THE HOR CORE CONVERSION PROGRAM DEVELOPMENT AND LICENSING EXPERIENCES

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ABSTRACT

This paper deals with the experiences in the development of a fuel conversion program for a 2 MW university type research reactor, the HOR. It gives an overview of the technical and administrative aspects concerning the fuel conversion program development since the eighties, including the safety review and licensing process. The overall final safety report was submitted in 1995, together with the environmental impact report, and a licence application was submitted accordingly. The licence permitting the conversion was issued in 1996, coming into force at the beginning of this year, although an appeal case is still pending. At the moment the necessary preparations for starting the actual conversion of the HOR are made. The general program characteristics are addressed.

HOR CONVERSION BACKGROUND

It is generally recognized that the research reactor conversion issue effectively got momentum on an international scale in 1978 on the basis of:

- Nuclear Non-Proliferation Act (NNPA) in the United States;
- Guidelines for Nuclear Transfers ("London Guidelines"), IAEA doc. INFCIRC 254;
- Establishment of the Reduced Enrichment for Research and Test Reactors (RERTR) Program by the U.S. Department of Energy;
- Assessment of the technical and economic aspects of possible research reactor conversion in the framework of the International Fuel Cycle Evaluation (INFCE), in particular commencing Subgroup C (Research Reactors) of Working Group 8.

The summary and findings of Subgroup C were adopted and published at the conclusion of INFCE in 1980 [1]. The possibility of enrichment reduction, preferably to 20 % or less, was one of the main issues which was emphasized to increase proliferation resistance. Also, in connection with the incentives of the

U.S. administration on limiting the use of HEU fuel to the maximum possible extent, IRI was confronted more directly with the consequences of this policy by experiencing fuel supply uncertainties in the late seventies.

From 1980 on, IRI has joined and has been participating in the RERTR Program. A preliminary statement on the intention to convert was issued in the beginning of 1980, subject to the availability of suitable fuel material and acceptable solutions to anticipated problems. It was followed by study and analysis of possible ways to convert to low enrichment, and the impact of such a move on the design and operation. In particular, a research program on thermalhydraulics was initiated and fuel temperature measurements were performed at the HOR for different experimental core conditions [2]. Following the promising results of the silicide fuel development, decisions on the strategy and boundary conditions for the conversion process were taken, and in 1986 a formal statement to convert to LEU was issued.

HOR CHARACTERISTICS

The Interfaculty Reactor Institute (IRI) of the Delft University of Technology has been operating the HOR, a 2 MW pool-type reactor since 1963. The reactor is used in a variety of research and educational activities, mainly in the fields of neutron and positron beam physics research, radiochemistry and neutron activation analysis, and reactor physics. The HOR is the one and only university type research facility of its kind in the Netherlands. The research program is linked to many national universities, as well as institutions abroad. Table 1 gives the general data of the reactor in the present configuration.

Nuclear design, originally	American Machine & Foundry Company
Date of first criticality	April 24, 1963
Maximum power licensed	3 MW (forced cooling mode)
Normally scheduled power	2 MW
Operating schedule	5 days/week continuously; weekends shutdown
Cooling modes	Natural upward or forced downward flow
Coolant nominal flow rate	288 m^3/h
Fuel	HEU, 93 % enrichment
Fuel element burnup at discharge	approx. 55 % ($\approx$ 84 MWd)
Typical core loading	3.6 kg of U-235
Control rods	4, boron carbide type
Reflector	Water and Be
Maximum licensed excess reactivity	6 %

