PRODUCTION OF RADIOISOTOPES ON THE JULES HOROWITZ REACTOR

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ABSTRACT

This paper describes the design studies of radioisotopes production facilities which are parts of the Jules Horowitz Reactor (JHR) under construction. It focuses on the ^{99}Mo irradiation systems and associated equipments. The ^{99}Mo is produced by irradiation of uranium targets. JHR will contribute to the security of supply of medical radioisotopes, especially for the ^{99}Mo-^{99m}Tc. Start-up of radioisotopes production is foreseen as soon as possible after the JHR criticality.

1. Introduction

The production of molybdenum 99 (^{99}Mo), and its decay product, technetium 99m (^{99m}Tc), the most widely used medical radioisotope for diagnostic purposes, is important for public health. As a matter of fact, disruptions in the supply chain of these medical isotopes, which have half lives of 66 hours for ^{99}Mo and 6 hours for ^{99m}Tc, can lead to cancellations or delays in Department of Nuclear Medicine where this isotope is used as Single Photon Emission Computed Tomography (SPECT) tracer. Unfortunately, supply reliability has declined over the past decade, due to unexpected or extended shutdowns at the few ageing ^{99}Mo producing research reactors and processing facilities. These shutdowns have created global supply shortage. As an answer to minimize this risk for the next decades, the Jules Horowitz Reactor (JHR) under construction at CEA Cadarache in France took into account as a new major challenge, the production of radioisotopes.

In this paper, we very briefly present an overview of JHR project, an update of the construction of the reactor and also the MOLY project. Then, we describe physical and technological studies undertaken, as well as the circuit's architecture and the nuclear safety issues. Finally, we conclude with the Jules Horowitz Reactor capacity for ^{99}Mo production.

2. Jules Horowitz Reactor Project

The Jules Horowitz Reactor (JHR) is a Material Testing Reactor currently under construction at CEA (Commissariat à l'Energie Atomique et aux Energies Alternatives) Cadarache in France. It will represent a major research infrastructure for scientific studies dealing with material and fuel behaviour under irradiation. The reactor will perform Research and Development programs for the optimization of the present generation of Nuclear Power Plants (NPPs), support the development of the next generation of NPPs and also offer irradiation possibilities for future reactors. The reactor will also be devoted to medical radioisotope production. [Ref 1]. JHR will offer irradiation experimental capacities to study material and fuel behaviour under irradiation. JHR will be a flexible experimental infrastructure to meet industrial and public needs. It is designed to provide high neutron flux, to run highly instrumented experiments and to operate experimental devices with environmental conditions (pressure, temperature, flux, …) relevant for water reactors, or specific environments (eg. gas, sodium) related to other thermal or fast reactor concepts.

The construction of JHR is undergoing on and some major milestones have been achieved regarding, for example the construction of buildings. Since some months, electro mechanical works, as venting systems and piping systems, are undertaken.

Fig 1. Artistic view of JHR (copyright CEA)

Fig 2. Overview Reactor Building (copyright CEA)

The next important milestone will be the establishment of the dome on the top of the reactor building.

3. MOLY project

The objectives of the MOLY project are to be able to produce an annual volume of 25% of European needs on an average basis and up to 50% of European needs in peak production. The new facility will accommodate Low Enriched Uranium (LEU) targets. The objectives of the MOLY project became one of the major challenges at the beginning of JHR. For the business point of view, the project should set up long term agreements with industry. Then, our activities will strengthen the Mo-99 supply and the production of other RI within European network.

To answer to the industrial challenge, we decided to build an industrial project since 2011. An engineering team was structured. It was important to integrate different skills in the team to deal with numerous interfaces with the JHR construction and the development of the MOLY activities. The team is now consistent with the following tasks in different fields:

- Nuclear conception: physical studies, nuclear safety, technological studies. In this field, the iterative approach and the interfaces between skills are useful in order to converge into a final design ready to manufacture. It is the so called “pig tail” process;
- Nuclear manufacturing : manufacturing until factory acceptance as well as assembly on site
- Nuclear operating with tests, commissioning and normal operations;
- Project management;
- Business approach.

