



Agenzia nazionale per le nuove tecnologie, l'energia
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RICERCA DI SISTEMA ELETTRICO

Rapporto sulla progettazione dei sistemi di connessione rapida per tubazioni denominati FDS

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Report RdS/2012/262

RAPPORTO SULLA PROGETTAZIONE DEI SISTEMI DI CONNESSIONE RAPIDA PER TUBAZIONI DENOMINATI
FDS

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Abstract

The International Fusion Materials Irradiation Facility (IFMIF) will be equipped with a lithium Target Assembly (TA) to produce the required neutron flux for the irradiation of candidate fusion materials up to a damage rate of 100 dpa (cumulated damage in five years). Due to this severe operating condition the TA has to be refurbished at least one time per year. Nevertheless this maintenance operation could be required more frequently. The design for remotely operated connections of the bayonet target is focusing on the use of clamped flanges with a sealing metal gasket.

Accordingly the European IFMIF Target assembly system has been designed to be connected with the main lithium pipes and to the beam line by means of Fast Disconnecting System (FDS). So far similar systems, already commercially available, have been used for several types of applications including nuclear ones, even if never used neither under the IFMIF like operating conditions nor fully remotely. This document defines the design requirements of the FDS to satisfy the operational working condition foreseen for IFMIF in terms of functionalities, safety and maintainability .

In particular this document describes the design of the FDS for the connections for the inlet pipe of the IFMIF Target Assembly.

Introduction

The International Fusion Materials Irradiation Facility (IFMIF) will be equipped with a lithium Target Assembly (TA) to produce the required neutron flux for the irradiation of candidate materials for the future fusion power reactors up to a damage rate of 100 dpa (cumulated damage in five years). Due to this severe operating condition the TA has to be refurbished at least one time per year. Nevertheless this maintenance operation could be required more frequently. Two concepts of TA are under design: the TA with integrated backwall, known also as Integral Target (IT), in Japan, and the so called Bayonet TA, which is provided with a removable bayonet backwall, in Europe. Among the differences between the two target concepts there is the connection type of the target with the Li loop and the accelerator beam.

The design for the remotely operated connections of the IT is focusing on:

- Clamped flange connection with lip-seal for direct exposure to the Li liquid
- Clamped flange connections with a sealing metal gasket for exposure to the gas phase.

The design for remotely operated connections of the bayonet target is focusing on the use of clamped flanges with a sealing metal gasket.

Accordingly the European IFMIF Target assembly system has been designed to be connected with the main lithium pipes and to the beam line by means of Fast Disconnecting System (FDS). So far similar systems, already commercially available, have been used for several types of applications including nuclear ones, even if never used neither under the IFMIF like operating conditions nor fully remotely. This document describes the design of the FDS to satisfy the operational working condition foreseen for IFMIF in terms of functionalities, safety and maintainability.

The European Target Assembly concept

The present EU TA design, based on a removable backplate, the so called backplate bayonet concept, is illustrated in Fig. 1. It was designed with the possibility of inserting and removing the backplate without dismounting the TA from the Test Cell (TC).

