LATEST DEVELOPMENTS ON VALVE SEAT-SEAL ASSEMBLY

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ABSTRACT

The Helicoflex® metallic seal initially designed for static assemblies is presently used as a valve primary seal for some specific applications where the elastomeric seal commonly used in such configuration becomes totally unsuitable due to low resistance to radiation and high temperature, and incompatibility with ultra-high vacuum conditions.
The hydrogen injection quick valves on JET fusion reactor, as well as the aluminium ultra-high vacuum valves on TRISTAN accelerator already operate using this technique over a rather narrow range of working conditions.
In order to widen the field of applications and establish the basic principles of the sealing function applied to a valve seat-seal assembly, tests were carried out in the Sealing Techniques Laboratory of the French Atomic Energy Commission (CEA).
Seat configuration and seal holding device have been reconsidered. Seals have been tested using different grade of sealing lining material i.e. successively aluminum, silver and copper. In that respect, such assembly configuration was found in full compliance with the requirements of the new types of valve, those which are being considered for applications where ultra-high vacuum is combined with a leak rate requirement of 1.10.e-10 Pa.m3.s-1 and a high bake-out temperature.

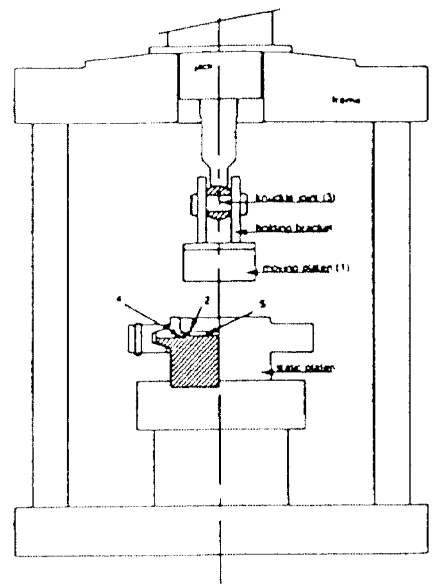
INTRODUCTION

The latest research programs such as ITER, TPX, VIRGO [ref. (a)] require large size valves of about 1.5 m (60 inch) diameter which will have to operate under ultra-high vacuum in a radioactive environment with possible high-energy impurities which can be found in plasma conditions.
Aiming at an appropriate seal design in order to cope with such operational conditions, the purpose of this study is to identify and describe the typical phenomena which characterize the behaviour of a metallic seal such as the Helicoflex® in a repetitive mechanical cycling context.

DESCRIPTION OF THE TEST FIXTURE

Simulation of a plug valve operation is done using a mechanical testing press (fig.1 & fig.2). The moving platen (1) is actuated by an air-operated jack which applies a constant compression load F on the plug seal (2). The knuckle-joint (3) allows the moving platen to rotate on two different axis. A second seal (4) compressed by means of a quick-disconnect system ensures proper tightness between the lower part of the plug seal and the static platen.

The inner volume (5) of the primary seal is connected to a helium leak detector which allows monitoring of seal performance as a function of the number of cycles, measurements being taken after each closing phase from cycle #1 to cycle #10, then at cycle #20, #100, #200, #500, #1000.



TEST FIXTURE

figure 1

DESCRIPTION OF THE SEAT-SEAL ASSEMBLY

The seat-seal assembly comprises a plug (moving platen) which can have its cone angle ∂ modified, and a HELICOFLEX® - HN290 seal type (2) having either aluminum, copper, or silver outer jacket (6), 304L stainless steel inner lining (7) and high strength alloy spring (8).

