EURISOL-DS
Multi-Megawatt Target Remote Handling Equipment

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Abstract:
The design proposed within Task #2 of the EURISOL Design Study for the remote handling of the mercury converter target and its associated loop is presented with particular emphasis on achieving rapid turn-around during routine maintenance. The converter target needs to be completely exchanged every four months due to the high irradiation damage sustained. Other components are less susceptible to damage but may need periodic maintenance; in particular the on-line isotopic separation unit in the mercury loop.
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1 The EURISOL Target Station Concept

The EURISOL Design Study has set out to prove the viability of a concept in which a series of different targets produce rare isotopes under the impact of a proton beam. The different types of targets illustrated below in Figure 1 cover:

- Three direct targets, which when impacted by the beam produce proton-rich isotopes.
- A converter target producing neutrons due to spallation under a proton beam, the neutrons are then used to fission UCx contained in six fission targets surrounding the converter resulting in the production of neutron-rich isotopes.

![Figure 1: Schematic of the EURISOL facility](image)

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Figure 2 shows the proposed facility whose operations are described in detail in report M5.3.

![Figure 2: Layout of the facility including targets and buildings](image)

Figure 2: Layout of the facility including targets and buildings
2 The Converter Target Facility

The Multi Megawatt target station is composed of a proton beam accelerator, followed by a mercury target. This target is surrounded by 6 fission tubes. On the back of the mercury target is placed all the services of the mercury loop and the hot cell where the maintenance is performed.

The concept envisaged for the multi-MW target is to place the loop and the target on a mobile trolley for reasons explained in D5/M5.1. Concerns related to safety particularly in accidental cases are the main motive for selecting a design where the system affected by radio-activity, namely the targets and the loop, is essentially self-contained.

![Image: Handling of the MMW Target]

**Figure 3: the converter target, loop and associated servicing equipment**

As depicted in Figure 3, the loop cooling the liquid metal is placed behind a 2.3 [m] thick mobile steel shield which is associated with the trolley as can be seen from the detail engineering drawing in D5/M5.1. The target is fixed to the front of the shield and is inserted
through the shielding wall with at tolerance of approximately 1 [cm] into the irradiation position in front of the beam tube, where the target is exposed to the 4 MW proton beam.

The converter target is surrounded by a safety hull which acts as a containment in the event of the target window breaking and leaking mercury. The converter target and safety hull are surrounded by the fission target. The entire assembly is located on the other side of the shielding and positioned on the same trolley. The reflector and the biological shielding as well as the safety hull are shown in Figure 4. More on the operation of the converter target and its integration may be found in deliverable report M5.3.

**Figure 4: Fission target assembly (l.) and safety hull (r.)**

The hot cell behind the mobile shield contains all the loop equipment necessary for evacuating the heat dumped into the target as well as all ancillary equipment, interfaces to all the targets, health monitoring systems and for data acquisition as illustrated in Figure 5 below.

**Figure 5: Mercury loop in hot cell**

The only fluid exiting the hot cell is cooling water from the liquid metal heat exchanger which will not be heavily tritiated as it is not activated by the proton beam, but only experiences some $\gamma$ from the decay of spallation products.

The water used in cooling the beam window of the safety hull remains in the hot cell and is not passed to the outside as it is tritiated and needs dedicated handling in the hot cell.
The overall dimensions of the target station and its associated hot cell are shown in Figure 6 hereafter.

![General dimensions (1)](image1)

![General dimensions (2)](image2)

**Figure 6: Dimensions of the Multi-Megawatt target station hot cell**

Remote handling of the converter target and its loop are needed for:

- Converter target periodic dismantling and replacement at 4 month intervals.
- Fission block and reflector maintenance.
- Loop component cleaning and replacement of defective parts, including emptying of the loop using drain tanks.
- Measures taken in relation to the isotope separator for isotope extraction and radiation mitigation.
- Shielding checks and reinforcements where needed.

These separate actions are next examined in the following pages from the point of view of the handling procedures needed.
3 Handling of the converter target

When the trolley supporting the target is retracted inside the hot cell, the fission target block surrounding it moves with the entire trolley to a position inside the hot cell where access is possible using robots (shown in green in Figure 7).

Figure 7: Converter target on trolley with fission target retracted

Once inside the hot cell, the fission target block can be moved away from the converter target as shown in Figure 7, thus liberating the converter target from its surrounding fission block reflector.

The operator can perform remote maintenance on the target and the loop services using robots or tele-manipulators which can be operated using lead windows situated alongside the servicing area as depicted below (cf. Figure 8, with target blocks removed for clarity).

The advantage of having both tele-manipulators and robots is that the latter can serve to perform the more robust tasks such as holding the target in position whilst it is being detached from the mobile shield/loop interface or indeed pulling on the target if it has jammed on the shield interface. The tele-manipulators meanwhile can be used for more flexible tasks such as unscrewing the attachment bolts or realigning the seals.

