Remote disconnection system for the beam dump of the LIPAc accelerator

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ABSTRACT

The International Fusion Materials Irradiation Facility (IFMIF), will be a test facility in which candidate materials for the use in fusion reactors can be fully qualified [1]. The LIPAc (Linear IFMIF Prototype Accelerator) is a prototype of one of the two IFMIF accelerators [2]. Its objective is to validate the low energy part (9 MeV) of the IFMIF linacs (40 MeV, 125 mA of D+ beam in continuous wave). It will not have a target and hence a dump is needed to stop the deuteron beam.

The LIPAc BD (Beam Dump) which stops the deuterons, consists of a cone made of copper, whose inner surface absorbs a power of 1.12 MW, with up to 2.5 MW/m² peak power density in nominal conditions [3]. The cone is assembled inside a cylinder closed at the rear by a flange with the inlet and outlet pipes for the cooling water.

The RDS (Remote Disconnection System) includes the articulated collar that allows remote disconnection, the two adjacent bellows one at each side of the collar, and the support and mechanisms to align and operate the disconnection system, see Fig. 1.

One of the bellows connects to the BD, the other to a conical tube passing through the shielding wall (700 mm thick). The conical tube ends up on a chamber with the Lead Shutter that defines the end of the HEBT (High Energy Beam Transport Line). The lead shutter is closed for beam off phases in order to avoid the gamma ray streaming to the vault, allowing therefore hands on maintenance on the beam line.

The assembly of the cone with the cylinder is called BD cartridge and it is enclosed by a shielding. The inner layer of the shielding is a neutron barrier including water tanks in the middle and polyethylene rings at the front and rear areas. The outer layer of the shielding is made of steel providing a barrier for gamma rays. More details of the shielding can be found in [4].

The interaction of the beam deuterons with the beam dump lead to the activation of the copper. This activation is dominated by Zn 65 with a half-life of 249 days. Once the accelerator has been running over 5.5 days (integrated time) at 1% duty cycle, doses due to Zn65 coming from the cartridge and computed at the bellows zone will be over 250 microSv/h preventing any hands on maintenance on the RDS, therefore this system has been designed maintenance free.

At the end of the life cycle of the accelerator, for the decommissioning phase, it will be necessary to separate the BD cartridge and introduce it in a container with the required shielding, without direct handling. Therefore a disconnection system that can be operated from outside the shielding was required. After such disconnection the remote opening of the shielding and the extraction of the cartridge with an electromagnet would follow, using the bridge crane for such operations.

As it is shown in the article (Sections 2 and 3), the design of the LIPAc RDS system faces challenging space restrictions which requires bespoke solutions to provide the necessary movements for disconnection.

Similar systems have been used for remote disconnection in J-Parc [5,6], and SNS [7], allowing a flexible connection and a disconnection.

1. Introduction

The International Fusion Materials Irradiation Facility (IFMIF), will be a test facility in which candidate materials for the use in fusion reactors can be fully qualified [1]. The LIPAc (Linear IFMIF Prototype Accelerator) is a prototype of one of the two IFMIF accelerators [2]. Its objective is to validate the low energy part (9 MeV) of the IFMIF linacs (40 MeV, 125 mA of D+ beam in continuous wave). It will not have a target and hence a dump is needed to stop the deuteron beam.

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system that prevents the close proximity of the workers to the area with higher radiation.

In contrast with the LIPAc RDS system, other remote handling designs require the possibility of reinstalling the components and a retrieval system or carrying out operations such as welding ([8–10]), which makes those systems more complex.

2. Requisites for the remote disconnection system

The main requirement of the RDS system is to provide a means of disconnection of the BD cartridge from the rest of the beam line from outside of the shielding, such disconnection is possible through an articulated collar shown in Fig. 2. Other requisites including radiation, vacuum and alignment have been taken into account for the design.

The prompt dose requirement in the vault is fulfilled with the designed shielding, which provides values below 12.5 μSv/h outside the vault and below 0.5 μSv/h outside the fence boundary of the accelerator building [11].

The dose inside the shielding, at the zone where the RDS is placed, is over 1 × 10^4 μSv/h, with beam off and after 6 months operation full power, therefore any operation to be performed by removing part of the shielding should be remote.

Concerning vacuum requirements, pressure values in the vicinity of the BD will be in the order of 1 × 10^{-5} to 1 × 10^{-4} mbar, therefore the RDS has a requisite in the vacuum forces to be balanced in the bellows as well as the allowable leak rate in the system (welds and leaktightness of the o-rings). The gas rate produced in the BD is in the order of the 1.5 × 10^{-2} mbar l/s coming from the deuteron beam converted in deuterium gas by neutralisation and recombination on the cartridge surface. The requisite imposed to the RDS is a He leak rate smaller than 1 × 10^{-8} mbar l/s.

With regard to alignment requirements, the RDS includes two bellows that provide the required flexibility to compensate manufacturing and assembly deviations in the elements connecting the lead shutter chamber with the BD cartridge.

Concerning the elements connected to the bellows of the RDS, the total allowed deviations of the manufactured pieces with respect to the nominal values are: 4.5 mm lack of coaxiality, 5 mm accumulated axial deviation and 0.6° angular deviation.

The inner diameter for the elements that make up the RDS is limited by the Beam Stay Clear (BSC) defined in that section. Those elements have been chosen with a minimum inner diameter of 400 mm, this allows us to assure that no losses are present in the transport line, even considering alignment and power supply errors. As the beam is divergent, only in the second bellows, closer to the beam dump, some beam losses (lower than 100 W) could take place during the startup and tuning of the accelerator.

3. Design of remote disconnection system

The RDS is divided into two main parts:

- Elements of the wall side, Fig. 3.
- Elements of the cartridge side, Fig. 4.

3.1. Elements of the wall side

These elements will remain in place when the cartridge is removed during the decommissioning phase.

The bellows connecting the conical tube (at the section of the wall and HEBT connection), is a membrane or edge welded bellows. It has been chosen membrane type because its high flexibility in a small space, facilitating thereby the assembly and compensating for the deviations from the nominal of manufactured pieces. The size of the beam in this section is smaller and it is consequently further away from the beam tube surface.

The articulated collar of the Quick Disconnection System (QDS) is operated with only two bolts, see Fig. 3. The assembly process can be
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