Morgan special carbon gland rings

(for steam, air and other gases)

1. Introduction

During the past 50 years the gland ring has become a standard method for sealing medium and large diameter shafts. This publication is concerned only with the special carbon gland rings for steam turbine applications and similar glands sealing hot or dry gases. A separate brochure is available covering the use of Morgan special carbon rings for liquid sealing applications.
The main features of the special carbon gland ring as a seal are discussed in the following pages, but as most gland rings are designed for specific applications, it is not practical to deal with the subject in depth. Our Technical Applications Department is always ready to advise on the application and detail of special carbon components and to make recommendations on the most appropriate type of gland or seal and the selection of the appropriate grade of special carbon.

2. Advantages

Special carbon gland rings are extensively used in steam turbines both as pressure seals in high pressure (H.P.) glands and vacuum seals in low pressure (L.P.) glands. They also find many applications as air or gas seals in industrial plants such as compressors, blowers and fans. Their particular advantages in these applications may be summarised as follows :

- Sealing with special carbon gland rings is efficient. The special carbon gland ring can be mounted, safely, with smaller clearance than is possible with the alternative metallic labyrinth seal where metal to metal contact must be prevented under all working conditions.
- This high sealing efficiency can be obtained with limited axial length.
- Carbon gland rings are not affected by axial movement of the shaft relative to the gland, and also can accommodate considerable radial displacement of the shaft from its normal axis without danger of seizure or loss of sealing efficiency.
- Carbon gland rings are inexpensive, both in purchase price, installation and maintenance costs. Our manufacturing technique ensures an accuracy which permits all segments of identical rings to be completely interchangeable. Rings which have been correctly specified can be fitted directly to the shaft without further hand fitting or adjustment; they will require little or no maintenance, and in many cases survive several normal turbine overhauls.

2.1 Operation of carbon gland rings (for sealing steam, air and other gases)

Each element of a carbon sealing gland consists of a segmental ring encircled by some form of garter spring. Each ring, almost invariably, consists of a number of 'butt-jointed' segments. The ends of these individual segments are cut on the radial line so that they form a complete and true circle with no clearance between segments when assembled. Such a ring is in effect solid, and the steam pressure which acts radially and equally upon the external periphery of the ring cannot cause the bore to decrease beyond its manufactured diameter. The ring's bore diameter should be specified to fit the shaft when both are at their working temperature. However, a very small clearance at the bore of the ring must necessarily exist which produces a throttling action on the gas being sealed and gives rise to a pressure drop across the ring. The differential pressure of the steam on each side of the ring not only holds the ring firmly against the 'downstream' wall of its housing compartment, but also acts radially inwards upon all segments. Because the ends of the segments abut and the ring is 'arch bound' the steam pressure cannot cause the segments to bear against the shaft with any great pressure. The garter spring thus serves mainly to hold the ring together, until there is sufficient steam pressure to do so.

2.2 Number of rings per gland and sealing pressure

A complete gland is built up of a number of gland rings in separate housing compartments. Normally, however, the entire first stage pressure of a H.P. reaction turbine is broken down by labyrinth seals on the balance piston or dummy piston to a comparatively low pressure corresponding to one of the exhaust end stages. When this arrangement has been made, it is then customary to fit at least two special carbon gland rings between the balance chamber and the gland steam leak-off annulus, and a third ring between the leak-off and atmosphere. Where a 'goose-neck' or sighting vent is fitted, a further ring is required beyond the vent connection to prevent steam and water flowing towards the bearing.
Vacuum sealing glands are similar, except that steam is supplied to the central annulus for 'packing' the gland and the tendency for leakage is both towards the turbine and towards the atmosphere. Frequently the packing steam is taken from a H.P. main through a reducing valve, and necessitates the use of high temperature carbon materials for the L.P. as well as the H.P. glands. In this case we would recommend the use of a high temperature electrographitic carbon material throughout. Generally the differential pressure across the carbon gland rings will not exceed 2.1 bar.
Where high pressures are required to be sealed entirely by carbon gland rings, the number of rings is usually specified so that the pressure drop across each ring is approximately 2.1 bar. The small leakage past each ring helps to equalize the pressure drop, but for high pressure sealing it is desirable to arrange controlled pressure balancing leak-off connections to various turbine stages which will enforce equalization of pressure. In this way

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pressures of many tens of bars can be effectively sealed by carbon gland rings.
Fan and blower seals dealing with air and gas are usually low pressure seals and often a single check ring is fitted, although for more important glands two rings are considered a desirable minimum.

2.3 Shaft speed

Steam turbine shaft speeds may result in surface velocities up to 50 m/sec. Provided that the initial cold clearance is correctly assessed, a 'butt-jointed' ring that does not make contact under pressure with the shaft is satisfactory for normal steam turbine shaft speeds. The inherent self-lubricating property of carbon will permit contact without undue frictional heating at these speeds. However, for very high surface speeds, or for high rotational speeds with small diameter shafts (conditions which are frequently a feature of gas turbine and compressor applications), the 'carbon labyrinth' gland which is discussed later, has particular advantages.

