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Ricerca di Sistema elettrico

Fabbricazione del sistema Fast Disconnecting System (FDS) per la giunzione delle tubazioni da remoto e validazione delle procedure di manutenzione remotizzata

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FABBRICAZIONE DEL SISTEMA FAST DISCONNECTING SYSTEM (FDS) PER LA GIUNZIONE DELLE TUBATURE DA REMOTO E VALIDAZIONE DELLE PROCEDURE DI AMNUTENZIONE REMOTIZZATA

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Indice

Sommario

L' International Fusion Materials Irradiation Facility (IFMIF) è provvisto di un target a litio fluido per la produzione del flusso neutronico necessario ad irraggiare i campioni di materiale da impiegare nei futuri reattori a fusione nucleare. Le severe condizioni di lavoro a cui tale componente è soggetto impongono che esso venga sostituito ogni anno, durante la fase di stop dell'acceleratore, a titolo di manutenzione preventiva. Tale operazione di manutenzione preventiva deve essere completata entro un tempo massimo di 168 ore (1 settimana) e ciò al fine di garantire la disponibilità d'impianto prevista per IFMIF che è del 70%. Per facilitare ed accelerare le operazioni di sostituzione il target è stato progettato e realizzato il prototipo di un dispositivo utilizzato per la connessione delle tubazioni del target stesso con l'impianto a litio, chiamato Fast Disconnecting System(FDS), che permette la chiusura e l'apertura di tutte le connessioni manovrando un numero limitato di bulloni (tipicamente da 1 a 3 per ogni connessione). Il prototipo realizzato riguarda quello relativo alla connessione delle tubazioni d'ingresso del target stesso, ma tale progetto di connessione è facilmente, con poche modifiche, adattabile alle altre connessioni aventi dimensioni differenti. Il dispositivo FDS, utilizzato al posto delle tradizionali flange bullonate o saldate, consente di disconnettere il target di IFMIF dalla restante parte dell'impianto in qualche ora ed il suo completo rimpiazzo, entro il tempo limite delle 168 ore previste, con un ampio margine di sicurezza. Esso è costituito da cunei tra loro connessi per mezzo di maglie. I cunei, che si chiudono attorno alla flange dei tubi da connettere come una catena, esercitano la forza di schiacciamento necessaria sulle due flange. La tenuta tra le due flange è realizzata per mezzo di guarnizione metallica. Considerato l'ambiente in cui tali componenti operano particolare attenzione è stata posta alla scelta di materiali da impiegare e ai sistemi di sicurezza da implementare. Il prototipo di FDS realizzato è infatti provvisto di:

- un sistema di mantenimento in posizione del meccanismo FDS;
- un sistema di rilevamento fuga litio;
- un sistema di distacco delle flange in caso di fenomeni di adesione delle stesse;
- un sistema di apertura di sicurezza dell'FDS in caso di bloccaggio di una delle viti di manovra;
- un sistema per la completa rimozione dell'FDS stesso.

Al completamento della fabbricazione il prototipo dell'FDS è stato sottoposto ad una serie di collaudi per verificare il pieno soddisfacimento delle specifiche tecniche. In particolare sono state testate tutte le funzionalità su elencate oltre alla verifica della possibilità di gestione tale dispositivo da remoto.
Alla fine dei test il prototipo dell'FDS è stato assemblato sul prototipo del target assembly che sarà utilizzato per le prove di validazione delle procedure di manutenzione di tale componente.

1 Introduction

The International Fusion Materials Irradiation Facility (IFMIF) will be equipped with a lithium target assembly to produce the required neutron flux for the irradiation of candidate fusion materials up to a damage rate of 100 dpa. The present European target assembly design is based on the so called replaceable backplate bayonet concept that was developed with the objective to simplify the maintenance operations for its refurbishment/replacement and to reduce the material for disposal as well. To this purpose it was also conceived to be attached to the lithium pipes and to the beam line by means of remotely operated connections based on clamped flanges with sealing metal gaskets. Accordingly, a custom design of this remotely operated connection, named Fast Disconnecting System (FDS), has been developed for the inlet flanged connections of the European IFMIF target assembly system. The FDS is based on a commercial chain, which provides the required tightening force for sealing of the edge of the flanges, that can be locked/unlocked by means of a reduced number of screws. The designed FDS prototype is provided with several additional features, to satisfy the operational working condition foreseen for IFMIF in terms of functionalities, safety and maintainability. A prototype of the FDS has been manufactured and, based on the preliminary tests carried out, its suitability to remote handling of the system has been proved. In the following chapters a description of the design of the FDS is given together with the outcomes of the remote handling validation tests.

