METSEALS POLICY

HISTORY-FOREWORD

METSEAL AB

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HISTORY-FOREWORD

Metseal is a company with patented products that represent the latest developments in sealing technology for high pressure in the linear and slowly rotating movements.

The products have been out in practical operation since 1988. They are available today in a wide variety of applications in the field of hydraulics. During these years, the seal worked well in the hundreds of thousands of products and demonstrated its high technical class and its secure consistent quality.

Marketing has until now been restricted to a small number of qualified customers. It has been a goal in itself, not to broaden the marketing before the company has achieved such a standard in all that is done, that it might be an adequate development partner to companies that are world class. When this information is first distributed, starting Metseals work towards the goal of promoting the unique technology "world wide".

Metseals strength today is the sealing technique in itself, with can solve demanding sealing tasks in a winning way, together with a very rational production with high quality assurance.

Metseal focus today is directing more and more energy to introducing our products onto the market and to find efficient "world wide" distribution channels. Companies that are distributing Metseals products to different markets have good knowledge in sealing techniques. They will provide technical support to customers with low resources. They must also give big international customers with good technical resources and knowledge, a rational distribution service at lowest cost. Examples of this group are the Original Equipment Manufactures (OEM)

Metseal is striving to establish direct contact with big OEM customers and offer development co-operation to more readily solve difficult sealing problems. Also to give the customer new and better conditions to crease totally new and improved products.

BUSINESS IDEA

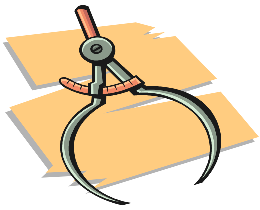
Metseal shall:

- Being an important and appreciated co-operation partner within the areas of sealing technique and sealing products, for customers whose products are depend on a good seal function, good tightness, long life span and low total cost of for the customer's final product.

- Give the customer access to patented products that offer solutions and advantages that the two competitive, conventional seal types, split piston ring in metal and soft or half soft seals in polymer materials, cannot offer.

- Carry out serious and qualified development work within the areas where the market today and henceforth have or will have problems.

POLICY OF QUALITY

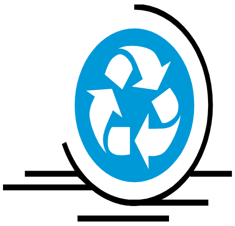


Metseals customers are in most cases companies of world class. Our goal is that the customers shall comprehend us as a co-operation partners of the same calibre in all our activities.

This means that:

- The customer's experience of us is the base for all work in the company. Planning and following-up shall be carried out against known and measurable goals.
- Certification of our operations according to ISO-9001 and ISO-14001 is obvious, but the 0-fault and ideal consideration to the environment is our utmost goal, that we methodically and persistently strive for.
- Besides the sealing product according to Metseals own patented seal types the customer shall be given technical advisory or co-operative product development that gives the customer the best possible solution. We shall in our recommendations to the customer be serious and neutral and not put our own products in favor but strive to build up an entirely confidence for Metseal as advisors and sealing expert.
- Competent, creative and motivated employees are our biggest asses. All employees shall be given the possibility to participate, grow and be appreciated.
- We shall develop long-term business relationships with suppliers of all types, who have a documented high level of quality.
- Permanent changes for the better shall be built in all processes.
- Equipment and tools shall be maintained in good condition, in order to keep quality and efficiency on a high level.

POLICY OF ENVIRONMENT



Metseal shall:

- Protect the environment by taking into consideration energy saving precautions minimize pollution, encourage recycling and maintain a good work environment for all employees.

- In all parts of the company continuously try to minimize possible hazardous output on the environment from our work, at the same time our service and product quality shall always correspond to our customer's expectations.

- Contribute to a long-term reliable development, by close with our suppliers, to offer and develop products with a minimum of environmental implications.

- Always carry on our activity in accordance with valid environmental regulations.

POLICY OF DELIVERY

Metseal shall:

- Standard products are normally delivered from stock. The Metseal seal and the O-ring are delivered separately. Seals with Ø95 and less are delivered in packs in form of cylinder rolls with 50 pieces. Bigger seals are delivered with 25 pieces in each. All packs or rolls are marked and have full traceability. It is practical and safe that orders and deliveries are made in multiples of 50 and 25 pieces respectively. Special seals are generally manufactured to order and are stocked after agreement with each customer.

POLICY OF PRICING

Big distributors and big customer of type OEM with direct supplies have the same prices dependent on the yearly quantities.

E-Trade Price List:

www.metseal.se

When a customer reach high numbers per year and not longer ask for the distributor's service in form of stocking and technical advisory, he shall, as a direct customer, reach the lowest price level. For the service that the distributor then continued to give, Metseal will pay a commission, which is adjusted to the extent of the service.

METSEAL-PISTON SEALS

Introduction

Seals are often the weakest and most sensitive machine element in components that make up various sorts of machinery. It is mostly the seals that set the limits, both of the components and the entire machine´s length of life, their function their servicing requirements. The sealing function in general is characterized of the seals themselves making up a very small part of the total cost. However, with the seal´s demand for dimensional accuracy and surface finish of the cylinder bore, it will force high costs that will take a big share of the total value of the finished product. As an addition, the functioning and the life for the total product and therefore the total economy is generally settled and limited by the seal. The total cost for tightness is thus not only a highly dominating cost, apart from material cost, but also the cost where you have greatest change to get a good economical improvement as a result of altered and improved sealing technique.

Metseal is a patented totally new seal technique for applications within hydraulics, pneumatics and control engineering and for piston machinery of varying kinds, e.g. in compressors, pumps, motor etc. The sealing system consists normally of a primary seal ring of metal with a hard and smooth contact surface and usually an O-ring, providing secondary sealing between the ring and the piston´s sealing groove. In example within the area of hydraulics, the seal is made of quenched and tempered high-alloyed special steel. For pneumatic cylinders with the cylinder tubes in aluminum, the seal is also manufactured in aluminum but with a very hard surface. By choosing material with the same thermal expansion coefficient in the cylinder and in the sealing ring the influence of temperature can be minimized.

GOOD TOTAL ECONOMY

The principle of function of the Metseal seal differs in most cases that of conventional seals. This has brought new possibilities and properties, in the first hand to linear movements, but also to low speed rotating.

The technology eliminates the restrictions that are so closely and permanently fixed with conventional sealing systems. Metseal is very well meeting the target that the product, of which the seal is a part, shall have a low total cost of production and a lower life cycle cost. This is dependent upon the superior seal life span and the good comprehensive good functional properties. The sealing principle will simultaneously manage many very complicated and highly demanding working conditions regarding functionality. In components where Metsels piston seals are present, it is not the seal that is the weakest part, but the durable. As the seal practically does not wear the cylinder surface, but in fact improves the smoothness, the lifetime of both cylinder bore and piston bearing, will be longer. The very low wear rate on cylinder bore, piston bearing and seal ring, also results in very low generation of abrasive particles. This will have o positive influence on the purity and lifetime of the total system and thus also the total economy. The Metseal seal will accept surfaces that are both drawn over mandrel and fine turned, without decreasing the lifetime and with very low generation of metal particles. The cost for production of the components can thereby be lowered.