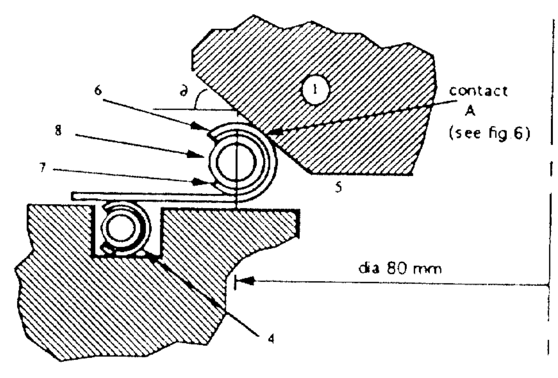


figure 2

DISCUSSION & COMMENTS

The sealing function relies on the quality of the contact between (1) and (2). The typical compression curve (load versus deflection) of the Helicoflex® seal is as shown on figure (3). On that curve appear the 2 points defined as sealing thresholds i.e. ,in the compression phase, Y0 which is the minimum load to be applied to reach the required sealing performance and, in the decompression phase, Y1 which is the minimum load to be maintained on the seal in order not to fall below required performance.

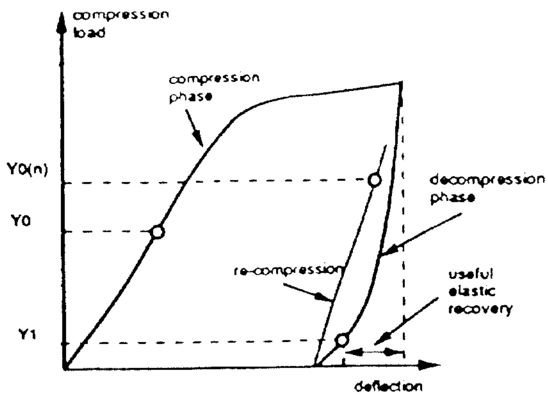


figure 3

Getting to successive compression-decompression cycles of the same seal will show that for each new cycle the Y0(n) threshold is such that Y0(n) > Y0(n-1), with Y0(n-1) relating to the previous cycle.
As a consequence such a seal installed between 2 parallel flat faces cannot be expected to ensure a consistant performance over successive compression-decompression cycles due to the fact that greater and greater load would be required, therefore leading very quickly to a major mechanical limitation of the system.
In order to overcome this "increasing Y0" drawback, it becomes necessary to modify and adapt the geometry of the seat-seal contact.
Let us get back to the parallel-flat-faces configuration as shown figure 4a. It must be noted that the increasing Y0 value relates to the combination of both seal faces i.e. the static face S and the semi-dynamic face N. The overall increase of Y0 value is such that a linear law appears between Y0 and LogC, C being the number of compression-decompression cycles (fig. 4b).

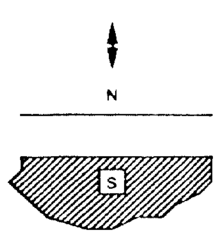


fig 4a

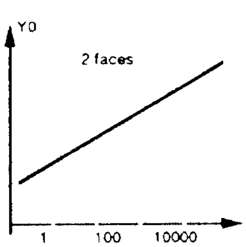


fig 4b

In the present design, one specific feature is that only the semi-dynamic face N is a concern with respect to repeatability, due to the fact that the static face N is actually sealed by means of a static seal which can be either attached to the primary seal or separate. Another specific feature of the system is the non-parallelism of the sealing faces (fig.5a).

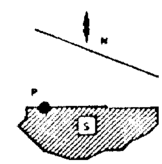


fig 5a

This feature allows the seal to be prevented over numerous compression-decompression cycles from excessive cold-hammering and sealing track widening phenomena. This is actually shown on figure 6 where A being the initial contact point between the moving platen and the seal, the geometric place of this contact point over successive cycles is the vertical segment AA'. As a corollary, figure 6 also shows the actual compression of the ductile jacket material which occurs over segment AB. As a consequence, a rubbing zone BA' appears such that