2 Description and outcomes of the activities

2.1 The EU Target Assembly concept of IFMIF

The present EU Target Assembly (TA) design (Fig 1), typically identified as the backplate bayonet concept [1,2], is based on a removable backplate to have the possibility of inserting and removing it without dismounting the TA from the Test and Target Cell (TTC). Due to the extreme operating conditions of the TA components (due to neutron irradiation and heat transfer with hot lithium flow) its substitution is expected to be carried out at least every year, and to fulfill the stringent requirement of the IFMIF plant availability maintenance of the TA has to be completed within 7 days.

To this purpose the EU TA concept has been conceived to be attached to the lithium loop and to the beam chamber by means of Fast Disconnecting Systems (FDSs) which allow a quick TA replacement operation. A prototype of the FDS system for the inlet pipe of the IFMIF TA has been designed, manufactured and tested.

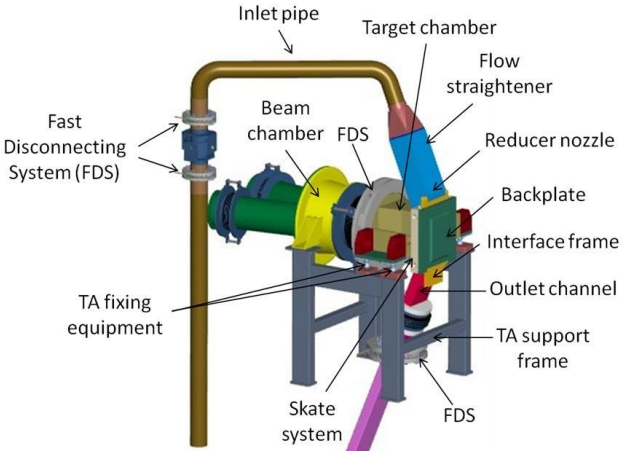


Figura 1. The European concept of IFMIF Target Assembly.

2.2 The Fast Disconnecting System

The scope of the FDS system is to have a remotely operated connection to be placed on the liquid lithium piping and ensuring the same functionality of the standard flanged connections.
The main requirements for the design of the FDS are listed in the table. 1[3]

Table 1 Design requirement for the FDS

Item	Requirement
Operating temperature	250° C
Design temperature	350°C
Environment	Lithium in contact
Internal operating Pressure	0,2 MPa
External pressure	0,5 KPa -0,1 MPa
Bolting points	1
Pipes dimensions	6 inch - sch. 40
Clamps reference	EVAC (Swiss)
Type of gasket	Metallic gasket
Load on the gasket	170 N/mm
Max Leak (He)	$< 10^{-7}$ Pa m^3 / s
Torque max for sealing	As low as possible
Insulation Temperature	350° C → 50°C
Insulation material	Pyrogel XT (TBC)

