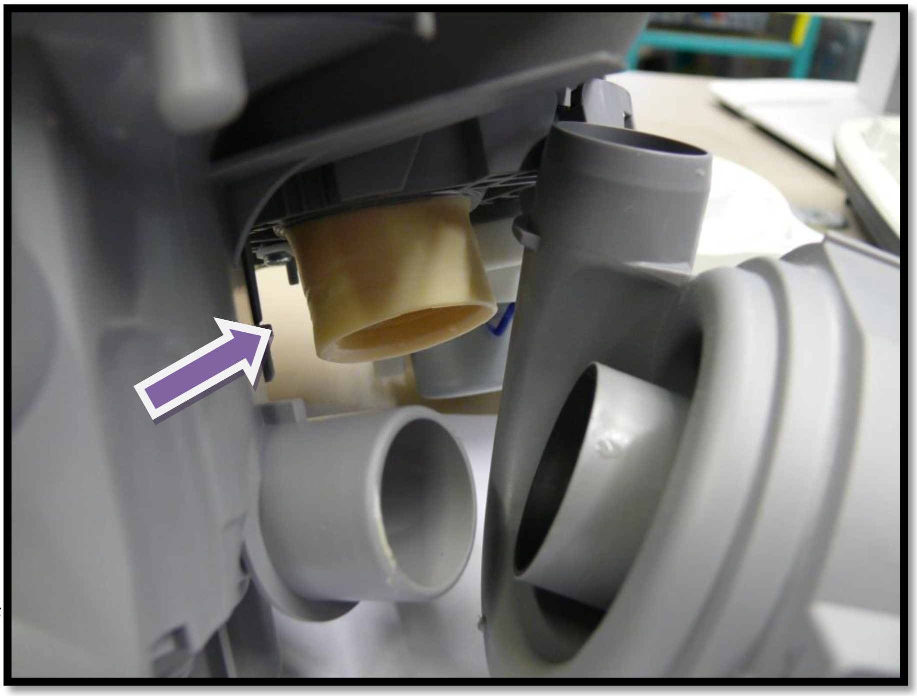
Observations:



It is important to have more than one sealing ring due to safety. If there is a leakage in one ring, then there is an other to assure the seal. For radial force it is better to have less sealing rings but thicker.

2.18 Main pump and water switch seal





#

Function description:

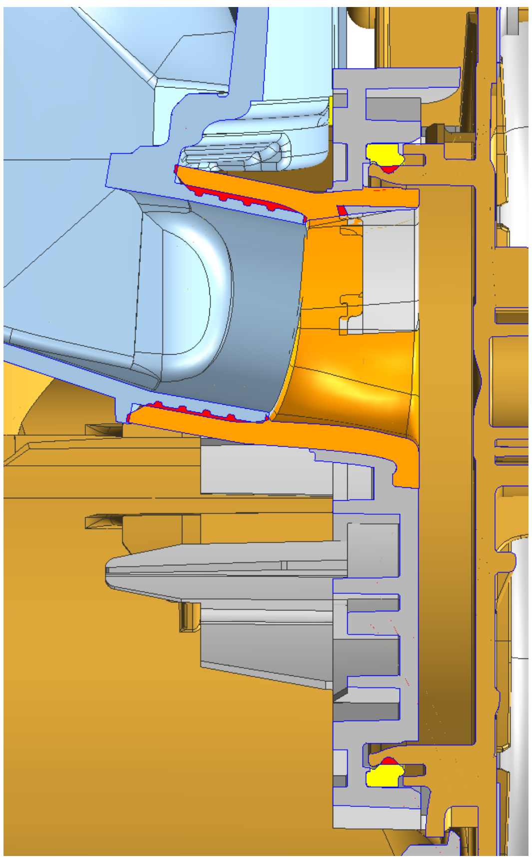
It is the sealing between the water switch and the main pump. Normally they fit very well but a clamp is added for a major security. The sealing is a TPE one molded with the PP part of the water switch. The sealing rings into the TPE hose ensure a fit sealing and without leakages.

Section view:

Specifications:

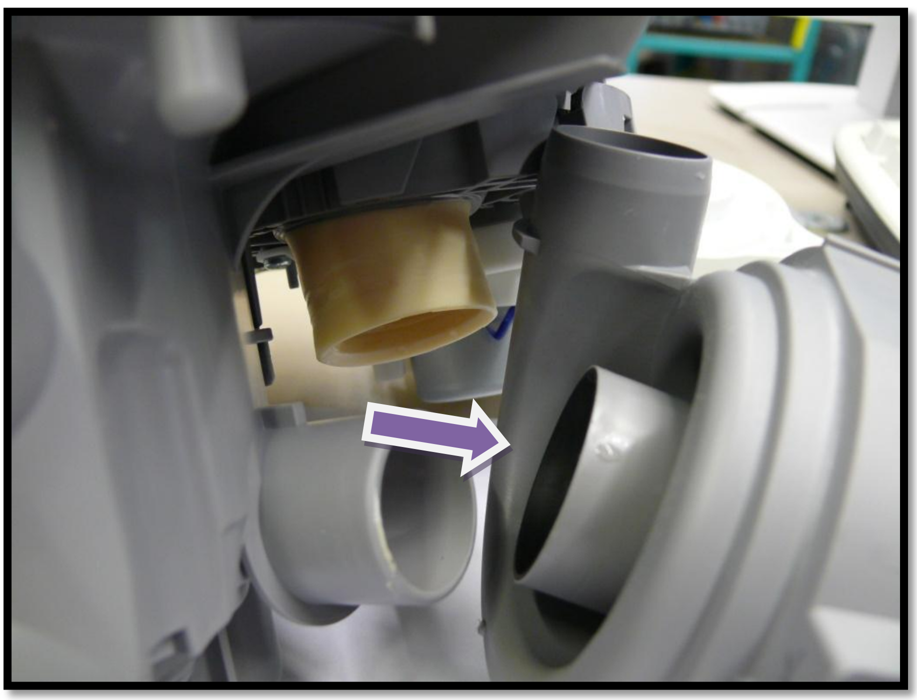
Main pump and water switch seal	
Shore Hardness A	79±5
Lubricant	………………………………………
Torque	………………………………………
Material	TPE
Water/Air	Water
Temperature(°C)	70°C max
Type	Radial
Weight	12g

Observations:



There are test increasing the pressure from 0´2bar to 1 or 1´2bar. In this final moment leakages appear. So if there is a leakage before 1bar, then this sealing does not have the required conditions.

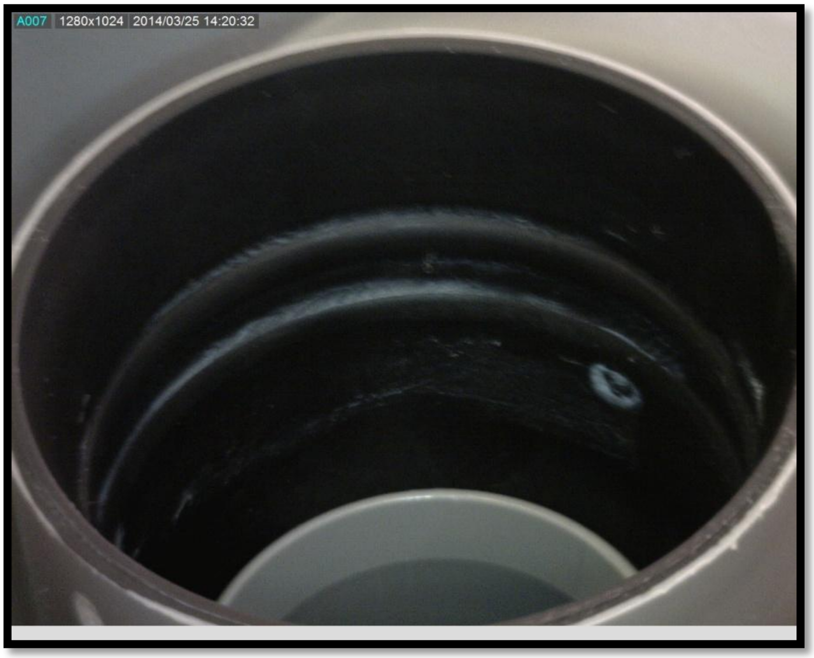
2.19 Main pump and sump seal



Function description:

It is the sealing between the sump and the main pump and assure a close-fitting seal for water leakages.

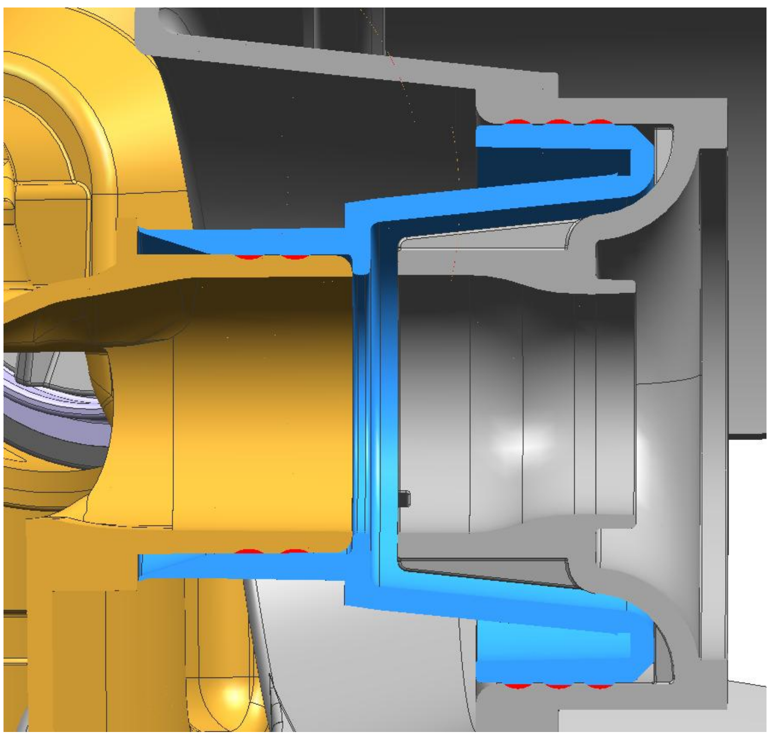
Section view:



Specifications:

Main pump and sump seal	
Shore Hardness A	55±5
Lubricant	Promol
Torque	………………………………………
Material	EPDM
Water/Air	Water
Temperature(°C)	75-80°C max
Type	Radial
Weight	Not specified → Directly molded

Observations:



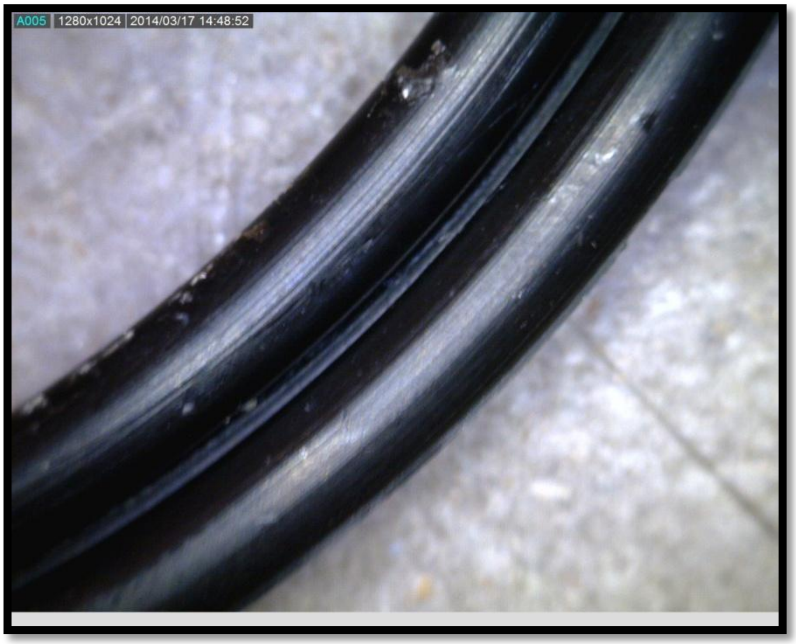
The sealing is very important in order to not permit the entrance of air, which can produce steam, noise and vibrations. Inside the main pump, water runs around the rotor and avoids having boiling water due to friction.

2.20 Main pump heat system seal

Function description:

This sealing from the main pump heat system prevents the water to escape to the surroundings so water can be canalized and heated to the water switch without leakages.

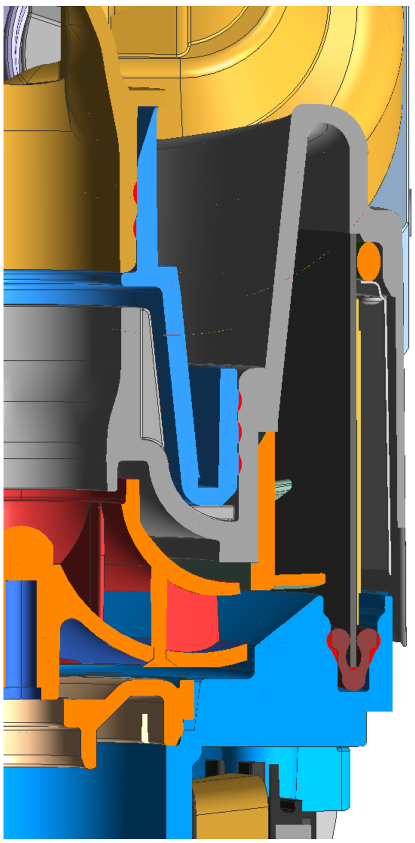
Section view:



Specifications:

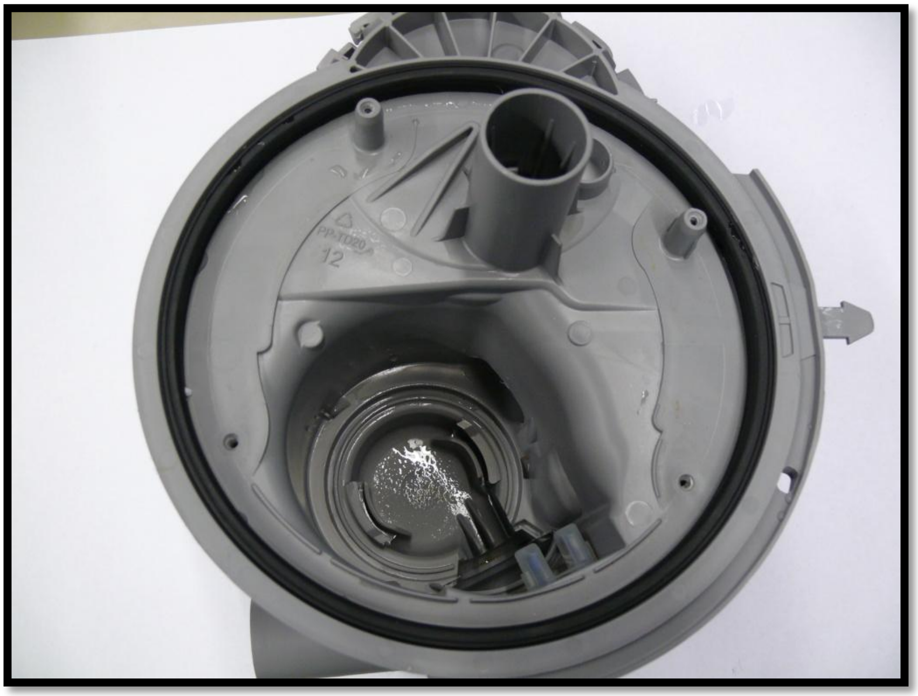
Main pump heat system seal	
Shore Hardness A	50±5
Lubricant	Silicon oil
Torque	…………………………………………
Material	EPDM
Water/Air	Water
Temperature(°C)	80°C max
Type	Radial
Weight	6´7g

Observations:



The heat system is from Stainless Steel (The part without resistances (1-2mm)) so it is not a good heat conductor material. That is the reason why the seal has the water temperature only.

2.21 Sump and tub seal



Function description:

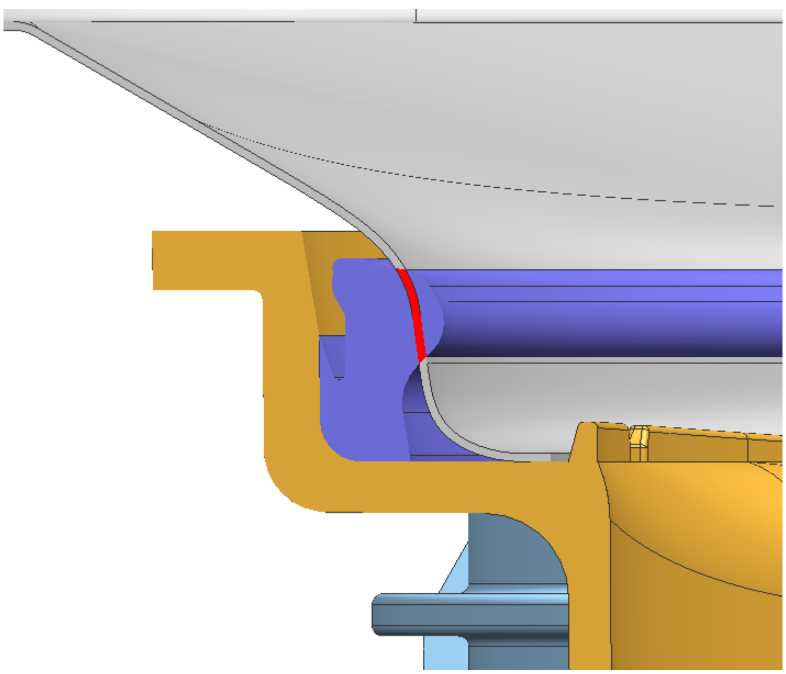
It is one of the most important sealing in a dishwasher. The aim of this molded TPE seal is to not have water leakages between the sump and the tub.

Section view:

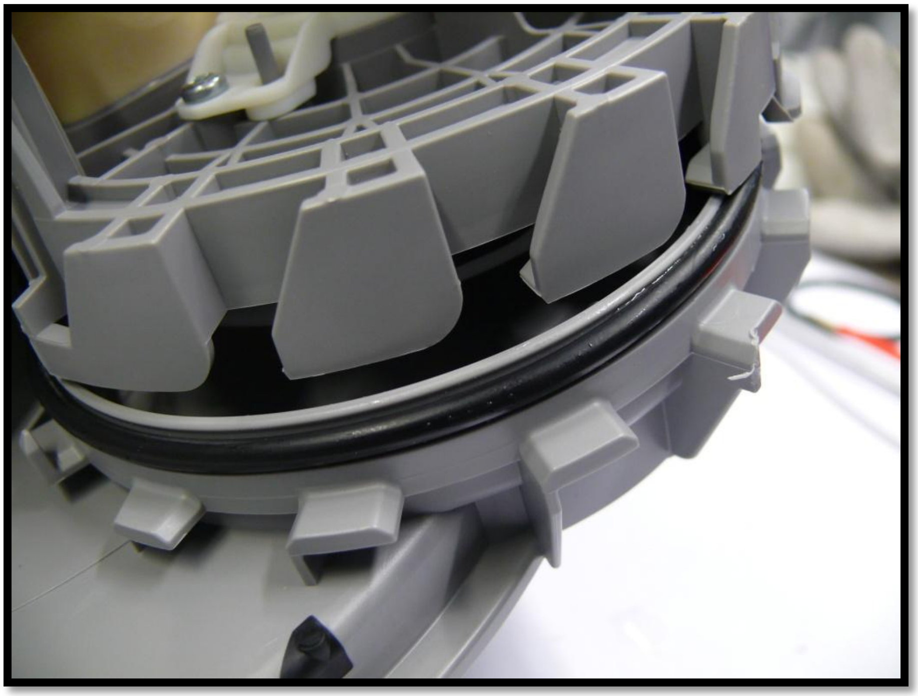
Specifications:

Sump and tub seal	
Shore Hardness A	50±5
Lubricant	Promol
Torque	…………………………………………
Material	TPE (Santoprene)
Water/Air	Water (Dirty)
Temperature(°C)	80°C
Type	Radial
Weight	21´97g

Observations:



2.22 Water switch seal (O-ring)



Function description:

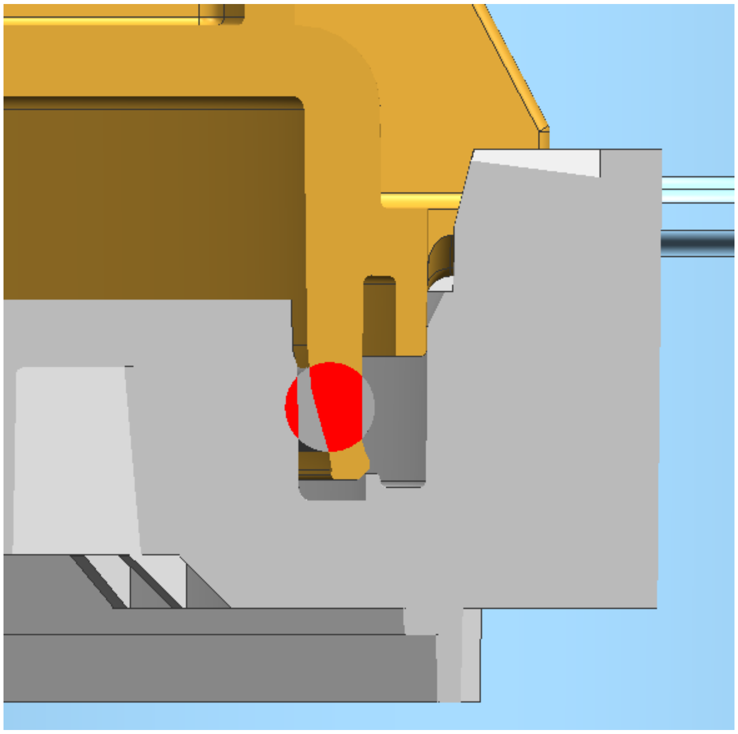
The target of the water switch seal is to not permit leakages and also to not allow to the water switch piece bending. This is the reason of the modification of 0´1mm in the radio of the water switch, which is forming a little stair. The seal´s molding has to be centered and without ribs for a perfect performance.

Section view:

Specifications:

Water switch seal	
Shore Hardness A	70±5
Lubricant	Promol
Torque	65Ncm
Material	NBR
Water/Air	Water
Temperature(°C)	70°C max
Type	Radial
Weight	3 gr

Observations:



A new half moon shaped seal has been tested, which has only two punctual points of pressure and it is better because less force is needed to deform it. However, the difficult assembly makes impossible the change. The molding of the seal has to be perfect to do not have leakages.

2.23 Zeolith heat system seals

Function description:

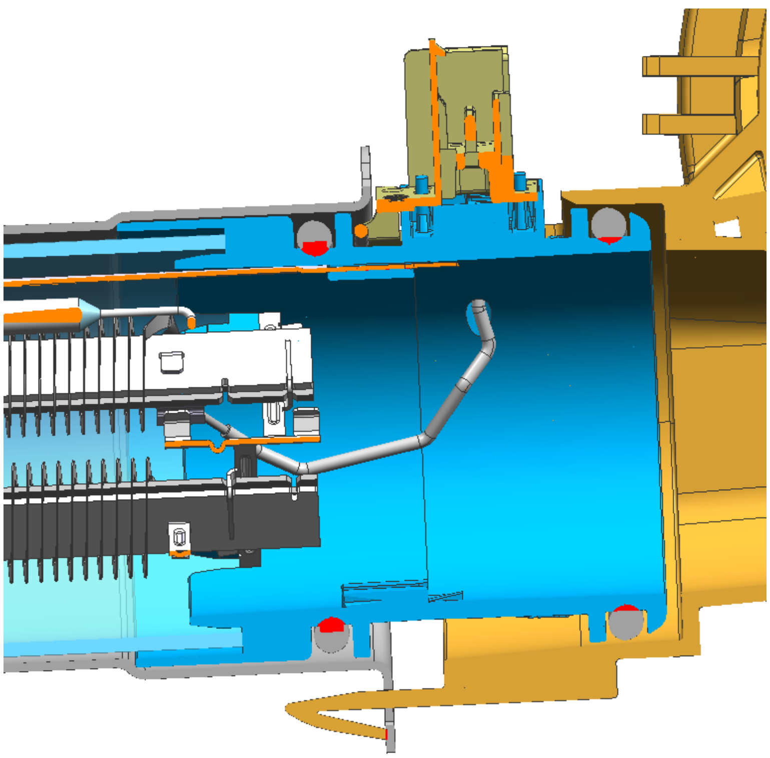
This pair of seals are situated between the heat system and the Zeolith box and between the heat system and the Zeolith fan. His function is to seal the heat system in order to do not let escape the air (or do not let enter cold air from the ambient). Everything has to do with the efficiency.

Section view:

Specifications:

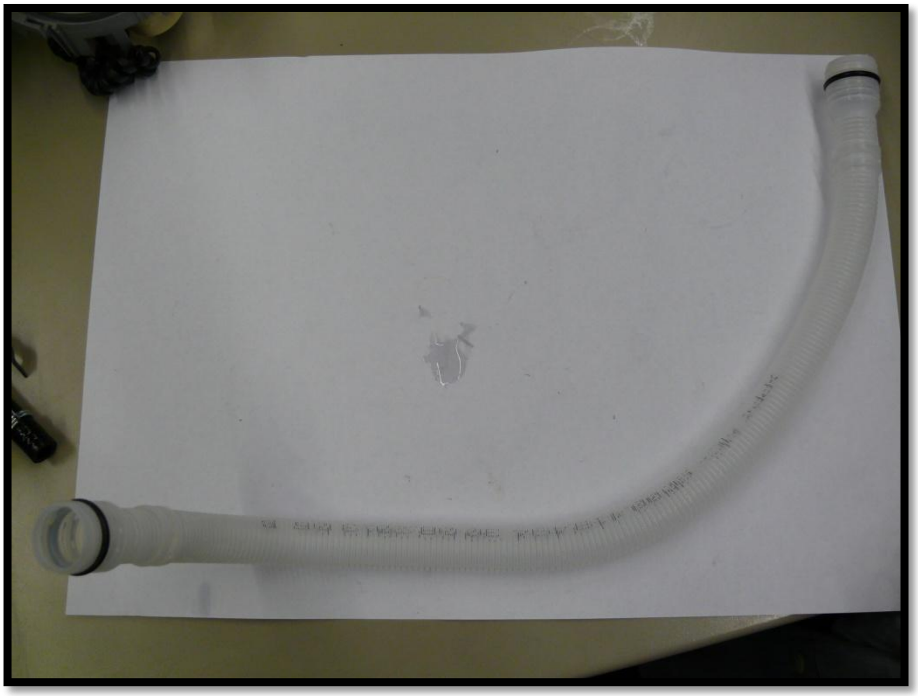
Zeolith heat system seals	
Shore Hardness A	50±5
Lubricant	Silicon oil
Torque	………………………………………
Material	EPDM
Water/Air	Air
Temperature(°C)	50-60°C / 100°C
Type	Radial
Weight	2´2g (x2)

Observations:



The two seals are identical and have the same dimensions for the easy assembly. It is a compromise between efficiency and assembly.

2.24 Drain hose seals (O-ring)



Function description:

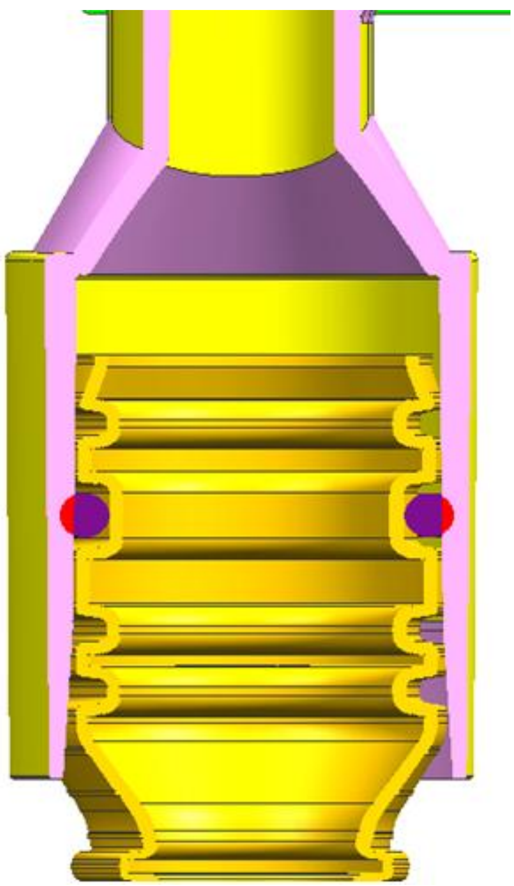
This hose comes from the drain pump to the heat exchanger and his function is to transport the dirty water from the sump.

Section view:

Specifications:

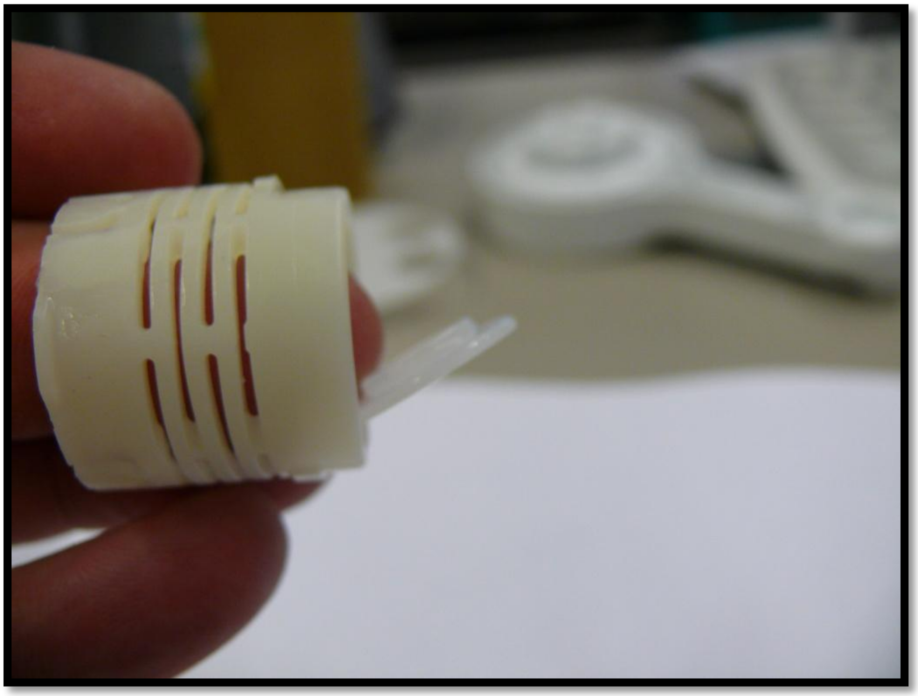
Drain hose seals	
Shore Hardness A	70±5
Lubricant	Promol
Torque	……………………………………….
Material	NBR
Water/Air	Water (Dirty)
Temperature(°C)	70°C max
Type	Radial
Weight	0´6g (x2)

Observations:



The density of the material is 1´24g/cm³. The tests on worse conditions are for 2bar, 5 minutes and 70°C.

2.25 Drain check valve seal



Function description:

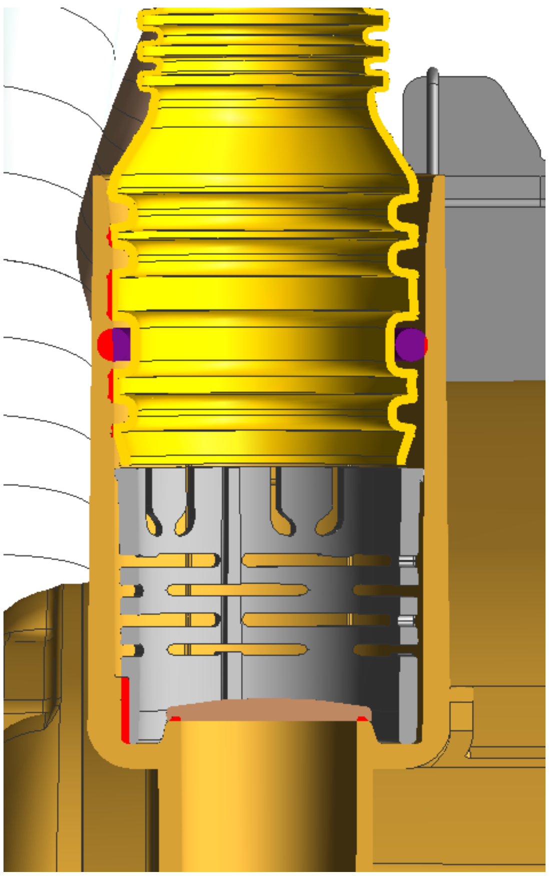
It is a non-return valve and his aim is to do not let the dirty water to come into the drain pump once the water is in the drain hose. Tests discovered that the valve was bending so in the new ones, a circle has been added to be stabilized.

Section view:

Specifications:

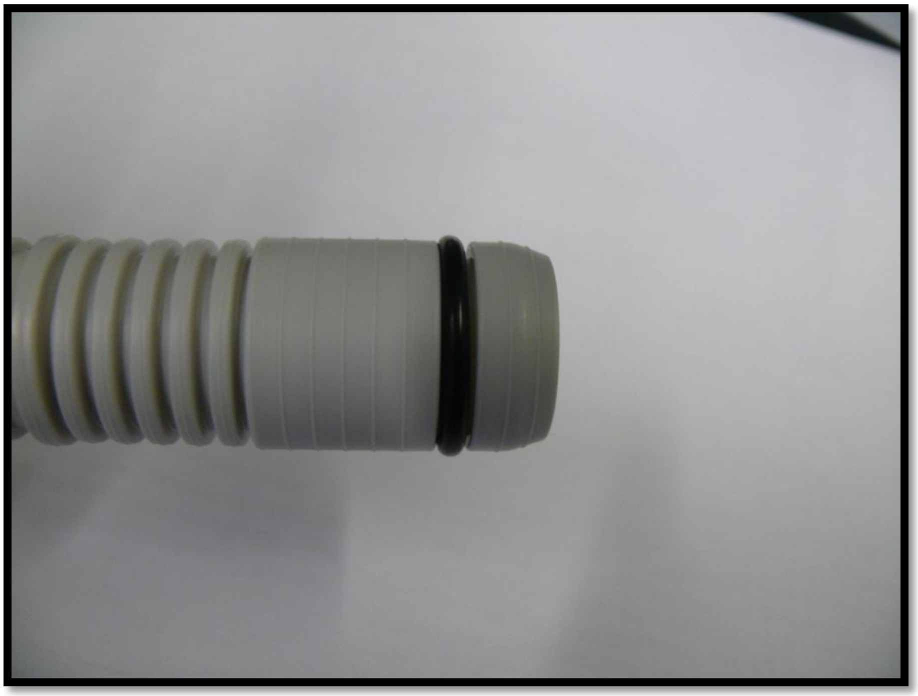
Drain check valve seal	
Shore Hardness A	50±5
Lubricant	………………………………………
Torque	………………………………………
Material	Fluid Silicone (Wacker Elastosil)
Water/Air	Water (Dirty)
Temperature(°C)	70°C max
Type	Axial
Weight	3´7g

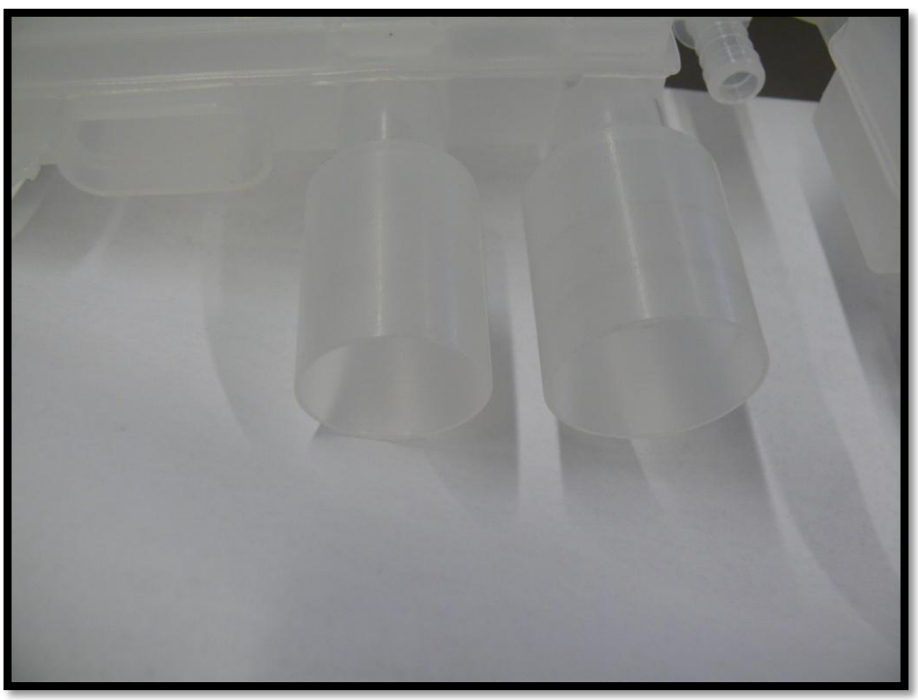
Observations:



The drain check valve seal works only with water pressure.

2.26 Seal outlet bellows





Function description:

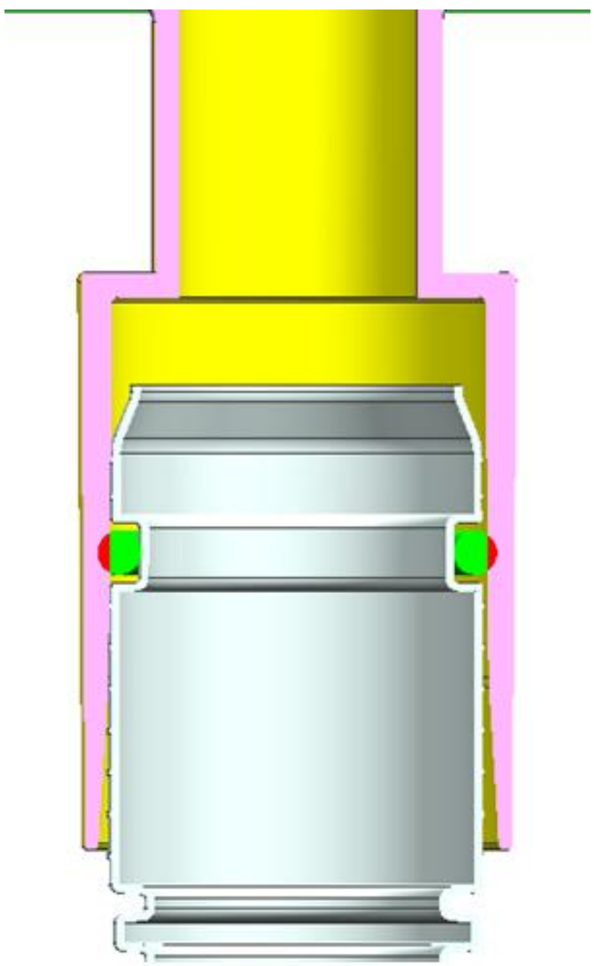
This hose comes from the heat exchanger to the installation and his function is to transport the dirty water out of the dishwasher.

Section view:

Specifications:

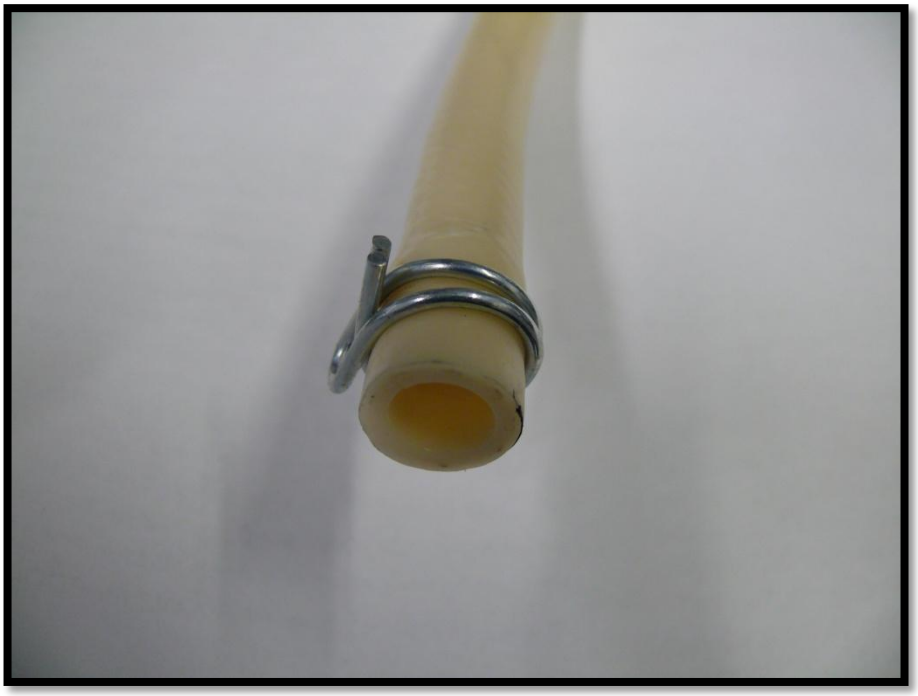
Seal outlet bellows	
Shore Hardness A	70±5
Lubricant	Promol
Torque	……………………………………
Material	NBR
Water/Air	Water (Dirty)
Temperature(°C)	70°C max
Type	Radial
Weight	0´6g

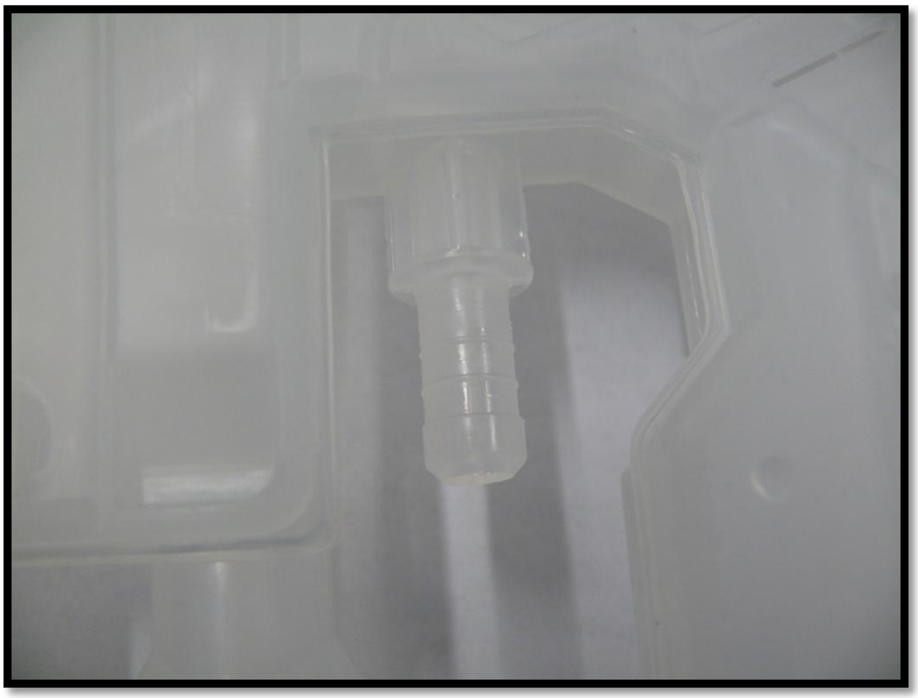
Observations:



The density of the material is 1´24g/cm³. The tests on worse conditions are for 2bar, 5 minutes and 70°C.

2.27 Seal aquastop

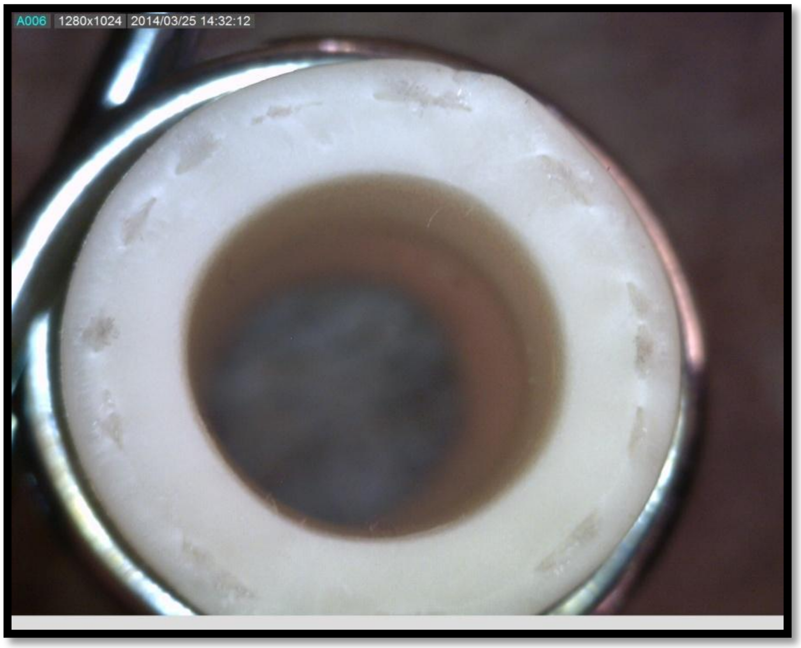


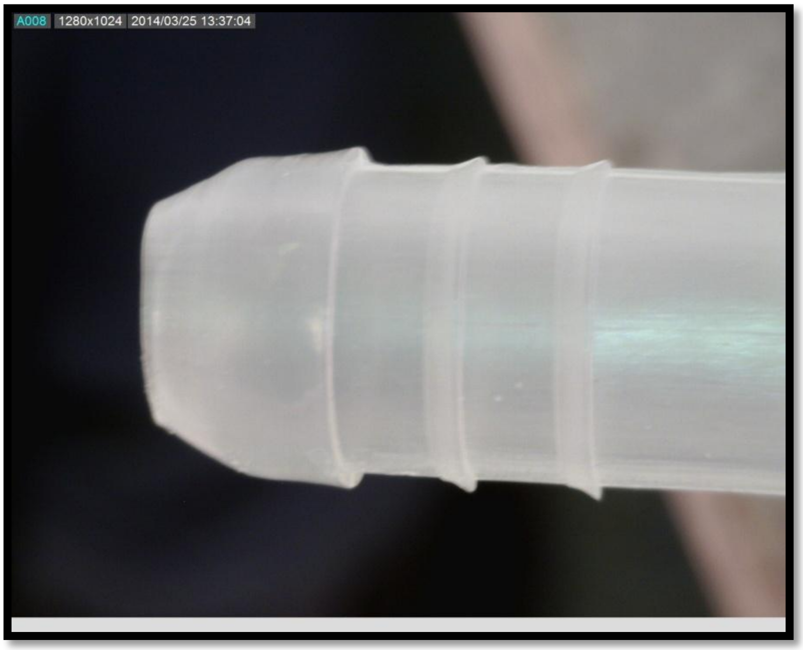


Function description:

This hose comes from aquastop to the heat exchanger and his function is to transport the clean water from the installation to the dishwasher.

Section view:

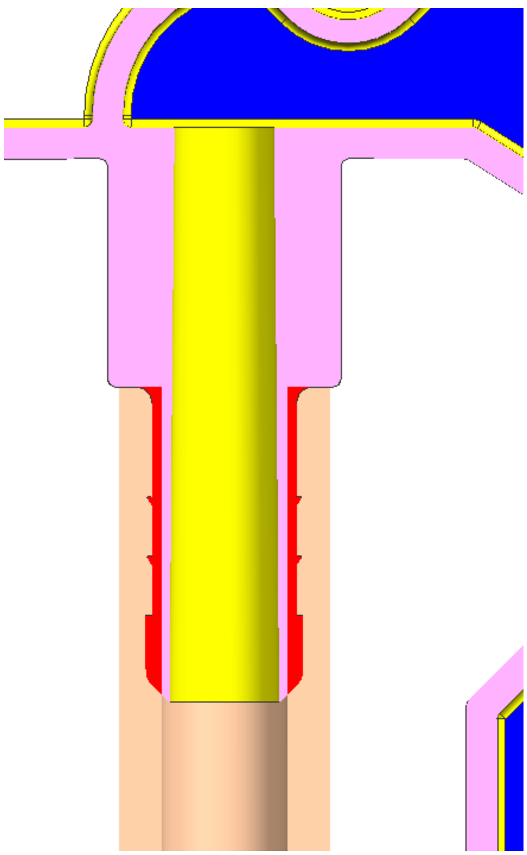




Specifications:

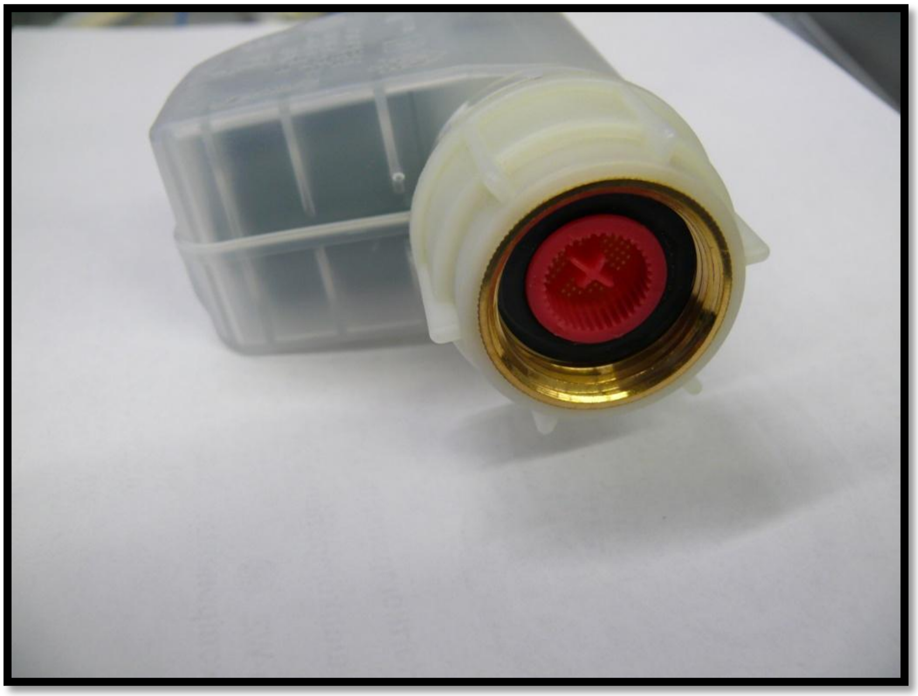
Seal aquastop	
Shore Hardness A	80±5
Lubricant	Promol
Torque	………………………………………
Material	PVC to PP
Water/Air	Water (Fresh)
Temperature(°C)	70°C max
Type	Radial
Weight	233,9g

Observations:



The density of the material is 1´35g/cm³. The clamp has not a sealing function but a safety one. The ideal pressure in the hose would be 1´5-2 bar (estimated value).

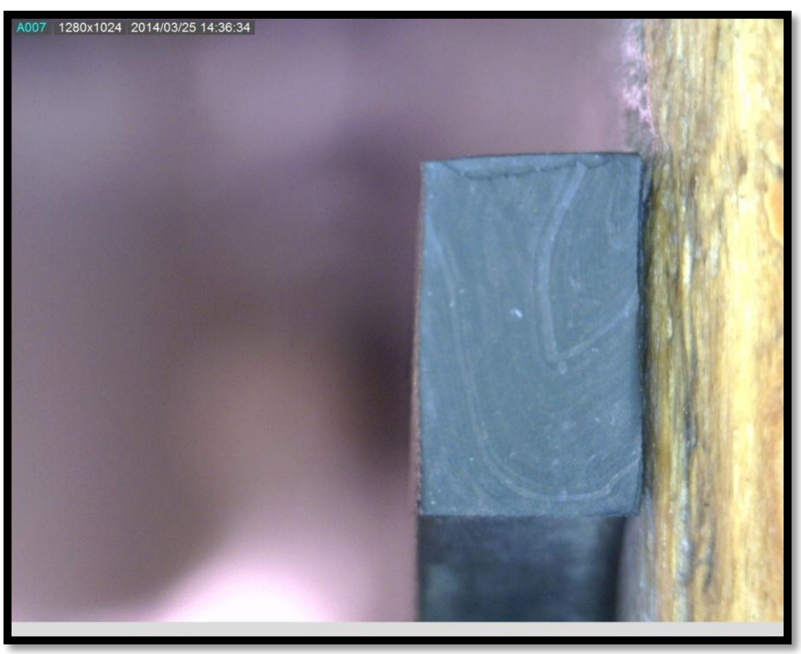
2.28 Aquastop valve seal



Function description:

The aquastop valve seal is a security system between the installation and the dishwasher. In some dishwashers this valve is already in the basic carrier so there is not such security. It also controls the amount of water that comes into the dishwasher.

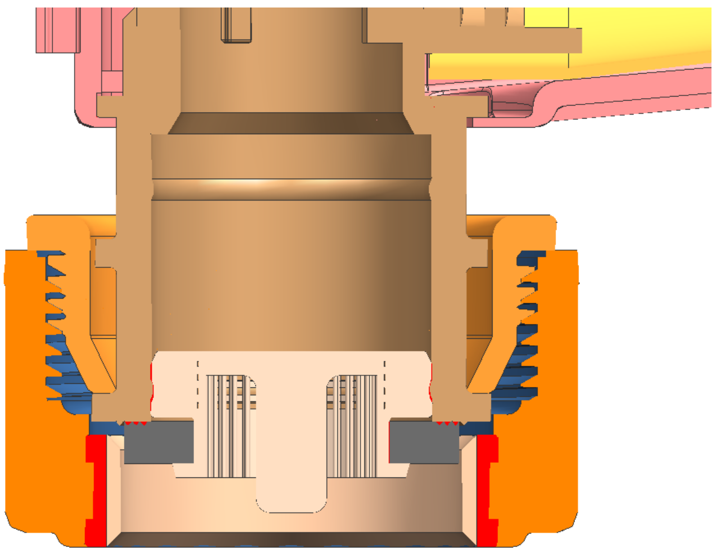
Section view:



Specifications:

Aquastop valve seal	
Shore Hardness A	70±5
Lubricant	Promol
Torque	....
Material	EPDM
Water/Air	Water (Fresh)
Temperature(°C)	70°C max
Type	Axial
Weight	0´8g

Observations:



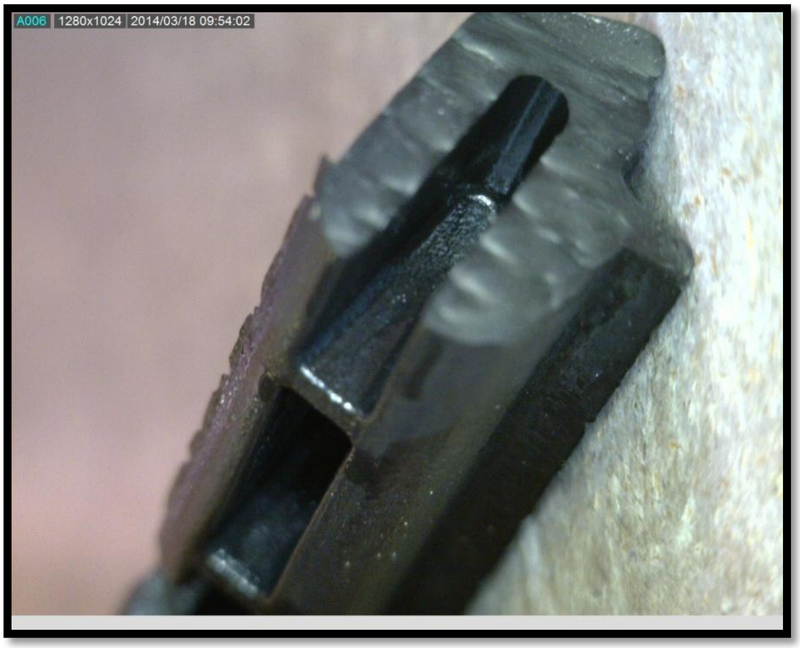
The density of the material is 1´12g/cm³. The tests on worse conditions are for 60bar and 5 minutes. The seal´s surface has little grooves to have less contact surface and more pressure (P=F/A).

2.29 Seal dispenser

Function description:

The seal dispenser protects the displays and control parts from the water. It produces the certainty that water never comes into the door and do not have leakages.

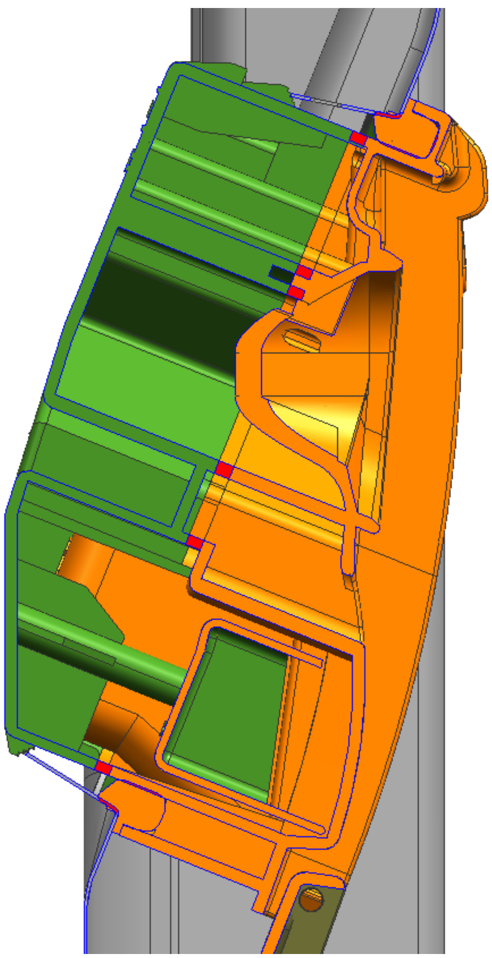
Section view:



Specifications:

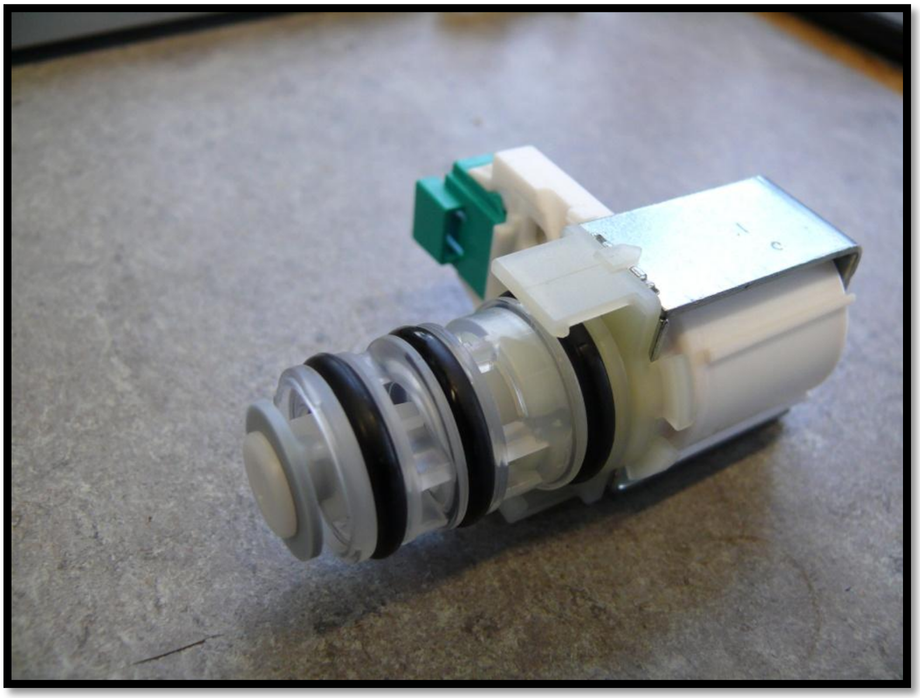
Seal dispenser	
Shore Hardness A	50±5
Lubricant	Promol
Torque	………………………………………
Material	EPDM
Water/Air	Air
Temperature(°C)	70°C max
Type	Axial and radial combined
Weight	13´5g

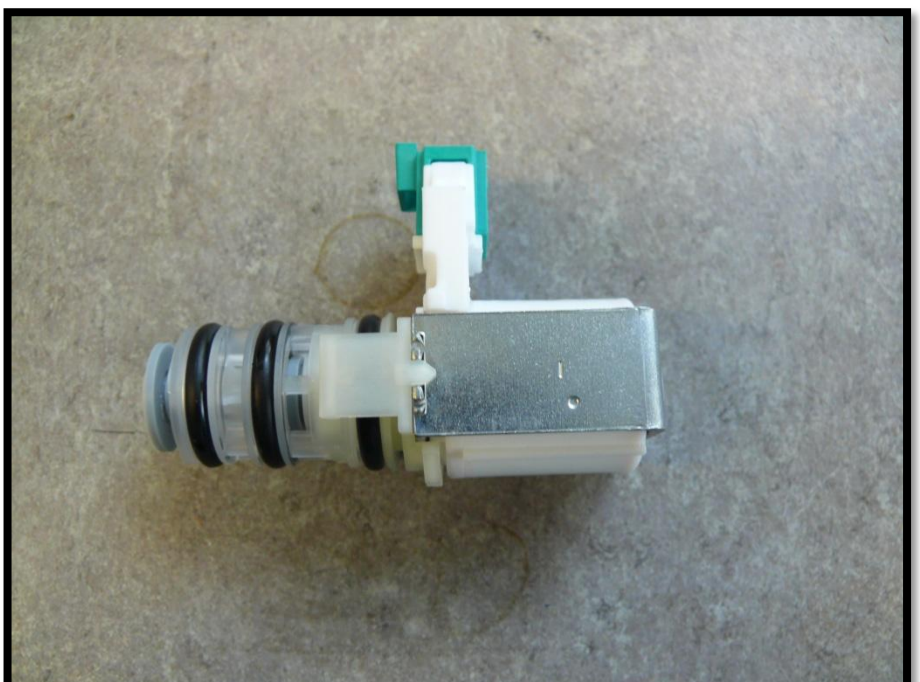
Observations:



The dispenser is introduced into the dishwasher´s door in the assembly line with a force of 1200N.