GOOD OPERATIONAL SUITABILITY

METSEALS operation in comparison to conventional seals is characterized by the following facts:

- Effective sealing throughout the cylinders lifetime, without change of seal, even with bad or damaged cylinder bore.
- Effective sealing and smooth and responsive cylinder movements, together with both high and low temperatures and hydraulic media of varying type, quality and purity.
- Unaffected by long periods of rest or storage, as for example, machinery for seasonal or military use.
- Low friction even at low speed.
- As far as is known, the smallest built in measurement on the market.
- Possibility to run over holes and rifles.

The Metseal principle is a very young seal technology, which is still under rapid development. The process of development carried out together with Metseals customers, has highlighted a number of valuable and outstanding characteristics:

The functional lifetime, still with good tightness, of the seal is dramatically longer than that of conventional seals. This is especially noticeable with high pressure and when sealing against poor or damaged surfaces and by high or low temperatures as well as by polluted hydraulic media. The seal is very good endurance to surface defect and allows the cost for producing the cylinder bore to be lowered.

As the seal at the same time, in one and the same seal, has extremely good function, property by property, the seal initially has been used as problem solver and to avoid a particular problem of the application, together with opportunities of reducing total cost.

In the future, Metseal sealing system is expected to take a high market share within standard products, for example ISO-cylinders. Especially here one and the same cylinder type will be used in widely differing tasks, where the seals capacity to cope with different extreme conditions, are a fundamental qualification for the whole idea of about standard cylinder program.

For mobile machines that are supplied to many geographical markets, with their differing weather conditions and for various applications and working conditions, one can take advantage of the Metseal seal´s tolerance of pressure and temperature variations and simultaneous good capability regarding numerous essential functions. The producer of the machines can use one sole global solution for the sealing design, from Sahara to Antarctica.

As a result of the seal comprehensive good qualifications, as well as the extremely narrow proportions, designers can take advantage of the new conditions that the Metseal seal provide and create new compact products with have both a very good functionality and economy.

FUNCTIONAL PRINCIPLE FOR METSEAL

Pre-stressing

Seals, regardless of their principle, are usually preloaded so that their contact surface is pressed towards the surface it seals against, even before there is a pressure drop over the seal. In conventional seals made from polymeric materials, one normally achieves the pre-loading or pre-stress by compression of the cross section. To be able to counteract the materials predisposition for settlement, the cross section has to be considerable bigger than for piston rings in metal. Despite this, seals in polymeric materials will lose their pre-stress and tightness during service and this becomes a determining weakness for the sealtype. Metal split rings will have the pre-stress introduced by the curvature stress in their high and narrow cross section. Because of the normally small form errors found in the cylinder bore, these piston rings do not achieve full contact around the entire cylinder bore. The rings will just touch on a number of "high spots". Before a pressure drop over the seal has developed, this functional principle lacks the power that can bend the seal and generate full contact between the seal and the cylinder bore. In the Metseals piston ring one creates the surface contact between the seal and cylinder bore by applying high compressive stress in peripheral direction. This will force out the thin and flexible seal so that it has, and only can have, a good and even surface contact with regular contact pressure. The relatively high-pressure stress on the periphery is due to the fact that the circumference of the sealing ring, before fitting, always is slightly bigger than the biggest allowable circumference for the cylinder bore. For every tolerance on the cylinder bore, H8, H10 etc., and their maximum diameter, there is a seal suited for the actual tolerance. The seal is selected to ensure that the seal’s outside diameter exceeds the maximum permitted bore diameter by a specified minimum dimension. Thus, the pre-stress is achieved. As a rule the same diameter difference and pre-stress is chosen for all different cylinder bore tolerances. The maximum contact pressure will naturally increase with increased tolerance and difference in diameter. A seal suited for H8 will produce a maximum contact pressure that is only 40 % of corresponding pressure for an H10 tolerance. The pre-stress will arise when the piston seal and piston is fitted in the cylinder bore. As it is principally only the piston ring in metal that is responsible for the pre-stress, a Metseals piston seal is free from settlement. The O-ring can be allowed to have considerable settlement, otherwise the capability to seal between piston ring and sealing groove in the piston is jeopardized. The magnitude of the contact pressure that is developed by the pre-stress is normally about 25-50 bar, both for Metseal and newly installed seals in polymeric materials.

Contact pressure

The contact pressure between the seals contact surface and the cylinder bore is build up partly as a result of the sealing rings pre-stress and partly from the pressure drop over the seal. Thanks to the Metseal rings very stiff cross section, one can achieve a contact pressure that is suitably spread over contact surface and with a low maximum value. By varying and thinning of the seal's cross section, one can influence that portion of the contact pressure that comes from the pre-stress By minimizing that part of the seal's width, which is influenced by the pressure drop over the seal, one can counterbalance a big percentage of the power, which provides the contact pressure. The total force and mean value for the contact pressure will now be lowered. Above all, the maximum contact pressure, which is close to the low-pressure side, can be reduced, benefiting the life span and the wear decisively. This is achieved, thanks to the torque, that twists the seal towards the gap between the piston and the cylinder will redistribute the total contact pressure, but not change its mean value. Therefore the contact pressure nearest to the low-pressure side will be reduced and moved over to the contact surface on the high pressure side. Metseals seals can in this way, by determination of sizes and shapes in the cross section, be given both a low mean value and a low maximum value for the contact pressure. As an example of how the contact pressure is affected, picture 2 shows the contact pressure for the double acting piston seal, type D, when the seal is only working as single acting with pressure loss in only one direction. Picture 3 shows the same seal, type D, after it has been worn in to an arrow like form, when the seal works double acting, i.e. with variable direction of pressure loss. Over the sealing surface, the pressure drop is linear. The pressure drop, i.e. the difference in pressure between the high-pressure side and the low-pressure side, is consequently influencing the contact pressure only by about 50 % or by the mean value of the pressure loss over the sealing surface. In soft seals with polymeric material, the contact pressure in the important sealing zone, will be approximately the same as the pressure loss over the seal, i.e. about 100 %. By counterbalancing the pressure loss over a wide part of the Metseal seal and then allowing the whole contact surface to have a relatively equal allocated contact pressure, one can reach a very low average contact pressure, and also a very low maximum contact pressure. Metseals piston seals always have full contact between the seal's outer wall contact surface and the surface of the cylinder bore. In consequence of the fact that the cylinder bore is elastic with the overpressure, the cylinder bore always will be slightly conical at the seal's position. The flank sides of the Metseal seal will be twisted to the same degree as the amount of taper in the cylinder bore. This will lead to the flank sides not always touching the side surface in the piston's groove to their full height. The sealing contact surface for a Metseal seal remains flat, with little wear, while the side surface may be worn towards a rounded surface. This is not a problem but rather an advantage. When the double acting piston seal, type D, works as a single acting seal, the whole contact surface remains flat, even after wear. If type D works as a double acting seal, it will be worn to a slight arrow shape. Half the seal width will then be sealing surface in each direction of the pressure loss. After the wearing-in period, the pressurized width will be half the original. In consequence, the friction is also halved. Thanks to the half width, the pressure distribution will be more favorable and the maximal contact pressure on the low-pressure side will be lower.