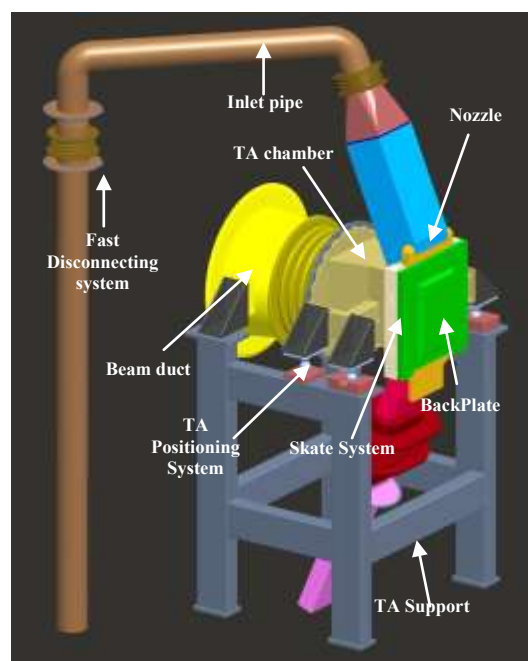


Fig. 1 3D view of the EU TA

A special locking system was developed in the past to provide the demanding force required on the backplate to maintain the vacuum gradient between the target chamber and the TC, and to prevent any Lithium leakage. Sealing of the target chamber is ensured by metallic gasket. The locking system consists of two skates located in the lateral sides of the Backplate itself and of 8 bolts, four located on the upper and four on the lower sides. The EU TA is attached to the Lithium loop by means of Fast Disconnecting Systems (FDSs) which allow a fast TA replacement. This system was introduced with the objective to simplify the TA exchange operations. It is well known that the TA replacement has to be completed within one week during the annual preventive maintenance phase of IFMIF and this system could be the solution. All the flanged connections of the TA, including the backplate, are provided of a Lithium leak detection system. Attention has been paid in the design of the TA positioning and supporting system, a crucial system to keep the TA in position during the heating up phase and irradiation. This position system is extremely important since the closeness with the High Flux Test Module (HFTM) and during the above mentioned phases deformations or motions of the Target assembly could cause its impact on the HFTM. Detail on the present Target design is given in [1].

The Fast Disconnecting System (FDS)

The FDS system hereinafter described is related the connection of the inlet pipe of the TA. Further developments are required to adapt it to the others two TA’s connections with the Li loop (the outlet pipe) and with the duct beam (vertical connection).

Design requirements

The design requirements for the FDS for the inlet connection are summarized in the Tab.1.

Tab.1 Design requirement of the Inlet pipe connection of the TA

Position	Item	Requirement
Inlet pipe (see-fig 5)	Operating temperature	250° C
	Design temperature	350°C
	Environment	Neutron + photon fields and Lithium in contact
	Internal Pressure	Low pressure (2 bar)
	External pressure	50 mbar (inert gas)
	Bolting points for inlet	1 or 2 (MAX)
	Pipes dimensions	6" /T= 40
	Flanges dimension	DN 200
	Clamps reference	EVAC (swiss)
	Type of gasket	Helicoflex® type (metallic gasket)
	Load on the gasket	Low seating load is preferable

	Max Leak (He)	$< 10^{-7} \text{ Pa m}^3 / \text{s}$ (He test)
	Torque max for sealing (inlet)	As low as possible
	Insulation Temperature	250° C → 50°C
	Insulation material	Suitable for nuclear application. No pollution, no dust
	Max relaxation admissible	to stay within a safer margin for the tightening of the system
	Seizure prevention of the bolt driver	Use of antifriction material for nuclear application

In addition the system has to be integrated with the following functionalities:

- easy replacement of the FDS itself in case of failure or reduced life time
- easy replacement of the insulation system
- detection of Li leak
- retention of the gasket during installation and removal of the target
- handling of the system even in vertical position.

Description of the Fast Disconnecting system

The FDS consists of a chain that provides, through a number of wedges, the force needed for the sealing of the flanges; opening and closing of the chain mechanism is obtained by maneuvering up to three screws (number of screws depends from the dimension of the connection). The FDS is entire made in SS316L.

