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The DONES Programme: Status and next steps

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ABSTRACT

The mission of the DONES Programme is to develop a database of fusion-like neutron irradiation effects in the materials required for the construction of fusion power reactors. To achieve this goal, a neutron source producing high-energy neutrons at sufficient intensity and irradiation volume must be built.

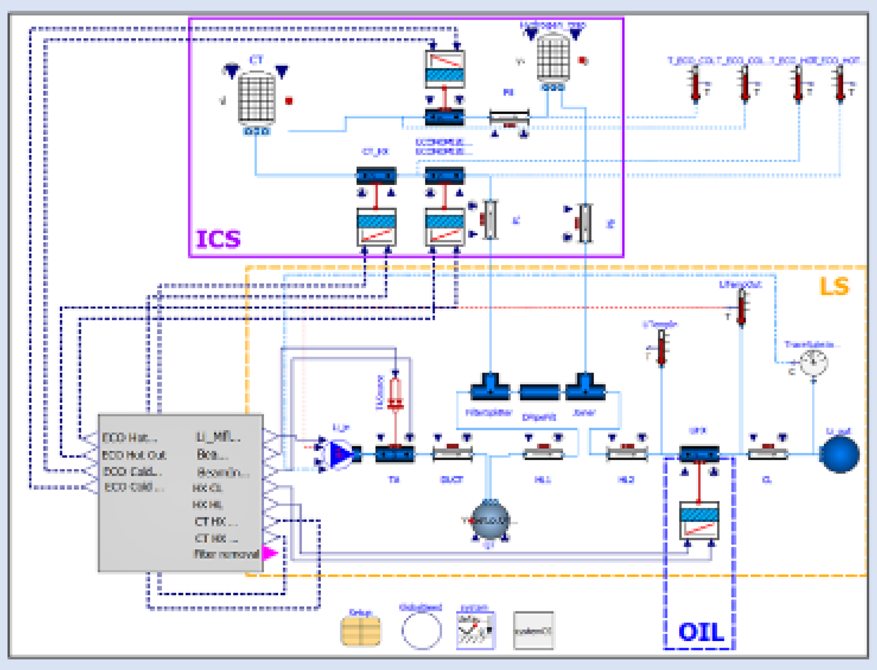
THE IFMIF-DONES FACILITY

The International Fusion Materials Irradiation Facility - DEMO Oriented Neutron Source (IFMIF-DONES) is a scientific infrastructure designed to provide the intense neutron source (in the order of $1\text{-}5{\cdot}10^{14}$ n/cm^{2}s) required for the qualification of materials. Its implementation and exploitation are currently considered in the critical path for the construction of the DEMOnstration Power Plant (DEMO). It will be an accelerator-driven neutron source, based on a 40 MeV deuteron superconducting LINAC directed towards a flowing liquid lithium target to produce neutrons by stripping nuclear reactions. For several years now, the engineering design of the IFMIF- DONES facility is being developed intensively [1]. In order to confirm the feasibility of this design a number of **modelling and prototyping activities** has been developed in the last few years. **The following paragraphs show a set of examples of these validation activities**