2.30 Regeneration valve seal





Function description:

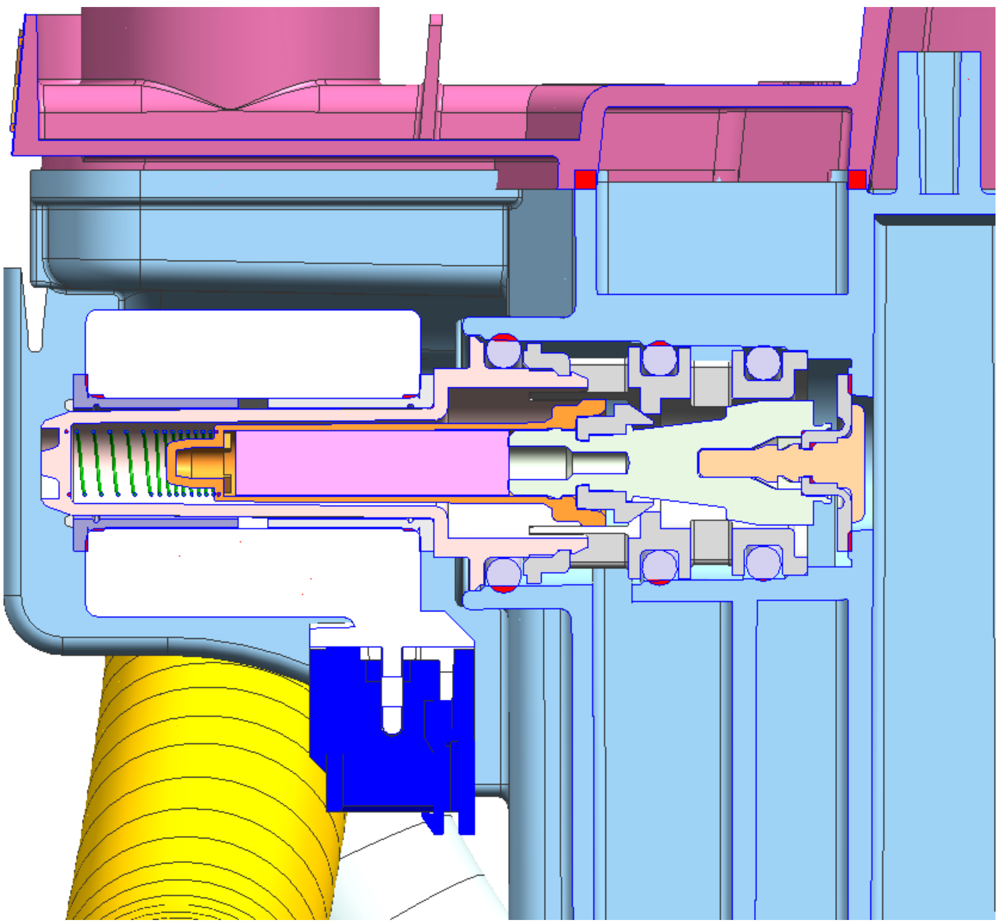
The purpose of this seals is to create different channels for the water depending of the valve position. This seals avoid the water to pass from one channel to another and avoid having leakages to the outside.

Section view:

Specifications:

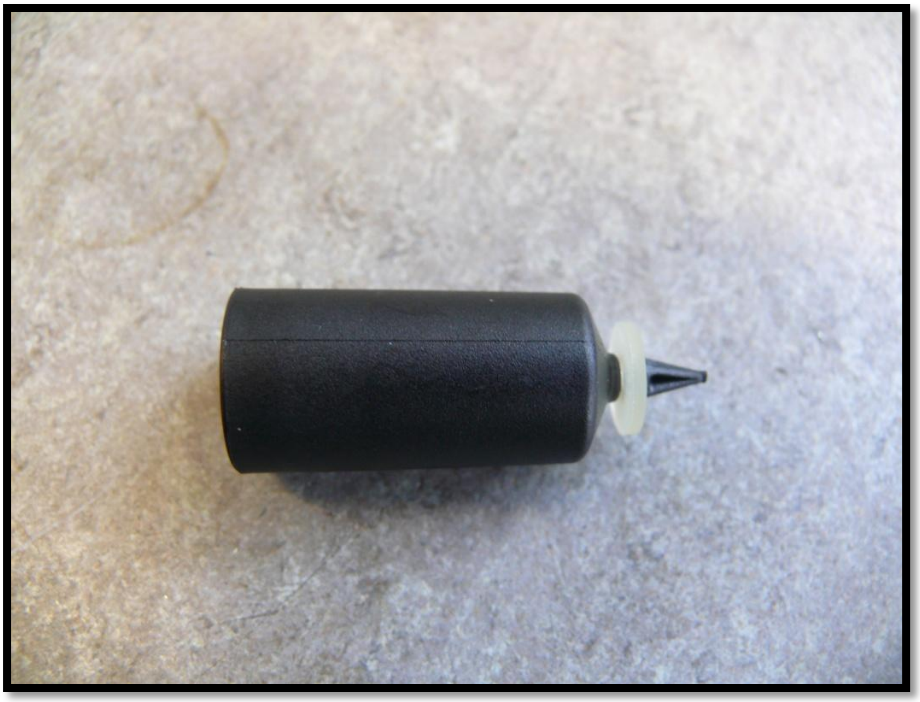
Regeneration valve		
Shore Hardness A	60±5	30±5
Lubricant	Promol/Water	Promol/Water
Torque	…………………………………….	…………………………………….
Material	EPDM	Silicone
Water/Air	Water (Fresh)	Water (Fresh)
Temperature(°C)	It depends on the customer	It depends on the customer
Type	Radial	Axial
Weight	0´5g (x3)	0´5g

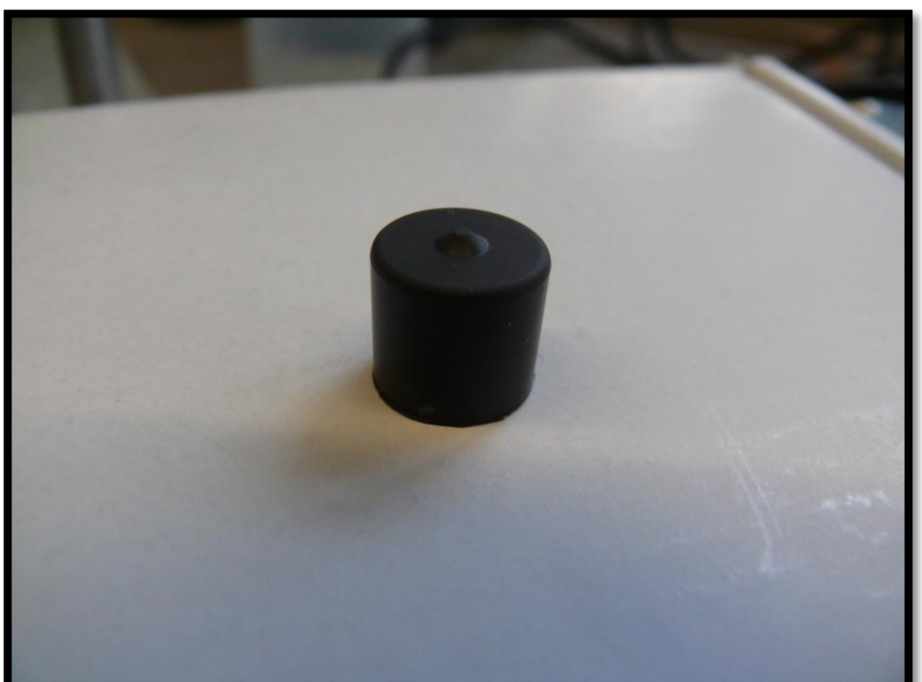
Observations:



The pressure varies from 5% until 30% in the radial seals. The first o-ring has the lowest pressure: 5%; the second: 10-15%; and the third is the most important because avoids the water to go out of the dishwasher: 30%. The first column represents the radial o-rings and the second the axial seals.

2.31 Ventilation valve seal

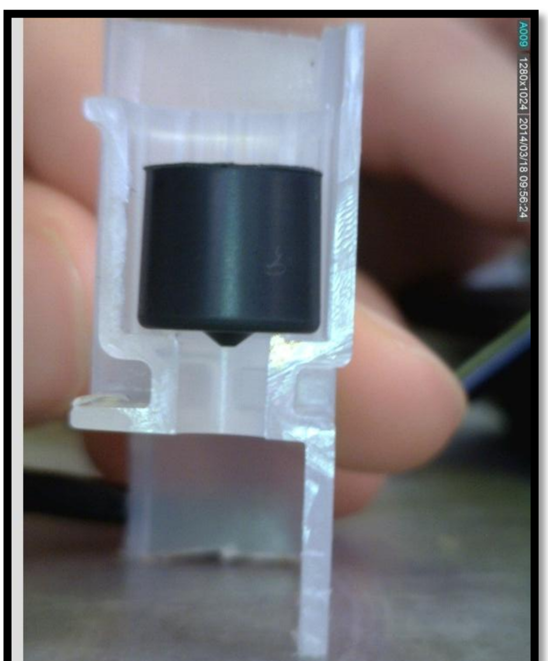




Function description:

This valve seal is used to stop the progress of water when the drain pump turns off. When the valve is open, the air can go through and cut the passage of water.
There are different types of ventilation valve depending on the hole´s position (up and down) and if the cavity is filled with air or water.

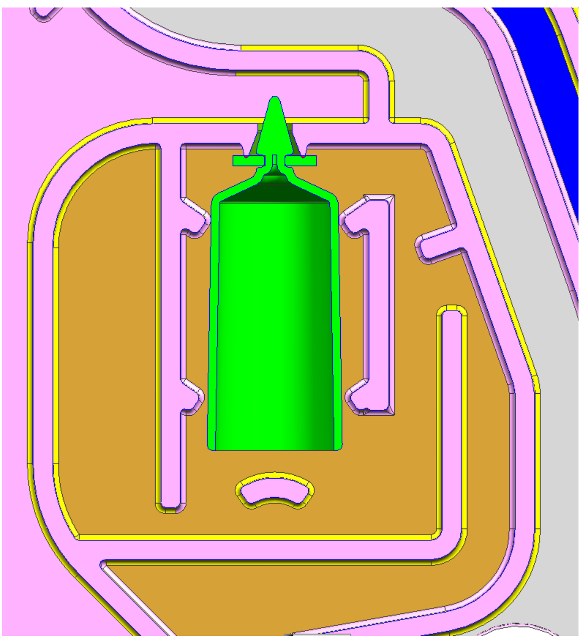
Section view:

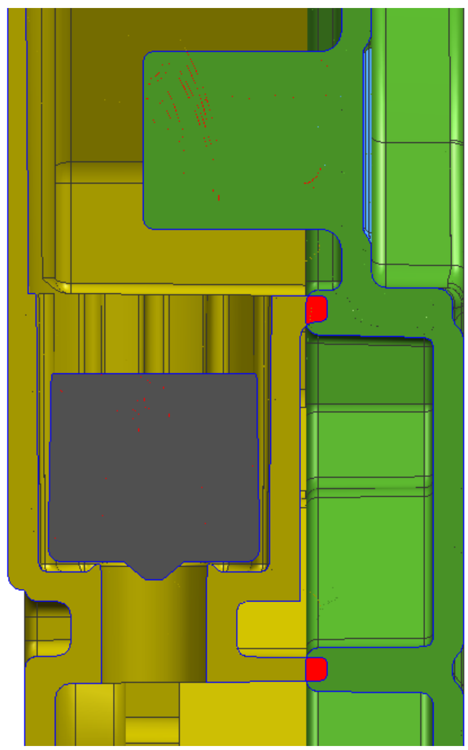


Specifications:

Ventilation valve		
Shore Hardness A	50±5	40±5
Lubricant	………………………………………	……………………………………..
Torque	………………………………………	……………………………………..
Material	Fluid Silicone	Fluid Silicone
Water/Air	Air	Water (Fresh)
Temperature(°C)	20-50°C	20-50°C
Type	Axial	Axial
Weight	0´7g	1´8g

Observations:





A high weight would be better referring to the sealing but it does not compensate thinking about money. The first column refers to 640A and the second to 640B.

3. Pressure calculations for the seals (With the interference).

With the characteristics and specifications review of the seals done, it can be said that there is a property which is the most important one in order to have sealing and not have leakages. This property is the pressure the seal is submitted to. This pressure depends on many factors such as dimensions, tolerances, torque, forces (distribution of forces), mechanical stops, materials and geometries.

The pressure can be expressed by different forms like in N/m^2 (Pa), percentage, interference… In this section it is analyzed especially the interference between pieces and all the dimensions and tolerances which can be seen are expressed in millimeters (mm).

The first calculations that are done express the diametric interference but then, they are refined to radial interference which shows more conveniently the pressure idea.

Below, the seals are going to be analyzed separated in radial ones and axial ones depending on how and in what direction the force is done. This is because they are very different on the way to calculate one from the others. Nevertheless, there are some seals that do not have totally a sealing function so they will be not analyzed.

The radial seals can be easily calculated by a current axis-hole method with the aid of the theoretical drawings and its dimensions and tolerances.

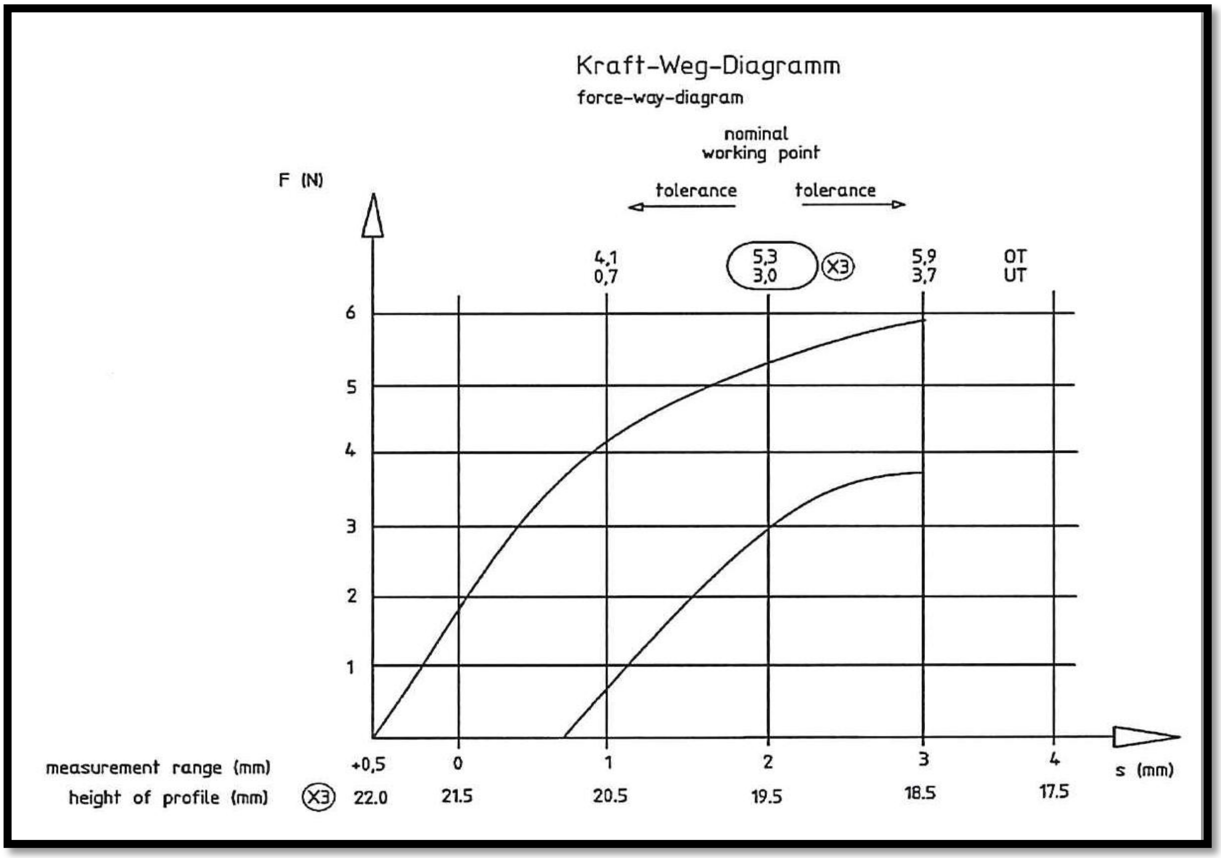
However, the axial seals are very complicated to calculate because all the factors above described are now involved. Is for this reason that the normal calculation makes almost impossible and a simulation process needs to be made in order to achieve the target. This is very costly in time so a unique sealing will be analyzed in detail and the others will have the same procedure but with different refinements.

AXIAL

RADIAL

3.1 RADIAL

Door seal

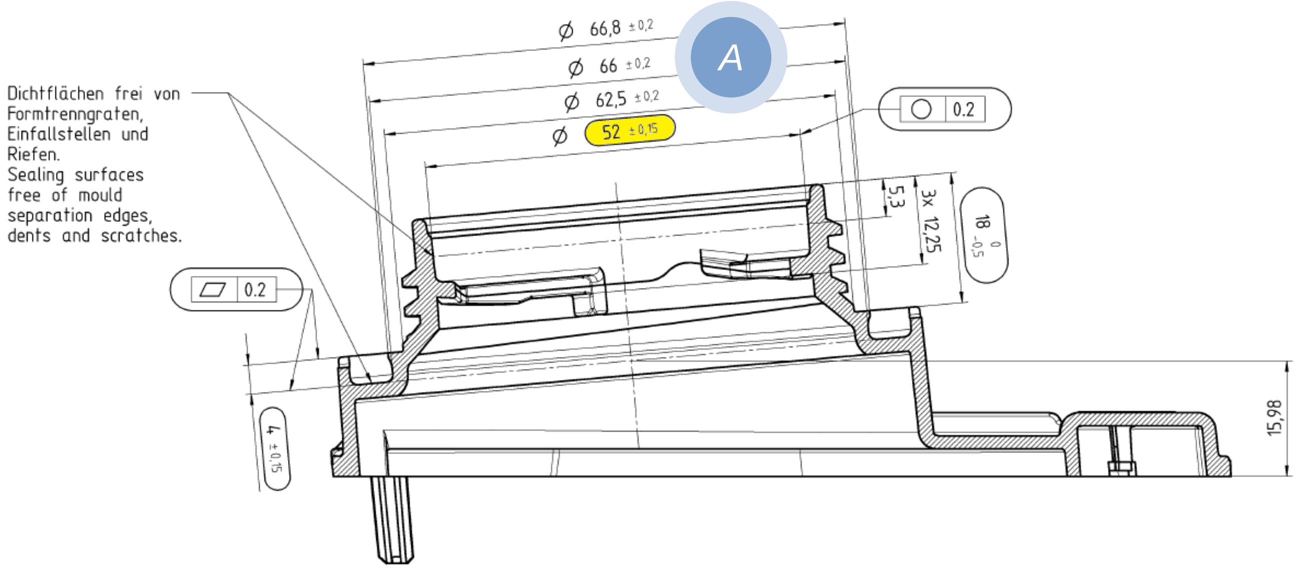


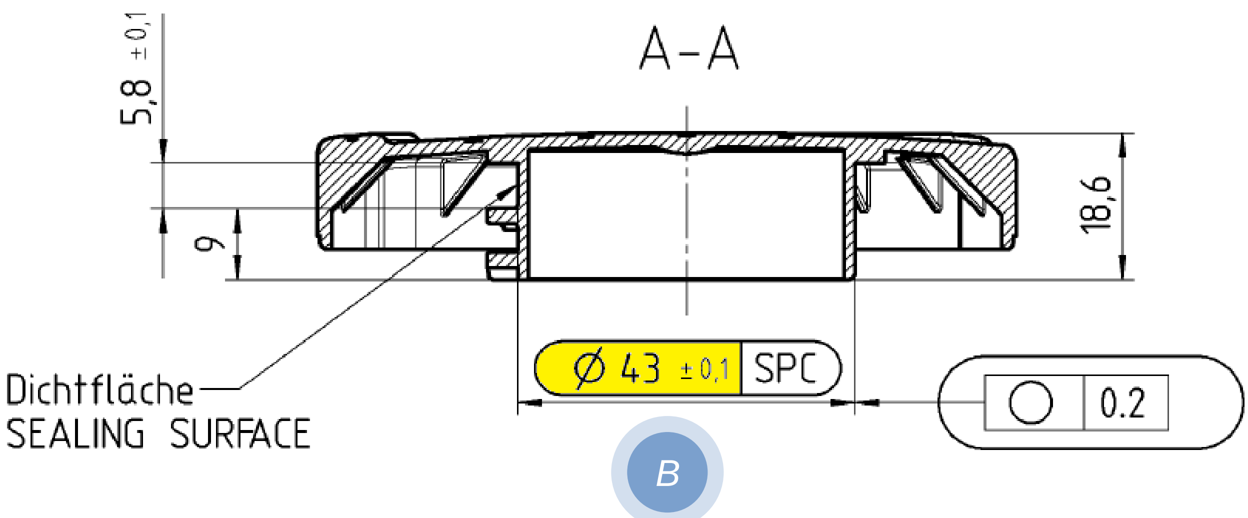
The door seal is very difficult to calculate by hand due to the hard and complex geometry, so every type of door sealing of each dishwasher variation has a determined curve based on test and on life-long experiences where the relationship force-way can be seen in the diagram above.

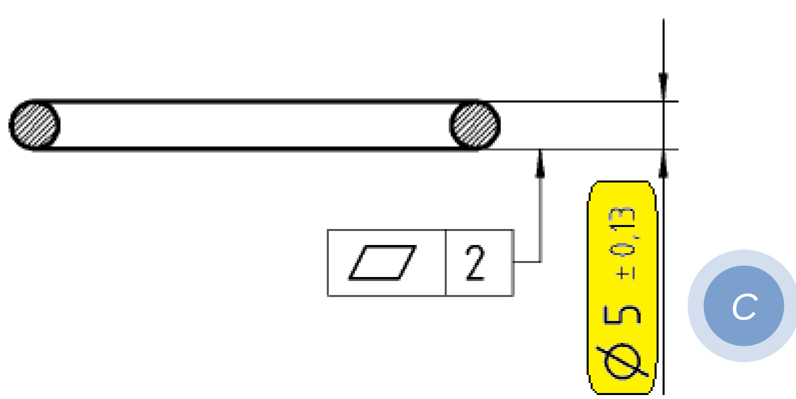
The diagram shows a range of values (maximum and minimum) and the test values do not have to overpass them in order to have a correct behaviour on the sealing zone.

In this case, the dishwasher GV640 has been taken as an example and it is possible to see that the nominal working point is about 3 to 5´3 N of force and 2 mm of way (estimation) .

Water softener tap seal







PRESSURE WITHOUT TOLERANCES

52 – 43 – 2 x 5 = -1 →Radial:-1/2 = -0´5

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

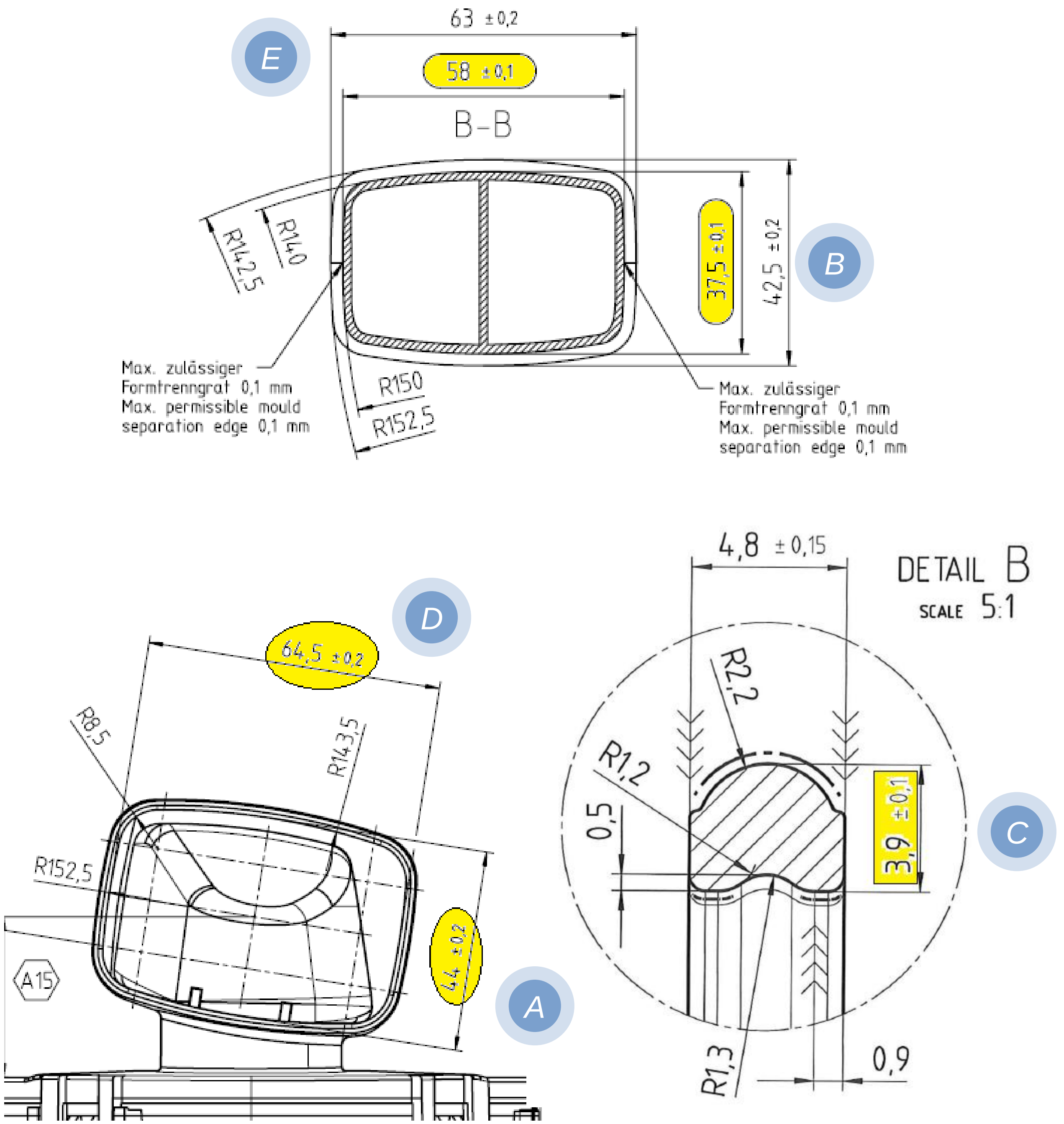
A min
B max
C max } A min – B max – 2C max→51´85 – 43´1 – 2 x 5´13= -1´51→Radial:-1´51/2= -0´755

MINIMUM PRESSURE

A max
B min
C min } A max – B min – 2C min→52´15 – 42´9 – 2 x 4´87= -0´49→Radial:-0´49/2 = -0´245

Zeolith fan seal.

a) Actual



BREADTHWAYS:

PRESSURE WITHOUT TOLERANCES

44 – 37´5 – 2 x 3´9 = -1´3 →Radial: -1´3/2 = -0´65

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

A min.
B max.
C max.
} A min – B max – 2C max → 43´8 – 37´6 – 2 x 4 = -1´8 →Radial: -1´8/2 = -0´9

MINIMUM PRESSURE

A max.
B min.
C min.
} A max – B min – 2C min → 44´2 – 37´4 – 2 x 3´8 = -0´8 →Radial: -0´8/2 = -0´4

LENGTHWAYS:

PRESSURE WITHOUT TOLERANCES

64´5 – 58 – 2 x 3´9 = -1´3 →Radial: -1´3/2 = -0´65

PRESSURE WITH TOLERANCES

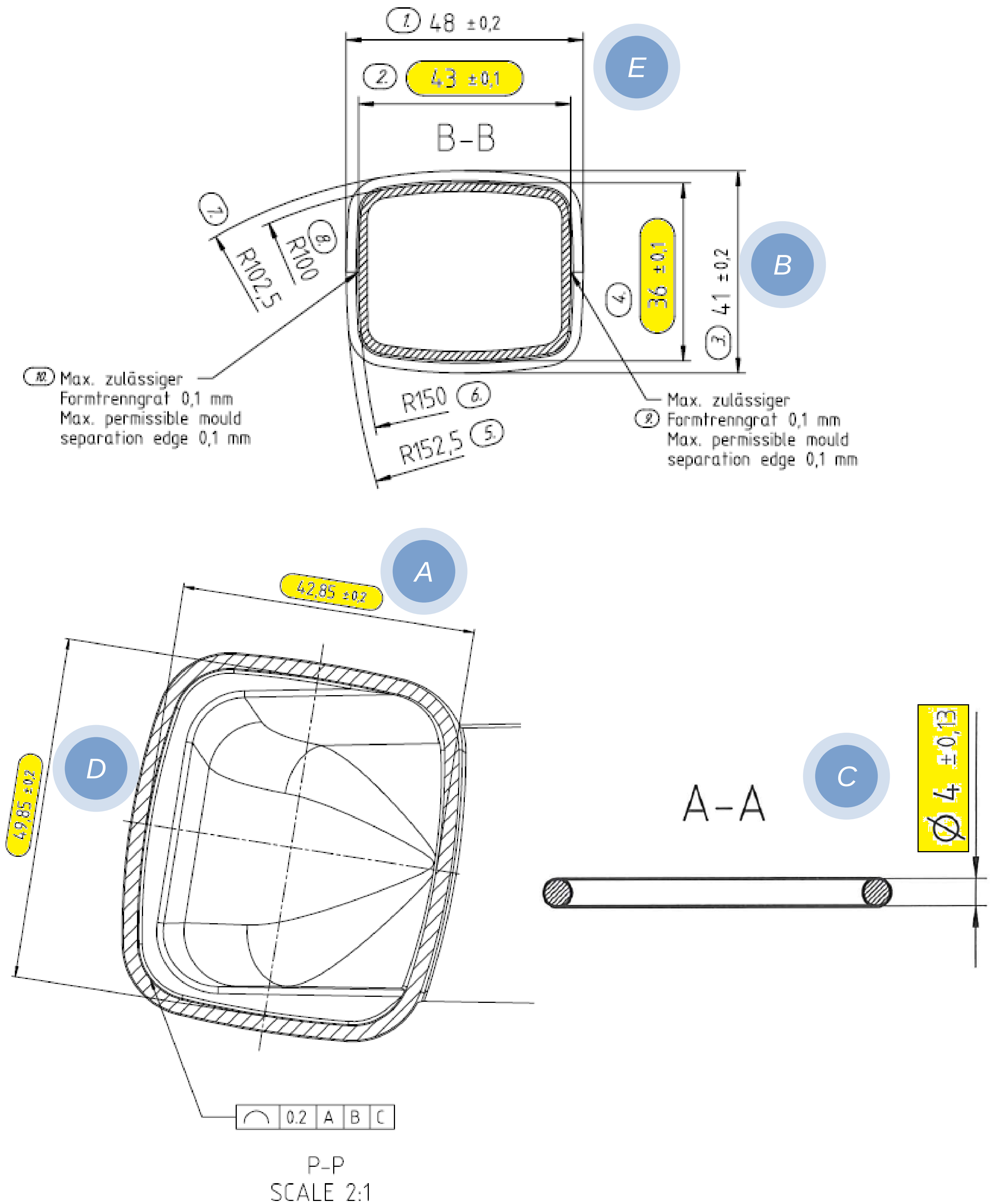
MAXIMUM PRESSURE:

D min.
E max.
C max.
} D min – E max – 2C max → 64´3 – 58´1 – 2 x 4 = -1´8 →Radial: -1´8/2 = -0´9

MINIMUM PRESSURE

D max.
E min.
C min.
} D max – E min – 2C min → 64´7 – 57´9 – 2 x 3´8 = -0´8 →Radial: -0´8/2 = -0´4

b) New


1. 48 ±0,2
2. 43 ±0,1
E
B-B
7. R102,5
8. R100
4. 36 ±0,1
3. 41 ±0,2
B
10. Max. zulässiger Formtrenngrat 0,1 mm Max. permissible mould separation edge 0,1 mm
R150 6.
R152,5 5.
9. Max. zulässiger Formtrenngrat 0,1 mm Max. permissible mould separation edge 0,1 mm
A
42,85 ±0,2
D
49,85 ±0,2
A-A
C
Ø 4 ±0,13
0.2 A B C
P-P
SCALE 2:1

BREADTHWAYS:

PRESSURE WITHOUT TOLERANCES

42´85 – 36 – 2 x 4 = -1´15 →Radial: -1´15/2 = -0´575

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

A min
B max } A min – B max – 2C max→42´65 – 36´1 – 2 x 4´13 = -1´71→Radial:-1´71/2 = -0´885
C max

MINIMUM PRESSURE

A max
B min } A max – B min – 2C min→ 43´05 – 35´9 – 2 x 3´87 = -0´59→Radial:-0´59/2 = -0´295
C min

LENGTHWAYS:

PRESSURE WITHOUT TOLERANCES

49´85 – 43 – 2 x 4 = -1´15 →Radial: -1´15/2 = -0´575

PRESSURE WITH TOLERANCES

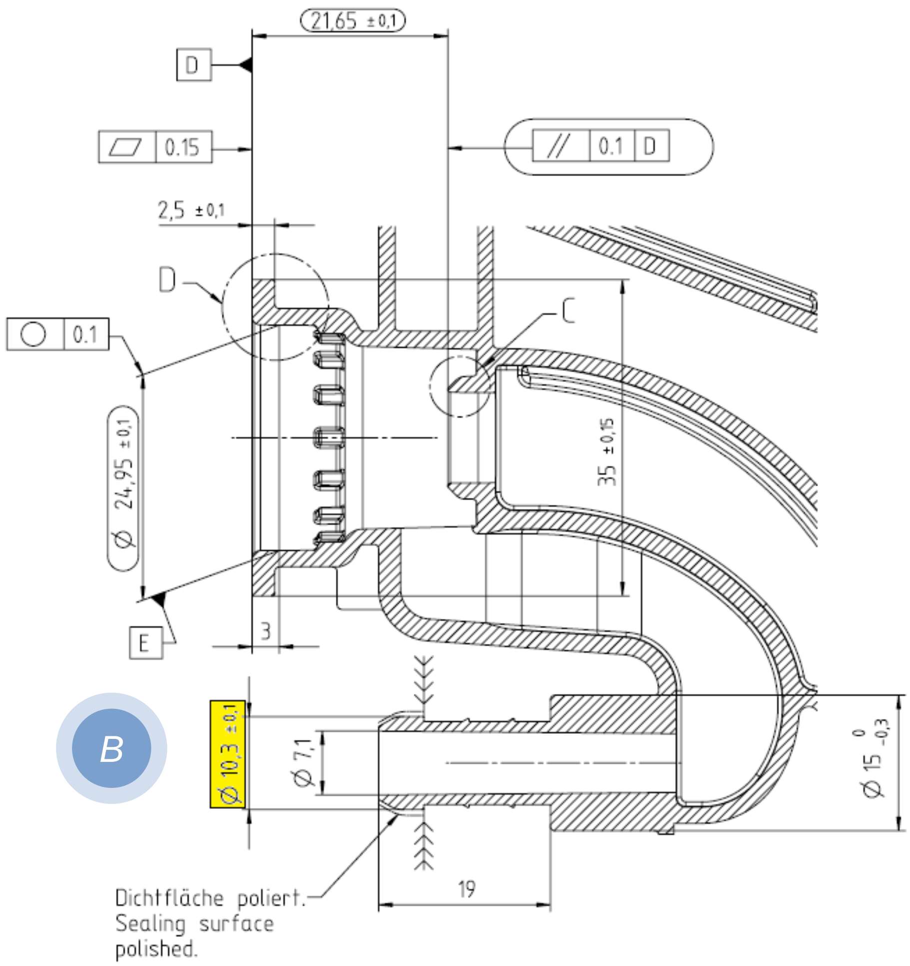
MAXIMUM PRESSURE:

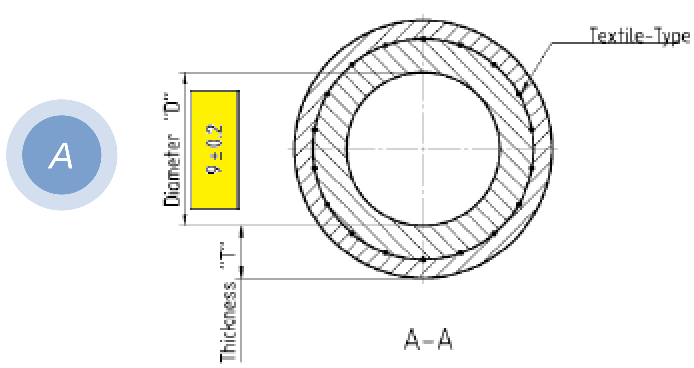
D min
E max } D min – E max – 2C max→49´65 – 43´1 – 2 x 4´13 = -1´71→Radial:-1´71/2 = -0´885
C max

MINIMUM PRESSURE

D max
E min } D max – E min – 2C min→50´05 – 42´9 – 2 x 3´87 = -0´59→Radial:-0´59/2 = -0´295
C min

Water storage hose seal.





PRESSURE WITHOUT TOLERANCES

9 – 10´3 = -1´3 →Radial:-1´3/2 = -0´65

PRESSURE WITH TOLERANCES

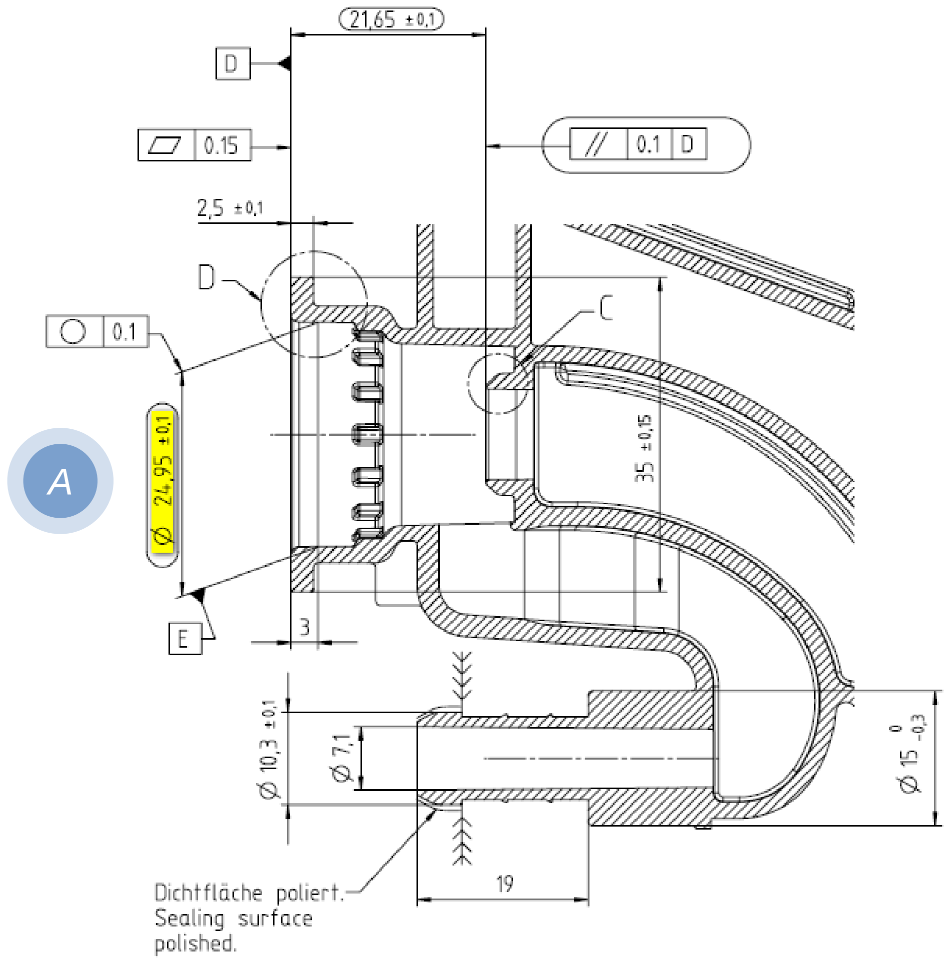
MAXIMUM PRESSURE

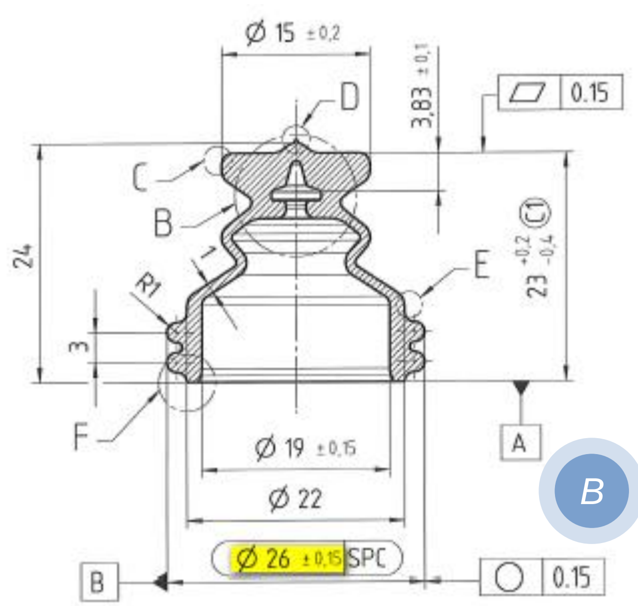
A min
B max
} A min – B max → 8´8 – 10´4 = -1´6 →Radial:-1´6/2 = -0´8

MINIMUM PRESSURE

A max
B min
} A max – B min → 9´2 – 10´2 = -1 →Radial:-1/2 = -0´5

Storage valve seal.





RADIAL COMPONENT:

PRESSURE WITHOUT TOLERANCES

24´95 – 26 = -1´05 →Radial:-1´05/2 = -0´525

PRESSURE WITH TOLERANCES

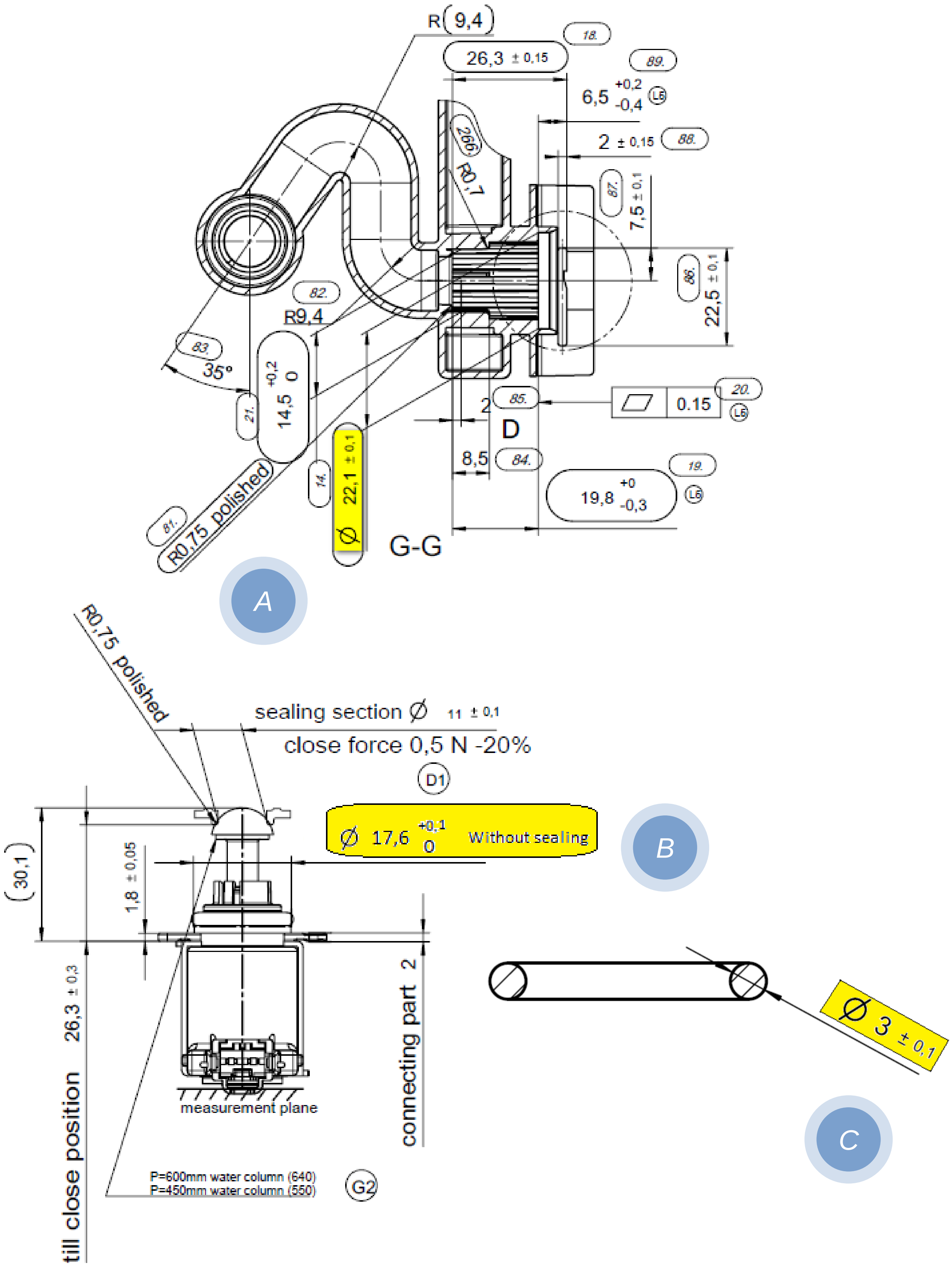
MAXIMUM PRESSURE

A min
B max } A min – B max → 24´85 – 26´15 = -1´3 →Radial:-1´3/2 = -0´65

MINIMUM PRESSURE

A max
B min } A max – B min → 25´05 – 25´85 = -0´8 →Radial:-0´8/2 = -0´4

Heat exchanger valve seal n°1



PRESSURE WITHOUT TOLERANCES

22´1 – 17´6 – 2 x 3 = -1´5 →Radial:-1´5/2 = -0´75

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

A min
B max
C max

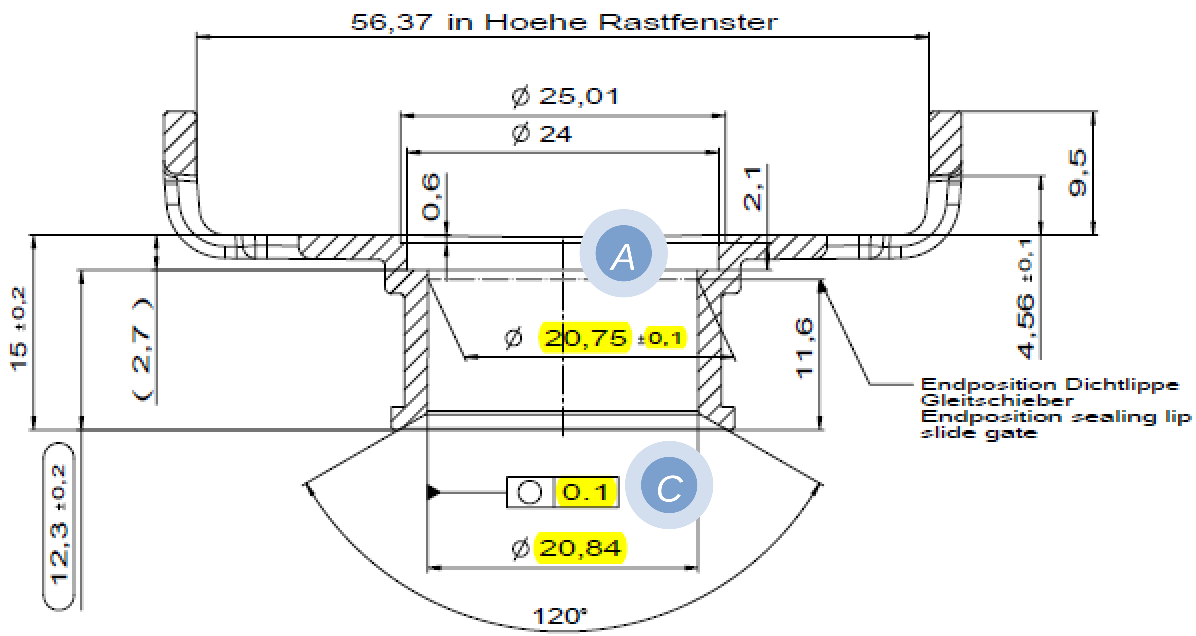
} A min – B max – 2C max→22 – 17´7 – 2 x 3´1= -1´9→Radial:-1´9/2= -0´95

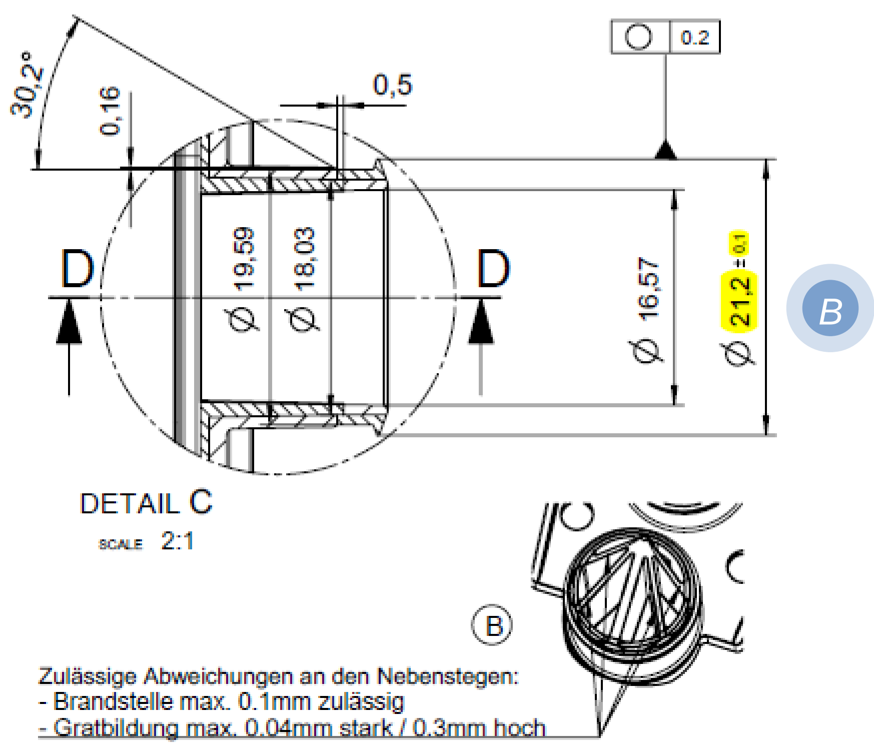
MINIMUM PRESSURE

A max
B min
C min

} A max – B min – 2C min→22´2 – 17´6 – 2 x 2´9= -1´2→Radial:-1´2/2 = -0´6

Inlet pipe seals





FINAL POSITION

PRESSURE WITHOUT TOLERANCES

20´75 – 21´2 = -0´45 →Radial:-0´45/2 = -0´225

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE

A min
B max } A min – B max → 20´65 – 21´30 = -0´65 →Radial:-0´65/2 = -0´325

MINIMUM PRESSURE

A max
B min } A max – B min → 20´85 – 21´10 = -0´25 →Radial:-0´25/2 = -0´125

INITIAL POSITION

PRESSURE WITHOUT TOLERANCES

20´84 – 21´2 = -0´35 →Radial:-0´35/2 = -0´175

PRESSURE WITH TOLERANCES

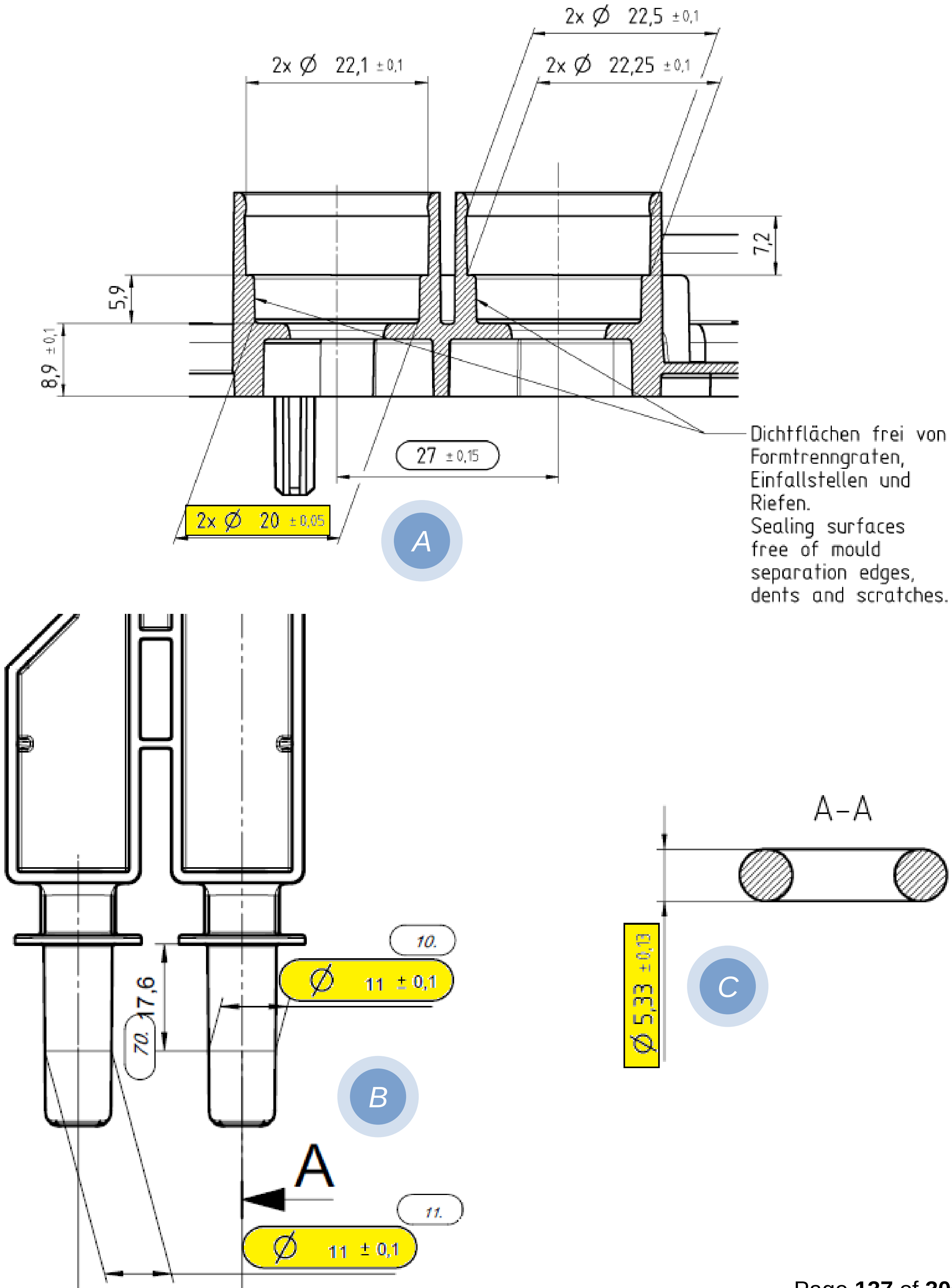
MAXIMUM PRESSURE

C min
B max } C min – B max → 20´74 – 21´30 = -0´56 →Radial:-0´56/2 = -0´28

MINIMUM PRESSURE

C max
B min } C max – B min → 20´94 – 21´10 = -0´16 →Radial:-0´16/2 = -0´08

Water softener inlet and outlet seals



PRESSURE WITHOUT TOLERANCES

20 – 11 – 2 x 5´33 = -1´66 →Radial:-1´66/2 = -0´83

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

A min
B max
C max

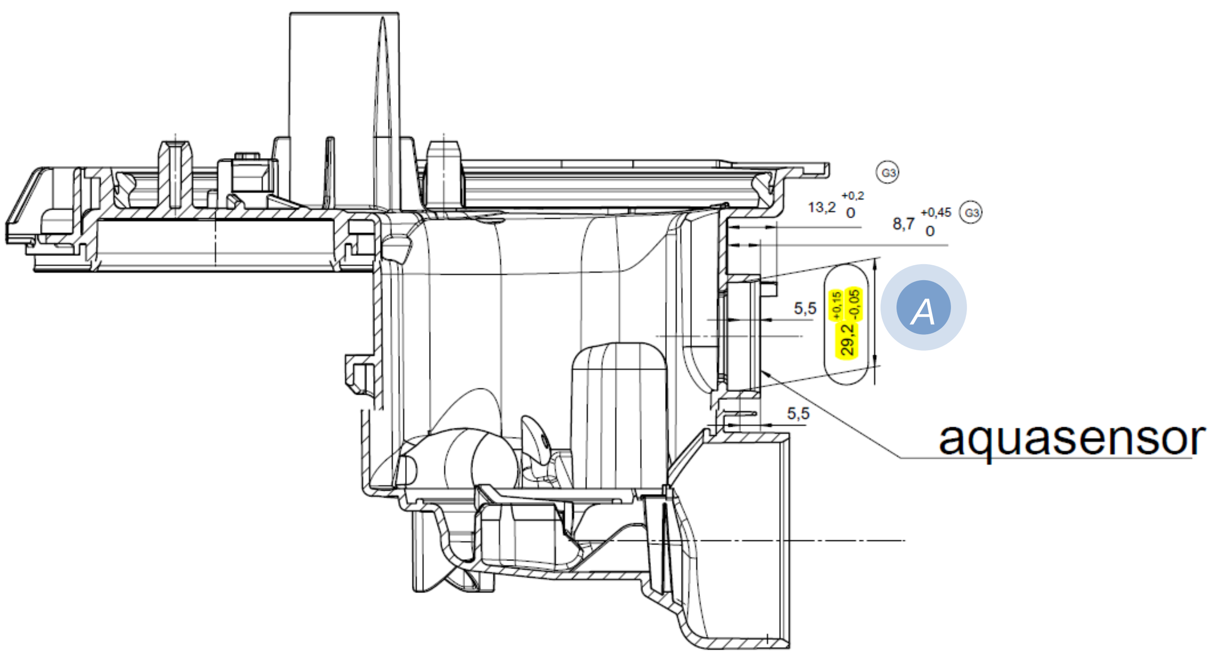
} A min – B max – 2C max→19´95 – 11´1 – 2 x 5´46= -2´07→Radial:-2´07/2= -1´035

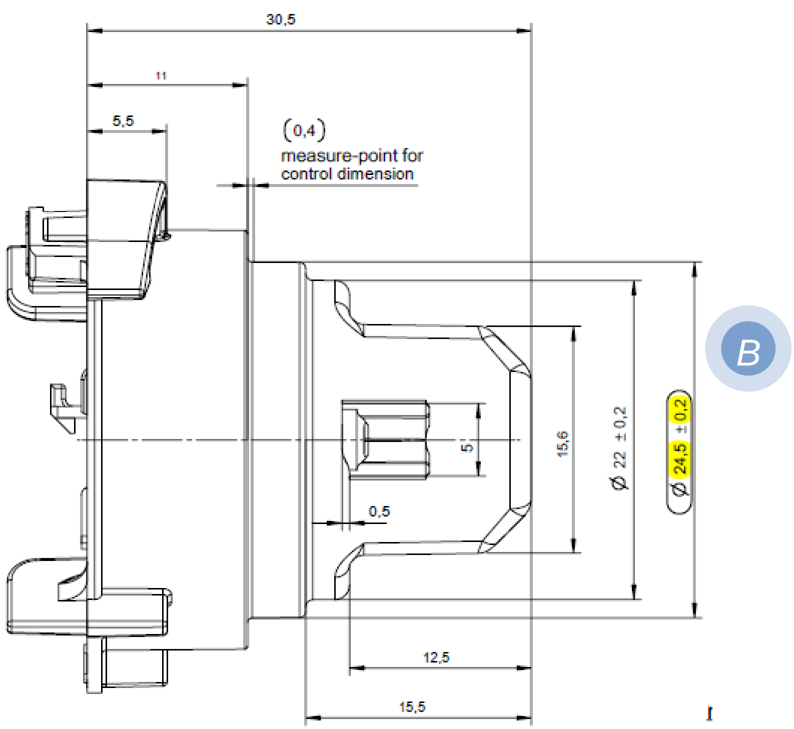
MINIMUM PRESSURE

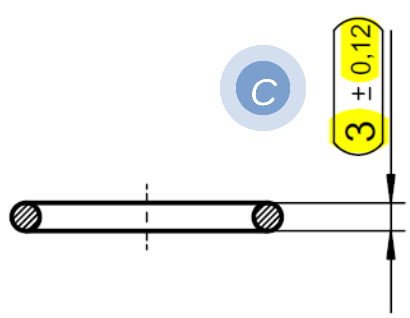
A max
B min
C min

} A max – B min – 2C min→20´05 – 10´9 – 2 x 5´2= -1´25→Radial:-1´25/2 = -0´625

Aquasensor seal







PRESSURE WITHOUT TOLERANCES

29´2 – 24´5 – 2 x 3 = -1´3 →Radial:-1´3/2 = -0´65

PRESSURE WITH TOLERANCES

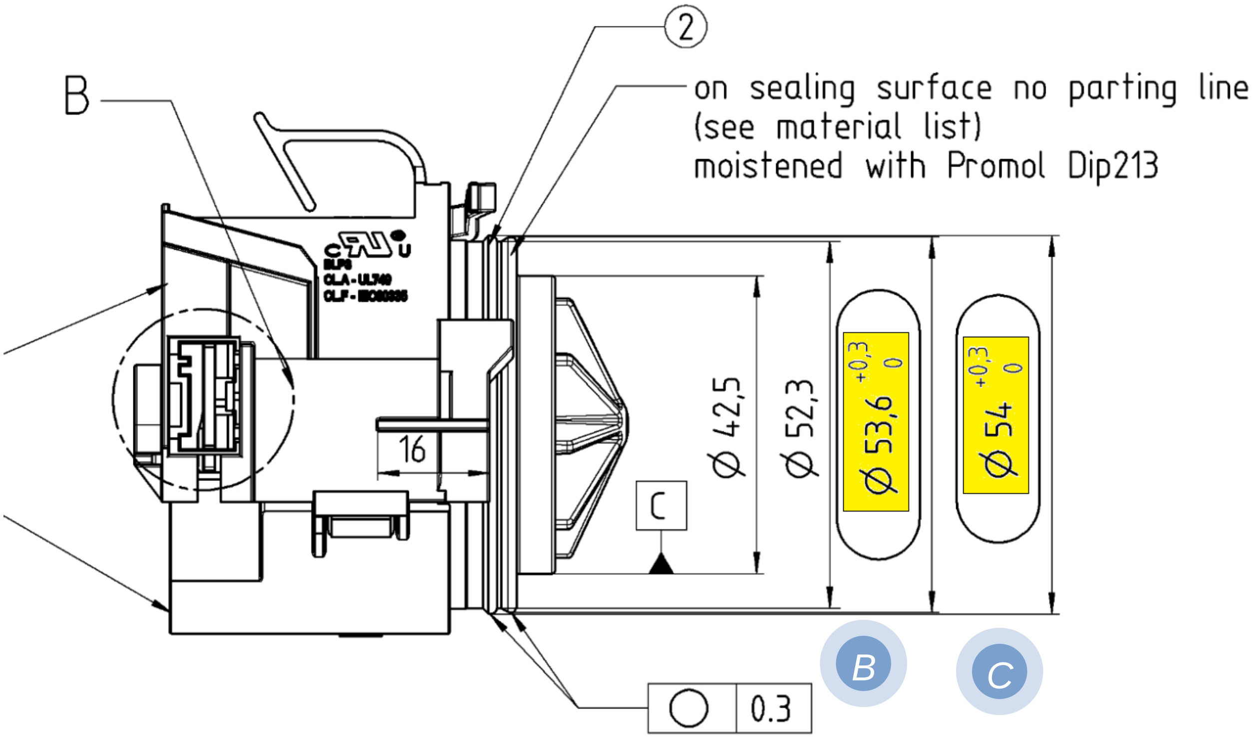
MAXIMUM PRESSURE:

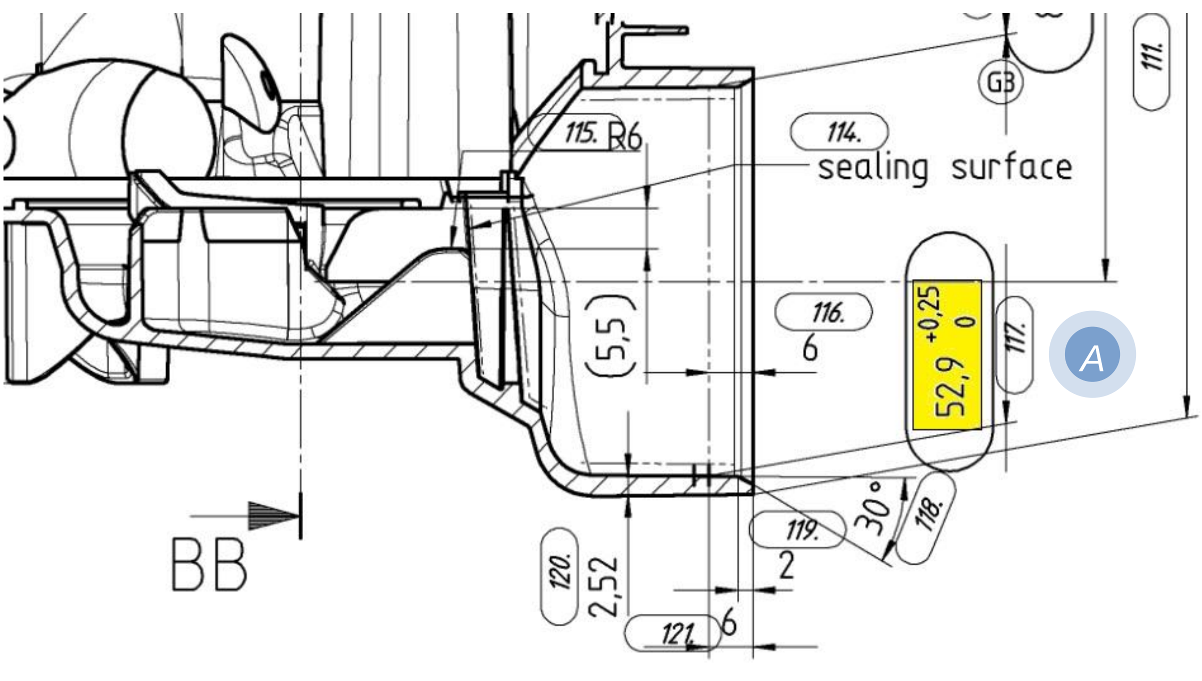
A min
B max } A min – B max – 2C max→29´15 – 24´7 – 2 x 3´12= -1´79→Radial:-1´79/2 = -0´895
C max

MINIMUM PRESSURE

A max
B min } A max – B min – 2C min→29´35 – 24´3 – 2 x 2´88 = -0´71→Radial:-0´71/2 = -0´355
C min

Drain pump seal.