2.4 Temperature and oxidation resistance

During the past 50 years, we have evolved various grades of special carbon to meet the requirements of the British Admiralty and leading turbine constructors. We are therefore able to offer carbon grades appropriate to most temperature and oxidation conditions.
Our carbon-graphite grades are suitable for gland rings operating in super-heated steam at temperatures up to 350℃ These grades combine homogeneity with high mechanical strength and good self-lubricating properties. In the normal conditions where the oxygen content of the steam is low, and where there is infrequent subjection to atmospheric contamination at high temperature, this grade has proved capable of withstanding the disintegrating action of steam at 400℃ for periods extending to several normal turbine overhauls.
Glands which will be required to work under greater steam temperatures or, conversely, subject to more than the normal moderate oxidising influences, should be equipped with electro-graphite grades which have a high mechanical strength and resistance to oxidation. Grade EY9106 is completely resistant to super-heated steam temperatures up to .500℃, and for abnormally oxidising conditions at lower temperatures. For applications concerned with temperatures up to 600℃ grade EY9106BY is suitable. Because of the widely differing conditions, individual applications should be considered on their merits. Our Applications Department is always ready to assist with the design of conventional glands and the solution of new problems.

3. Design and details of carbon rings

3.1 Type of joint

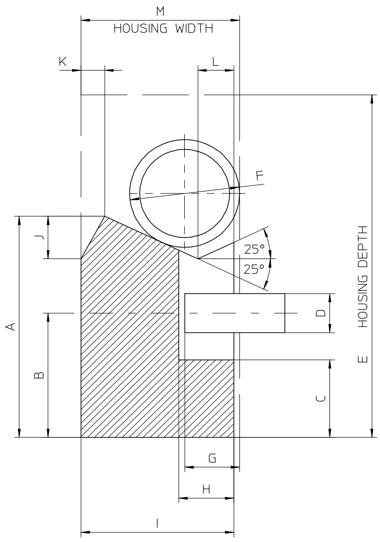
As mentioned earlier, gland rings for steam turbines are now made almost invariably as 'butt-jointed' rings. The ends of the segments are accurately cut on the radial line, so that no clearance exists between segments when the ring is assembled around the shaft.
Earlier designs of gland rings are still made however with a small clearance between segments, which therefore bear directly on the shaft, i.e., they form a contact seal rather than a throttle. To avoid leakage losses through the clearance of the joints, the segments used in these rings can be machined with very accurately fitting lap joints. This type of ring however is only suitable for low pressure sealing and where a certain amount of lubrication is available from the saturated steam.
'Contact' type rings with special joints are occasionally useful for low pressure gas sealing applications, but are more appropriate to fluid sealing applications and are used extensively for water turbine glands for which segmental rings in diameters up to 1000 mm and over are frequently manufactured.

3.2 Number of segments per ring

Short segments have a better arch strength than long segments, and an even distribution of pressure is assisted, to some extent, by increasing the number of segments. With carbon-graphite materials it has been customary to employ rings consisting of three segments for shaft diameters up to 200 mm and 6 segments per ring for steam turbine shafts above this size. Any particular number of segments can be provided if desired. When adopting electro-graphite materials, however, it is desirable to use more segments per ring for the larger diameter rings than would be the case with carbon-graphite materials.

3.3 Cross-section

Sketch 1 indicates the general proportions which we have found suitable for the relationship of the ring cross-section to shaft diameter. Whilst there is considerable design latitude in this relationship, these recommended standard proportions take into consideration the factors of adequate arch-strength and stability, combined with reasonably small housing dimensions.



	Dimensions [mm]			
Shaft Ø	25 to 65	65 to 125	125 to 190	190 to 280
A	19,05	22,23	25,4	28,58
B	11,11	12,70	14,29	15,88
C	6,35	7,94	7,94	9,53
D	4,76	4,76	5,56	6,35

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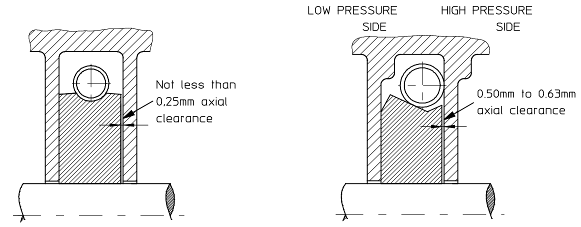
E	28,60	33,35	38,10	44,45
F	8,50	11,00	13,00	15,25
G	3,97	4,76	5,56	6,35
H	5,16	6,35	6,35	7,94
I	$12,15^{+0,05}$	$15,30^{+0,05}$	$18,35^{+0,05}$	$21,55^{+0,05}$
J	3,97	4,76	6,35	7,94
K	1,98	2,38	3,18	3,97
L	2,38	3,18	3,97	4,76
M	12,70±0,05	15,88±0,05	19,05±0,05	22,23±0,05

Sketch 1 Recommended Profiles for Bevel Section Gland Rings



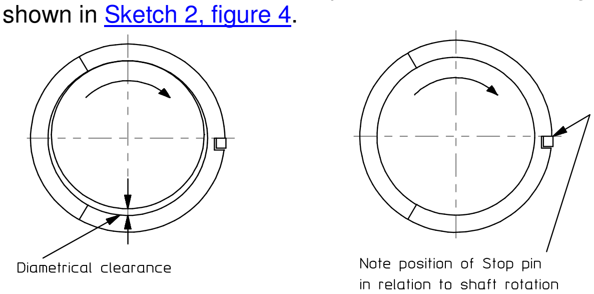
Sketch 2 Clearance to be allowed for Carbon Gland Rings

It should be noted that these sketches specify a bevelled cross-section, and the advantages of this are discussed under the next heading. Rectangular cross-sections are still employed for many large gland rings. These are generally made with the ratio of radial depth to axial width similar to that shown for the bevelled cross-section. In rectangular cross-sectioned rings however, the garter spring can be recessed into a periphery groove and the diameter of the housing can therefore be smaller than that required for bevelled rings.

