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Status in 2000 of the High Flux Reactor Fuel Cycle

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ABSTRACT

The High Flux Reactor located at Petten (The Netherlands) is managed by the European Commission and operated under contract by NRG (Nuclear Research and consultancy Group). This plant, located in the “medical valley" is the main provider in Europe of facilities and radioisotopes for nuclear medicine, as well as for research and industrial purposes.

The plant is in operation since 1961 using HEU. After preparatory work begun in 1998 and 1999 [ref. 1 and 2], the decision to convert the reactor to LEU was taken and the official diplomatic notes were signed in January 2000 with the US authorities. This decision allows two co-operation possibilities. First on a limited HEU fuel supply until the HFR has obtained a new licence for operation with LEU. Secondly on possibilities of shipment to the USA of spent fuel. This paper details the status of the work begun with the US authorities and DOE to ensure the fuel supply: export licence, container licence, transportation, etc. Other ways to supply necessary HEU until the conversion licence is valid are also presented.

For the conversion studies [ref. 3], a new status is made of the end of Phase 1. A comparison between the results of ANL calculations and NRG calculations is made. The final choice of LEU elements for conversion is presented. It enables a longer cycle (28,3 operating days instead of 24,7) with only small penalties (less than 5%) on thermal flux. A short description of Phase II is given, with a global planning estimation for obtaining licences.

For the new MTR fuel, a presentation is made of the tests that have begun in 2000 on the reactor and of the projects in the study of new tests. HFR is participating actively in this research field [ref. 4].

For the back-end of the fuel cycle, this presentation shows the status of the HABOG facility under construction, to allow the storage of the HFR spent fuel (1400 elements) after 2003. So HFR will be ready before 2006 with its own storage capacity that could begin in 2004. Until this date an extra funding was given by the Dutch Ministry of Environment, for a shipment to the USA of about 120 elements. A status is given on this action.

In conclusion great progress have been made during this year, towards a stabilised situation, with a reactor converted to LEU and a facility available for spent fuel storage.

1. Introduction

The HFR located at Petten (The Netherlands) is managed by the Institute for Advanced Materials of the Joint Research Centre (JRC) of the European Commission. The day-to-day operation and maintenance of the plant are carried out under contract by the Nuclear Research and Consultancy Group (NRG).

The HFR is of the tank-in-pool type, light water cooled and moderated. It is operated at 45 MW. In operation since 1961, and following complete refurbishing with a new vessel in 1984, the HFR still has a technical life beyond the year 2015. It is one of the most powerful multi-purpose material testing reactors in the world.

The reactor provides a variety of irradiation facilities and possibilities: in the reactor core, in the reflector region, in the poolside. Horizontal beam tubes are available for research, and medical application with neutrons. Gamma irradiation facilities are also available. Excellently equipped hot cell laboratories, on the Petten site, can provide all necessary post-irradiation examinations.

The close co-operation between the Joint Research Centre and the Nuclear Research and Consultancy Group (NRG) on all aspects of nuclear research and technology is essential to maintain the key position of the HFR amongst research reactors worldwide. This co-operation has lead to a unique HFR structure, in which both organisations are involved with the aim to adopt a more market oriented approach and offer their long standing and recognised competence in exploiting a powerful, reliable set of nuclear facilities to world- wide interested parties.

HFR is also in the core of the Medical Valley association. This association between IAM, NRG, Mallinckrodt and hospitals leads to a medical structure unique in the world, and about 50% of the reactor is already used by medical applications; radio-isotope production, Boron Neutron Capture Therapy, etc.

The present HFR operating schedule consists of I 1 cycles of 28 days (24.7 days of full power operation and 3.3 days of core reloading and check-out procedures) and 2 maintenance stops of about 4 weeks resulting in at least 275 days of full power operation per year. The yearly operational plan for the HFR is followed as closely as possible to offer the users a predictable timetable for reliable experimental and isotope production planning.

2. Core and fuel description

- The core lattice is a 9 x 9 array (729 mm x 750.4 mm) containing 33 fuel assemblies, 6 control assemblies, I 9 experiment positions and 23 beryllium reflector elements.
  The row at the eastside of the core lattice normally loaded with 9 beryllium reflector elements is arranged outside the core box of the reactor vessel.

- The fuel assemblies (horizontal cross section 81 mm x 77 mm, height 924 mm) contain 23 parallel, curved, fuel plates with an active height of 600 mm.

