INTRODUCTION.

For many years engineers involved in the design of sophisticated vacuum and ultra-high systems such as accelerators had been looking for a static metal seal which would offer the same advantages as an elastomer O-Ring, which means to be adaptable to the same light-duty flange configuration where low thermal inertia and limited weight are priority parameters. Within a special collaboration agreement between the C.E.A. (the French Atomic Research Center) and LE CARBONE LORRAINE – CEFILAC ETANCHEITÉ it was decided to look into this field. The HELICOFLEX seal is the answer to this challenge. It is now commercialized and can be manufactured in diameters ranging from 10 mm to 2 m with all types of metallic materials compatible with ultra-high vacuum conditions. As shown hereafter, its fully-metallic design puts the HELICOFLEX seal in a better position than elastomer seals for many applications.

PERFORMANCES OF SEALS REQUIRED BY NEW ACCELERATORS.

The new types of accelerator require new sealing performances, such as:
- Ultra-high vacuum (10^-11 mbar).
- Metallic construction.
- High efficiency at extreme temperatures negative or positive.
- Compatibility with aluminium – indium flanges without risk of damage on sealing surfaces.
- Low outgassing rate.
- Resistance to radiations.
- Steady sealing performance over the life of the accelerators.

As described in the paragraph “discussion”, the HELICOFLEX delta fulfils all those characteristics, but, let's first define the principle of this seal and its main characteristics.

THE SPRING.

The spring is of the close-wound type and provides the adequate reaction of the seal against the flange faces, which reaction is initiated by the tightening load applied on the bolts. It will ensure over the whole seal life a double function which we can call reaction load generation and springback storage, thus allowing external phenomena (such as creeping, bolts relaxation, temperature changes, ...) to occur without losing the required sealing level. In order words, the spring maintains between the sealing lining and the flange faces the most intimate contact which guarantees the seal performance over a long period of time.

THE INNER LINING.

The inner lining ensures a uniform distribution of the spring reaction load against the sealing lining.

THE SEALING LINING.

The sealing lining made from a metallic material is meant to be plastically deformed against the micro-defects of the flange faces. It has 2 sharp ridges which feature the HELICOFLEX seal. As can be seen on sketch NR 1, those ridges made on each side of the torus in line with the spring median axis are acting as contact circles. Due to their profile, they generate a high specific pressure and gradually disappear with increasing compression. This leads to a very good sealing performance (Q ≤ 1.10^-11 MPa m^3 s^-1) which can be reached already very early in the compression phase. Let's emphasize the fact that because of its metallic nature, the sealing lining material exposed to this high specific pressure will penetrate the micro-defects of the flange faces much more efficiently than an elastomer material which always tends to creep before getting to an intimate contact.
The HELICOFLEX seal can be designed with all kind of lining materials.

Some compression tests, which have been followed by CEA at Pierrelatte (French Atomic Center) [2] have enabled to define the necessary compression load to obtain the Helium sealing with each of these linings.

The table hereafter insists on the low compression load required by this metallic seal.

<table>
<thead>
<tr>
<th>Material/Neoprene</th>
<th>HELICOFLEX</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression (N/mm)</td>
<td>0.3 0.5 0.7</td>
<td>0.3 0.5 0.7</td>
</tr>
<tr>
<td>Decompression</td>
<td>0.2 0.4 0.6</td>
<td>0.2 0.4 0.6</td>
</tr>
<tr>
<td>Effective springback</td>
<td>0.1 0.3 0.5</td>
<td>0.1 0.3 0.5</td>
</tr>
</tbody>
</table>

**Tableau des valeurs caractéristiques**

Main references for HELICOFLEX A seals are now being used on many ultra-high vacuum systems operating in the industry and the main research institutes. Some examples are mentioned below:

**CRFN**

The 450 Gev proton accelerator SPS (Super Proton Synchrotron) was refurbished using HELICOFLEX A seal between 80 mm diameter and 400 mm diameter in order to conform with following new specifications:

1. Necessity to reach a vacuum of pressure of $5 \times 10^{-10}$ mbar (average) together with an allowable leak rate of $2 \times 10^{-9}$ mbar L/s (max per seal).
2. Necessity to absorb the synchrotron radiation whenever the SPS is used as L.E.P. pre-injection device.

For this special application, in addition to its features described earlier (resilience and high specific pressure), the HELICOFLEX A seal is built in such a way that the inside diameter is acting as a support for a Tungsten piece which is used to limit the synchrotron radiation and which requires an accurate positioning within 0.2 mm.

Several thousands of those seals have already been supplied for this application.

**INDIA**

India has very important natural Thorium reserves and therefore holds a leading position worldwide as far as Thorium production is concerned.

A Thorium process plant has been built which required important ultra-high vacuum systems. HELICOFLEX A seals ranging from 10 mm diameter to 800 mm diameter have been supplied for the sealing of the ISO-PNEUROP flanges used on those installations, quantities being typically of 100 to 300 pieces per size.

**BROOKHAVEN**

The Brookhaven laboratory in USA is also using the HELICOFLEX A seal for various applications including the sealing of quartz sight-glasses.
DISCUSSION

The standard HELICOFLEX seal without ridge requires, despite of great sealing properties, a too important tightening load with respect to high and ultra-high vacuum systems used on particle accelerators, so the idea of concentrating the specific force on a ridge without interfering with the performance was attractive but difficult to carry out.

Today, the technical problems are solved and we can say that the HELICOFLEX fulfills the requirements of ultra-high vacuum systems.

It guarantees the already mentioned performances, which means that:
- a 10^-11 mbar vacuum is ensured by the manufacturing quality of the ridge.
- it is made from a metallic strip and a spring in "super" alloys, such as Nimonic 90 or Inconel X750.
- this metallic material can withstand temperatures from 180 K up to 1000 K.
- the superficial hardness of aluminium sealing lining is lower than hardness of aluminium flanges, differential hardness being around 40.
- polishing and cleaning operations are carefully carried out, thus allowing an extremely low outgassing rate.
- all metallic materials used can resist to radiations, we can mention aluminium, silver, super-allow...
- the spring ensures an internal elasticity which enables the seal to "breathe" and to prevent from deterioration of the intimate contact between the flange and the sealing lining.

CONCLUSION

The originality of the HELICOFLEX seal design has led to numerous applications on accelerators or ultra-high vacuum systems.

However, its application field is not limited and could be widely extended at the demand of conceptors.

It has already been selected for various other applications where the basic requirements can only be fulfilled by this solution.

Examples are:
- Space application: low weight and an unlimited life.
- Cryogenics: low thermal inertia and high reliability.
- Electronic: replacement of viton seals to improve vacuum and cleanliness.

[1] T. Wickberg, 11th International Vacuum Congress in Köln, FEM calculation of UHV AL-Metal demontable joints for LEP.