Table 1 HOR General data

PREPARATORY STAGES

In 1987, the preliminary LEU fuel element design characteristics were adopted in close cooperation with the fuel fabricator on the basis of proven fabrication technologies. The LEU fuel element geometry remained unchanged from the existing HEU type fuel, but with a considerable increase of the uranium loading in order to improve the economics of the LEU fuel cycle. Subsequently an order for third party safety analysis and review of the HOR with HEU, LEU and mixed fuel operation was given in 1988. The results of these activities were reported in the course of 1989 and the final fuel element design was fixed. An overview paper of the conversion study was submitted at the RERTR meeting at Berlin in 1989 [3]. It was the general perception at that time, that LEU fuel could be applied from 1991 on. This, of course subject to a positive outcome of the license application, but there were no indications of serious objections. In view of the fuel supply situation at that time, a first batch of LEU fuel elements was ordered in 1990 and manufactured during 1991. Table 2 gives the LEU fuel element design parameters in comparison with the existing HEU design.

	HEU	**LEU**
Number of plates per fuel element	19	19
Number of plates per control element	10	10
U-235 loading per fuel element [g]	190	300
U-content per fuel element [g]	204	1519
U-235 loading per control element [g]	100	158
U-content per control element [g]	108	800
Enrichment [%]	93	19.75
Meat material	UAl_x-Al	U_3Si_2-Al
U-density in meat [g/cm^3]	0.58	4.3
Meat thickness [mm]	0.5	0.5
Cladding thickness [mm]	0.3	0.35
Coolant gap width [mm]	3.1	3.0

Table 2 HEU and LEU fuel element design parameters

In particular in the mixed core situation, for certain stages of the gradual conversion process the thermalhydraulics analysis indicated a reduced safety margin, implicating a decreased limit for power operation. In order to keep the full performance of the reactor, it was decided to increase the coolant flow rate and an upgrading program for the coolant loops was started accordingly in 1991. The nominal primary flow rate was increased from 220 m^3/h to the present value of 288 m^3/h, based on the thermal-hydraulics study results. For the increased flow rate case for mixed core operation, an updated safety review of the earlier work reported in 1989 was performed in 1993. Moreover, an experimental program to assess the hydraulic performance of the reactor core with increased flow, including validation of the core thermalhydraulic model was established [4], and the results were used for validating the updated safety review.

SAFETY CASE AND LICENSING EXPERIENCES

The safety analysis work in 1988 was performed on the basis of the technical information [5] and IAEA-standards/guidelines [6] available at that time. The safety analysis review results were submitted in 1990 to the authorities in the framework of an intended licence application for conversion, followed by technical discussions with the authorities in 1991. Based on the information submitted, the regulating authorities agreed that there were no major objections from the safety point of view for converting the HOR, and a simple, short licensing procedure was considered to be appropriate. Figure 1 gives an overview and the key data for the whole of the planning and preparatory stages related to the conversion process.