Static sealing

The very good static sealing for the Metseal seal is based on three fundamentally important factors. The first and most determining factor is that the Metseal piston ring of metal is slender and can follow the cylinder bore and maintain full contact around the whole circumference. The only practical flow path for a possible leakage is inside the profile of the area of contact between the cylinder bore and the seal. Such a flow could take place inside the surface profile in between grooves and crests and give laminar flow. We are talking about flow paths with a dimension of less than 1 micrometer (μm) between the walls. The volume of such a flow is proportional to the wall distance, elevated to 3 or 4. One can compare with formulas for flows in plain parallel gaps or circular bores. With the minute dimensions between the walls involved, the potential flow will be so low that clogging phenomena will prevent it occurring. The second determining factor that entirely prevents flow within the surface structure, is the phenomenon that ensures that the surfaces will be covered by a semisubstantial boundary layer. This same boundary layer provides lubrication at the highly loaded points of contact in ball and roller bearings and between the teeth of toothed gear drives. The presence of this thin boundary layer in the surface grooves between the Metseal and the cylinder bore ensures that absolute sealing takes place. In addition to the solid boundary layer, long oil molecules are trapped at scratches, craters and other relatively big surface imperfections to contribute to the oil tightness of the seal. Oil tightness can thus be achieved even with poor and damaged surfaces. The third determining factor for the highest possible oil tightness is that the Metseal seal, like the cylinder bore has hard and rigid surfaces. The seal and bore make contact only at their surface crests. Freedom from elasticity ensures that the contact area remains stable. The sealing layer located in the valleys is therefore undisturbed by the sliding movements of the seal inside the bore. From the point of view of flowing, the seal and cylinder are operating with entirely flat surfaces and no open flow. Example of this function is a high-pressure gas spring (300 bar) which become entirely static tight with the aid of a few drops of oil. In a seal made from polymeric material the sealing surface will distort and the seal will move elastically into the surfaces valleys. This movement will inhibit and prevent the formation of the desirable thick semi-solid boundary layers.

Dynamic sealing

In seals made from polymeric material there is a natural ability to form films, when moving in all combinations of motion direction and pressure drop direction. In the Metseal seal, this spontaneous ability does not exist. For example the double acting seal, type D, will form a film in only one combination of motion and pressure drop direction. This gives different degrees of friction in the two moving directions. The explanation for this characteristic is that the Metseal seal has a small compact cross-section of metal that does not allow deformation of the cross - section and contact surface. If, on the other hand the contact pressure over the seal's total width is almost constant, the whole cross section can be twisted and film formation is obtained. The double acting asymmetrical piston seal, type DA, as well as the single acting counter balanced piston type SB, are examples of seals where the cross section has been designed to obtain optimum characteristics regarding friction and leakage. These will then adapt to various applications and their specific demands and difficulties. Formation of films and low friction at the same time involves the transportation of pressure media across the seal. Leakage is normally the result of transport of medium in two motion directions. To get low resulting dynamic leakage one requirement is that transportation in the dangerous leakage generating direction is smaller or equal to transportation in the harmless leakage generating direction.

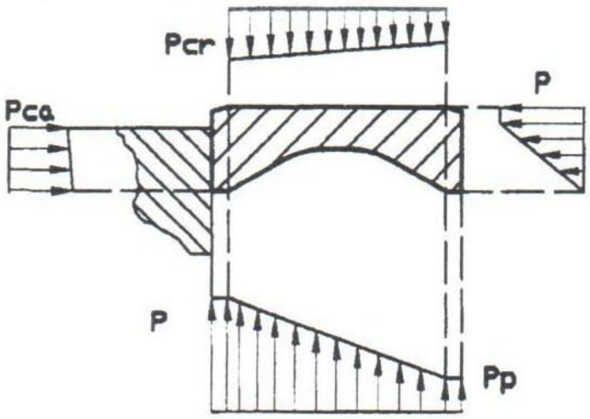
Fig 2 Type D

PCR = Contact pressure
PCA = Axial contact pressure
Pp = Pre-stress pressure
Δp = Pressure difference

Fig 3 Type D,

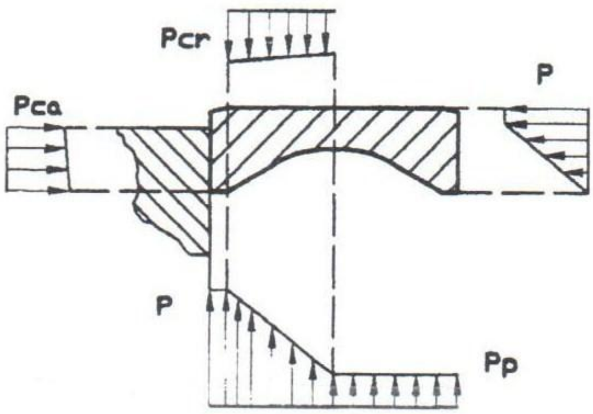
after wearing in

Fig 2 Type D



p_{CR} = Contact pressure
p_{CA} = Axial contact pressure
p_p = Pre-stress pressure
Δp = Pressure difference

Fig 3 Type D, after wearing in



Double acting Piston Seal Type D

Type D is Metseals oldest seal with the highest sales. It is intended for sealing cylinders with double acting linear movements. It has the highest maximum contact pressure of all Metseals seal types, but never the less insignificant wear characteristics. It is most suited for applications where it can work as a double acting and not primarily as a single seal. After the wearing in period as a double acting sealing, the Type D will demonstrate a sealing surface corresponding to half the width of the seal. Therefore, it has a friction level that is higher than for example type SBF. Type D has, in the same direction of pressure, the ability to form hydrokinetic film in only in one direction of movement only. That means that above a certain speed, the friction will be lower in one of the direction of movement.

Type D is available for all diameters suited to cylinder diameters with H8 tolerance. For Ø80 and over, it is also variable for H10-tolerance.