VALIDATION ACTIVITIES: Li CORROSION AND PURIFICATION

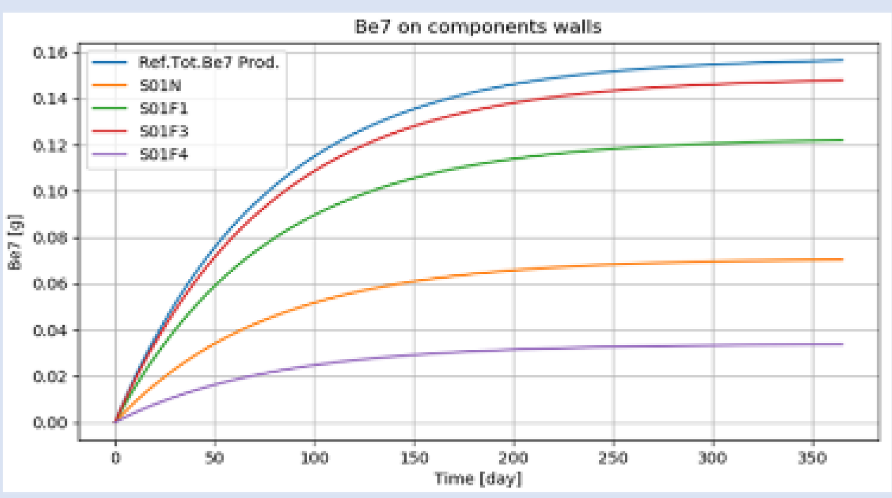
A significant experimental effort has been put in these areas with the construction of **LIFUS-6 facility** [4], for the measurement of the DONES Target and Li loop materials (EUROFER and SS316L) corrosion rate in flowing lithium, in representative conditions and **ANGEL**, to study nitrogen getters. Moreover, a novel code has been also developed to model the generation and distribution of impurities in the Li loop (**see figure 1**). Special attention has been paid to the distribution of ^{7}Be in the loop, which has led to an appropriate selection of new working conditions to reduce its deposition along the loop. New sensors are being developed mainly for the nitrogen and hydrogen detection (resistivity/electrochemical) (**see figure 2**) [5].

Schematic model of the Li loops



A numerical code has been developed to estimate generation and distribution of ^{7}Be, Activated Corrosion Products (ACP) and other impurities in the Lithium Loop

18 ACPs are tracked: ^{28}Al, ^{55}Fe, ^{60}Fe, ^{52}Mn, ^{53}Mn, ^{54}Mn, ^{56}Mn, ^{51}Cr, ^{55}Co, ^{56}Co, ^{57}CO, ^{58}Co, ^{60}Co, ^{63}Cu, ^{64}Cu, ^{65}Cu ^{52}V, ^{64}Zn



Deposition of Be7 as function of temperature on the cold line

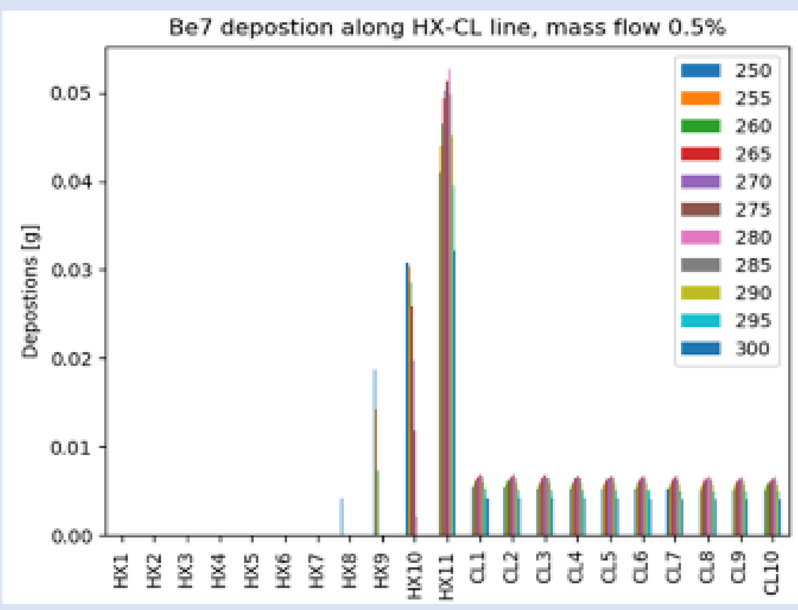


Figure 1. Numerical model to estimate the generation and distribution of impurities in the Li loops