The fast disconnecting system designed is shown Fig. 2

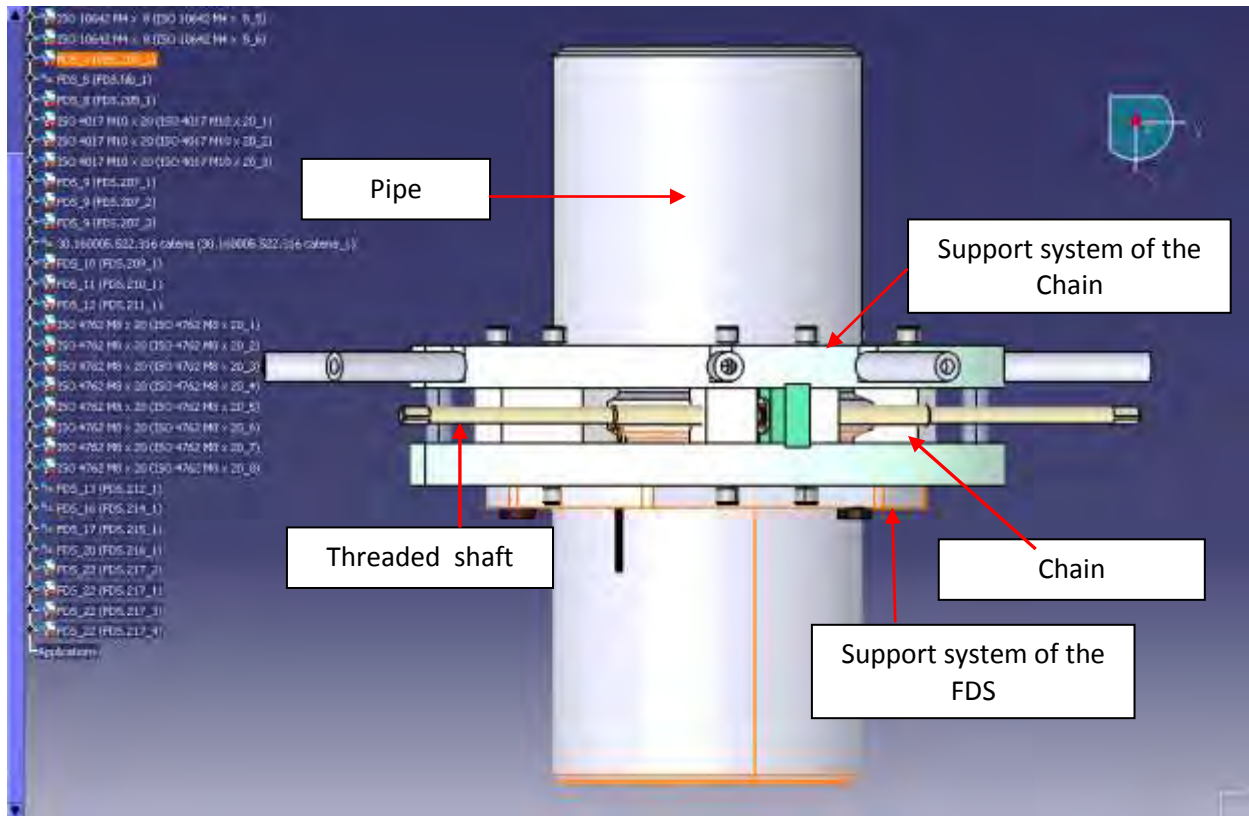


Fig. 2 Fast Disconnecting system

It consists of:

The chain that provides the required tightening force to seal the edge of the flanges. A commercial one, used in this project is shown in Fig. 3. The chain, entire made by SS316L, comprises the clamps connected by means of links and the thread shaft for tightening the chain itself.

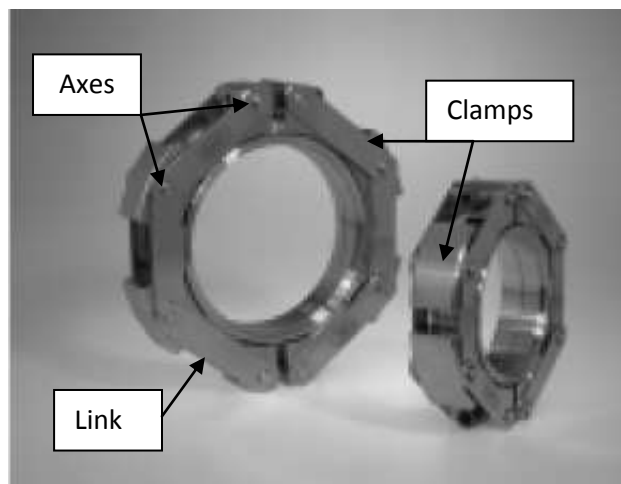


Fig. 3 Chain, commercially available- EVAC Swiss, used in this project

To avoid seizure of the shaft during closing/opening of the chain it will be coated with antifriction material (at present material is not yet fixed but Dicronite is one of the candidate). The tightening of the chain is obtained by means of one shaft that can be accessed from two sides. The chain actually used is from EVAC (Switzerland).