Single-acting piston seal type SBF

Type SBF is a single acting pressure balanced piston seal that is fatigue free. In the first hand it is intended as a piston seal in high torque motors for industrial applications where a life span of 30,000 to 50,000 hours in continuous use at 35 MPa is required. In addition, the SBF type also possesses the ability that, even with abnormal wearing, it will not suffer fatigue and break. Such high wears can only take place if for some reason abrasive particles of silicon carbide and aluminum oxide get into the system. From the beginning the Type SBF was developed for one of Metseals most demanding customers. As the result was very good can we recommend it to all slowly operating hydraulic motors for example wheel motors for mobile applications. Type SBF is suited for H6 tolerance. It is not pre-stressed as Metseals other seal types but has an initial clearance between zero and the maximum deviation of for tolerance H6. At a certain relatively low pressure above zero, the seal will close. The Type SBF has an extreme low contact pressure and an extremely long life span. In case of abnormal high wear of the seal, it will gradually change to be of non-contact type, but with a very low sealing gap governed by the pressure. This allows very low leakage with negligible influence on the volumetric efficiency of the motor. Type SBF does not use an O-ring and can be with the same sealing groove as type D, but can also have shallower groove.

FUNCTIONAL PROPERTIES

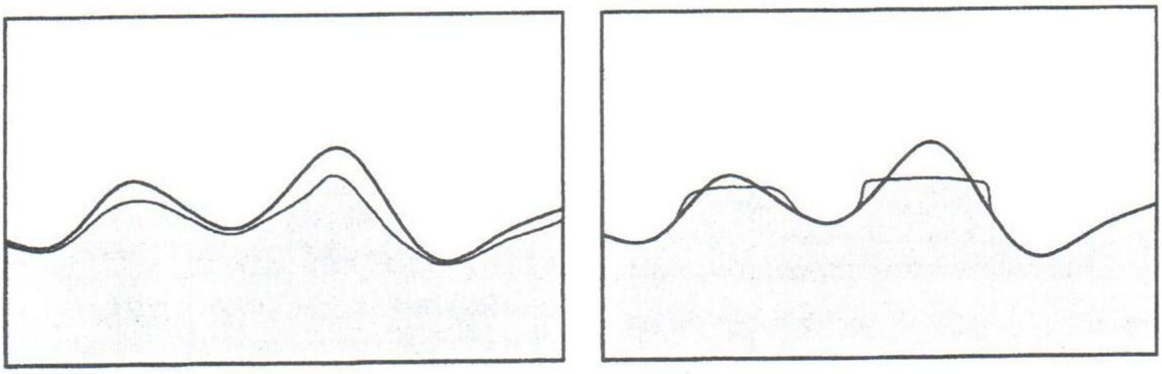
Wear on seal and cylinder bore

During hydraulic operation, conventional soft seals of polymeric material will initially wear in the cylinder bore during the first 1000 strokes. The wear will take place both on the surface profile peaks and valleys but mostly on the peaks. As a rule, the profile depth will already after a few thousands of strokes be reduced to about half the original value. The wear of the sealing surface and the cylinder bore will then proceed, but at a reduced rate. During this relative short wearing in period, many small particles will be generated. These will be a threat to the cleanliness of the whole system, if the filtration is not functioning. The wear on the cylinder bore can increase as time goes on and become a crucial problem if hard particles are trapped in the surface of the soft polymeric seal or the guide ring. These trapped particles can wear grooves in the cylinder bore. The wear of the soft polymeric seal can increase with time and be critical if the cylinder bore surface becomes damaged. For instance if it becomes scored for any reason or if it spoilt as a consequence of existing surface imperfection, such as a small crater caused by slag inclusions in the material close to the cylinder surface. The soft polymeric seals are totally dependent on very mooth surfaces without scratches and craters. On the whole there are only roller burnished and honed surfaces with Ra-values of 0,2 or better that will give acceptable results for demanding applications. One of Metseals best qualities is that it is practically unaffected by the surface finish of the cylinder bore surface and the possible occurrence of scratches and craters. This results in a superior length of life for the seal and cylinder surface and a possibility to lower the cost for manufacturing the surface. In addition to roller burnished or honed surfaces the Metseal seal can be used with the inferior surface smoothness as found for instance on drawn or fine turned surfaces The Metseals piston seal can be used with these comparatively rough surfaces, without generating large amount of particles. It will still provide a longer and more reliable length of life than the best combinations of smooth surfaces and piston seals in polymeric materials. As the Metseal seal works, it will improve the surface of the cylinder bore so that the piston guiding ring will have better conditions, a longer length of life and a lower generation of abrasive particles. Metseals piston seals for hydraulic applications are made in hardened high-alloyed steel and both the sealing surface and surfaces of the flank faces have very low friction with a surface finish under Ra 0,2 μm.

When the Metseals piston seal makes the first strokes under high pressure, it will press down on the high peaks of the softer steel surface in the cylinder bore and plastically reduce their height. As the seal is considerably harder than the cylinder bore, the seal's surface will not be damaged. The bore surface will already after a few hundred strokes start to acquire a surface profile with pronounced plateau's that all have the same height. After an additional comparatively large number of strokes, these plateaux will assume a very smooth surface and be like a mirror. As a rule the wear on the cylinder bore is so small that it is not measurable. In fact, it is a gradual development of the surface and an expansion of the area of the plateaux. When the seals sealing surface is sliding against the cylinder bore the contact will only be against the smooth surfaces of the plateaux. The presence of scratches and craters will only influence the maximum contact pressure marginally. Scratches, craters and miscellaneous cavities are therefore not a problem as regards the length of life, nor, as a consequence of the surface phenomenon with half solid boundary layers, do they influence the static and dynamic leakage. Soft polymeric seals on the other hand, can elastically slide down in craters and scratches where the soft surface will be rapidly sliced or worn away and a breakdown of the seal is a consequent. Fig. 1 show respectively how soft seals and the hard Metseal seal wear or deform the surface profile in the cylinder bore.

Wear in the cylinder bore

FIGUR 1



Impurities

The Metseal piston seal can cope without problem with the abrasive particles it is generating itself. Working experience from varying working conditions indicates a wide insensitivity.

As the Metseal seal can accept proportionately very rough surfaces (up to a Ra-value of about 4 µm) without the seal being damaged, the choice of surface finish has to be made based entirely upon what the system and other components permit. In comparison with seals made in soft polymeric material, experience indicates that the Metseals piston seal is far more tolerant.

If the contamination consists of residual grinding material, for example particles of aluminium oxide or silicon carbide with a hardness equivalent to half the value for a diamond, no seal can work without a heavy wear rate.

This applies to all types of seals and sealing principles including Metseal seals. The only solution to this problem is not to allow such contaminants into hydraulic components and the system.