VALIDATION ACTIVITIES: IRRADIATION

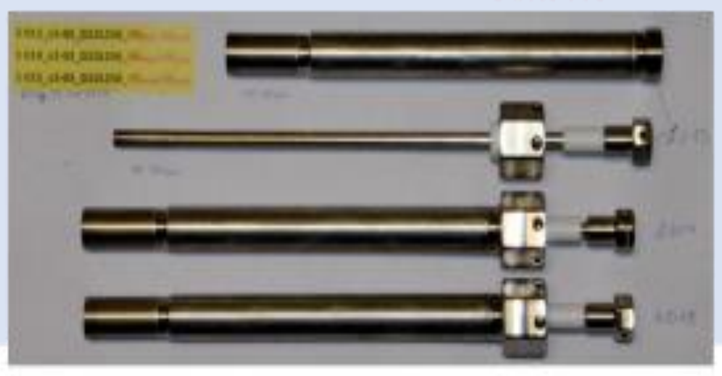
Neutron sensors are being developed to characterize the produced neutron field. These sensors are based on microfission and ionization chambers, SPND and activation specimens [6]. Obtained results up to now show up that reaction times as short as 10-20 µs are feasible with enough sensitivity (around 20 nA). A prototype integrating more than 60 of these sensors is under manufacture (STUMM Proto). In the planned irradiation modules, to be helium cooled, samples are grouped in rigs (up to 80 - 100 samples each). Minimal temperature gradients and long-term temperature stability are essential for a proper materials qualification. This approach has been also demonstrated in the HELOKA loop [7].

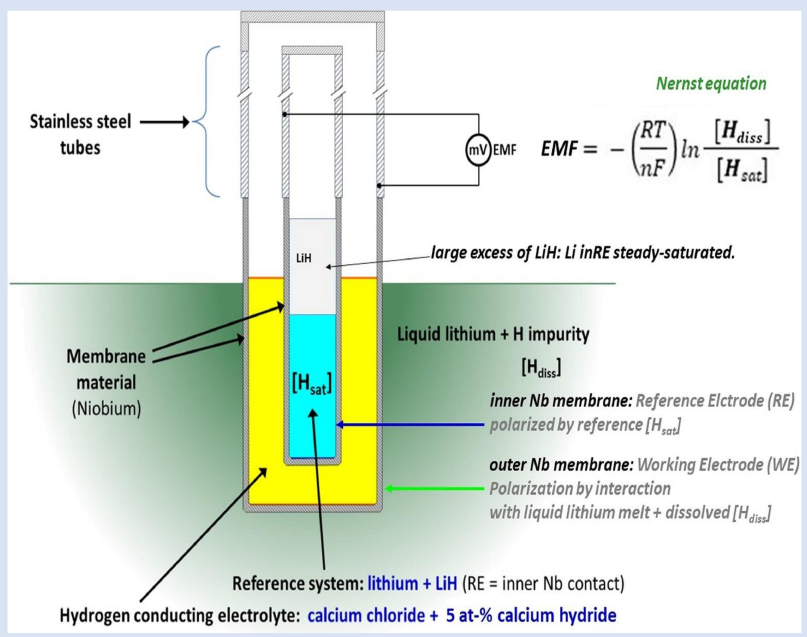
VALIDATION ACTIVITIES: ACCELERATORS

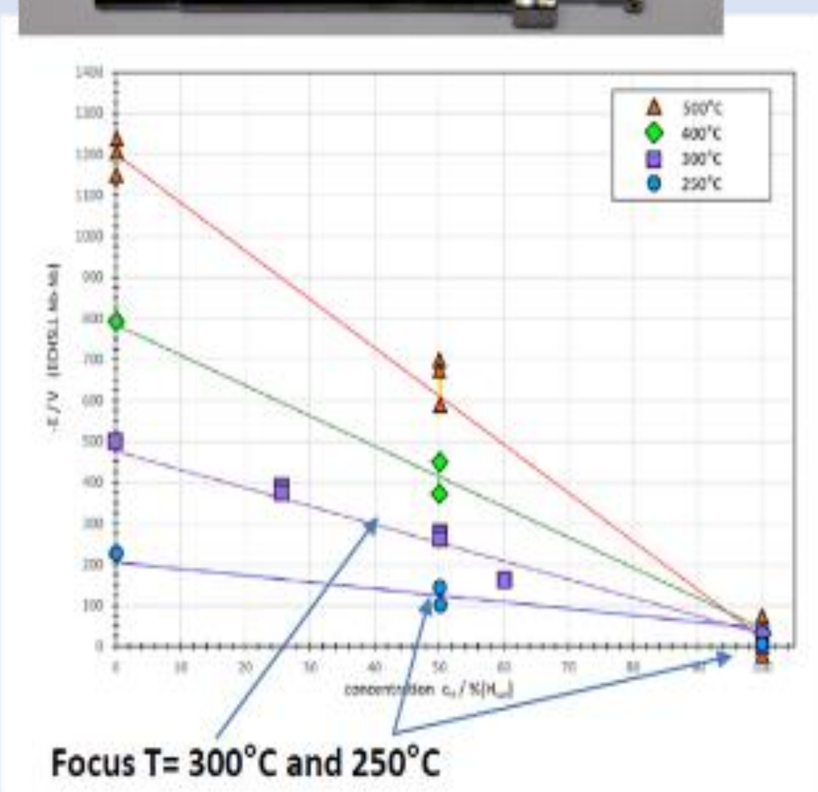
The most relevant one is the construction of a Linear IFMIF Prototype Accelerator (**LIPAc**) of the low energy section of the DONES one, presently under commissioning in Rokkasho (**IFMIF/EVEDA**) and that has already demonstrated the transmission of the nominal high-current beam in pulsed mode through the Radiofrequency quadrupole [2]. Besides this, and related to the DONES accelerator, the **design of the whole accelerator,** including updates on the SRF LINAC, solid state RF power amplifiers and a fully new High Energy Beam Transport line (HEBT), based on the beam dynamics model start-to-end error simulations, **is being developed**. A set of **diagnostics** to characterize the high intensity beam is being qualified in LIPAc and WPENS projects. Successful results on the development of a **naked high-beta cavity** have also been achieved [3].

