The Jules Horowitz Reactor MOLY system

Towards a concept proposal according a large Molybdenum production capabilities

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Introduction (1/2)

The production of Molybdenum 99 (Mo-99) radioisotopes is important for public health.

from **U-235 fission**
→ **Mo-99 production** - $T_{1/2}$ period =66h
→ **Tc-99m production** -$T_{1/2}$ period=6h
use for diagnostis nuclear medicine.

- The current number of medical procedures worldwide that use Tc-99m is approximately **30 millions** per year, of which **7 millions** are in Europe.
- At the **European level**, the production is primarily from
  -the **HFR reactor**, NRG Petten, 45MWth (the Netherlands),
  -the **BR2**,SCK-CEN Mol, 100MWth (Belgium),
  and **OSIRIS**, CEA Saclay, 70MWth (France).

- The current status is that most of the Mo-99 producing reactors are old and will soon reach the end of their operational lifetime.
- They need in the coming few years to be replaced by new facilities in order to assure the continuity of radioisotope production in the next decades.
- Within Europe, various projects have been started to replace the existing facilities

Introduction (2/2)

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- From 2014 in France, **the Jules Horowitz Reactor (JHR)** which is currently under construction, will allow the production of Mo-99 and will take the place of the OSIRIS reactor which will be stopped at that time.

- The Molybdenum 99 production objective for the JHR reactor is to be able to guarantee:
  - **25%** of the European base needs,
  - with the possibility to increase the production up to **50% European needs** if necessary.

The aim of this paper is to present the state of the investigation carried out for the JHR MOLY production facilities.

- This work is performed **in cooperation** with a team from **NRG in Petten** (HFR reactor) and **CEA in Saclay** (OSIRIS reactor).

- It started in **2009**

AFAQ ISO 9001 ISO 14001 OHSAS 18001

JHR facility (1/2)

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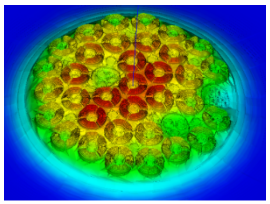
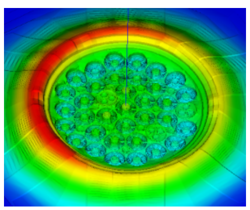
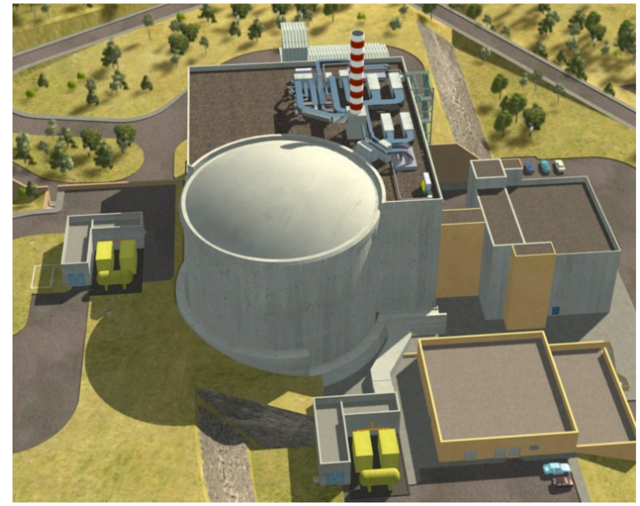


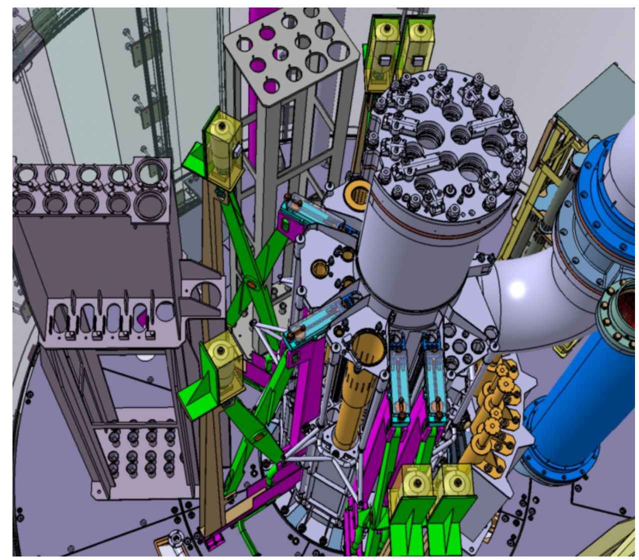


Main characteristics

designed at 100MWth,

- **Compact core geometry** (60cm diameter),
- **Reflector in Beryllium,**
- **Light water coolant** - closed primary circuit (12 bar pressurisation),
  - High materials damages capabilities: 15 dpa/year (core),
  - High thermal neutrons flux (reflector): 8 x PWR th. neutrons flux,
- **High experimental platform:** possibility to manage 25 irradiation devices (x13 in the core and x12 in the reflector),
- **Experimental and exploitation equipments integrated in the facility** (NDE systems, FP laboratory, hot cells with specific one for failures rods conditioning).