- Each plate consists of an UAl_x-AL matrix with a thickness of 0.51 mm, clad with aluminium of 0.38 mm thickness for the inner plates and 0.57 mm for the outer fuel plates.

The uranium is at least 89% enriched in ^{235}U. The uranium content of the fresh fuel assemblies is 450g^{235}U. The two side plates of each fresh fuel assembly contain together 1000 mg ^{10}B.

- There are six control assemblies, each of them consists of a cadmium section on top of a fuel section with Al driver section. The fuel section contains 19 fuel plates with a total fresh mass of 310g^{235}U. Their drive mechanism is situated below the reactor vessel, giving free access on the top of the reactor. The control assemblies move vertically. When a control assembly is moved upwards, the fuel moves into the core displacing the cadmium section.

- Apart from the 19 in-core irradiation positions, there are 12 irradiation positions at the poolside facility offering stationery as well as transient irradiation conditions. Surrounding the core box, 12 horizontal beam tubes are situated for basic and applied fundamental research and activation analyses. These include dedicated beam tubes for Boron Neutron Capture Therapy and neutron radiography of non-radioactive components and fuel pins.

- The fuel consumption is 4 to 5 elements by cycle [Ref. 1] and one control rod by cycle. Therefore, and with eleven cycles/year, the consumption of fuel is about 11 control rods and 50 elements per year.

3. Commitment of HFR to convert to LEU

After a lot of technical preparation work in 1998 and 1999, already presented in RERTR [ref. 1 and ref. 2], a collaboration began with ANL at the end of 1999 and gave confirmation of our first calculation results. So diplomatic notes were signed between JRC and DOE in January 2000, where the HFR took commitment to convert the reactor to LEU as soon as licensed with this new fuel.
In exchange of this commitment, the door was open for a limited HEU supply until the licence will be obtained and also for spent fuel shipment possibilities to the USA. All these subjects will be explained in the related chapters.

4. HFR conversion studies

4.1 Organisation

The work to obtain the licence for the new LEU fuel is organised in 3 phases:

Phase 1 : Technical choice of the element after a first analysis of all consequences.
Phase 2 : Detailed calculations and analysis in nine parts, of all consequences related to the conversion. Justification of all the choices.
Phase 3 : Updating of all related documentation: safety analysis, safety reports, environmental impact, etc…

Studies are made by NRG teams, with ANL as independent expert, to validate all the results.

4.2 Phase 1 results

The phase 1 is ended and the final report has been sent out to the safety authorities. This report explains the parametric studies made, the reason for the chose and the final design chosen for the new fuel element.

This choice was made with the following parameters [ref. 3 and 5]:
- 5 elements/cycle with an increase of cycle length from 24,7 days to 28,3 days (this point allows to have four necessary irradiation's, in the same place, for technetium production);
- same power, same geometric distribution.

The final optimised element is the following (see ref 5):
- 20 plates with 0.76 mm thick fuel meat;
- < 4,8 g/cm^3 silicide;
- 20 cadmium wires of 0.5 mm per element;

With this element we arrive to the final result:
- less than 5% of thermal flux reduction;
- less than 3% of gamma fluxes modification;
- same fast flux.

4.3 Phase 2

The phase 2 has just begun with 9 technical points to study that covers all the technical qualifications of the new element.

These 9 points are the following:
1. Neutronic calculations (during progressive conversion and for several cores).
2. Hydraulic pressure drop measurements.
3. Thermo-hydraulic calculation (verification of margins).
4. Behaviour of fuel: bibliographic review.
5. Mechanical consequences (weight/control-rod and loading).
6. Consequences on experiment safety (BNCT, test, etc.).
7. Consequences on HFR fuel cycle.
8. Consequences on accident calculations (change in source term, transient behaviour, etc…).
9. Test of two elements in the reactor as industrial prototypes.

4.4 Planning

The planning is now the following:
- Phase II: 2001 (test with industrial prototypes ended in 2002).
- Phase III: 2002/2003
- Licence application: 2003.
- Procurement of LEU fuel: 2004.

N.B.:
The other works necessary for the obtention of the new licence will begin in parallel:
- safety re-evaluation;
- environmental impact studies;
- updating of safety reports.