FUNKTIONAL PROPERTIES

Environmental resistance

As long as the Metseal seals and the cylinder bore surface are of the same material type or have the same or nearly the same coefficient of thermal expansion, the Metseal seal is very insensible to extreme temperatures. In hydraulic systems, it should be possible to operate with temperatures from -50 °C to +200 °C for standard material. In conjunction with special tempering of the standard material, an operating temperature up to +300 °C could be possible. The temperature limits should normally be established by the O-ring and not by the steel ring. The O-rings, which follow American standard, are readily available in most materials. As it is the Metseal seal in steel alone, that is responsible for the seal's prestress without compression set, the O-ring material can be allowed to have a compression setting. In seals made in soft polymeric material the material can be chemically affected by the pressure media. Apart from the risk that the seal material will expand, a lot of other changes, that can affect the properties of the material and jeopardize the seal's functions, can take place. Exchange of pressure media must be carried out with great precautions and will quite often call for a change of seal type or seal material to match the new media. In the Metseal piston seal, where the primary seal is made in hardened high-alloyed steel, the media can normally not affect the seal's material chemically. The O-ring is not responsible for the pre-stressing. The O-ring therefore has an easy task as a static seal and primary during the time when the primary seal change the contact side in the sealing groove, while the pressure direction is changed. For O-rings, that are following the American standard, one has the biggest choice of O-ring materials and that to a low cost. Practically and economically it is easy to select an O-ring material that can manage quite a number of divergent media, thanks to the fact that the functional demands for the material can be set low and relatively high swelling and settlement can be allowed.

Extrusion

In soft polymeric seals, extrusion can occur at high pressure, provided the seals do not have special protection rings for extrusion, which are made of proportionately hard material. Another way to avoid extrusion is to limit the clearance gap to about 0,05 to 0,3 mm.
When using Metseals metal ring there is no risk for extrusion. The gap have a standard value of 0,25 mm, just to permit a small wear of the piston guiding ring, but in the first hand to produce a twisting power on the seal. This will reallocate the contact pressure over the seal so it will decrease on the low-pressure side and increase on the high-pressure side. One will then get a relatively even and low contact pressure over the total width of the seal.

Permitted pressure

The capability for quenched and tempered steel to resist high contact pressure, the low contact pressure for the Metseal seal and the insensitivity for surface defects, makes it possible for Metseals piston seals to work with very high pressures which are higher then for other seal types. How high is determined by the lubricating properties of the pressure media and which Metseal seal type that is used. Experiences up to 100 Mpa have been made. When the customer so wishes, Metseal can develop and deliver special seals for extreme pressures, based on the techniques and "know how" already in existence.

Friction in general

The wear in process for all Metseal piston seals are done between surface materials that can be looked at as hard and rigid, which in principle has a decisive significance for the friction and the wear. In contrast to soft or semi-hard conventional seals in polymeric materials, the Metseal metal seal can neither elastically be pressed down in the dales of the cylinder bore surface nor be chemically fastened to the cylinder bore surface. The wear in for the Metseal seals creates flat surfaces, consisting of plateau's with very good surface roughness, in a original surface which can be both proportionately rough or proportionately less rough. When the plateaus are formed, the surfaces can not go down in each other and have lateral contact, but just have contact plateau against plateau. When this has occurred, the friction normally is decreased to about half. The plateau's surfaces then usually look like a mirror. Metseal of today do not have all the scientific know-how to be able to explain all friction phenomenon, but are working according to following hypothesis that is explaining our test result. The contact surfaces of the seals are manufactured with best possible surface finish (Ra) and an ultimate bearing resistance (Mr). The aim is that the contact surface shall be as close as possible to an already worn in seal, already when it is delivered. The seal will then very rapidly get a plateau- like look and a surface profile (Ra and Rz) that thoroughgoing is much better than the cylinder surface. Very early one then will get surface contact just plateau against plateau. When the surfaces slide against each other, friction and heat is developed. The pressure media, that exists principally is in the dales of the cylinder bore surface, is rapidly heated, whereupon pressure in the media will occur. Thus because the media to a big part is trapped in the surface profile. One will then get a film development or a reduction of contact pressure and friction. The possible creation of film is different from the hydrokinetical film that one always will have in soft seals in polymeric material and to a certain extent even the Metseal seal types.

Friction Type D

During the initial phase of wear in of type D, the contact pressures at the low pressures flanks are much higher than in the middle of the seal. This will cause the surface profile of the seal will wear more at its flanks than in the centre. The seal will than have a slight arrow form on its contact surface. The sealing length is then gradually changed from the whole seal width to half. Even after this arrow form is obtained, the contact pressure at the flanks is higher than in the centre of the width, why the slight arrow form can be maintained.

Friction Type SBF

In type D the contact pressure on the seal surface at the flanks, is still higher than optimum, even after the seal width has decreased to half. In the type SBF, one has been able to decrease the seal width and the friction and get closer to an optimum level. A shorter sealing length will result in lower total contact power and, with help of a twisting moment over seal's cross section, a redistribution of the contact pressure so it will be relatively even over the seal width. The capability to establish a hydrokinetic film in both directions and gain a lower friction will increase, at the same time, as transport of the media will be more even in both directions of movements.

CYLINDER BORE - CYLINDER TUBES

Diameter tolerances

Metseals piston seals are always matched to the tolerance of the cylinder bore. The match is made with the seal's outside diameter slightly bigger than the biggest diameter for the actual cylinder bore and tolerance grade.
In Europe, H8 tolerance is the predominate standard for hydraulic cylinders. The Metseal types that are suitable for use in hydraulic cylinders are therefore always, as a standard, adapted to the H8 tolerance. Seals with 80 mm diameters and above are in most cases also available in H10 tolerance. Choice of bigger tolerance will give higher pre-stress and when the cylinder bore is close to the minimum diameter, always a higher friction. For seals in the upper diameter range, the maximum pre-stress and friction is low, despite the H10 tolerance and a H10 tolerance seal can be used even if the cylinder bore tolerance is H9 or H8. Cylinder tubes which are drawn over mandrel and not further machined on the surface, very often, at first glance, have a very poor diameter tolerance due to the elliptical form of the cylinder bore. The minimum and maximum diameters being located about 90° from each other. To get the pre-stress, Metseals piston seals are not dependent on the diameter, but solely the circumference of the cylinder bore. The circumference of an ellipse is proportional to the mean value of the minimum and maximum - diameter. Thin wall tubes that are roller burnished will also become elliptical and out of round but even they, like the drawn tube, have in general a circumference that is much closer to the circumference of a truly round tube than is suggested by the diameter tolerance. The pre-stress for Metseals piston seals will thereby correspond to the mean value for the minimum and maximum diameter of the cylinder bore. This is often equal to the middle value in a narrower tolerance. In general it is more common for the guiding ring and not the piston seal to establish if elliptical and out of round cylinder bore can be accepted. One useful method to establish the quality of the cylinder bore is to fit a Metseal seal on a piston with an outside diameter corresponding to the smallest acceptable cylinder diameter and then draw the piston with the seal along the bore. At a too small diameter the friction will be too high and if in any part the circumference is too big, the sealing friction will be to low. One can then approve the cylinder bore within a certain range of frictional resistance.