A 3D model of the FDS design is shown in Fig. 2

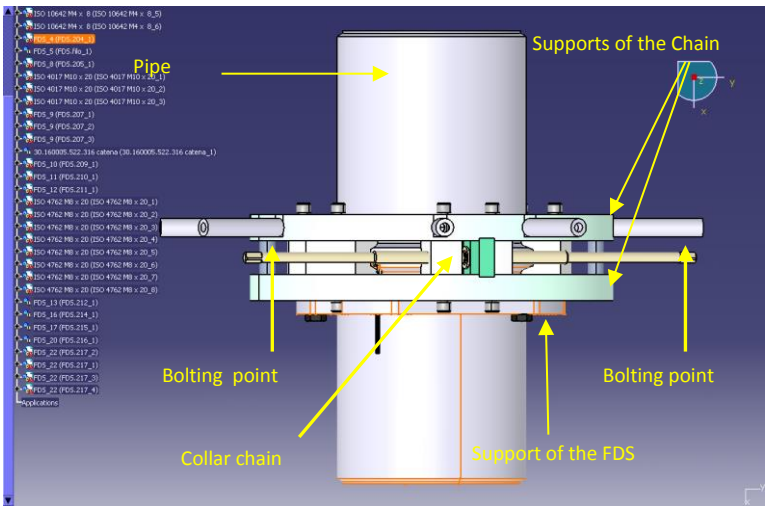


Fig. 2 3D model of the FDS

It consists of a collar chain that provides, through a number of wedges, the pushing force to be transmitted to the gasket for the sealing of the flanges. The opening and closing of the chain mechanism is obtained by maneuvering only a reduced number of bolts . Number of bolting points depends from the dimension of the flanges to be connected. The FDS designed for the connection of the inlet pipes of the TA has been designed with only one bolting point. Considering the environment in which this system will work particular attention was put in the design of the emergency systems: the FDS design has to fulfil the requirements for a safer and reliable operation. Accordingly the FDS design comprises the following features:

- a supporting plate for the system replacement;
- a Li leak detection system;
- emergency unlocking systems which allow the FDS opening in case of failure;
- a flanges detachment system;
- a retention system of the gasket during the removal.
- Metallic sealing system
- Low tightening torque.

A prototype of the FDS for the connection of the inlet pipes of the TA of IFMIF has been manufactured. In Fig. 3 all the sub components of the FDS are shown. The FDS is entire made in AISI 316L.

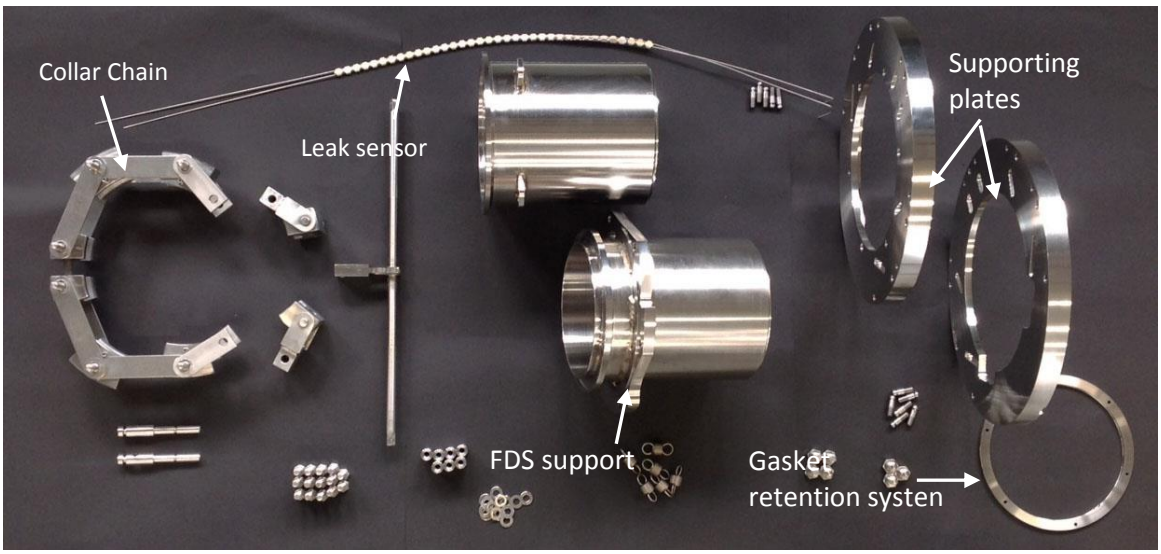


Fig. 3 FDS components

Here below a description of the main components and features of this system is given.

2.2.1 The clamp collar chain

The collar chain comprises a number of wedges connected by means of links and axes. The tightening of the chain is obtained by means of one shaft accessible from two sides. To prevent any seizure of the shaft during the locking/unlocking operations of the FDS, it will be coated with antifriction coating material (coating material not yet decided, but today the most promising are the Dicronite or molykote for high temperature). The clamp collar chain used is a market component of EVAC AG (Switzerland) . It is shown in Figs. 4,5.