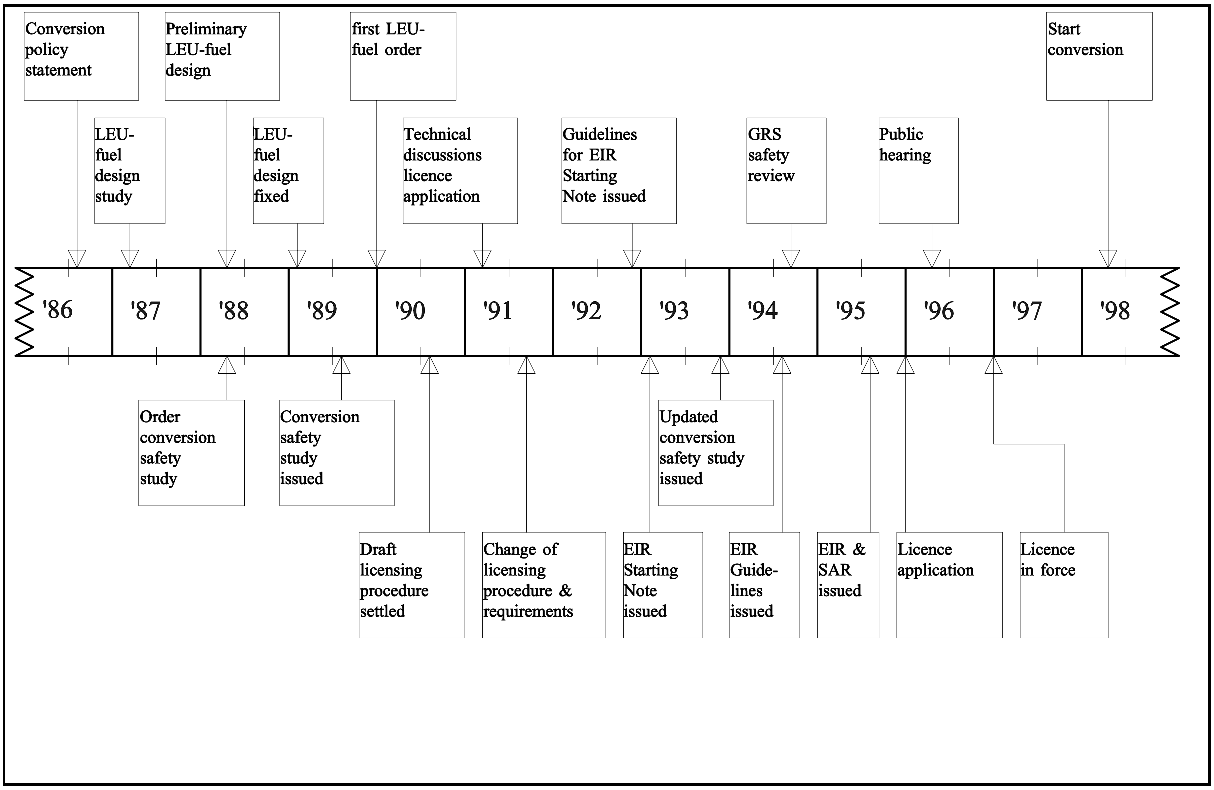

Figure 1 Overview and key data of the HOR conversion planning and preparations

Also, in 1991 a safety analysis report (SAR) in the framework of a licence revision, including the fuel conversion, was drafted and discussed with the licensing body. The authorities concluded on the basis of the information submitted, that the LEU application would not introduce additional and more serious hazards beyond the scope of hazards that had been under consideration for the licence in force. Further, an extended licence procedure including an environmental assessment was not deemed to be necessary. So, during the first half of 1991 draft versions of the material to be submitted for a licence application were prepared and discussed accordingly on different occasions. In the discussions the authorities pointed out that drafts of new IAEA-standards [7] had been issued, and that these were to be used for our application. So, accordingly a review and revision of the material submitted in 1990 became necessary. Also, it was made clear that any LEU fuel was only allowed to arrive at the Delft site after successful completion of the licence procedure. The schedule for conversion was postponed accordingly, and a target date of November 1, 1991, was set for submitting a draft licence application.

In the meantime, in a final appeal case in connection with another licensing procedure for one of the power stations, a crucial court verdict was given which turned out to be of great impact on nuclear licensing in the Netherlands in general. The legitimacy of the licence in force for the involved power station was denied and the procedure followed was declared inadequate. The authorities were rather confused for a while by this verdict, but a general conclusion was that in practice a nuclear licence procedure involving a change or modification of any nuclear installation should always be associated with an environmental impact review in accordance with the Environment Law, including public involvement and public hearing. This had immediate impact on the HOR relicensing procedure, as the need for a licence revision had been formally justified earlier by the authorities in connection with the fuel change from HEU to LEU. The authorities asked us to postpone our application and to make further preparations on a technical level. Because of the considerable delays, IRI was forced to procure additional HEU supplies for guaranteeing continued reactor operation.

