STATUS IN 1998 OF THE HIGH FLUX REACTOR FUEL CYCLE

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ABSTRACT

The High Flux Reactor located at Petten (The Netherlands), is owned by The European Commission and is operated under contract by ECN (Netherlands Energy Research Foundation).

This plant is in operation since 1962 using HEU enriched at 90%. Conversion studies were conducted several years ago with the hypothesis of a global conversion of the entire core. The results of these studies have shown a costly operation with a dramatic decrease of the thermal flux which is necessary for the medical use of the plant (Molybdene 99 production). Some tests with low enriched elements were also conducted with several companies, several geometrical configurations and several enrichments. They are described in this paper. Explanations are also given on future possibilities for new fuel testing.

Recently new estimations were made with progressive conversion of the core and with new types of elements. These estimations show promising results but need to be confirmed by final calculations, specifically in the thermal-hydraulic field to verify the necessary safety margins. These final studies could also confirm the final cost of a conversion (fuel consumption, loss of flux, cycle length, etc ....).

For the back end of the fuel cycle, this paper presents the interim storage in the pools of the plant before dry storage with containment in helium.

1) Introduction

The HFR located at Petten (Netherlands) belongs to 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 Netherlands Energy Research Foundation (ECN).

The HFR is of the tank-in-pool type, light water cooled and moderated. It is operated at 45 MW. In operation since 1962, and following complete refurbishing in recent years, 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 [1] : 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 virtually provide all envisaged post-irradiation examinations.

Fig. 1 gives a cross section of the facility at core centre line.

The close co-operation between the Joint Research Centre and the Netherlands Energy Research Foundation (ECN) 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, ECN, Mallinckrodt and hospitals leads to a medical structure unique in the world, and more than 50% of reactor is already used by medical applications; radio-isotope production, Boron Neutron Capture Therapy, etc.

The present HFR operating schedule consists of 11 cycles of 28 days (24.7 days of full power operation and 3.3 days for core reloading 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 issued in October and is followed as closely as possible to offer the users a predictable timetable for reliable experimental and isotope production planning.

Figure 2 shows HFR operational record from 1962 to 1997.

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, 19 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 UALx-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 active length of the fuel inside the plate is 600 mm. The uranium is at least 89% enriched in 2-15U . The uranium content of the fresh fuel assemblies is 450g235U . The two side plates of each fresh fuel assembly contain together 1000 mg '013.

- 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 31 Og235U - 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.

3) HFR Conversion studies

- Historical studies
  From 1990 to 1996 studies were made for the HFR, to see if conversion of the core from HEU to LEU was possible.
  These first studies were made for a global conversion of the core, which conducts to a very expensive solution.
  Neutronic problems appeared very soon in the studies. If we replaced with the same geometry directly HEU by LEU, no sufficient excess reactivity remains.
  Therefore we have tested several parametric possibilities : decrease the Boron from 500 to 300 mg and decrease the number of plates (to increase the U5 mass). But if there was no problem for the fast flux - that is roughly proportional to the power of the plant and remains constant - for the thermal flux the augmentation of U5 mass - in order to increase reactivity - conducted at a proportional decrease of the thermal flux in the core experimental positions.
  But HFIR is the main reactor for radio-isotope production in Europe and needs for that, a good thermal flux out of the core in the poolside facility.
  These problems, joined to the prohibitive cost of global core conversion, have conducted to stop the studies.

- New studies
  New hypothesis permit to begin new studies with LEU : possibility of progressive conversion and qualification progress for silicide with higher density (to 5.8g/CM3).
  On this new basis calculations have begun with the objective to obtain a progressive conversion without significant loss of thermal fluxes.
  These studies should also clarify a lot of questions where a response before any choice is needed.

4) HFR fuel testing

- length of the cycle and elements consumption (in this field a higher density can give possibilities)
- thermal-hydraulical margins (the reduction of plates number from 23 to 20 conducts to an increasing power of 15% by plate. A verification of thermal-hydraulic margins is necessary before any choice)
- control rods efficiency during the cycle
- estimation of gamma flux decrease (this is necessary to see if we have to change all our in-core devices for thermal reasons).

- Conclusion
  The new studies have begun and should permit at the beginning of year 1999 to confirm if it is technically possible to make a progressive conversion of the plant without significant loss of flux and with the respect of all necessary criteria (safety margins, length of cycle, fuel element consumption, etc…).

4. HFR Fuel testing

- Within the framework of the US sponsored RERTR programme, a total of 6 LEU elements have already been test irradiated in the High Flux Reactor (HFR) during the period 1981 to 1991. These elements containingU3 08 , U3Si2-AI and U3Si1.5-AI were fabricated by NUKEM (Germany), CERCA (France) and B&W (USA) respectively. The results of the in-core behaviour and the findings during PIE were reported at different RERTR meetings [2]. These tests were conducted in-core of the reactor with elements scale 1 and with a number of plates reduced from 23 to 20 for each element. The tests were conducted until a bum-up of 50% to 75%, without mechanical problems (swelling or fuel deformation).

- More recently tests scale 1 of LEU elements produced by UKAEA, (Dounreay, U.K.) were conducted in the core of the reactor [3], [4]. The two LEU elements completed 12 HFR cycles (307 full power days) to a burn-up of 55%. Coolant gap checks and visual inspections were performed after each cycle throughout the irradiation period that verified good in-pile behaviour of the fuel elements. At present the agreed post irradiations examination is being performed at ECN's hot-cell laboratories. The objective of these tests was mainly the qualification of UKAEA silicide production process.