Supports of the chain

They have been designed with the objective to keep in place the chain and to help the chain itself to follow the direction for its opening and closing motion. A view of the support is given in Fig. 4

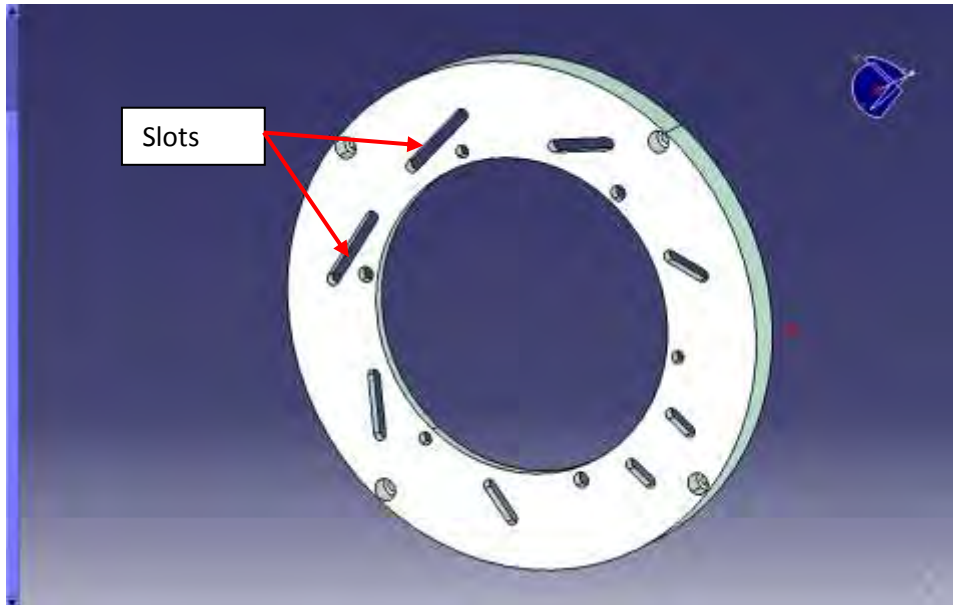


Fig. 4 Support of the chain

The support holds a number of slots (vertically, horizontally and inclined oriented) connected with the chain by means of axes. The design of the slots takes into account that the FDS can be installed in vertical and in horizontal position. Fig. 5 shows the how the chain is accommodated on the support.