4. Studies

In 2010, first feasibility studies have been carried out [R2]. Since 2011 design studies were conducted in order to adapt to new objectives assigned and, from 2012, to the conversion of Uranium targets from High Enriched Uranium (HEU) to LEU. The references [R3] and [R4] present and summarize the existing studies. In the design area, iterations might be required for take into account new input data. This process which can be long has to be formalized by important milestones. In our case, we had:

- In late 2011, a review process on the preliminary definition studies with HEU targets
- In late 2012, a review process on the preliminary definition studies with LEU targets

By the end of the year, we will organize a review process on the detailed design studies. The main goal of the milestone will be the decision to launch the manufacturing the specified MOLY equipments.

4.1 Physical Studies

The MOLY irradiation devices will be located in the JHR beryllium reflector. In order to increase the JHR means of radioisotopes production, without decreasing the global experimental capacity, the design of the JHR reflector was redefined. by the beginning of 2011. Consequently, the irradiation devices will be placed on movable systems in order to achieve the loading and unloading operations out of the neutron flux. Four locations are devoted to the ^{99}Mo production. The movable systems should be well interfaced with reactor structures. They should be very robust. The irradiation devices are connected by hoses to a dedicated cooling circuit.

Numerous physical calculations were performed. The main objective of neutronic calculations was to define the ^{99}Mo production performance of the uranium target in the environment of the reflector of the JHR. We have to take into account many input data:

- Target: enrichment in ^{235}U, shape, size, density …
- MOLY irradiation devices: material, shape, location…
- Interfaces with others equipments of the Jules Horowitz Reactor

In order to be able to compare our different results, we needed to define a parameter which was independent of the input data and representative of the performance we are looking for. We define the following criteria: Curie de ^{99}Mo created/g initial ^{235}U.

As main result, we have shown that JHR will be able to produce ^{99}Mo with high level MOLY production rate, so even with a JHR medium thermal power.

The thermo-hydraulics calculations are also an important issue of these studies. Calculations have been realized for both operational and nuclear safety purposes. They allowed us to check the heat removal from U targets and to define the main cooling circuit. The safety circuit was also defined in order to deal with accidental situations.

We also performed thermo-mechanicals calculations on some equipments which are under this kind of constraints.

4.2 Nuclear Safety Studies

Nuclear Safety Studies are very important in the conception phase of the MOLY facility. As already discussed, they were done in an iterative manner with the technical conception.

Safety documents are produced:

- Safety options file and updates;
- Nuclear safety analysis of irradiation conditions;
- Nuclear safety analysis of operation conditions (without neutrons).

MOLY safety documents will be integrated in the general JHR licensing documentation (Safety Analysis Report, General Operating Rules…).

As required by the French Nuclear Safety Authority, Post Fukushima aspects will be studied as necessary on MOLY equipments.

4.3 MOLY Circuits Architecture

As described in [R5], the Jules Horowitz Reactor is designed to provide the largest experimental capacity possible with the largest flexibility. The MOLY production is an industrial process. Since both objectives should be compatible, it is needed to implement MOLY equipments in a dedicated location. It was decided to use the so called “REP cubicle” for the main part of the cooling system, located near the reactor pool. The figure 3 presents the schematic diagram of the MOLY circuits.

We have defined the mains components for the electric power supplies (normal and rescued). The main principles for the MOLY command control are determined. Finally, the MOLY equipments in dedicated cubicle and the implementation of electrical cabinets are defined. The MOLY equipments were defined and located in order to minimize the interfaces with those of the reactor and of the experiments.