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JHR facility (2/2)

View on the JHR site (March 2010).

2014 objective

The JHR MOLY radioisotope production system

Input data

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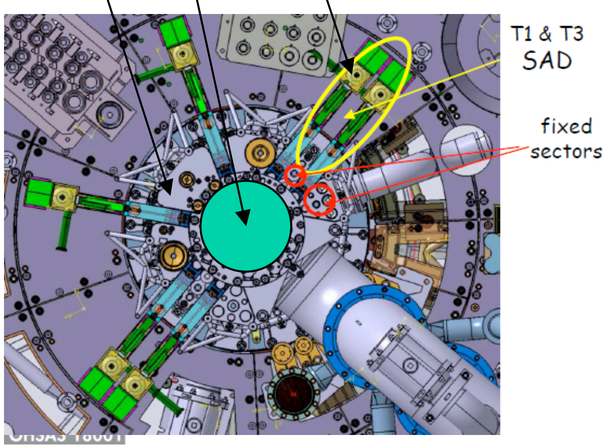
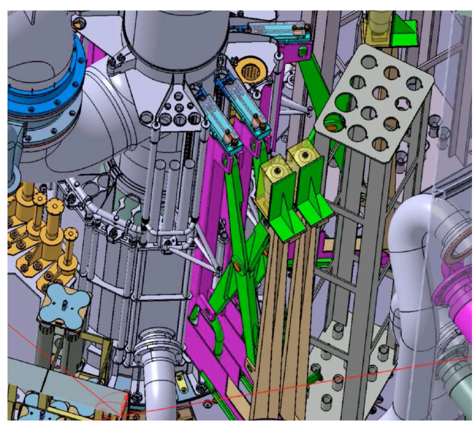
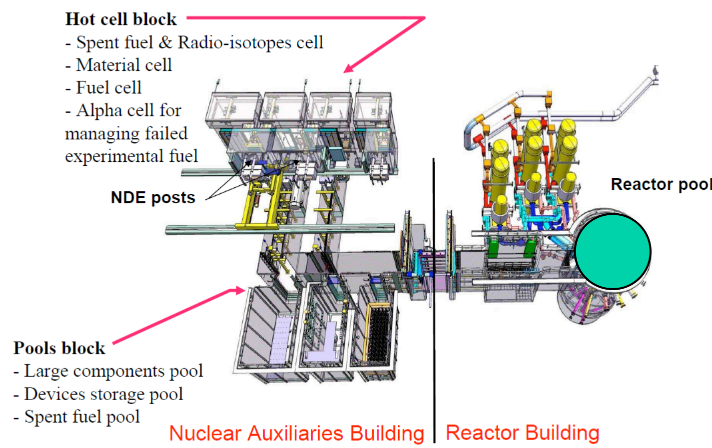
- The **production system** for MOLY targets will be placed **in the JHR reflector in fixed positions** and will also allow **movable positions** using displacements systems (called SAD).

- They will be localised in a sector of the Be-reflector that allows easy operation and will be positioned **closed to the Nuclear Auxiliary Building (NAB)** where the targets will be placed in the transport containers before being transported to the customers.

- The systems (especially the movable positions) will offer **a great deal of flexibility** in radioisotope production. It also permits the possibility to modify the device configuration on displacement systems from a "radioisotope production" to a "standard fuel rod irradiation"







OSIRIS and HFR reactor feedbacks (1/2)