The licensing process was interrupted for almost a year. By November 1992 a draft of a so-called Starting Note on the environmental reporting was discussed and by March 1993 the approved Starting Note on the Environmental Impact Report (EIR) was submitted for public review and comment. By July 1994 the final guidelines for the Environmental Impact Report were received from the authorities, and by August 1995 the EIR and the overall Safety Report were ready for approval. Moreover, the German safety body GRS performed an expert safety review in 1994 of the anticipated conversion and the submitted safety analysis on request of the regulating authorities. In December 1995 a formal licence application was submitted and in February 1996 it was announced to the public. The licence to convert was issued in November of that year and came into force in the beginning of January 1997. An appeal procedure is still pending now.

CONVERSION PROGRAM OUTLINE AND STATUS

The core conversion process will be performed by stepwise introduction of LEU fuel assemblies during core reload operations at the start of each operation cycle [3]. The conversion process will be completed in about five years. Also, it is the intention to compact the core further during the conversion process from the present configuration with 28 fuel elements and 11 beryllium reflector elements to a configuration with 20 fuel elements and 21 beryllium reflector elements.

For the present HEU core configurations, a Centre-to-Outside core-reloading pattern is followed, i.e. new fuel elements are introduced in the centre of the core and the fuel elements with the highest burnup are at the outer core region. For the transition phase with mixed fuel cores this pattern cannot be maintained, because of the considerable higher fuel loading of the LEU fuel elements and the thermalhydraulic constraints. Therefore, new LEU fuel will be introduced in the outer core positions when starting the transition phase, and an Outside-to-Centre reloading scheme is followed. Also, in order to limit the power peaking factors, the first replacement of control elements will be performed rather late in the transition phase. For the first LEU core, the fuel elements with the higher burnup are concentrated mainly in the core centre, in contrast with the LEU working core. So, the initial LEU burnup distribution and reloading pattern has to be changed smoothly in order to arrive at the quasi-equilibrium distribution with high burnup at the outside. Figure 2 displays the present and the intended core configurations (LEU working core).

A program has been designed for scheduling and monitoring the conversion process, including guidelines for core design and follow up measurements for validation and evaluation of core calculations, performed with IRI's INAS code system [8]. Also, a measurement program of the reactor characteristics during conversion will be performed, including monitoring of safety parameters. Figure 3 gives an overview of the program items as they are linked together. The program is being detailed further now and the actual conversion should start in the first quarter of 1998. The first 10 LEU fuel elements, which are still in storage at the supplier, are expected to be delivered at the Delft site on short term.