Surface roughness - Surface machining methods

The Metseal piston seals are very tolerant of poor bore surfaces. Score marks, scratches, surface inclusions and other material defects can be tolerated. The Metseal seal can cope with very high Ra-values. Earlier we stated a maximum of Ra=4 µm**.** However, it seems meaningless to set up such a limitation, as the methods that can be considered, will give a surface finish better than Ra=4µ and without difficulty and additional costs. Another factor in deciding if a certain surface finish can be accepted is determined from whether the surface can be worn in and used for a long time without harmful generation of wear particles. Consideration must also be given to the surface functioning without harmful wear on the pistons guiding device. As the Metseal piston seals will deform and polish a rough surface so the wear on the piston guiding equipment will be reduced, a number of rational and cost saving surfaces can be used as a result. Smooth rollers burnished or honed surfaces are of course acceptable even if they are better than required. It is also clear that these surfaces can be permitted to have minor local surface defects as scratches and craters. Turned and smooth drilled surfaces can also be accepted. With today's specially adapted and commonly available hard metal cutting tools for fine surfaces, surface finishes around or better than Ra=1 µm are easily produced. Small scratches and craters can of course be accepted even here. Drawn surfaces with oxide coating from heat treatment operations can also be accepted. Obviously, there is a limit to how heavy these deposits can be. Many times, it looks worse than it really is. The Metseal steel ring will relatively quickly deform and compress the material parts that stick up. The surface in the bottom of scratches will not hurt the rings sealing surface in the same way that it would seals of polymeric material. For all above mentioned surfaces and other possible surfaces of the same type, it is a rule that a comparatively rough surface pattern between the plateaux not is an obvious disadvantage. Full knowledge of this subject is still lacking but it seems that an entirely smooth surface should not necessarily be better than a surface with dales and plateaux. To specify a surface demand for Metseal is not very easy. Leading manufacturers of seals of soft polymeric material, give the following approximate recommendations:

Rmax = 0,63 to 2,5 µm
Rz = 0,40 to 2,5 µm
Ra = 0,05 to 0,4 µm
MR = 50 to 95 %

One can see that permitted **Ra**-values are slightly higher, when the demand for **MR** is in the range 80 to 95 %. The demand is, despite smaller differences, in reality similar for soft seals. Especially the highest **Rz**-value 2,5 seems to be a common value.
Only surfaces without scratches and craters can consequently be accepted.

For Metseal can following recommendations be given:

Rmax= **Rz<10 µm**
Ra<2 µm
MR > 30 %

The recommendation is set to simultaneously give low generation of wearing particles and a low negligible wear on cylinder surface, piston steering ring and seal.

The demand for **MR** is especially difficult to specify with the conventional methods to describe the quality of a surface. For the Metseal piston seals, when they are in contact with soft ductile steel surfaces, it is a better to specify that the surface shall have such a surface profile that after wearing in it will have plateaux surfaces that are at least 30 to 40 % of the total surface.

Bevelled ends for assembling

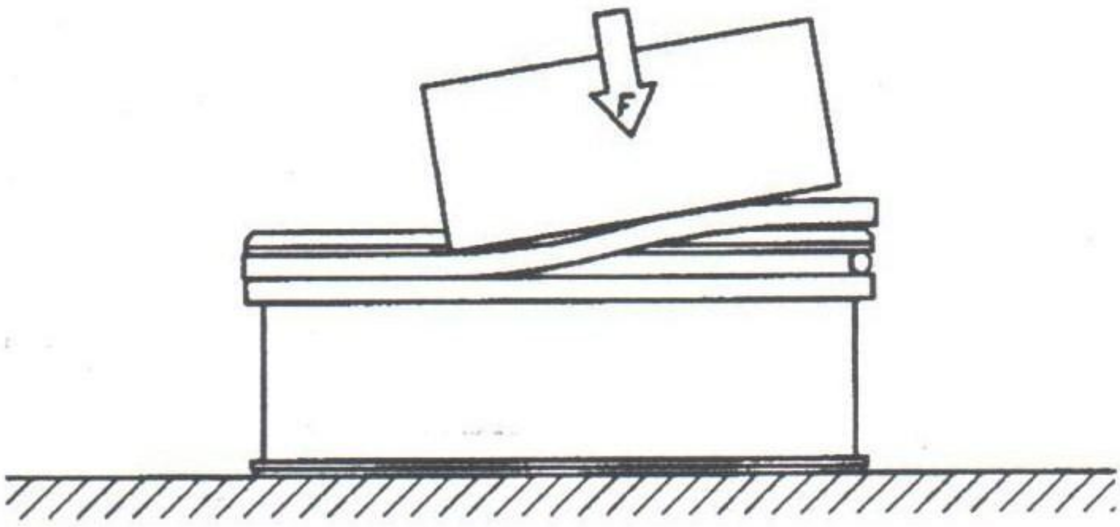
When the seal enters the cylinder bore, one can choose a chamfer angle of 10° to 20°. The seal usually has a chamfer on the flank of 15° plus a small radius between the sealing surface and the flank. A minor angle is preferred. The surface roughness on the chamfer should be better than **Ra < 4 µm.**

