Mo-99 production using a high-power accelerator – The story of a challenging project.

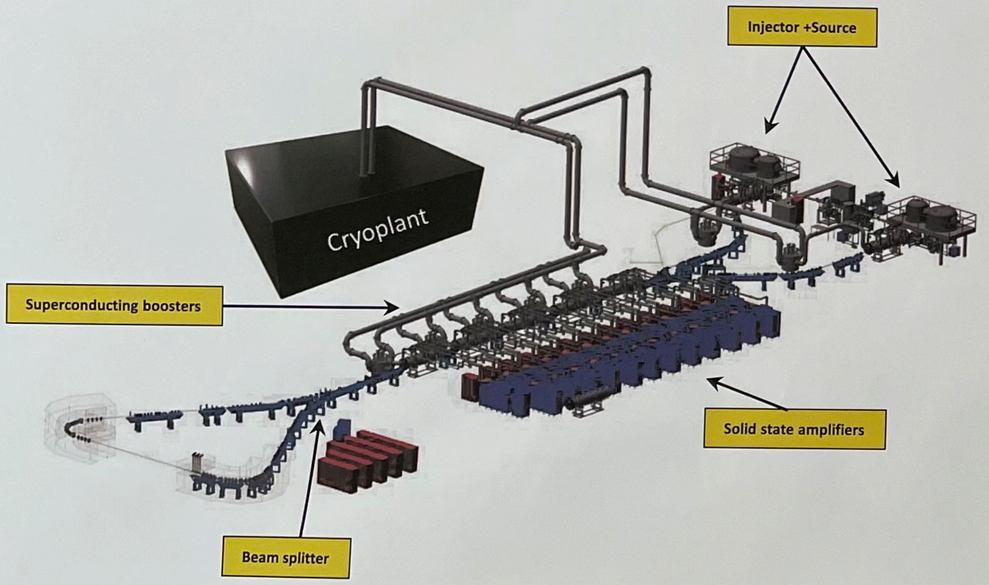
Introduction

For the past 5 years, IRE has been working on a way to produce ^{99}Mo without using the uranium fission process. The main motivation for moving away from this process was to improve the sustainability of production by becoming independent of research reactors, reducing drastically the quantity of radioactive waste and off-gases produced but also to address all the safety issues associated with the use of enriched uranium. The main constraint of not using fission process was to keep the specific activity of ^{99}Mo high enough so that existing generators could still use it. The most promising solution was to use a very high power accelerator to produce ^{99}Mo using the ^{100}Mo (γ,n)^{99}Mo reaction. The main challenge was therefore to achieve a very high-power density on the ^{100}Mo target which required sophisticated cooling. This big project was done in collaboration with ASML, RI, DEMCON and CEA.

The accelerator

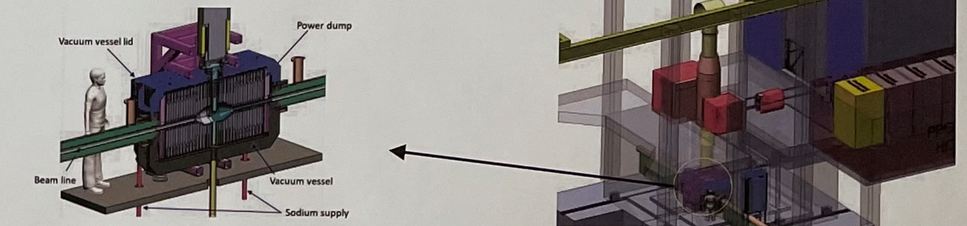
In order to reach those objectives, a very high energy and power accelerator was required. No "off the shelf" accelerator was existing to reach 75 MeV – 40 mA which was needed to obtain a ^{99}Mo specific activity superior to 130 Ci/g allowing to keep the existing generator technology. This accelerator has been designed with the following characteristics:

- Linear electron accelerator
- 300 KV injector
- Source made of a laser pulsed photocathode
- Injector and sources are doubled for redundancy
- 5 superconducting boosters using solid state amplifiers
- 75 MeV – 40 mA
- Beam split in 2 to hit the target on both size
- Size of a soccer field



The exposure cell and cooling

The target is made of enriched ^{100}Mo which also serves as a converter for gamma rays. It has to resist to the very high power (3 MW) but also high power density (300W/mm^3) as its size is only a few cm^3.
In order to evacuate the heat, the most valid and possible solution was the use of liquid sodium that has to circulate inside the target. This implies to build a specific facility to circulate, filter and cool down the sodium.
The target itself is made of an assembly of ^{100}Mo parts (not presented here for trade secret) in order to extract the most activated ones while the others continue to be irradiated.
The target itself is contained in a exposure cell constituted of a tungsten shielding absorbing a huge part of the radiation emitted by the target.

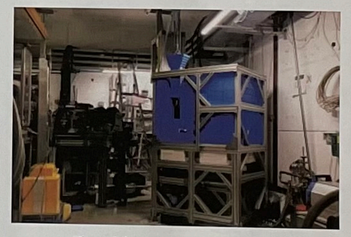


View of the exposure cell

Proof of concept

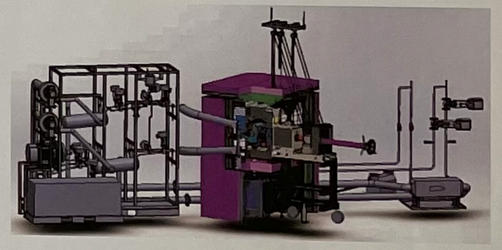
The main challenges of this project are the resistance of the target to the high power density, to radiation damages and the sodium cooling. Many experiments have been performed to validate each parameter isolated but a specific one has been designed to demonstrate that the full concept was working by making a small scale setup with a liquid sodium cooling loop.

This setup has been installed in an accelerator facility (HZDR – Germany) where a small target has been irradiated with a focused beam (1 mA – 30 MeV) in order to reach the 300 W/mm^3 power density.



View of the experiment setup

View of the target + beam spot (total height ~ 5 cm)



Full setup drawing (Na loop, power dump, target, irradiation chamber, shielding)

We ran the experiment during one week in order to be representative of what the target will endure in real life conditions. The results were clear: the target survived with no sign of fatigue, the sodium loop has fulfilled its role with no issues and the level of activity produced was in the expected range. This demonstrated that all the simulations were validated and gave the green light for the full scale design.

A project promising but....

Despite the feasibility was demonstrated and major issues would be overcome after the 5 years of development, the hazards linked to the liquid sodium cooling (fire, activation) was leading to a very high technical complexity in terms of use and maintenance hardily compatible with a nuclear environment, but mainly, the most issue was that the rentability of such an installation was no longer guaranteed due to evolution taken by the ^{99}Mo market since the beginning of the project.