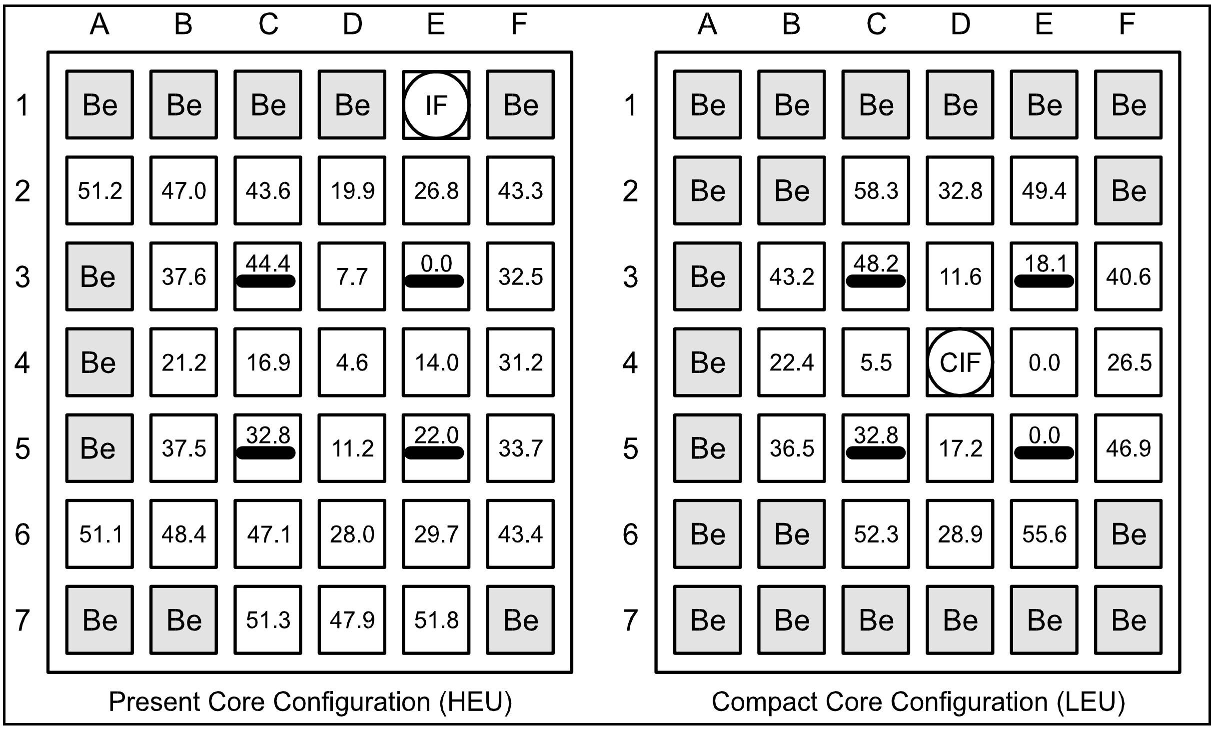

Figure 2 Present core and LEU working core configurations

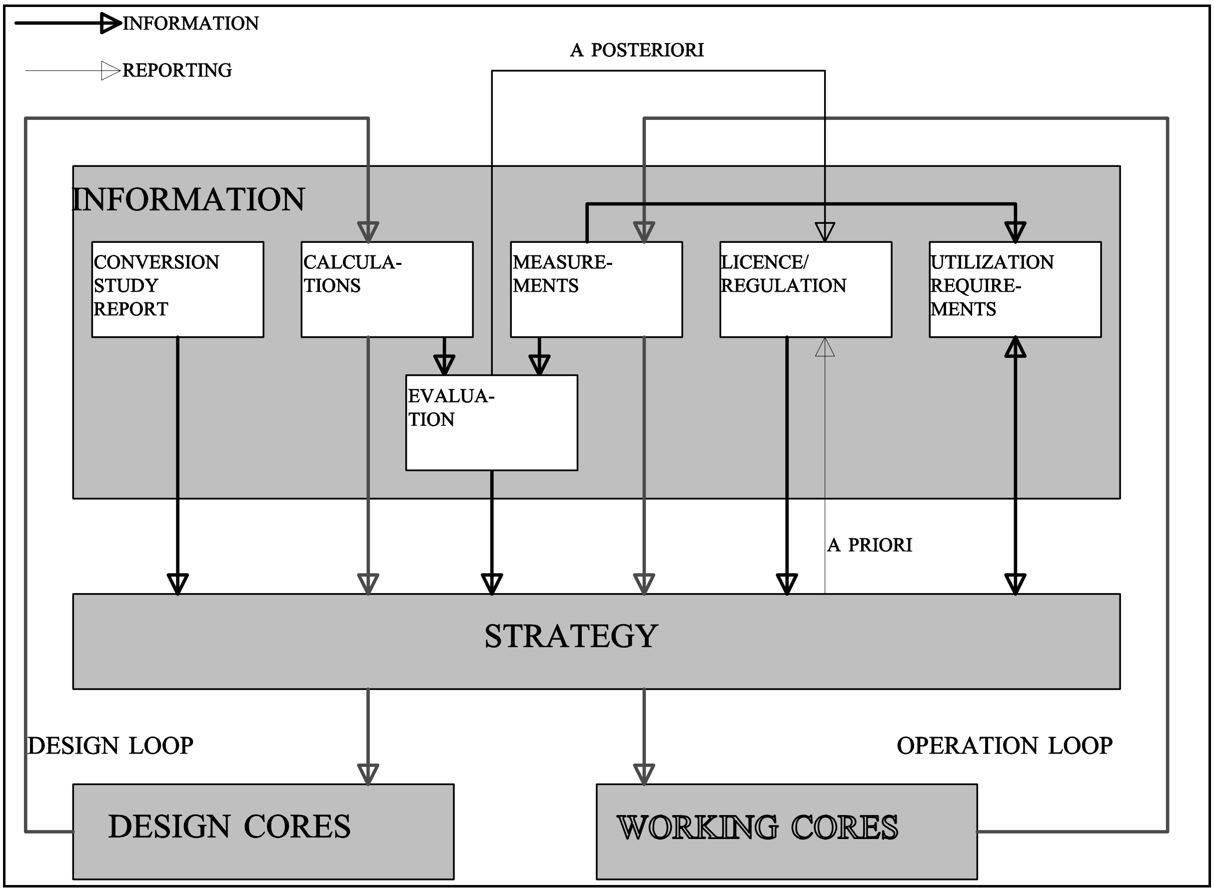

Figure 3 Overview of the HOR core conversion program items

CONCLUSION

Starting from the preliminary intention note in 1980, evidently the HOR fuel conversion program mission turned out to be a long term process, much more costly and time consuming than anticipated in the eighties and involving additional issues like a separate environmental impact licensing procedure. For a university type institute like IRI with rather limited resources, and many external factors and non-technical items having a major influence, the careful planning and realization of that mission turned out to be complicated and not so straightforward. The lead times, partly overlapping in calendar time, have been rather long: generic fuel development and testing: 8 years; fuel specification and procurement: 3 years; safety analysis and review: 3 years; licensing procedure and conclusion: 5 years. The conversion process is yet to begin and will take another 5 years. Under the assumption of successful completion, the whole program mission effort from conception of the idea to full implementation will have lasted 23 years. In preparing the conversion process, the program efforts have been quite substantial in comparison to the remaining useful lifetime of this research reactor.

REFERENCES

[1] INFCE Summary Volume, International Fuel Cycle Evaluation, INFCE/PC/2/9,1980