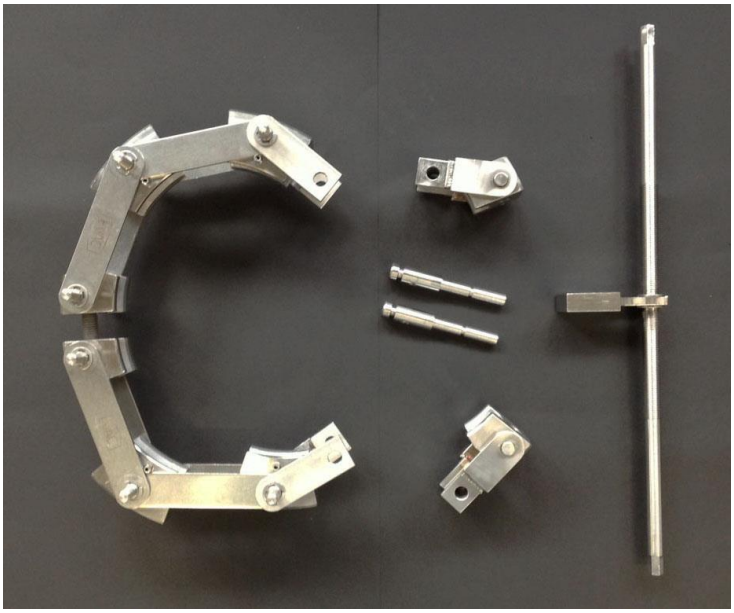


Fig. 4 Evac chain collar modified

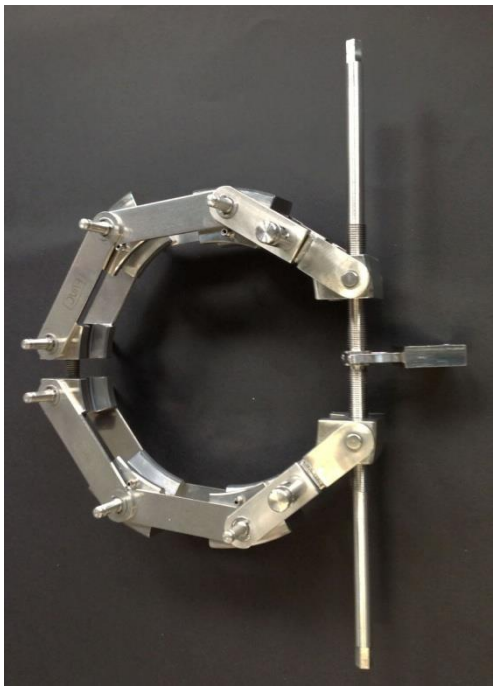


Fig. 5 Chain collar assembled

It should be pointed out that the original design of the chain has been modified to meet the FDS requirements and to comply with the requirements to Remote handling as well.
The model of the channel adopted is of the series *ISO-CeFix* whose characteristics are:

- Extreme performance applications with particular attention to nuclear.
- Ultra wide temperature range from -270 to 450 deg C.
- Suitable for overpressure up to 100 bar.
- Suitable for ultra high vacuum up to 10E-11 mbar.

2.2.2 *Supporting plates of the collar chain*

The main scope of the supporting plates are to keep in position the clamp collar chain during the opening and closing operations. To this purpose they hold a number of slots (vertically and inclined oriented) connected with the chain by means of pins. The design of the slots takes into account that the FDS can be installed in vertical, horizontal and inclined positions. The supporting plates are shown in Fig. 6.

Fig. 6 FDS supporting plates

In case of emergency a number of springs drive and help the axes of the collar chain to follow the guide directions up to the end mechanical stop and allowing the release of the two flanges.

2.2.3 *Main flanges*

The main flanges of the FDS system are two: a “base” flange and a “removable” flange (see Fig. 7). Each flange includes a conic profile in order to comply with the wedges of the collar chain.