3.4 Bevelled section gland ring

The bevel cross-section gland ring has largely replaced rectangular section designs in recent years, particularly for small diameter shafts. The advantage of the bevelled section is that it permits the garter spring to bear both on the bevelled periphery of the ring and against the upstream wall of the housing compartment. The spring therefore not only holds the segments together, but also forces the entire ring against the 'downstream' wall in the same direction as the force due to the differential pressure of the steam being sealed. These effects stabilise the ring and help prevent vibration or chatter upon the shaft or rings when there is little steam pressure, such as on the atmospheric side of the gland housing. The axial tension of the garter spring is sufficient to sustain the weight of the ring evenly in contact with the 'downstream' housing wall. Thus there is no reason for the ring to wear more at the top of the bore than the bottom and become oval, and the old idea of a coach spring to support the weight of the ring becomes superfluous.

A generous chamfer should be provided on the 'downstream' side of the outer periphery to enable the top half of a split housing to be assembled without difficulty. A reverse bevel is provided on the opposite side to prevent the garter spring from rolling off the main bevel during assembly. The housing compartment should, if possible, be shaped so that the rings with their garter springs can only be installed when facing in the correct direction, i.e., with the spring pushing the ring in the same axial direction as the action of the differential pressure across the ring, as shown in Sketch 2, figure 4.



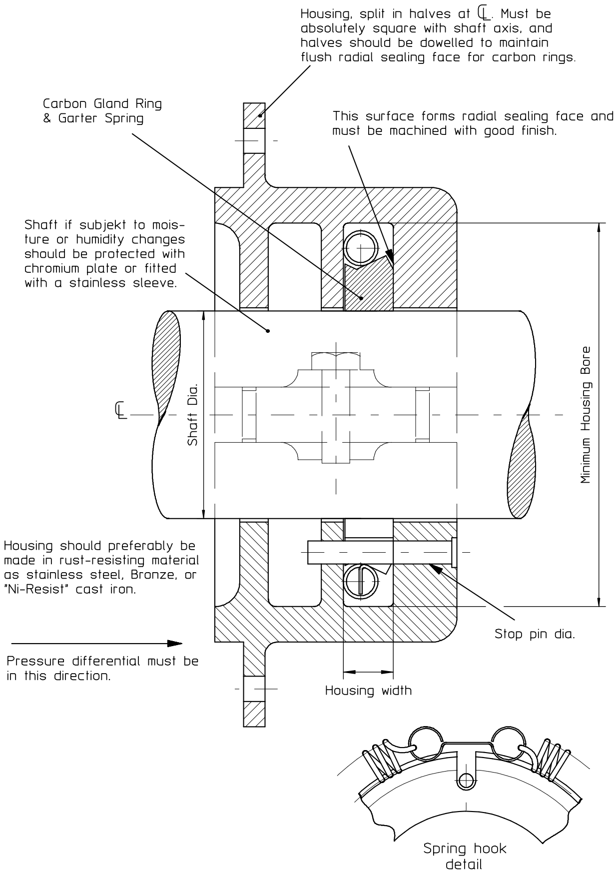
3.5 Stop pins, slots or key ways

Each gland ring must be provided with some form of stop or key to prevent its rotation with the shaft. The location, shape and size of the stop pin and slot in the rings are important, because these points affect the stability and strength of the gland ring.

Experience indicates that the stop should be placed so that the trailing end of a segment bears against it. This helps stability and prevents any tendency for the segments to 'wrap' around the shaft.

A slot cut radially into the end of a segment, as in Sketch 2, or half into each of two butting segments, will not cause a notching effect. Such a slot can be cut right across the axial width of the segment so that a long stop pin on the joint line going right through several housing compartments can be common to all gland rings. An arrangement of this nature is shown in Sketch 3, and the standard type of carbon ring used for this assembly in Sketch 5. An alternative arrangement where each gland ring is provided with a separate stop pin is shown in Sketch 4 and details of the rings in Sketch 6. This arrangement is preferred to the 'through' stop pin assembly.

The slot should be deep enough, in a radial sense, to allow some clearance between the bottom of the slot and the pin so that the rings have free radial movement. With large diameter butt-jointed rings it may be desirable to use more than one stop pin so that the tangential friction forces are evenly distributed between segments. This will, however, restrict the movement of the rings to some degree. Stop pins with flat or square surfaces where they contact the carbon segments are preferred because they avoid 'line contact' as with round pins. Square headed pins should, however, be free to rotate and align them-selves, and the bottom of the slots in the carbon should be radiused.