[2] H. van Dam, J.W. de Vries, "Research activities relevant to the application of LEU at the HOR", in Proceedings of the Int. RERTR Meeting, Argonne, Illinois, November 8-10, 1982, Argonne Nat. Lab., ANL/RERTR/TM4, CONF-821155, 1983

[3] A. Strömich, J.W. de Vries, "Core conversion studies for the use of LEU Fuel at the Delft Reactor HOR", in Proceedings of the Int. RERTR Meeting, Berlin, September 10-14, 1989, Forschungszentrum Jülich GmbH, 1991

[4] H.P.M. Gibcus, J.W. de Vries, P.F.A. de Leege, "Thermal hydraulic model validation for HOR mixed core fuel management", in Transactions 1st International Topical Meeting on Research Reactor Fuel Management, February 5-7, 1997, Bruges, Belgium, European Nuclear Society, Berne, 1997

[5] Research Reactor Core Conversion from the Use of Highly Enriched Uranium Fuels to the Use of Low enriched Uranium fuels, Guidebook, IAEA-TECDOC-233, IAEA, Vienna, 1980

[6] Safe Operation of Research Reactors and Critical Assemblies, Code of Practice and Annexes, 1984 Edition, Safety Standard, Safety Series No. 35, IAEA, Vienna, 1984

[7] Codes on the Safety of Nuclear Research Reactors, Safety Standards, Safety Series No. 35: Design (No. 35-S1) and Operation (No. 35-S2), IAEA, Vienna, 1992

[8] P.F.A. de Leege, H.P.M. Gibcus, J.E. Hoogenboom, and J.W. de Vries, "Calculation of Mixed HEU-LEU Cores for the HOR Research Reactor with the SCALE Code system", Proceedings of this Meeting, to be published