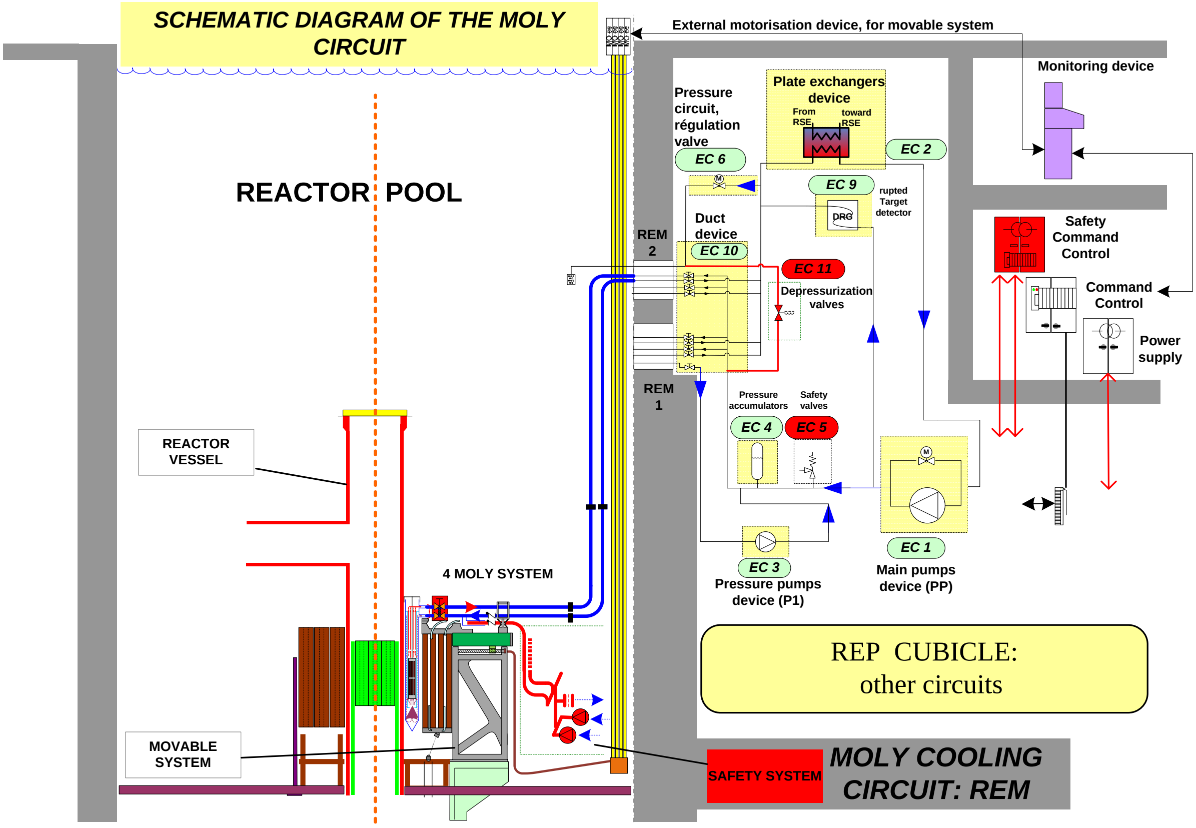

Fig 3 schematic diagram of the MOLY circuits (copyright CEA)

4.4 Technological Studies

In support to the physical studies, numerous technological studies have been carried out. For example, figure 4 presents the evolution between 2011 and 2013 for the MOLY circuits in JHR reactor pool.