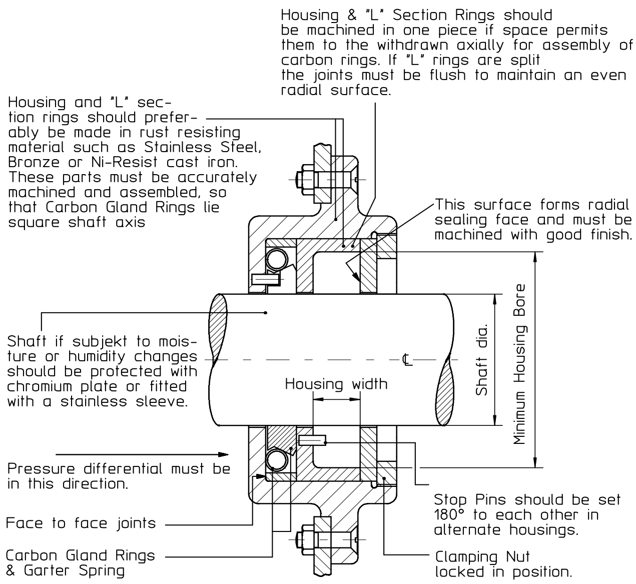
Sketch 3 Bevel Section Carbon Gland Rings in Split Housing

4. Specification of bore size for 'butt-jointed' special carbon gland rings

Morgan special carbon gland rings are completely machine finished when they leave the factory, and their accuracy will be maintained provided they can be assembled without further hand fitting. It is advantageous therefore to specify the diameter of the bore and thickness with some accuracy so as to avoid the necessity of further adjustment or hand fitting when the rings are assembled in the component.

In practice, this means that the bore of a new gland ring must be so specified that it will form a proper and safe fit with the shaft when both carbon ring and shaft are at their working temperature. The thickness of the ring must be specified to allow proper clearance between ring and housing walls. When estimating the correct diameter of the bore of a new special carbon ring, allowance must be made for the fact that the carbon has a coefficient of expansion of approximately one quarter of that of steel. In other words, the bore of the carbon gland ring will only expand by about one quarter the amount that a steel shaft will expand when both are raised to the same working temperature. For this reason the bore of a new carbon gland ring must be made larger than the diameter of the cold shaft by an amount that will make allowance for this unequal expansion of the two materials.

When a new carbon gland ring is mounted on a cold shaft there should be a clearance between the bore of the ring and the shaft as depicted in Sketch 2, figure 1.



Sketch 4 Bevel Section Carbon Gland Rings in 'L' Section Housing

The amount of this diametrical clearance should be calculated as follows.

$$c = d_S * t_w * (\alpha_S - \alpha_C)$$

c = diametrical clearance [mm]
d_S = nominal shaft diameter [mm]
t_W = working temperature [°C]
α_S = coefficient of thermal expansion of shaft material [1/°C]
α_C = coefficient of thermal expansion of carbon material [1/°C]

It should be appreciated that accurate knowledge of the working temperature of the shaft is essential if minimum working clearance is to be attained. Over-estimation of shaft temperature will lead to too much clearance and a reduction of sealing efficiency. Under-estimation will lead to a degree of interference between ring and shaft, but this is not dangerous unless shaft speeds and pressures are high. A mild degree of interference on first reaching working temperature will cause the segments to make full contact with the shaft and provided that the speed of the shaft is moderate and sealing pressures not too high, the rings will rapidly bed-in to the shaft and an optimum fit will be obtained.

In general, it is advisable to make the allowance correspond to the maximum temperature of the steam or gas adjacent to the gland, although experience may dictate where a smaller allowance is safe. When several rings are mounted in line, the clearance is frequently stepped down on the outer rings in conformity with an estimated temperature gradient along the shaft. Where glands are packed with steam at a greater temperature than that being sealed by that particular gland, it is generally assumed that the shaft temperature will be controlled by that of the packing steam which will tend to keep the gland temperature even despite load changes on the turbine.

5. Axial clearance of ring in housing

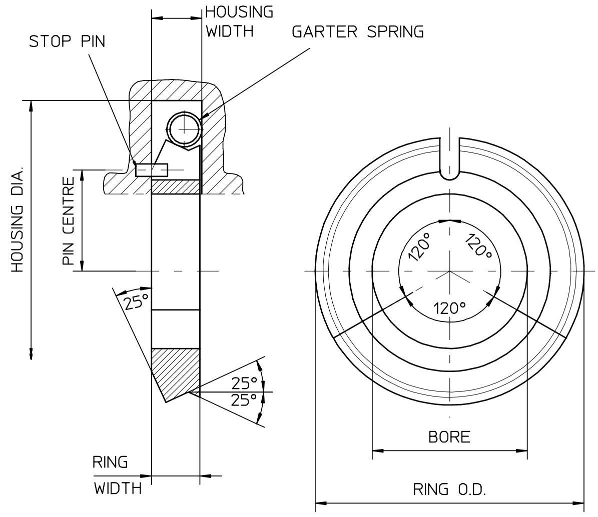
Axial clearance between the gland rings and the walls of their housings should be sufficient to allow free sliding movement of the ring in any radial direction. Under low or fluctuating pressure conditions it is desirable to keep this clearance to a minimum, otherwise the rings may not be held firmly against the downstream housing wall, and leakage may occur around the back of the ring. With bevel-section rings the garter spring will hold the ring always against the radial sealing face of the housing. Allowance must be made for the possibility of some, thermal distortion of the housing, and also there may be a slight build-up of scale or rust. The minimum safe axial clearance for a steam turbine gland ring is 0.25 mm and with the larger diameter rings this may be increased. It is usual to allow 0.5 mm to 0.64 mm axial clearance with bevel-sectioned rings as depicted in Sketch 2, figure 4.