Once released the clamp collar chain, the removable flange can be easily removed being totally free from the clamp collar sections. On the base flange is welded a collar ring for the connection to the supporting plates group. In fig. 7 it is also shown the chain supporting plate.

The flanges have an internal diameter of 153 mm (6 inches) with a thickness of 7,50 mm.

Fig. 7 main flanges

2.2.4 The FDS detachment/tightening system

The standard opening and closing operations of the chain, in order to detach/tight the two main flanges, are obtained by rotating the main screw as shown in Fig. 8.
To detach the flanges all the clamp collar sections are totally enlarged to their end stroke, has shown in fig. 9, and the "removable" flange is ready to be detached
The tightening operation is the inverse of the detachment one. The locking of the two flanges is obtained by a torque of about 30 N/mm.

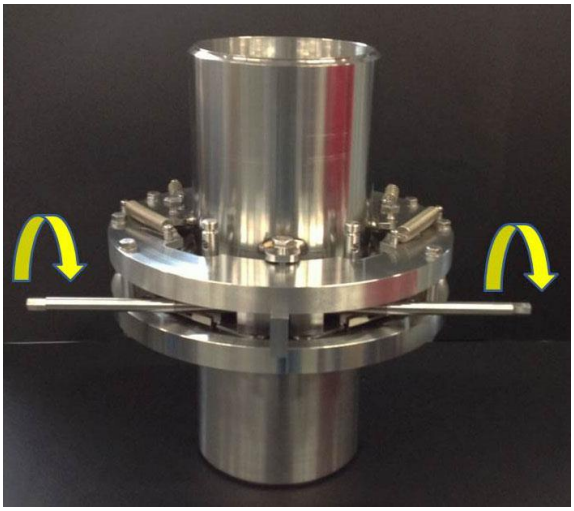


Fig. 8 FSD prototype

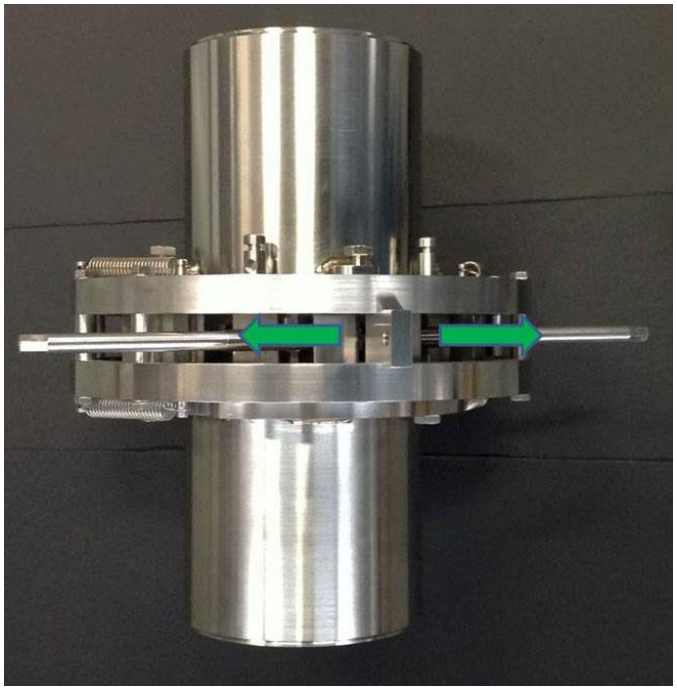


Fig. 9 opening operation of the collar chain

2.2.5 The leak detection system

The leak detection device is one of the most important safety system implemented for the FDS. In fact it is used to get an alarm in case the liquid lithium would flow out of the sealing gasket. The device is simply composed by two metal wires inserted in a series of ceramic spacers. The choice of this detection system is based on the possibility to form a collar that is positioned just outside the sealing system of the two main flanges (see Fig 10). Being the ceramic spacers, not fully closed, in case of loose of Li liquid, the two metal wires would close a circuit getting a consequent alarm. Dimensioning of this system takes into account the following aspects:

- the response time has to be as low as possible;
- sensitivity of the system in terms of minimum detectable amount of lithium leakage.