Design and test of an electrochemical sensor able to measure the contents of hydrogen isotopes in flowing lithium

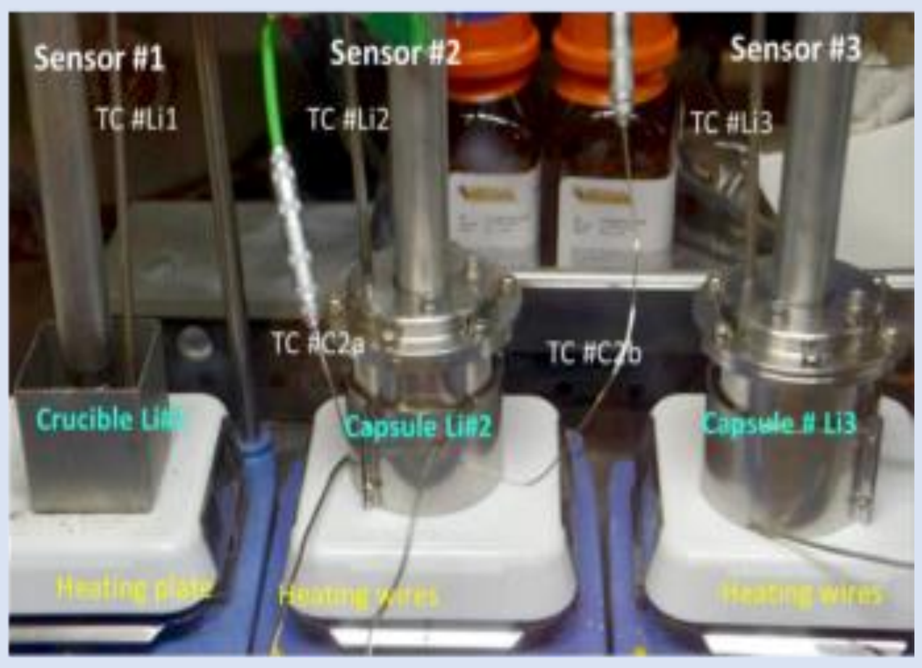
Sensors







Measurement of EMF vs H concentration. In line with theoretical behaviour (solid line)



Test rig for the electrochemical sensors

Figure 2. Electrochemical sensor for hydrogen measurement in lithium

VALIDATION ACTIVITIES: SAFETY MODELLING

In order to properly integrate the safety credited components and requirements in the engineering design it is needed to predict the progression of very different accidental scenarios in the facility. The MELCOR-fusion code capabilities are being reviewed and dedicated models are being developed and adapted for application. Models under study include redundant electromagnetic pumps configurations for the Li loop to address pump trips and lithium loop breaks at several points in the loop, accelerator tube rupture and air ingress (see, for example figure 3), or spilled lithium cooling on cell floors, all of them under several exploratory assumptions [8]. The generated information will be also useful for dimensioning of prototypes for accident analysis, as MuVacAS and LIFIRE facilities, now in procurement phases.