6. Shaft finish

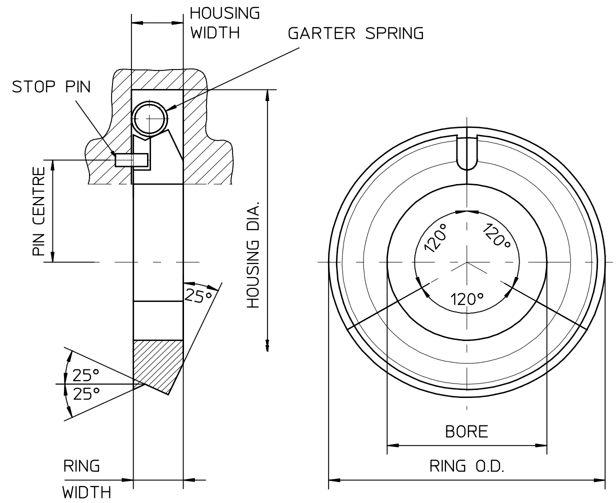
In steam turbines, carbon gland rings are normally fitted directly to the steel shaft which should have a fine turned or ground finish. Provided that the housing is properly drained, corrosion difficulties are not usually experienced and the shaft is, to some degree, protected by a fine graphitic skin which is built up by its contact with the carbon ring.
With auxiliary turbines, and with glands or fans and blowers dealing with corrosive gases, the shafts are usually chromium or sometimes nickel plated. Hard chromium plating of not less than 0.13 mm thickness has been found a satisfactory protection for turbine shafts where use is intermittent or infrequent and where there is more than the usual condensation in the gland.
Sleeves are occasionally fitted to shafts. With large diameter shafts, differences in expansion between the sleeve and the shaft may be fairly large, particularly if the sleeve is made of stainless alloy. If sleeves must be fitted, then they must have an adequate interference fit when cold to avoid any risk of loosening when at working temperature, and they must permit good heat transfer from sleeve to shaft.

7. Gland ring housing

While the design of the gland ring housing is, of course, a matter for the constructor, we include Sketches 3 and 4 showing representative forms of housing, which indicate essential requirements, particularly in regard to dimensions, which must be resolved before a gland ring can be recommended. Both types of housing shown are designed for use with the rings illustrated in Sketches 5 and 6.



Sketch 5 Bevel Section Carbon Gland Ring



Sketch 6 Bevel Section Carbon Gland Ring

With steam turbines the gland ring housing is usually split in halves and the half-housings, which are separate components, are slid around the shaft into a recess in the lower half of the turbine casing and are clamped in position by a separate cover. In simple gases, as for some fans and blowers, the split half housings may be dowelled and bolted together, and then bolted directly to a facing on the turbine or blower casing as shown in Sketch 3.
With split housings it is essential that the two halves should register accurately when fitted together so that the carbon ring lies against a smooth and flush radial surface. Accurate assembly of the rings and housings will be assisted if the stop pins are located in the lower half casing or at the joint line between halves. Segmental rings can, of course, be fitted without removing the shaft.
The alternative type of housing illustrated in Sketch 4, has advantage if there is sufficient clearance to permit the ‘L’ ring components and their respective gland rings to be withdrawn axially. In this case an unbroken radial sealing surface is presented to the carbon ring, and this surface is readily machined to a good finish.

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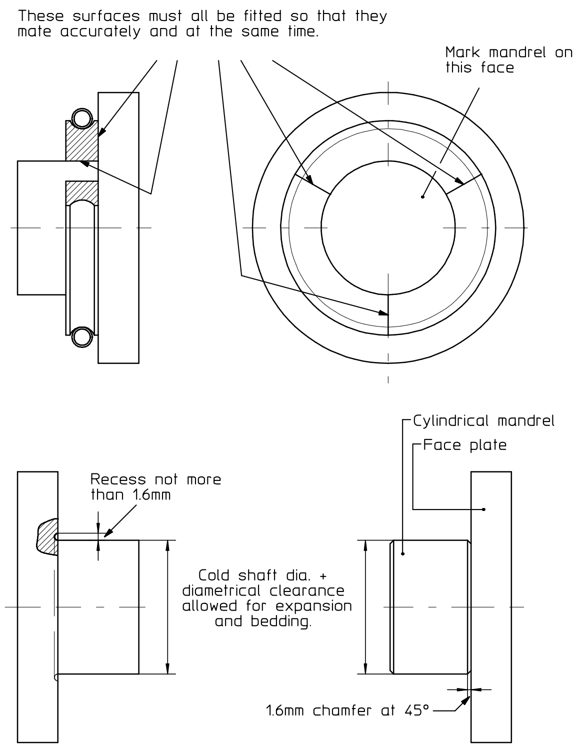
With either type of housing, care must be taken that the housings are mounted perfectly square to the shaft axis. Clearance in the housing should permit free sliding movement of the carbon ring radially. The inside diameter of the housing should be sufficient to permit not less than 3 mm clearance between the outside periphery of the garter spring and the housing. Housings for steam turbines are frequently made in bronze. Corrosion-resisting material is essential with most glands. Slow-rusting cast-irons such as 'Ni-Resist' which also exhibits good heat resisting properties, have been found suitable for glands where condensation is not severe.
Drainage of the housing is important as a water-logged gland can cause heavy wear on the carbon gland ring although not affecting the shaft. With steam turbines, the gland compartments should be drained by a connection to condenser or vacuum while starting up or shutting down. Entry of scale or other debris into the gland is very undesirable, and in many steam turbine installations fine strainers are provided in gland sealing steam supply lines to prevent such ingress.