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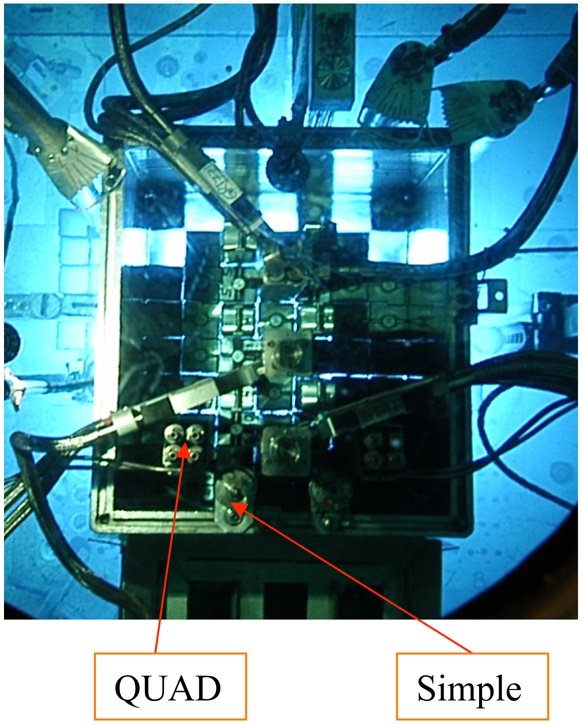
The **OSIRIS reactor** is a **70MWth MTR** type.

Experimental capability up to 16 devices where the fast neutron flux (E > 1 MeV) ranges from 1 to $2.10^{14} n.cm^{-2}.s^{-1}$.
The maximum thermal flux in the middle of the side on the first periphery is close to $3.10^{14} n.cm^{-2}.s^{-1}$.



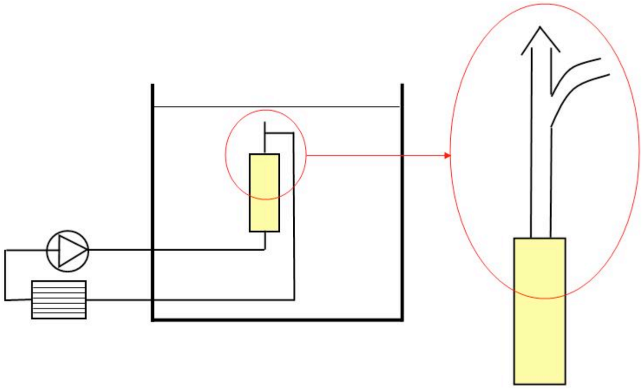
Irradiation of MOLY targets

In the core, there are 2 Quad MOLY and several MOLY locations available (these last are in the Beryllium reflector).

These targets are laid out in simple devices or in multiple devices of Quad MOLY type.

Each device is placed in a cell of the core.

Water of the primary circuit cools the fuel elements of the core, the in-core experiment and also the MOLY targets.



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OSIRIS and HFR reactor feedbacks (2/2)

The **HFR** is a **45MWth** reactor tank in pool type.

It's used for both material and fuel testing and for the production of radioisotopes.

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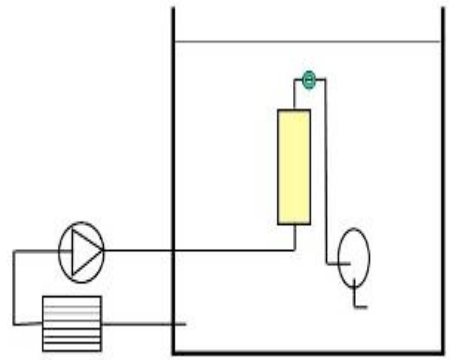
The MOLY targets are contained in a range of irradiation devices located **in the core zone and in the reflector zone**.

The in-core positions have the advantage that the neutron flux is higher than the positions out-of-core.

The out-of-core positions have the advantage that the loading and unloading of the targets is relatively simple and that simpler irradiation devices can be used.

All four irradiation devices are constructed in such a manner that the targets **can be loaded and unloaded** from the HFR **during full power operation**.

The coolant circuit of the targets can be pressurized in the irradiation zone of the targets



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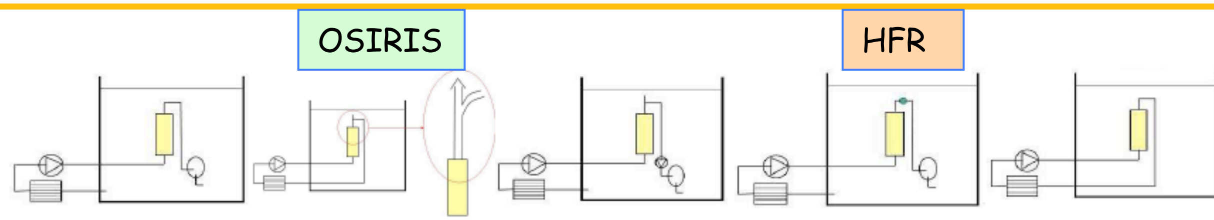
Research of a concept for MOLY circuit in JHR (1/2)