FIRST SEALING RING:

PRESSURE WITHOUT TOLERANCES

52´9 – 53´6 = -0´7 →Radial:-0´7/2 = -0´35

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE

A min
B max } A min – B max → 52´9 – 53´9 = -1 →Radial:-1/2 = -0´5

MINIMUM PRESSURE

A max
B min } A max – B min → 53´15 – 53´6 = -0´45 →Radial:-0´45/2 = -0´225

SECOND SEALING RING:

PRESSURE WITHOUT TOLERANCES

52´9 – 54 = -1´1 →Radial:-1´1/2 = -0´55

PRESSURE WITH TOLERANCES

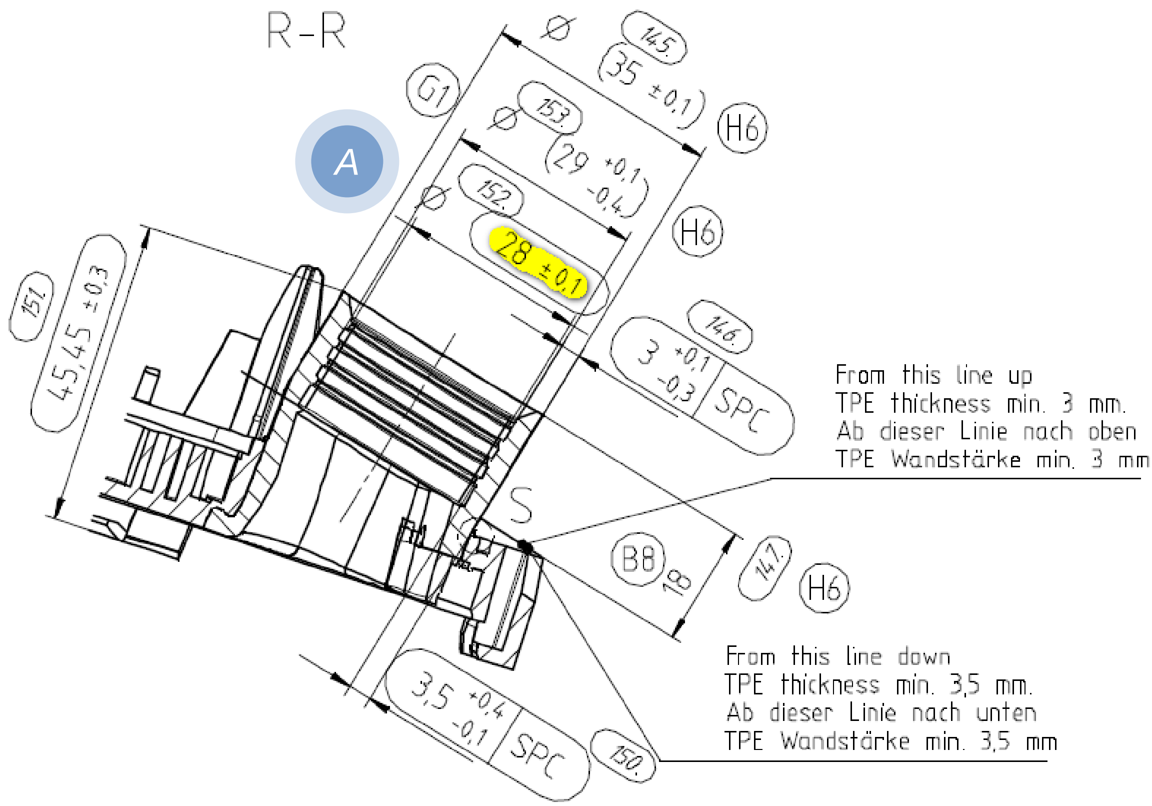
MAXIMUM PRESSURE

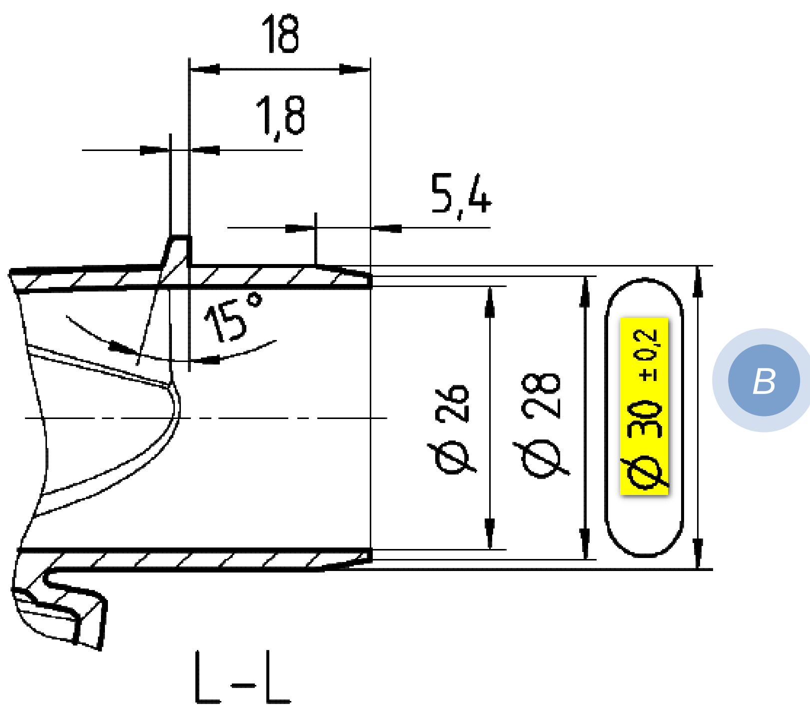
A min
C max } A min – C max → 52´9 – 54´3 = -1´4 →Radial:-1´4/2 = -0´7

MINIMUM PRESSURE

C max
C min } A max – C min → 53´15 – 54 = -0´85 →Radial:-0´85/2 = -0´425

Main pump and water switch seal.





PRESSURE WITHOUT TOLERANCES

28 – 30 = -2 → Radial:-2/2 = -1

PRESSURE WITH TOLERANCES

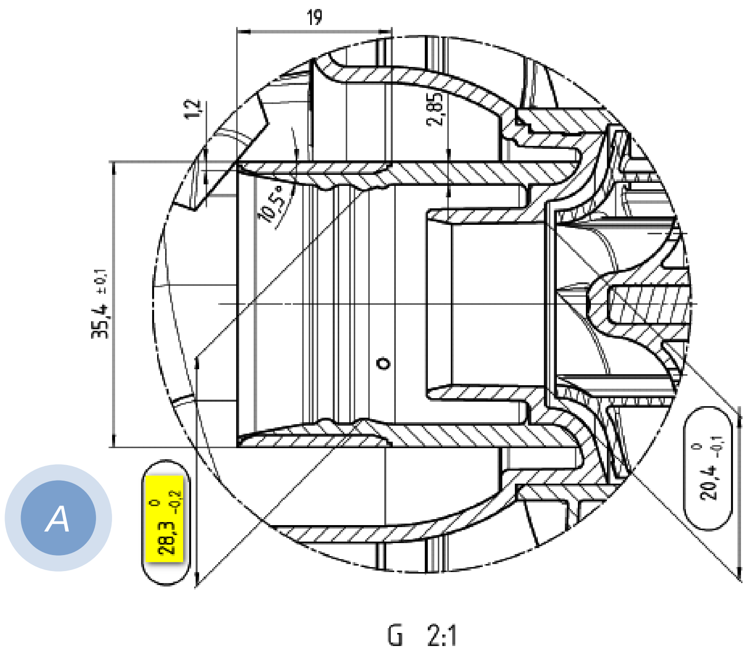
MAXIMUM PRESSURE

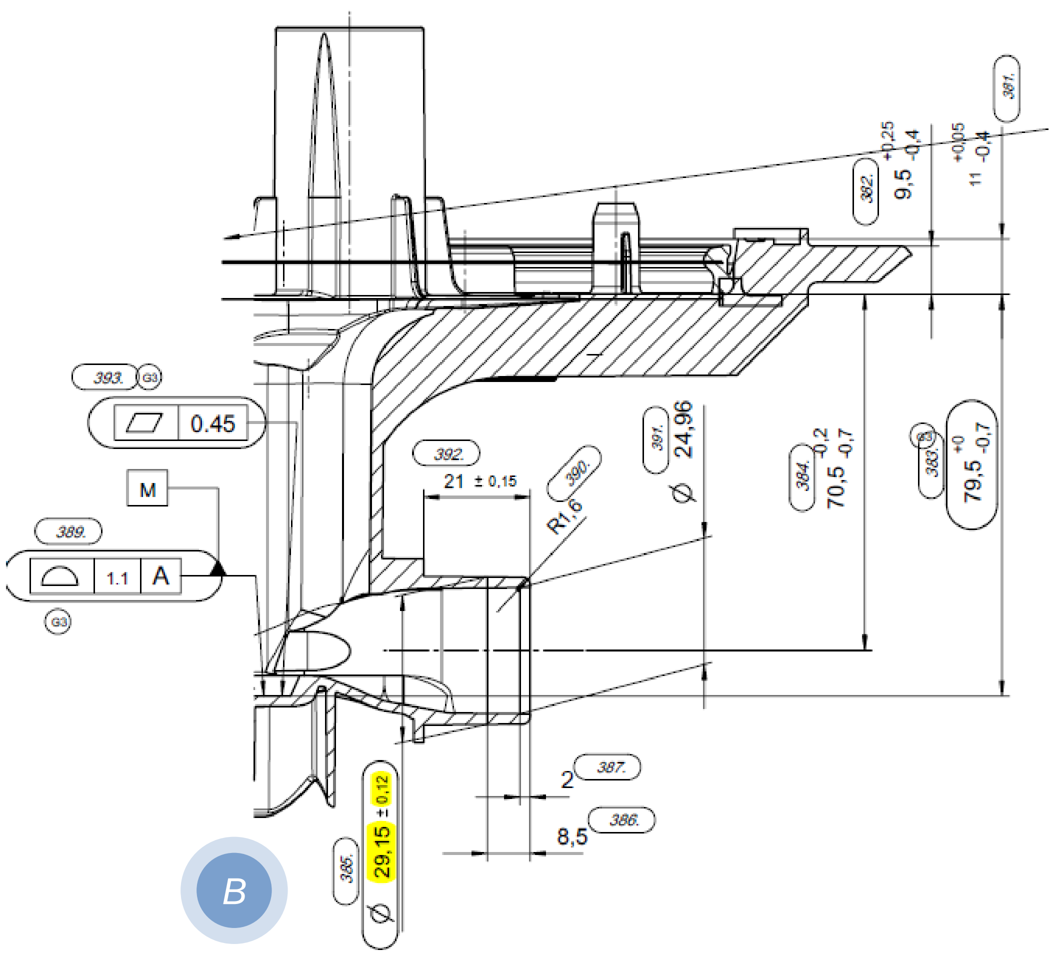
A min
B max } A min – B max → 27´9 – 30´2 = -2´3 → Radial:-2´3/2 = -1´15

MINIMUM PRESSURE

A max
B min } A max – B min → 28´1 – 29´8 = -1´7 → Radial:-1´7/2 = -0´85

Main pump and sump seal.





PRESSURE WITHOUT TOLERANCES

28´3 – 29´15 = -0´85 →Radial:-0´85/2 = -0´425

PRESSURE WITH TOLERANCES

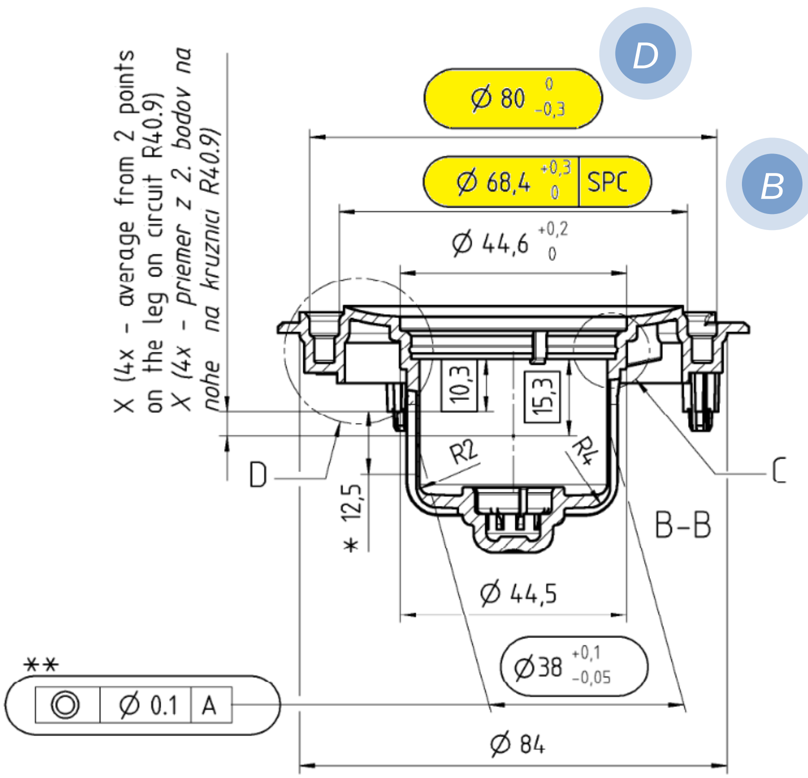
MAXIMUM PRESSURE

A min
B max } A min – B max → 28´1 – 29´27 = -1´17 →Radial:-1´17/2 = -0´585

MINIMUM PRESSURE

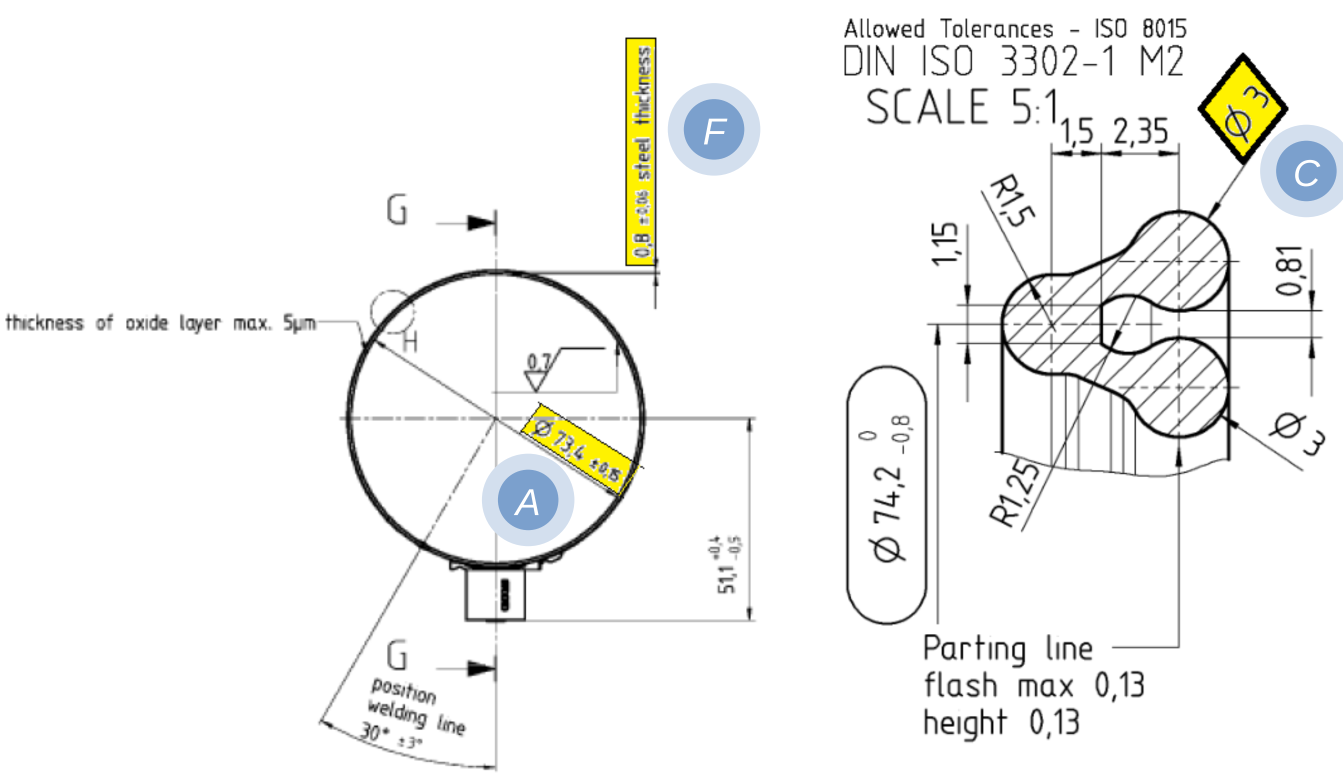
A max
B min } A max – B min → 28´3 – 29´03 = -0´73 →Radial:-0´73/2 = -0´365

Main pump heat system seal



Max: 73´55+2x0´85
Min: 73´25+2x0´75

E= A+F



INNER POSITION:

PRESSURE WITHOUT TOLERANCES

73´4 – 68´4 – 2 x 3 = -1 →Radial:-1/2 = -0´5

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

A min, B max, C max } A min – B max – 2C max→73´25 – 68´7 – 2 x 3´15= -1´75→Radial:-1´75/2 = -0´875

MINIMUM PRESSURE

A max, B min, C min } A max – B min – 2C min→73´55 – 68´4 – 2 x 2´85 = -0´55→Radial:-0´55/2 = -0´275

OUTER POSITION:

PRESSURE WITHOUT TOLERANCES

80 – 73´4 – 2 x 0´8 – 2 x 3 = -1 →Radial:-1/2 = -0´5

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

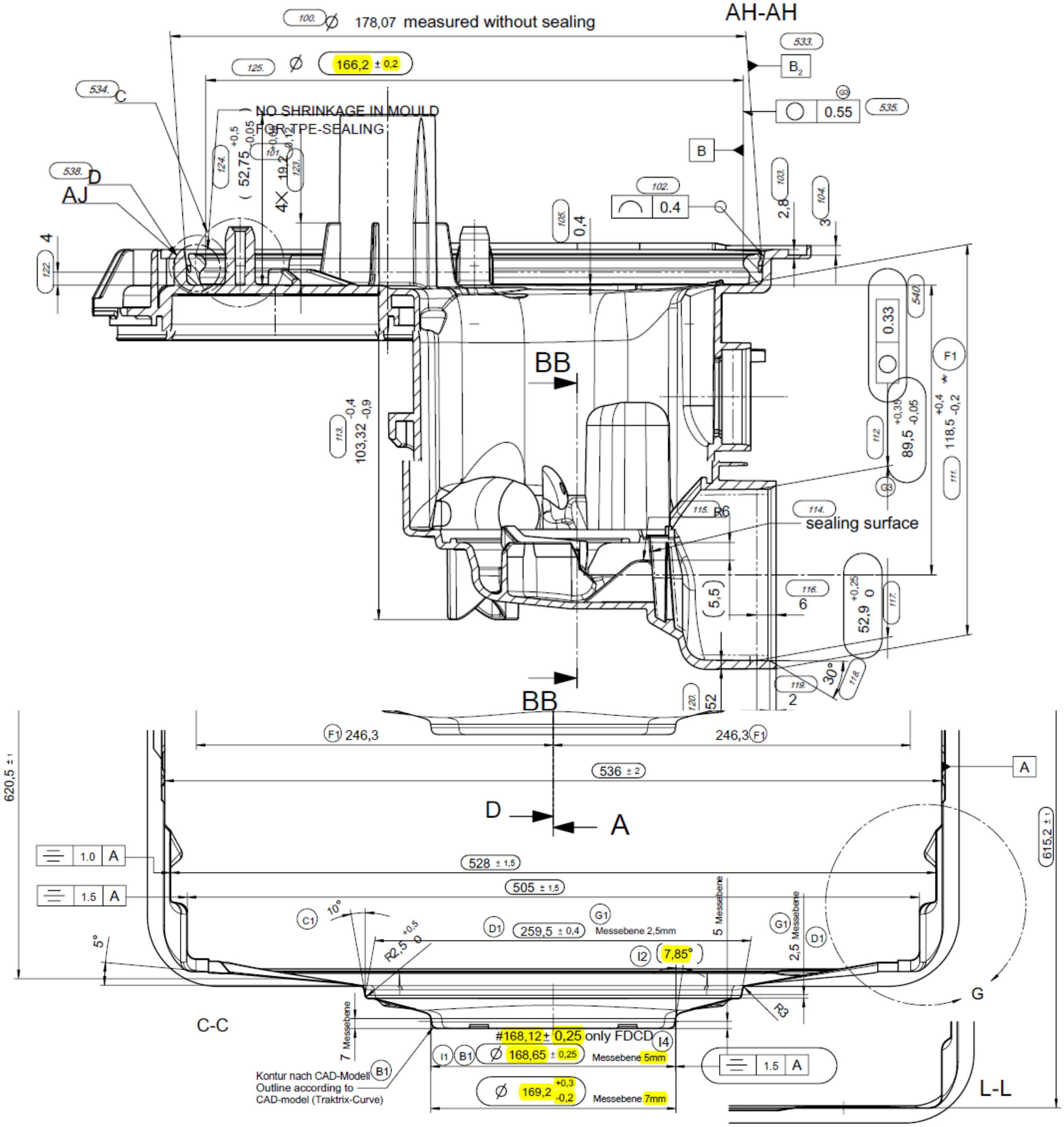
D min, E max, C max } D min – E max – 2C max→79´7 – 75´25 – 2 x 3´15= -1´85→Radial:-1´85/2 = -0´925

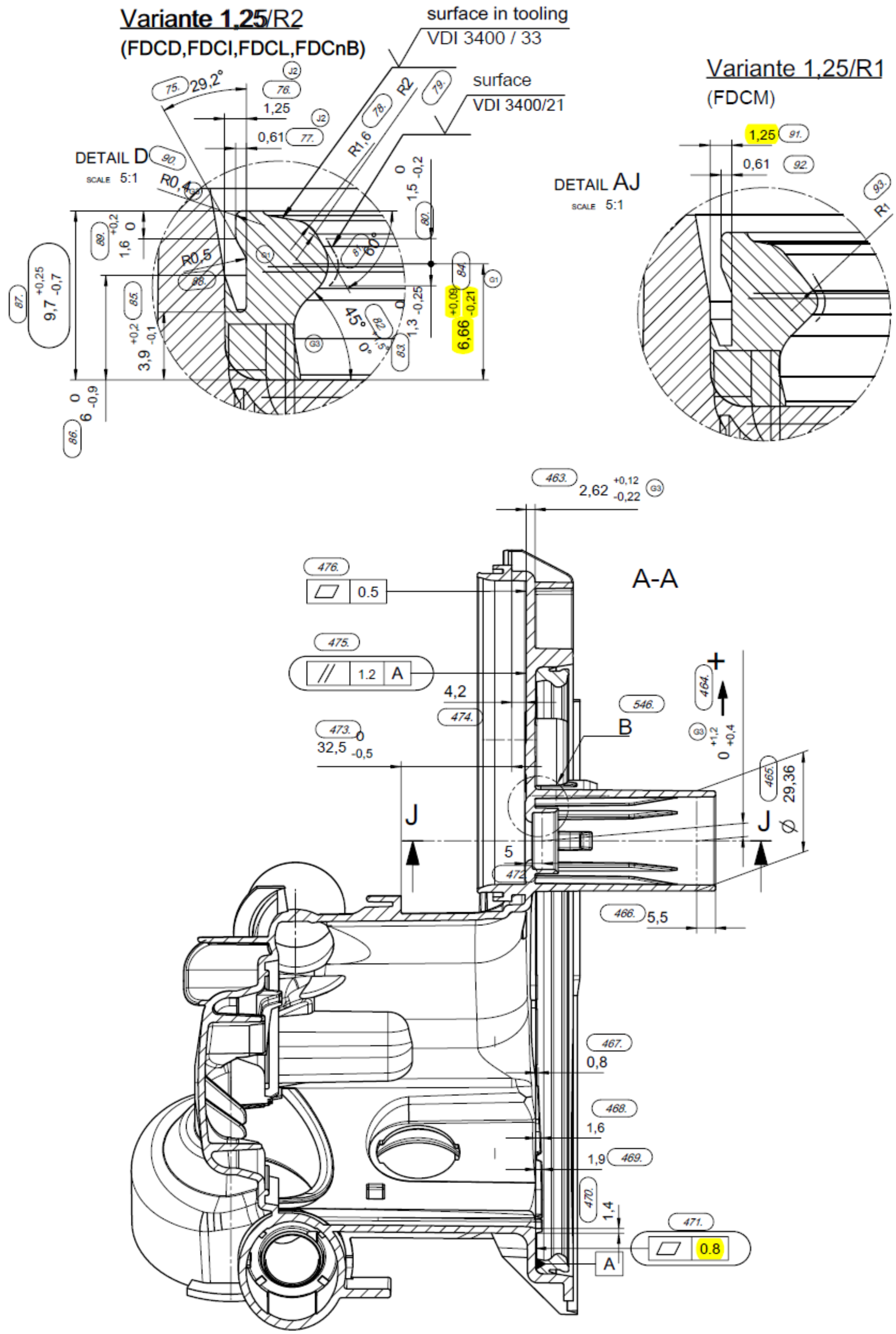
MINIMUM PRESSURE

D max, E min, C min } D max – E min – 2C min → 80 – 74´75 – 2 x 2´85 = -0´45→Radial:-0´45/2 = -0´225

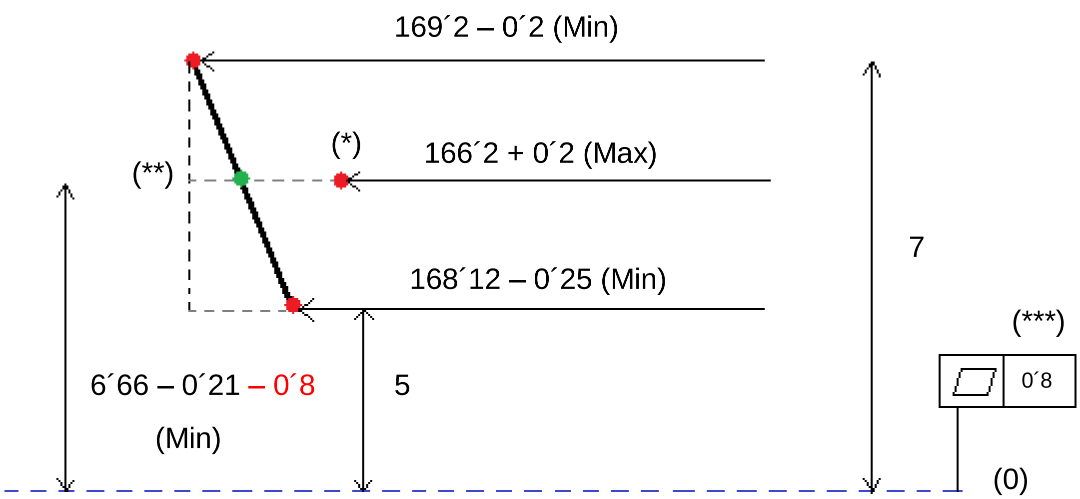
Sump and tub seal.

For 7´85°:




Variante 1,25/R2
(FDCD,FDCI,FDCL,FDCnB)
surface in tooling
VDI 3400 / 33
surface
VDI 3400/21
DETAIL D
SCALE 5:1
Variante 1,25/R1
(FDCM)
DETAIL AJ
SCALE 5:1
A-A
B
J
A

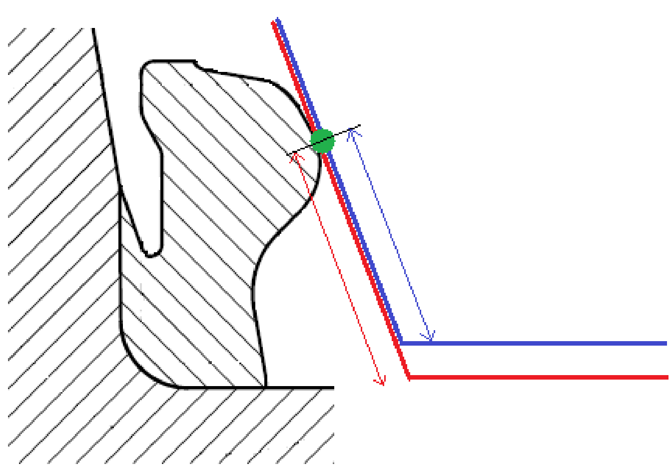
MINIMUM PRESSURE



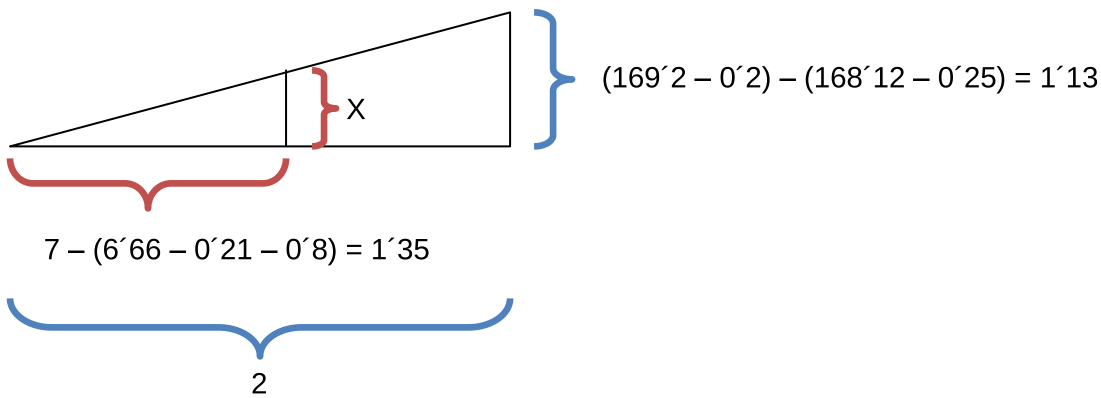
(*) → Contact point between the TPE seal and the tub.

(**) → Detail view

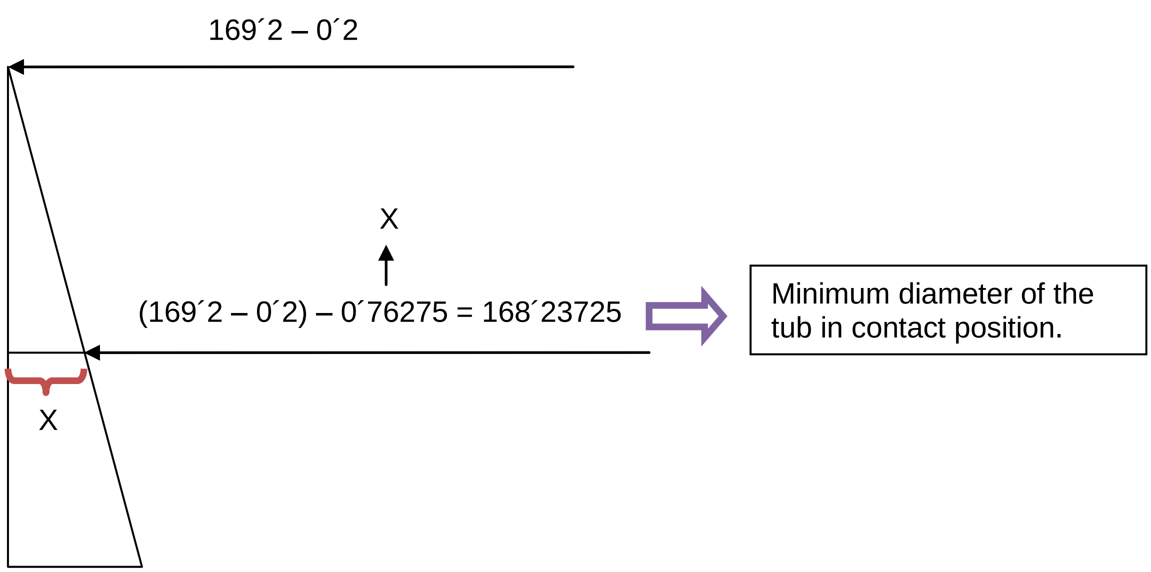
(***) → For minimum pressure it is needed the maximum tolerance +0´8 because the contact point goes down:



(**)



By the equivalence´s rule → X/1´35 = 1´13/2 → X = 0´76275



- Final pressure calculation → Maximum diameter TPE seal
  → Minimum diameter tub

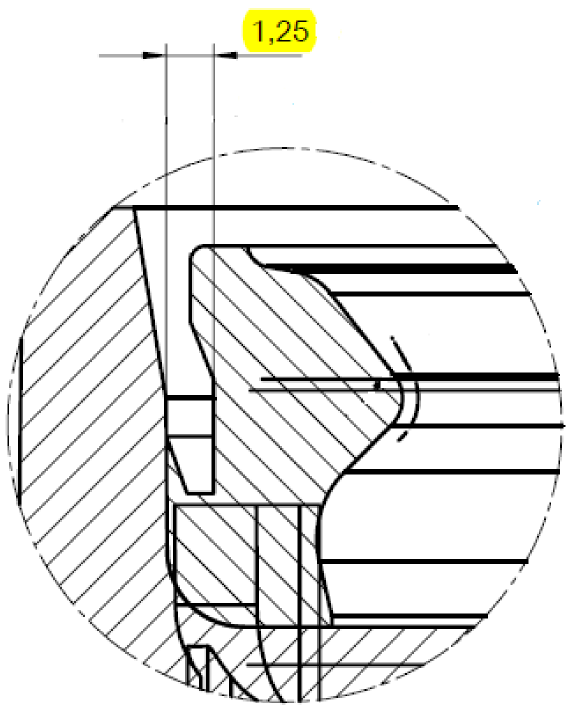
MINIMUM PRESSURE

(166´2 + 0´2) – 168´23725 = -1´83725 (Relative to the diameter)

Relative to the radius:

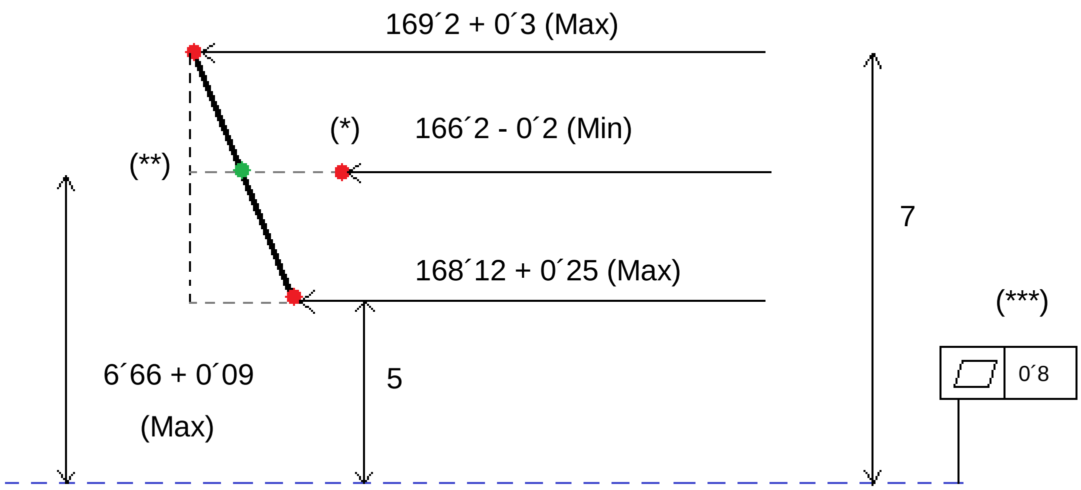
-1´83725/2 = -0´918625

1´25 is added because the gap between the sump and the TPE seal.



It is easy to see that the gap (1´25mm) is bigger than the interference. Due to this, the TPE seal is not going to be pressed against the hard component. For this reason, the seal has an interference of -0´918625mm but as the seal is not pressed against the hard component the real pressure is about 0%. The TPE seal is going to move 0´918625mm but that is not enough to have a pressure and avoid leakages.

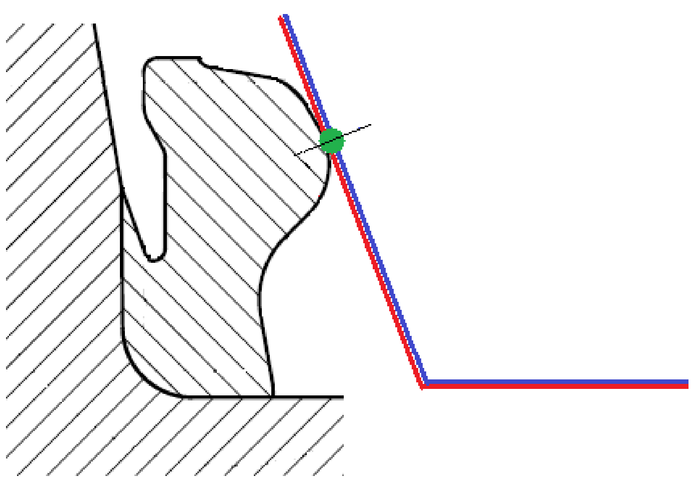
MAXIMUM PRESSURE



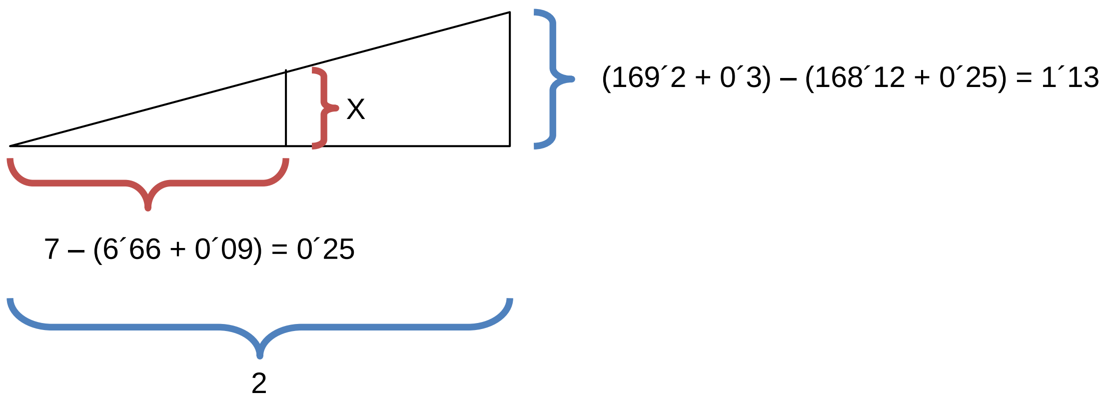
(*) → Contact point between the TPE seal and the tub.

(**) → Detail view

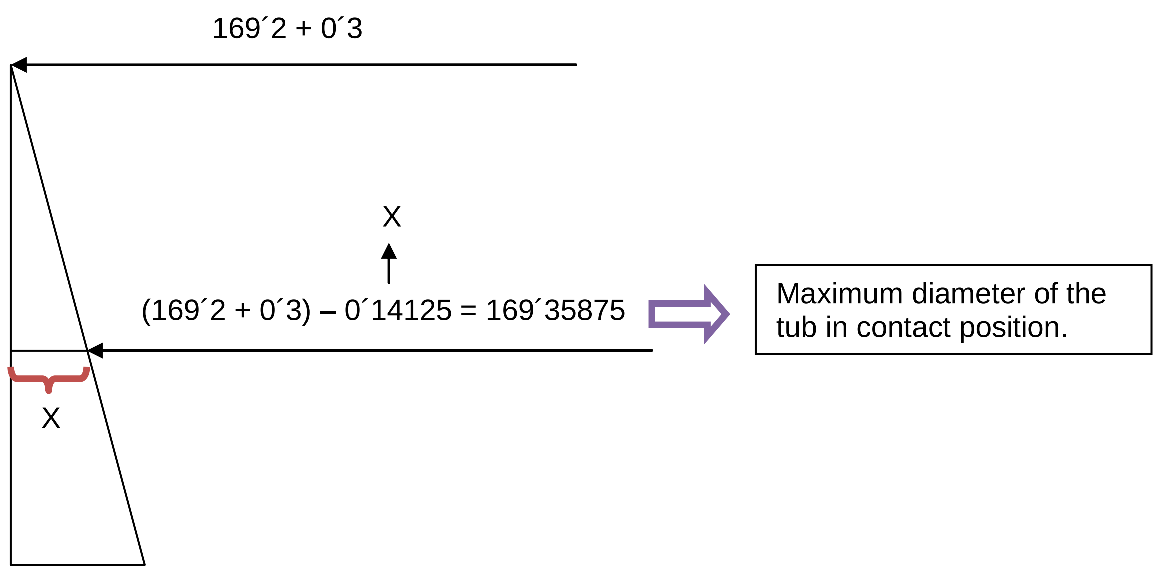
(***) → For maximum pressure it is needed the minimum tolerance 0, so the contact point does not move:



(**)



By the equivalence´s rule → X/0´25 = 1´13/2 → X = 0´14125



- Final pressure calculation → Minimum diameter TPE seal
  → Maximum diameter tub

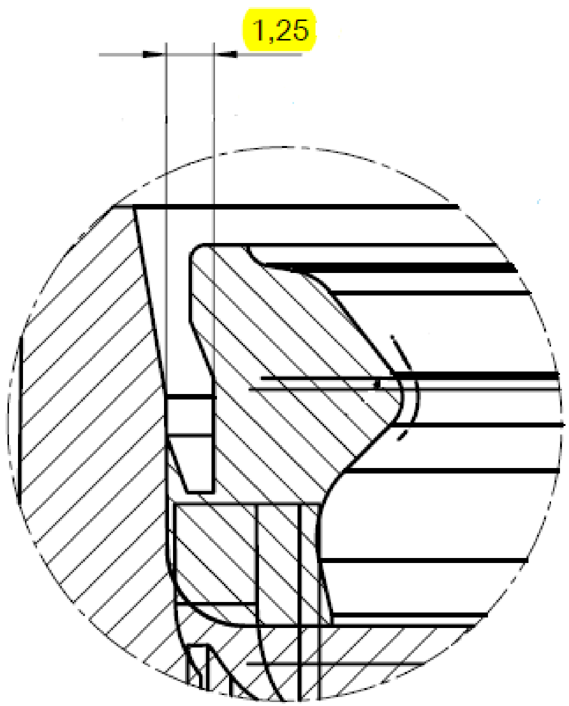
MAXIMUM PRESSURE

(166´2 - 0´2) – 169´35875 = -3´35875 (Relative to the diameter)

Relative to the radius:

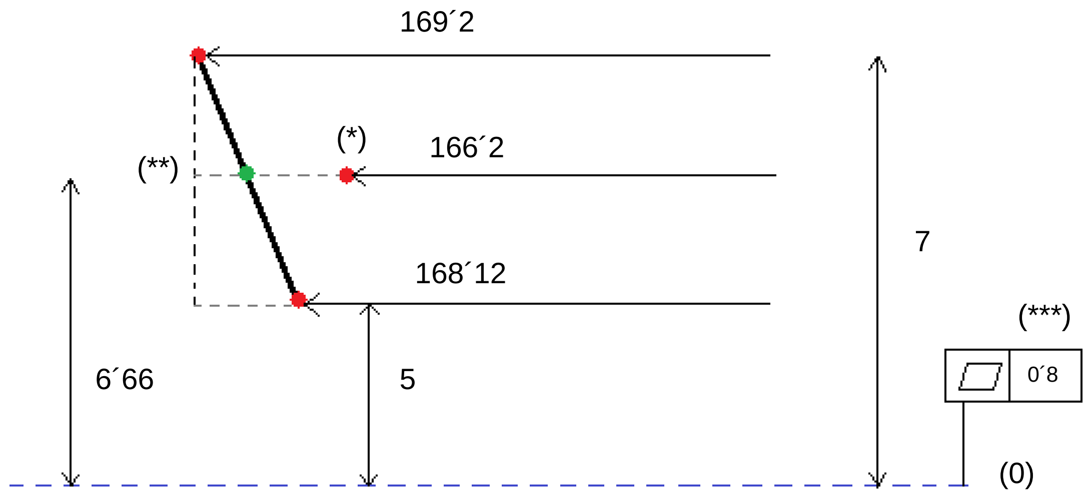
-3´35875/2 = -1´679375

1´25 is added because the gap between the sump and the TPE seal. (Reduces the interference)



-1´679375 + 1´25 = -0´429375 ≈ -0´43

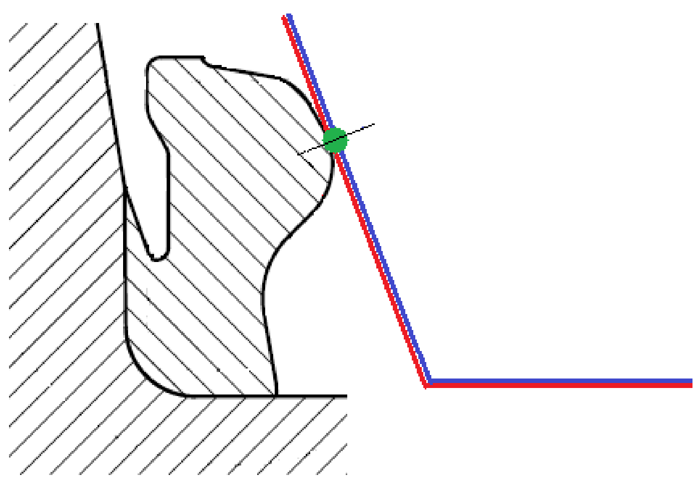
PRESSURE WITHOUT TOLERANCES



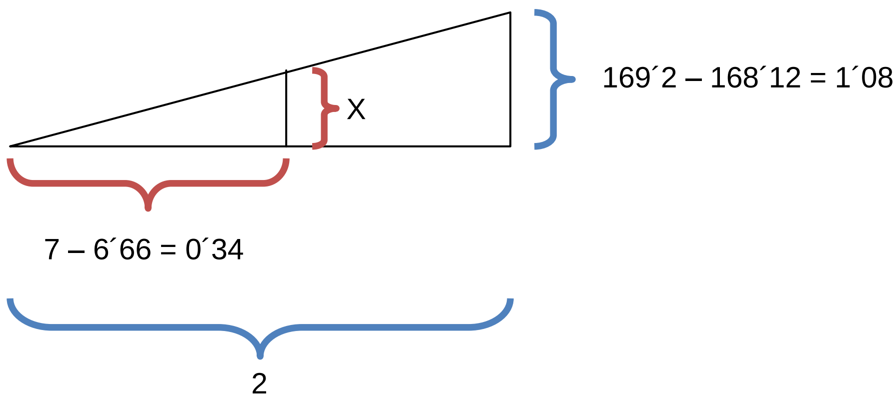
(*) → Contact point between the TPE seal and the tub.