Furthermore robots are dependent on complex electronics which need to be shielded, whereas tele-manipulators are essentially force-multiplying mechanical devices less susceptible to radiation damage. Thus common-mode failures may be avoided by designing a facility with two very different devices relying, for the latter on pneumatics, the former being reliant on servo-hydraulics.
Figure 8: Operator performing remote handling through lead glass window

The detail of the operation necessary for the exchange of a used converter target is shown in a series of CAD animation stills in Figure 9.

Once the target is in position inside the maintenance area, the screws securing the target to the loop interface on the shielding block may be released. The robots hold the target in place whilst the screws are being unfastened. All screws are captured on the target interface plate so there is no need to collect them. The same applies to the seals which are captured on the back face of the converter target interface plate. The design of the converter target preferred a single interface plate to allow the entire target to be detached/attached using simple tooling accessing bolts from the front, there is no need to access behind the target interface as this would require unloading the target shielding a long and arduous process.

Once the target interface screws are loose, the lateral hold can thereafter be released by the robots (in green in Figure 9) after the crane has been positioned above the target. The crane interfaces with the hook placed on top of the target (detail drawings to be found in D5/M5.1). Then the crane may be used to lift the target from its position on the shielding

It is then placed inside a maintenance area within the hot cell, where either the entire target can be disassembled and replaced, or only parts thereof. Partial disassembly should be favoured as it produces less waste. The position shown in Figure 9 is ideal in this respect as it locates the target close to the leaded windows where the operator has a clear view and can access the converter target with tele-manipulators which are far more flexible.
Figure 9: Operations leading to the removal of the converter target

The safety hull surrounding the target is handled in the same manner as the target itself, but not shown for clarity in the preceding figures.
4 Handling of the loop

The components of the loop do not need replacing other than in the case of an incident or an accident. In this case the part would be lowered through a hatch located in the top of the hot cell towards the rear, as shown schematically below in Figure 10. The overhead crane in the target loop hot cell may then be used then to load the component onto the trolley into its required position. A smaller airlock along the back of the hot cell gives access to personnel wearing full-body pressurised suits which may allow specialised operations requiring greater dexterity such as replacement of instrumentation, cleaning etc.

![Figure 10: Introduction of loop equipment into the hot cell](image)

The mobile shielding may be removed to access the target pipes, as the blocks are stacked on top of one another. The blocks are heavy (up to 10 tonnes each) and contaminated by neutron bombardment and streaming. Therefore such an operation as depicted below is not routine and would only occur in the event of a serious accident with a leak for instance or if the inner surface of the piping became so contaminated with radio-toxic oxides (cf. D5/M5.1) that the pipes needed replacing. It is not necessary to remove the mobile shielding to replace the converter target which can be detached from the loop interface by bolts accessible from the front face. Shielding checks should be performed regularly to ensure radiation levels behind the shield are safe, appropriate repairs may be undertaken if it is not the case.

![Figure 11: Top View of the hot cell and removal of the mobile shielding blocks](image)
The liquid metal in the loop can be emptied from the piping and sent to a drain tank integrated to the trolley by opening and closing of appropriate valves.

The shielding surrounding the drain tank is sufficient to guarantee access in a suit to personnel needed for maintenance operations. Further shielding of the piping is foreseen for the case if, as indicated in chapter 7 of deliverable D5, radio-active oxides cling to the inner surface of the loop.

The isotope separator is not yet designed but it may be expected that the separator will produce relatively small amounts of items in terms of mass. The containers shielded by lead may be transported out of the hot cell through the lateral airlock.

The main component of the fission block needing maintenance is likely to be the water-cooled reflector. The reflector is positioned as shown in Figure 7 at a location where it is possible to use tele-manipulators. Exchange of seals, repair of leaks and faulty instrumentation is then possible without entering the hot cell.

The water circuit dedicated to the safety hull (and which may also be used to cool the reflector) needs periodic emptying for treating the accumulated tritium. The volume of the cooling water needing treatment is sufficiently low to allow purging of the system so as to transfer the waste outside the hot cell using the transfer hatch at the top of the hot cell. The tritiated water can then be treated in the facility used for handling the water cooling of the fission targets.
5 Handling of the fission targets

The fission targets are removed at the end of a long tube which is not strictly vertical, but inclined. The overhead crane will therefore need to be adapted to avoid jamming the fission target tube by a dedicated guidance system outside the tube shaft.

Once the fission target tubes are extracted they may be removed by the overhead crane to a dedicated storage facility in which robotics and manipulators may be used for dismantling and storage.

Fresh target fission tubes are stored in a vertical position inside the fission target hot cell, which implies the need for sufficient height to move the 5 metre long assembly in a vertical position whilst maintaining sufficient overhead for the crane gantry.

Figure 12: Fission target removal process
6 Conclusions

Target handling and placement have been studied in detail using the latest developments in Computer Aided Design with a view to minimising dose rates to the personnel and facilitating rapid exchange of defective parts. Ease of access for operators as well as rapid turnaround may be expected from the design.

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