The first phase of the investigation was to propose **different types of possible concepts** for the new JHR MOLY circuits with a analysis based **on different criteria**, such as

- Operation scenario (targets loading and unloading),
- Safety,
- Fission Product (FP) gas release management (detection, trapping),
- Design & Manufacturing complexity,
- Cooling performances,
- Regulation constraints.

different configurations have been studied:
- Opened to the pool water or not,
- Closed loop,
- Pressurised or not

Research of a concept for MOLY circuit in JHR (2/2)



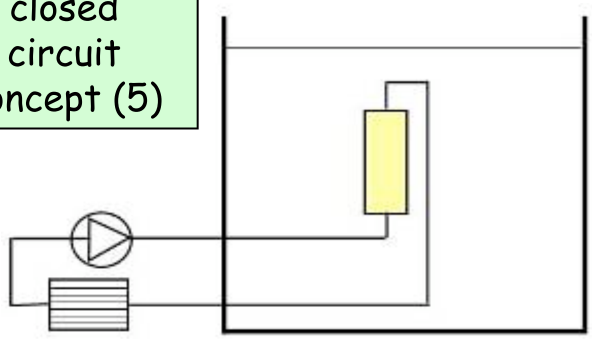
Criteria / configurations	1	2	3	4	5
Exploitation (un) loading	Difficulty Lev.1	**Difficulty Lev.0**	**Difficulty Lev.0**	Difficulty Lev.2	Difficulty Lev.2
Safety	LOCA consequence studies Lev.3	**LOCA consequence studies Lev.1**	**LOCA consequence studies Lev.1**	LOCA consequence studies Lev.2	**LOCA consequence studies Lev.1**
FP gas trapping	FP gas trapping containment	**FP gas trapping in the circuit**	FP gas trapping containment	FP gas trapping containment	**FP gas trapping in the circuit**
Realisation	Difficulty, Level 1	Difficulty, Level 2	Difficulty, Level 3	Difficulty, Level 2	Difficulty, Level 2
Design	Difficulty, Level 1	Difficulty, Level 0	Difficulty, Level 3	Difficulty, Level 1	Difficulty, Level 2
CFD detection	Difficult (CFD in the pool)	**CFD on REM circuit**	Difficult (CFD in the pool)	Difficult (CFD in the pool)	**CFD on REM circuit**
^{16}N , FP releases problematic	Detection difficult Need circuit adaptation	**Managed by design**	Detection difficult Need circuit adaptation	Detection difficult Need circuit adaptation	**Managed by design**
Regulation	ESPN	ESPN	ESPN	ESPN	ESPN
Cooling performances	Low - MOLFI water comes from the pool	**High – water comes from MOLFI circuit**	Low - MOLFI water comes from the pool	Low - MOLFI water comes from the pool	**High – water comes from MOLFI circuit**

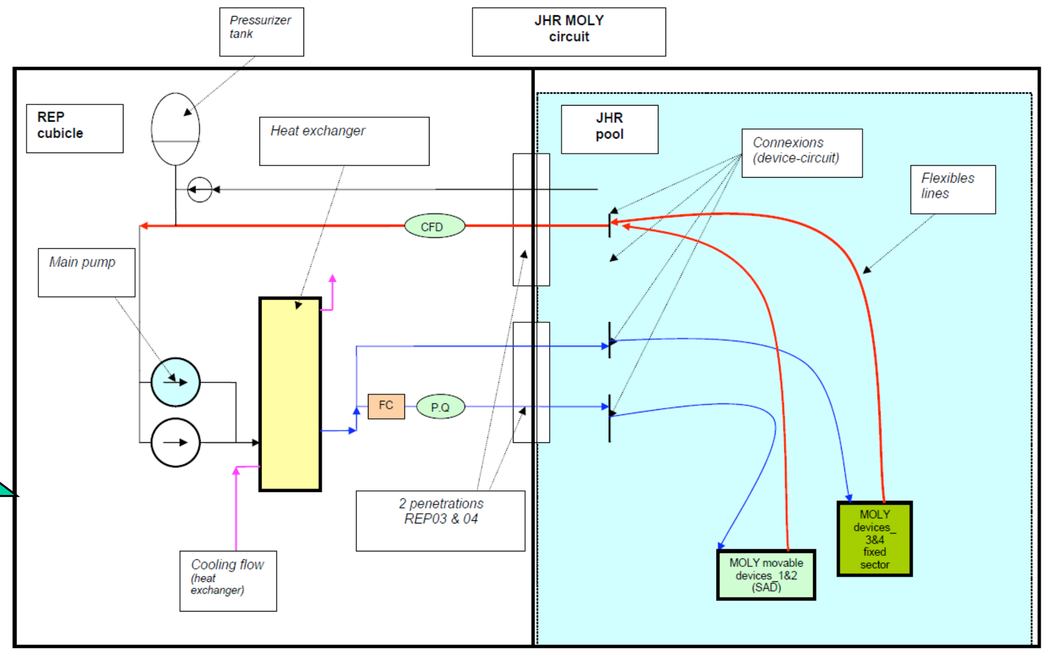
Comparative analyse of different concepts for JHR MOLY circuit
Legend:
level 0 (simple) - level 1 (medium) - level 2 (complex) - level 3 (very complex)