8. Fitting carbon gland rings

The point has been made in preceding pages, that carbon gland rings should be correctly specified with regard to bore size and thickness, so that hand fitting on assembly is unnecessary. It is realised, however, that small adjustments may be required on occasions, such as when rings are fitted to shafts of a slightly different size than that for which the rings were manufactured, or sometimes where an incorrect allowance has been made for the thermal expansion of the shaft. Such adjustments call for very careful hand fitting, as three surfaces must mate accurately and simultaneously when the ring is sealing properly.
Accurate fitting is impossible without the use of a mandrel. In order to simulate the condition of the hot ring fitting a hot shaft the mandrel should be made larger in diameter than the actual cold measurement of the shaft by the amount calculated in Section 4.
A cylindrical mandrel may be used in conjunction with a surface plate; alternatively, a stepped mandrel may be made as shown in Sketch 7, which also illustrates how the ring must be fitted to mate at the bore, the radial surface and at the segment butts.
Material may be removed from the carbon segments with a fine file or scraper, and it is permissible to finish the filed or scraped surfaces with a really fine grade of emery cloth, but all abrasive debris must be carefully wiped away.
When decreasing the bore size of a ring, it is generally sufficient to remove a slight and equal amount of material from each joint face of all the segments, until the segments just touch the mandrel when butting fully at their ends. It should not generally be necessary to scrape the bore of the segments unless considerable size changes are necessary. Morgan gland rings are manufactured to a tolerance of 0,05 mm on specified bore size and thickness. Adjustment therefore will rarely be necessary provided that the specified dimensions on the gland ring design are correct for the shaft and housing when they are at their appropriate working temperature.



Sketch 7 Use of mandrel when fitting carbon gland rings

9. Garter springs

We supply suitable garter springs for most types of carbon gland rings, and generally recommend a close coiled helical spring, which completely encircles the ring.
With 'butt-jointed' gland rings the actual spring tension is not critical, because the steam or gas pressure which acts on the segments will generally exert the larger proportion of the forte necessary to hold the segments together. The spring serves mainly to retain the segments in position when differential pressure across the gland is absent or is very small. As a general rule the spring tension should be specified so that it gives an inward radial force of about 0,014 N/mm² of contact area of carbon at the bore of the ring.
The coil diameter of the spring is usually fixed by the proportions of the gland ring and clearance available in the housing. For rectangular-sectioned rings it is usually about half the width of the ring, but with bevel-sectioned rings it should not be. less than two-thirds of the axial width.
The garter spring is usually specified so that it is stretched by 10% of its free length when it encircles the gland ring. The foregoing rules give a spring that is very moderately stressed when stretched to its working length. This is important where springs are required to work at high temperatures because 'creep' or relaxation is proportional to applied stress as well as temperature and time. A close-coiled spring, with a comparatively low percentage extension, is easy to fit and is not readily over-stretched when assembling around the ring, A spring that completely encircles the ring will exert even pressure on all segments and is preferred to the cheaper alternative of

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a short spring and wire loop which may cause displacement of some segments.

9.1 Material

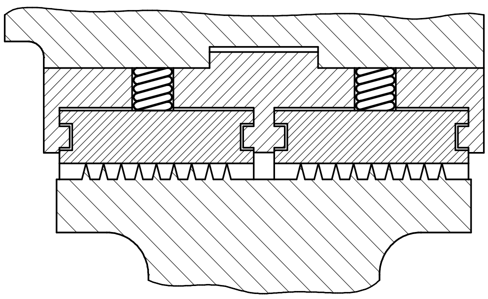
For springs required to work at temperatures greater than 250℃, 'Inconel' nickel alloy wire is preferred. When designed low stress, as above, 'Inconel' garter springs will be found to give very little relaxation for extended periods at temperatures up to 370℃. Springs required to work at temperatures below 250℃ are generally specified in stainless steel such as Firth 'F.D.P.' variety. These materials offer exceptionally good corrosion resistance, and are suitable for most sealing applications. For temperatures in excess of 400℃ specially heat treated 'Nimonic 90' wire is employed.

9.2 Hook and links

Complicated hook forms should be avoided. The simple method of turning up the last coil of the spring at 90" to the main barrel of the spring gives an entirely satisfactory end, provided that sharp points are eliminated. Where the spring must bridge a stop or key, a separate short connecting link should be used. The link may be shaped to clear the stop pin or projection, and should be made in a wire that is one or two gauges heavier than that used for the spring.