(**) → Detail view

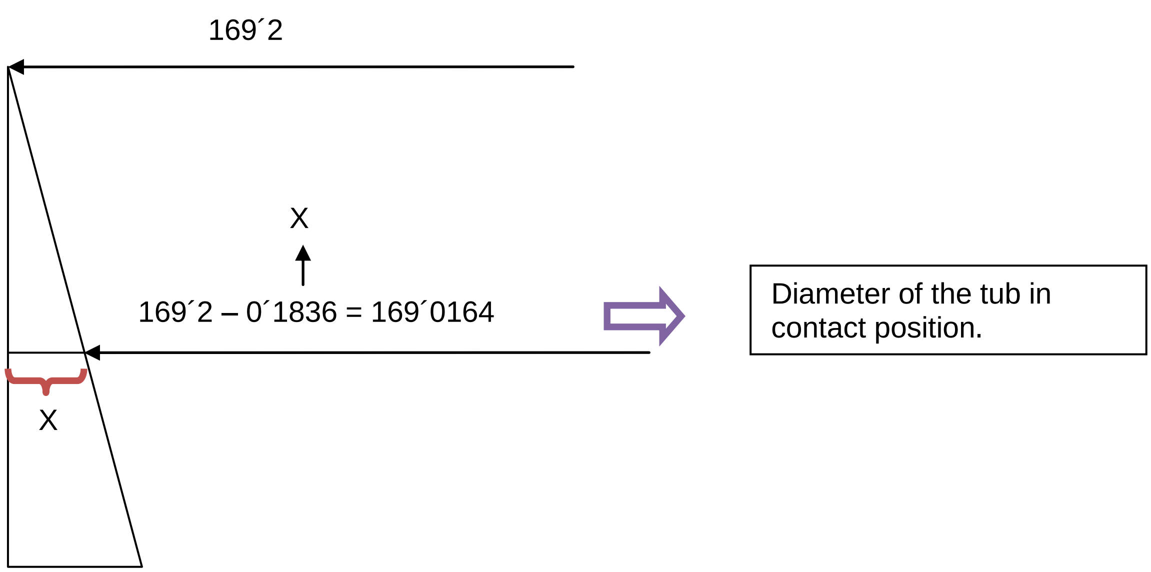
(***) → For the pressure without tolerances it is needed the value 0, so the contact point does not move:



(**)



By the equivalence´s rule → X/0´34 = 1´08/2 → X = 0´1836



- Final pressure calculation → Diameter TPE seal
  → Diameter tub

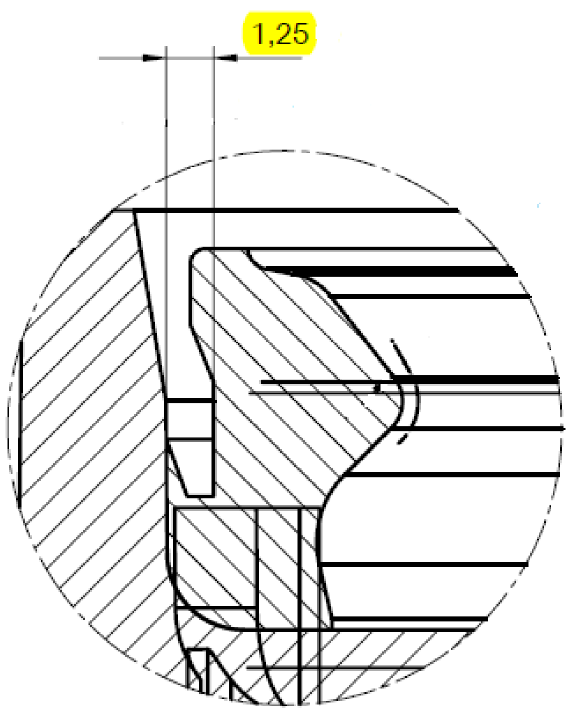
FINAL PRESSURE

166´2 – 169´0164 = -2´8164 (Relative to the diameter)

Relative to the radius:

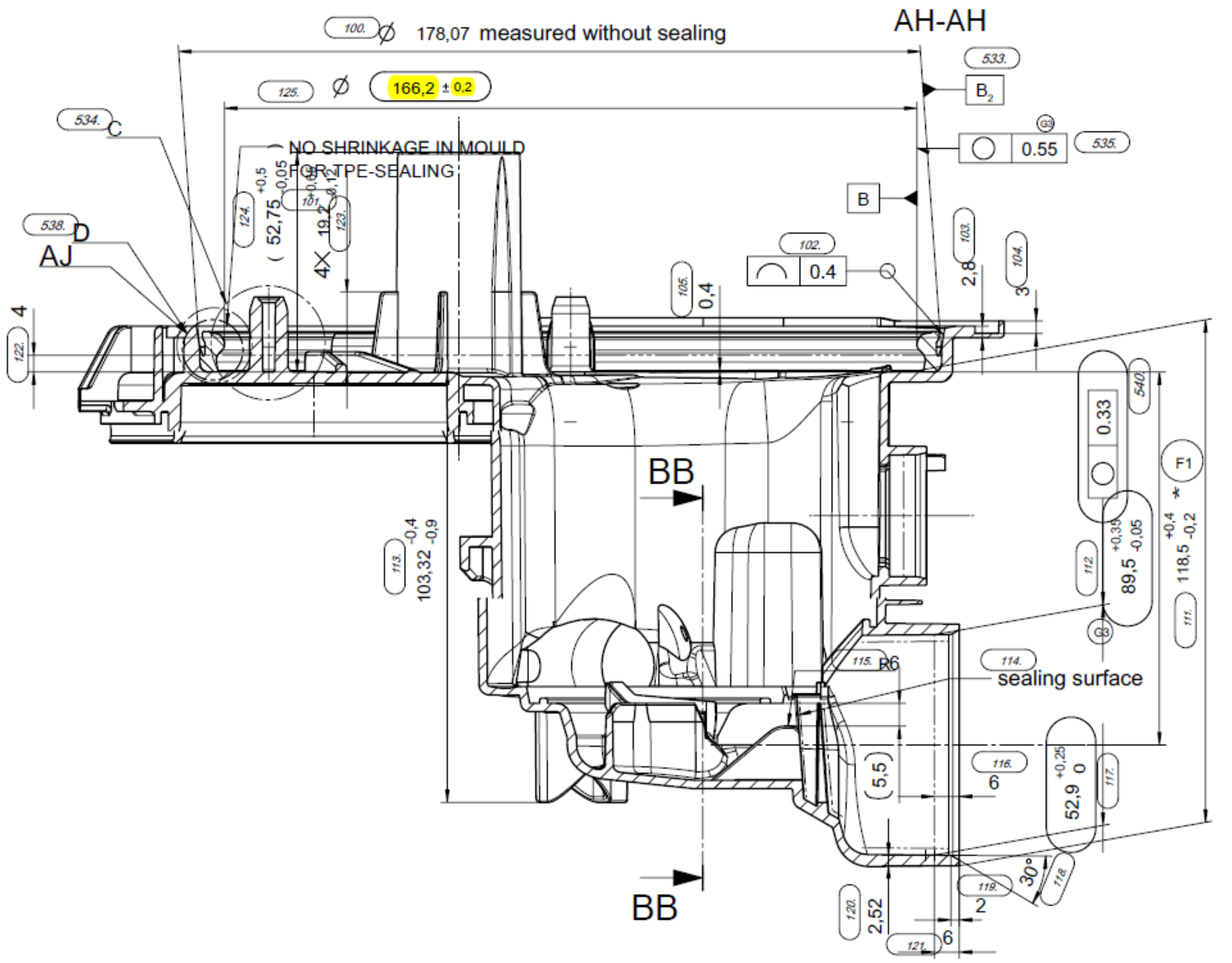
-2´8164/2 = -1´4082

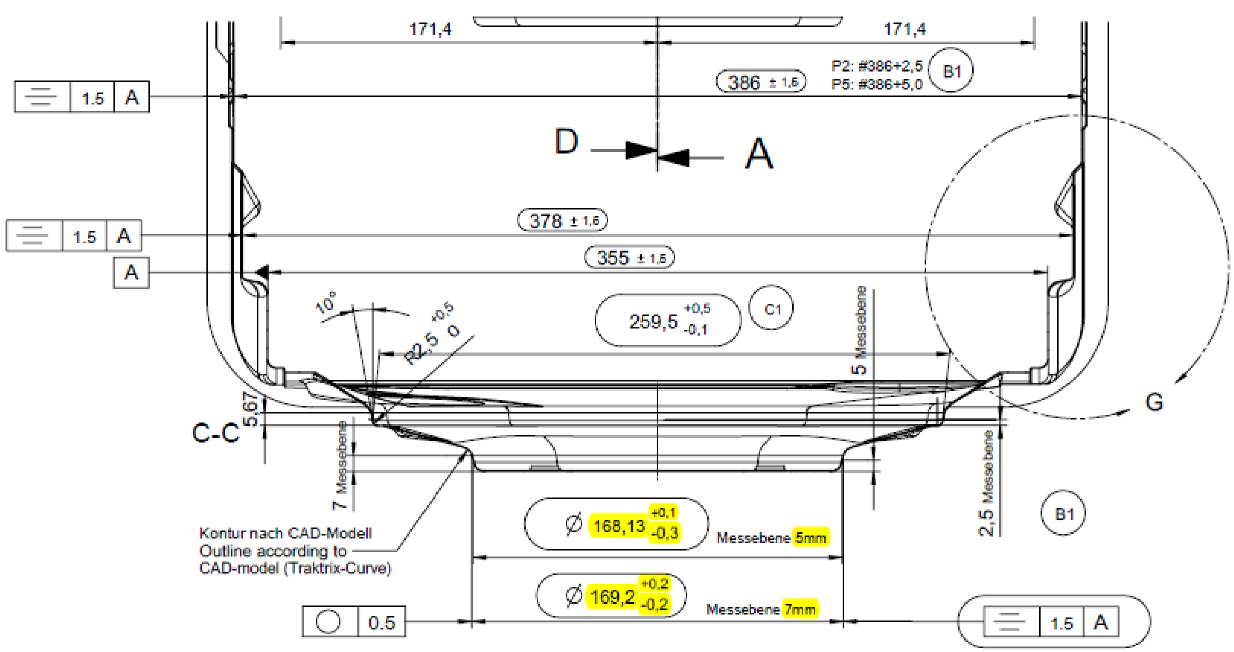
1´25 is added because the gap between the sump and the TPE seal. (Reduces the interference)

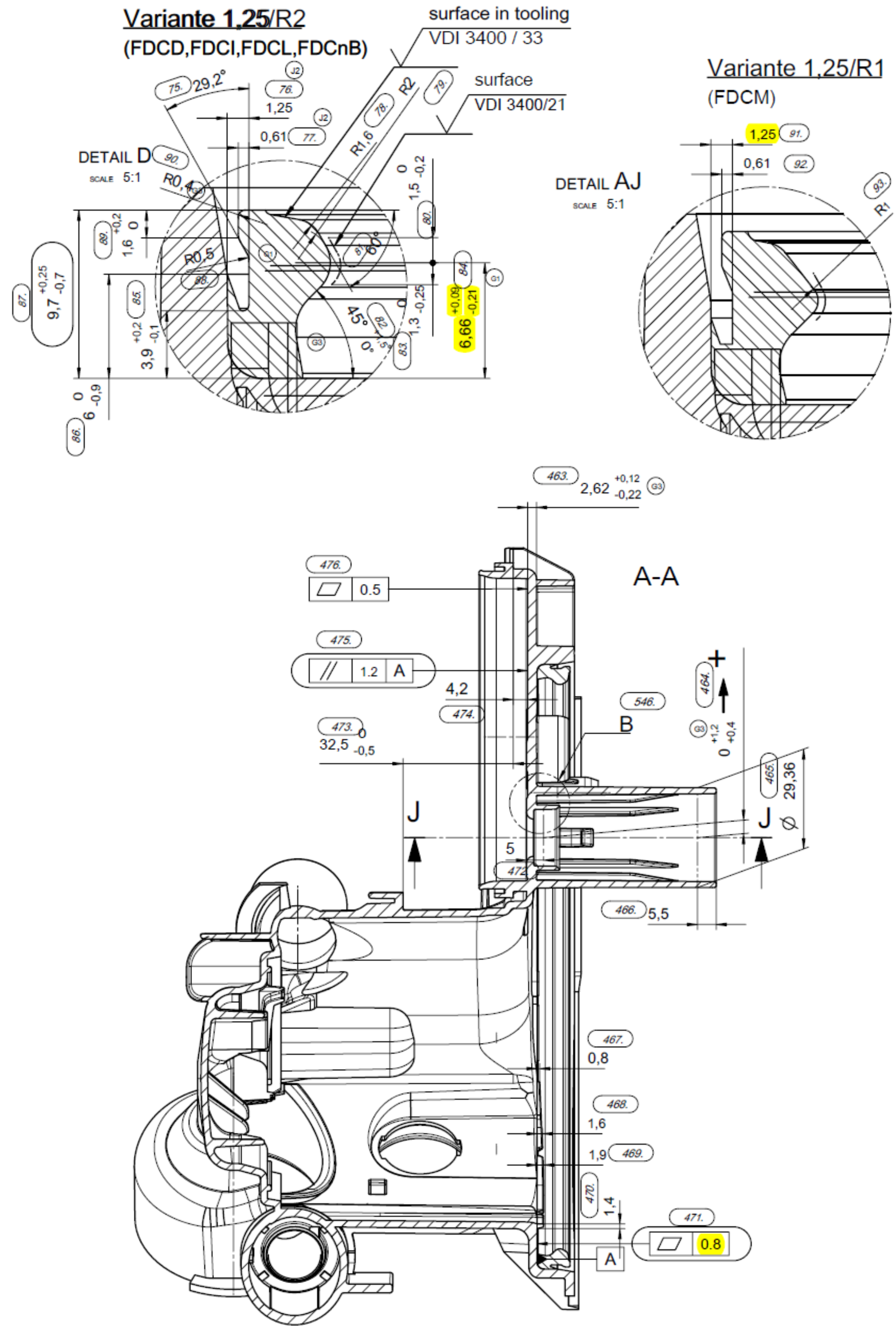


-1´4082 + 1´25 = -0,1582 ≈ -0´16

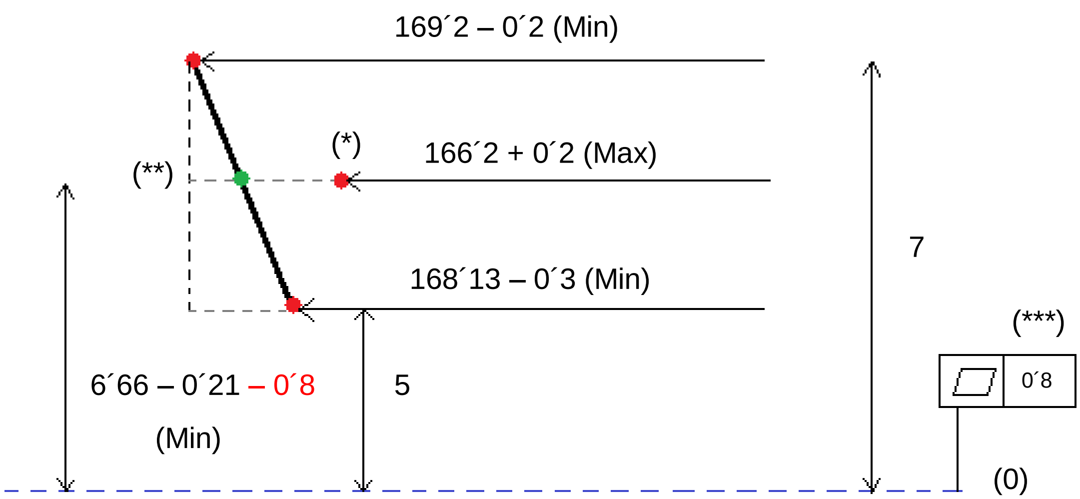
For 15°:


AH-AH
178,07 measured without sealing
166,2 ± 0,2
NO SHRINKAGE IN MOULD
FOR TPE-SEALING
0.55
0.4
0.33
BB
BB
sealing surface
R6
103,32
52,75
89,5
118,5
52,9
2,8
2,52
30°


171,4
171,4
386 ± 1,6
P2: #386+2,5
P5: #386+5,0
B1
D
A
378 ± 1,6
355 ± 1,6
259,5 +0,5 -0,1
C1
10°
R2,5
5 Messebene
G
C-C
5,67
7 Messebene
2,5 Messebene
B1
Kontur nach CAD-Modell
Outline according to
CAD-model (Traktrix-Curve)
168,13 +0,1 -0,3
Messebene 5mm
169,2 +0,2 -0,2
Messebene 7mm
1.5 A
0.5


Variante 1,25/R2
(FDCD,FDCI,FDCL,FDCnB)
surface in tooling
VDI 3400 / 33
surface
VDI 3400/21
DETAIL D
SCALE 5:1
Variante 1,25/R1
(FDCM)
DETAIL AJ
SCALE 5:1
A-A
J
B
0.5
1.2 A
0.8
A

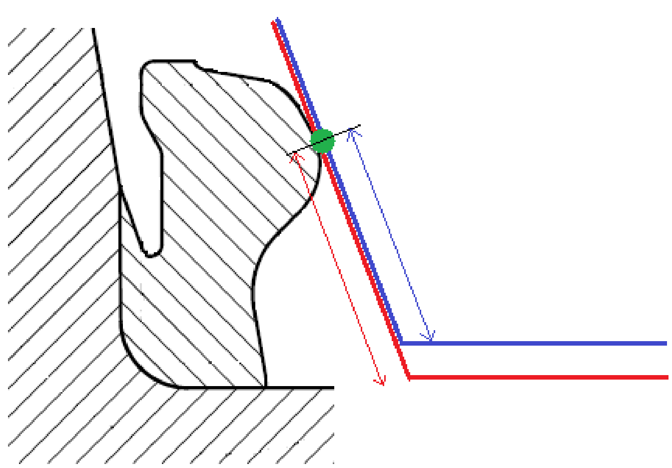
MINIMUM PRESSURE



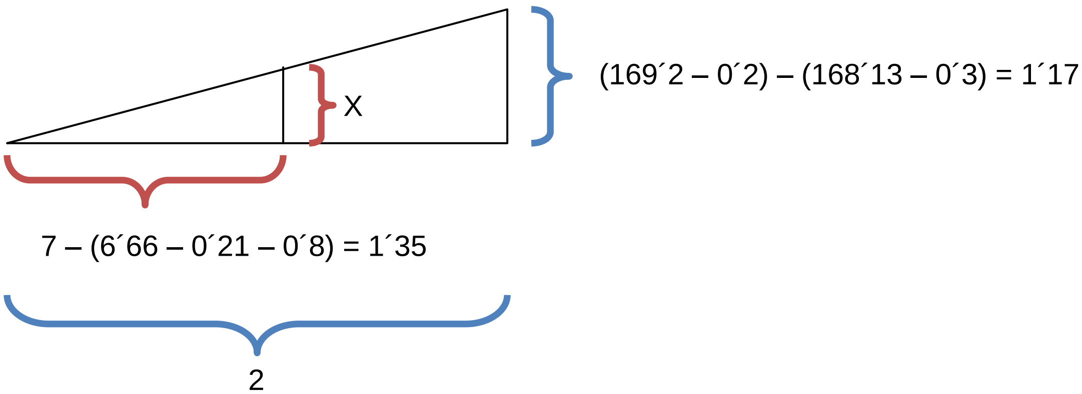
(*) → Contact point between the TPE seal and the tub.

(**) → Detail view

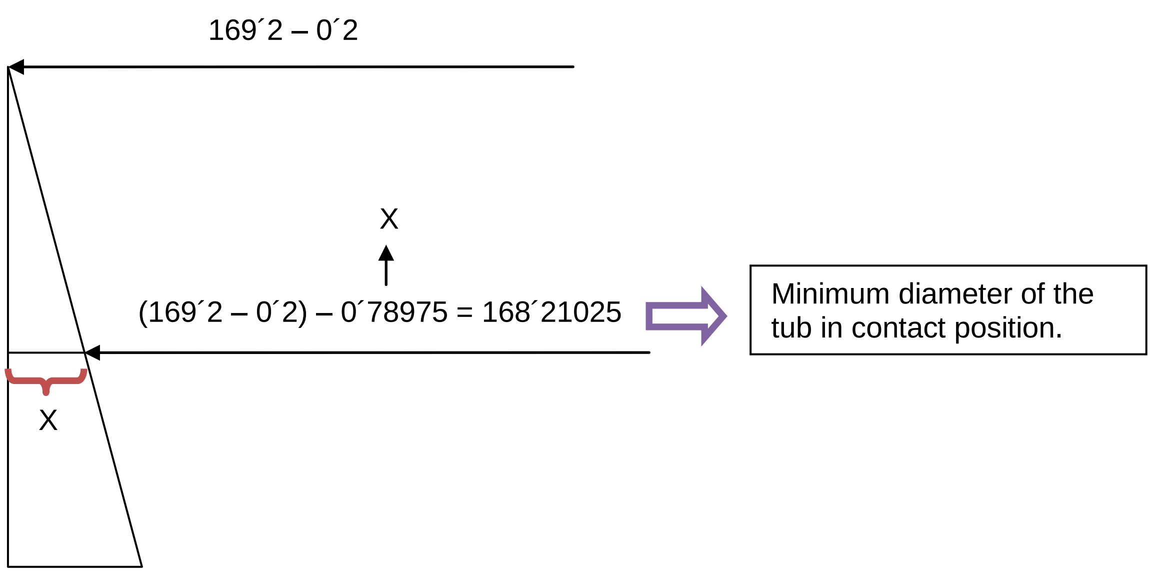
(***) → For minimum pressure it is needed the maximum tolerance +0´8 because the contact point goes down:



(**)



By the equivalence´s rule → X/1´35 = 1´17/2 → X = 0´78975



- Final pressure calculation → Maximum diameter TPE seal
  → Minimum diameter tub

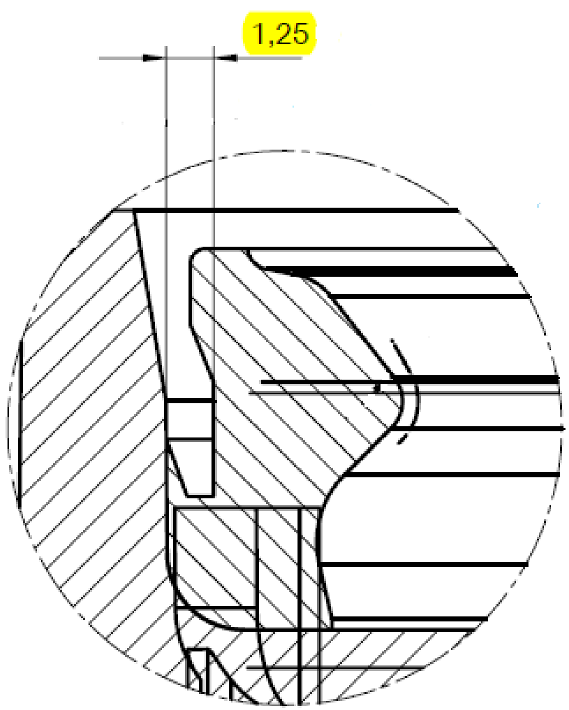
MINIMUM PRESSURE

(166´2 + 0´2) – 168´21025 = -1´81025 (Relative to the diameter)

Relative to the radius:

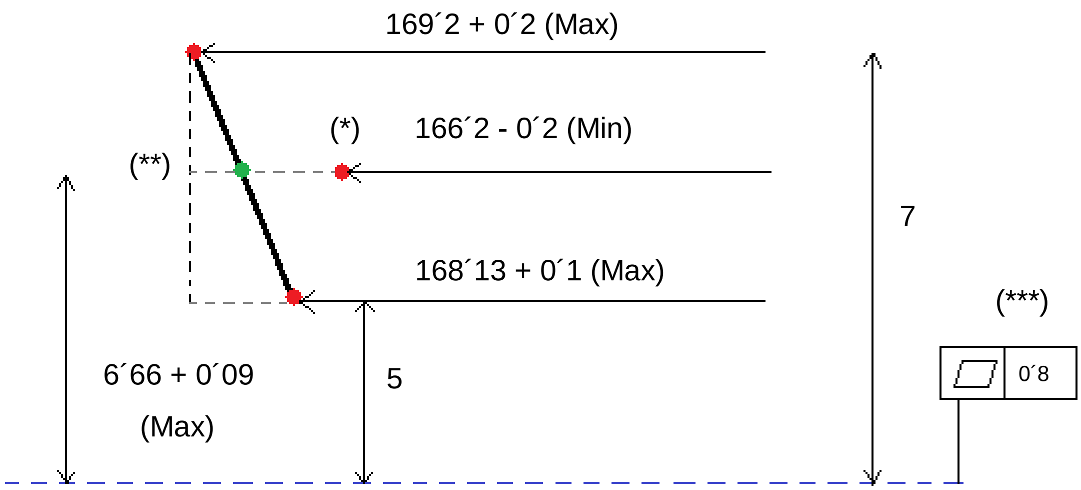
-1´81025/2 = -0´905125

1´25 is added because the gap between the sump and the TPE seal. (Reduces the interference)



It is easy to see that the gap (1´25mm) is bigger than the interference. Due to this, the TPE seal is not going to be pressed against the hard component. For this reason, the seal has an interference of -0´905125mm but as the seal is not pressed against the hard component the real pressure is about 0%. The TPE seal is going to move 0´905125mm but that is not enough to have a pressure and avoid leakages.

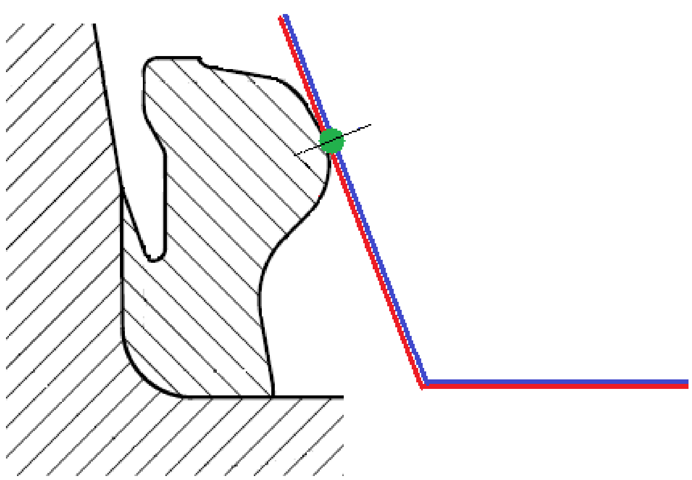
MAXIMUM PRESSURE



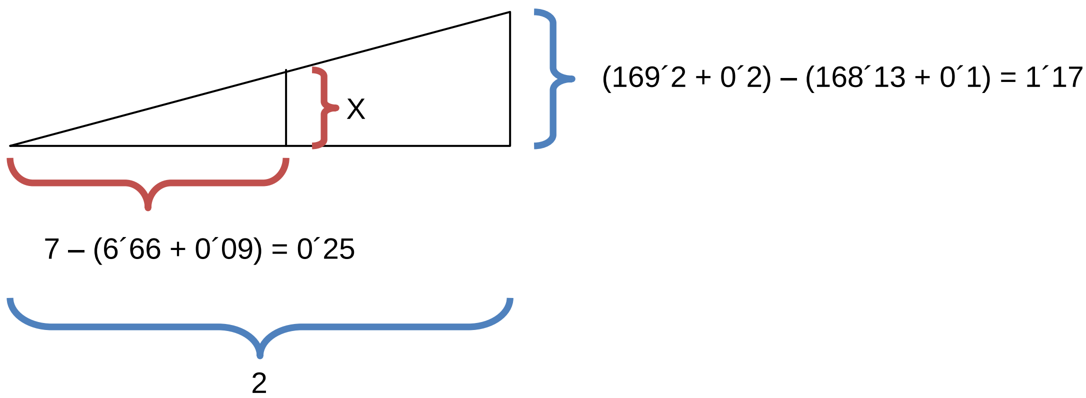
(*) → Contact point between the TPE seal and the tub.

(**) → Detail view

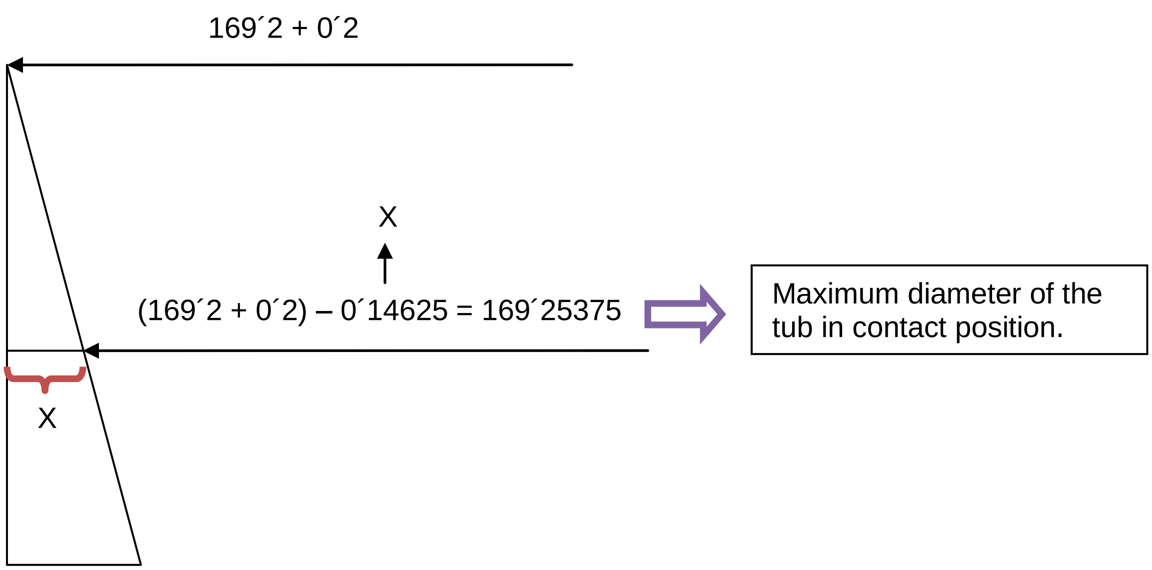
(***) → For maximum pressure it is needed the minimum tolerance 0, so the contact point does not move:



(**)



By the equivalence´s rule → X/0´25 = 1´17/2 → X = 0´14625



- Final pressure calculation → Minimum diameter TPE seal
  → Maximum diameter tub

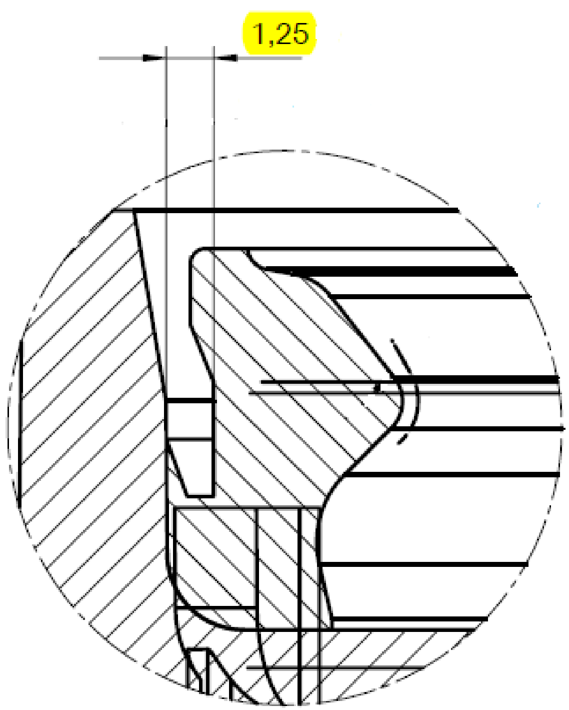
MAXIMUM PRESSURE

(166´2 - 0´2) – 169´25375 = -3´25375 (Relative to the diameter)

Relative to the radius:

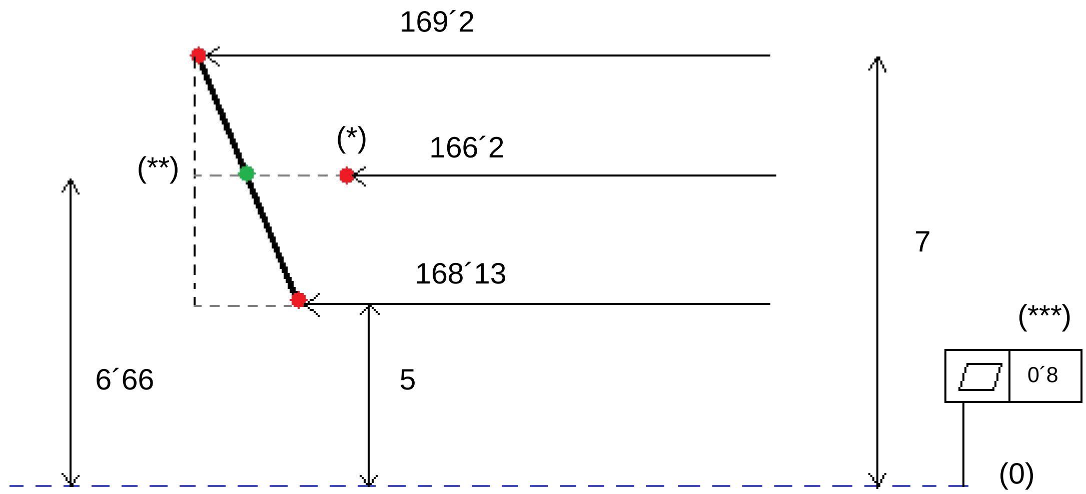
-3´25375/2 = -1´626875

1´25 is added because the gap between the sump and the TPE seal. (Reduces the interference)



-1´626875 + 1´25 = -0´376875 ≈ -0´38

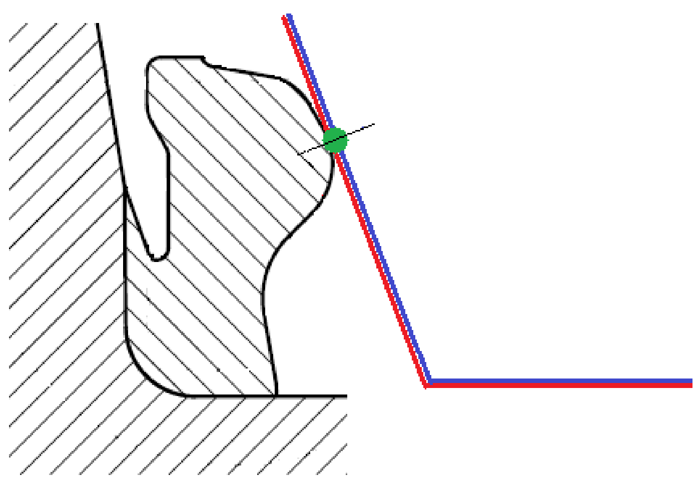
PRESSURE WITHOUT TOLERANCES



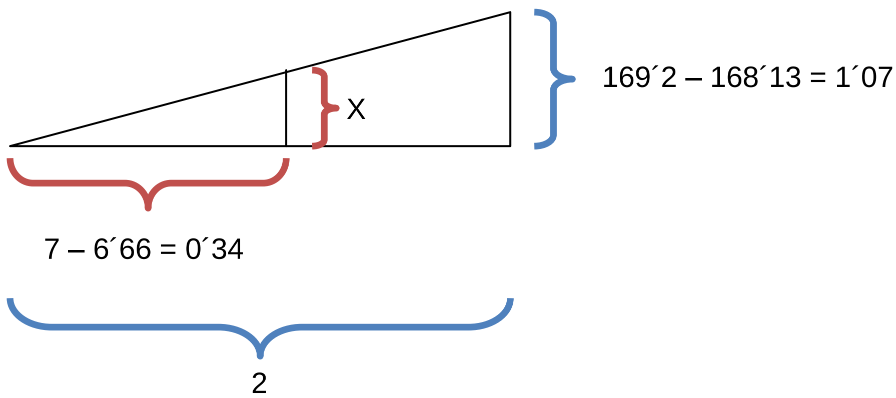
(*) → Contact point between the TPE seal and the tub.

(**) → Detail view

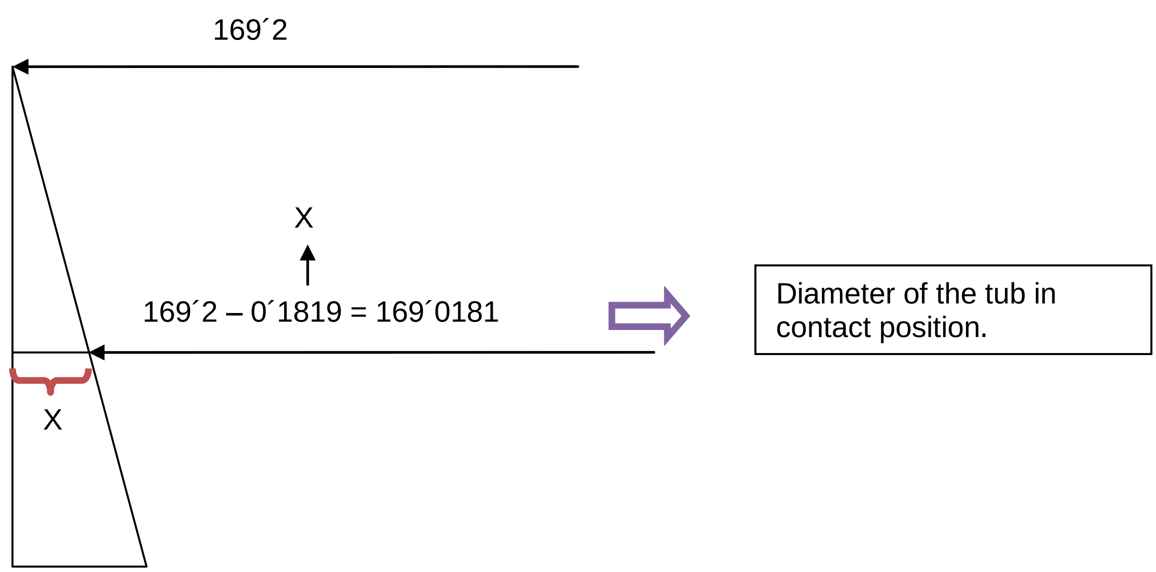
(***) → For the pressure without tolerances it is needed the value 0, so the contact point does not move:



(**)



By the equivalence´s rule → X/0´34 = 1´07/2 → X = 0´1819



- Final pressure calculation → Diameter TPE seal
  → Diameter tub

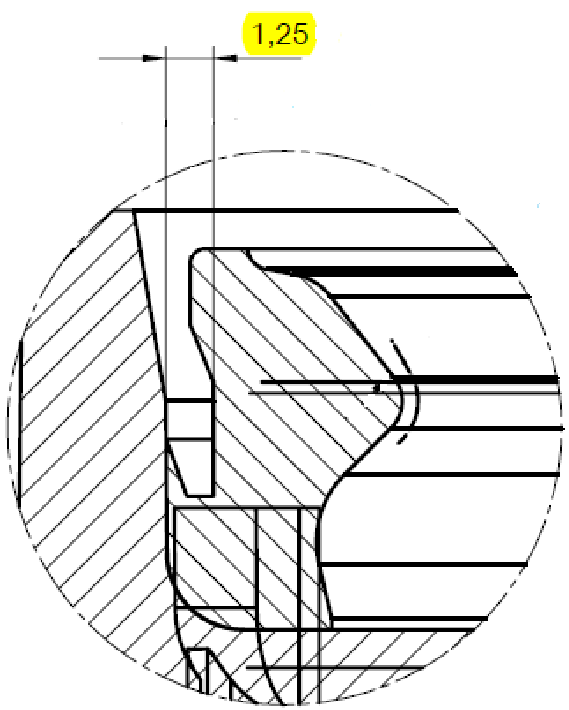
FINAL PRESSURE

166´2 – 169´0181 = -2´8181 (Relative to the diameter)

Relative to the radius:

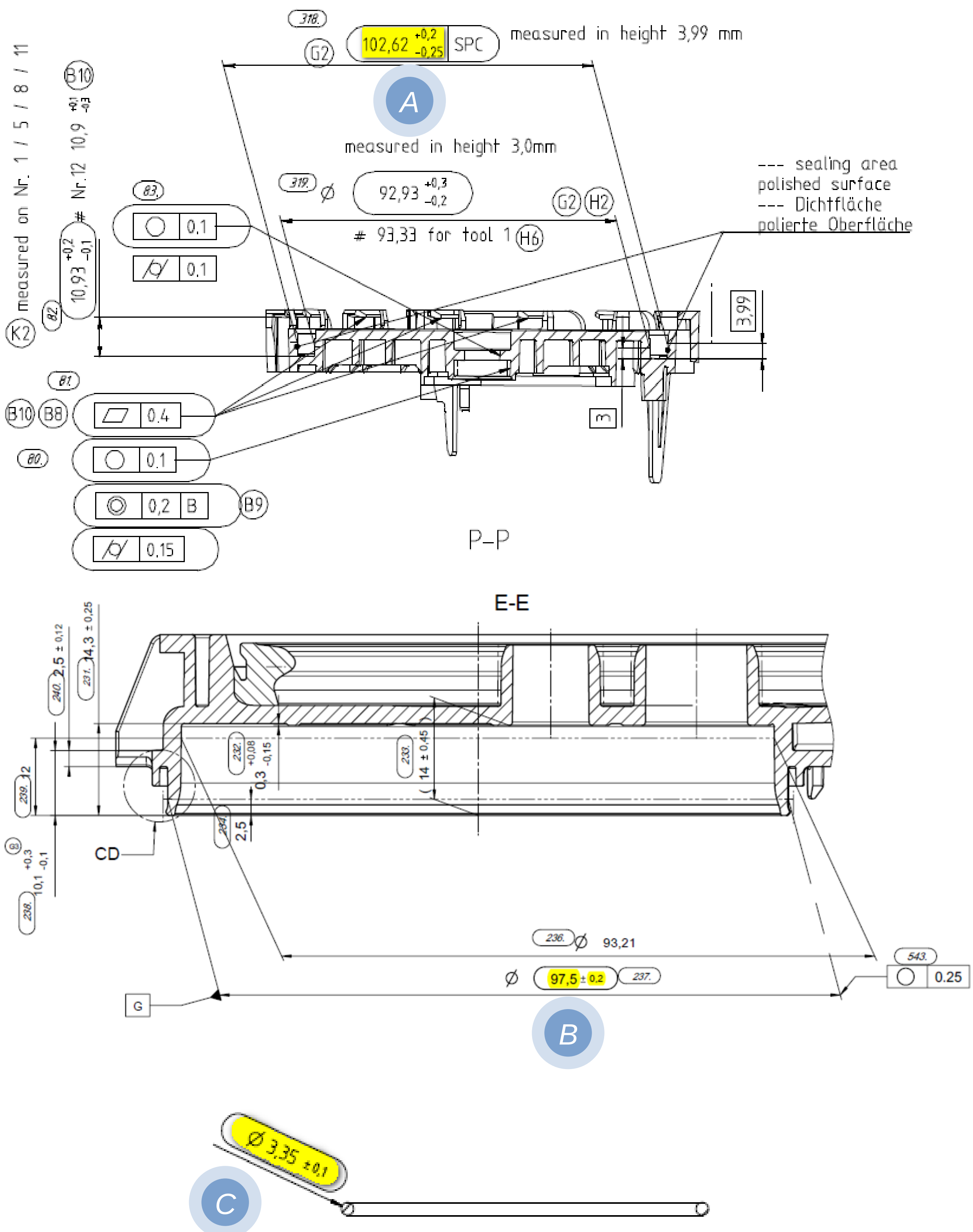
-2´8181/2 = -1´40905

1´25 is added because the gap between the sump and the TPE seal. (Reduces the interference)



-1´40905 + 1´25 = -0,15905 ≈ -0´16

Water switch seal.



PRESSURE WITHOUT TOLERANCES

102´62 – 97´5 – 2 x 3´35 = -1´58 →Radial:-1´58/2 = -0´79

PRESSURE WITH TOLERANCES

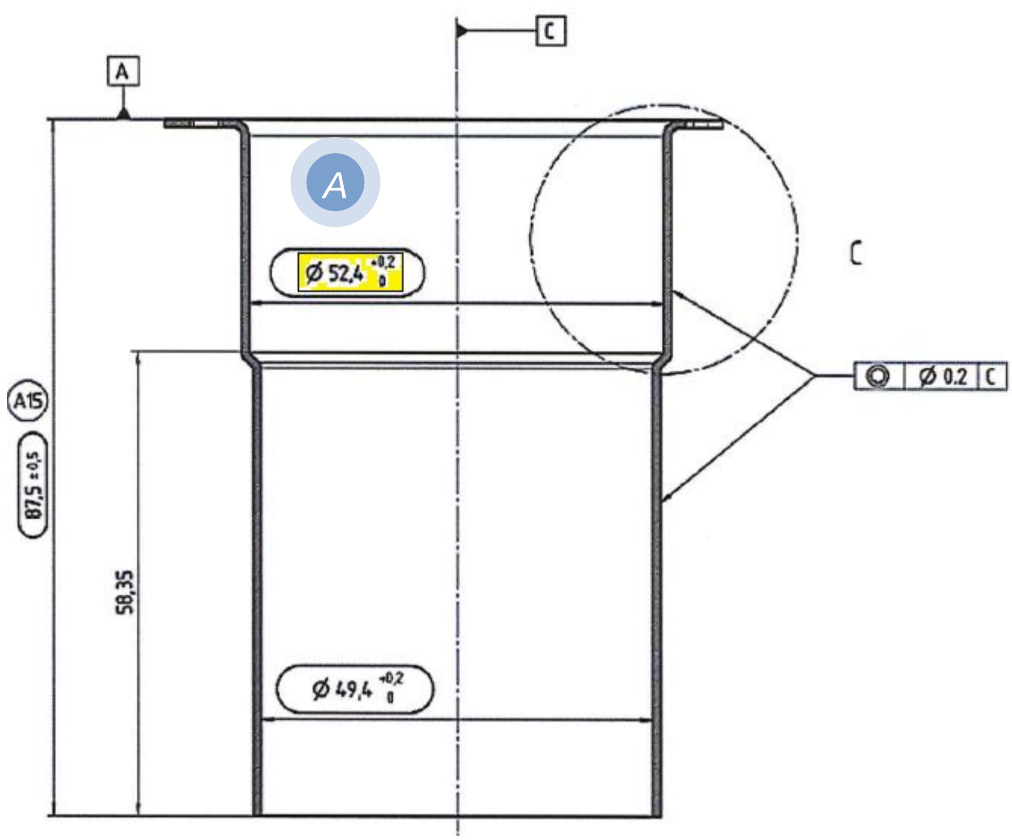
MAXIMUM PRESSURE:

A min
B max } A min – B max – 2C max→102´37 – 97´7 – 2 x 3´45= -2´23→Radial:-2´23/2 = -1´115
C max

MINIMUM PRESSURE

A max
B min } A max – B min – 2C min→102´82 – 97´3 – 2 x 3´25= -0´98→Radial:-0´98/2 = -0´49
C min

Zeolith heat system seals.



insert values Eingabefeld	tube side rohrseitig (B)		blower side lüfterseitig (E)		
Adapter-Außen-Ø Adapter-Toleranz ±	45,5 mm 0,1 mm	adapter outer diameter tolerance of outer diameter	Adapter-Außen-Ø Adapter-Toleranz ±	43,5 mm 0,1 mm	
O-Ring-Ø O-Ring-Schnurstärke	42 4,1 (C)	O-ring inner diameter diameter of cross section	O-Ring-Ø O-Ring-Schnurstärke	42 4,1 (C)	
Toleranz O-Ring-Schnurstärke ±	0,3 mm	tolerance of cross section diameter	Toleranz O-Ring-Schnurstärke ±	0,3	
Rohr-Innen-Ø Rohr-Toleranz ±	52,5 mm 0,1 mm (A)	tube inner diameter tolerance of inner diameter	Lüfter-Innen-Ø Lüfter-Toleranz ±	50,8 mm 0,2 mm (D)	blower inner diameter tolerance of inner diameter

ZEOLITH BOX PART:

PRESSURE WITHOUT TOLERANCES

52´5 – 45´5 – 2 x 4´1 = -1´2 →Radial:-1´2/2 = -0´6

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

A min.
B max.
C max.
} A min – B max – 2C max → 52´4 – 45´6 – 2 x 4´4 = -2→Radial:-2/2 = -1

MINIMUM PRESSURE

A max.
B min.
C min.
} A max – B min – 2C min → 52´6 – 45´4 – 2 x 3´8 = -0´4→Radial:-0´4/2 = -0´2

FAN PART:

PRESSURE WITHOUT TOLERANCES

50´8 – 43´5 – 2 x 4´1 = -0´9 →Radial:-0´9/2 = -0´45

PRESSURE WITH TOLERANCES

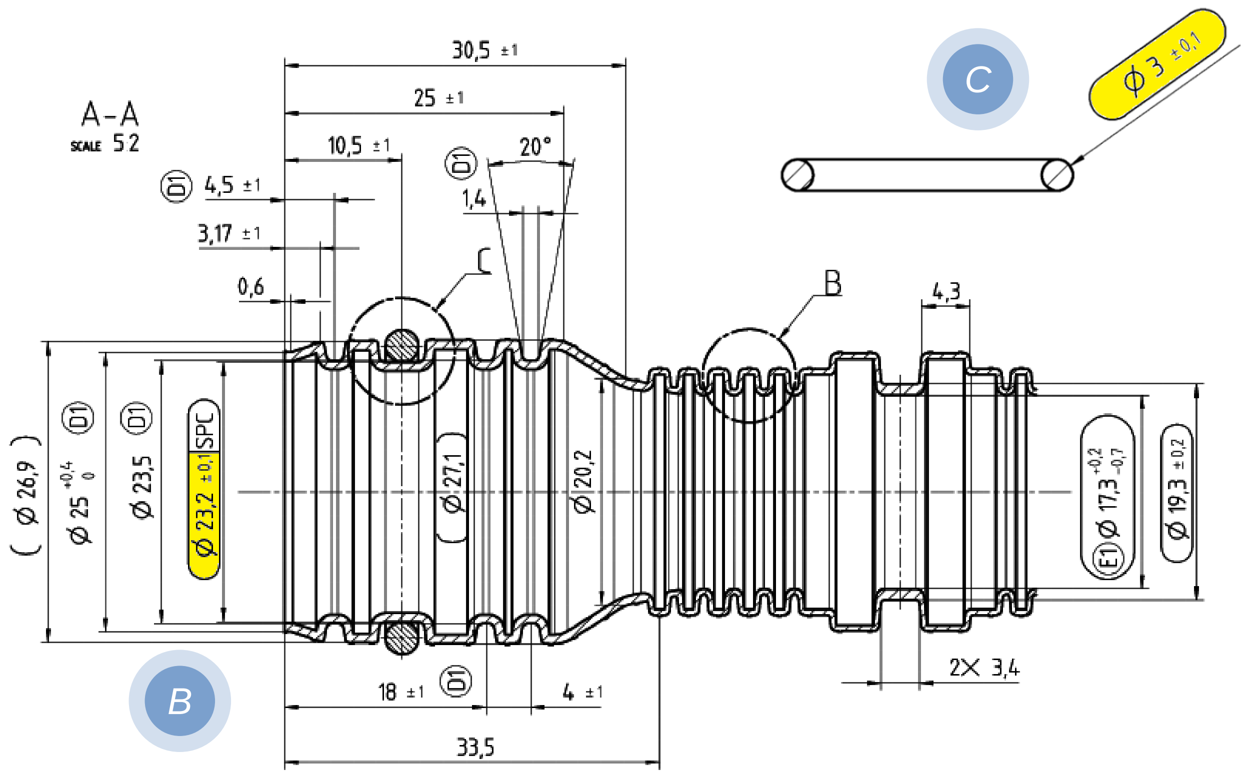
MAXIMUM PRESSURE:

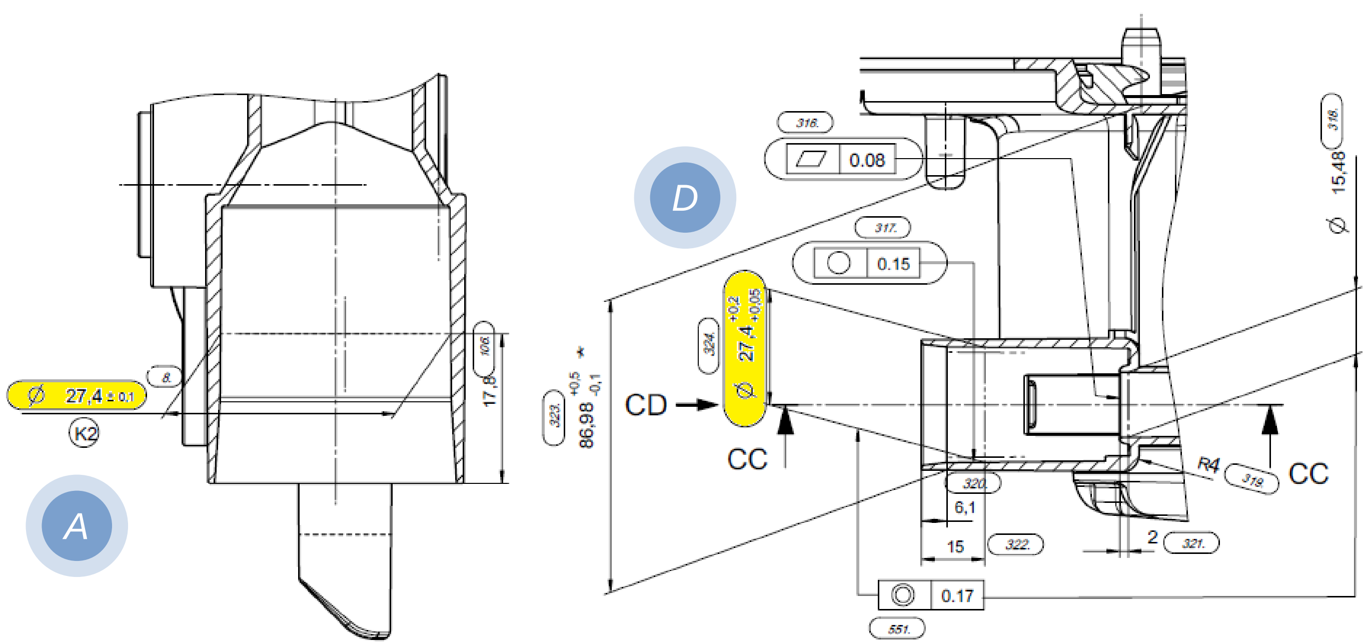
D min.
E max.
C max.
} D min – E max – 2C max → 50´6 – 43´6 – 2 x 4´4 = -1´8→Radial:-1´8/2 = -0´9

MINIMUM PRESSURE

D max.
E min.
C min.
} D max – E min – 2C min → 51 – 43´4 – 2 x 3´8 = 0→Radial:0/2 = 0

Drain hose seals.





WITH THE HEAT EXCHANGER:

PRESSURE WITHOUT TOLERANCES

27´4 – 23´2 – 2 x 3 = -1´8 →Radial:-1´8/2 = -0´9

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

A min.
B max. } A min – B max – 2C max → 27´3 – 23´3 – 2 x 3´1 = -2´2→Radial:-2´2/2 = -1´1
C max.

MINIMUM PRESSURE

A max.
B min. } A max – B min – 2C min → 27´5 – 23´1 – 2 x 2´9 = -1´4→Radial:-1´4/2 = -0´7
C min.

WITH THE SUMP:

PRESSURE WITHOUT TOLERANCES

27´4 – 23´2 – 2 x 3 = -1´8 →Radial:-1´8/2 = -0´9

PRESSURE WITH TOLERANCES

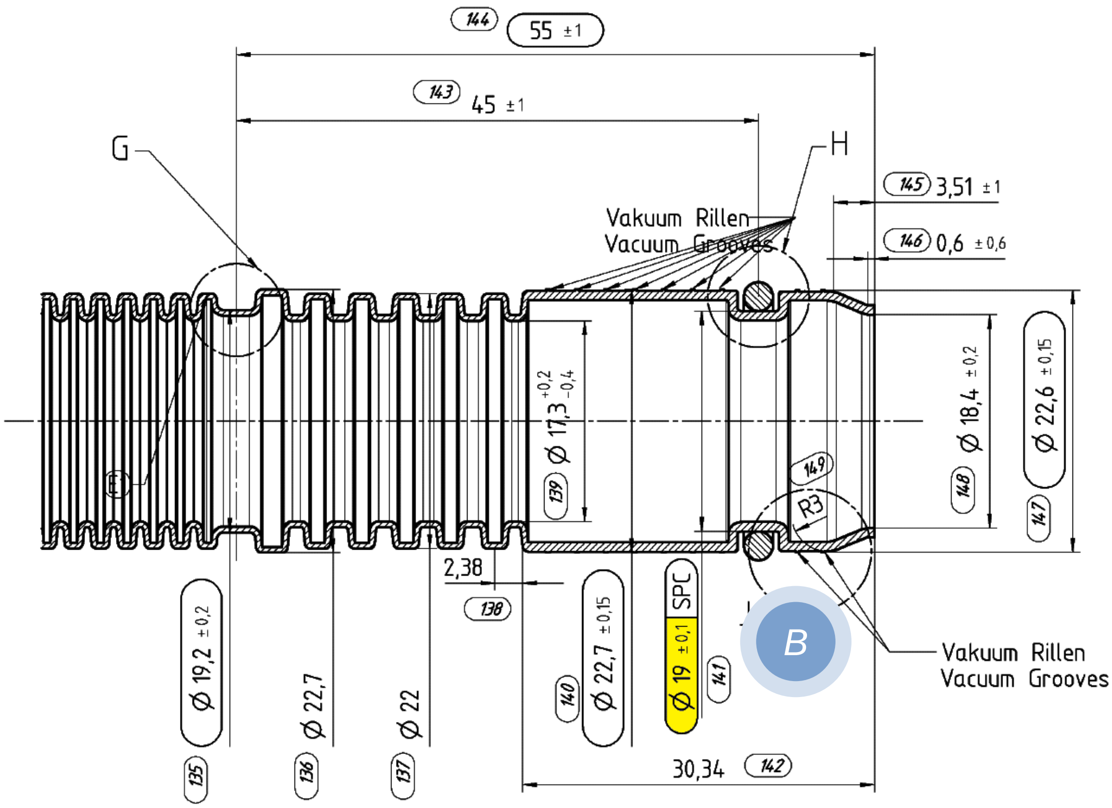
MAXIMUM PRESSURE:

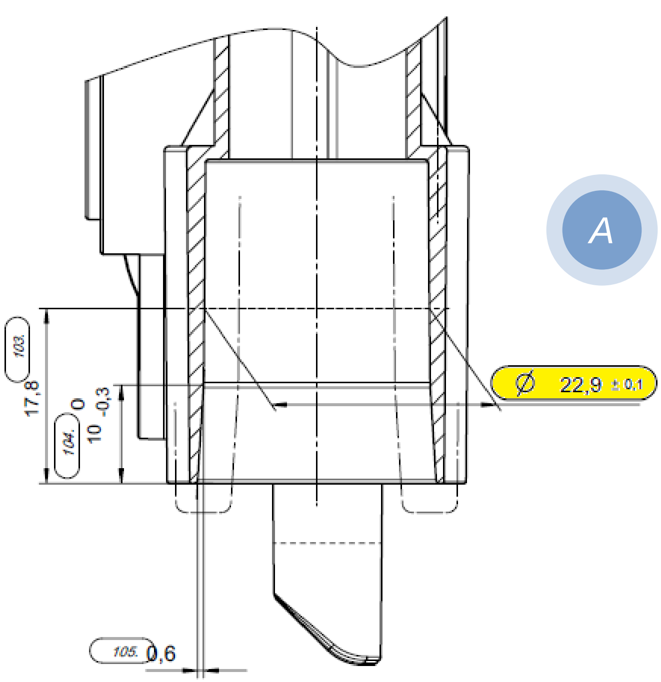
D min
B max } D min – B max – 2C max→ 27´45 – 23´3 – 2 x 3´1 = -2´05→Radial:-2´05/2 = -1´025
C max

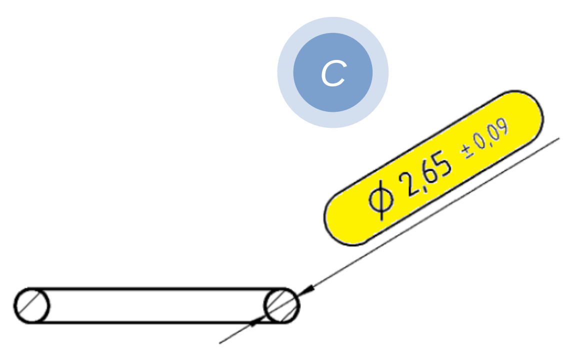
MINIMUM PRESSURE

D max.
B min. } D max – B min – 2C min → 27´6 – 23´1 – 2 x 2´9 = -1´3→Radial:-1´3/2 = -0´65
C min.

Seal outlet belows







PRESSURE WITHOUT TOLERANCES

22´9 – 19 – 2 x 2´65 = -1´4 →Radial:-1´4/2 = -0´7

PRESSURE WITH TOLERANCES

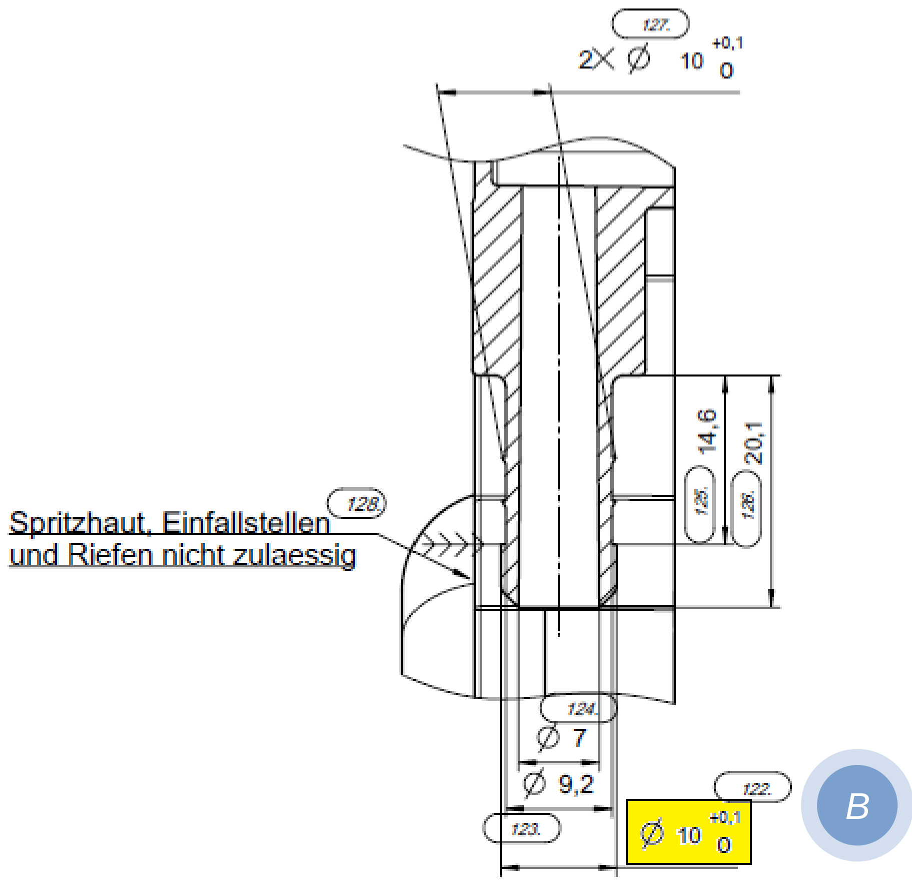
MAXIMUM PRESSURE:

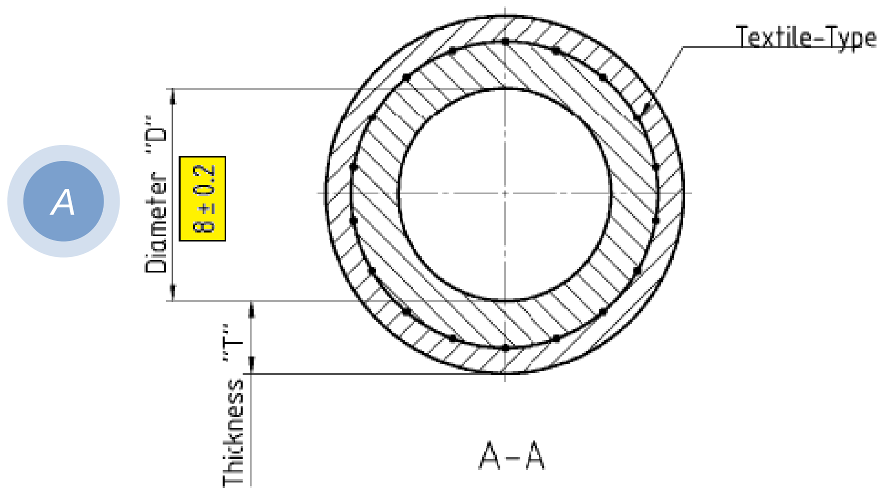
A min
B max
C max } A min – B max – 2C max → 22´8 – 19´1 – 2 x 2´74 = -1´78→Radial:-1´78/2 = -0´89

MINIMUM PRESSURE

A max
B min
C min } A max – B min – 2C min → 23 – 18´9 – 2 x 2´56 = -1´02→Radial:-1´02/2 = -0´51

Seal aquastop.





PRESSURE WITHOUT TOLERANCES

8 – 10 = -2 →Radial:-2/2 = -1

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE

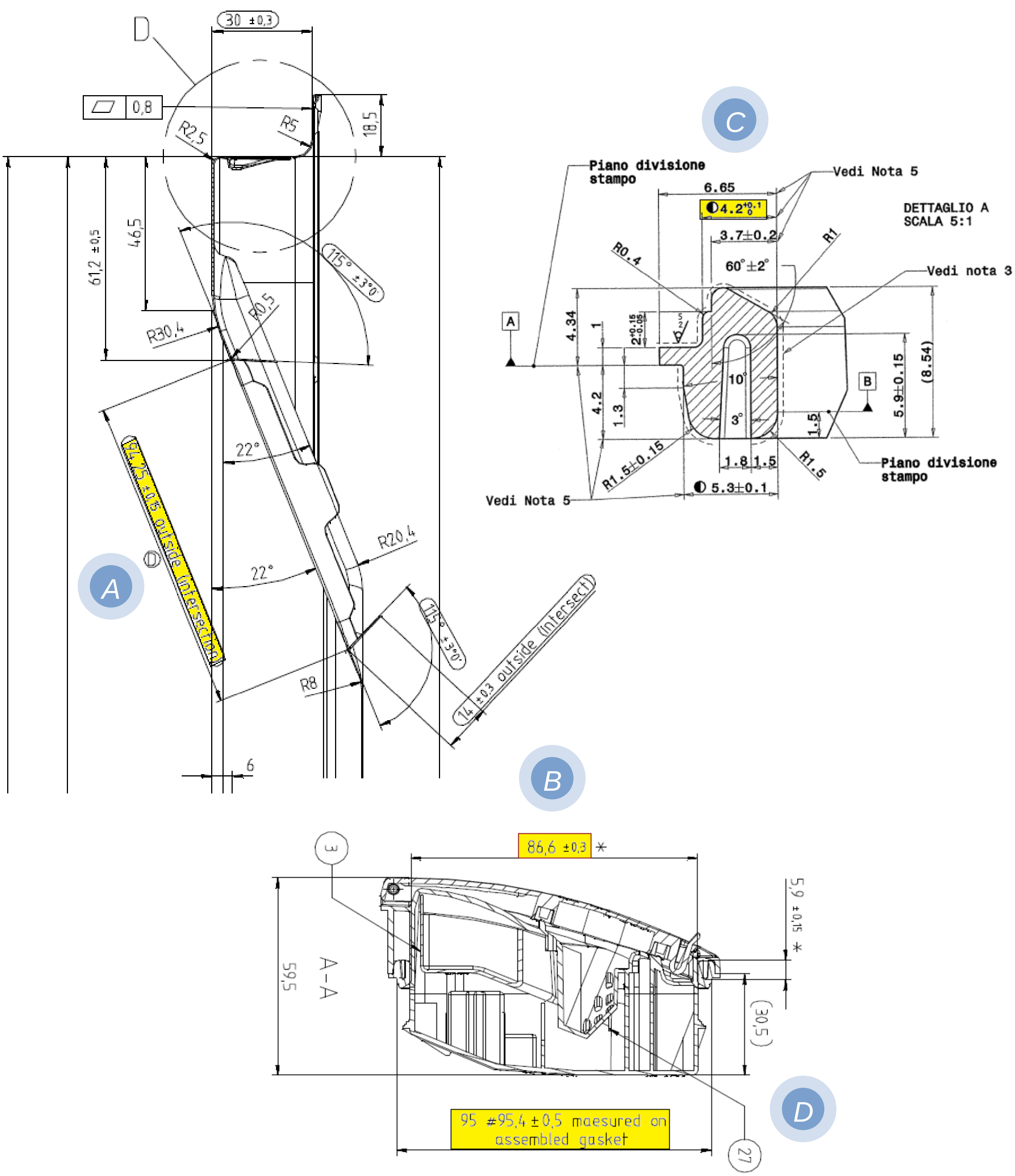
A min
B max
} A min – B max → 7´8 – 10´1 = -2´3 →Radial:-2´3/2 = -1´15

MINIMUM PRESSURE

A max
B min
} A max – B min → 8´2 – 10 = -1´8 →Radial:-1´8/2 = -0´9

Seal dispenser.

a) *Breadthways*



THEORETICAL WITH SEPARATELY PARTS:

PRESSURE WITHOUT TOLERANCES

94´25 – 86´6 – 2 x 4´2 = -0´75 →Radial:-0´75/2 = -0´375

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

A min.
B max.
C max.