No tests of this system has been carried out in lithium environment. However this technique was developed and extensively used in NA environment and we are confident that its use in IFMIF is possible. Nevertheless further investigations are required.

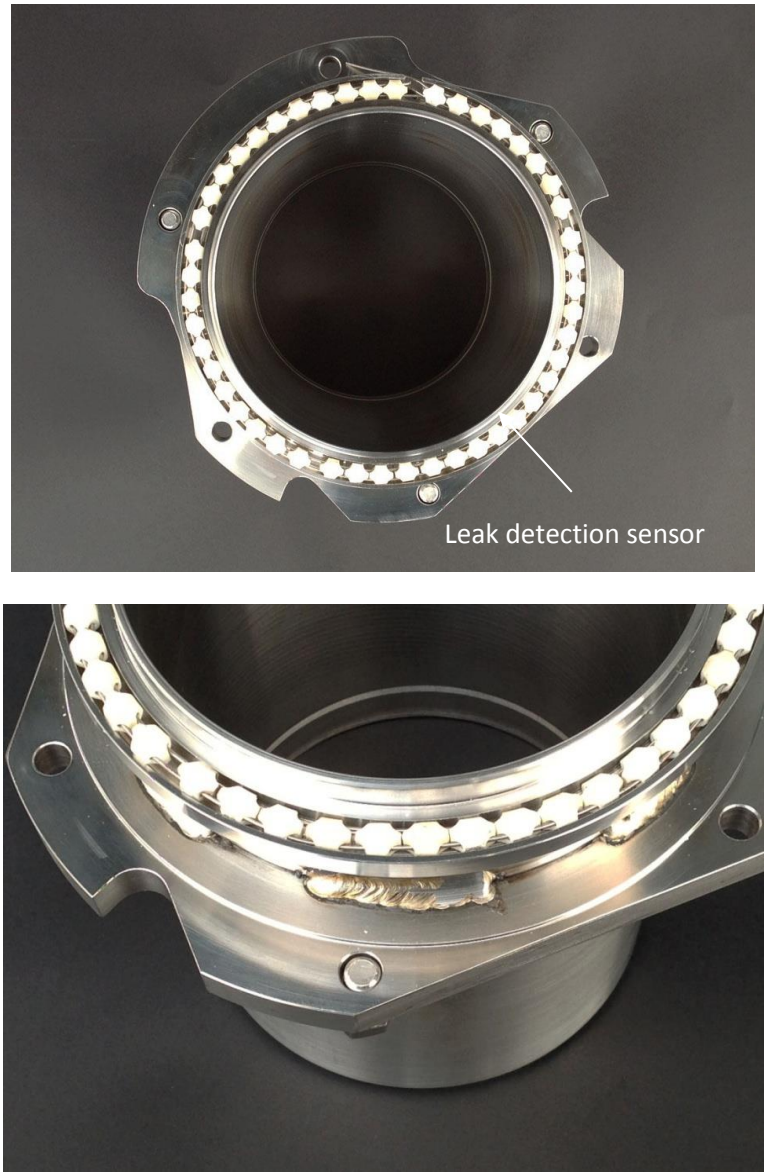


Fig. 10 leak detection system.

2.2.6 Emergency unlocking and flange detachment systems

Since the FDS in operation has to be handled remotely, emergency procedures have been developed and two emergency features implemented. Two operative cases are considered critical: the seizure of the manoeuvering screw and the sticking of the flanges.

The seizure of the manoeuvering screw is the most critical failure because the pipes jointed cannot be opened. To this purpose the FDS has been provided of a couple of pins that can easily removed by pulling the pins out. This mechanism is shown in Fig. 11. The procedure to open the FDS in case of failure has been implemented, as follow:

1. The collar in the rear part is provided with a screw that can be released (see fig. 12). The first action is to unscrew this screw. The torque normally required for this unscrewing operation is of about 6 Nm.
2. In the second step of the procedure the pins can be extracted (see Fig. 11).

As a consequence of the extraction of the pins, the clamp collar sections are free and pulled to their opening position by dedicated springs.