10. The carbon labyrinth gland

This type of gland has been used extensively by continental steam turbine constructors for many years, and is now becoming popular in Great Britain for high speed auxiliary steam turbine, gas turbine and aircraft gas turbine compressor seals. The gland consists of a carbon ring which may be keyed or supported in a stationary housing by various methods, in close proximity to a number of circumferential fins on the shaft or rotor. The carbon rings are usually made in segments, with radial butt-joints, in the same manner as the steam turbine rings described earlier.
The advantage of the carbon labyrinth system over a metallic labyrinth lies in the possibility of reducing the clearance between the rotating and static parts to a very small amount. With all-metal labyrinths this clearance has to be comparatively large and must be sufficient to prevent actual contact between the co-operating surfaces under any working condition. Allowances therefore have to be made for expansions and distortions, for bearing clearance, and in particular for the possibility of eccentric running of the rotor under certain conditions. With carbon labyrinths, however, actual contact, even at very high speeds, is not normally damaging to the moving fin, nor dangerous to the rotor or turbine and clearances may be held to the small amounts required for assembly. Any contact between the fin tips and the carbon counter surface will result in finely cut grooves in the bore of the carbon ring, if the ring is rigidly fixed to the housing. With a ring free to move in the radial sense, the depth of penetration will be much reduced, if not negligible. The cutting of grooves, does not reduce the sealing efficiency, as the clearance at the sides of the rotating fins still remains very small.
All-metal labyrinths generally employ fins machined on two or more diameters, with the mating part stepped accordingly, to prevent a straight 'blow-through', and create turbulence between the fins. This is unnecessary with carbon labyrinths operating with much finer clearances, and the sealing efficiency is not impaired by machining the carbon ring with a plain bore, and the fins to a common diameter. In addition, this arrangement reduces the complexity of the gland, and the cost of machining the various components.
It will be readily appreciated that any reduction in running clearances will bring about a relatively large increase in sealing efficiency. In steam turbine practice, constructors have been able to reduce leakage to as little as one-tenth of the figure obtained with a comparable metal labyrinth, and similar improvements have been obtained with the carbon labyrinth applied to the compressors of gas turbines. An important advantage lies in the possibility of reducing axial length and pressures up to 7.0 bar can readily be dealt with by glands not exceeding 50 mm in axial length.
With the fine clearance of a carbon labyrinth gland the sealing efficiency of a single fin is high, and the overall effect of increasing the gland length beyond 6 to 8 fins for pressures up to 7.0 bar is small. Where weight reduction is important, a high efficiency is maintained with glands reduced to a minimum number of fins. On the other hand, if erosive conditions are likely to increase the gland clearances, then a larger number of fins should be employed.



Sketch 8 Carbon labyrinth gland

10.1 Glands for steam and gas turbines and compressors with split casings

A typical form of carbon labyrinth consists of a butt-jointed segmental ring as shown in Sketch 8, where the segments are keyed into the housing and the ring retained in a circular form by the action of compression springs acting radially on the outer periphery of the segments. The segments are held in the housing by keys recessed into both half casings at the horizontal joint. This is the preferred design, and a typical gland employing rings of this type is illustrated in Sketch 9. It is necessary to bore

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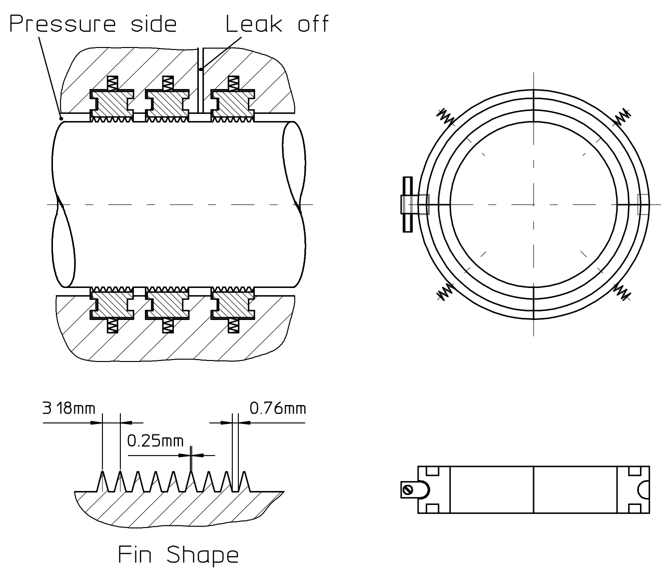
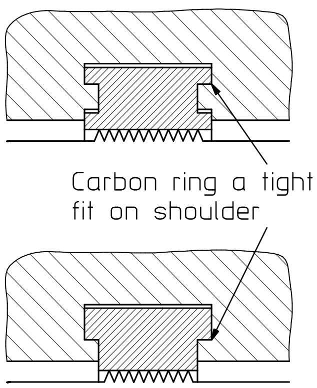
the rings to give a small cold clearance over the shaft, thereby allowing for differential expansions, so that the required clearance is obtained at the operating temperature (see earlier remarks on specification of bore size for ‘butt-jointed’ carbon rings).
Alternatively, the segments may be keyed into the half housings in such a manner that the expansion of the carbon ring is controlled by the metal housing, and a constant bore clearance is thereby maintained over a wide temperature range. The disadvantage of this method is that clearances introduced at the joints between the segments, as they move radially outwards, can give rise to leakage under operating conditions. This leakage is small, however, since the clearance is distributed amongst the joints. Two rings located in this manner are shown in Sketch 10.