} A min – B max – 2C max → 94´1 – 86´9 – 2 x 4´3 = -1´4→Radial:-1´4/2 = -0´7

MINIMUM PRESSURE

A max.
B min.
C min.

} A max – B min – 2C min → 94´4 – 86´3 – 2 x 4´2 = -0´3→Radial:-0´3/2 = -0´15

MEASURED WITH TOGETHER PARTS:

PRESSURE WITHOUT TOLERANCES

94´25 – 95´4 = -1´15 →Radial:-1´15/2 = -0´575

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

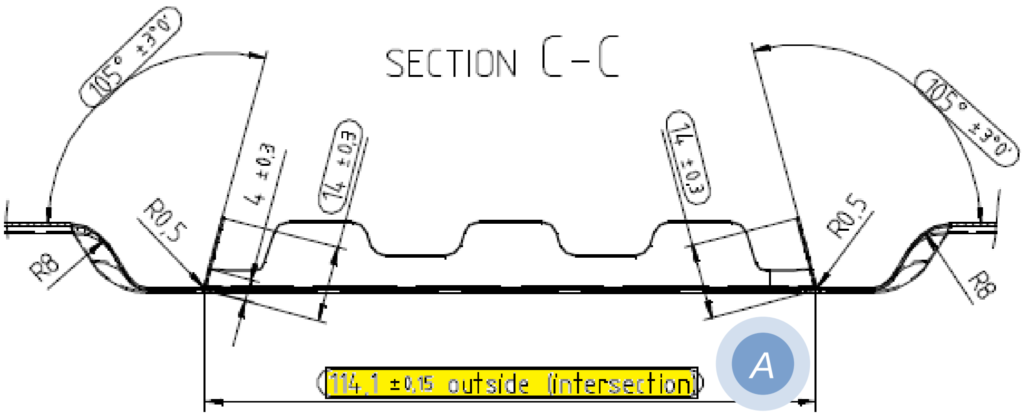
A min.
D max.

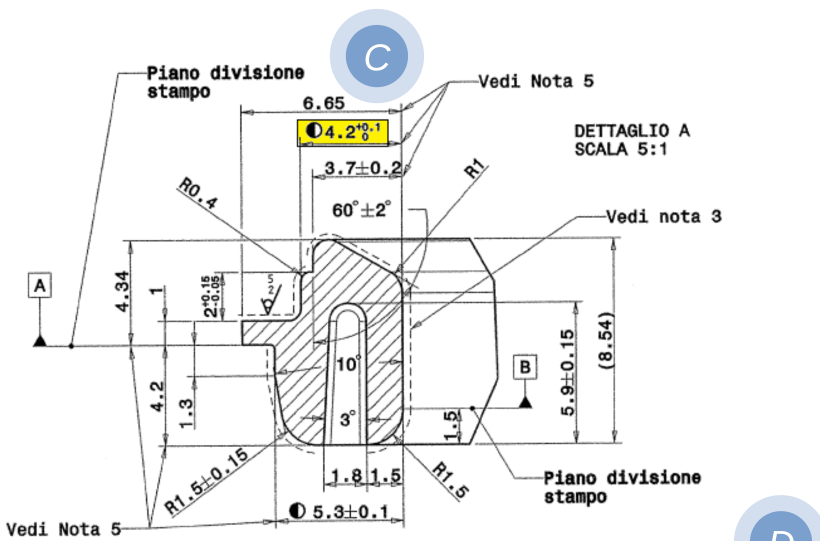
} A min – D max → 94´1 – 95´9 = -1´8 →Radial:-1´8/2 = -0´9

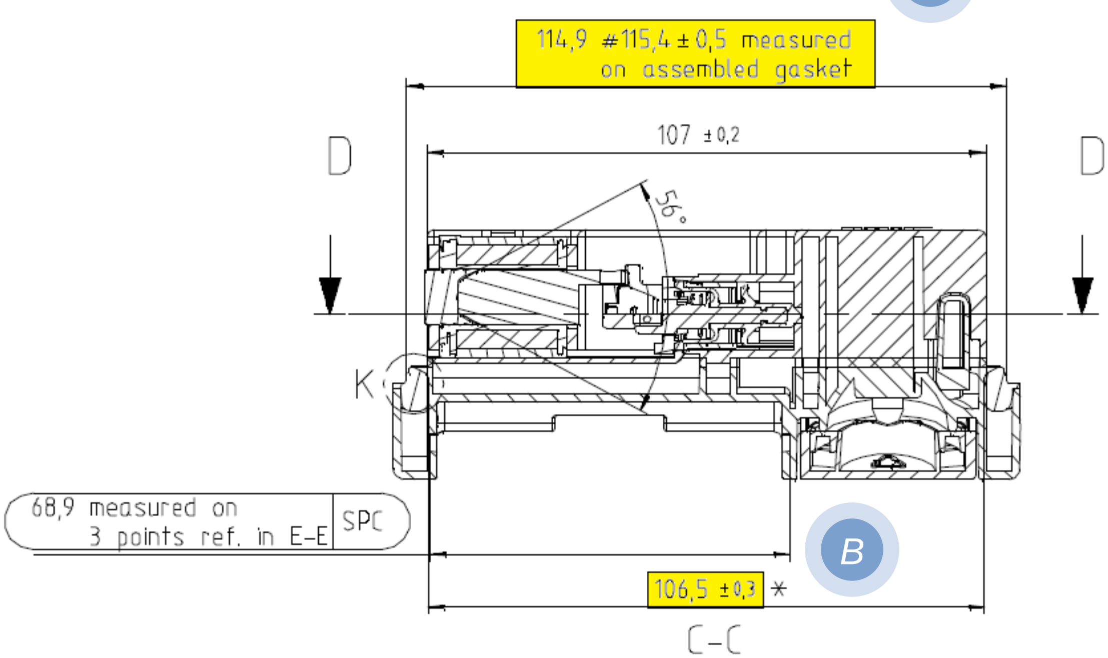
MINIMUM PRESSURE

A max.
D min.

} A max – D min → 94´4 – 94´9 = -0´5 →Radial:-0´5/2 = -0´25 *b) Lengthways*







THEORETICAL WITH SEPARATELY PARTS:

PRESSURE WITHOUT TOLERANCES

114´1 – 106´5 – 2 x 4´2 = -0´8 →Radial:-0´8/2 = -0´4

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

A min, B max, C max } A min – B max – 2C max→113´95 – 106´8 – 2 x 4´3= -1´45→Radial:-1´45/2 = -0´725

MINIMUM PRESSURE

A max, B min, C min } A max – B min – 2C min →114´25 – 106´2 – 2 x 4´2= -0´35→Radial:-0´35/2 = -0´175

MEASURED WITH TOGETHER PARTS:

PRESSURE WITHOUT TOLERANCES

114´1 – 115´4 = -1´3 →Radial:-1´3/2 = -0´65

PRESSURE WITH TOLERANCES

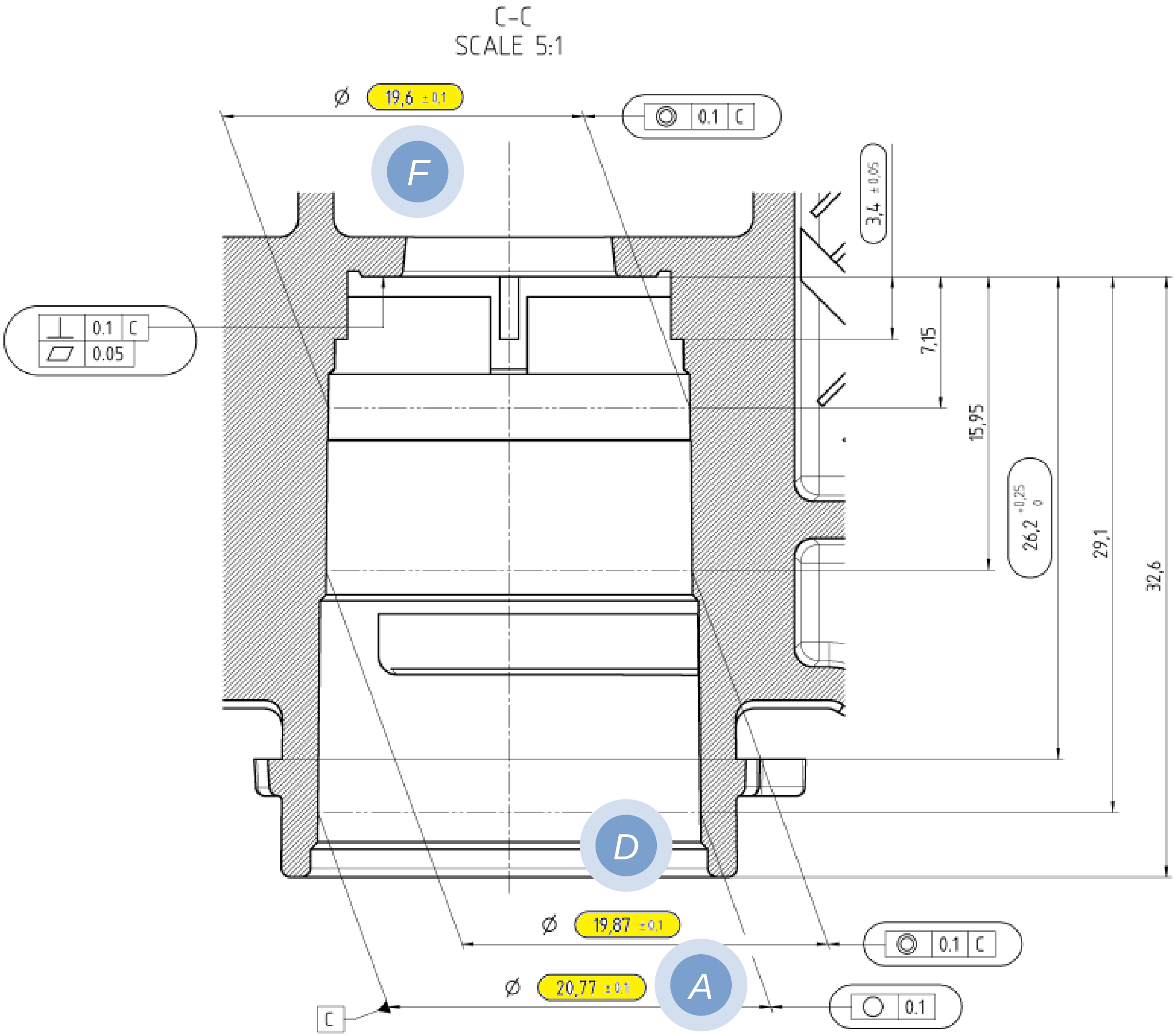
MAXIMUM PRESSURE:

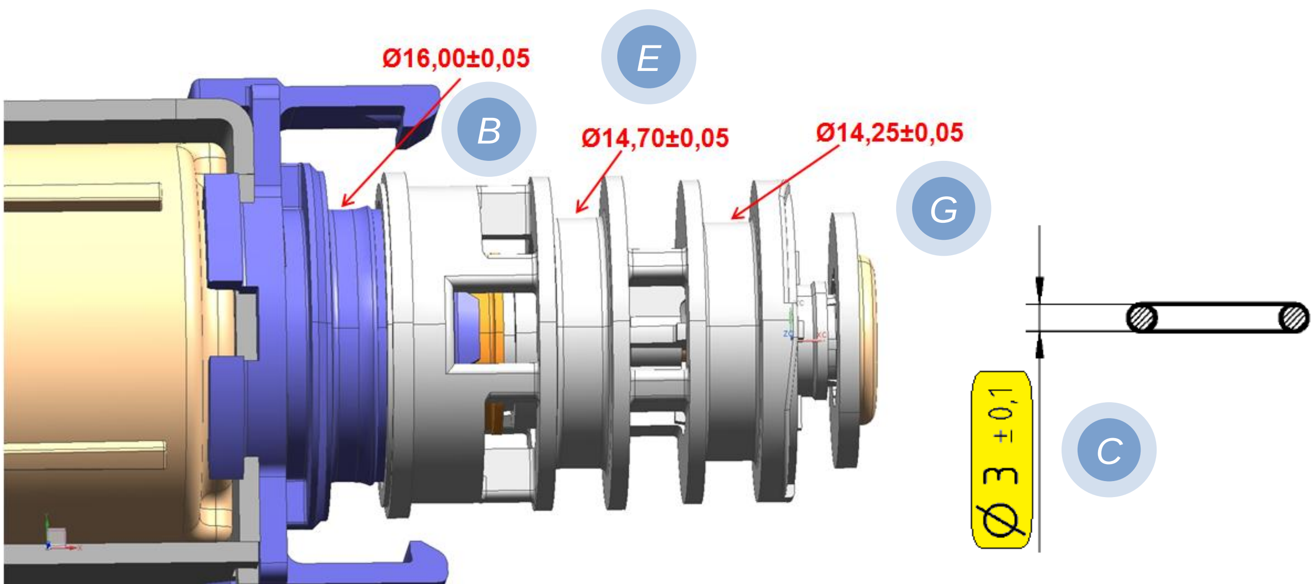
A min., D max. } A min – D max → 113´95 – 115´9 = -1´95 →Radial:-1´95/2 = -0´975

MINIMUM PRESSURE

A max., D min. } A max – D min → 114´25 – 114´9 = -0´65 →Radial:-0´65/2 = -0´325

Regeneration valve





a) ***FIRST SEALING:***

PRESSURE WITHOUT TOLERANCES

20´77 – 16 – 2 x 3 = -1´23 →Radial:-1´23/2 = -0´615

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

A min.
B max. } A min – B max – 2C max→20´67 – 16´05 – 2 x 3´1= -1´58→Radial:-1´58/2= -0´79
C max.

MINIMUM PRESSURE

A max.
B min. } A max – B min – 2C min→20´87 – 15´95 – 2 x 2´9= -0´88→Radial:-0´88/2 = -0´44
C min.

b) ***SECOND SEALING:***

PRESSURE WITHOUT TOLERANCES

19´87 – 14´7 – 2 x 3 = -0´83 →Radial:-0´83/2 = -0´415

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

D min
E max } D min – E max – 2C max→ 19´77 – 14´75 – 2 x 3´1 = -1´18→Radial:-1´18/2 = -0´59
C max

MINIMUM PRESSURE

D max.
E min. } D max – E min – 2C min → 19´97 – 14´65 – 2 x 2´9 = -0´48→Radial:-0´48/2 = -0´24
C min.

c) ***THIRD SEALING:***

PRESSURE WITHOUT TOLERANCES

19´6 – 14´25 – 2 x 3 = -0´65 →Radial:-0´65/2 = -0´325

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE:

F min.
G max.
C max.

} F min – G max – 2C max→19´5 – 14´3 – 2 x 3´1= -1→Radial:-1/2= -0´5

MINIMUM PRESSURE

F max.
G min.
C min.

} F max – G min – 2C min→19´7 – 14´2 – 2 x 2´9= -0´3→Radial:-0´3/2 = -0´15

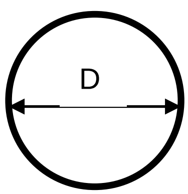
3.1.1 Percentage ´s pressure calculation.

Once the interference has been calculated, it is very useful to obtain the pressure in percent in order to better analyze and the possibility of comparing it with theoretical values. The o-ring catalogues divide the theoretical values into dynamic and static seals. In this case, all the seals are from the static group. These data can change depending on the enterprise or the people from this sector, which decide the values for his own products.

First, all the calculations are going to be made and afterwards, a data sheet is going to be shown depending on the enterprise and the different acceptable values. Like this, it is possible to see that in the first option, 48 of 96 pressure values are inside the limits (50%), in the second option 49 of 96 (51,04%) and in the third option 69 of 96 (71,88%).

All the calculations are going to be made with the following theoretical basis:

- Sealing before pressure:



- Sealing after pressure:

$$P\ (\%) = \left(\frac{D-L}{D}\right) \times 100 = \left(1 - \frac{L}{D}\right) \times 100 = \left(1 - \frac{D-I}{D}\right) \times 100 = \left(1 - 1 - \frac{I}{D}\right) \times 100 = \left(-\frac{I}{D}\right) \times 100$$

The interference is a negative value so the final formula is:

$$P\ (\%) = \frac{|I|}{D} \times 100$$

3.1.2Theoretical calculations of the parts:

- Water softener tap seal

Nominal

$$\frac{0,5}{5} \times 100 = 10\%$$

Maximum

$$\frac{0,755}{5,13} \times 100 = 14,72\%$$

Minimum

$$\frac{0,245}{4,87} \times 100 = 5,03\%$$

- Zeolith fan seal
  - Actual

Nominal

$$\frac{0,65}{3,9} \times 100 = 16,67\%$$

Maximum

$$\frac{0,9}{4} \times 100 = 22,5\%$$

Minimum

$$\frac{0,4}{3,8} \times 100 = 10,53\%$$

- New

Nominal

$$\frac{0,575}{4} \times 100 = 14,38\%$$

Maximum

$$\frac{0,855}{4,13} \times 100 = 21,43\%$$

Minimum

$$\frac{0,295}{3,87} \times 100 = 7,62\%$$

- Water storage hose seal

Nominal

$$\frac{0,65}{2,7} \times 100 = 24,07\%$$

Maximum

$$\frac{0,8}{2,9} \times 100 = 27,59\%$$

Minimum

$$\frac{0,5}{2,5} \times 100 = 20\%$$

- Storage valve seal

Nominal

$$\frac{1{,}05}{26-19} \times 100 = 15\%$$

Maximum

$$\frac{1{,}3}{26{,}15-19{,}15} \times 100 = 18{,}57\%$$

Minimum

$$\frac{0{,}8}{25{,}85-18{,}85} \times 100 = 11{,}43\%$$

- Heat exchanger valve seal n°1

Nominal

$$\frac{0{,}75}{3} \times 100 = 25\%$$

Maximum

$$\frac{0{,}95}{3{,}1} \times 100 = 30{,}65\%$$

Minimum

$$\frac{0{,}6}{2{,}9} \times 100 = 20{,}69\%$$

- Inlet pipe seal
  - Final position

Nominal

$$\frac{0{,}45}{21{,}2 - 18{,}03} \times 100 = 14{,}20\%$$

Maximum

$$\frac{0{,}65}{21{,}3 - 18{,}18} \times 100 = 20{,}83\%$$

Minimum

$$\frac{0{,}25}{21{,}1 - 17{,}88} \times 100 = 7{,}76\%$$

  - Initial position

Nominal

$$\frac{0{,}35}{21{,}2 - 18{,}03} \times 100 = 11{,}04\%$$

Maximum

$$\frac{0{,}56}{21{,}3 - 18{,}18} \times 100 = 17{,}95\%$$

Minimum

$$\frac{0{,}16}{21{,}1 - 17{,}88} \times 100 = 4{,}97\%$$

- Water softener inlet and outlet seals

Nominal

$$\frac{0,83}{5,33} \times 100 = 15,57\%$$

Maximum

$$\frac{1,035}{5,46} \times 100 = 18,96\%$$

Minimum

$$\frac{0,625}{5,2} \times 100 = 12,02\%$$

- Aquasensor seal

Nominal

$$\frac{0,65}{3} \times 100 = 21,67\%$$

Maximum

$$\frac{0,895}{3,12} \times 100 = 28,69\%$$

Minimum

$$\frac{0,355}{2,88} \times 100 = 12,33\%$$

- Drain pump seal
    - First sealing ring

Nominal

$$\frac{0,35}{2,8} \times 100 = 12,5\%$$

Maximum

$$\frac{0,5}{2,95} \times 100 = 16,95\%$$

Minimum

$$\frac{0,225}{2,8} \times 100 = 8,04\%$$

-
    - Second sealing ring

Nominal

$$\frac{0,55}{3} \times 100 = 18,33\%$$

Maximum

$$\frac{0,7}{3,15} \times 100 = 22,22\%$$

Minimum

$$\frac{0,425}{3} \times 100 = 14,17\%$$

- Main pump and water switch seal

Nominal

$$\frac{2}{35-28} \times 100 = 28{,}57\%$$

Maximum

$$\frac{2{,}3}{35{,}1-28{,}1} \times 100 = 32{,}86\%$$

Minimum

$$\frac{1{,}7}{34{,}9-27{,}9} \times 100 = 24{,}29\%$$

- Main pump and sump seal

Nominal

$$\frac{0{,}85}{35{,}4-2\times 1{,}2-28{,}3} \times 100 = 18{,}09\%$$

Maximum

$$\frac{1{,}17}{35{,}5-2\times 1{,}29-28{,}3} \times 100 = 25{,}32\%$$

Minimum

$$\frac{0{,}73}{35{,}3-2\times 1{,}11-28{,}1} \times 100 = 14{,}66\%$$

- Main pump heat system seal
  - Inner position

Nominal

$$\frac{0,5}{3} \times 100 = 16,67\%$$

Maximum

$$\frac{0,875}{3,15} \times 100 = 27,78\%$$

Minimum

$$\frac{0,275}{2,85} \times 100 = 9,65\%$$

  - Outer position

Nominal

$$\frac{0,5}{3} \times 100 = 16,67\%$$

Maximum

$$\frac{0,925}{3,15} \times 100 = 29,37\%$$

Minimum

$$\frac{0,225}{2,85} \times 100 = 7,89\%$$

- Sump and tub seal
  - For 7,85°

Nominal

$$\frac{0{,}1582}{5{,}31} \times 100 = 2{,}98\%$$

Maximum

$$\frac{0{,}429375}{5{,}31} \times 100 = 8{,}09\%$$

Minimum

$$\frac{0}{5{,}31} \times 100 = 0\%$$

  - For 15°

Nominal

$$\frac{0{,}15905}{5{,}31} \times 100 = 3\%$$

Maximum

$$\frac{0{,}376875}{5{,}31} \times 100 = 7{,}1\%$$

Minimum

$$\frac{0}{5{,}31} \times 100 = 0\%$$

- Water switch seal

Nominal

$$\frac{0,79}{3,35} \times 100 = 23,58\%$$

Maximum

$$\frac{1,115}{3,45} \times 100 = 32,32\%$$

Minimum

$$\frac{0,49}{3,25} \times 100 = 15,08\%$$

- Zeolith heat system seals
    - Zeolith box part

Nominal

$$\frac{0,6}{4,1} \times 100 = 14,63\%$$

Maximum

$$\frac{1}{4,4} \times 100 = 22,73\%$$

Minimum

$$\frac{0,2}{3,8} \times 100 = 5,26\%$$

- Fan part

Nominal

$$\frac{0,45}{4,1} \times 100 = 10,98\%$$

Maximum

$$\frac{0,9}{4,4} \times 100 = 20,45\%$$

Minimum

$$\frac{0}{3,8} \times 100 = 0\%$$

- Drain hose seals
  - With the heat exchanger

Nominal

$$\frac{0,9}{3} \times 100 = 30\%$$

Maximum

$$\frac{1,1}{3,1} \times 100 = 35,48\%$$

Minimum

$$\frac{0,7}{2,9} \times 100 = 24,14\%$$

- With the sump

Nominal

$$\frac{0,9}{3} \times 100 = 30\%$$

Maximum

$$\frac{1,025}{3,1} \times 100 = 33,06\%$$

Minimum

$$\frac{0,65}{2,9} \times 100 = 22,41\%$$

- Seal outlet belows

Nominal

$$\frac{0,7}{2,65} \times 100 = 26,42\%$$

Maximum

$$\frac{0,89}{2,74} \times 100 = 32,48\%$$

Minimum

$$\frac{0,51}{2,56} \times 100 = 19,92\%$$

- Seal aquastop

Nominal

$$\frac{1}{2,7} \times 100 = 37,04\%$$

Maximum

$$\frac{1,15}{2,9} \times 100 = 39,66\%$$

Minimum

$$\frac{0,9}{2,5} \times 100 = 36\%$$

- Seal dispenser
  - Breadthways
    - Theoretical with separately parts

Nominal

$$\frac{0,375}{4,2} \times 100 = 8,93\%$$

Maximum

$$\frac{0,7}{4,3} \times 100 = 16,28\%$$

Minimum

$$\frac{0,15}{4,2} \times 100 = 3,57\%$$

- Measured with together parts

Nominal

$$\frac{0,575}{4,2} \times 100 = 13,69\%$$

Maximum

$$\frac{0,9}{4,3} \times 100 = 20,93\%$$

Minimum

$$\frac{0,25}{4,2} \times 100 = 5,95\%$$

- Lengthways
  - Theoretical with separately parts

Nominal

$$\frac{0,4}{4,2} \times 100 = 9,52\%$$

Maximum

$$\frac{0,725}{4,3} \times 100 = 16,86\%$$

Minimum

$$\frac{0,175}{4,2} \times 100 = 4,17\%$$

- Measured with together parts

Nominal

$$\frac{0,65}{4,2} \times 100 = 15,48\%$$

Maximum

$$\frac{0,975}{4,3} \times 100 = 22,67\%$$

Minimum

$$\frac{0,325}{4,2} \times 100 = 7,74\%$$

- Regeneration valve
  - First sealing

Nominal

$$\frac{0,9}{3} \times 100 = 30\%$$

Maximum

$$\frac{1,1}{3,1} \times 100 = 35,48\%$$

Minimum

$$\frac{0,7}{2,9} \times 100 = 24,14\%$$

- Second sealing

Nominal

$$\frac{0,415}{3} \times 100 = 13,83\%$$

Maximum

$$\frac{0,59}{3,1} \times 100 = 19,03\%$$

Minimum

$$\frac{0,24}{2,9} \times 100 = 8,28\%$$

- Third sealing

Nominal

$$\frac{0,325}{3} \times 100 = 10,83\%$$

Maximum

$$\frac{0,5}{3,1} \times 100 = 16,13\%$$

Minimum

$$\frac{0,15}{2,9} \times 100 = 5,17\%$$

3.1.3 Result´s sheet

According to Busak+Shamban,Trelleborg, NewDealSeals and Simrit (From 15 to 30%)			Minimum	Nominal	Maximum
Water softener tap seal			5,03%	10%	14,72%
Zeolith fan seal	Actual		10,53%	16,67%	22,50%
	New		7,62%	14,38%	21,43%
Water storage hose seal			20%	24,07%	27,59%
Storage valve seal			11,43%	15%	18,57%
Heat exchanger valve n°1			20,69%	25%	30,65%
Inlet pipe seals	Final position		7,76%	14,20%	20,83%
	Initial position		4,97%	11,04%	17,95%
Water softener inlet/outlet seals			12,02%	15,57%	18,96%
Aquasensor seal			12,33%	21,67%	28,69%
Drain pump seal	First sealing ring		8,04%	12,50%	16,95%
	Second sealing ring		14,17%	18,33%	22,22%
Main pump and water switch seal			24,29%	28,57%	32,86%
Main pump and sump seal			14,66%	18,09%	25,32%
Main pump heat system seal	Inner position		9,65%	16,67%	27,78%
	Outer position		7,89%	16,67%	29,37%
Sump and tub seal	7.85°		0%	2,98%	8,09%
	15°		0%	3%	7,10%
Water switch seal			15,08%	23,58%	32,32%
Zeolith heat system seals	Zeolith box part		5,26%	14,63%	22,73%
	Fan part		0%	19,98%	20,45%
Drain hose seals	With the heat exchanger		24,14%	30%	35,48%
	With the sump		22,41%	30%	33,06%
Seal outlet belows			19,92%	26,42%	32,48%
Seal aquastop			36%	37,04%	39,66%
Seal dispenser	Breadthways	Theoretical with separately parts	3,57%	8,93%	16,28%
		Measured with together parts	5,95%	13,69%	20,93%
	Lengthways	Theoretical with separately parts	4,17%	9,52%	16,86%
		Measured with together parts	7,74%	15,48%	22,67%
Regeneration valve	First sealing		15,17%	20,50%	25,48%
	Second sealing		8,28%	13,83%	19,03%
	Third sealing		5,17%	10,83%	16,13%

According to Parker (From 12 to 25%)			Minimum	Nominal	Maximum
Water softener tap seal			5,03%	10%	14,72%
Zeolith fan seal	Actual		10,53%	16,67%	22,50%
	New		7,62%	14,38%	21,43%
Water storage hose seal			20%	24,07%	27,59%
Storage valve seal			11,43%	15%	18,57%
Heat exchanger valve n°1			20,69%	25%	30,65%
Inlet pipe seals	Final position		7,76%	14,20%	20,83%
	Initial position		4,97%	11,04%	17,95%
Water softener inlet/outlet seals			12,02%	15,57%	18,96%
Aquasensor seal			12,33%	21,67%	28,69%
Drain pump seal	First sealing ring		8,04%	12,50%	16,95%
	Second sealing ring		14,17%	18,33%	22,22%
Main pump and water switch seal			24,29%	28,57%	32,86%
Main pump and sump seal			14,66%	18,09%	25,32%
Main pump heat system seal	Inner position		9,65%	16,67%	27,78%
	Outer position		7,89%	16,67%	29,37%
Sump and tub seal	7.85°		0%	2,98%	8,09%
	15°		0%	3%	7,10%
Water switch seal			15,08%	23,58%	32,32%
Zeolith heat system seals	Zeolith box part		5,26%	14,63%	22,73%
	Fan part		0%	19,98%	20,45%
Drain hose seals	With the heat exchanger		24,14%	30%	35,48%
	With the sump		22,41%	30%	33,06%
Seal outlet belows			19,92%	26,42%	32,48%
Seal aquastop			36%	37,04%	39,66%
Seal dispenser	Breadthways	Theoretical with separately parts	3,57%	8,93%	16,28%
		Measured with together parts	5,95%	13,69%	20,93%
	Lengthways	Theoretical with separately parts	4,17%	9,52%	16,86%
		Measured with together parts	7,74%	15,48%	22,67%
Regeneration valve	First sealing		15,17%	20,50%	25,48%
	Second sealing		8,28%	13,83%	19,03%
	Third sealing		5,17%	10,83%	16,13%

According to APG (From 10 to 35%)			Minimum	Nominal	Maximum
Water softener tap seal			5,03%	10%	14,72%
Zeolith fan seal	Actual		10,53%	16,67%	22,50%
	New		7,62%	14,38%	21,43%
Water storage hose seal			20%	24,07%	27,59%
Storage valve seal			11,43%	15%	18,57%
Heat exchanger valve n°1			20,69%	25%	30,65%
Inlet pipe seals	Final position		7,76%	14,20%	20,83%
	Initial position		4,97%	11,04%	17,95%
Water softener inlet/outlet seals			12,02%	15,57%	18,96%
Aquasensor seal			12,33%	21,67%	28,69%
Drain pump seal	First sealing ring		8,04%	12,50%	16,95%
	Second sealing ring		14,17%	18,33%	22,22%
Main pump and water switch seal			24,29%	28,57%	32,86%
Main pump and sump seal			14,66%	18,09%	25,32%
Main pump heat system seal	Inner position		9,65%	16,67%	27,78%
	Outer position		7,89%	16,67%	29,37%
Sump and tub seal	7.85°		0%	2,98%	8,09%
	15°		0%	3%	7,10%
Water switch seal			15,08%	23,58%	32,32%
Zeolith heat system seals	Zeolith box part		5,26%	14,63%	22,73%
	Fan part		0%	19,98%	20,45%
Drain hose seals	With the heat exchanger		24,14%	30%	35,48%
	With the sump		22,41%	30%	33,06%
Seal outlet belows			19,92%	26,42%	32,48%
Seal aquastop			36%	37,04%	39,66%
Seal dispenser	Breadthways	Theoretical with separately parts	3,57%	8,93%	16,28%
		Measured with together parts	5,95%	13,69%	20,93%
	Lengthways	Theoretical with separately parts	4,17%	9,52%	16,86%
		Measured with together parts	7,74%	15,48%	22,67%
Regeneration valve	First sealing		15,17%	20,50%	25,48%
	Second sealing		8,28%	13,83%	19,03%
	Third sealing		5,17%	10,83%	16,13%

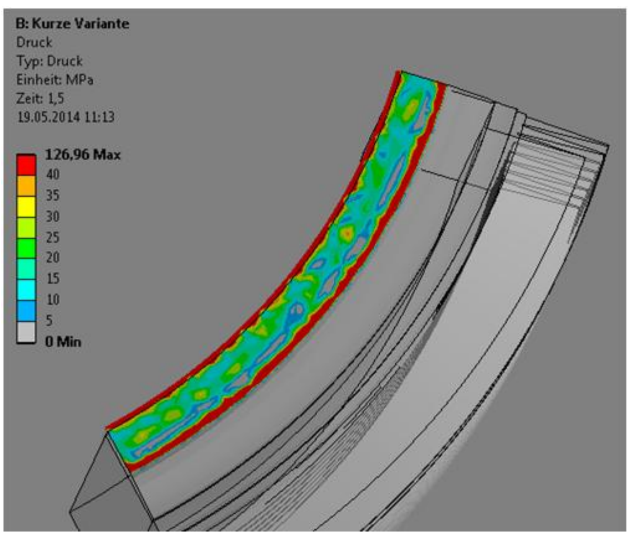
3.2 AXIAL

The axial seals, which present a few ways to calculate them, are going to be analyzed in a detailed manner. More precisely, two axial seals are going to be analyzed.

In the first one, the seal and the environment are founded in a way that makes possible a calculation like the other radial seals above. It can be considered, in the moment of the calculations, as a radial seal itself. This piece is the water softener and tub seal and due to the fact the tub is flat and rigid; this sealing can be calculated as a radial seal. It is a mechanical stop that makes the tub to be always in the same position.

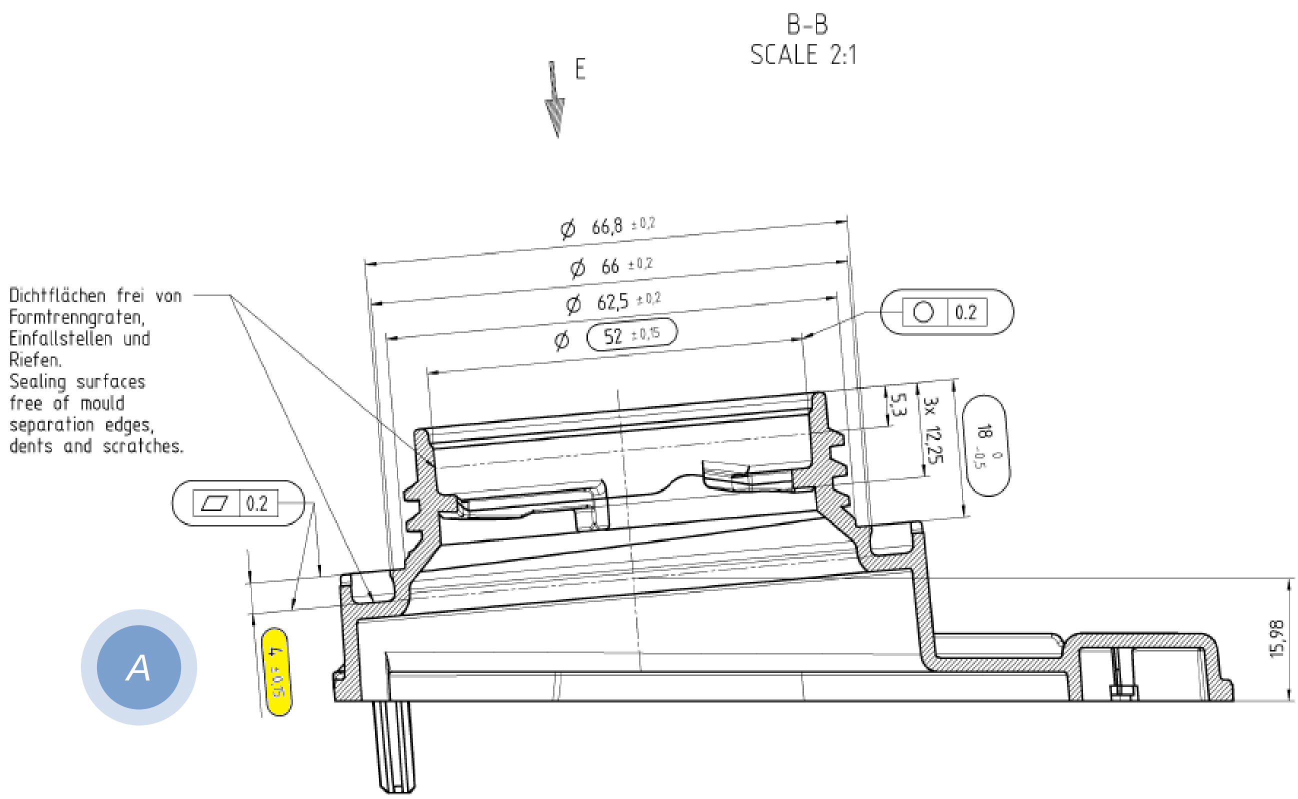
The second one, however, results more interesting due to the introduction of a simulation program in order to help with the resolution because the calculations made by hand are nearly impossible. Thus, it is like this because various factors appear in the process and not only the dimensions and tolerances as in the radial ones (material´s characteristics, forces distribution, dimensions and tolerances…).

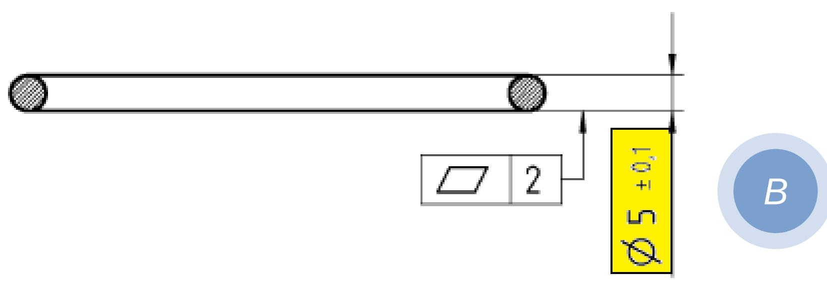
In this one, the steps are going to be shown and observed with the detailed information and data as well as different descriptive pictures to make it easier to understand. For example in this way (it is not the real analyzed part, just an example):



Important parts of this process are the mechanical simplifications of the pieces in order to optimize the analyzed system and also the restrictions, which simulate the real process through the forces and fixed supports.

Water softener and tub seal.





Due to the fact the tub is flat and rigid; this sealing can be calculated as a radial seal. It is a mechanical stop that makes the tub to be always in the same position.

PRESSURE WITHOUT TOLERANCES

4 – 5 = -1 → Radial:-1/2 = -0´5

PRESSURE WITH TOLERANCES

MAXIMUM PRESSURE

A min
B max } A min – B max → 3´85 – 5´1 = -1´25 → Radial:-1´25/2 = -0´625

MINIMUM PRESSURE

A max
B min } A max – B min → 4´15 – 4´9 = -0´75 → Radial:-0´75/2 = -0´375

Heat exchanger valve seal

The simulation that is going to be shown needs of some tools and procedures in order to simplify the operations and obtain the possibility to get a right solution of it. The simulation program used in this case is “ANSYS Workbench”, which is an extension of the most-known “ANSYS Classic” but with the 90% approximately of the possibilities from the original one. However, this one has a more user friendly interface and it owns all the characteristics needed in this process.

The first thing to keep in mind is that the design is going to be taken and imported from a CAD program called “NX”. Otherwise, the geometry has to be designed directly in the simulation program.

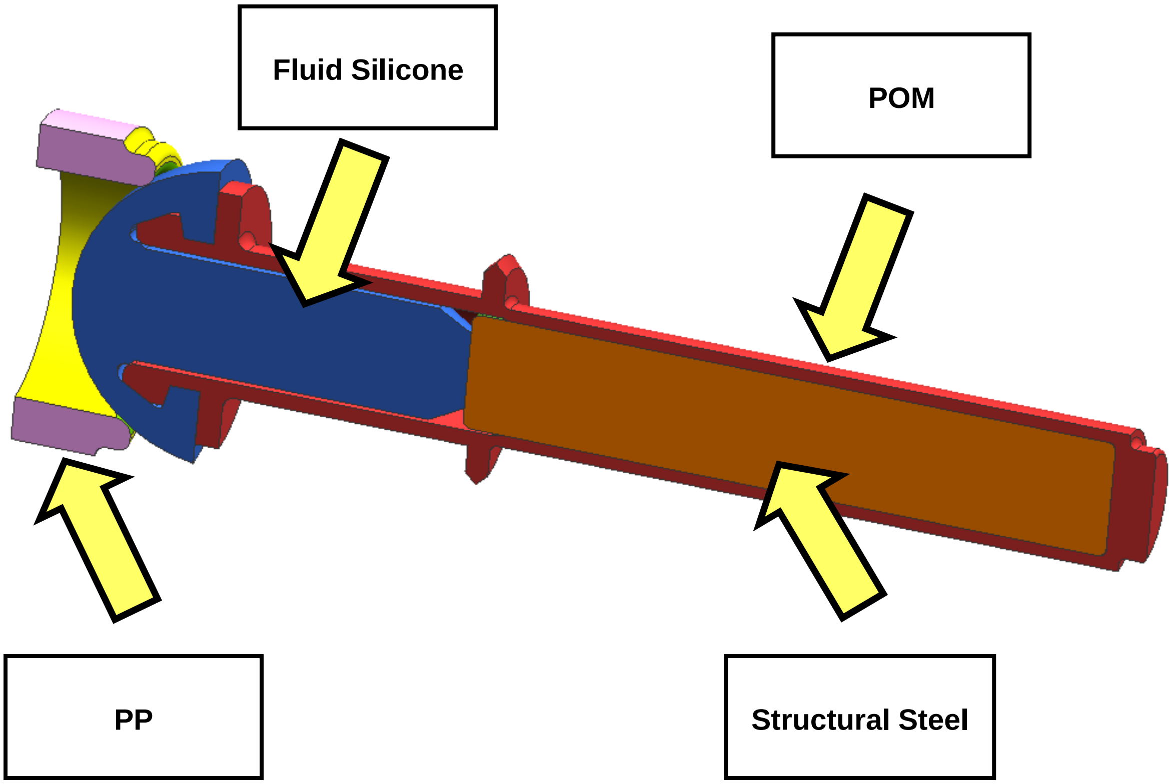
Moreover, it is very important in simulation stuff to try to achieve some simplifications owing to do not have a mesh (which has not more elements in it than necessary, but enough elements to get a sufficient accuracy for the problem) and to save calculation time and result data size. The most remarkable one is the “Volume simplification”, which can accomplish a reduction of more of the 50% of the final simulation time. In fact, the simulation is going to work with a half model because of symmetry.

ANSYS Workbench offers a huge quantity of analysis systems. The one that is used in the simulation of the heat exchanger valve due to the function and the characteristics of this seal is the “Static-Structural”. From here, the simulation process is going to follow a strict order of steps which are going to define the success of the final solution. These steps are the followings:

- Engineering data

The materials involved in the operation need to be defined above. Each one has his own properties as for example: Young´s Modulus, Poisson´s Ratio, Tensile Yield Stress, Compressive Yield Stress… The two lasts are principally to compare the final solution with the theoretical data and not for the calculations.

Material	Young´s Modulus	Poisson´s Ratio	Bulk Modulus	Shear Modulus
POM	2,8E+09 Pa	0,35	3,1111E+09 Pa	1,037E+09 Pa
PP	1,6E+09 Pa	0,42	3,3333E+09 Pa	5,6338E+08 Pa
Structural Steel	2E+11 Pa	0,3	1,6667E+11 Pa	7,6923E+10 Pa



In this case, one material is rubber (Fluid silicone). There are several material models to describe this hyperelastic material e.g. "Neo-Hooke", "Polynom Form", "Ogden", "Arruda-Boyce" or "Yeoh".

Here the Mooney Rivlin 2 Parameter Model was chosen. So three parameters are needed, which are the two Mooney Rivlin Constants and the Incompressibility parameter.

These ones can be calculated from measurement data by a curve fitting procedure. With these three parameters, a diagram stress (Pa)-strain (mm^{-1}) can be made.

Properties of Outline Row 3: Dichtung Shore A 50

	A	B	C
1	Property	Value	Unit
2	Density	1,15E-06	kg mm^-3
3	Mooney-Rivlin 2 Parameter		
4	Material Constant C10	0,31072	MPa
5	Material Constant C01	0,07768	MPa
6	Incompressibility Parameter D1	2,1459	MPa^-1

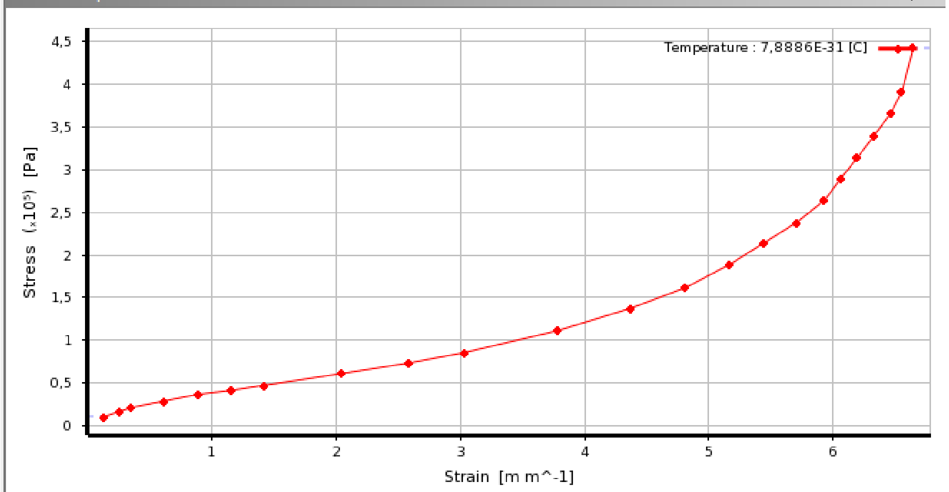
Here is an example of the view of the program with the diagram of one material done based on the properties above:

Table of Properties Row 2: Uniaxial Test Data

	A
1	Temperature (C)
2	
*	

	B	C
1	Strain (m m^-1)	Stress (Pa)
2	0,1338	10691
3	0,2675	16800
4	0,3567	21383
5	0,6242	29019
6	0,8917	36656
7	1,1592	41238
8	1,4268	47347
9	2,051	61093
10	2,586	73311
11	3,0318	85530
12	3,7898	1,1149E+05
13	4,3694	1,3746E+05
14	4,8153	1,619E+05
15	5,172	1,8939E+05
16	5,4395	2,1383E+05

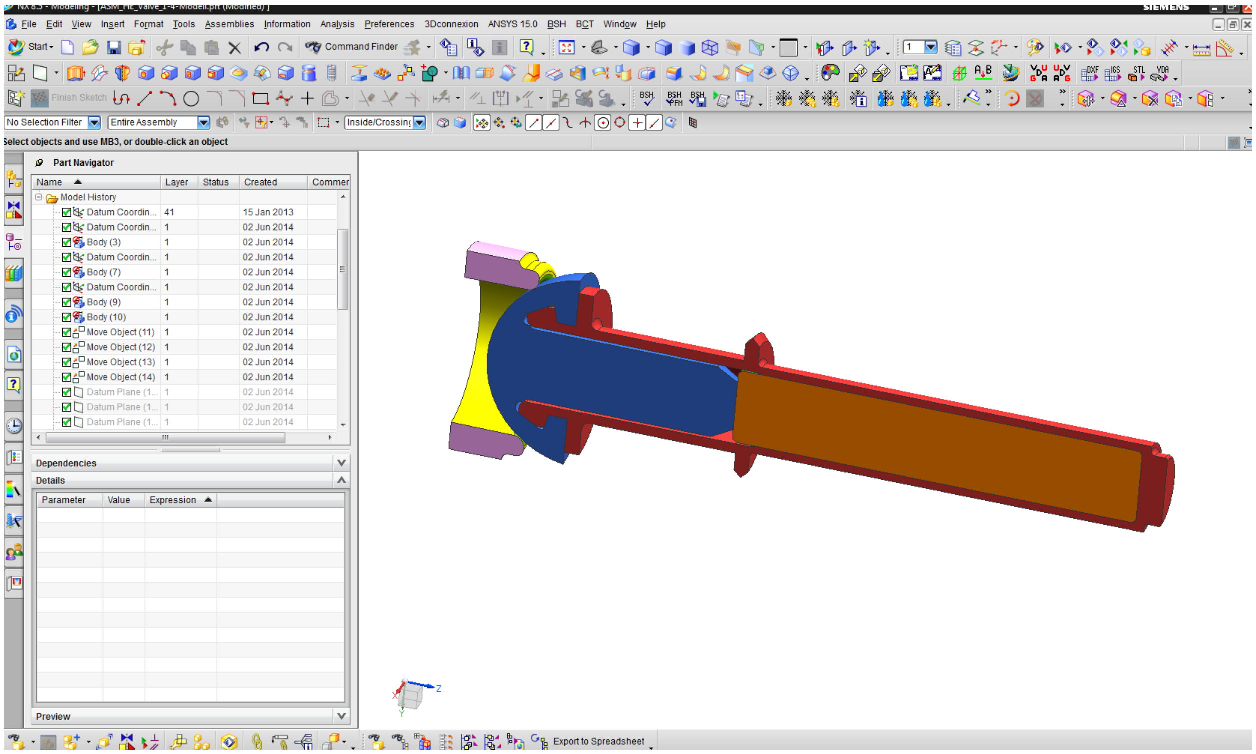
Chart of Properties Row 2: Uniaxial Test Data



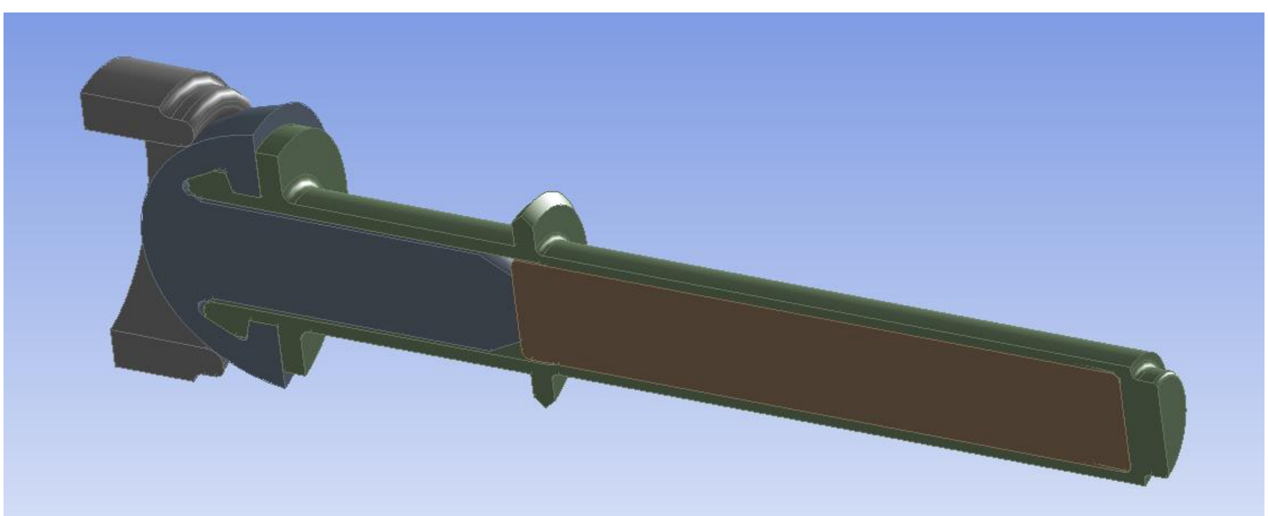
- <u>Geometry</u>

The CAD designs of the parts needed and involved in the sealing are inserted through exportation from the “NX” program. It is preferable to do the volume simplifications required directly in the CAD program and not in the simulation one despite having the possibility.

Here it is the “NX” design:

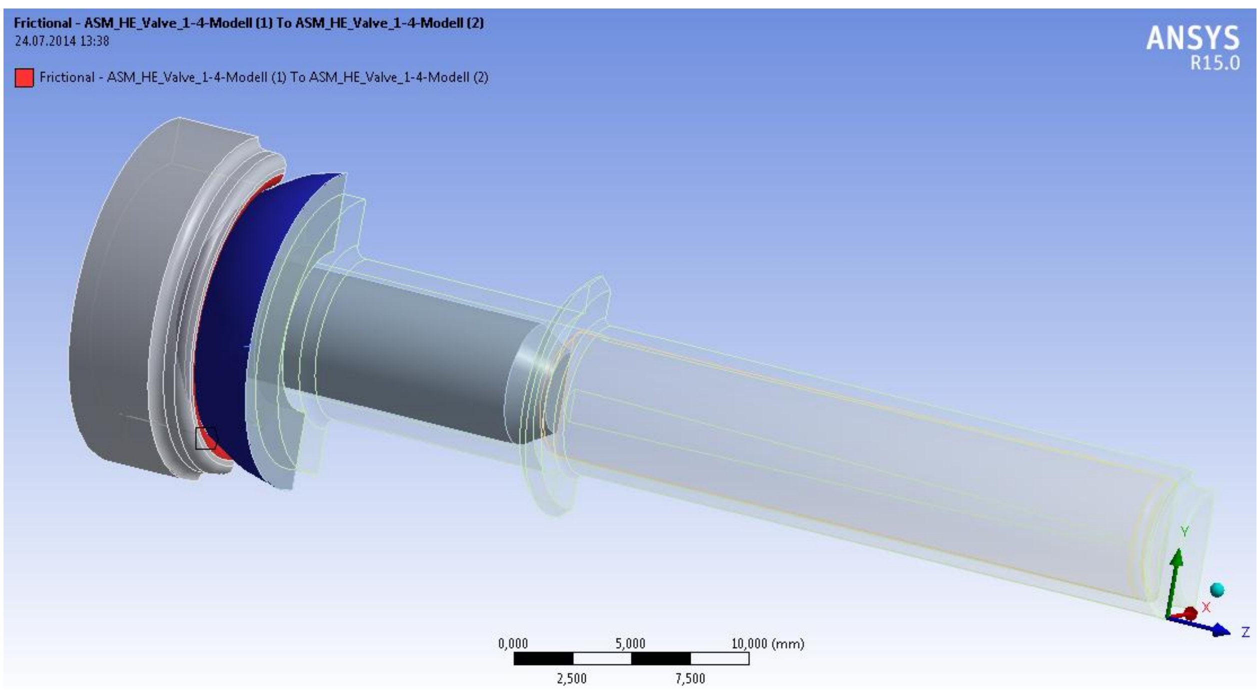


And now the “NX” design is exported to “Ansys Workbench”:

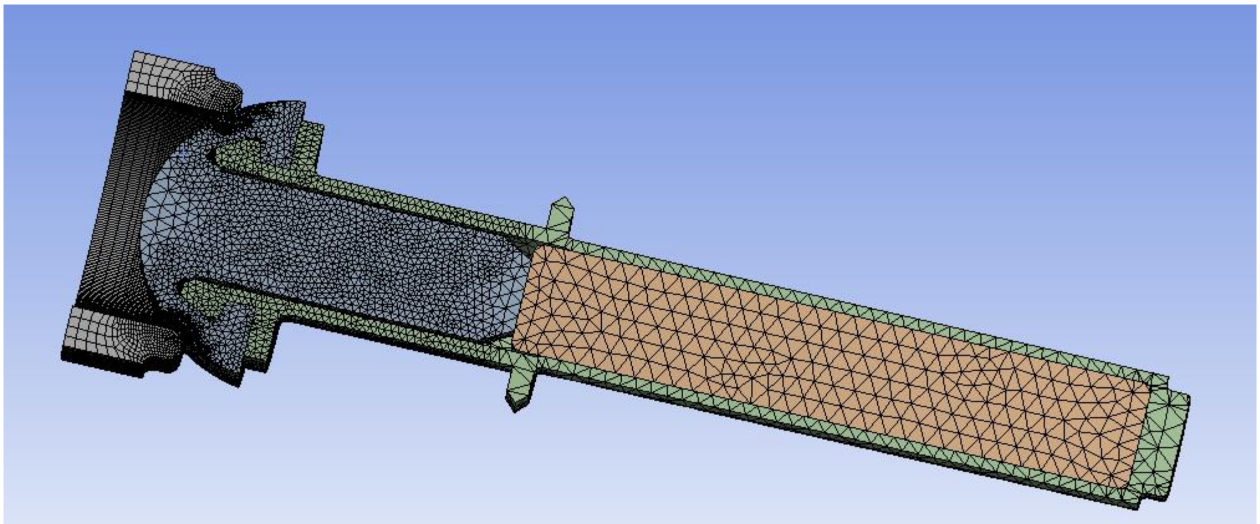


- Model

The material needs to be set with the right part so every part is required to be with its own properties. Here is very important to define the points of contacts between materials. In this case, four contacts are defined; one between the rubber mushroom and the heat exchanger, another between the rubber mushroom and the plastic part which is inside the mushroom, another between the plastic part and the structural steel part and the last one between the structural steel and the rubber mushroom. These contacts in this case are from a “Frictional type” so the friction coefficient, which depends of the material pair, needs to be set. For example a friction coefficient of 0.4 is a possible value to a rubber contact. Moreover, in the second contact (rubber mushroom-plastic inside valve), a little trick or simplification need to be done in order to bring down the gap between both. For this reason, the tolerances of the pieces can be raised and now these sides of the pieces can be introduced in the second contact.



Now is the moment to establish the correct mesh for the pieces involved in the sealing and in the process. It is very important to have a smaller size of mesh just in the contacts to achieve more exact results. In this case, a possible size is estimated to be 0.1 mm. In the rest of the pieces a bigger size of mesh can be determined (0.8 mm). Approximately 141500 elements were created in this simulation.