- 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
  - 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
  - the high number of operating days (>280 days/year), together with the high flux, gives a possibility to reach quickly the high burn-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.

Several fuel tests for the future are presently under preparation.

- Conclusion
  The HFR has already made several tests using different types of fuel as well as different densities for research reactor fuel qualification.
  On the other hand, and for conversion studies, the HFR is very interested by all new fuel development especially on high density fuels.

5) Back end of the fuel cycle

A contract was signed with COVRA (central organisation for radioactive waste) to build a storage facility for the HFR spent fuel.
It is a dry storage of the elements in welded canisters with inert gas in the cavity.
This storage facility should contain about 1400 elements.
The beginning of building is waiting for licence authorisation for all the COVRA site.
At present about 800 elements are stored in the HFR pool, awaiting further transportation from HFR to COVRA site.

6) Conclusion

- HFR has begun studies to see if it is possible without significant thermal flux losses to start a progressive conversion of the core.

- The development of new fuel with higher density could help in the final choice and therefore HFR is interested to test and qualify these new fuels.

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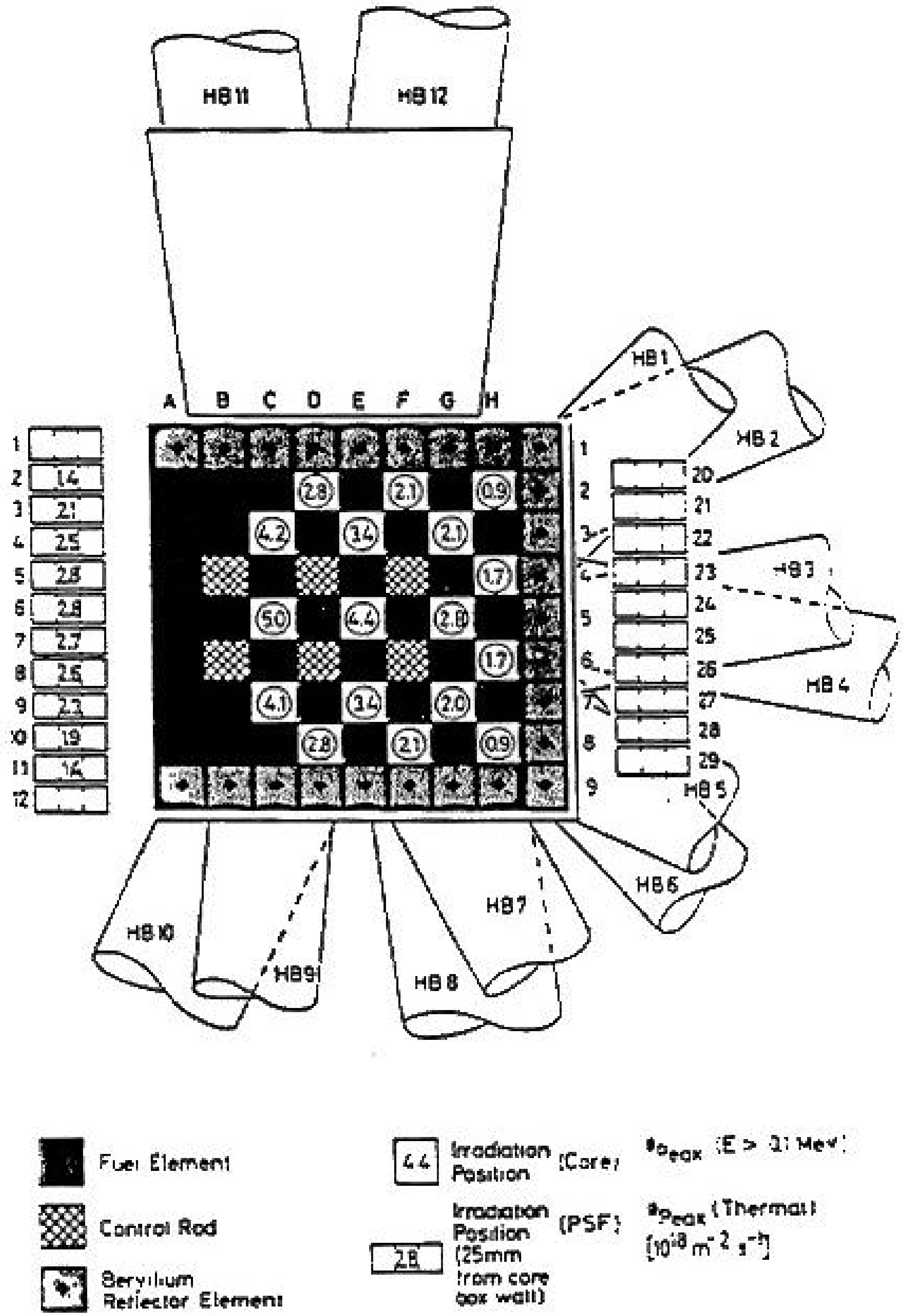

Figure 1 : HFR core configuration and beam tubes

Figure 2 : HFR operation days, 1962 - 1997