The “removable” flange is therefore totally free to be removed.

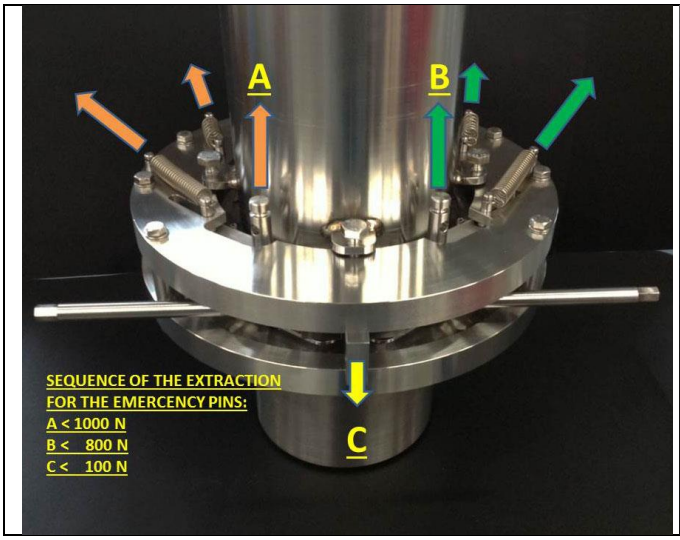


Fig. 11 Emergency opening system

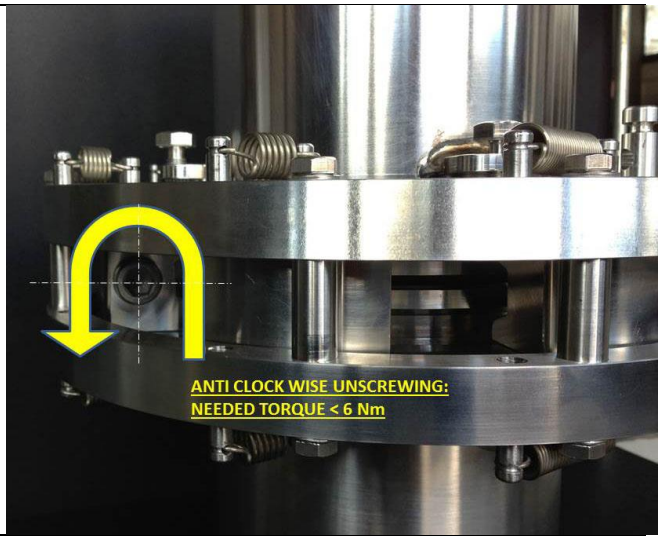


Fig. 12 Emergency opening system

As for the sticking of the flanges due to the solid lithium between the flanges themselves, four bolts have been attached to the upper pipe of the FDS which act on the upper supporting plates (see fig. 13)

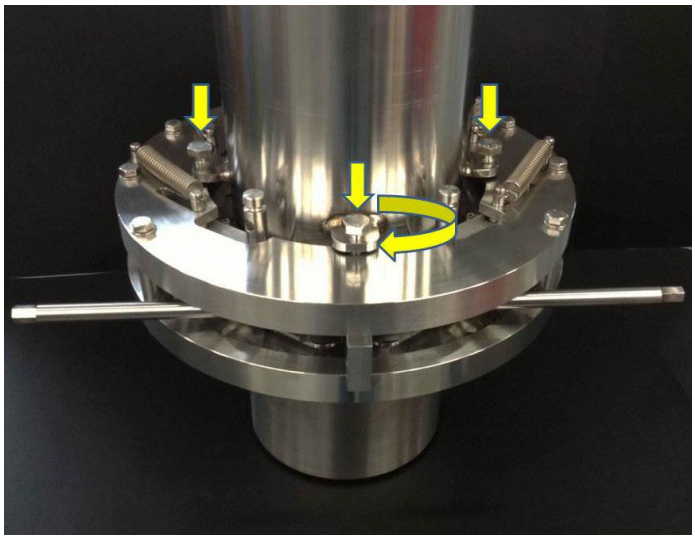


Fig. 13 Flanges detachment system in case of sticking.