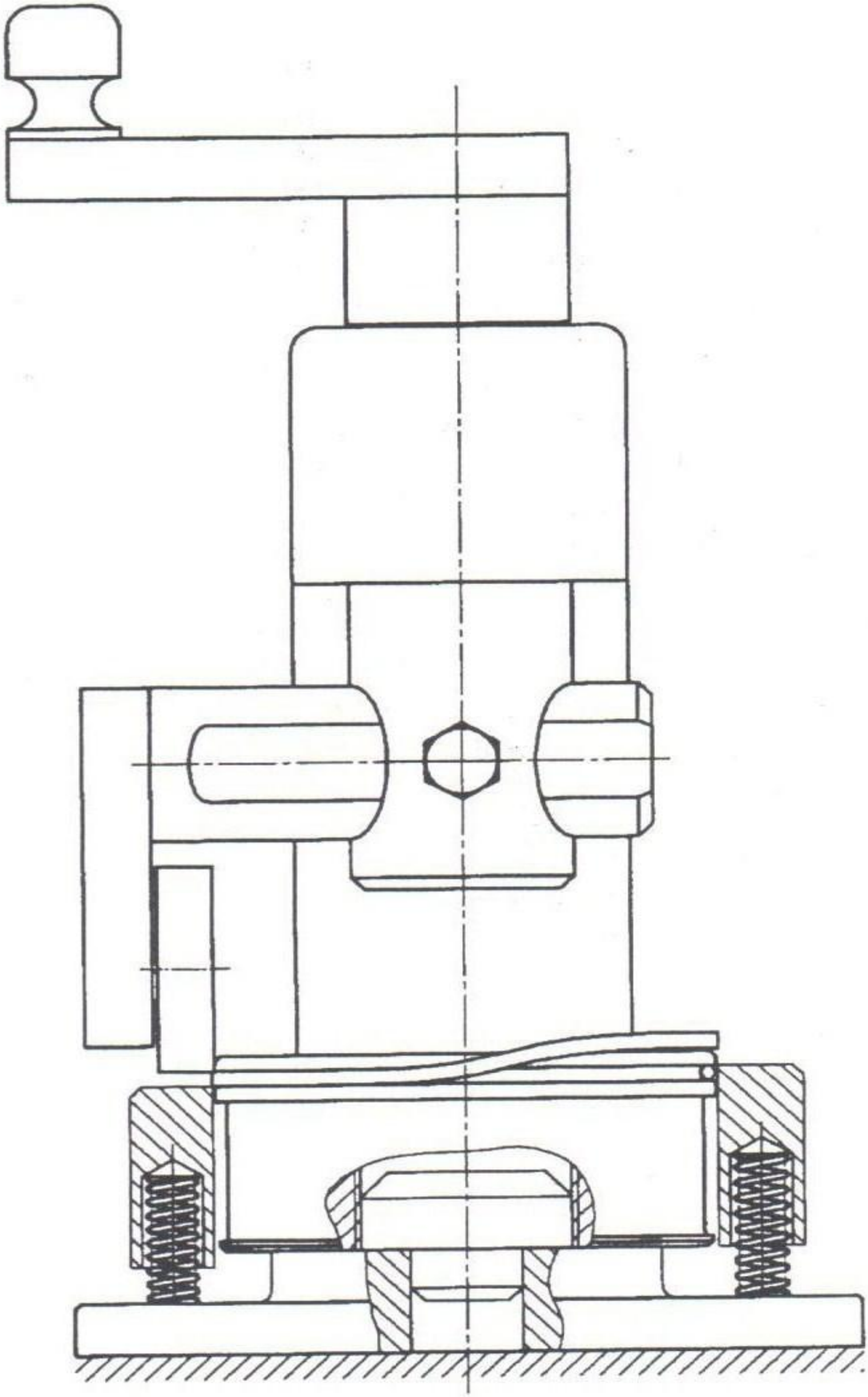
ASSEMBLING

The sealing groove for Metseals piston seals is machined into a solid piston. The seal is located in the sealing groove in a similar way to how a tyre is mounted on a rim. To facilitate the passing of the seal over the piston's outer diameter, the piston is shaped in a special way. Before the sealing groove, there is first a cylindrical surface that is 1 mm wide, followed by a radius of 2 mm which changes over to a conical section with an inclination of 45°. The first step in the assembly operation is to lubricate the O-ring with oil or grease and mount it in the seal groove. The O-ring, according to American standard, has been selected to provide a small pre stress against the bottom of the groove. The second step is to tilt the seal ring towards the piston groove and move the seal in to the groove against the O-ring on one side of the piston. The seal is now also in contact with other parts of the pistons circumference. First against the cylindrical surface with 1 mm width, then against the radius 2 mm and then, for most of the circumference, against the conical section with the inclination of 45°.
See Figure 4.
The third step is to press against the seal's plain flank with a tool starting alternately on both sides of that part of the seal that already is seated in the groove against the O-ring. Then alternately further and further round so that more and more of the seal is tensioned against the conical surface and compresses the O-ring. The seal gradually slides over the radius and the inclined plane and down into the groove. When the seal is pressed sideways and stretched circumferentially, it is also bent sidewise a little. Before the last piece of the seal slides down in the groove, a small piece of the O-ring may stand proud. Before the seal is allowed to slide completely home, the O-ring must be pressed down into the groove so that it will not become jammed between the side planes of the groove and the seal. See Figure 4, which shows how with a simple hand tool of for instance plastic or aluminium, one can mount the seal. Please note that solid hard tools like screwdrivers etc. which can hurt the surface on the seal's side plane should not be used. After some training, assembly by hand can be carried out without problems and be appropriate for individual assembling operations. For production line assembly however, it is better to use an assembly tool, which can be easily adjusted for varying diameters.
See Figure; Page 29, shows functional principle of such a device. The tool has a bearing that rolls against the side plane of the seal.

The piston is placed in the centre of a fixture. In the same centre a revolving spindle is mounted with an arm, which can move axially along the piston, this arm carries the roller bearing. The radius between the centre of the fixture and the roller bearing can be easily adjusted to suit the diameter of the piston and the seal. One starts by locating a part of the seal in the groove on one side and then rolling the arm under axial pressure, back and forward from side to side until the whole seal slides over the edge and down in the groove. Outside the piston, a tube is axially movable and can be slid down in the final moment of mounting and so avoids the O-ring jamming between the piston groove and the seal. To simplify assembly, the width of the groove can be made equal to or greater than the diagonal of the cross section. In this way, the seal will not be jammed in the groove. In practice it has been shown however, that it is quite in order to mounting the seals in a groove that is only 0,03 mm wider than the maximum width of the seal. The width of the groove for seal diameters 40 to 95 mm, can then be made 3,03 +0,05/0 mm. For diameters 100 mm and bigger the width can be made 4,42 +0,05/0 mm. Both widths have functioned well. In the first hand, we recommend the narrower width. If the seal is to be disassembled, the steel ring is pushed into the groove in one direction so that a gap between the seal and the piston is established on the opposite side. By help of a tool, for instance, a small screwdriver, the O ring can be lifted out and cut away, piece by piece. When the O-ring is removed, it is easy to take the Metseal seal away.

FIGUR 4



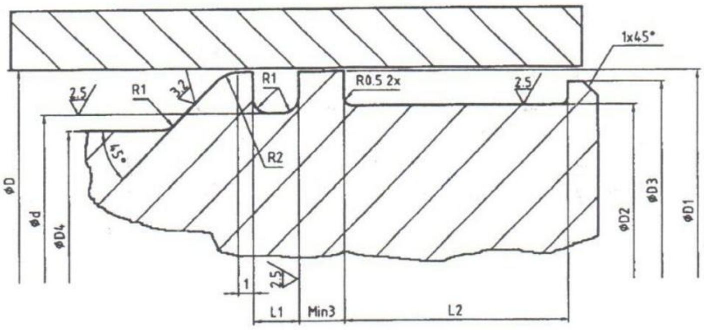


DIMENSIONS — TYPE D

Catalogue number:
Example MET-D80 H8

Steel grade of piston:

