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# WHAT JOINING METHOD FOR THE NEW GENERATION OF ACCELERATORS (SSC and LHC)

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*Abstract*

More than 8600 Superconducting magnets will equip the SSC (Superconducting Super Collider) accelerator and about 3000 will be used for the LHC (Large Hadron Collider).Those magnets require a specific piping system with about 10 different lines ranging in diameter from 43 to 150 which are meant to provide ultra-high vacuum and helium cooling down to 1.8°K.

One of the joining method under consideration is welding.

We have developed another solution which allows a quick and ultra-clean joining method, using a chain-clamp on tapered flanges sealed with a HELICOFLEX® resilient metal seal.

## I. OPERATING CONDITIONS OF THE LHC PROTON COLLIDER MAGNETS.

Those magnets will be installed above the existing LEP accelerator built in a 27 km tunnel in Geneva-Switzerland.

To be reached, the 7.7 TeV beam energy implies the use of magnets allowing a magnetic field of about 9.5 T, which have to operate at 1.8°K.

A magnet is built with 2 tubes which are located inside the magnet body and have a 43 mm inner diameter where ultra-high vacuum is created, such configuration being known as the "two-in-one design".The required vacuum level is, for a beam lifetime of 24 hours :

< 2. $10^{-9}$ Torr at 5°K for hydrogen

< 2. $10^{-10}$ Torr at 5°K for carbon monoxide

All around the magnet body, in order to help reaching superconducting mode, there are:

2 tubes of 50 mm inner diameter containing a cryogenic fluid at about 80°K for cooling purposes

2 tubes of 50 mm inner diameter for thermal exchange
2 times 2 tubes of 65 mm and 150 mm inner diameter to carry superfluid helium at 2.2°K and 1.8°K.

All together there are 10 tubes ranging in diameter from 43 to 150 mm which, once joined, must comply with operating conditions as extreme as < 1.$10^{-12}$ Torr (<1.33 $10^{-10}$ Pa) initial vacuum, 1.8°K superfluid helium, and 20 bar helium pressure when a magnet quenches.

## II. EXPECTED NUMBER OF JOINING OPERATIONS

Each one of the junctions is expected to be assembled 3 times over the life of the machine:

-the first time by the magnet manufacturer in order to allow final inspection in terms of performance, i.e. vacuum, superconductivity, and magnetic field

-the second time during construction of the accelerator.

-the third time for eventual modifications of the accelerator which are likely to be decided over an expected operating life of 20 years.

## III. TWO JOINING METHODS CAN BE CONSIDERED

### *A. Welding*

The TIG-ORBITAL welding process is probably one of the most commonly used methods in industry for joining 2 tubes end-to-end in a reliable way.

Without rejecting totally such a solution, it still must be remenbered that connecting superconducting magnets implies specific requirements which this method makes it difficult to comply with. For example testing the magnets means having to weld all junctions and plugs which then have to be cut-off for final installation on the machine. The cut in that case can only be performed in



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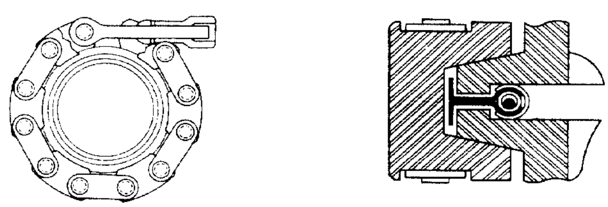
accordance with UHV requirements, that is to say without cutting oil and without any particle getting inside the piping system. Furthermore the welding operations must be carried out without oxidization in order not to have to perform afterwards chemical cleaning of the surfaces. Over the life of the machine similar difficulties will also be encountered whenever on-site modifications are necessary.

*B. A demountable metallic junction: (fig.1)*

In order to overcome the difficulties mentioned earlier regarding the welding and cutting operations, we have developed and tested in collaboration with the CEA (Commissariat à l'Energie Atomique) a joining system the principle of which is already well-known in UHV applications (chain-clamp, tapered flanges, and seal), which allows disassembling-reassembling cycles without ever having to cut the tubes.



## IV. TESTS

*A. Description of the tested system : (Fig 2 and 3)*

A tested junction consists of :

2 - 63 mm- 304L stainless steel tapered flanges,

1 Helicoflex seal having aluminium gr-1050 sealing jacket,

1 stainless steel chain-clamp.
The chain-clamp when being tightened brings the tapered flanges together therefore compressing the seal.

The Helicoflex seal centered by means of metal cups ensures the required tightness by the plastic deformation of its aluminium jacket against the flange faces, the inner spring providing the elasticity needed to keep the performance steady over the operating life .

One of the major aspect of the test is to check the reliability of the system at LHC operating conditions.Tests were carried out at the CENG (Centre d'Etudes Nucléaires de Grenoble)[2] and CEA [1].

*B. Test set-up and procedure:*

Phase 1:

The 3 junctions are installed inside a cryostat having a 300mm inner diameter.The cryostat is successively filled with liquid nitrogen, then liquid helium, then pumped using a turbomolecular pump in order to reach the 1.8K superfluid helium temperature.