MOLY circuit architecture proposal (1/2)

- **The flow circuit** will allow the cooling of the MOLY devices in both the fixed and in moving sectors.
- The coolant water circulation is ensured by pumps (for normal operations and one back up for safety) which will work in parallel under normal conditions.
- In the event of failure of the main pump, the safety pump will ensure the cooling of the targets with a flow defined by the safety studies.
- The instrumentation on each line will be composed of pressure sensors and flow meters. CFD (cladding failures detectors) will be fitted in the circuit in order to detect any cladding rupture.

closed circuit concept (5)





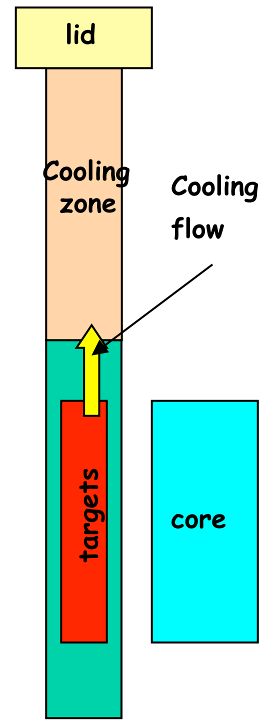
MOLY circuit architecture proposal (2/2)

-Each irradiation MOLY device can embark several targets (up to 12 targets / device).

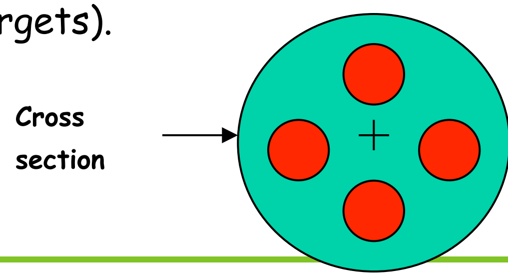
-The circulation of the coolant water will be upward along the targets.
-The fluid velocity around the targets will be approximately 7 to 8 $m.s^{-1}$.

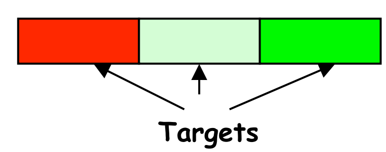
-The devices will include in the upper part a zone of forced convection cooling ("chimney" arrangement) to cool the targets after irradiation and before unloading from the device.

-Any fission gas releases (in accident conditions) will be managed by placing a sealed removable lid on the top of the device. The detection of any activity released in the circuit will be measured by a CFD (cladding failure detector) located in the coolant circuit in the cubicle (out-of-pile part of the MOLY circuit).



•The devices both in the fixed and movable sectors will be very similar in term of design in order to facilitate easy operation (i.e loading and unloading of the targets).





Conclusion and next steps

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After the preliminary phase of analysis and research of concepts, **Reference Architecture for JHR MOLY** circuit has been proposed.

- The next phase will concentrate on **the conceptual design of the MOLY circuit**, the irradiation devices and targets holders (3D CATIA design studies, thermo-mechanical dimensioning studies following RCC-MX rules, ESP(N) regulation verification, etc.)

- In parallel, **a preliminary analysis of Safety** will be performed to evaluate the consequences following a theoretical rupture of the MOLY coolant circuit (LOCA type).

- An analysis will be also performed in order to determine the necessary **level of redundancy of components** (e.g. number of pumps, heat exchangers) in order to ensure the best availability of the MOLY circuit for production while costs and benefits.

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