$$BA' = AB \ tg \ \partial$$

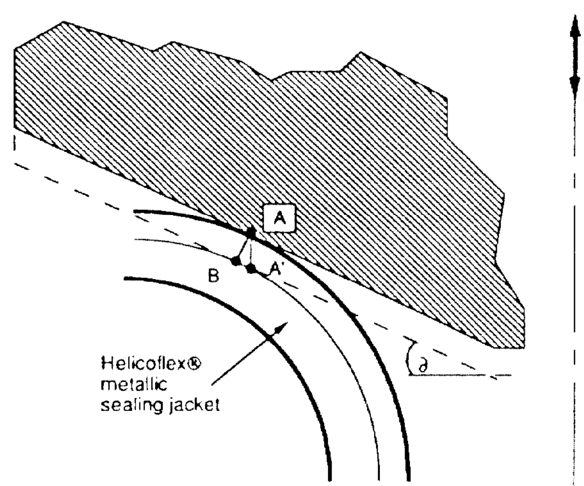


figure 6

At each open-close plug cycle, the length of segment AB is going to increase by a few hundredth of a millimeter due to cold-hammering effect and consequently the width of the sealing track is also going to increase through the constant ratio BA'/AB = tg ∂.

As a result the microgeometrical structure of the seal surface is going to change in such a way that it will be comparable to a polished finish which will tend to be self-maintained cycle after cycle. Such consequence is obviously very much of an advantage with respect to performance consistancy. In actual facts the Y0 threshold mentioned earlier appears to start stabilizing between 1.10.e1 and 1.10.e2 cycles (fig 5b).

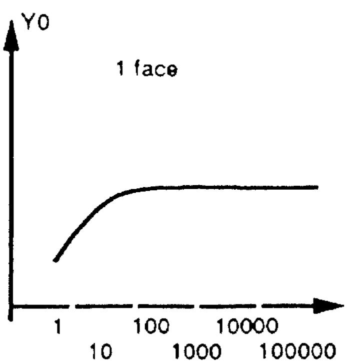


fig 5b

It must be noted that the surface roughness of the conical plug (platen) sealing face should be adapted to help get the polishing effect on the seal. In other words this roughness will have to be neither too low nor too high, which means within the range 0.5 to 1.0 µm.
The operational features described above apply regardless of the type of metallic material considered for the sealing jacket. Extensive tests have especially been performed with Aluminum, Silver and Copper which are typically used for ultra-high vacuum and other high-tech applications.
Two other parameters must be considered in order to optimize and maintain the polishing effect. First the compression load which should be correlated to the jacket material type, and kept constant over the operating life of each given configuration. Secondly and most important the ∂ angle which should be directly correlated to the expected compression (AB) of the sealing jacket which in turns depends upon the ductility of its material. Lower length of AB segment for less ductile material will have to be compensated by a wider ∂ angle so that the rubbing zone BA' remains within the same range.

Experimental values obtained from extensive testing lead to very conclusive results such as a leak rate of 1.10.e-9 to 1.10.e-10 Pa.m3.s-1 per meter of seal circumference over 1000 cycles.

Influence of temperature :
Baking out of subject valves and operational thermal transients generate minor dimensional changes which will be compensated for due not only to the seal springback capacity but also to the self-adjustment of the system occuring at the rubbing zone BA'.

Test data related to 80mm seal : [ref.(b)]

Sealing jacket	Compression load	∂ angle	Sealing performances
aluminum	80 to 120 daN/cm	10 to 15°	1.10.e-10 Pa.m3.s-1
silver	80 to 120 daN/cm	20 to 30°	1.10.e-10 Pa.m3.s-1
copper	90 to 130 daN/cm	25 to 35°	1.10.e-10 Pa.m3.s-1

CONCLUSIONS

Above results allow a better understanding of the working principle of the Helicoflex® seal in semi-dynamic configuration such as the subject plug valve.
Scale 1:1 testing (valve diameters of 1 meter and above) in collaboration with Research Laboratories having interest in such equipment is going to be the next development step for what appears to be a very promising solution.

references:
(a) : ITER : International Thermonuclear Experimental Reactor / LIGO : Laser Interferometer Gravitational Wave Observatory / TPX : Tokamak Physics Experiment

(b) : CEA report : Evolution du debit de fuite d'un joint Helicoflex® soumis a des desserrages et resserrages successifs (March 1994) (by R. de Villepoix - C. Rouaud - Y. Briançon)