The inner volume of the junctions is evacuated to $10^{-5}$ atm at ΔP=1bar and connected to an ASM52 Alcatel leak detector which features a sensitivity better than $1.10^{-11}$ Pa.m3.s-1. The leak rate is permanently monitored over the 300°K/1.8°K/300°K temperature cycle which is repeated 6 times in a row, thus giving test data from 18 different samples. The results are shown in Table 1.

**TABLE 1**
**PHASE 1**
**CENG Test results**

| TEST CONDITIONS | JUNCTION TYPE | SEAL TYPE | CYCLE NUMBER | 300°K | 77°K | 4.2°K | 1.8°K |
|---|---|---|---|---|---|---|---|
| Liquid Helium outside ΔP = 1 bar | ND 63 3 Junctions in series | Helicoflex HL 290 P Aluminum 3.2 mm C.S. | 1 | Et | Et | Et | Et |
| | | | 2 | Et | Et | Et | Et |
| | | | 3 | Et | Et | Et | Et |
| | | | 4 | Et | Et | Et | Et |
| | | | 5 | Et | Et | Et | Et |
| | | | 6 | Et | Et | Et | Et |

**Et = Performance equal or better than 1. 10-11 Pa m3 / s**
**1. 10-11 Pa m3 / s =1. 10-10 atm cm3 / s**

Phase 2:

In order to check further the behaviour of those junctions, an inverted testing arrangement has also been used.

This arrangement, even more stringent than the first one, is such that the junctions are pressurised with cryogenic fluid and installed inside a vacuum chamber connected to a leak detector. Liquid nitrogen is first introduced until 77°K temperature is measured at the thermocouple. Gaseous helium is then brought in instead, while the leak detector is monitoring the vacuum chamber for eventual leak. Then helium pressure is increased up to 25 bar, the leak rate being monitored over the whole temperature cycle (300°K/77°K/300°K) which is repeated 30 times in a row. The results are shown in Table 2.

**TABLE 2**
**PHASE 2**
**CEA Test results**

| TEST CONDITIONS | JUNCTION TYPE | SEAL TYPE | CYCLE NUMBER | 300°K | 77°K | 25 bar He 77°K | 25 bar He 300°K |
|---|---|---|---|---|---|---|---|
| Gaseous Helium Inside | Tapered flanges with flat sealing faces | Helicoflex HL 290 P Aluminum 4.8 mm C.S. | 1 to 30 | Et<br>Et | Et<br>Et | Et<br>Et | Et<br>Et |
| | Special lightweight chain clamp (Tightening Torque 30 m.N) | Helicoflex HL 290 P Aluminum 4.8 mm C.S. with Inner Ring | 1 to 30 | Et<br>Et | Et<br>Et | Et<br>Et | Et<br>Et |
| | Tapered flanges with grooved sealing faces<br>Special lightweight chain clamp (Tightening Torque 30 m.N) | Helicoflex HL 290 P Aluminum 4.8 mm C.S. | 1 to 30 | Et<br>Et | Et<br>Et | Et<br>Et | Et<br>Et |

**Et = Performance equal or better than 1. 10-11 Pa m3 / s (1. 10-10 atm cm3 / s)**

## V. DISCUSSION

Before all, it must be noted that it was decided to use aluminium as sealing material for 2 major reasons which are:

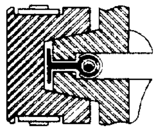
-firstly, pure aluminium is a very ductile metal which, except for indium which finds itself limited by some major drawbacks such as sticking, creeping, quick oxidization,..., has no equal for UHV applications,

-secondly, it was meant to check that this material is compatible with superfluid helium conditions.In that respect, no leak has been observed using aluminium under test conditions i.e. 1.8°K/liquid helium outside junction (see phase 1 results).

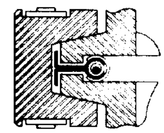
In phase 2 (liquid nitrogen + gaseous helium inside junction), we have checked the behaviour of 3 different configurations , using in each case a CEFILAC® newly-designed light-weight chain-clamp and an aluminium Helicoflex seal having a 4.8 mm cross-section diameter which features high springback capacity to compensate for differential expansion during thermal transients especially during the cooling phases.

The 3 configurations were:

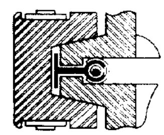
-a) symmetrically grooved flange-faces with metal-to-metal contact as close to tube inner diameter as possible



-b) flat flange-faces with compression stopped by the Helicoflex internal compression limiter-



-c) flat flange-faces with compression stopped by a metal ring located in the void space between Helicoflex inner diameter and tube inner diameter-



In all 3 configurations, no leak has been observed (see phase 2 results)

As a conclusion, we can say that those demountable metallic joining systems are a perfectly suitable solution for the future in the new accelerators using superconducting magnets.

Complying with the most stringent reliability and cleanness requirements, they also allow a much shorter assembling time and make easier any further modification of the machine.

## VI. REFERENCES

[1] CEA : Nuclear Research Center- Rhone Valley -Dpt DCC/DTE/SLC

[2] CENG : Nuclear Research Center- Grenoble -Dpt Cryogenics