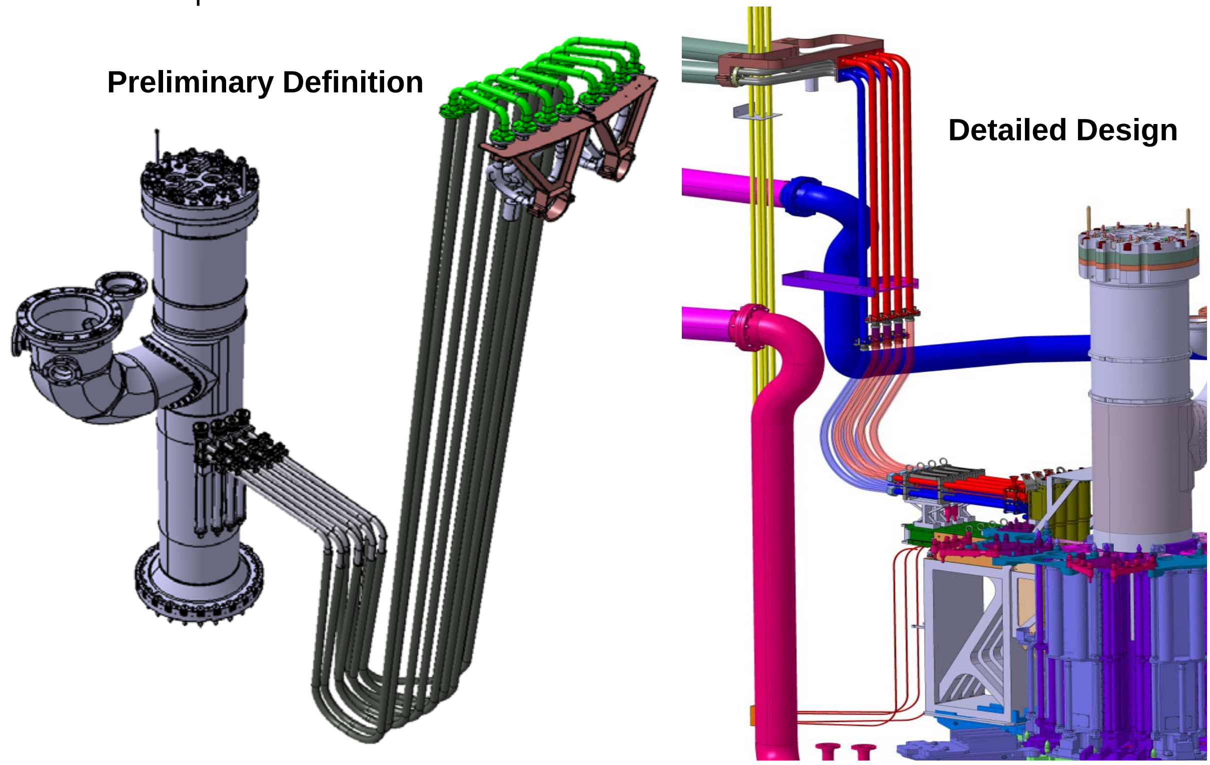

Fig 4 design evolution for the MOLY circuits in JHR reactor pool from (copyright CEA)

Other more specific studies have been carried out on other equipments (irradiation devices, movable systems, pumps, hoses, test materials, tools…). By 2014, a comprehensive plan for development of mock-ups will be specified.

5. Conclusion

The construction of JHR is going on with more than 95 % contracts passed and 75% civil work progress. The common target of commissioning by end 2017 is defined.
On MOLY aspects, studies are carried out in connection with the decision to irradiate LEU targets. Studies have been focused on JHR ability to produce 25% of European needs on an average basis, and up to 50% in peak production. They showed us that we could achieve thermal neutron flux densities for an adequate production of ^{99}Mo. As announced in the OEDC-NEA High Level Group on the Security of Supply of Medical Radioisotopes (HLG-MR), JHR irradiation capacity will be the following:

- Annual operation days : 220 days;
- Annual basic production : 500 LEU targets/year;
- Possibility to extend for limited periods;
- Weekly maximum capacity :
    - From 32 to 48 targets/week of production;
    - ^{99}Mo production level foreseen (6-days Ci) : 2400 Ci/week of production;
- Production flexibility according to customer's orders.

On MOLY project timeline, we can highlight the following points:

- Design studies for 99Mo irradiation systems based on LEU targets completed;
- Design assessment : review planned end of 2013;
- The irradiation tests of LEU targets are foreseen in 2nd part of 2018 to date. In the general frame work of the reactor [R6],the MOLY project team is working on dedicated commissioning;
- Normal level of production : foreseen in 2019;

CEA is experienced in the ^{99}Mo supply chain, since operating for many years uranium target irradiations in OSIRIS (CEA Saclay). CEA is committed to remain a major actor of European network for sustainable ^{99}Mo long-term production, as well as for the other radioisotopes.
JHR should exhibit enhanced target capacity and significantly contribute to ^{99}Mo world market as soon as possible after JHR criticality. JHR develops irradiation capacity for LEU targets and associated logistics in coordination with European fleet of reactors, to better ensure the back-up, and hence mitigate future risks of shortages.

6. References

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