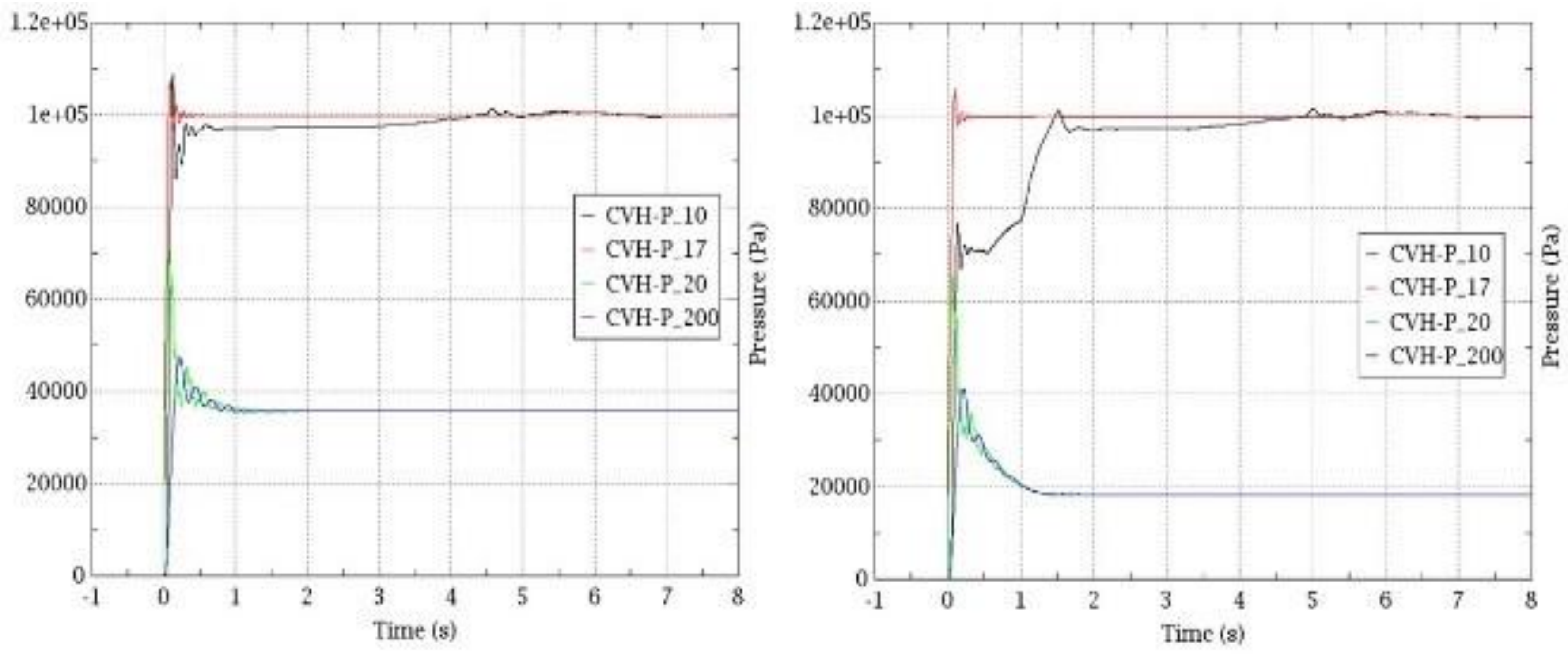


Figure 3. Pressure transient in several points of DONES accelerator predicted by MELCOR for beam duct rupture and air ingress scenario (10 & 17 in the broken segment; 20 & 200 in isolated segment close to target); left picture, case of vacuum system isolation coincident with break event, right picture, case of vacuum system isolation after 1.5 s of break event

CONCLUSION AND NEXT STEPS

Taking into account the results obtained up to now, the engineering design is ready for the launch of the construction phase of the facility. The start of the construction phase of the DONES Programme took place with the constitution of the DONES Steering Committee in Granada in March 2023. According to the current schedule, the IFMIF-DONES Facility will start the Operational Phase eleven years after the launch of the Construction Phase.

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