MYRRHA Draft-2 Design accomplishments

Background

One of the main SCK•CEN research facility, namely the Materials Testing Reactor (MTR) BR2, is nowadays in operation for more than 40 years. The need for a safe and economic operation of the European nuclear park for preserving the natural resources, demand the start-up of one or more new MTRs in a very near future. On the other hand the closing of the fuel cycle as well as the development of future energy systems request clearly the use of fast spectrum irradiation facilities.

Objectives

The MYRRHA project started at SCK•CEN in this context, the concept of a new irradiation and testing facility to replace BR2. MYRRHA, being a **fast neutron** facility, would be a complementary project to the **thermal** MTR Jules Horowitz Reactor in France. That would give Europe a full research capacity in terms of nuclear R&D for Gen.III and IV reactors.

At mid-2002, a first pre-design file of MYRRHA (namely the "MYRRHA Draft – 1" file with a core nominal power of 30 MW_{th}) has been submitted to an International Technical Guidance Committee (ITGC) for reviewing. No show stopper has been identified in the project. Nevertheless, the ITGC members have recommended:

- to give more attention to safety studies and iterate to the pre-design before entering the detailed engineering phase;
- to address some R&D topics to avoid bottlenecks such as fuel pin and assembly development and qualification;
- to make a decision on the accelerator option (cyclotron or LINAC) and possibly revisit the beam parameters that were already at that moment fixed to 350 MeV*5 mA but mainly derived from the cyclotron technology possibilities.

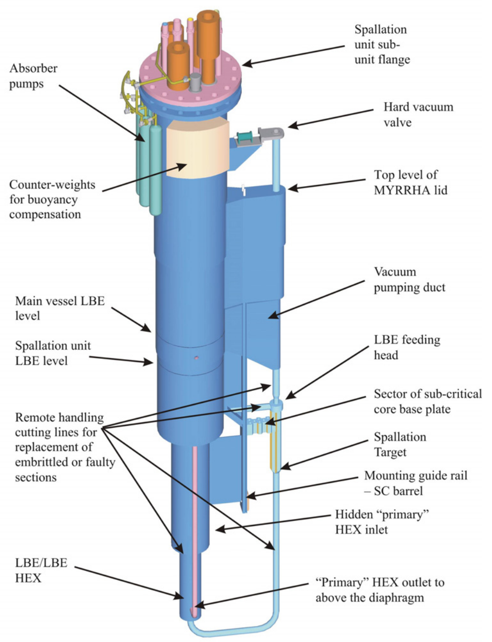
The objective of this effort in the period 2003-2005 was to update and progress the MYRRHA Draft-1 design based on the ITGC evaluation results, the consequences of the safety studies that had to be accomplished on basis of the Draft-1 design and holding the initial objectives of the MYRRHA facility. This resulted at mid-2005 in producing the MYRRHA Draft-2 design file.

Principal results

MYRRHA Draft-2 design meets the objectives of the experimental ADS Facility in terms of demonstration and the aimed performances, and proposes solutions that satisfy the key issues related to the LBE ADS such as:

- limiting the LBE corrosion and erosion by leaving the major parts of the system at “cold” conditions and by limiting the LBE velocity below 2.0 m/s in the hot parts;
- avoiding the risk of criticality insertion during fuel handling by leaving the spallation target in position and loading fuel assemblies from underneath;
- eliminating the risk of spallation target window break by choosing the windowless design;
- reducing the risk of the core melting by adequate design of fuel elements and cooling systems;
- reducing the personnel exposure and achieving a high availability of the facility (~75%) by performing the in-service inspection and repair (ISI&R) and the operation and maintenance (O&M) from the conceptual design on, by means of robotics and ultrasonic visualisation.

The accelerator of MYRRHA is now based on LINAC technology in order to be fully demonstrative for the industrial scale ADS and to be responding to the very demanding conditions in terms of beam reliability (less than 5 beam trips per MYRRHA cycle of 3 months). The windowless spallation target concept of MYRRHA has been progressed in terms of design and demonstration on the basis of an important international experimental programme complemented by an international CFD effort for the free surface treatment. The evidence of the feasibility of the proposed design is no longer questioned with respect to its fundamental aspects. The conceptual design of the spallation loop is finished, including its stable and safe operation in both steady-state and transient conditions, vacuum generation and LBE conditioning. The off-centre servicing of the spallation loop (see figure below) has an added value. Indeed, it limits the central hole where the spallation module will be housed increasing thereby the maximal flux levels. On the other hand, the radiation damage of all the sensitive components of the spallation loop will be reduced. The chosen core maximum sub-criticality level of $k_{eff} \sim 0.950$ ($k_s \sim 0.96$) assures a comfortable margin for safe operation (~2400 pcm margin with beam off when accounting for all reactivity insertion sources and still ~1300 pcm even when the proton beam is on). The total power of MYRRHA is now amounting to ~50 MWth with acceptable values of the radial and axial power form-factors; 1.1 and 1.3 respectively in the hottest fuel assembly. The high fast (E > 0.75 MeV) and total neutron flux levels are achieved within the facility ($1.0\ 10^{15}$ and $5.0\ 10^{15}$ n/cm².s respectively) in large irradiation volumes in the core (about 20.000 cm³ in total), in the neighbourhood of the spallation target.