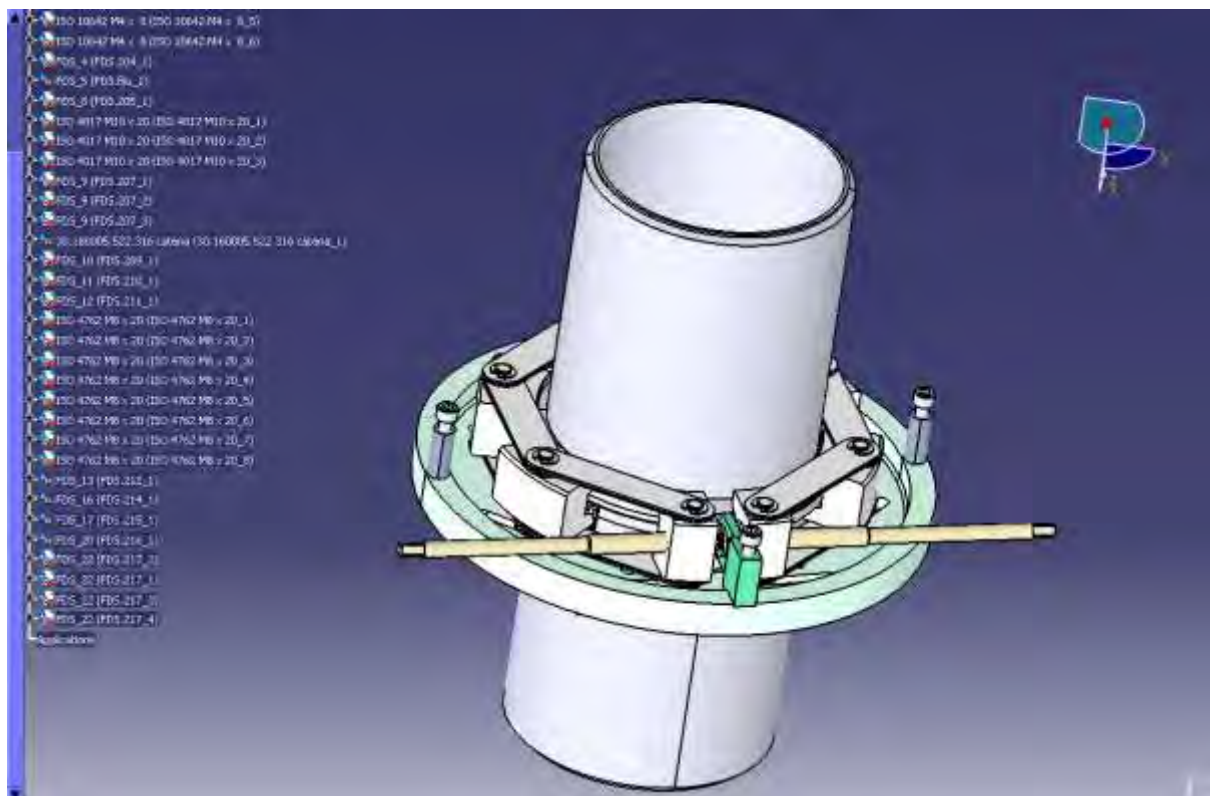


Fig. 5 Chain connected with the supporting plate.

Support system of the FDS

This system is shown in fig 6. It consists of a plate located on the bottom of the support of the chain and it is welded on the outlet pipe. Function of the system is to allow the replacement of the FDS in case of failure. This feature has to be guaranteed for safety reason: the system has to be replaceable in any case. The plate of the FDS's chain is blocked onto this supporting plate by means of screws. To ensure the alignment of the two plates they are provided of holes and pins, as shown in fig. 7.

Lithium leak and sealing systems

These are among the main features concerning the safety operation of the Li loop. Accordingly the FDS system has been equipped with a leak sensor to detect Li leakage at an early stage. This detection system is based on simple electric switch that in case of lithium leakage closes the contacts of the switch itself in short circuit.

The lithium leak is accommodated between the flanges and as close as possible to the gasket. Among the main requirements to be fulfill by this system there are: the response time that has to be as low as possible and the sensitivity of the system in terms of minimum detectable amount of lithium leakage. These two features, still under study, depend from the dimension of the detection sensor.

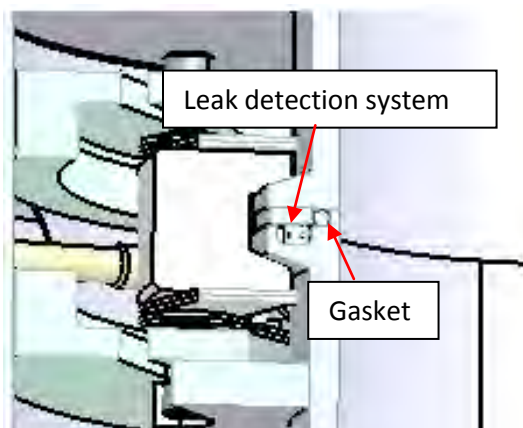


Fig. 8 Leak detection system of the FDS and layout of the flanges



Fig. 9 leak detection system implemented

A view of this system and its position is given in fig. 8. While in fig. 9 it is shown the system implemented for the FDS. The system shown in fig 9 is based on a ceramic support as insulator and two cables for the electric circuit. This system was used in the past as leak detection system in Sodium.