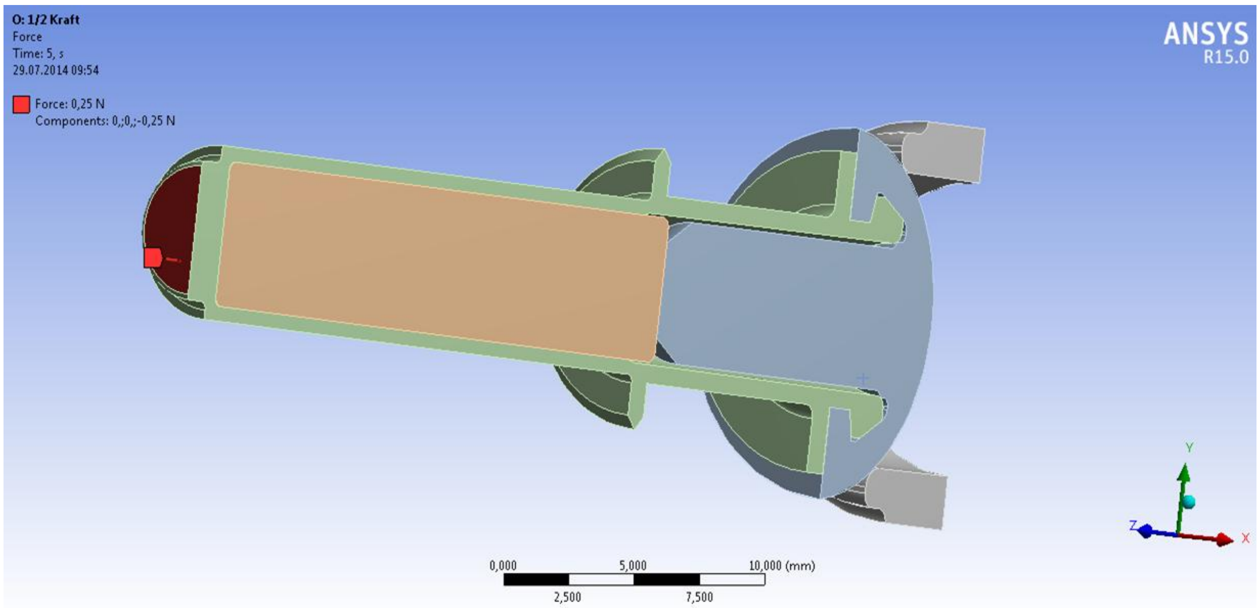
It is also possible to see the exact number of nodes and elements created:

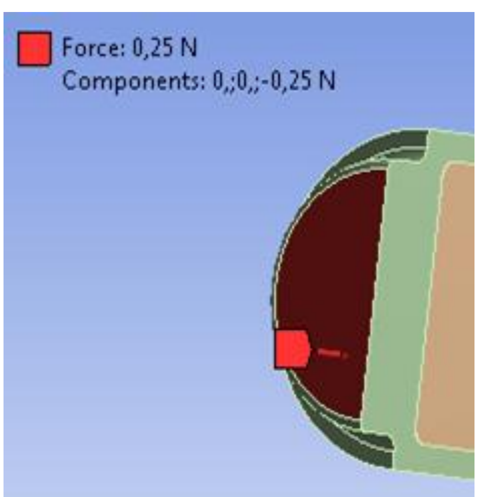
Details of "Mesh"	
Defaults	
Physics Preference	Mechanical
Relevance	100
Sizing	
Inflation	
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Patch Independent Options	
Topology Checking	Yes
Advanced	
Defeaturing	
Statistics	
Nodes	70876
Elements	141330
Mesh Metric	None

- <u>Setup</u>

In this phase of the process it is very important to establish the environment of the parts involved in the sealing (Boundary conditions). This means forces and restrictions to the parts to simulate the real behavior of them.

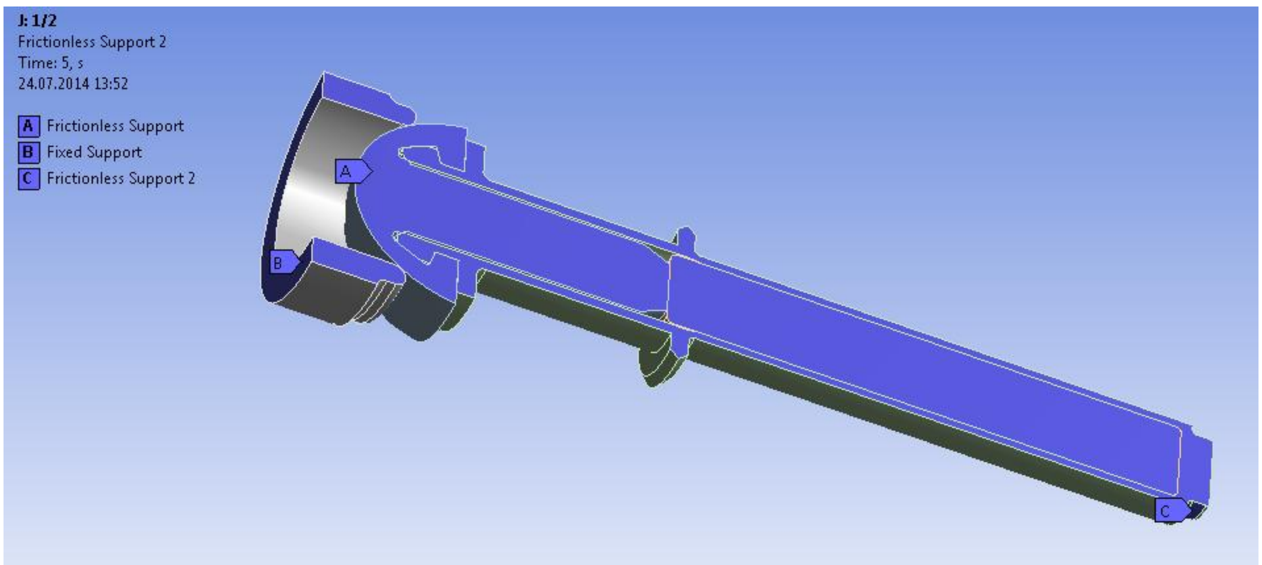
The first thing is to put forces in the faces (it is better to begin with low forces and see if it is correct and then increase them little by little to see if the behavior is the same and the solution is reliable.





A force of 0.25N is set because it is a half model simulation. In summary it is a force of 0.5N, which is the maximum close force indicated in the drawings and specifications.

Now it is time to set the restrictions and mechanical stops. In this case, the opposed face of the forced part, ergo, the heat exchanger, needs to be fixed as in reality so the option “Fixed support” is the one that fits perfectly. Additionally, the environment of the plastic part of the valve and all the inner side of the valve need to be set with “Frictionless support”. The reason for why the inner side of the valve needs to be fixed like that is because another simplification is to cut the pieces in two parts due to his axial symmetry, and these are required to be not deformed inwards. Finally, another “Frictionless support” is set on an outer ring of the plastic part on the edge of the valve in order to not move to all sides.



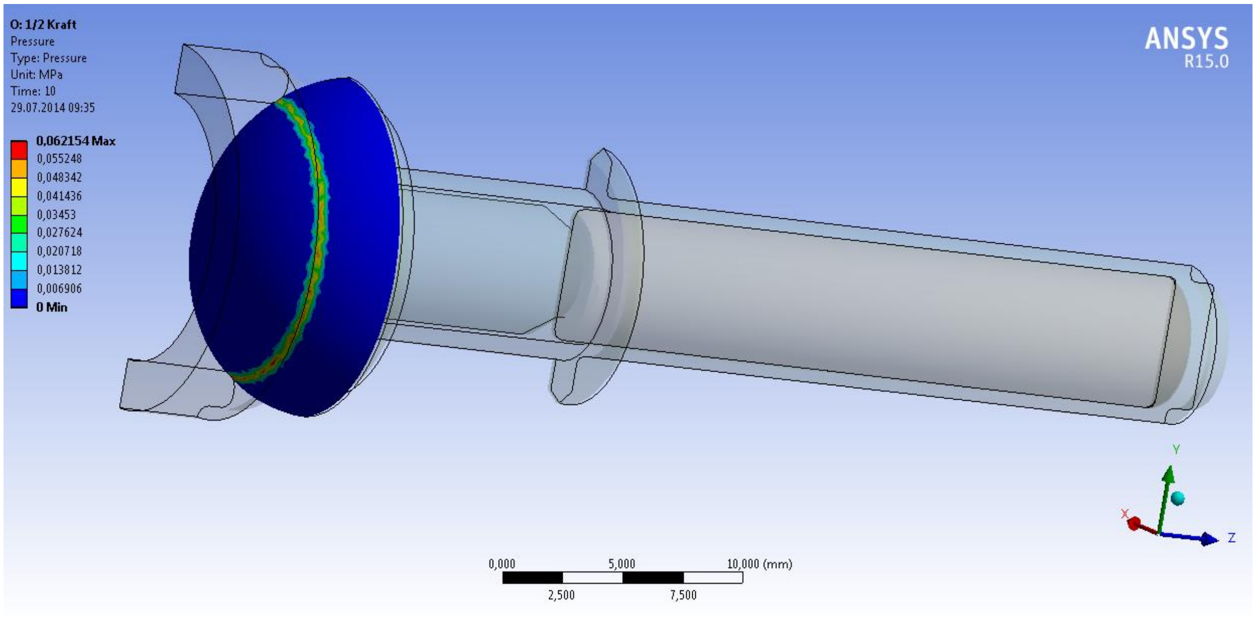
- Post processing

This is the end of the simulation where the solution is given and where the results can be reviewed and checked searching if the resulted parameters are the right ones or not. In many cases the solutions are very disproportionate with the system so it is needed an analysis of why and where the fail is coming from.

The results are given with only the numbers or instead with complete diagrams where colored levels are shown.

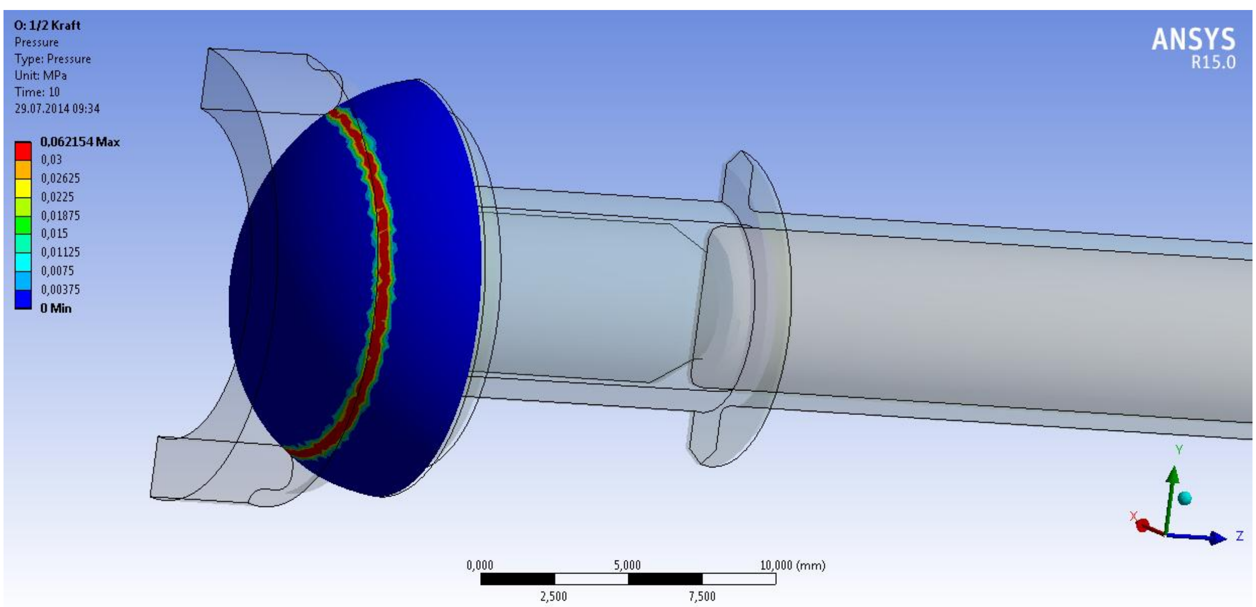
The two first pictures represent the contact pressure in MPa. In the first one, it is possible to see that there is a maximum pressure of 0.6 bar (0.06MPa) and the maximum pressure of the water in contact with the seal has a pressure of 50mbar (50 cm of difference of high for pressure), so the seal is tight

Here is the picture:

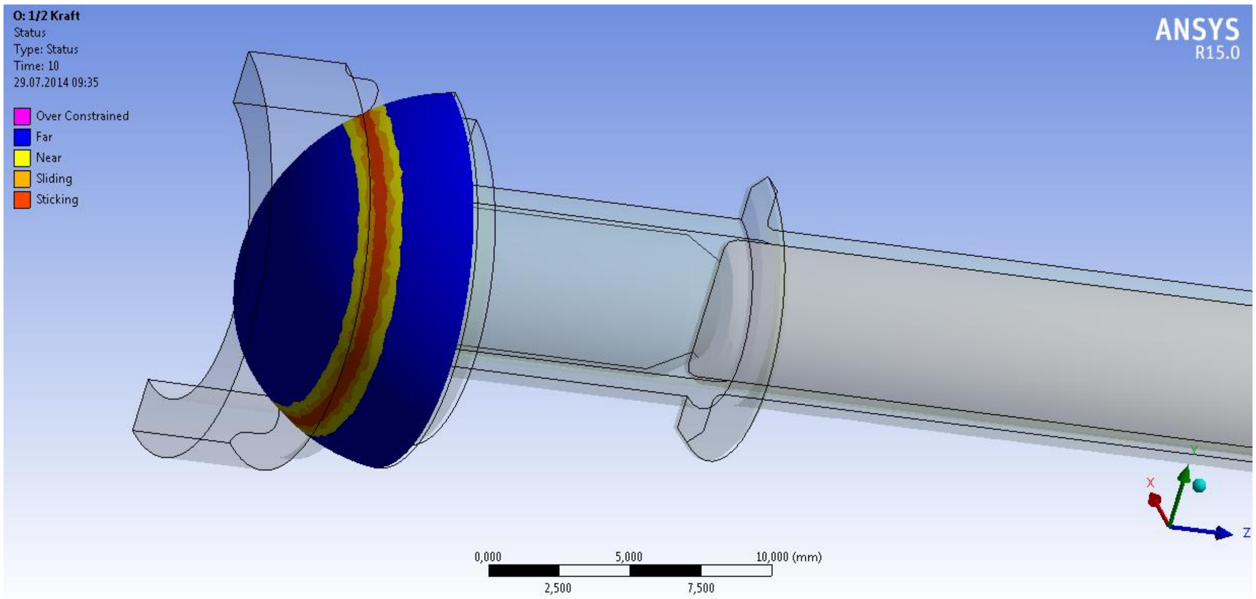


There is a trick to put limits to when there is going to be a leakage. The only thing to do is to delimit by hand writing and see the result with the aid of the data and the colors. If it is not correct, then a new limit needs to be set again. In this case it is visually easy to see that the limit is on 0.3 bar. With all the pressure between 0.3 bar to 0.6 bar the seal achieve his target. Here is the example:

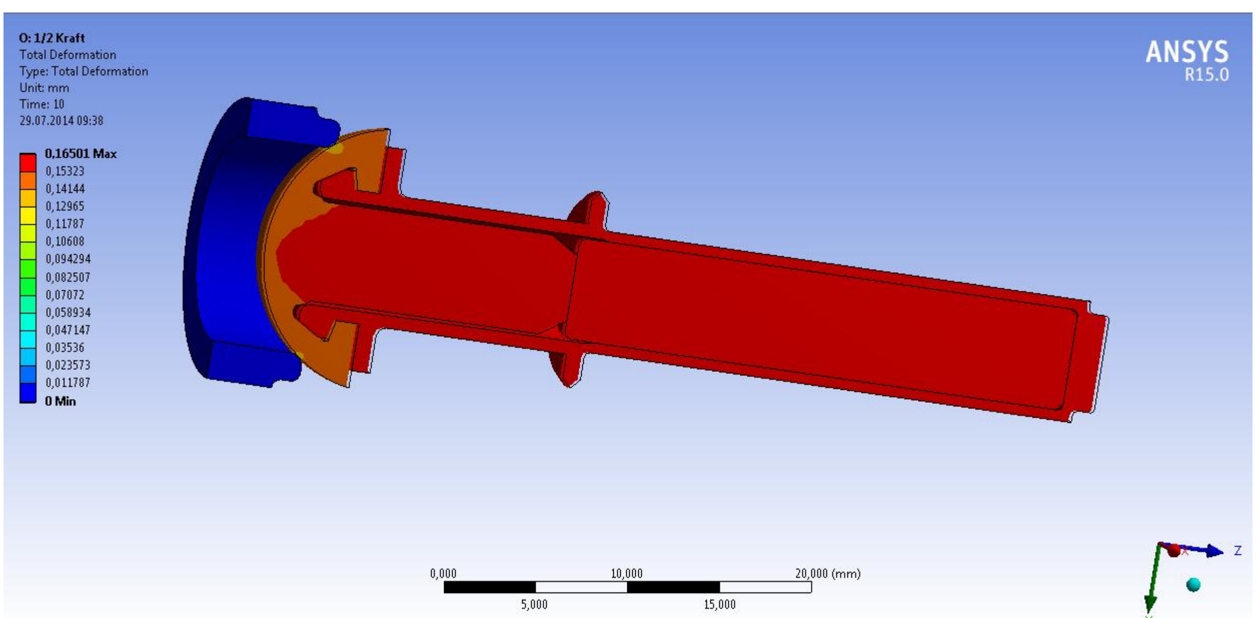
.



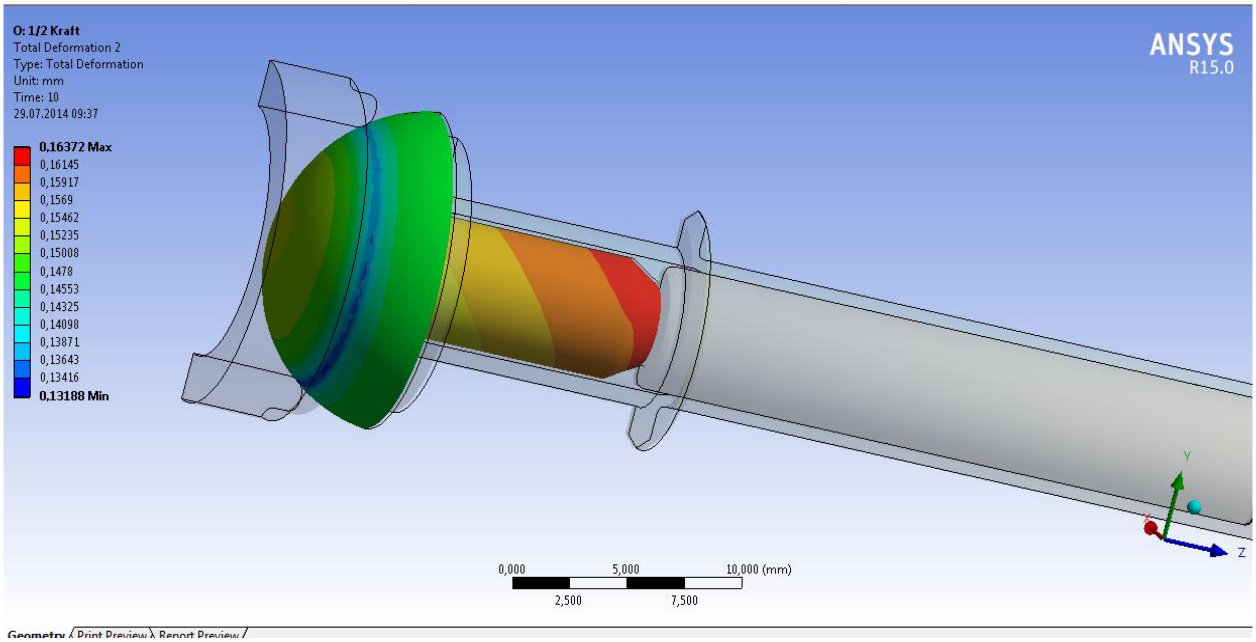
Another result obtained is the contact. With this, an idea of the proximity to the exact contact part is done:



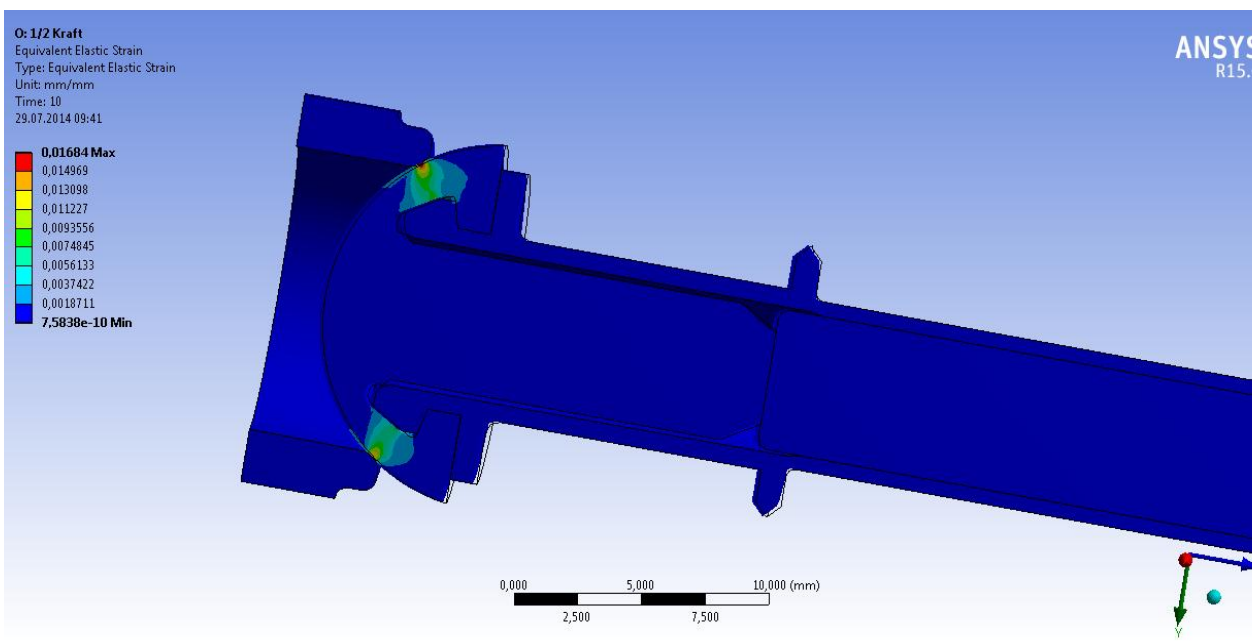
Moreover, here it is shown the total deformation, which it is in this case in the whole valve:



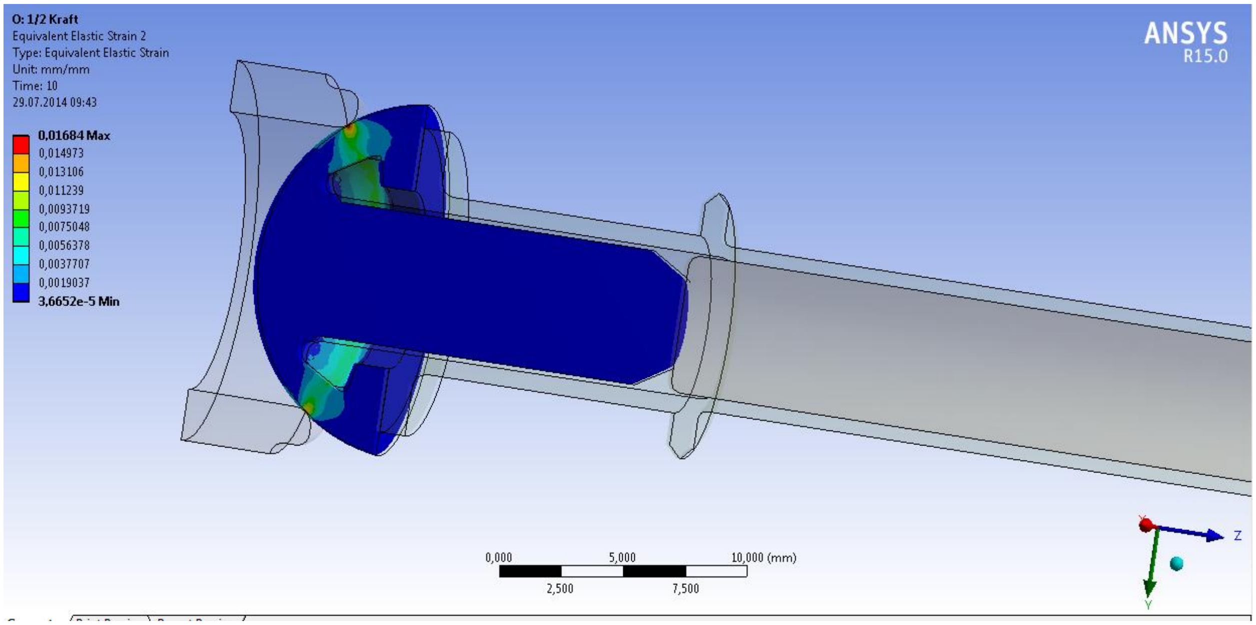
And now, here it is the total deformation only on the sealing part. It is easy to see the summary effect of the total deformation.



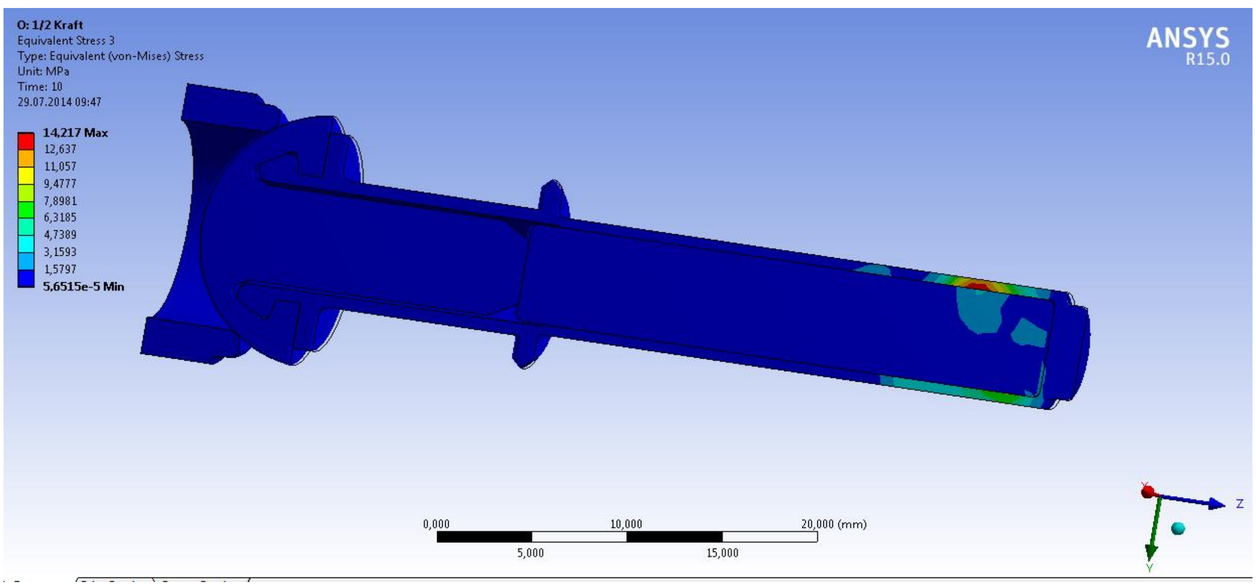
The same analysis for the equivalent elastic strain is made, first with the whole valve and then with the sealing part only:



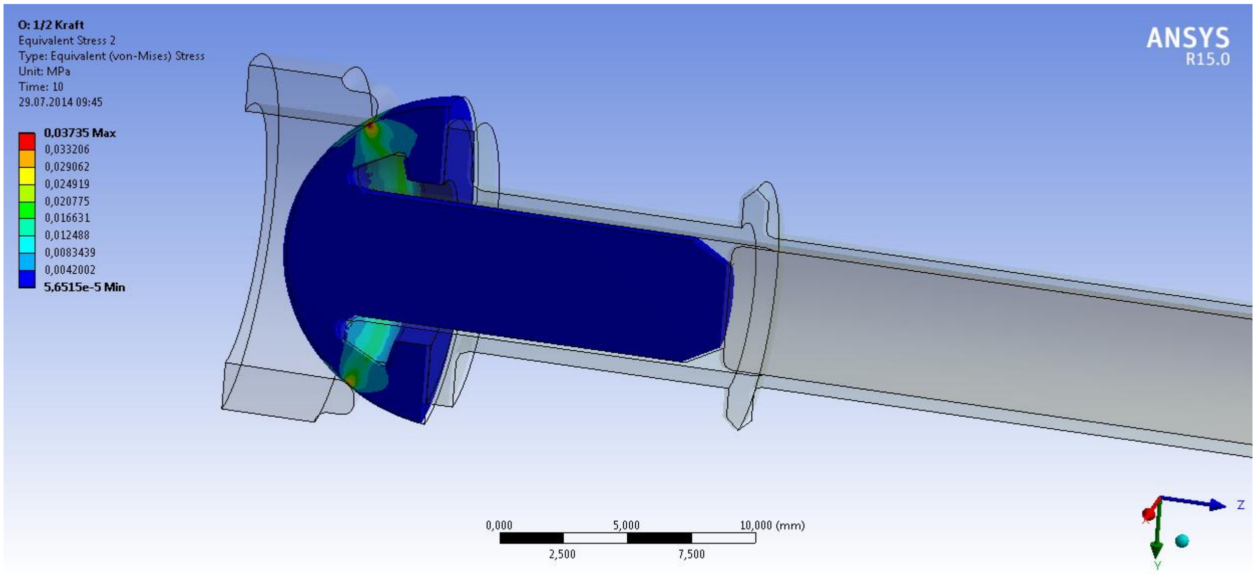
With the sealing part only:



Finally, the stress is analyzed. The rubber material has high deformation but low stress. Again the same formula is repeated. With the whole valve, the scale is so big so the stress on the sealing part is insignificant:



If the sealing part is analyzed alone, the scale is correct and then it is easy to see the stress:



Finally, with the whole valve stress picture, a comparison can be made. This is because the maximum stress of the valve is set. The only thing to do is to look in which material the maximum stress is made and search his theoretical specification data. In this case, the maximum value is 14MPa on the POM part. Searching on the data, the traction test of this material is for 55MPa so the POM part is going to resist and tolerate this load.

4. Introduction to leakage test

4.1 What is a Leak?

A leak is a flow of gas (or liquid) through the wall of a vessel (via an imperfection such as a hole, crack or bad seal).

Leaks require a pressure difference to generate the flow; they always go from higher pressure to lower pressure.

Leaks are pictured as going from positive pressure (inside an object) to outside (at atmospheric pressure).

This is not always the case (a leak could be from atmosphere to inside an evacuated object), but it helps to think about it this way because the units and terminology are based on this model.

4.2 Leak Testing - what units do you use?

For leaks of air into atmosphere, units are usually expressed as mm^3 or cm^3 (cc) per second or minute. So 16.6 mm^3/sec = 1 cm^3/min. For water is better l/min.

A bubble under water is about 30 - 50 mm^3, so 1 bubble per second is about 30 mm^3/sec or 2 cm^3/min.

A standard unit of leakage which takes account of air pressure is the mbarl/sec. (Millibar-litre per second). A leak into atmosphere of 1 mbarl/sec is equivalent to a volume leak of 1000 mm^3/sec.

4.3 Leak Testing - what technique should be used?

Key questions at the start of any leak test requirement are:

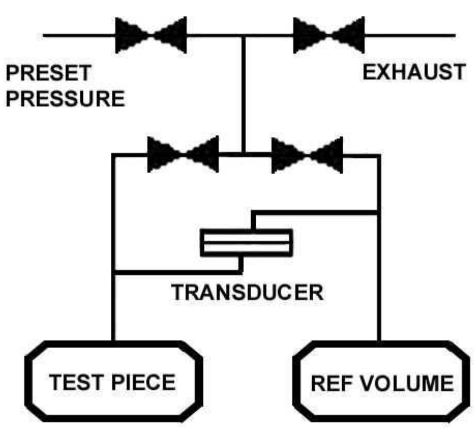
What size is the component and what is it's internal volume?	Is there access to inside or is it a sealed unit?
What is the leak limit?	Is it rigid or flexible?
Does it have hidden internal volumes that may affect leak measurements?	Are parts at ambient temperature?
Are the parts clean and dry?	What is the surface finish of any sealing surfaces?

Based on the acceptable leak rate limit (shown in ml/sec) alone the following test method can be used

				Tracer Gas				Flow Rate		
						Water Submersal / Dunk Tank				
High Vacuum Helium							Air Decay			
10^{-9}	10^{-8}	10^{-7}	10^{-6}	10^{-5}	10^{-4}	10^{-3}	10^{-2}	10^{-1}	1	5

4.4 Leak Testing - generic systems

Pressure/vacuum

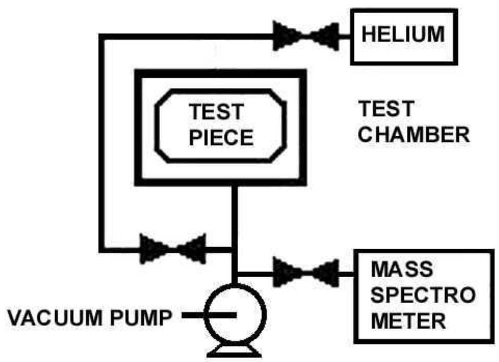


The test piece and the reference volume are simultaneously pressurized (or evacuated) to a preset pressure. The air in the system is then allowed to stabilize, with the supply valves all closed. The Differential Pressure Transducer is automatically zeroed.

After this stabilization time, the pressure change in the test piece is compared to the pressure change in the reference volume, using the Transducer. If the test piece is leaking, the difference will increase and be measured; an alarm limit may be set for a pass/fail decision.

The sequence is fully automatic, the accuracy and sensitivity of the system is defined by the method of setting the preset pressure together with the quality and type of control valves and Differential Pressure Transducer.

Helium systems



A vacuum pump evacuates the test chamber and test piece simultaneously to a preset vacuum. At this preset level, the chamber and the test piece are isolated and the chamber evacuated further to a very low pressure. A positive pressure variation is therefore created between the test piece and the chamber.

Helium gas is then introduced into the test piece, often in a 10% concentration. A Mass Spectrometer analyses a sample from the chamber as the vacuum continues to be drawn. The Mass Spectrometer measures the helium leakage and sets the pass/fail decision.

The test piece pressure is often compared to the chamber pressure before dosing with helium, to avoid saturating the Mass Spectrometer in the event of a gross leak

4.5 Leakage test

In the abstract, it seems like such a simple thing-figuring out whether or not a product is leaking. However, the reality of performing this task quickly and reliably can be incredibly complex.

Pressure decay systems, mass flow systems, helium or hydrogen accumulation, helium or hydrogen sniffers, mass spectrometers, residual gas analyzers: Life has changed dramatically since when you were a kid and would dunk a bicycle inner tube in a bucket of water to figure out where to patch a slow leak. (Although there are still some manufacturers using “water dunk test” systems to check their products)

Nonetheless, for all the different technologies on the market today, every leak test system has one thing in common: The products being tested need to be effectively sealed and fixtured. Otherwise, as is the case with assembly in general, the most carefully engineered system in the world will fail to provide reliable results.

Unfortunately, many leak test systems have something else in common: Manufacturing engineers treat them as an afterthought. This state of affairs can lead to all kinds of problems down the road, especially in an automated production system.

“Fixturing is often the weak link in a system,” says Chuck Wilkinson, director of industrial leak detection sales at Vacuum Instrument Corp. (Ronkonoma, NY). He adds that he’s seen a number of instances in which a customer believes a leak detector is not working, when the true culprit lies elsewhere in the process.

According to Greg Popp, vice president of sales at Cincinnati Test Systems (Cleves, OH), planning ahead is especially important when manufacturing some of today’s cutting-edge products. “It seems there are more complex casting designs today, for example, that have 90 degree and half-moon-type designs that require sealing during a leak test,” Popp says. “These become a real challenge, and require a lot of force and the right seal design to create a repeatable test. Sometimes we have to be creative to seal on a seal.”

4.6 First Principles

No matter how sophisticated the actual leak detection method, there are a few basic principles that need to be adhered to. For example, engineers should test an assembly in the same "direction" as the pressure gradient the assembly will be facing when it is in use. This means that if a product will contain a liquid or gas when in use-examples, include everything from automotive fuel tanks and radiators to refrigeration coils and medicine delivery systems-then the testing system will need to create a high-pressure region within the assembly and then monitor the product for any escaping gas.

If, on the other hand, the product needs to remain impermeable with respect to outside gasses or liquids, the test will be conducted the other way around. Examples of products in this category include sealed electronic packages, vacuum vessels or systems, and some types of manifolds or valves.

In many cases, the reason for this approach is obvious: Submitting a product to forces it isn't designed to withstand could easily result in its being ruptured or crushed. An example would be a relatively lightweight component with a large surface area, like an automotive fuel tank.

Another important reason for testing in the same direction is that you don't want to "mask" the effects of a component's more subtle or borderline defects.

Let's say, for example, you are testing the welds on a coil for an air conditioner unit. Pressing "in" on the assembly could also compress the welds, causing them to block the escape of the tracer gas being used, even if they are of questionable quality. Pressing "out," on the other hand, will tend to open up those same welds, quickly exposing a defective part.

Masking is something that also needs to be kept in mind when thinking about fixturing. It's important to ensure that the part or parts are stabilized. But, that doesn't mean clamping the part down so firmly it can't flex and expose any defective joints. Similarly, you don't want the nesting itself to operate as a kind of plug, stopping up, and therefore masking, any potential leaks.

Note that in addition, engineers sometimes need to fixture parts so that their orientation is the same as that which they will be experiencing when in use. Jacques Hoffmann, president of testing systems manufacturer InterTech Development Co. (Skokie, IL), says some automotive customers require "true car position" of components during testing from their suppliers, so they can be confident the part will perform in the field. Some medical devices, like inhalers, also need to be oriented correctly for a leak test to be legitimate.

"When leak testing medical devices, it's critical to test the parts in a manner that is consistent with how they will actually be used," Hoffmann says.

4.7 Seal for Approval

Equally important to securing each assembly for testing is creating an adequate seal between the assembly and the leak detector. This is especially true when performing a pressure or vacuum decay test, or when using a mass flow system to examine an assembly for defects.

In the first case, the test device either pressurizes an assembly or pulls a vacuum to a predetermined setting. It then monitors that pressure to see if it changes-which would indicate a leak. In a mass flow system, the test device pressurizes an assembly to a predetermined level and then holds it there. If any air is required to maintain pressure, the tester will register this fact by quantifying the amount of air flowing by.

In both cases, it is imperative that there be a stable seal between the test device and the product being tested. If the seal shifts, or "creeps," at any time, it will affect the total volume being tested, resulting in an error.

Ray Hula, leak detection specialist with Varian Vacuum Technologies (Lexington, MA), warns engineers to be aware that, because test pressures are often higher than the pressures a product will be subjected to when in use, additional measures may be required to create a good seal. For example, Hula says, even though a product employs a flat seal when in use, it may require an O-ring seal during quality assurance. Engineers also need to be careful that the materials used to fabricate a seal are tough enough to remain stable under test conditions.

"If the seals move around, that will cause problems....Seal for the test, not just the real world," Hula says.

InterTech's Hoffmann adds that assemblers need to be able to create an effective seal without using undue pressure, especially on less robust components. "Anyone can clamp down with a huge amount of force. The trick is avoiding damaging the assembly," Hoffmann says.

Finally, Todd Nguyen, marketing manager for the testing division at ATS Automation Tooling Systems Inc. (Cambridge, Ontario), warns that sealing test parts can be especially difficult given some of today's assembly technologies. "A lot of modern products use a liquid gasket seal material in the final assembly and thus have features that work against the automation seal," Nguyen says.

In terms of the different options available, engineers can create a seal around the outside or the inside of a port leading into the assembly. Or, if there is no port, they can create a "face seal" along the same surface where the component will mate with the rest of an assembly. The latter arrangement may require the use of hydraulic clamps, because larger sealing areas require higher clamping pressures. Inner-diameter (ID) or outer-diameter (OD) seals often employ pneumatic clamps, although a hybrid "air-over-oil" system may be necessary if the sealing mechanism is operating within the confines of a vacuum test chamber.

The decision to go with an ID or OD seal is often dictated by part geometry. Nonetheless, all other things being equal, an OD is preferable in that it frees up the entire orifice for either pumping in a tracer gas or pulling a vacuum. This, Wilkinson notes, translates into shorter cycle times.

In either case, engineers can go with standardized sealing systems from companies, like InterTech Development Co.; Cincinnati Test Systems, which manufactures what it calls its CTS Connecters; Uson LP (Houston), which manufactures everything from complete turnkey systems to its PrexSEALS pneumatic and mechanical seal line; and ATEQ (Canton, MI), which also manufactures an extensive line of leak detectors. If necessary, there is the option of implementing a custom sealing device or devices to ensure efficient and consistent sealing. These devices are available from those same companies that manufacture standardized devices.

In addition, Popp warns that it's important to create a system that will hold up under the rigors of repeated use. "Most manufacturing processes are designed to provide maximum uptime and can ill afford to stop the assembly process every few hours to change seals," he says. "The seal design and material type are very important considerations."

"Sealing surfaces...must survive thousands of uses, while mimicking final application seal," agrees Nguyen. A reliable seal that has a reasonable life span is key to limiting the number of false negatives, especially in an automated system, he says.

Along these same lines, it's important to ensure that the sealing material is compatible with the tracer gas being used. Running an air-based leak test doesn't pose any undue restrictions. However, Hula points out that silicone is highly porous to tracer gasses like helium and hydrogen. Instead, engineers should use materials like Viton and BunaN. According to Hula, Teflon seals are also poorly suited for use with hydrogen and helium tracer gasses.

Finally, when thinking about seals, don't forget the role played by the fixturing. "Proper fixture-to-part tolerance helps maintain a stable condition and eliminates part movements. These tolerances are also important to maintain proper seal contact to the part," Popp says. "Any variances in sealing angle will affect the repeatability of the test by causing changing conditions in the sealing process. Proper sealing sequence can sometimes also affect proper mating of the part to the tooling fixture."

4.8 Plan Ahead

In the end, the key to effective, trouble-free leak testing is to not wait until the last minute. Design-for-assembly is all the rage these days-at least in theory-and these same lessons apply to leak testing.

According to Hoffmann, creating an effective, efficient leak-testing arrangement requires a particular skill set. In maybe a fifth of all cases, Hoffmann says, a general knowledge of engineering may be enough to get the job done. But a certain level of expertise is necessary in the overwhelming majority of applications.

Wilkinson agrees, saying that implementing a leak test system is a lot easier if manufacturing engineers begin thinking about how they are going to test for leaks before the rest of the assembly process is in place. Many assemblers are surprised to find that the same pallets and fixturing they use to build their products may not work when it comes time to perform their leak-testing operations. But, the requirements of, say, an automated screwdriving station, are much different than those of a helium-based, multi-site accumulation system.

Then there are a number of ancillary issues that can be much more easily addressed before the rest of an assembly process has been set in stone. For example, Popp notes that a leak test instrument should be placed as close to the test part as possible to eliminate line test volume. Assemblers can also employ filler blocks to reduce the volume being evacuated or charged with test air or tracer gas.

Finally, why not think about leak testing during product design? Granted, creating a product that is easy to hook up to a leak detector is probably the last thing on many engineers' minds. But, Wilkinson says he's had customers do just that-and be glad that they took the trouble to do so afterwards.

4.9 How does a leak detector works?

A leak detector is a device which enables to reveal the escape of different substances, either they are liquids or gaseous. It exists a huge variety of leak detectors, depending on if they permit detection by direct contact or otherwise, by indirect contact. Then, here are exposed some of the most known and the general performance of someone of them.

4.10 What is a leak detector?

It is denominated leak detector to those devices that permit the leak detection of different substances of a transport system (pipes) or storage (tanks and others), substances that can either be liquids or gaseous.

4.11 Types of detectors

Leak detectors can be divided by two essentials judgements:
Depending on the type of contact: It is because some ones are applied directly upon the system, as those of water based or the electrochemical and other indirectly, such as the infrared or ultrasound.
According to the state in which the substance to detect is: This one can be liquid or gaseous.
For example, the most common used to the leak detection of liquids are indirect, because these systems of detection are generally applied for liquids which are stored or transported on underground systems, cemented and so on, that it means, systems inaccessible directly, because the liquids leakage in visible systems can be visually detected.

4.12 How do they work?

The operation of some of the existing types of leak detectors is now explained.

By direct contact:

-Electrochemical: Gas leakages penetrate through an electrode by a certain porous membrane. Then, through an oxidation-reduction process, the concentration of this gas (in dependence with the amount of current produced) is determined.
-Water based: It is applied on the zone wanted to be analyzed and this produces a bubble in the leakage area which is easily visible.
-Semiconductor: The gas enters in contact with a sensor, causing a chemical reaction which induces a diminution of the electric resistance of the sensor. This resistance variation facilitates the leak detection.

By indirect contact:

-Ultrasound: They detect changes on the background noise by the using of acoustic sensors, because the huge majority of the leakages emit sounds in an ultrasonic level.
-Point (infrared sensors, IR): They use the radiation which crosses a determined substance to detect leakages. In these ones, the range of those wave-lengths depends of the specific properties of the substance.

-Holographic: These ones measure the color reflection in a hologram to determine in this way any variation on his constitution, which would reveal the presence of a gas on leakage.

These are the performances of the main leakage detectors but of course, each type and model has its specific variants that make it more or less useful for a particular purpose.




5. Leak test methods

5.1 Introduction

In the industry, components and systems must be leak tested to ensure that leakages are below specified limits. The three basic functions of leak testing are: 1) determining if there is leakage or not (detection), 2) measurement of leak rate and 3) leakage location. There are many methods and types of test equipment for solving these problems, but unfortunately there is no single technique that fits every situation. Each test method is suitable only for a specific leak rate or for fixed forms and technologies. In most instances where leak detection is used, explicit leak rate measurement is not required, but the system must be able to recognize if the leak rate is above or below a specified level. This reference limit depends on the maximum acceptable leak rate, consistent with the reasonable working life expectation for final products, and, especially in certain countries, on rules and regulations constraints. The acceptable leak rate, depending on type and application, usually spans from 15 g/y (0.5 oz) of refrigerant (for example) for large air conditioning systems and/or automotive applications to 0.5 g/y (0.01 oz) for domestic refrigerators.

This acceptance level is the main parameter to consider when selecting the appropriate method or combination of testing methods. Several other factors must be taken into account as well. In particular, system costs, complexities, environmental impact, reliability, influence of external conditions, operator dependence and user-friendless should all be considered.

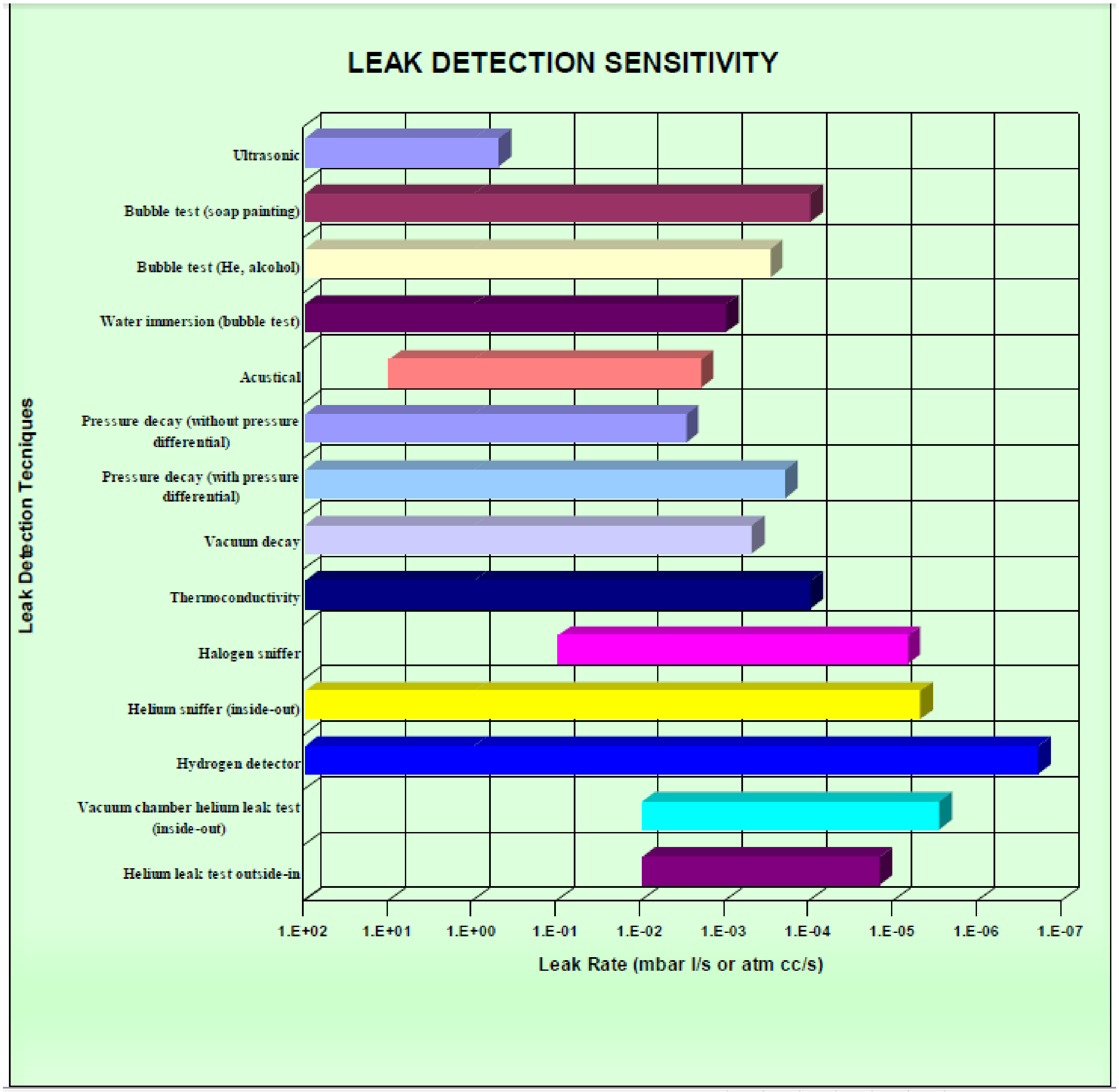
There is a lot of literature available about leak-testing, leak detection and leak location methods. This analysis presents some leak detection techniques and compares their performance.

5.2 Leak testing methods

A leak can be defined as an unintended crack, hole or porosity in an enveloping wall or joint, which must contain or exclude different fluids and gases allowing the escape of closed medium. Critical leak spots in closed systems are usually connections, gaskets, welded and brazed joints, defects in material, etc. A leak test procedure is usually a quality control step to assure device integrity, and should preferably be a one-time non-destructive test, without impact on the environment and operators. Several leak-testing techniques are available, spanning from very simple approaches to systems that are more complex. The most commonly used leak test methods are underwater bubble test, bubble soap paint, pressure and vacuum decay, and tracer gas detectors (halogen, helium and hydrogen). The first three techniques, due to their characteristics and sensitivity, can be used only for gross leak detection (300 g/y (10.5 oz) or more refrigerant leakages). Tracer gas leak testing methods are much more precise than the previous group but, in many cases, their theoretical sensitivity is more than is required. In a practical sense, however, this is limited by environmental and working conditions.

Each method mentioned above and each its advantages and drawbacks are discussed briefly in the following.

In the diagram below, the performance of various leak-test techniques are summarized.



5.2.1 Water immersion bubble test method

The water-immersion bubble test, also called "bubble testing" or "dunking", is a traditional and relatively primitive technique of leak detection. It consists of immersing a charged or pressurized part, usually with high-pressure dry air or nitrogen, in a water tank and watching for escaping bubbles. The larger and more frequent the bubbles, the bigger the leakage. Relatively small leaks are possible, but very difficult, to detect.

The main limitation of this method is sensitivity, which is the minimum detectable leak rate. Considering a spherical bubble of radius R, its internal volume V will be:

$V = 4/3 \cdot \pi \cdot R^3$

Let p the pressure inside the bubble and t the time required to form the first bubble, the leak rate Q will be:

$Q = (p \cdot V) / t$

The two key parameters determining the sensitivity of this method are the smallest bubble detectable by the operator and the waiting time for bubble generation. This time must be compatible with the production rate and with operator attention.

It is reasonable to consider that the smallest bubble an operator could detect has 1 mm radius and that the waiting time is 30 seconds. Assuming that the pressure inside the bubble is at atmospheric pressure, it can be stated from the previous equations that the bubble volume is $V = 4.2 \cdot 10^{-3}$ cm^3 and therefore the minimum detectable leak rate is:

$Q= (p \cdot V) / t = 1000 * 4.2 \cdot 10^{-6} / 30 = 1 \cdot 10^{-4}$ mbar · l/s

This is a theoretical value. The real sensitivity is strongly influenced by many external factors, such as illumination conditions, water turbidity, unit location and placement, and water movement. All these issues, together with operator dependency, limit the useful sensitivity to $5 \cdot 10^{-4}$ mbar · l/s, although $1 \cdot 10^{-3}$ mbar · l/s is usually considered.

Some tricks to can be used improve to this method.

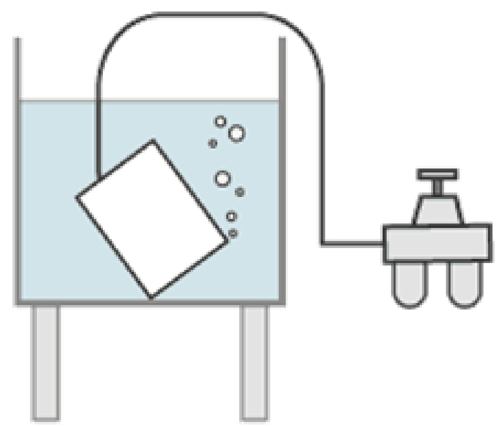
- Increasing the internal pressure in increments may increase the probability of finding a leak and can be less time-consuming in pinpointing the leak.

- A detergent can be added to the water to decrease surface tension, which helps to prevent the leaking gas from clinging to the side of the component.

- Using different gases (e.g. helium) and/or liquids may give some advantages in system performance, but at a cost disadvantage.

 Hot water in the tank sometimes helps to increase the pressure inside the component or piping system. If dry nitrogen is used, this does not help because nitrogen does not increase its pressure significantly. If refrigerant is contained in the system or component, it may help considerably to increase the pressure and, therefore, increase the chance of finding the leak.

In conclusion, this technique does offer leak detection accuracy in the 10^{-3} mbar · l/s range in high volume production applications and, in most cases, leak location and is very economical. However, the disadvantages range from a relatively low sensitivity, high operator dependency and possible part contamination, to fluid waste and the likelihood of having to dry the parts after testing. Moreover, especially when dealing with big coils, excessive unit handling, putting parts in and out of tanks, adds to the complexity of production and results in higher part damages. There are also some more hidden costs. In fact, this process requires use of a large amount of space and produces a certain amount of wastewater. This is especially true for big units, such as large heat exchangers; the tank could be very large and require a lot of water. Dryers cost money to operate and maintain as well.



5.2.2 Soap solution bubble test

Instead of submersing the part in water, the pressurized unit to be tested is sprayed with a soap solution and the operator is able to see the bubbles formed by gas escaping from where the leak is.

Soap solutions are available in many different types. Some have a brush applicator and others have a dabber (an absorbent ball attached to a stiff wire inside of the cap.) Some brands may even have a spray applicator to quickly cover large areas of tubing in a short amount of time. This is an advantage but is also messy and time consuming to clean up.

Some soap solutions even have an antifreeze base to prevent them from freezing in the winter time. Others may have a lower density to make them even more sensitive to very tiny leaks.

This method has a higher sensitivity than water immersion. It allows detection of leaks up to 10^{-5} mbar · l/s and is suitable for very large systems.

This soap solution method is best used when the approximate area where a leak may exist is known. In this case, the soap solution is only used in that specific area to test for and pinpoint a leak. It is the simplest and least expensive method, material wise, known today. However, if the operator does not know where the leak might be, it can be more expensive because of labor costs.

Increasing the gas pressure raises the probability of pinpointing the leak and is less time-consuming. However, for operator safety, the pressure must be limited to 1700 kPa (250 psi).

The soap-solution bubble test is limited by some drawbacks. The area to be sprayed must be a simple and easily accessible surface. On finned pipes or the bottom part of a large heat exchanger, it could be extremely difficult, if not impossible, for the operator to spray the part and watch for a bubble. Moreover, the application is not well suited for high productivity lines.

5.2.3 Pressure decay test

This method consists of pressurizing the system with a high pressure gas, usually dry air or nitrogen. Then the part is isolated from the gas supply and, after a stabilizing period, its internal pressure is monitored over time. The pressure drop Δp is measured in the time Δt. If the pressure in the system drops fast, there is a large leak present in that component or section of the system. If the system's pressure drops slowly, there is a small leak present. If the pressure remains the same, that component is leak-free. The leak rate Q can easily be computed considering the volume V of the component. That is:

$$Q = (\Delta p \cdot V) / \Delta t$$

Leak detection sensitivity is related to the testing time, the pressure transducer resolution and the volume. The most advanced systems allow for measuring pressure variation up to 70 Pa (0.010 psig) at test pressure and, depending on the volume of the units to be tested, the leak detection cycle can be as short as 30 seconds and guarantees high resolution. Considering V = 1.5 dm^3 (0.4 gal) internal volume component with a Δp = 70 Pa (0.010 psig) of pressure decay at 3450 kPa (500 psig) test pressure in Δt = 60 seconds, the leak rate is:

$$Q = (\Delta p \cdot V) / \Delta t = 0.7 \cdot 1.5/60=1.7\cdot10^{-2} \text{ mbar} \cdot \text{l/s}$$

Several external factors, such as temperature variations and mechanical deformations, affect this test. The internal pressure, in fact, depends on temperature, and thermal fluctuations may cause changes in pressure, altering the results. Fortunately, dry nitrogen experiences very little pressure changes when it is exposed to small temperature changes.

The sensitivity of this testing technique depends on pressure measurement resolution, test time and pressure values. Longer test times allow for a more sensitive check but, in this way, the test can be very time-consuming because some low-level leaks may require a very long holding period, some even hours. The higher the pressure, the faster you can determine if a leak is present. However, operator safety concerns limit the maximum admissible pressure value without safety precautions. Components can be leak tested at low pressures, less than 2 MPa (290 psig) without protection, and higher pressures, 7 MPa (1000 psig), may be used adopting safety interlocked protection hoods. Using the proper pressure, this test method also allows compliance with technical specifications, such as American Underwriters Laboratory (UL) as well as burst test and the European EN378 rules. Burst test is designed to test the mechanical strength of the refrigeration tubing circuit, to find ruptured tubing, and badly brazed joints with material separation. Pressure ranges for the test vary depending on if the test unit is a component of the refrigeration circuit, or if it is a complete refrigeration circuit with a compressor.

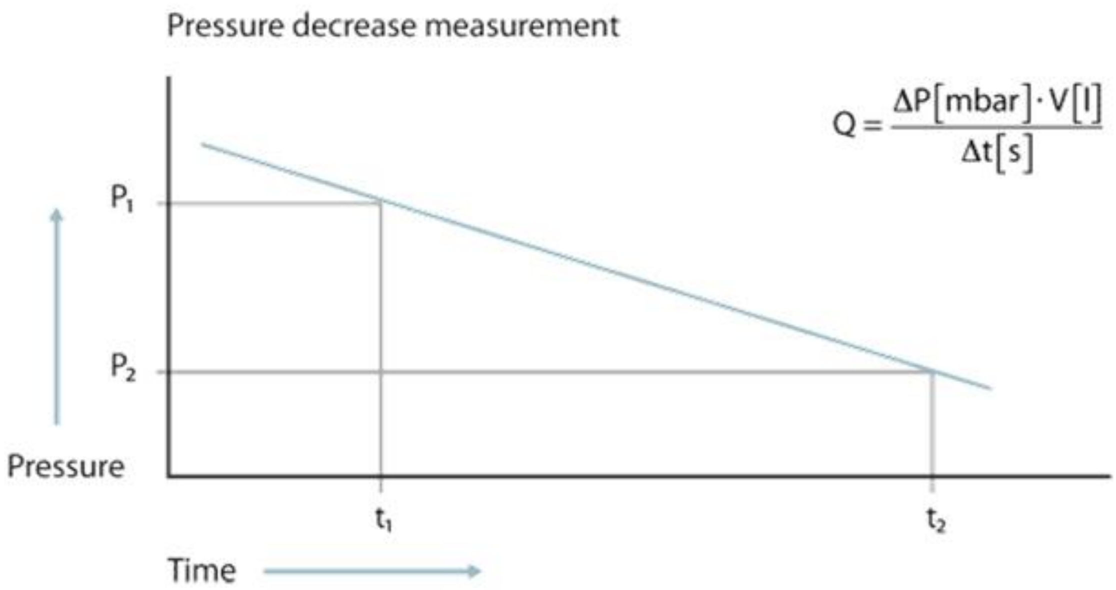
The testing performance can be improved using a pressure differential. In this mode, the test unit is pressurized together with a reference volume and the two pressure trends are compared.

Pressure decay proof is a go/no-go test. While it detects the presence of a leak, locating the leak requires the use of other techniques such as soap bubbles, or better, tracer gas detection.

Usually, the limit of sensitivity for pressure decay test is in the range of 10^{-3} mbar · l/s without pressure differential and 10^{-4} mbar · l/s for pressure decay test with pressure differential.

This leak testing technique has some advantages. This method will positively identify whether or not a leak exists by monitoring the pressure drop. If any pressure drop occurs, it means a leak is definitely present. Furthermore, this method can be realized completely automatically, so as to avoid operator errors. This procedure is a preliminary leak test that detects large leaks before the final automatic leak test operation using a tracer gas, e.g. helium. This test will detect over 90%, of the defective parts, especially those not brazed correctly. If the test unit has a large leak (i.e. an over looked brazed joint) without doing the pressure decay test first, large quantities of tracer gas will leak out of the test unit. The resulting helium contamination, in this much volume and concentration, would render the system inoperable for hours. Another advantage of nitrogen filling, besides the mechanical stress and leakage test, is the purging of the circuit to be tested, lowering its humidity. Upon a successful completion of the pressure decay test, the component is ready for final test.