4.5 Conclusion

The phase I has defined a good candidate for a progressive conversion with very classical and qualified silicide fuel, giving minimal penalties on fluxes and increasing cycle length to 28,3 days. This 20 plates element has already been tested in the HFR, and the tendering offer for prototypes will be made only for qualification of the industrial fabrication.

5. HFR contribution to UMo qualification

- The UMo was not chosen for delays in qualification, and for difficulties of optimisation in the case of HFR [see ref. 4]. But HFR is providing a good help for his qualification.

- For qualification test of research reactor fuel, HFR has a possibility of test scale 1, or possibility to test separate plates in special devices.
  For this type of test, the High Flux Reactor has many specific advantages [Ref. 4]
  - a large core, providing a variety of interesting positions with high fluence rates;
  - a downward coolant flow simplifying the engineering of the device;
  - easy access with all handling possibilities to the hot-cells;
  - a high number of operating days (>280 days/year), together with the high flux, giving a possibility to reach quickly the high bum-up needs;
  - an experienced engineering department capable of translating specific requirements in tailor-made experimental devices;
  - a well equipped hot-cell laboratory on site to perform all necessary measurements (swelling, y-scanning, etc.) and all destructive examinations.

- In the frame of the French supplementary program, one test with 4 plates has begun in March 2000. This test, names UMUS, will allow study the behaviour of UMo fuel with different densities and compositions for the French qualification programme.

- The test of two UMo elements scale 1 are under preparation for 2001.

<u>Conclusion</u>
HFR is interested in all new fuel development especially on high-density fuel (UMo) and is involved in these fuel qualification test programs.

6. Fuel supply

After the signature of the diplomatic notes in January 2000, a meeting was held with NRC, DOS and DOE in Washington to ask an export licence for 4 years of HEU, until the possibility to operate with the new LEU fuel.
From January to October, a very good co-ordinated work was held with all the actors: NRC, DOE, Oakridge, Trans Nuclear, CERCA, NUKEM, …
The key actions during these periods were preparation of US quantities by Oakridge, pré-transport, chemical analysis, establishment of all necessary contracts, obtention of container licence extension in all related countries, etc….
At the end the export license was issued just in time (August) to allow the first transportation’s that begun early in September.
We have to underline here the very good co-ordination, efficiency and co-operation of all US authorities involved.

<u>Conclusion</u>

The export licence and this first transportation allow us to continue the fuel fabrication during the conversion studies.

7. Back end of the fuel cycle

- A contract was signed several years ago with COVRA (Central Organisation For Radioactive Waste) to build a storage facility for the HFR spent fuel (HABOG facility).
  It is a dry storage of the elements in welded canisters with inert gas.
  This storage facility should contain about 1400 elements.
  The building has begun end 1999, after licence authorisation and should continue until 2003.

- The maximum value of spent fuel element storage in the HFR pools authorised by safety authorities has been reached in July 1999 and 2 MTR-II containers were loaded and stored in reactor containment. This limit was reached again in July 2000 and 2 other containers have been loaded.
  A transportation of these 4 MTR-II containers for the provisory storage on the COVRA site has begun, with the first transportation the 20th of September.

- After the exchange of diplomatic notes, it was theoretically possible to send spent fuel of American origin, back to the USA.
  A special budget for the shipment of about 120 elements was allowed in June 2000 by the ministry of environment. On the basis of this commitment , 2 contracts are to be concluded. One with DOE and one with a transport company.
  These 2 contracts are under finalisation and the planning for this shipment is under discussion (begin 2001).

<u>Conclusion</u>
The transport of the MTR-II containers to the COVRA site, the budget for an US shipment of about 120 elements and the HABOG facility under building for 1400 elements storage, are all very positive points that show a real progress in the back end of HFR fuel cycle.

8. Conclusion

The policy followed by HFR on the fuel cycle is clear, transparent and in the direction of an equilibrium status to be reached with the reactor beginning his conversion with LEU and the HABOG facility available for the final storage of spent fuel.
A lot of key actions were made this year:

- signature of diplomatic notes;
- export licence obtained;
- first HEU transportation;
- first MTR-II transportation to COVRA site;
- extra budget allocated for US shipment of spent fuel;
- end of conversion studies phase I and organization of phase II.

All these points are coherent and going in the same direction. The co-ordination of all these actions, and especially with our US correspondents was very good and was the key of all these successful actions.

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