The sealing system is based on a metallic gasket from Helicoflex. The selected one is the type HN (radial compression) having an external jacket in soft iron, a spring in inconel x750 and the outer jacket in SS 304. The suitability of the external jacket material to Lithium was proved in the past. Test of the gasket (HN200)

was performed over 2000 h of exposure at 350°C and no leakage or extended corrosion were found. Fig. 10 shows the post analyses performed on the gasket.

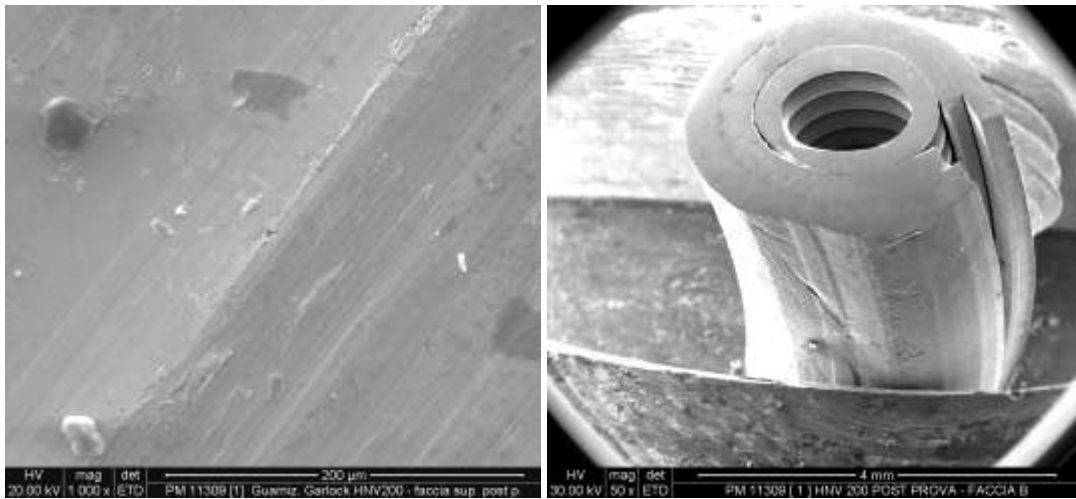


Fig. 10 Test of the external jacket material of the Gasket.

Use of gasket for radial compression has the advantage of reduce the torque to be apply on the screw of the FDS. Based on the type of gasket selected (radial compression) the torque to be applied for sealing the edge of the flange is of about 120 Nm.

Retention of the gasket

During the operation the lithium could come in contact with the gasket and at the shutdown of the system lithium solid deposition could remain on the gasket itself causing also its sticking on the flanges. To prevent this issue the system has been provided of a retention system to keep the gasket always attached to the flange on the target side. The gasket is blocked in the groove by means a thin circular plate and bolted to the flange.

Insulation system

All the pipes and components of the TA system will be insulated. However the FDS is designed to allow the replacement of the TA. Accordingly the FDS is designed is such a way that the insulation can be removed together the target. In Fig. 11 it is shown a section of the FDS where is highlighted how the insulation is removed with the TA. The insulation has been realized in three pieces: two pieces are attached to the inlet and outlet pipes of the connection and one is attached to FDS mechanism.