The disadvantage of this method is that it does not identify where the leak is, only if a leak is or is not present.



5.2.4 Vacuum decay test or Pressure rise test

A vacuum decay test or pressure rise test works in the opposite way of the pressure decay test. This method involves evacuating the part to suitably low pressures and, after stabilizing the pressure, measuring the increase in pressure caused by test media entering the part. Only parts that are able to withstand external pressure can be tested in this way (e.g. thin-walled plastic parts cannot be tested due to the danger of collapsing).

Even if in the vacuum decay test it is not possible to get more than one atmosphere of pressure difference from inside to outside, using some solvents (i.e. alcohol, acetone or similar) exalts the pressure increment due to the solvent entering into the leak. This approach, however, has some shortcomings, such as the possibility of solvent freezing, causing temporary leak-stuffing, or elastomer gaskets becoming damaged by solvents.

With respect to the pressure decay test, this technique has some advantages. This method is less sensitive to temperature changes since the pressure inside the part is lower than atmospheric pressure. Vacuum-meters are usually very sensitive to small pressure changes, so the theoretical sensitivity might be very high, up to $1 \cdot 10^{-5}$ mbar · l/s.

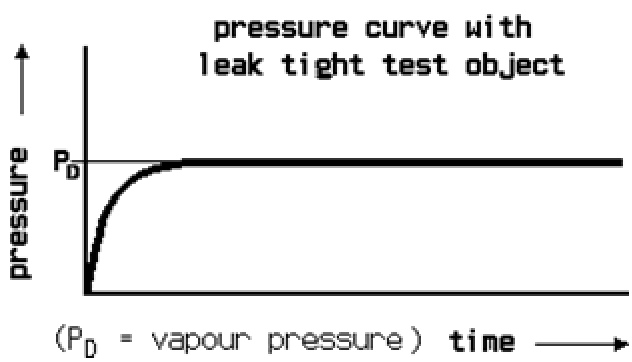
However, surface out-gassing and liquid evaporation affect and limit the real sensitivity. For instance, a small quantity of water, even a few grams, starts evaporating at 2 kPa (0.3 psia) and at 1 Pa (7.5 µm Hg) the water vapor content is so high that the consequent pressure increase is comparable to a leak, creating a false positive.

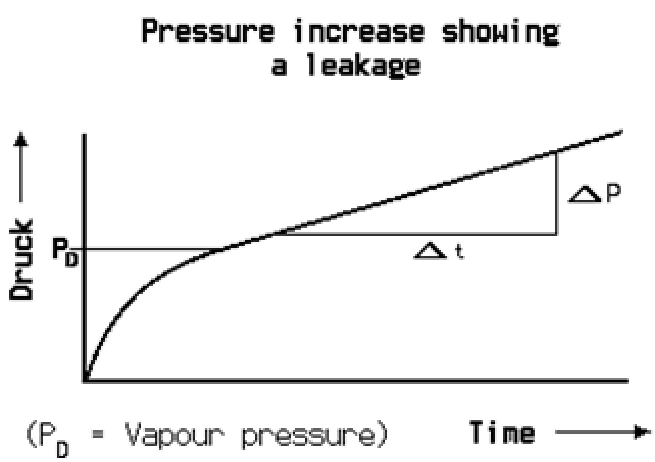
In refrigerating circuits where the out-gassing from oil is so significant that could be mistaken for a leak, the sensitivity is limited to $1 \cdot 10^{-3}$ mbar · l/s

The vacuum decay method can be realized in a fully automatic procedure and, in this way, it is independent of the operator.

This technique is a “go no-go” test. It detects the total system leak and more than one leak can exist; leak location requires other techniques.

In a vacuum decay test, the unit to be tested is evacuated and its internal pressure is lower than atmospheric pressure. Therefore, this leak testing method will stress the part in the opposite way, if the working condition requires an internal pressure.





$$Q = \frac{\Delta P\,[\text{mbar}] \cdot V\,[l]}{\Delta t\,[s]}$$

5.2.5 Tracer gas leak testing

The term "tracer gas leak testing" describes a group of test methods characterized to detect and measure a tracer gas flowing through a leak. These techniques differ for the tracer gas used and for the realization technology.

The most commonly used tracer gases are halogen gas (CFC, HCFC and HFC refrigerant), helium, and a mixture of nitrogen 95% hydrogen 5%. Despite the simplicity of their electronic detection devices, halogens are loosing their appeal as a tracer gas, due to environmental protection rules following Montreal and/or Kyoto protocols. On the other hand, helium and especially hydrogen/nitrogen mixture are gaining more interest.

Helium has been used successfully as a tracer gas for long time due to its physical properties. It is neither toxic nor flammable and is an inert gas and does not react with other compounds. Helium has low viscosity and relative molecular mass, so it easily passes through cracks. In the same environmental conditions, it flows through orifices 2.7 times faster than air. Since its concentration in air is low (5 ppm), it is easy to detect an increment of helium concentration. However, there are some shortcomings. Helium disperses slowly into the atmosphere, so, in the case of big leaks, its high concentration will contaminate the area for a long time, even hours. Also, Helium is costly, even if it is less expensive than halogen gases. The most suitable helium detector is based on a mass spectrometer, which is an expensive and delicate apparatus requiring much care and maintenance, and is more suitable for a laboratory than for the manufacturing industry.

A relatively new tracer gas is a mixture of nitrogen 95% and hydrogen 5%. Hydrogen has a number of properties that make it an excellent tracer gas for leak testing, even in production environments. It is the lightest element, with higher molecular speed and lower viscosity than any other gas, so it is easy to fill, evacuate and dissipate. It finds and passes through a leak faster, it is easier to flush out and vent away, and its molecules do not stick to surfaces as easily as helium atoms. It is environmentally friendly and renewable. More importantly, it has the highest leakage rate of any gas. Moreover, the normal background concentration of hydrogen (0.5 ppm) is ten times less than helium. Hydrogen tracer gas detectors use a semiconductor sensor and have no moving parts, making them completely maintenance free. These devices are not affected by the presence of other gases. Pure hydrogen should never be used as tracer gas, but a standard industrial grade mix of 5% hydrogen in nitrogen is inexpensive, non-flammable (as for ISO10156 specification), and readily available from industrial gas suppliers.

It is important to remember that background concentration in air is a limiting factor for any tracer gas detector. There are two ways to carry out leak testing with tracer gas: external detection of tracer gas escaping from leaks of a filled unit (inside-out method), and internal detection of tracer gas entering from leaks (outside-in method). For each of these two methods there are two realization techniques. The inside-out methods can be executed with atmospheric sniffing or with vacuum chamber detection, while the outside-in method is generally implemented by putting the unit to be tested in a room containing the tracer gas or, very rarely, spraying the tracer gas on the unit surface.

Each of these methods is described in detail in the following sections.

5.2.5.1 Sniffing

“Sniffing” is the simplest realization of an “inside-out” test. The sniffing technique of leak detection utilizes a detector probe or sniffer to sense leaks from a unit previously filled and pressurized with a tracer gas. Before filling the unit with a tracer gas it must be evacuated, so a pumping group, even a small one, is required. This method is very operator dependent. In fact, the probe (or wand) is moved over the part and detects the leak as it passes over that leak. The speed, distance from the part and the probe sensitivity determine the accuracy of leak detection. However, sniffing will locate a leak on a part, unlike the other methods described, and has the ability to sense leaks as small as 10^{-7} mbar · l/s, depending on the tracer gas. Sniffing is not recommended in a high volume production environment, other than for locating leaks for repair. Depending on the tracer gas, sniffing may involve a relatively low tooling cost investment, representing an economical method of leak detection. However, the cost of the tracer gas may be significant and, in case of a particularly expensive gas, the use of a suitable gas recovery and reclaim system should be considered, further increasing the overall costs.

Disadvantages include a high chance of missing leaks due to operator dependency, fragile equipment in rugged environments, and rejecting good parts (because of the inability to quantify the leak). Some sniffers and the relevant detectors require periodic maintenance to assure proper functioning, since they are complex systems composed of vacuum pumps, mass spectrometer and vacuum fittings. Electronic detectors, without moving parts, are very profitable. Some detectors are sensitive to other gases than the tracer used. Therefore, when using these sensors, attention to the chemical environmental conditions is required.

The minimum leak rate measurable by a sniffer is the concentration of the tracer gas in the working area, a value known as “background level.” This level may change during the production cycle and increases due to leaking units. Relating to the tracer gas used, in case of a big leak in the part under test, a lot of tracer gas escapes from it and may remain for a long time in the working area, strongly affecting the subsequent tests causing rejection of good parts. It is good practice to use a preliminary leak testing system to reject parts with gross leakages. It is possible to integrate this preliminary test, (i.e. a pressure decay test) in the tracer gas-filling machine, in order to simplify the equipment.

It is important to note that sniffing techniques are local methods, allowing testing of single points. Each of the tested points can have a leak below the sniffing sensitivity, but the overall leakage may be above the acceptance limit. As a result, the test is successful, but the part is defective. Global tests, such as vacuum chamber inside-out and outside-in methods, avoid this problem.

5.2.5.2 Accumulation leak testing

This method is a variation of sniffer leak testing. The part to be tested is placed in an enclosed containment hood, then pressurized with the tracer gas. The sniffer is connected to the hood where the leaked tracer gas has accumulated during the test time. When accumulated, the tracer gas is more readily sensed by the detector. The gas sensor will measure the global leak.

In addition to the characteristic limitations of the sniffer testing method, this technique has other drawbacks. The larger the accumulation volume, the longer the time needed to detect the leakage. Leak rate and sensitivity depend on the residual volume and the test time. The tracer gas partial pressure increment Δp, the tracer gas flow Q, residual volume V and the test time Δt can be expressed with a sample equation:

$$\Delta p = (Q \cdot \Delta t) / V$$

This method is used in very special applications (e.g. small components are to be tested for small leaks).

5.2.5.3 Vacuum chamber inside-out leak testing

Vacuum chamber inside-out leak testing is the most complex system of leak detection, but it is theoretically suitable to find very small leakages, using the proper tracer gas. The equipment is composed of one or more vacuum chambers, large enough to house the unit to be tested. The chamber is connected to a vacuum pumping group equipped with the tracer gas detector, for chamber evacuation and gas detection. A second vacuum group is required to evacuate the unit under test before filling it with gas. A tracer gas-filling device completes the testing apparatus. The unit to be tested is put into the vacuum chamber and connected to service hoses. Then the vacuum chamber and the unit are evacuated. During chamber evacuation, the part is pressurized with the tracer gas and, after a stabilization time, the detector is linked to the vacuum line so as to detect the tracer gas flow through a leak and drawn in by the pumping group. In this way, the leakage is detected. It is a go/no-go" test, so finding the leak location requires other techniques.

This method has some advantages. This technique is fully automatic, so it depends very little on an operator. Its sensitivity, depending on tracer gas and test time, can reach 10^{-10} mbar · l/s, even if for a practical application in the refrigeration industry the limit is 10^{-6} mbar · l/s.

There are also some drawbacks. Depending on the vacuum chamber dimensions, the evacuation group could call for a high pumping speed. Some gas detectors require periodic maintenance to ensure proper performance, since they are complex systems composed of vacuum pumps, a mass spectrometer and vacuum fittings. The cost of the tracer gas may be significant besides and, in case of a particularly expensive gas, the use of a suitable gas recovery and reclaim system should be considered, further increasing the overall costs as well as the system complexity. In the case of big leak in the part under test, a lot of tracer gas escapes, relative to the tracer gas used. A long pumping time could be required to lower the tracer gas in the detector to an acceptable level compatible with system function. The system is unusable during this time. To avoid this, it is good practice to use a preliminary leak testing system to reject parts with gross leakages. It is possible to integrate this preliminary test, (i.e. a pressure decay test) with the vacuum chamber test to simplify the equipment.

Another disadvantage is that this method does not identify where the leak is, only if a leak is or is not present. It detects the total system leak and more than one leak can exist. Leak location requires other techniques.

5.2.5.4 Outside-in leak testing

In this testing technique, the unit to be tested is put into an enclosure containing the tracer gas. The part is connected to a vacuum group and evacuated. A tracer gas detector (i.e. helium mass spectrometer) is placed in the vacuum line in order to detect the tracer gas flow in a leak and pulled in by the pumping group.

This method has some advantages. This technique is fully automatic, so it is not operator dependent. The sensitivity, depending to tracer gas and test time, can reach 10^{-6} mbar · l/s. The gas containment hood can be realized to prevent dispersion, in order to reduce working area pollution and tracer gas consumption, saving money by avoiding the need for a recovery system.

There are also some drawbacks. The difference from inner and outer pressure is limited to values slightly above the atmospheric pressure. Relating to the tracer gas used, in case of a big leak in the part under test, a lot of tracer gas escapes from it. A long pumping time could be required to lower the tracer gas in the detector to an acceptable level compatible with system function. The system is unusable during this time. It is good practice to use a preliminary leak testing system to reject parts with gross leakages. It is possible to integrate this preliminary test, (i.e. a pressure decay test), in the tracer gas-detecting machine, so as to simplify the equipment.

Another disadvantage is that this method does not identify where the leak is, only determines if a leak is or is not present. It detects the total system leak and more than one leak can exist. Leak location requires other techniques.

5.2.6 Applications

In the following sections, the main applications of the previously reported methods are described.

5.2.6.1 Halogen leak detectors

The working principle of the halogen detector is based on the measurement of positive ion emission due to the halide presence inside an electronic cell. This ion current is related to the halogenated gas concentration and, therefore, to the leak size. Less sensitive detectors are based on infrared light absorption by halogenated gas. The main application for halogen detectors is for an inside-out system; their use for outside-in methods is very limited.

In an inside-out method, they are used in the detector-probe mode, requiring that the system be pressurized with a tracer gas containing an organic halide, such as CFC, HCFC and HFC refrigerant. The exterior of the system is then scanned with a sniffer probe sensitive to traces of the halogen-bearing gas. The achievable sensitivity can be 10^{-5} mbar · l/s.

In an outside-in approach, an evacuated vessel is connected to a halogen detecting instrument and is sprayed with halogenated gas. In this manner, its performance is up to 5.10^{-7} mbar · l/s and is used in rough, medium and high vacuum. This method is quite complex and has a high environmental impact, so it rarely used.

Halogen leak detectors are used extensively in refrigerating and air conditioning maintenance to locate leaks in refrigerant-charged systems due to their high sensitivity.

In the manufacturing industry, however, their use is limited because of several disadvantages and drawbacks.

- Refrigerant has a higher specific volume than air; therefore refrigerants will fall when exposed to atmospheric pressures. This means leak detecting on the bottom sides of the piping or components will be more effective in detecting a leak.

- Since electronic halogen detectors are sensitive to many gases, included non-halogenated ones such as carbon monoxide and alcohol, their sensitivity is strongly determined by the tracer gas type and environmental conditions. The best performances are achievable if used in a controlled atmosphere room.

- If a unit previously charged with refrigerant has to be evacuated and re-charged, the pre-evacuation phase is tricky and very time consuming.

 Halogenated gases are costly, more expensive than other tracer gases like helium and nitrogen/ hydrogen mixture.

 Halogen gases have a high environmental impact and their dispersion in the atmosphere is severely regulated, if not forbidden, in many countries.

5.2.6.2 Inside-out helium sniffer detectors

A Helium sniffer detector probe is an ancillary accessory of leak detectors. A vacuum pump inside the leak detector maintains the helium spectrometer in high vacuum (up to $1\cdot10^{-2}$ Pa or $7.5\cdot10^{-2}$ µm Hg). One side of the sniffer is connected to this vacuum group, while its detection probe, provided with a calibrated orifice, is opened to the atmosphere. Air, with helium, flows through this hole into the mass spectrometer, where the helium concentration is measured and the leak rate is computed.

In "inside-out" techniques, the unit to be tested is evacuated and then pressurized with helium. The operator moves the sniffer over the part and tests with the probe around suspected leak sites.

The orifice dimension establishes the probe flow and then the detection performance. Flow, Q_{He}, pumping speed, S_{He}, and partial pressure, P_{He}, are related as:

$$Q_{He} = P_{He} \cdot S_{He}$$

The minimum leak rate measurable by a helium sniffer is the concentration of helium in the working area. In the ideal case, the atmospheric concentration of helium is 5 ppm, so its partial pressure is 0.5 Pa (3.7 µm Hg). Then, considering a standard pumping speed of 1 cm^3/s, the sensitivity is:

$$Q_{He} = P_{He} \cdot S_{He} = 0.5 \cdot 1 \cdot 10^{-6}\ Pa \cdot m^3/s = 5\cdot10^{-6}\ mbar \cdot l/s$$

The slower the pumping speed, the higher the sensitivity. However, the slower the pumping, the longer it will take the helium to arrive at the mass spectrometer to be measured. The most commonly used pumping speed, a trade-off between sensitivity and response time, is 1 cm^3/s that, with a pipe 5 m (16.4 ft) in length, which provides a delay time of about one second. Because of this delay time, the sniffer speed and its distance from the part to be tested are critical factors. The nearer the probe, the higher the helium concentration entering the mass spectrometer and therefore the better the test quality. Conversely, the faster the detector movement, the less helium is taken in.

Furthermore, the sensitivity of this method, strongly limited by the background helium level, is not as good as those achievable with other techniques based on mass spectrometers.

The helium sniffer leak testing method has the big advantage of determining leak location but, as stated above, has some drawbacks.

Helium sniffer leak detection implies manual operation, is strongly operator dependant, and operator experience is the determining factor in the outcome of the testing procedure.

Helium disperses slowly into the atmosphere, so in case of leakages, the background level increases limiting the successive tests. In case of a big leak, the working area may become contaminated for a long time. It is good practice to use a preliminary leak test (i.e. a pressure decay test) to detect gross leakages. This test may be integrated in the same helium inside-out machine.

Helium is an expensive gas and as stated before it is not advisable to spread it into the ambient area, so it is good practice to use helium recovery/reclaim stations to empty the unit at the end of leak testing. The recovered helium can be reutilized for successive tests.

5.2.6.3 Outside-in helium spraying

In the "outside-in" helium spraying technique, the sample to be tested is connected to a vacuum group and to a mass spectrometer. The unit is evacuated and its surface is "probed" with a pointed jet of helium by a suitable diffuser. Passing over a leak, the detector senses the helium entering from the leak, identifying the location and leak size data. This method is still classified under vacuum test methods, even if it is an exception.

This technique can be used where it is necessary to locate small leaks, since its sensitivity is not limited by the background helium level. However, it is not free of limitations. This method, like sniffing, is operator dependant. Moreover, helium is lighter than air so it rises, therefore helium sprayed in the bottom of the unit may pass through a leak in the upper part.

Helium has a tendency to accumulate and then saturate the working area if it is not well ventilated. In this condition, determining the leak location becomes difficult.

In case of a big leak, a lot of helium reaches the mass spectrometer and a long time is needed to reduce the helium level to a value compatible with testing, but, during this time, the operator can performs other tasks.

Since the unit to be tested is evacuated, its internal pressure is lower than atmospheric pressure. Therefore, if the working condition requires a pressure inside, this leak testing method will stress the part in the opposite way.

This testing technique is, however, widely used in research and in all those applications involving big plants, which cannot use other methods. It is not the most suitable solution for testing in high productivity lines or serious production manufacturing industries.

It is noteworthy that parts to be checked must be kept in an area free from helium contamination before leak testing. If high pressure air is used for a preliminary pressure decay test, the high pressure air compressor inlet must also be in a “fresh air” atmosphere.

5.2.6.4 Outside-in helium leak testing

In the "outside-in" helium leak testing technique, the part to be tested is placed in a containment hood suitable to contain helium and connected to a vacuum group equipped with mass spectrometer. The test consists of evacuating the unit and flooding the hood with helium. Helium, in fact, due to its atomic characteristics, has a high penetration capability. So a mass spectrometer can detect the helium leaked into the component through cracks and porosities not detectable using other systems. The part is evacuated to less than 15 Pa (100 µm Hg). The unit may be also subjected to a vacuum rise test to ensure that it is “clean” from water vapor contamination, other non-condensable gases, and free of very large system leaks. After evacuation, the internal circuit is connected to the mass spectrometer. If any helium has leaked into the circuit, the mass spectrometer detects it. In this way, it is possible to quickly establish whether a sample leaks and to establish the total leak rate. This method is able to detect leak rates up to $1.8 \cdot 10^{-5}$ mbar · l/s, that is 2.5 g (0.1 oz) of R134a refrigerant per year.

There are several practical realizations of this testing method. The test system can be designed with one or multiple stations, usually two, for production rate requirements since multi-station machines allow testing several parts, one for each station, simultaneously. The containment hood may be designed so as to reduce helium dispersion during loading and unloading operations. Advances in vacuum and helium technologies provide improved sensitivity and faster test cycles even with low helium concentration, even at only 10% helium. In this case, the containment hood uses a helium ratio transducer to monitor the mixture inside it. Recirculation fans and mixing ducts maintain the preset concentration of helium to air uniformly distributed in the internal volume. The system will only replenish the helium when needed. Adoption of this state of the art solution saves helium reducing operation costs.

The hood must be the appropriate size to completely cover the test unit and can be designed to be adjustable, “collapsing” and thereby lowering the volume and therefore helium consumption.

This leak testing method has some advantages. It is a final global leak test and is very useful on production lines where a test piece must be simply accepted or rejected.

The test technique is fully automatic and hands-free. The total process time to leak test a part is low, regardless of its volume, even less than 80 seconds for a medium size unit.

However, there are also some shortcomings and some precautions that must be taken for the proper use of this system. This method is a go/no-go test for leak detection only. To pinpoint the leak location another system is required. If the test unit has a large leak such as an overlooked brazed joint, the escaping helium, at this much volume and concentration, would render the system inoperable for long time. It is best to use a preliminary leak test for gross leakage identification. A pressure decay test can be easily combined in the outside-in leak testing machine. This initial nitrogen filling, besides the mechanical stress and leakage test, allows purging the circuit to be tested, lowering its humidity. Upon a successful completion of the pressure decay test the component is ready for final test. At the end of the cycle, the part may be filled again with nitrogen, at a low pressure, so as to avoid helium being “sucked into” it when disconnected.

Since the unit to be tested is evacuated, its internal pressure is lower than atmospheric pressure. Therefore, if the working condition requires a positive pressure inside, this leak testing method will stress the part in the opposite way. This problem can be mitigated using a proper preliminary pressure test.

It is worth noting that parts to be checked must be kept in an area free from helium contamination before outside-in leak testing. If high-pressure air is used for a preliminary pressure decay test, the high-pressure air compressor inlet must also be in a “fresh air” atmosphere. At the end of cycle, the unit may be filled with low-pressure nitrogen to avoid helium getting into the part when disconnected.

5.2.6.5 Inside-out helium vacuum chamber leak testing

In "inside-out" techniques, known also as “global hard-vacuum test”, the test configuration is reversed. The component is placed inside an airtight chamber provided with service hoses and a vacuum pumping group with a mass spectrometer. The unit is connected to the service hoses, the chamber is closed, the part is evacuated and then pressurized with helium. The chamber is subsequently evacuated and once a suitable vacuum level is reached, the inlet valve of the leak detector is opened. The leak detector begins to analyze to the residual gas molecules present in the chamber. Helium molecules escaping from the component are conveyed and measured by the leak detector. At the end of the cycle, the vacuum chamber is vented. The leak detector finds the leak and gives the total measurement. Referring to the complexity of the test and the desired degree of automation, different test systems may be realized from the simplest to more elaborate. As an example, a two chamber machine can be realized so that in one chamber the test cycle is in progress while in the other chamber a part is unloaded and reloaded. In many industrial applications, in order for the test chamber to reach the vacuum level in acceptable times, an auxiliary pumping group is needed. The dimensioning of the pumping group depends on different parameters, such as the body of the expected leaks, the dimensions of the parts to test and the cycle time.

Vacuum chamber helium inside-out leak test method has some advantages. A sniffer is not used; testing is automatic and not operator dependant. The sensitivity achievable with this test is very high. In a laboratory application, it is not impossible to get 10^{-10} mbar · l/s. However, in practical application in the refrigeration industry, the limit is considered 10^{-6} mbar · l/s.

Despite these advantages, vacuum chamber inside-out leak test method has several drawbacks. It is an expensive system. While the sniffing test requires only the leak detector and the ability of the operator, the hard-vacuum test requires more complex and expensive equipment, but it enormously limits the incidence of the human factor. This fact makes this test attractive in many industrial contexts, while the sniffing test has its applications in the maintenance and the analysis of the defective parts.

In design and realization of the vacuum chamber, particular care must be taken to avoid helium contamination. In fact, if some helium remains on the chamber's inner surface or in some internal components, the background helium level will be high and the sensitivity will consequently be reduced.

If the test unit has a large leak, a lot of helium would leak out of the test unit and into the vacuum chamber, the mass spectrometer and the vacuum pumping station. The helium, at this much volume and concentration, would render the system inoperable for a long time.

To avoid this occurrence, it is good practice to use a preliminary leak test to detect big leaks. A pressure decay test can be combined with the vacuum chamber inside-out leak test. This initial nitrogen filling, besides the mechanical stress and leakage test, allows purging the circuit to be tested, lowering its humidity. On a successful completion of the pressure decay test the component is ready for final helium test.

At the end of cycle, the part may be filled again with nitrogen, even at a low pressure, to purge its internal circuit from the helium residuals before vacuum chamber venting.

Unlike the sniffing test, the hard-vacuum test is a global method that quantitatively defines the total leak of the piece, but does not determine its position. Other techniques are required for leak location.

Since helium is an expensive gas, and to reduce the helium concentration in the working area, it is not convenient to spread it in the ambient air, so it is good practice to use helium recovery/reclaim stations to empty the unit at the end of leak testing. The recovered helium can be reutilized for successive tests. However, helium recovery systems are costly. It is beneficial to perform a feasibility study on the subject of helium recovery to determine if the equipment investment plus upkeep is financially viable when compared to the cost savings of recovering helium.

5.2.6.6 Inside-out hydrogen sniffer detectors

As in the other "inside-out" techniques, the unit to be tested is evacuated and then pressurized with the hydrogen/nitrogen mixture. An operator moves the sniffer over the part and tests with the probe around suspected leak sites.

Compared with helium sniffer leak testing, this method has the same difficulty of operator dependency, but has many advantages.

Hydrogen is ideal for leak testing. It is the lightest element, with higher molecular speed and lower viscosity than any other gas. Therefore, it easily fills the unit to be tested, mixes quickly with any gas, it is easily evacuated and dissipated. Since hydrogen mixes very quickly in other gases, this method requires a low vacuum level compared with helium filling. As a result, the vacuum group is very simple; a Venturi vacuum generator is often sufficient. Hydrogen easily disperses into air, so its concentration in the working area falls quickly to the background level even in the case of big leaks.

In addition, hydrogen has the highest leakage rate of any other gas. Hydrogen detectors are based on semiconductor sensors and since they contain no moving parts, are tough enough for industrial use and completely maintenance free. They are also unaffected by the presence of other gases. Moreover, these sensors do not require suction for functioning, so the probes can be used without worrying about dust. In addition, the probe can be equipped with a protective cover that allows it to be used on wet objects. Hydrogen has a very low background concentration (0.5 ppm) and the detectors are sensitive enough to detect up to $5 \cdot 10^{-7}$ mbar · l/s (or 0.5 g/y (0.018 oz/y) R134a refrigerant) using a mixture of 5% hydrogen 95% nitrogen, and are ten times more sensitive compared to helium sniffers. This blend is standard industrial grade mix, inexpensive, non–flammable (as for ISO10156 specification) and readily available from industrial gases suppliers.

There are some doubts that exist about using hydrogen as tracer gas. Hydrogen escapes rapidly from a leak in an almost vertical direction, so a leak can be precisely detected and located only if the detector is directly above it. This might cause someone to think that leak detection with hydrogen is more difficult than with helium. However, even if a skilled operator has no difficulty in managing this problem, detectors can be easily integrated in special designs, e.g. funnel-shaped devices, to facilitate leak detection. Another common doubt about using a hydrogen/nitrogen mixture is component separation and hazards related to hydrogen. Even though the hydrogen/nitrogen mix is widely available, large industries with high production lines think that in big cylinders hydrogen tends to accumulate in higher section of the bottle. This would cause a problem of working with different hydrogen concentrations during the bottle life. On other hand, in-house mixing of hydrogen and nitrogen would assure the proper mixture, but it is very hard to achieve due to the risks related to hydrogen handling.

Hydrogen leak testing is a manual operation but, with a proper sampling probe, it can also be automated. An approach similar to the accumulation method can be favorably applied.

Although hydrogen quickly disperses in air and, even in case of big leak, the working area is not saturated by hydrogen, it is convenient to save tracer gas using a preliminary leak test for gross leakage identification. A pressure decay test can be easily integrated in the hydrogen testing machine.

5.3 How to Choose the Test Method

The specification of the acceptable leak and the test method are the first parameters to take in consideration in the plan of a product.

The questions are:

- Which type of total leak can damage the product?
- How many points (weldings, joints etc…) must be tested?
- How much time must the product last?

The answer to these questions is usually established in terms of a volume or gas mass that flows in a definite time (e.g. 10 g (0.35 oz) of R134a refrigerant in seven years).

Sometimes answering to this question is not much straightforward. For example, to define the total leak specifications of refrigeration system is simple, but to define the valid specifications for the single components and the single welding point is much more complex.

Every leak testing methodology has advantages and disadvantages. For leaks comprised in the range 10^{-1} and 10^{-3} mbar · l/s all the test methods are able to recognize a leak. Besides sensitivity, in selecting the proper testing method, many parameters have to be considered. Among them are repeatability, accuracy, report capability, operator dependency and, least but not the last, cost of the equipment and the necessary work force. In addition, the cost of tracer gas has an important incidence especially in case of series controls. In some cases, a gas recovery system, cutting down consumption, is to be taken into account.

For sake of clarity, in the following a sample application is treated.

Let 84 grams (3 oz) of R134a in 5 years at internal pressure of 1800 kPa (261 psia) and room temperature an acceptable leakage. This leak corresponds to 16.8 g/y (0.59 oz/y) of refrigerant

F = 84/5 = 16.8 g/y = 16.8 / (365 · 24 · 3600) = $5.33 \cdot 10^{-7}$ g/s

The equivalent leak rate can be computed by the kinetic theory of perfect gas. Since the molar weight of R134a is 102.03, the equivalent molar flow is:

Fm = F / M = $5.33 \cdot 10^{-7}$ / 102 = $5.22 \cdot 10^{-9}$ mol/s

It is known that a mole or a gas occupies a volume of $22.4 \cdot 10^{-3}$ m^3 (0.79 ft^3) at atmospheric pressure and 0 ºC (32 ºF). Then the molar volume at room temperature and atmospheric pressure is:

Vm = $22.4 \cdot 10^{-3}$ · 300 / 273.16 = $24.6 \cdot 10^{-3}$ m^3/mol

Let p the atmospheric pressure, the volumetric leak flow will be:

Q = Fm · Vm · p = $5.22 \cdot 10^{-9}$ · $24.6 \cdot 10^{-3}$ · 105 = $1.28 \cdot 10^{-5}$ Pa · m^3/s = $1.28 \cdot 10^{-4}$ mbar · l/s

The internal pressure has effects on the leak rate. The flow through an orifice depends not only on the pressure difference at the two sides of the orifice, but also on their absolute values. Let P_1 and P_2 the absolute pressures, to both edges of an orifice, that cause the rate of Q_1 leak, and P_3 and P_4 the absolute pressures that cause, in the same orifice, the Q_2 leak rate. Then the following relationship yields:

$$\frac{Q_1}{Q_2} = \frac{P_1^2 - P_2^2}{P_3^2 - P_4^2}$$

This equation allows computing the equivalent leakage when different pressure values are used. For example, resuming the previous case, the leak of $Q_1 = 1.28 \cdot 10^{-4}$ mbar · l/s from P_1 = 1800 kPa (261 psia) to P_2 = 100 kPa (14.5 psia), corresponds to a flow rate Q_2 from the atmospheric pressure to vacuum:

$$Q_2 = 1.28 \times 10^{-4} \times \frac{1^2 - 0}{18^2 - 1^2} = 3.9 \times 10^{-7}\, mbar \times l/s$$

If the leak testing is done in vacuum chamber, pressurizing the unit to 100 kPa (14.5 psia), the limit leak rate should be 3.93.9·10-7 mbar · l/s.

The flow through a leak depends also on the fluid viscosity; the less the viscosity, the larger the flow rate. Therefore, the flow Q_1 of a medium of viscosity ν_1 is related to the flow Q_2 of a medium of viscosity ν_2 by the relationship:

$$\frac{Q_1}{Q_2} = \frac{\nu_2}{\nu_1}$$

Returning to the previous example, considering that the tracer gas is helium, the R134a leak can be converted in the equivalent of leak for helium, based on various the viscosity (v) of two gases

$$\frac{Q_{R134a}}{Q_{He}} = \frac{\nu_{He}}{\nu_{R134a}}$$

Since the viscosity of the R134a is 0.012 cP and that one of helium 0.0178 cP, follows that the permissible leak for helium is:

Q_{He} = 3.9·10-7 · 0.012 / 0.0178 = 2.6·10-7 mbar · l/s

Even though these considerations are useful to identify the best suited testing techniques, they are not precise. Several approximation and simplification errors are introduced in the various steps. The perfect gas assumption is a useful approximation but, especially for refrigerants that should be more properly considered vapors, it is not exactly respected. In addition, there is no confidence that if a leak occurs at 1800 kPa (261 psia), this leak happens also to 100 kPa (14.5 psia), especially if the pressure acts in opposite sense. Moreover, the flow computations are applicable accurately in known flow regimen, but, obviously, this is not the case. In order to obviate to these error sources, it is better to carry out the tests with sensitivity ten times higher than that obtained with theory, in order to create a wide safety margin.

5.4 Conclusion

The growing demand for components and systems with fewer acceptable losses is the industry trend, due to several compelling market demands, such as economic requirements, environmental protection specifications, safety constraints and quality products requirement. The end result is stricter quality controls for leak testing. Researchers, technicians, scientists, producers etc., working with hermetically closed elements and vessels, vacuum or only tight seals have to become familiar with measurements and location of leaks. Remarkably, this technical field is nearly unknown even in engineering and important project organizations. Brief analyses of some of the most commonly used leak detection techniques were presented. Every methodology has advantages and disadvantages; the right choice is a trade-off between them and the production requirements. For the choice of the test methodology that will be used, it is necessary to accurately consider all admitted leak limits and all the other factors, not only the technological requirements, but also the corporate image, regulation developments and the new requirements of the market.

6. Examples of some leak test equipment in the market

6.1 Basic Test Bench LTbase

dr. wiesner steuerungstechnik

The *LTbase* basic test bench is designed as a manual workstation for all types of pneumatic leakage and flow testing. It can be fitted with a clamping and sealing device for individual components but is already equipped as it is with all basic features making up a complete test workstation. All that need to be incorporated are the holding fixtures and the movement-sequence functions for customer-specific specimens.

Drawer unit for parts fixture

Basic Test Bench *LTbase*

Basic outfit

• Workbench complete with shielded-off working area
• Component feeding via drawer unit
• Protective device complete with maintenance access gate
• Safety design in compliance with DIN EN ISO 13849 (New Machine Directive) performance level d
• Emergency STOP circuit
• Leakage testing system INTEGRA RD1
• Complete sequence control system for individual testing devices
• Triggering of “good” component marking function
• “Bad” component handling function prepared for
• Basic pneumatic outfit (maintenance unit and valve center)
• Basic electrical outfit (230V / 50 Hz)

Description of sequence run

• The operator inserts the test specimen in the specific component holding fixture mounted to the drawer unit.
• The drawer in pushed in manually, which ensures that the protective device is completely closed off.
• The safety switch on the drawer closes the monitoring circuit controlling the protective gate and releases the operating-power function.
• The program test-run sequence is now unleashed on the INTEGRA leakage test system as follows:
- Interlocking of the drawer unit takes place in the rear end position.
- Subject to having previously been installed, the initiator/s denoting “Component inserted/attachments present on test specimen” will be queried
- All customer-specific sequence movements undergo querying in the basic position, provided the corresponding initiators have previously been installed.
- Customer-specific movement 1 (e.g. hold-down) is started up; arrival in working position (if monitored) is awaited.
- Customer-specific movement 2 (e.g. sealing 1) is started up; arrival in working position (if monitored) is awaited.
- Customer-specific movement 3 (e.g. sealing 2) is started up; arrival in working position (if monitored) is awaited.
- Test cycle is started up.
- If testing reveals a bad “NIO” part, a red lamp will light up and all follow-on sequences will be stopped until the result has been acknowledged by the operator via push-button control.
- If the test reveals a good “IO” part, a green lamp will light up and the test specimen will be marked as a satisfactory component, provided an appropriate marking facility is installed.
- All movements are run in the reverse order back to the home position.
- The drawer interlock function is released.

• The operator can now pull out the drawer, which in turn switches off the operating power through interruption of the safety circuit.
• The operator then removes the test specimen from the component holding fixture.
• Following a NIO result, the bad components need to be dumped into a reject bin through a discharge duct where installed.

Testing

Depending on the version of the INTEGRA leakage testing system employed, all common testing procedures are possible applying excess-pressure or vacuum action control, viz.:

Leakage testing applying the relative-pressure method,
Leakage testing applying the differential-pressure method,
Leakage testing applying the mass-flow method,
Leakage testing applying the volume-current method.

The INTEGRA leakage testing system also makes provision for numerous additional functions, e.g.

Measured-data recording facilities via a serial interface
Statistical functions
Integral measured-data storage module
256 test parameters with individually adjustable routine times and limiting values
Individual specimen-test result allocation where a scanner is linked up

The complete functional and performance scope of the INTEGRA leakage testing system will be gathered from the descriptions provided in the INTEGRA special brochure.

INTEGRA leakage testing system and optional lighted work station

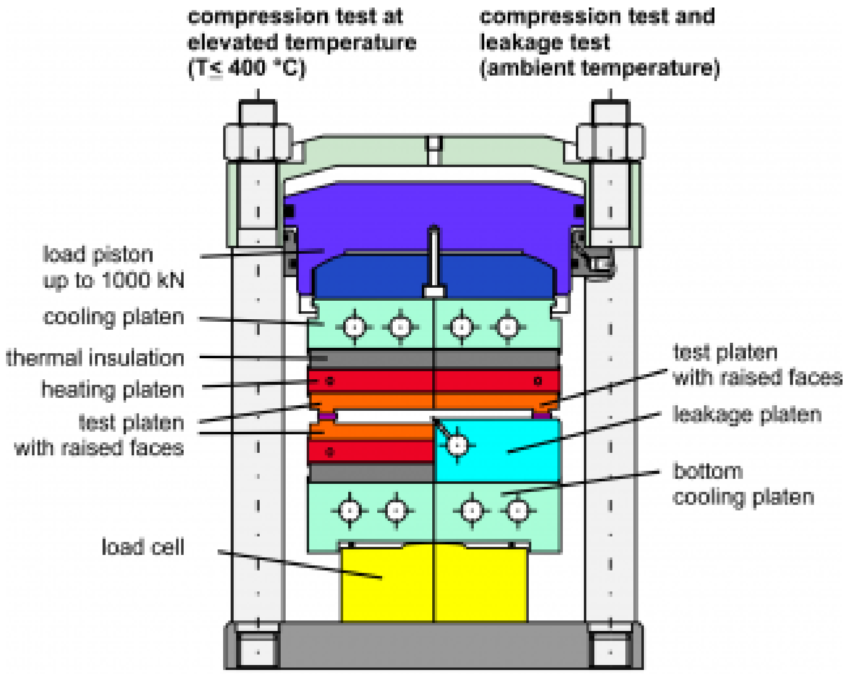
6.2 Multifunctional test rig

TEMES fl.ai1

The TEMES fl.ai1 enables you to carry out upsetting testing, leakage testing, compressive creep testing and/or creep/relaxation testing. This makes it a real all-rounder, justifiably carrying the suffix *"ai1"*, short for *"all in one"*.

Design and function

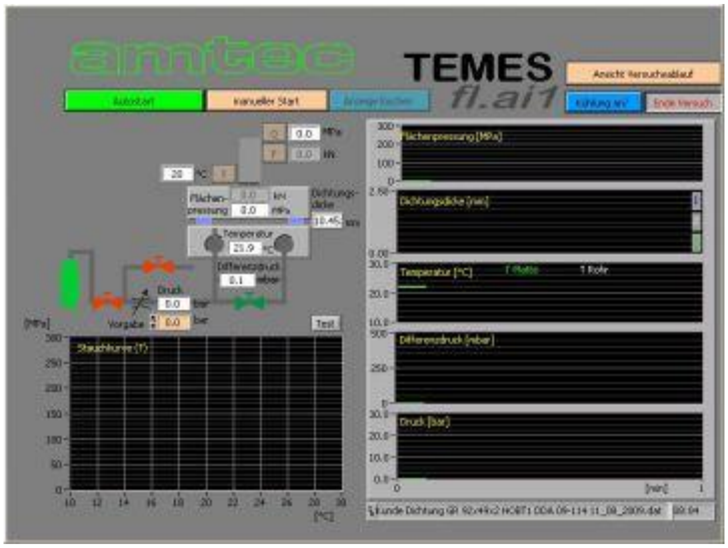
The TEMES fl.ai1 test rig is a servo-controlled hydraulic press. The test rig has modular construction, so different components can be used depending on the test type. This particularly concerns the cooling, insulating and heating plates, but different sealing strips can also be incorporated for the investigation of different gasket geometries.



Recording of the sealing force is performed by a load cell mounted on the base plate; deformation of the gasket is recorded by position sensors on three points of the circumference. Furthermore, temperatures are measured at various locations on the test rig, so that the temperature profile is known for each point in time.

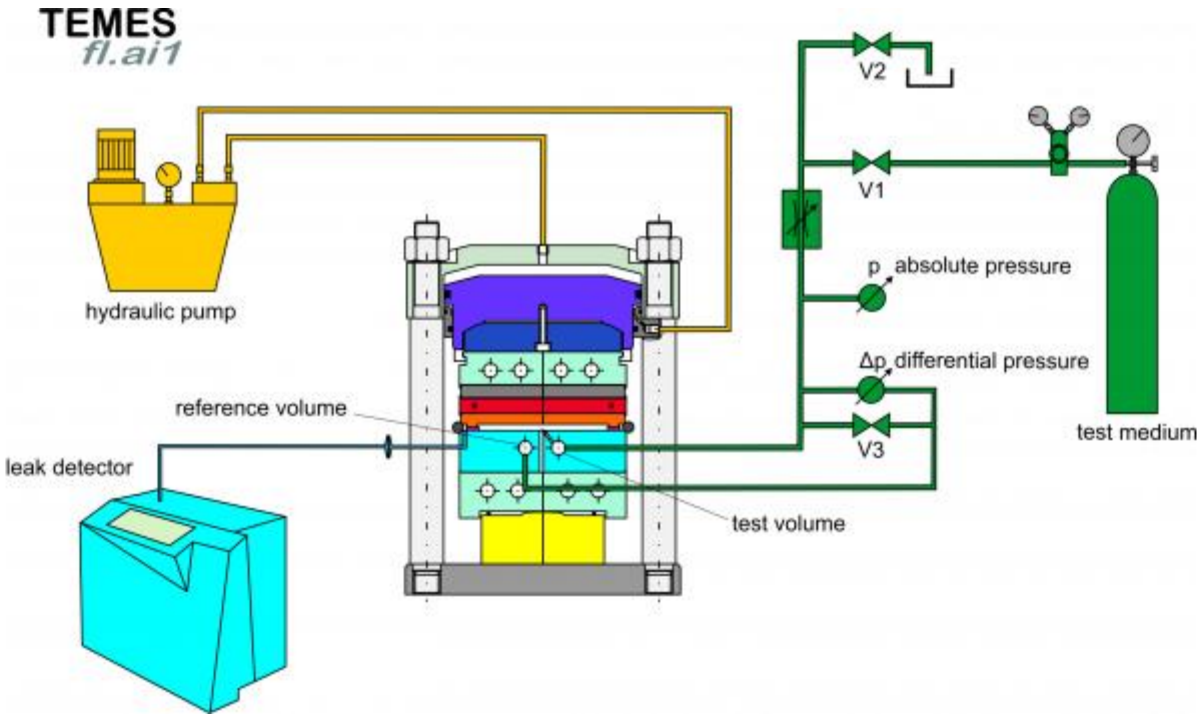
Software

Easy-to-use software permits the recording, representation and storage of all measurement values. The software can also be used to control the entire testing procedure, so that tests can be carried out fully automatically according to official standards (e.g. EN, DIN, ASTM) or according to individual specifications.



Leakage measurement

The standard measurement principle used for leakage testing is based on the pressure drop method with the differential pressure procedure. The membrane valves required for the different functions are controlled by the software – ensuring that the tests can proceed fully automatically. As an option, leakage measurement with a helium mass spectrometer is possible. Together these two measuring procedures cover a broad range of sealing requirements.



Generally, leakage testing is carried out at constant internal pressure and different levels of surface pressure. However, thanks to automatic filling and venting, it is also possible to carry out tests with several levels of internal pressure.

6.3Leakage test rig

TEMES
ta.luft

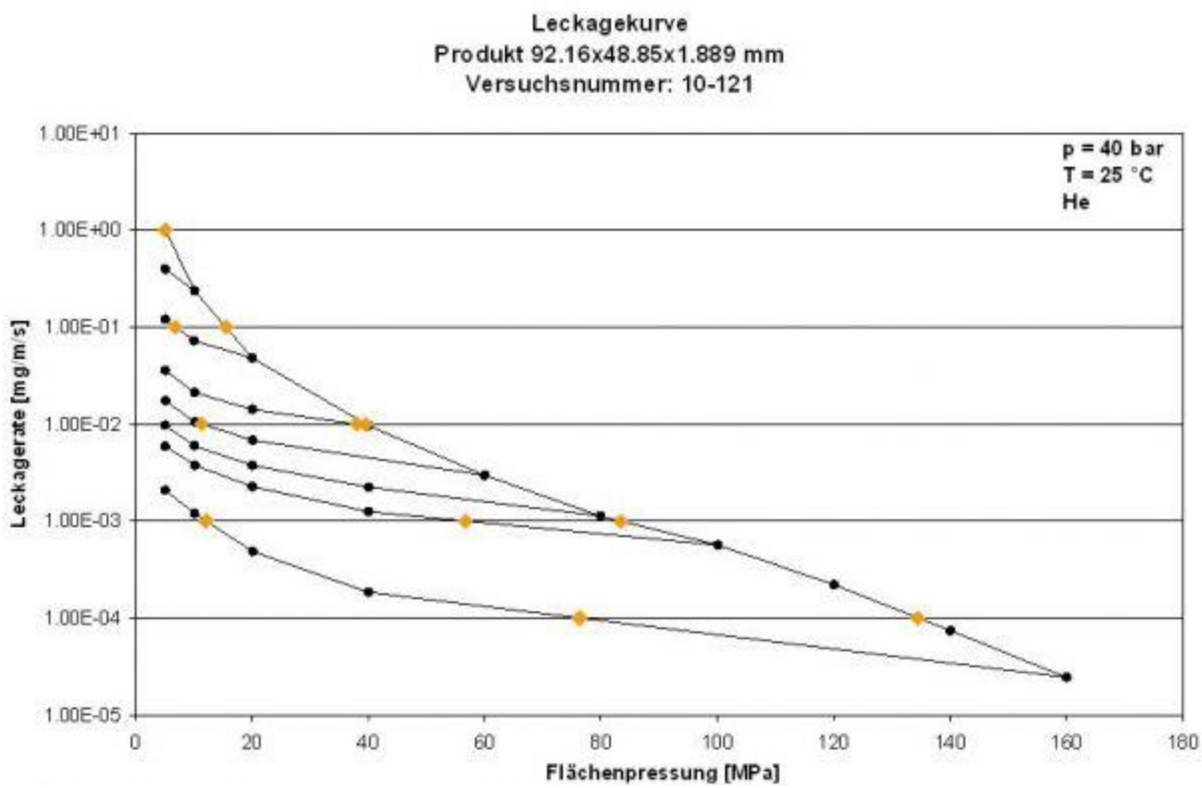
The TEMES ta.luft test rig was designed for component testing of real flanged connections to investigate gasket quality in terms of the TA-Luft (the German Clean Air Act). Here the sealing behaviour is determined after a previous exposure to temperature, as required in the VDI Guidelines 2440 and 2200.

The gaskets are held in place between two flanges with special measurement bolts, which enable the applied bolt force to be measured using digital indicators. The test flange can then be exposed to a maximum temperature of 400 °C in an oven. After cooling, the test flange is connected with a leakage unit. The vacuum chamber is assembled to the test flange with clamping bolts, and the rate of leakage is measured with a helium mass spectrometer.

Leakage testing

For determining the sealing properties depending on the internal pressure and the contact pressure of a gasket:

We also use the two TEMES fl.ai1 test rigs to carry out leakage testing in our test laboratory. Leakage testing is normally only carried out at room temperature. The external diameter of the test piece is therefore limited to 170 mm and the available force is 1000 kN. We developed the TEMES ta.luft test rig for component testing of real flanged connections. It is usually used to investigate gaskets with DN40/PN40 geometries, whereby a temperature exposure of up to 400 °C is possible.



Leakage characteristic at an internal pressure of 40 bar

6.4 API-527 DIGITAL BUBBLE COUNTER

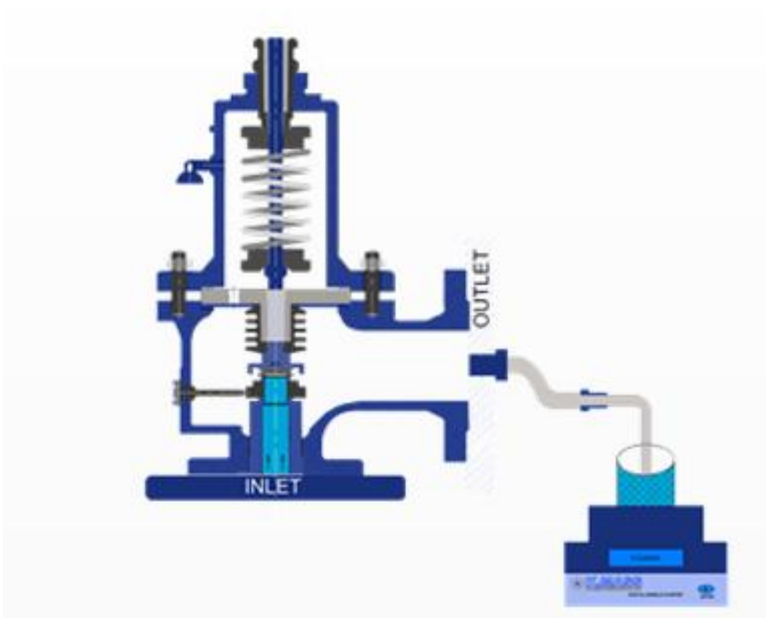
All Safety & Relief Valves operating on gaseous fluids are to be tested for seat leakage on Air in accordance with API-527 in order to ascertain their functional characteristics in line with their leakage class rating.

The Digital Bubble Counter developed by K.Mass enables the user to perform the seat leak test accurately & with ease, thus purging the need for a tedious manual counting procedure. This is an Independent standalone system which is connected to the discharge side of the valves by means of quick push type fittings and a PU tube

The Bubble counter is equipped with a Start/Stop button to start and stop data logging. The result is displayed in terms of total number of bubbles & duration in real-time while the test is in progress. Once the test is stopped the end result is displayed in Bubbles per minutes based on the total leakage spread over the duration of the test.

Features

- Complies with API-527 Seat Leak test procedure.
- Easy & Quick connection & removal.
- Accurate results
- Eliminates manual counting
- No preset maximum limit on the test duration or the number of bubbles

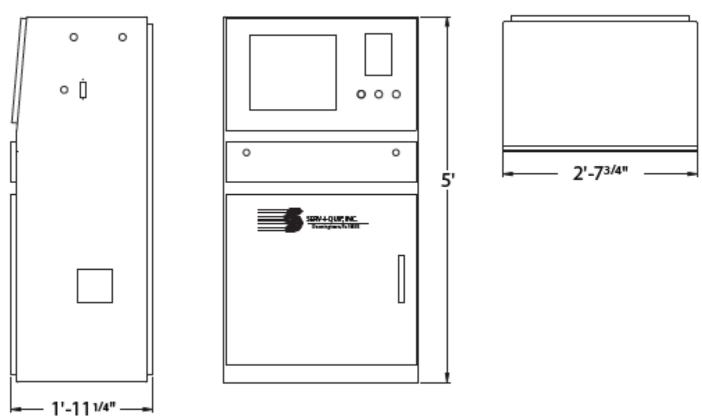


6.5 DataTest NH 150

These systems provide a wide range of testing options in an automated, PLC controlled test cycle. A proof /pressure test, pressure decay test, flow test (optional), and leak test can be configured and automatically sequenced to provide a comprehensive, efficient leak test process. Attaching DataServ.NET to this test system can create a very effective tool to monitor, record, and improve your process and product quality. These systems can operate from a local test gas supply or in conjunction with our centralized Helium Mix and Recycle System.

The addition of DataServ.NET to our comprehensive leak test station greatly expands the capability of this product. DataServ.NET provides a detailed operator interface, a process analysis tool, test result storage and retrieval, communication with upper level process scheduling systems, maintenance support, and remote intranet / internet access.

Dimensions:
63"H x 36"W x 24"D
Weight:
525 lbs.
Utility Requirements
- Electric: 120V, 20A
- Nitrogen: Pressurized supply to meet pressure test requirements
- Helium: Pressurized supply to meet volume requirements
- Air: 80 psig shop air



Features

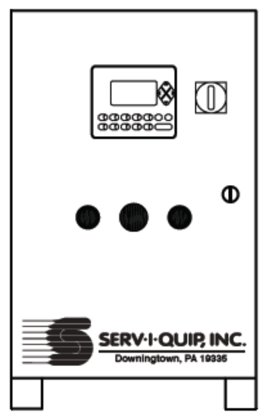
- Allen Bradley PLC and PanelView® O/I
- Dell PC with Windows XP®, 17" flat screen LCD, 10/100 NIC, CDRW
- DataServ.NET web enabled process configuration and report generation software
- Hand-held CCD or RF bar code scanner
- Industrial service control valves
- Venturi vacuum pump
- English or Spanish display
- Automatic test cycle can include:
    - Proof pressure test
    - Pressure decay test
    - Capillary flow test (optional)
    - Helium or Hydrogen leak test
    - Water line flow test (optional)
    - Test gas vent (recovery optional)
- Final evacuation

6.6 AccuTest NH 110

SERV-I-QUIP, INC.

This compact system delivers a comprehensive leak test process in an economical but durable control package. The adjustable leak test process performs a pressure test, pressure decay test, and tracer gas fill. A sniffer test is performed using a helium or hydrogen leak detector to locate leaks down to 10-5 cc/sec. This automated, economical system will effectively improve the quality of your leak testing process and your final product.

Dimensions
26"H x 16"W x 12"D (40% smaller footprint)
Weight
80 lbs.
Utility Requirements
- Electric: 120V, 10A
- Nitrogen: Pressurized supply to meet pressure test requirements
- Helium/Hydrogen: Pressurized supply to meet testing requirements
- Air: 80 psig shop air



Features

- New Allen Bradley Micrologix® 1100 PLC
- New Allen Bradley Panelview® C300 operator interface
    - View pressure and time set point screens,
    - Process step detail screens and failure mode screens
- Ethernet capable for future DataServ.NET connectivity
- Venturi vacuum pump
- High quality pressure transducers
- Hoses and quick couplers included
- Automatic leak testing cycle can include:
    - Proof pressure test
    - Pressure decay test
    - Capillary flow test (optional)
    - Helium or hydrogen test gas fill
    - Sniff test by operator
    - Test gas vent (recovery optional)
    - Water line flow test (optional)
- System can be bench or cart mounted

6.7 ATEQ 5 Series Leak Testers

	F580	F570	C540 + F20	F535
Technology	Differential pressure decay	Differential pressure decay	Differential pressure decay	Differential pressure decay
Measurement range	3 ranges of leak measurement (DP) Full scale : 50 Pa 500 Pa 5 000 Pa	3 ranges of leak measurement (DP) Full scale : 50 Pa 500 Pa 5 000 Pa	3 ranges of leak measurement (DP) Full scale : 50 Pa 500 Pa 5 000 Pa	3 ranges of leak measurement (DP) Full scale : 50 Pa 500 Pa 5 000 Pa
Test modes	Test modes : DP DP/Dt Flow units Blockage test Additional ones depending on your applications	Test modes : DP DP/Dt Flow units Blockage test Additional ones depending on your applications	Test modes : DP DP/Dt Flow units Blockage test Additional ones depending on your applications	Test modes : DP DP/Dt Flow units Blockage test Additional ones depending on your applications
Programs	64 programs / head	32 programs	64 programs / head	32 programs
Calibration	Manual calibration on front panel using calibrated leak	Manual calibration on front panel using calibrated leak	Manual calibration on front panel using calibrated leak	Manual calibration on front panel using calibrated leak
Networking	RS232: PC and configuration / storage module RS485: ATEQ network	RS232: PC and configuration / storage module RS485: ATEQ network	RS232: PC and configuration / storage module RS485: ATEQ network	RS232: PC and configuration / storage module RS485: ATEQ network
Dimensions W/H/D (mm)	537 x 157x 381	537 x 157 x 381	(C540) : 287 x 250 x 180 (F20) : 136 x 250 x 180	136 x 420 x 272
Weight (Kg)	15	15	(C540): 4.5 (F20) : 4	8
Interface	Graphical display High visibility LED alphanumeric display (14 digits) Results Indicator lights	Navigation keys Alphanumeric display (14 digits) LCD display 4 lines Results indicator lights	14 digits and graphical display (C540) 4-line LCD screen (F20 option) Results indicator lights (F20 option)	Navigation keys 4-line LCD display High visibility LED alphanumeric display (14 characters) Results indicator lights
Power supply	90- 260 V AC / 1 .6 A	90- 260 V AC / 1 .6 A	24 V DC 1 .6 A Main adapter included (110 - 240 V AC)	24 V DC 1 .6 A Main adapter included (110 - 240 V AC)

Air requirements	Clean and dry air required Air quality standard to be applied (ISO 8573-1)	Clean and dry air required Air quality standard to be applied (ISO 8573-1)	Clean and dry air required Air quality standard to be applied (ISO 8573-1)	Clean and dry air required Air quality standard to be applied (ISO 8573-1)
Temperature	Operating : 0°C to + 45°C Storage : 0°C to + 60°C	Operating : 0°C to + 45°C Storage : 0°C to + 60°C	Operating : 0°C to + 45°C Storage : 0°C to + 60°C	Operating : 0°C to + 45°C Storage : 0°C to + 60°C
Options	7 inputs / 5 outputs 14 inputs / 14 outputs Electronic regulator Dual pressure High speed valve Y valve: 2 test ports (1 head only) 2 pneumatic outputs for control of sealing connectors 6 x 24 V programmable outputs (per head) for external automation 2 analog outputs: 0 - 10 V or 4 - 20mA Automatic calibration check Temperature compensation Modbus (Field bus)	7 inputs / 5 outputs Electronic regulator Dual pressure High speed valve Y valve: 2 test ports 2 pneumatic outputs for control of sealing connectors 6 x 24 V programmable automation 2 analog outputs: 0 - 10 V or 4 - 20mA Automatic calibration check Temperature compensation Modbus (Field bus)	C540 : 14 inputs / 14 outputs F20 : 7 inputs / 5 outputs LCD display Electronic regulator Dual pressure High speed valve 2 pneumatic outputs for control of sealing connectors 6 x 24 V programmable outputs for external connection 2 analog outputs: 0 - 10 V or 4 - 20mA Automatic calibration check Temperature compensation Modbus (Field bus)	Electronic regulator Dual pressure High speed valve 2 pneumatic outputs for control of sealing connectors 6 x 24 V programmable outputs for external connection 2 analog outputs: 0 - 10 V or 4 - 20mA Automatic calibration check Temperature compensation

	F520	F510	F420	F405
Technology	Differential pressure decay	Differential pressure decay	Standard pressure decay	Standard pressure decay
Measurement range	3 ranges of leak measurement (DP) Full scale : 50 Pa 500 Pa 5 000 Pa	3 ranges of leak measurement (DP) Full scale : 50 Pa 500 Pa 5 000 Pa	3 ranges of leak measurement (DP) Full scale : 50 Pa 500 Pa 5 000 Pa	3 ranges of leak measurement (DP) Full scale : 50 Pa 500 Pa 5 000 Pa
Test modes	Test modes : DP DP/Dt Flow units Blocage test Additional ones depending on your applications	Test modes : DP DP/Dt Flow units Blocage test Additional ones depending on your applications	Test modes : DP DP/Dt Flow units Blocage test Additional ones depending on your applications	Test modes : DP DP/Dt Flow units Blocage test Additional ones depending on your applications
Programs	64 programs / head	32 programs	4 programs	8 programs
Calibration	Manual calibration on front panel using calibrated leak	Manual calibration on front panel using calibrated leak	Manual calibration on front panel using calibrated leak	Manual calibration on front panel using calibrated leak
Networking	RS232: PC and configuration storage module RS485: ATEQ network	RS232: PC and configuration storage module RS485: ATEQ network	RS232: PC and configuration storage module	RS232: PC and configuration storage module RS485: ATEQ network

Dimensions W/H/D (mm)	250 x 136x 367	426.5 x 194 x 108.5	250 x 136x 272	240 x 137 x 120.7
Weight (Kg)	8	8	8	5
Interface	Navigation keys LCD display 4 lines Results indicator lights	Navigation keys LCD display 4 lines Results indicator lights	Navigation keys LCD display 4 lines Results indicator lights	Results display (Good part - cycle in progress - Bad part)
Power supply	24 V DC 1 .6 A Main adapter included (110 - 240 V AC)	24 V DC 1 .6 A Main adapter included (110 - 240 V AC)	24 V DC 1 .6 A Main adapter included (110 - 240 V AC)	24 V DC / 1.25 A
Air requirements	Clean and dry air required Air quality standard to be applied (ISO 8573-1)	Clean and dry air required Air quality standard to be applied (ISO 8573-1)	Clean and dry air required Air quality standard to be applied (ISO 8573-1)	Clean and dry air required Air quality standard to be applied (ISO 8573-1)
Temperature	Operating: 0°C to + 45°C Storage: 0°C to + 60°C	Operating: 0°C to + 45°C Storage: 0°C to + 60°C	Operating: 0°C to + 45°C Storage: 0°C to + 60°C	Operating: 0°C to + 45°C Storage: 0°C to + 60°C
Options	Electronic regulator Dual pressure High speed valve Y valve: 2 test ports 2 pneumatic outputs for control of sealing connectors 6 x 24 V programmable outputs for external automation 2 analog outputs: 0 - 10 V or 4 - 20mA Automatic calibration check Temperature compensation Modbus (Field bus)	Electronic regulator Dual pressure High speed valve Y valve: 2 test ports 2 pneumatic outputs for control of sealing connectors 6 x 24 V programmable outputs for external automation 2 analog outputs: 0 - 10 V or 4 - 20mA Automatic calibration check Temperature compensation Modbus (Field bus)	3 inputs/ 4 outputs 2 pneumatic outputs for control of sealing connectors	Remote control RC5 mini Accessories Case Pneumatic kit (mechanical regulator + manometer + pipe cutter + couplings...)