MYRRHA off-centre spallation target loop

The fast fluxes are ranging between 1.0 10^{14} and 5.0 10^{14} n/cm².s in about twice this totalvolume located further on in the radial direction. The MYRRHA fuel design (pellet, fuel pin and fuel assembly) proposed in Draft-2 design is based on the FBR MOX fuel technology taking into account the targeted objectives of the MYRRHA facility in terms of performances and the present day knowledge concerning the ferritic-martensitic steel T91 that is considered as prime candidate material for the cladding and for the fuel assembly wrapper. The targeted performances to operate at high peak power density (about 1.5 kW cm^{-3}) in order to provide the needed neutron flux level in the core during a long term operation up to peak burn-up level of 100 GWd/t_{HM} and clad damage up to 100 dpa are estimated to be within the achievable range. The primary system of the MYRRHA facility is designed in such a way as to limit abrupt flow changes of the LBE in order to mitigate the erosion problems. Moreover, the operation temperatures were chosen in order to mitigate the corrosion due to LBE. The implementation of chicanes in the HLM circulation from the hot to the cold zone in the casing containing the heat exchangers will prevent water ingress in the core.

The MYRRHA building has been conceived taking into account the remote handling (RH) and robotics based operation and maintenance within a controlled atmosphere limiting the LBE contamination by O_2 trapping. The remote handling for both out-of-vessel and in-vessel operation and maintenance has been developed on the basis of existing and demonstrated technology in the JET facility. Its estimated life time is 15 years in the MYRRHA working conditions.

MYRRHA being a first of a kind ADS, is intended to be operated in a conservative way in terms of availability during the first years. For the moment, it is foreseen to have an operating cycle of a 3 months operation followed by a 1 month shut-down period for preventive maintenance for the reactor as well as for the accelerator. The k_{eff} drop during the 3 months operation is limited to ~1700 pcm, and in the present design it is not considered to compensate for it during the MYRRHA short operation cycle. This will result in an integral flux loss of 18 % over the 3 months cycle.

A visualisation system based on ultrasonic technology is proposed for the in-vessel, under-LBE inspection based on fixed camera to be deployed on “periscope”-like systems or on moving “snake”-like systems. A support R&D programme has been launched and has already produced promising results.

The safety analysis of the main initiating events in protected conditions (beam off) shows that the MYRRHA system - despite the very high power density targeted in the project - will survive without major difficulty. In particular the efficiency of the emergency cooling by natural circulation in the primary system is established. The conclusions are less favourable for the unprotected events - at least for some of them. For instance, loss of heat sink (LOHS) can lead to the maximum temperature limits of the cladding after 9 minutes even if the emergency cooling system (ECS) is activated. Also, loss of flow (LOF) will lead to cladding damage since a hot spot jump of the cladding temperature up to 1060°C can occur in 25 seconds. However the feedback effects of the primary system behaviour on the spallation target performance, that most likely would mitigate the accident consequences in unprotected situations, were not taken into account in the study.

A preliminary cost assessment of the investment has been conducted and led to a 440 M€ (June 2004) total cost as a average (best estimate) value and 560 M€ (June 2004) for the high figure when taking into account the contingencies on the most innovative components. These figures are the one based on the LINAC accelerator.

Future work

In the frame of the integrated FP6 project, EUROTRANS, the MYRRHA design parameters and choices are open to a larger European community in order to better meet the objectives of the experimental ADS for transmutation presently considered within the EUROTRANS community namely the XT-ADS facility. During the FP6 EUROTRANS period (2005-2008), the following topics are to be investigated:

- producing an advanced Pre-design File of XT-ADS starting from MYRRHA and keeping in mind EFIT;
- answering the potential show stoppers in Basic Technological (material, HLM technology, instrumentation);
- designing, building and testing the Key Accelerator components;
- designing the spallation module from the point of view of hydraulic, vacuum and mechanical design;
- realising a coupling of the ADS components at realistic power.

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Main reference

H. Aït Abderrahim et al., *"MYRRHA Pre-Design File – Draft 2*", SCK•CEN Report R-4234, June 2005 (2005).