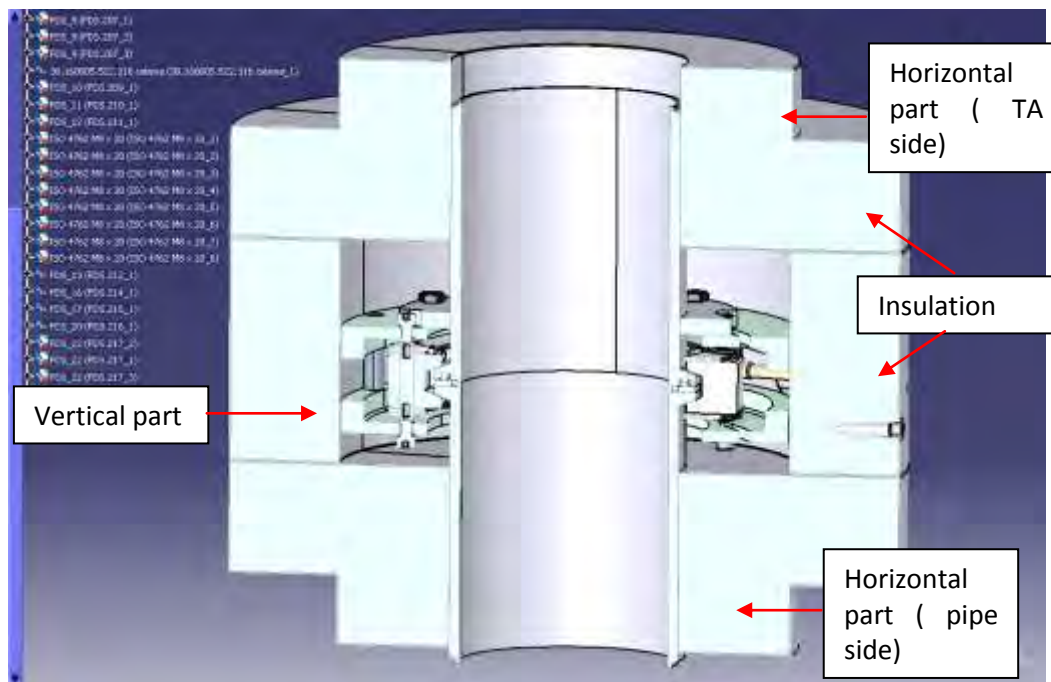


Fig. 11 Insulation system of the FDS

The circular one, that is accommodated around the FDS structure, has been divided in four pieces. The four pieces around the FDS structure are attached by means of screws easily accessible from outside –see fig 11. This allows their replacement and a fully accessibility to the FDS. Insulation material has to be compatible with the nuclear environment. This is still an open point. In any case among the main requirements of the insulation material there is that it has not to release any pollution or dust that can block the bolting system or contaminate the environment itself.

Qualification of the FDS

The activity shall be aimed at the qualification of the system from the RH point of view. The following activities and tests will be performed at ENEA Brasimone Research centre:

- 1) Development of the procedures for the whole remote handling operations to be performed;
- 2) Test of the main functionalities of the system;
- 3) Preliminary remote handling trials and optimization of the procedures;
- 4) Long term Remote handling trials and final qualification of the system.

In particular the following procedures and operations will be developed and tested:

- 1) Removal of the upper part of the FDS together with the pipe (this is a simulation of the TA replacement);
- 2) Removal and installation of the insulation;
- 3) Removal and installation of the FDS;
- 4) Test the repeatability of the connection system;
- 5) Test the opening operations of the FDS in case of seizure of the threaded shaft;
- 6) Test of the suitability of the detachment system

Outcomes of these activities will give a feedback to the designer for the improvement of the FDS design. The qualification activity will start in November 2012.

Conclusions

The TA of IFMIF needs to be replaced every year during the preventive maintenance period whose duration is 20 days and of which 7 days are for the maintenance of this component. To fulfill this stringent requirement the FDS system has been developed by ENEA in collaboration with an Italian Company. The designed system integrates all the features needed to guaranty a safer use of this system: a leak detection system; a sealing system based on metallic gasket; a detachment system to separate the two flanges in case of their sticking and finally a backup system to open the chain of the FDS in case of seizure of the threaded shaft. Testing of the system to prove its suitability to remote handling is expected early in November 2012

Riferimenti bibliografici

[1]- Rapporto preliminare del progetto del target di IFMIF comprensivo di disegni, analisi numeriche e valutazione dei costi-D. Bernardi, M. Frisoni, G. Micciché, T. Pinna, M.T. Porfiri, M.Serra

Abbreviazioni ed acronimi

FDS Fast Disconnecting System

TA Target Assembly

TC Test Cell