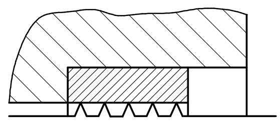
Sketch 9 Typical gland using carbon labyrinth rings



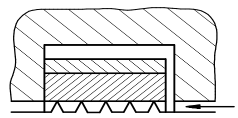
Sketch 10 Carbon Gland Ring

10.2 Compressors for aircraft gas turbines and similar applications where a complete ring can be fitted

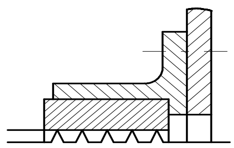
There are many applications where it is possible to fit a one-piece ring, and for these a different assembly is normally adopted whereby the differential expansion between the carbon ring and metal housing is overcome. The carbon ring, either as a solid one-piece ring, or in a number of segments, is shrink-fitted into a metal shroud with sufficient cold interference to ensure that the ring is firmly held in position at the operating temperature. Thermal expansion of the shroud controls the expansion of the carbon ring, and a constant clearance is maintained between the bore of the carbon ring and the rotating fins over a wide temperature range, provided that the shroud and the shaft are made from materials with a similar coefficient of expansion. Various assemblies of shrink-fitted glands are shown in Sketch 11.



a) Carbon bush shrink fitted direct into housing. Usually only suitable for small dia. Shaft where carbon is a whole piece ring



b) Carbon ring shrink fitted into metal shroud and assembly free to centralize itself around the shaft. Either a whole piece or segmental ring can be used for this assembly.



c) Carbon ring shrink fitted into a metal shroud which is fixed to main casing. Either a whole piece or segmental ring can be used for this assembly.

Sketch 11 Alternative arrangements for shrink fitted carbon labyrinth gland

10.3 Carbon material

Carbon labyrinth glands are suitable for use at high shaft speeds, their limitation being one of temperature, or rather susceptibility to oxidation. In an inert atmosphere, or vacuum, carbon materials can withstand temperatures of over 2000℃ with little or no deterioration or reduction in mechanical properties. In the presence of oxygen, however, electro graphitic grades begin to oxidise at approximately 450℃. A specially developed material of high strength, (EY9106) is resistant to oxidation in air at temperatures up to 500℃. Our research department is constantly developing new materials and treatments, to meet the requirements of the modern gas turbine industry. A new treatment recently developed permits the use of certain grades up to 600℃. The self-lubricating properties, high purity, and fine texture of the electro-graphitic materials make them particularly suitable for operation in conjunction with a wide variety of shaft materials.

10.4 Fin shape

The long, thin fin normally associated with all-metal labyrinths is not considered the most suitable for carbon labyrinth glands. A more stubby fin shape with a 0.25 to 0.5 mm land at the tip is preferred, so that any heat generated, should rubbing contact occur, will be quickly conducted away from the fin tip. Localised areas of high temperature which occur during severe rubbing may otherwise damage the fin tips, although the carbon gland itself would not suffer, beyond fine grooving in the bore.

10.5 Life

A life of several years is not unusual with carbon labyrinth glands in steam turbine applications.

10.6 Morgan special carbon gland rings for fans and blowers

Morgan special carbon gland rings are being increasingly used for shaft seals in auxiliary plant such as compressors, fans and blowers. Such gland rings are particularly suitable for plants installed in exhaust systems handling noxious, inflammable or toxic gases and in air refrigeration or gas systems. The self lubricating properties, high oxidation and chemical resistance of carbon make it an ideal material for a wide range of operating conditions. In these applications Morgan special carbon gland rings provide an effective seal which has a long life, thus reducing maintenance problems to a minimum.

Morgan grade CY2 has been found to give excellent results under the conditions most commonly encountered in this field, but other materials are also available for abnormally severe conditions such as those associated with very high temperatures or highly corrosive gases. In such cases reference should be made to our Applications Department to ensure that the most suitable grade of special carbon is chosen.

In low pressure machines it is normal practice to employ a single check ring of the bevelled section type, although for more important glands two rings are often considered a minimum. For sealing higher pressures, or where a leak-off must be provided to prevent toxic gases escaping into the atmosphere, a gland employing several rings may be necessary.

The fitting and the design of these glands should follow the recommendation made for steam turbine glands earlier. When sealing corrosive gases, care must be taken to prevent the formation of corroded particles in the gland ring housing, because this will cause an abnormal wear to the carbon rings. In such instances suitable corrosion resistance materials should be used for the shaft sleeve and ring housing.

Similarly, on blowers handling dust laden atmospheres, the ingress of dust particles into the gland will also cause wear of the carbon rings. In exceptional cases of this nature, the gland rings may jam in their housings. This problem can often be overcome however by a suitable housing design, and our Applications Department will give advice on this.

When pressures of 7.0 bar and over are to be sealed, it is usual to employ a carbon labyrinth of the type shown in Sketch 9. One or more leak-offs are normally provided to control the pressure drop through the gland. Leak-offs or pressure feed points may also be necessary to collect the leakage of toxic gases or to prevent contamination of the gas being handled.

Suitable designs for these special purpose glands can be prepared by our Applications Department.

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