	F420HP	MF520	G535	G520
Technology	Standard high pressure decay	Mass Flow	Continuous flow	Continuous flow
Measurement range	From 20 to 170 bar	3 ranges of measurement Full scale : 2 - 20 - 200 ml/min	2 flow measurement ranges : 100 or 1 000 cm3.atm/h	2 flow measurement ranges : 100 or 1 000 cm3.atm/h
Test modes	Test modes : DP DP/Dt Flow units Blocage test Additional ones depending on your applications	Test modes : DP DPI Dt Flow units Blocage test Additional ones depending on your applications	Measurement flow returned to standard condition	Measurement flow returned to standard condition

Programs	8 programs	16 programs	16 programs	16 programs
Calibration	Manual calibration on front panel using calibrated leak	Manual calibration on front panel using calibrated leak	Manual calibration on front panel using calibrated leak	Manual calibration on front panel using calibrated leak
Networking	RS232: Printer and configuration storage module	RS232: Printer, PC and configuration storage module RS232: Intelligent RC5 remote control RS485: ATEQ network	RS232: Printer, PC and configuration storage module RS232: Intelligent RC5 remote control	RS232: Printer, PC and configuration storage module RS232: Intelligent RC5 remote control
Dimensions W/H/D (mm)	250 x 136 x 381	250 x 136 x 381	136 x 420 x 272	250 x 136 x 381
Weight (Kg)	10	7	6	4
Interface	Navigation keys LCD display 4 lines Results indicator lights	Navigation keys LCD display 4 lines Results indicator lights	Navigation keys 4-line LCD display High visibility LED Results indicator lights Bar graph	Navigation keys 4-line LCD display High visibility LED alphanumeric display (14 characters) Results indicator lights
Power supply	24 V DC 1 .6 A Main adapter included (110 - 240 V AC)	24 V DC 1 .6 A Main adapter included (110 - 240 V AC)	24 V DC 11 .2 A Main adapter included (110 - 240 V AC)	24 V DC 11 .2 A Main adapter included (110 - 240 V AC)
Air requirements	Clean and dry air required Air quality standard to be applied (ISO 8573-1)	Clean and dry air required Air quality standard to be applied (ISO 8573-1)	Clean and dry air required Air quality standard to be applied (ISO 8573-1)	Clean and dry air required Air quality standard to be applied (ISO 8573-1)
Temperature	Operating: 0°C to + 45°C Storage: 0°C to + 60°C	Operating: 0°C to + 45°C Storage: 0°C to + 60°C	Operating: 0°C to + 45°C Storage: 0°C to + 60°C	Operating: 0°C to + 45°C Storage: 0°C to + 60°C
Options	3 inputs / 4 outputs 2 pneumatic outputs for control of sealing connectors	7 inputs / 5 outputs Electronic regulator Dual pressure High speed valve 2 pneumatic outputs for control of sealing connectors 6 x 24 V programmable outputs for external automation 2 analog outputs: current or voltage Fieldbus	7 inputs / 5 outputs 2 quick connectors for calibration checking 2 pneumatic outputs for control of sealing connectors 6 x 24 V programmable outputs for external connection 2 analog outputs: current or voltage	7 inputs / 5 outputs 2 quick connectors for calibration checking 2 pneumatic outputs for control of sealing connectors 6 x 24 V programmable outputs for external connection 2 analog outputs: current or voltage

Technology

The range of ATEQ Leak Testers can be fit with as many as 6 different technologies. Most Leak Testing companies around the world claim that this or that technology is better than the others ... and they are all right. Each technology is best suited for specific applications but ATEQ is the only company that masters them all.

Furthermore, ATEQ has improved each of these technologies thanks to its 50+ development engineers' team who work all year long with end users to solve real life application issues.

Differential pressure Decay:

The most popular

By far the most popular technology, differential pressure decay uses a reference volume to test your part. This helps compensate for any ambient pressure or temperature variations as they occur on both parts simultaneously.
Only a leak on the test part will result in a movement of our transducer's membrane.

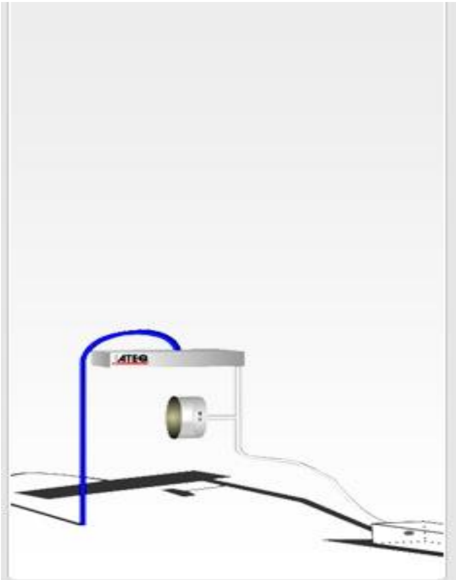
The second advantage of this method is that the accuracy does not drop with the test pressure as the transducer is measuring pressure differences between the two circuits, as opposed to the traditional pressure decay technology that measures pressure drops against the atmosphere.

Leak ranges (in Pascal/second): From 1 to 5000 Pa/sec pressure drops (Values in cm3.atm/min depend on the test volume)

Maximum resolution: 0.1 Pascal

Standard pressure decay

The one that started it all



As a stripped down version of the previous technology, standard pressure decay compares the pressure on the part with the atmospheric pressure. This technology is used when the application does not require a very high accuracy or a very fast cycle time.

Leak Ranges (in Pascal/second): From 10 Pa/sec

Maximum resolution: 10 Pascals

Maximum test pressure: 40 atmospheres

Pressure measurement: 1 % of the pressure + 2 digits and 0.1% of full scale resolution

Continuous flow

The most convenient

Often considered as a competitor to the Mass Flow technology, continuous flow relies on a differential pressure transducer and a very precise laminar flow tube to measure leak rates. Its internal volume ensures that the flow generated by the leak remains very stable over time. This technology is perfectly suited to the gas industry which sees it as a real time leak reader for gas appliances on production lines. While the instrument generates a leak and shows its value on the screen, the operator can tighten the connections of the gas product until it reaches an acceptable leak rate.

Leak Ranges (in cm3.atm/h): 0 to 100 or 0 to 1000 cm3.atm/h

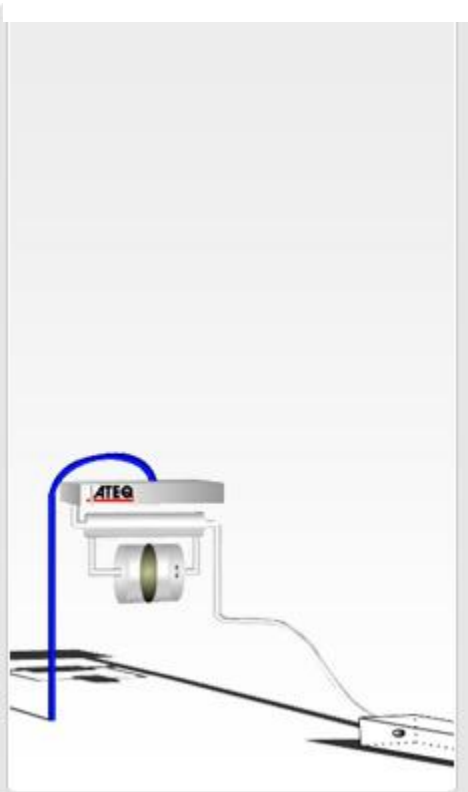
Maximum resolution: 0.1 cm3.atm/h

Maximum test pressure: 50 kPa

Pressure measurement: ± 1% of Pressure + 2 digits and 0.1% of full scale resolution

Laminar Flow

The one for large leaks



Sometimes a leak can be considered as a "small flow", or a flow as a "big leak". When your reject level is too high for other technologies, it may be necessary to use a laminar flow tester. A flow takes place between the pressure line and the leak hole of the part.

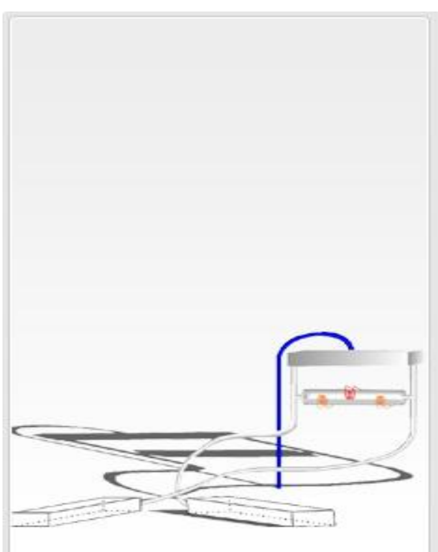
Our instrument features a laminar flow element across which our differential pressure transducer is connected.

Every flow generates a pressure difference between the inlet and outlet of the laminar flow element, and this variation is measured by the pressure transducer.

Leak Ranges (in L/H): 5, 30, 150, 500, 1500, 4000 or 10 000 L/H
Maximum resolution: >1% of full scale
Maximum test pressure: 350 kPa
Pressure measurement: 1% of the pressure + 2 digits and 0.1% of full scale resolution

Mass Flow

For those used to Mass Flow meters



The Mass Flow technology converts a mass of air going through a laminar flow element into a leak value. Should the test part leak, a flow will take place between a reference part and this leak, forcing the air to go through the Mass Flow measuring device that will convert it into a leak value such as cm3.atm/h.

However, unlike traditional Mass Flows, our technology can handle "large leaking" parts on the line without having to reset the unit.
And unlike our competitors again, we do not use heating elements to measure the mass of air, thus reducing the sensitivity to contamination.

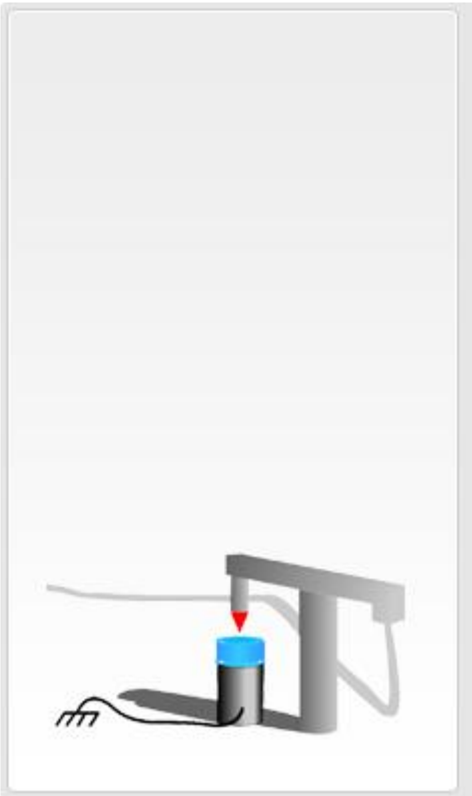
We've also put our expertise in high pressure testing into the pneumatics of this unit, allowing it to measure with a high level of accuracy at test pressures of up to 20 Bar (300 PSI).

Finally, our Mass-Flow technology comes with the latest temperature compensation feature making sure you get the best results in the industry in the toughest conditions.

Leak Ranges (in cm3.atm/min): 2 or 20 or 200 cm3.atm/min
Maximum test pressure: 20 Bar
Pressure measurement: 1% of the pressure + 2 digits and 0.1% of full scale resolution

IONIQ

The fastest



So far, all the technologies we have described use air to measure the leak rate.

In this case we use electricity.

A high voltage loaded sharp end is applied next to an earth connected base and in between lays the plastic part we test. Should a hole exist in the part, ions will start moving from the earth to the sharp end.

This will result in a loss of power and be translated into a leak.
While this method does not quantify the leak rate in terms of cc/min for example, it is the fastest ever invented to detect a leak in a go / no go process.
We have achieved cycle times of less than 7/10 of a second.

Leak Ranges: Depends on the size of the hole and the material of the part
Accuracy: Depends on the size of the hole and the material of the part

6.8 F5200 Leak Tester

SMALL PART TESTING

The ATEQ F5200 "MiniValve" is made for small part testing.

In the pressure decay world, volume is the big enemy. The more volume is filled, the longer it takes to get into the test pressure, to stabilize and to test the part.

For small parts (up to 5cc) the absurd situation is that most of the volume tested is in the pipes and internal pneumatics of the instrument.

A standard ATEQ valve is already twice as small as the nearest competitor. But ATEQ has gone further with its minivalve that has allowed it to achieve total cycle time (fill, stabilize, test, dump) down to 0.2 sec for leak rates as low as 0.5 cc/min.

TEMPERATURE COMPENSATION

This is the crown jewel technology of ATEQ. Not only does it compensate for temperature variations, but it learns from the results it gets and adapts itself to those results in a smart way.

BALISTIC FILL FEATURE & ELECTRONIC REGULATOR

Again, this feature is an ATEQ exclusivity.
In some applications, filling the part takes more than 1/3 of the total cycle time.

ATEQ has this innovative feature that will let the electronic pressure regulator open fully for a small amount of time, so the part fills up faster.

The "Balistic fill" does not only fill faster. It also helps stabilizing the part's volume faster.

HIGH PRESSURE

ATEQ F5200 can leak test components up to 80 bars (1250 PSI) in differential pressure mode. That remains unmatched in the industry.

SEALED PART TESTING

The F5200 "Sealed component" can test if the component is sealed.

What is so special about sealed components?
With pressure decay leak testers, the problem isn't so much to find a small leak in a sealed part, but rather to detect a gross one.

If the component has a big leak, then the internals will get filled at the fill stage, leaving no pressure to drop once the instruments gets into the test stage.

ATEQ has invented and patented the sealed component technique by performing a volume test prior to leak testing your part.

So if there is a gross leak, the volume will be higher than expected and the test will fail.

ACCESSORIES

Remote controls

4 remote controls available:
- The 2 functions TLC.
- The 5 TLC: 2 Functions, 2 Indicators, Increase/Decrease of the programs and displays.
- The onboard TLC.
- The remote display RC5.

5 Series interface / Series 3 and alphanumeric...

Enables the instantaneous swapping of a 3 series instrument with a new generation 5 series instrument whilst conserving the same connections as far as the PLC is concerned.
3 interfaces are available:
F5/F3 - F580/F3 - F580/F alphanumeric

Inputs / Outputs module

For the remote management of measurement units (heads) when long lengths of cables separate the measurement units from the central. Enables the minimization of the lengths of cable used between the elements.
Management of 3 units max.

Parameter storage / result modules

Two separate modules which enable the transfer of settings from one instrument to another and the recovery of the measurement results for software based assessment.

Y Valve and Mini Y Valve

The Y valves and mini Y valves are 3/2 spring recoil valves with pneumatic or electric control.
They offer a high level of protection against leaks.

CDF: Leak / Flow calibrator

The leak / flow calibrator allows the checking of the calibration of leak and flow measurement instruments, as well as calibrated leaks and jets. This portable, compact and user friendly instrument is essential for checking the accuracy and repeatability of all leak and flow testers.

2 pneumatic outputs

The optional pneumatic outputs (internal or external) are Two pneumatic pulses that are being activated at anytime during the cycle and under pre-set conditions such as: Start of cycle; end of cycle; Good part; Bad part; ...Etc. They allow the user to operate simple jigs without having to rely on a PLC.

Electronic regulators

Thanks to electronic regulators, an instrument can be programmed with a different pressure on each test cycle.
It can also be used as a pre-fill pressure to speed up the cycle time.

Dual pressure

The dual pressure option of ATEQ's differential pressure decay instruments allows the reduction of cycle time through faster fill time. Used in conjunction with the pre-fill software option, the dual pressure raises the test pressure faster than conventional fill times. It also helps reduce cycle on flexible parts.

Calibrated Leak / Jet

The calibrated leak or jet allows the checking of the calibration of leak or flow measuring instruments. Available in standard and customized versions, they simulate an exact leak or flow rate inside the test circuit to check that the instrument detects the right value.

Quick sealing connectors

The quick sealing connectors pneumatically compress a soft rubber cylinder around an internal or external diameter.
Together with the optional pneumatic outputs of ATEQ' instruments, these devices offer a perfect solution to build fixtures quickly and inexpensively.

Filtration kit

ATEQ instrument require a clean and dry operation to remain reliable. The Ethafilter ensures that the ATEQ operates under the ISO 8573-1 standard.

Winateq

Winateq is an integrated software which is compatible with our custom windows based applications.
It is easy to install and includes a system configuration back up.
It can also be used as a base to develop customized applications.
(Import and export function to spread sheet application).

Thermal printer

Connected to the RS 232 port of ATEQ's instruments, this thermal printer can print results in ASCII format, including the details of cycle times and results.

Very handy in laboratory operation to automatically print dozens or hundreds of results.

6.9 OPTIMA VT

More flexibility, more capability, more technique.

Optima vT offers Uson's industry-leading reliability and advanced testing technology in a highly configurable and versatile package. A comprehensive user interface puts control and information directly at your fingertips via the large, clear, touch screen display.

Uson has set the standard for fast, reliable and repeatable leak testing when applications get tough and others turn away. The Optima vT provides a comprehensive link between the user and Uson's customizable pneumatics –the tangible result of over 40 years of application development and experience.

The most versatile leak tester.

Uson's engineering team has designed the Optima vT with utmost versatility in mind. Mounting options include standard and custom cabinets, flat panels, articulated pendants and more. Testing techniques include pressure decay, differential pressure decay, mass flow measurement, burst and occlusion testing and others.

At the heart of the Optima vT is Uson's powerful TCU2, the second generation Test Control Unit offering unparalleled flexibility in a single test channel. TCU2 allows up to four high resolution sensors and with its available custom pneumatic configurations, the sky is the limit on your leak and flow test design creativity.

Incredibly, a single channel Optima vT tester can test up to four independent cavities simultaneously while the two channel tester can handle up to eight, allowing for significant cost advantages.

Like other Uson products, the Optima vT features a comprehensive software toolbox that enables users to quickly set up tests and communications. It even comes loaded with the most common test types–just add the information about your part and it will set up the test for you to fine tune.

Key features

1 – Large easy-to-read full color touch screen display.

2 – Intuitive and easy-to-use interface makes set up and programming easy.

3 – Variety of installation options.

4 – Scroll and click menu navigation.

5 – TCU2 resource manager with advanced ARM processor w/ Vector floating point co-processor for fast data handling.

6 – Pop-up keyboard for easy increment/decrement of numerical parameters.

7 – Unix based software with a mini-ITX platform.

Powerful TCU2 Processor

Proven Testing Techniques

• Flow - Mass, Differential, Laminar, Back Pressure, Continuous

• Pressure/Vacuum Decay - Differential or Gage

• Occlusion

• Burst

• Cracking

• Pressure Rise

• Sealed Component

• Force Decay

• Volumetric

• Exercise/Fluff

Specifications

Model Series: Optima vT

Description: Configurable Leak and Flow Tester

Display: 15" diagonal color, touch-sensitive LCD

A/D Inputs: 1-8 24 bit resolution

Digital I/O: 16 24 VDC digital inputs expandable to 32
1 2 High current digital outputs expandable to 24

Communication: Profibus
Modbus
DeviceNet
EtherNet IP
RS-232
Email Alerts

Language: English, Spanish, *French, *Chinese, *Korean, *Japanese, *German

Test Programs: 199

Test Channels: Single or Dual Configurations

Concurrent Tests: Scalable to 8

HMI Dimensions: 10" x 14" x 5" (Without Enclosure)

Power Supply: 24 VDC (Optional Auto-switching 110 to 220 AC Power)

Pressure Range: Vacuum to 1,500 psig std.

Flow Range: 0 to 560 lpm std.

Smart Units: User selectable 15 flow and pressure units with two custom available

Calibration: Single Point
Dual Point (Comp & Cal)
Multipoint

Sensitivity: Down to 1 Pascal

Accuracy: +/- 0.25% Full Scale

Linearity: +/- 0.25% Full Scale

6.10 9012 XRS – Xtra Rapid Search– faster and more accurate

The new Sensistor 9012 XRS Leak Detector constitutes a complete fieldbased system based on proven hydrogen-gas detection technology. It offers the most sensitive and flexible leak detection system on the market in a heavy-duty, smart and ergonomically designed package. The leak detector instrument is very easy to use, and its rugged construction makes it close to maintenance-free. The 9012 XRS is completely selective – it only reacts on hydrogen gas, which in very low concentrations is used as tracer gas. Sensistor Technologies has developed its own hydrogen gas sensor, which when combined with advanced computing electronics results in an unsurpassed sensitivity threshold of an impressive 200 ppb (0.2 ppm).

This extreme level of sensitivity is necessary to quickly detect even the smallest leaks. However, to be able to detect major leaks, it is a necessity to be able to decrease sensitivity. This is why the 9012 XRS features a sensitivity adjustor to instantly adapt to any detection condition. The instrument instantaneously responds to the tracer gas, and additionally it has a very short reset time to enable a new measurement to be performed immediately.

Tracer gas facts

Pure hydrogen gas is never used as tracer gas, since it is highly inflammable. Instead, a gas mixture of 5% hydrogen and 95% nitrogen is used. This mixture is not flammable (refer to ISO 10156), non-toxic, non-corrosive and pro-environmental. Hydrogen and nitrogen both exist in all biological systems. (Some gas suppliers have their own trade name for this gas mixture, e.g. Naton 5 from AGA, Shielding Gas NH5 from Air Liquid and Protec5 from Air Products). Standard mixtures are much cheaper than custom made mixtures and cost around 0.005 Euro / litre.

Moreover, hydrogen gas is approved as a foodstuffs additive under code E949.

9012 XRS Specifications

Sensitivity: 0,2 ppm H2 in air

Response time: <1 sec.

Pre-heating time: <6 sec.

Outputs: - Display with 10-segment LED indicator
- Speaker, 5-1,600 Hz
- Earphone, standard 3.5 mm jack, > 8 ohms

Battery type: Rechargeable lead batteries (gel electrolyte)

Battery capacity: 13 hours at 20°C, 6 hours at - 20°C

Charger: AC charger (100-240 VAC) and Car charger (9-15 VDC) included

Casing: Aluminium

Protection: Waterproof (IP65)

Dimensions and weight: 250 x 120 x 85 mm, 1.9 kg
In carrying case: 260 x 220 x 95 mm, 2.5 kg

6.11 Sensistor ISH2000

Alternative alarms through different types of audio signals and/or visual indicators on the screen.

Combined screen display for "Measure" and "Locate" improves the efficiency of the operator's work.

Adjustable audio indication makes the measurement procedure easier. Choose between continuous audio signal, audio signal only at alarm level, or audio signal at a defined percentage of the alarm level.

The audio alarm can be clearly heard even in noisy environments, and in cases where the measurement point and the instrument are far apart.

Easy sensor fitting makes it simple to replace the sensor in a matter of seconds.

Short recovery time reduces downtime when detecting gross leaks.

Built-in illumination source of the probe helps precisely position the probe tip.

LED Leak/Tight indication in the hand probe provides the operator with fast information during the leak detection process.

High sensitivity – detects smaller leaks and shortens the time for each test cycle.

A choice between pre-defined measurement units for leak flow, PLUS programmable unit, supports the setting up of the instrument for different measurement situations.

Multi-point measurement with accumulation of the values makes it possible to add several leaks and compare with the total threshold value.

Long autonomy – fast charging (for battery-powered model).

Automatic and manual zero setting eliminates problems with high background levels of tracer gas. Simply push a button to eliminate background disturbance.

Ergonomic hand probe with built-in intelligence facilitates the operator's control of the instrument.

Applications

INDUSTRY

INFICON hydrogen leak detectors are used to reliably test a variety of industrial products, such as plastic containers, hoses, valves and hydraulic components. High sensitivity and flexibility make the Sensistor ISH2000 the natural choice for several industrial applications.

- High sensitivity
- Simple and accurate location of leaks
- Suitable for both automatic and manual measurement
- Inexpensive tracer gas
- Accurate leak size measurements

SPECIFICATIONS

Minimum detectable leak rate	
Detection Mode with P50 standard probe Analysis Mode with P50 standard probe	1x10-7 mbarl/s or cc/s with 5% H_2 0.5 ppm H_2; 5x10-7 mbarl/s or cc/s with 5% H_2
Start time	1 Minute
Calibration	External reference leak or calibration gas
Operating time (Sensistor ISH2000C)	>9h at 20° C
Charging time (Sensistor ISH2000C)	<7h at 20° C
Inputs / Outputs	25 pin, D-Sub with status signals 24V DC / 0.5A 9 pin, D-Sub with RS232 Probe connector (Sensistor ISH2000P)
Maintenance	Maintenance-free
Power supply Sensistor ISH2000 Sensistor ISH2000P Sensistor ISH2000C	 100 – 240V AC, 50/60 Hz, 2 A 24V DC, 3 A Internal, rechargeable battery* (Li-Ion)
Dimensions (W x H x D) Sensistor ISH2000 Sensistor ISH2000P Sensistor ISH2000C	 275 x 155 x 170 mm (11 x 6 x 7 inch) 275 x 140 x 75 mm (11 x 6 x 3 inch)275 x 190 x 170 mm (11 x 7 x 7 inch)
Weight Sensistor ISH2000 Sensistor ISH2000P Sensistor ISH2000C	 3.9 kg (8.6 lb) excl. probe and probe cable 1.8 kg (4.0 lb) 4.0 kg (8.8 lb) excl. probe and probe cable

*Charged using adapter supplied, 100-240 V, 50/60 Hz, 0.3 A

7. Sump seal testing and lay out (Main testing)

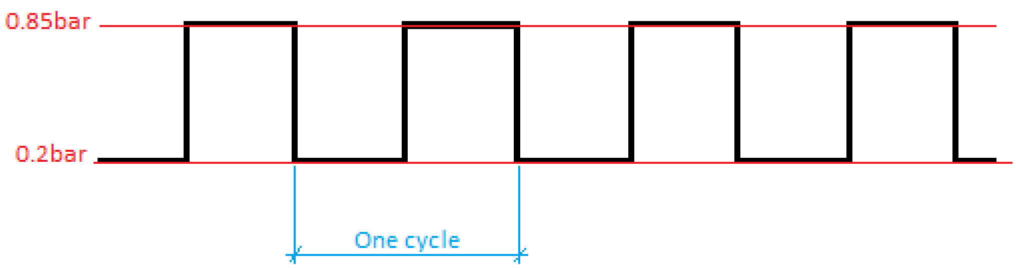
7.1 General explanations

The main test of the sump seal is going to be described in the following text. This seal is maybe the most important sealing in a household dishwasher and perhaps one of the most difficult designs. Therefore, a complete test is needed in order to assure a correct performance.

This test needs two different channels of water because the behavior of the sump seal depends directly on the working of the water switch. It is on this way because the characteristics of the water switch material can change during his long life. Furthermore, the two different parts need very varied specifications, so it is impossible to do it with only one channel.

First, to fill the sump with water, it is needed that this one is with a temperature of 90°C. Moreover, a defined pressure is not needed.

However, in the water switch, the water needs to be with a temperature of 70°C. It is clear now that two different water heaters are needed due to the two running temperatures. In this case, the water switch is working with two pressures that are changing between them in cycles of 30 seconds. At first, the water switch starts with a pressure of 0.2 bar during 30 seconds and then it changes to 0.85 bar during also 30 seconds. This one minute period is now called a total cycle.



These cycles are now repeated simulating the long life of a household dishwasher. Normally, on average, a dishwasher can be untight from the sumps seal after 3 to 5 years. This is the reason why the test is running nonstop 24 hours a day. This needs a very severe conditions of safety because the test machine needs to be in a place with fire cutters, safety switch buttons, protecting cover and with the periphery protected all the time (Not be forgotten that 90°C water is running all the time).

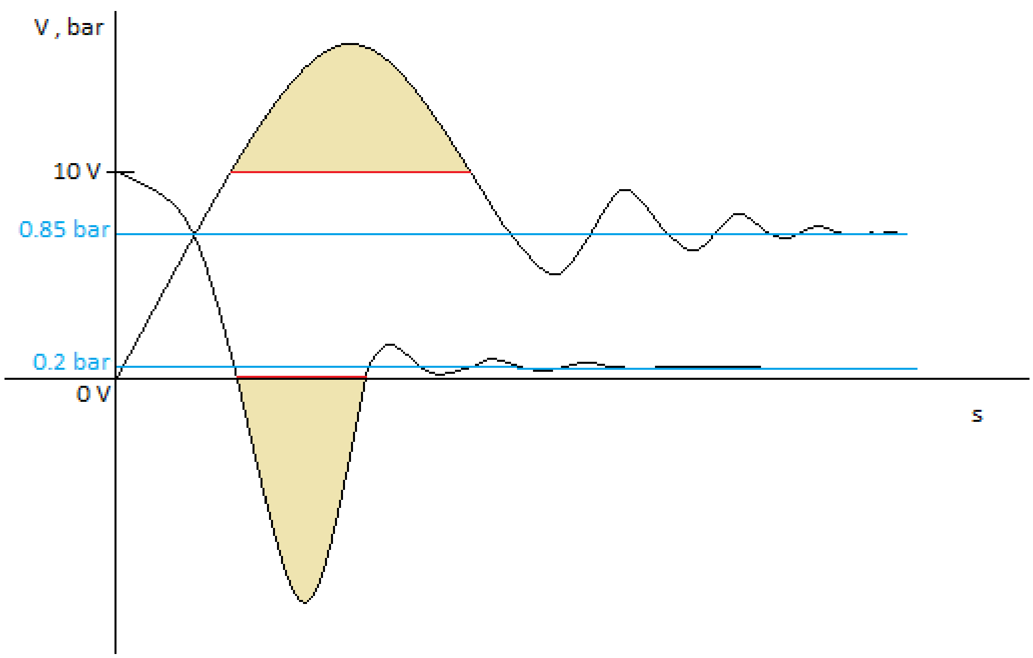
Returning to the water switch stuff, this one starts to have leakages with 0.9 to 1 bar. Thus, the top of the water switch begin to bulge a little bit and with the aid of the sump screws, a cavity is made and it is the reason of the sump seal leakage.

Now, a few important generalities are going to be shown in order to understand a little bit the performance of this leakage test. All the parameters such as leakage limit, time, pressures range and so on can be directly changed through the program created for this target. The parameters that are settled at the moment in the program are the best ones which combine efficiency of time and performance. For example the times maybe can be different (with maybe better results) but a quick response is needed in order to have a result in days and not in weeks or months.

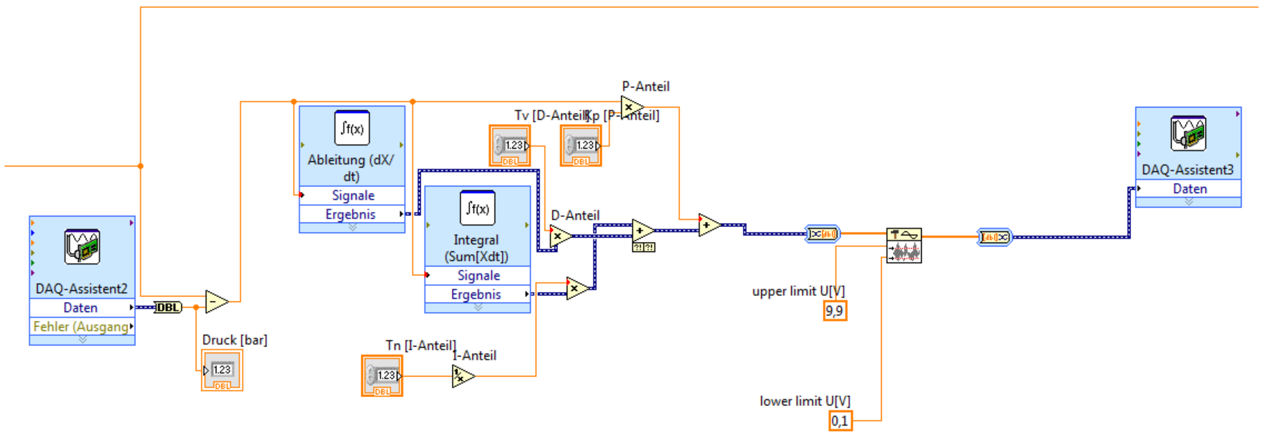
According to this, in this case, 50 ml is going to be the limit (maximum) leakage acceptable. When 50 ml of water have leaked from the sump seal, then a signal is given to the system in order to stop the process or test. This amount of water is measured with the help of a bascule connected to the computer directly with a port RS 232, which is very similar to the most known USB port.

When the system register a 50 ml leakage then the program shows the number of cycles that have been necessary to have it. For this reason, this is a very useful tool or implement for doing comparisons between the product (in this case the sump) and new developed pieces or possible improvements. In this way, when the system stops with the 50 ml leakage with a new piece under development, a comparison can be made and if the number of cycles goes under these ones from the real piece, then the improvements have failed.

Furthermore, the test system has a regulation or adjustment due to the necessity of maintaining the pressure in the same point. This is achieved through a nozzle in the end of the hose that comes from the water heater and also by a controller. This controller is, more exactly, a PID controller (image below) which allows maintaining the pressure in the correct range of values. For this, it also very important a frequency-voltage converter to have the possibility of change the velocity of the pumps.



Here it is the PID controller directly on the program:

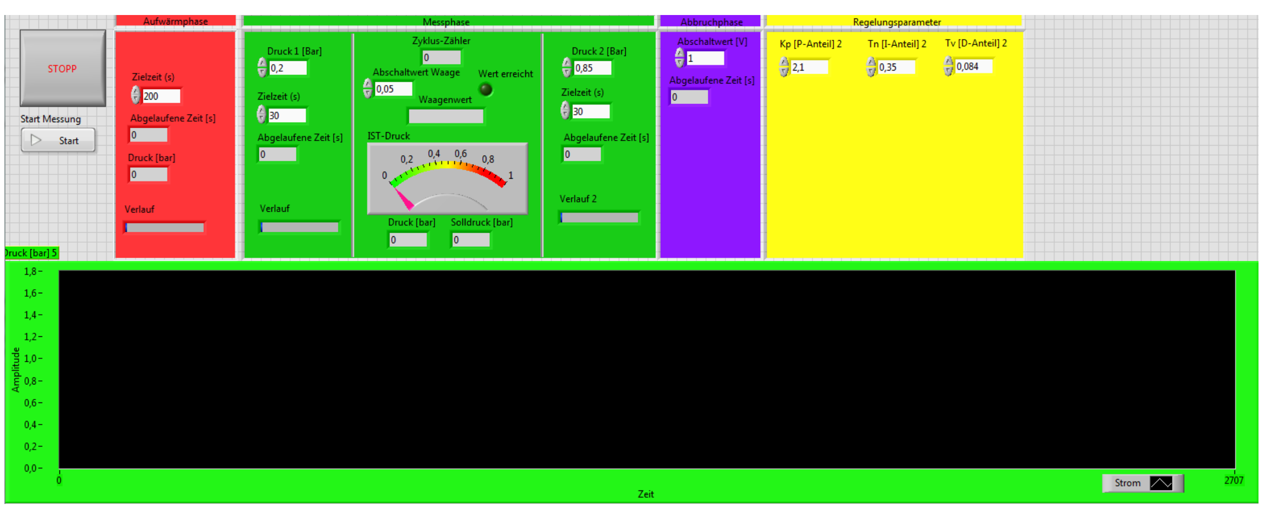


"LabView" is the program used for programming all the testing process in this case. Normally, it is used for little programs without very large codes. However, this program has very large codes, instructions, closed loops and so on so it was very difficult and it took a lot of time to do it. Moreover, it was wanted that the program, could fill in an automatic way, a complete data sheet. As it was mentioned above, a port RS 232 is needed to achieve all these directions.

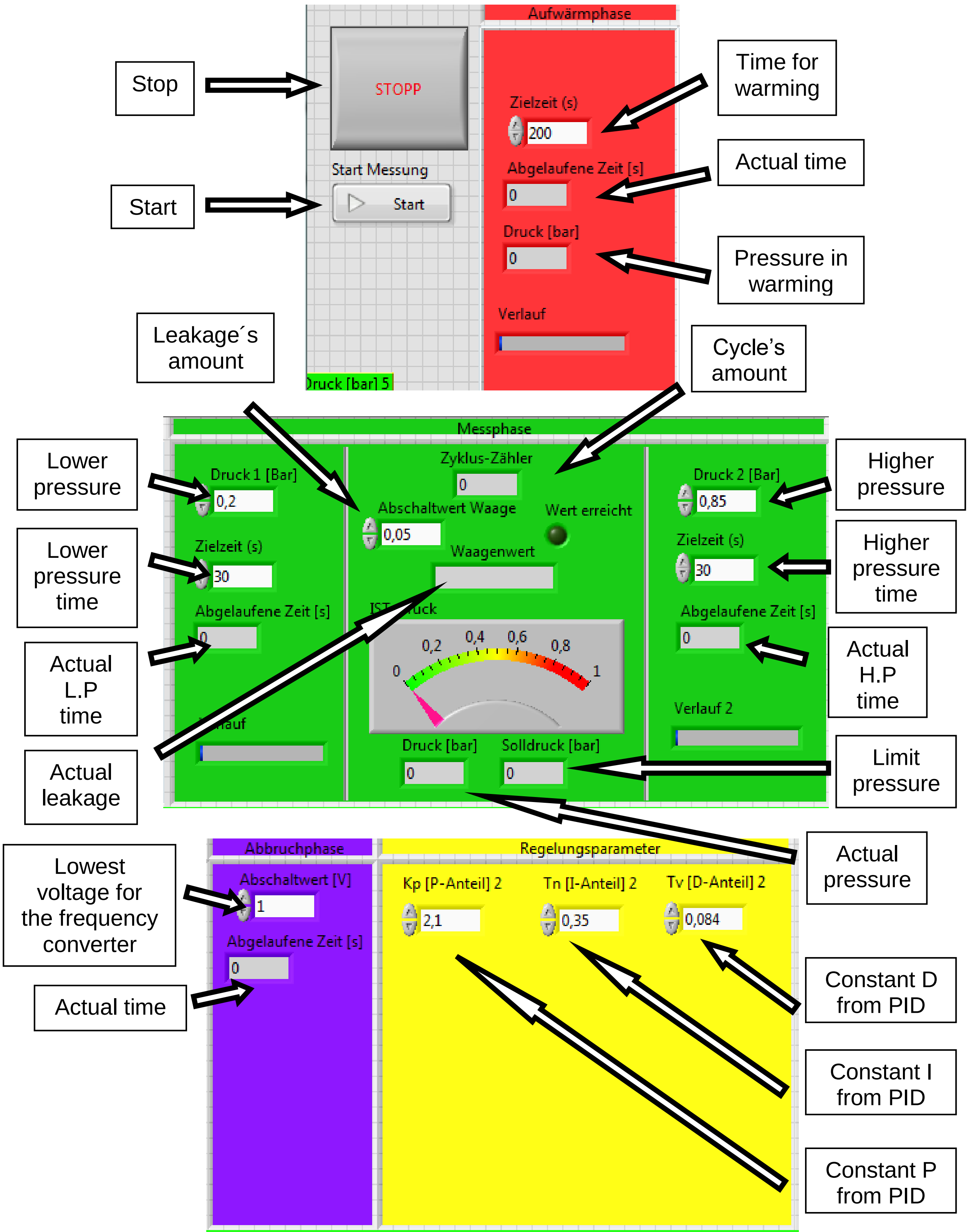
Finally, when the test is stopped due to the total leakage (in this case 50 ml), a final step is needed to change from 0.85 bar to 0.2 bar. So it is just like a stabilization step. Thus, a new test can be started after this pause.

7.2 Program´s screenshots.

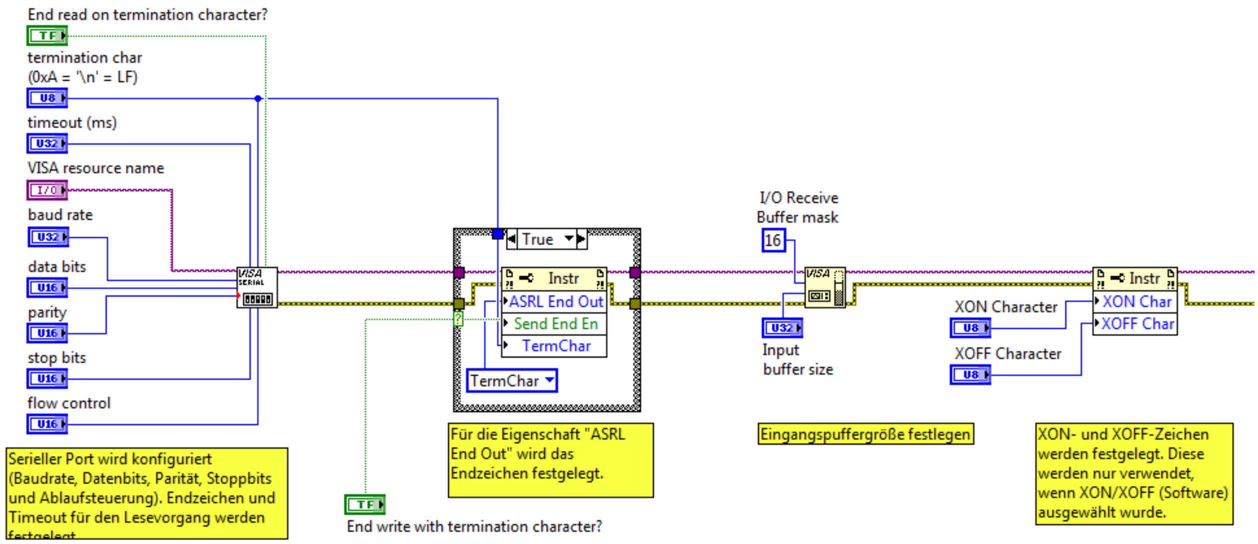
This is the general view of the control panel of the program:



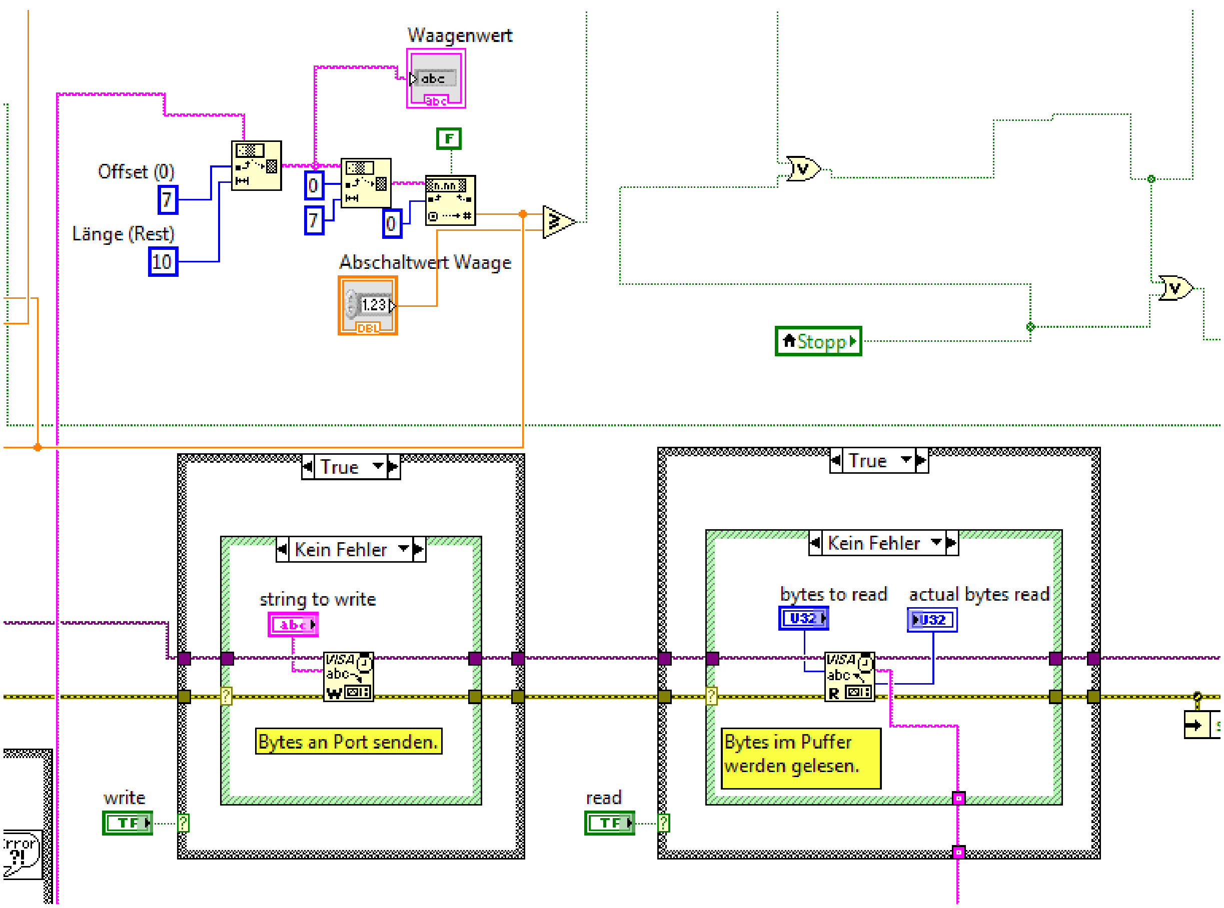
If the image is increased it is easier to see the different inlets, outlets and parameters of the program:



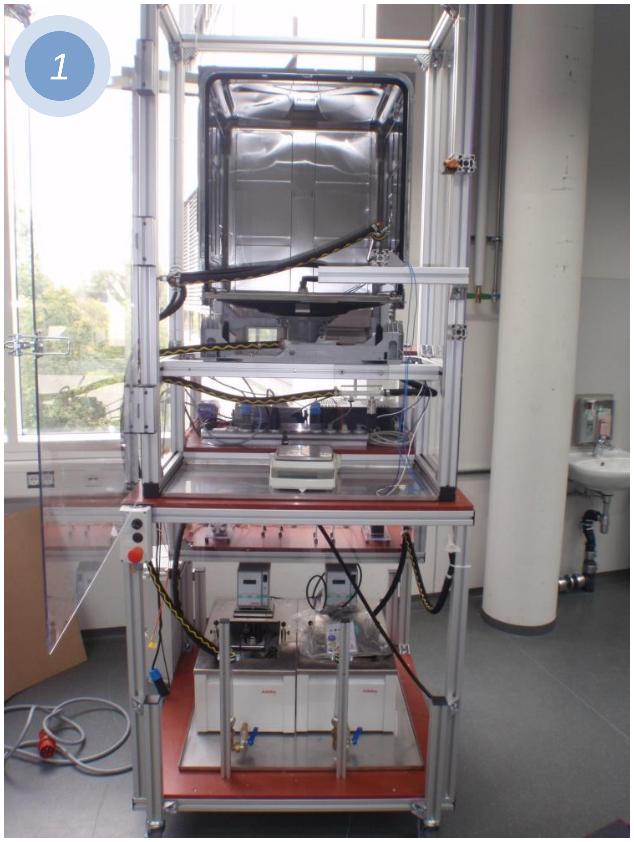
These are the inlet parameters of the scale used to analyze the amount of water leakage:

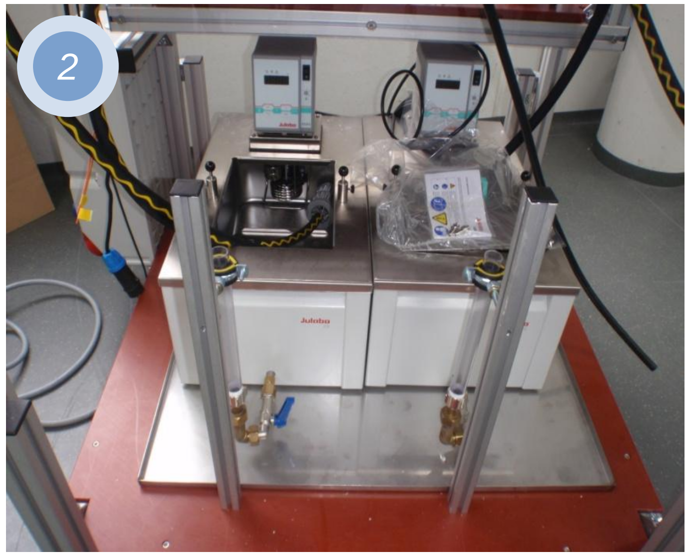


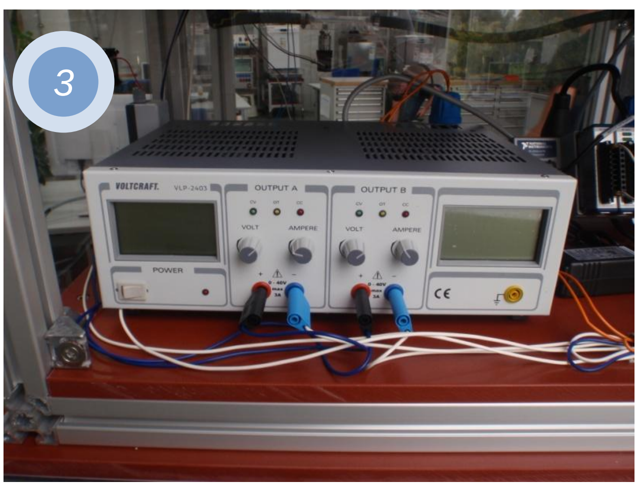
And finally, this is the circuit and elements needed for programming this scale:



7.3 Descriptive images of the test.

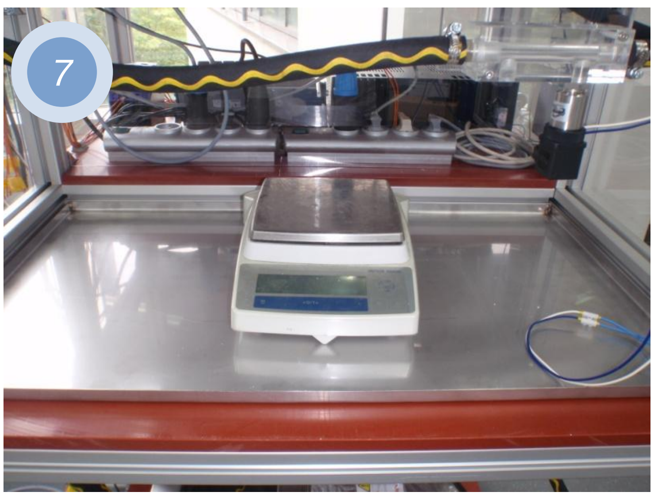






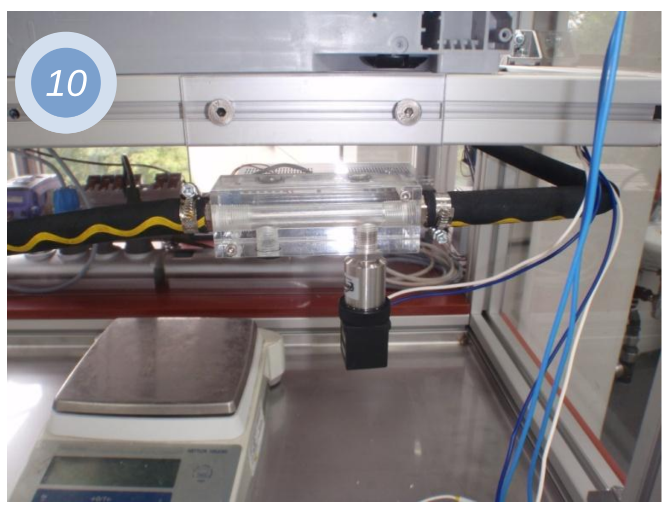

5

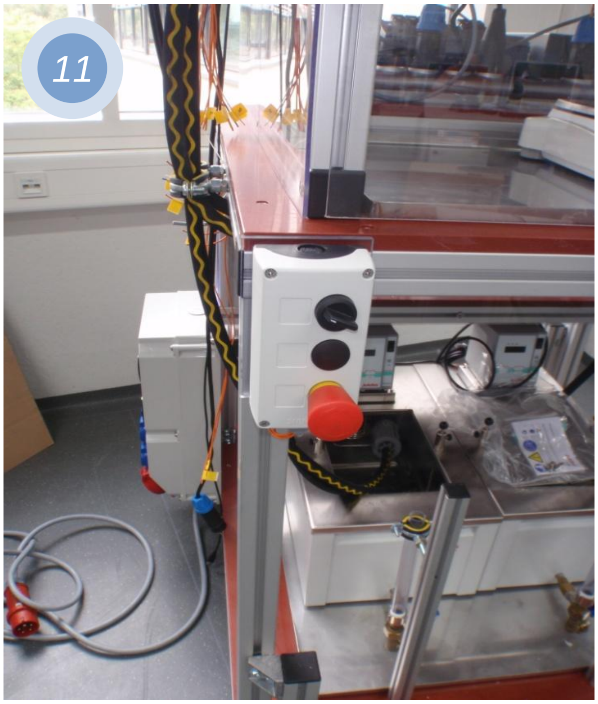

6


7


8


9


10



1. → Complete appearance of the test bench.
2. →Two differencied water heaters to both channels.
3. → Power voltage for sensors.
4. →Two membrane pumps for both channels.
5. → Programming cards.
6. → Frequency-voltage converter
7. → Scale for the amount of leakage measurements.
8. → Sump with safety water switch.
9. → Water filling system of the sump.
10. → Air remover from the hoses.
11. → General safety switch.
12. → Safety switch system when opening the protection door.

8. Design´s bases of a test bench to verify seals.

According to all the requested information above, an analysis of the design´s bases of a test bench to verify seals is going to be done. The principal idea is to set the background of a future test bench for the analysis of every type of sealing. This is a very difficult task because in a household dishwasher, the seals have very different materials, shapes, sizes, temperature ranges, pressure ranges, leakage ranges… In summary, they have very different and varied theoretical specifications.

The first thing is to know which method will be the correct one for all the seals. This is a very complex target due to the several available methods and the different specifications of each one.

Old tests in the enterprise inform that all this methods are more accurate with air instead of water. One of the principal reasons is that the most of the parts and pieces are designed for water utilization. This thought reveal a very important thing when thinking about a test bench, which is the importance of an easy design of the parts to make easier the subsequent test. It means, for example, to design of the parts thinking on a posterior test so the test hoses can be connected easily or with easy geometry in order to facilitate the filling with some tracer gas or water.

One of the most important things about leakage test is to test always in the same direction of the real operation. It is like this to verify and ensure the correct behavior and truthfulness of the test. It means that if normally the water comes from inside to outside of the part, the test has to simulate the same direction. So it is not correct to test in this case with water that comes from outside to inside of the part.

Another important point when designing a test bench is to know that normally the pressure tests are with higher pressure than the real ones. This is like this in order to verify that in the worst cases, the part is going to react well enough. Thus, it is very important to keep in mind this when selecting the material and accessories for obtaining the needed pressure. A fail with the pressure specifications may cost lot of money losses in new material and devices.

Furthermore, it is essential that the test has to be a one time and non destructive test in order to preserve all the pieces involved in the process and not waste time and material, ergo money.

In this case, another characteristic which determine the selection on a huge way is that it is not needed to localize the leakage. The most important thing is to quantify the leakage. This is like this, because when dealing with water it is very simply to locate the water leakage with a naked eye. This simplifies very much the assembly of the test bench and makes cheaper the equipment and accessories' costs. Despite all of this, it would be very good to create and design a test bench with the possibility of localizing the leakage but economically it does not pay off.

Following the line of the easiness and the good economy of the equipment, the principal and best method would be with any doubt the “Pressure Decay Test”. However, this method is preferable for leakages with bigger sizes. It is for this reason why the pressure decay test would be not very accurate. Normally, the size of the leakages in parts of a household dishwasher is not big enough.

Because of the characteristic described above, a more precise method will be some method using a tracer gas. Nevertheless, a huge quantity of seals and o-rings are made from silicone and it is very important to keep in mind the chemical compatibility between the two environments. In this case, tracer gas is not very compatible with silicone because this one is very porous and the tracer gas can escape easily through it.

Finally and attending to the real experience in these years, the most convenient thing is to create a test bench capable to work with water and simulating a real household dishwasher like this one seen above in the main testing of the sump. This means with the aid of pumps to get the ideal pressure, heaters to have the exact temperature in each channel and the aid of programming cards and power voltages. The difficulty of this way of testing is that the seals tested are very different between them so a special device is going to be needed in order to be able to connect and test them or at least, lot of hoses to switch between them each time.

When thinking about the new test bench specifications, it is necessary to lay down the limit values in order to know the needed equipment. For example, the pressure is one characteristic very important. Depending on the parts running at the same time on testing, one or more pumps are needed for example. The maximum pressure on the dishwasher takes part in the Aquastop with a pressure of 10 bar, then the next one is on the Water Switch with 0,85 bar approximately. So a pump capable of giving 10 bar is needed. Furthermore, the maximum channels required are two (For example sump and water switch running at the same time) therefore, 2 pumps are needed.

Easier is the case of the temperature because nearly the most of the seals are working with maximum temperatures of about 70-80°C. Thus, heaters like those ones from the sump main testing are enough for the new test bench. Normally, it is going to be tested with limit values of temperature of 90°C. As in the case of the sump, two heaters would be the possible amount of them.

At last it is remarkable to recognize the range or level of acceptable leakages. With this, limits are going to be set for the program, which will stop when reaching this amount. In this manner, the final amount of cycles is going to be known, which is the most important target searched.

9. Bibliography

- http://www.assemblymag.com
- http://www.amtec.eu
- http://www.cincinnati-test.com
- http://es.over-blog.com
- http://www.drwiesner.de
- http://www.vtechonline.com
- http://www.leaktesting.co.uk
- http://www.leakdetection-technology.com
- http://www.epa.gov
- http://www.kmasscontrol.com
- http://www.siqinc.com
- http://www.ateq-leaktesting.com
- http://www.uson.com
- http://www.satoriseal.com
- http://www.columbiaerd.com
- http://www.parker.com
- http://hydraulicspneumatics.com
- http://www.johnmorris.com.au
- http://www.sensistor.com
- http://www.tss.trelleborg.com
- http://www.elteflon.com
- http://www.callapg.com
- http://www.simrit.se
- http://www.newdealseals.com
- http://www.ebah.com.br
- Busak+Shamban catalogue (Dichtungen und führungen)