2.2.7 The sealing system and the retention system

The Main requirements for the selection of the gasket are:

- Max leak admitted 10^{-7} [Pa $m^3 s^{-1}$];
- Material compatible with lithium;
- Low compression force (170 N/mm);

Accordingly the sealing system is based on a Helicoflex gasket HN type in soft Iron for nuclear application. The selected is HN200 Soft Iron/Nimonic90/AISI 304. Compatibility of the gasket materials with lithium was proved at ENEA Brasimone laboratory and up to 7000 hrs no leakage was observed.

The seating groove of the sealing system has been designed to host a gasket working by axial compression. In order to proceed with the leak test and to evaluate the performance of the FDS a custom sealing system , shown in fig. 14, was manufactured. Here it is shown also the ring used as gasket retention system. This system is extremely important during the installation d removal phases of the removable flange: during the installation of the flange it prevents the fall of the gasket from its seat, while during its removal, due to the

potential sticking of the two flanges, it keeps firmly attached the gasket to the removable flange.
The FDS has been fully tested by Helium as gas tracer and a directly connected Mass Spectrometer settled for mass 4. The adopted instrument for the test is a Balzers HLT160 with an external auxiliary vacuum pump having a nominal capacity of 12 [m3/h]. The auxiliary vacuum pump is a double stage, oil lubricated vane type.

Fig. 14 Components of the sealing system

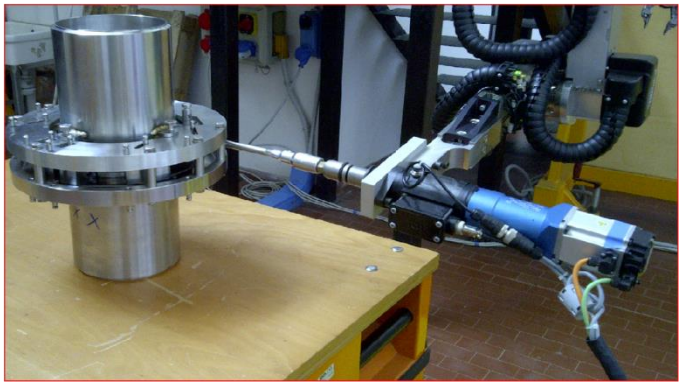
Fig. 15 Assembly of the sealing system

2.3 Remote handling tests

The FDS has been designed to be remotely operated. Thus the validation of all the remote handling operations to be carried out on this component is mandatory[4]. A series of preliminary tests has been carried out. A complete validation of the system can be completed only after its installation on the Target prototype. The following remote handling operations were tested:

- opening and closing of the system;
- flanges detachment in case of sticking of the flanges themselves;
- opening of the collar in case of failure.

In Figs. 16 the closing and the emergency detachment operations for the FDS are illustrated.



Closing operation of the FDS

Emergency detachment operation of the FDS

Fig. 16 Remote handling operations

The test performed proved the suitability of this system to remote handling: opening and closing operations are rely simple to be carry out as well as for the emergency detachment system. However a number of modifications were identify for the improvement of the FDS, like:

1. the availability of dowel pins and holes on the base flange and on the removable flange respectively, and between the supporting plate of the FDS and the supporting plate of the collar chain ;

2. the reduction of the dimensions of the leak detection system;

3. the lighten of the supporting plates of the chain since they do not play any heavy structural function and then they could be made by aluminium, for instance .

3 Conclusions

A prototype of a FDS system for the inlet pipe of the IFMIF Target assembly has been designed, manufactured and tested during the period from October 2012 to September 2013. The FDS design integrates several features for the handling of this components remotely. The design includes also a number of functionalities to renew the normal operating conditions in case of failure. On the basis of the preliminary tests performed the effectiveness of this system to be used in IFMIF was proved including the suitability to remote handling. For this latter scope the fully validation will be completed during the remote handling test campaign for the refurbishment of the target assembly. The outcomes of those tests have highlighted specific issues to be solved for the improvement of the FDS design. The modifications to the present design and new features are now going to be implemented on the new FDS system for the Outlet pipe of the IFMIF Target assembly.

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