SS-EN 10083-1	C45
DIN 17200	CK45
BS 970	060 M47
SAE	1045
AFNOR	XC 45



x = Type D

(Not in stock) D_2 = D-5 (h7) D_3 = D-2 (0/-0,2) D_4=D-8

Ø D Stock	Ø D Special	H8	H10	L_1 - (L_1) +0,05 (+0,05) 0 0	Ø d h8	Ø D_1 h8	O-ring Nr.	O-ring 2,62 +/-0,09 3,53 +/-0,10	CATALOGUE NO. xx = H8 or H10
40		x		3,03-3,06	34,45	39,5	125	32,99x2,62	MET-D 40 H8
	(42)	x			36,45	41,5	126	34,59x2,62	MET-D 42 H8
45		x			39,45	44,5	129	39,34x2,62	MET-D 45 H8
	(46)	x			40,45	45,5	129	39,34x2,62	MET-D 46 H8
	(48)	x			42,45	47,5	130	40,94x2,62	MET-D 48 H8
50		x			44,45	49,5	132	44,12x2,62	MET-D 50 H8
55		x			49,50	54,5	135	48,90x2,62	MET-D 55 H8
	(56)	x			50,50	55,5	135	48,90x2,62	MET-D 56 H8
60		x			54,50	59,5	138	53,64x2,62	MET-D 60 H8
63		x			57,50	62,5	140	56,82x2,62	MET-D 63 H8
65		x		3,03-3,12	59,50	64,5	141	58,42x2,62	MET-D 65 H8
	(68)	x		3,03-3,12	62,00	67,5	142	59,99x2,62	MET-D 68 H8
70		x			64,00	69,5	144	63,17x2,62	MET-D 70 H8
75		x			69,00	74,5	147	67,95x2,62	MET-D 75 H8
80		x	x		74,05	79,5	150	72,69x2,62	MET-D 80 xx
	(82)	x	x		76,10	81,5	151	75,87x2,62	MET-D 82 xx
85		x	x		79,10	84,5	151	75,87x2,62	MET-D 85 xx
90		x	x		84,10	89,5	152	82,22x2,62	MET-D 90 xx
95		x	x	3,03-3,12	89,10	94,5	153	88,57x2,62	MET-D 95 xx
100		x	x	4,42-4,49	92,3	99,5	239	91,67x3,53	MET-D 100 xx
	(105)	x	x		97,3	104,5	240	94,84x3,53	MET-D 105 xx
110		x	x		102,30	109,5	242	101,19x3,53	MET-D 110 xx
115		x	x		107,30	114,5	243	104,37x3,53	MET-D 115 xx
120		x	x	4,42-4,49	112,30	119,5	245	110,72x3,53	MET-D 120 xx
125		x	x	4,42-4,51	117,20	124,5	246	113,89x3,53	MET-D 125 xx
130		x	x		122,20	129,5	248	120,24x3,53	MET-D 130 xx
140		x	x		132,25	139,5	251	129,77x3,53	MET-D 140 xx
150		x	x		142,25	149,5	254	139,29x3,53	MET-D 150 xx
160		x	x		152,25	159,5	258	151,99x3,53	MET-D 160 xx
170		x	x		162,25	169,5	259	158,34x3,53	MET-D 170 xx
-		x	x	4,42-4,51	172,25	179,5	261	171,04x3,53	MET-D xx
-		x	x	4,42-4,58	182,15	189,5	262	177,39x3,53	MET-D xx
-		x	x		192,15	199,5	264	190,09x3,53	MET-D xx
-		x	x		212,15	219,5	267	209,14x3,53	MET-D xx
-		x	x	4,42-4,58	242,15	249,5	272	240,89x3,53	MET-D xx

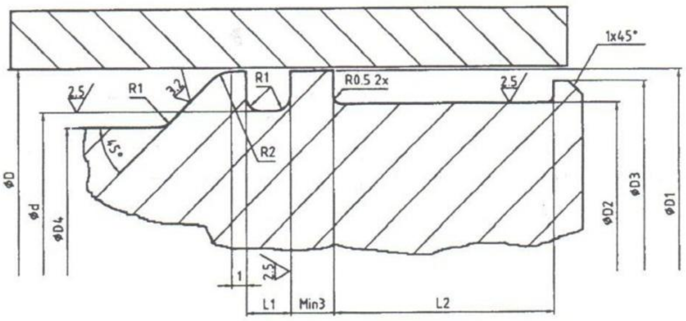
The tolerance on the piston guide ring shall be Ø40-180 = 0/-0,05 ˃ Ø 190 = 0/-0,07 mm
For best possible lifespan, the corners of the seal groove can be induction hardened. □ Type DW L_1 is 0,39mm longer.

DIMENSIONS — TYPE SBF

Catalogue number:
Example MET-SBF60 H0

Steel grade of piston:

SS-EN 10083-1	C45
DIN 17200	CK45
BS 970	060 M47
SAE	1045
AFNOR	XC 45



(Not in stock) **D_2 = D-5 (h7) D_3 = D-2 (0/-0,2) D_4=D-8**

Ø D Stock	**(Ø D) (Special)**	**(1) H0**	**L_1 - (L_1) +0,05 (+0,05) 0 (0)**	**Ø d h8**	**Ø D_1 h8**	**CATALOGUE NO.**
40		x	3,03-3,06	34,05-35,6	39,5	MET-SBF 40 H0
	(42)	(x)		36,45-37,6	41,5	MET-SBF 42 H0
45		x		39,45-40,6	44,5	MET-SBF 45 H0
46		x		40,45-41,6	45,5	MET-SBF 46 H0
48		x		42,45-43,6	47,5	MET-SBF 48 H0
50		x		44,45-45,6	49,5	MET-SBF 50 H0
55		x		49,50	54,5	MET-SBF 55 H0
	(56)	(x)		50,50	55,5	MET-SBF 56 H0
60		x		54,50	59,5	MET-SBF 60 H0
	(63)	(x)		57,50	62,5	MET-SBF 63 H0
65		x	3,03-3,12	59,50	64,5	MET-SBF 65 H0
68		x	3,03-3,12	62,00	67,5	MET-SBF 68 H0
70		x		64,00	69,5	MET-SBF 70 H0
75		x		69,00	74,5	MET-SBF 75 H0
80		x		74,05	79,5	MET-SBF 80 H0
	(82)	(x)		76,10	81,5	MET-SBF 82 H0
85		x		79,10	84,5	MET-SBF 85 H0
	(90)	(x)		84,10	89,5	MET-SBF 90 H0
	(95)	(x)	3,03-3,12	89,10	94,5	MET-SBF 95 H0

Type SBF, as well as the non-preloaded versions of DR and SB requires more information than is provided in this brochure for best build-in measurements.

Contact us for more information and suggestions of built-in measurements.

The tolerance on piston guide ring shall be ∅40-180 = 0/-0,05 **(1) Not preloaded**
For best possible lifespan, the corners of the seal groove can be induction hardened.