SAFETY ASPECTS OF THE RECH-1 CORE CONVERSION

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ABSTRACT

When the RECH-1 research reactor joined the core conversion program for low enrichment fuel, the need to review some safety related aspects, which are currently under way with different degrees of progress, became apparent. The mentioned aspects can be grouped into:

Evaluation of the technical specifications of the new fuel elements: the technical specifications were carefully verified and contrasted with the recommendations of the IAEA and with those of manufacturers which are widely known for their expertise.

RECH-1 relicensing: considering the new fission products inventory, a reevaluation of accident scenarios based on risk analysis tools, deterministic calculations and atmospheric dispersion studies is being accomplished.

Qualification of the fuel element manufacturing process: the qualification of the fuel elements relies, mainly, on the application of a rigorous program of Quality Assurance during fabrication.

Monitoring the new fuel elements performance during irradiation: the core conversion program envisages the initial loading of four lead fuel elements, which will be submitted to periodical controls in order to verify their performance under irradiation conditions, pryor to proceeding to the new full core.

INTRODUCTION

The research reactor RECH-1 was commissioned in October of 1974 and it has operated, since then, with an average utilization of 24 hours per week. Its original core consisted of 34 MTR type fuel elements of uranium enriched at 80%, with 16 fuel plates each, whose meat contained 11 grams of U^{235} in the form of uranium aluminide homogeneously distributed in an aluminium matrix. The RECH-1 was operated with this fuel during little more than 10 years, until January of 1985, when a first conversion to a mixed core was accomplished, using 45% enriched uranium, together with the original high enrichment fuel, since their physical characteristics were compatible both in neutronic as in thermohydraulic aspects[1].

In 1994 it was decided that the next fuel load would be a low enrichment one and that the fuel elements would be manufactured in Chile, by the Fuel Elements Plant of the Chilean Nuclear Energy Commission. This determined the accession of the RECH-1 reactor to the reduced enrichment conversion program for research and test reactors, RERTR.

EVALUATION OF THE TECHNICAL SPECIFICATIONS FOR THE NEW FUEL ELEMENTS

The enrichment change compelled the manufaturer to modify the fuel composition, from uranium aluminide to uranium silicide, in order to allow the greater loads of uranium without submitting the fuel elements to dimensional modifications, condition imposed by the operator of the reactor in order not to vary their thermohydraulic characteristics.

The technical specifications of the new fuel were initially developed by the chilean manufacturer[2], based on the specifications of the original high enrichment fuel elements. These were checked, firstly, by the operator of the reactor. The specifications were subsequently reviewed by the regulatory body which was acting, for these effects, as a quality assurance auditor. Resulting from this review, some specifications were amended and new specifications were added, and the technical document[3] was given a format and contents based on the specifications developed by the Argonne National Laboratory, published as Appendices K-4[4] and K-2[5] of the IAEA-TECDOC-643.

The approved document contains specifications associated with:

a) Documentation, that include, for each document:

Approval method	Identification of the persons that check and approve the document
Distribution	Units or persons to whom copies of the documentation are delivered: before the qualification, during the manufacture and with the delivery of the fuel elements
Control and filing	Security classification and filing period of the documents
Final disposal	Quantity of copies to be kept in the history file and disposal method of the rejected copies

b) Materials, that include, for each specified characteristic:

Requirement or standard	International standard, or experienced fuel elements manufacturer's recommended value adopted as such a standard
Specification and acceptance criteria	Nominal value and tolerances adopted by the manufacturer, in compliance with the requirement
Sampling plan	Quantity of samples to be taken and their sampling methods

Testing method	Analytical method to be used in order to prove out the compliance of the specifications

c) Components, that include, for each specified parameter:

Requirement or standard	International standard, or experienced fuel elements manufacturer's recommended value adopted as such a standard
Specification and acceptance criteria	Nominal value and tolerances adopted by the manufacturer, in compliance with the requirement
Sampling plan	Quantity of samples to be taken and their sampling methods
Testing method	Analytical method to be used in order to prove out the compliance of the specifications

d) Processes and procedures, that include, for each process variable or specified action:

Requirement or standard	International standard, or experienced fuel elements manufacturer's recommended value or procedure adopted as such a standard
Specification and acceptance criteria	Nominal value and applicable tolerances for the process variables, or procedures adopted by the manufacturer
Approval method	Identification of the persons that check and approve the procedure
Control plan	Definition of the coverage of the supervision or of the process controls to be registered

Associated with the specifications document there exists a "Procedures Manual"[6], in which it is described, in detail, each one of the manufacturing and quality control procedures: responsibilities; prerequisites (availability of equipment, materials and special working conditions); step by step procedures descriptions; process records; reference information (drawings, manuals and other documents); and rejection criteria are defined.

The quantity and quality of the data to be registered will allow the reactor operating staff to make a better estimate of the so called "technological factors" of the fuel elements, what will permit, in due time, to improve the operational calculations, such as fuel burn-up, and those associated to safety, e.g.: accident analises calculations of transients.

RELICENSING OF THE RECH-1 REACTOR

The RECH-1 was built under the "turnkey" modality, by the British company FAIREY Engineering Ltd., and its first licensing process was conducted by the manufacturers, since the contract established that the said reactor would have to be built and delivered giving fulfillment to all applicable British regulations.

When its core was converted to mixed fuel, the relicensing activities were reduced to the verification, by calculation, of the neutronic and thermohidraulic behaviour of the new core, and its operation was authorized when that behaviour was proven not to be significantly apart from that corresponding to the original core. The calculation results were verified, thereinafter, upon carrying the reactor to its first criticality with the mixed core and, later, during the subsequent normal operations stage.

Given that safety regulations have suffered drastic changes since the initial commissioning of the RECH-1, and due to the unavoidable ageing experienced through the course of 24 years of operation, it was decided that, on the occasion of the conversion to low enrichment, an in-depth relicensing process would have to be carried out in two stages: firstly, devoted to the systems directly related to the safety and whose operating characteristics could have been directly affected by the core change and, secondly, the remaining systems of the reactor[7,8].

The first stage is currently under way and should be completed before the end of the year. The systems to be analyzed are those that intervene in the prevention of accidents caused by the anticipated operational events or in the mitigation of their consequences: losses of flow, losses of coolant and reactivity insertions. According to this, the systems that are currently under evaluation are:

a) the reactor core coolant circuit and its extensions, that constitute the core coolant boundary

b) most of the reactor protection system:

- neutronic channels: logarithmic, linear and ^{16}N
- thermohydraulic channels: flow, pressure drop through the core and coolant temperature at the pool inlet
- radioactive levels: reactor containment atmosphere and core coolant dose rates
- scram logic circuits

c) the automatic control system

d) the emergency ventilation and containment isolation systems

A domestic licensing approach called "hybrid method"[9,10], for it makes use of both deterministic and probabilistic methods, is being used. For analysing the systems listed above, Risk Analysis tools were employed, in particular, the "What-if" technique, assisted by the computer code PHAWORKS[11]. A probabilistic safety analysis of the reactor protection system is foreseen, to be accomplished using the code RISKSPEC[12], during the second stage, even though the recently completed risk analysis has demonstrated that the safety characteristics with which it was provided: multiple redundancies and fail-safe components, make the complete loss of one of its protection channels to be considered a "non credible event", this is, that its occurrence probability is less than $1 \cdot 10^{-8}$.

In addition, transients calculations considering the characteristics of the new core have been made in order to characterize the evolution of the anticipated operational events, which had not been carried out for the preceding cores. Even though the risk analysis shows that a protection channel failure probability is extremely low, the hybrid method assumes, in a conservative position, that the protection channel of lower delay time fails and that the scram of the reactor is accomplished by the second safety trip in the events sequence. Based on these premises and assuming extreme conditions, source terms for various accident cases have been determined, in terms of percentages of core affected by the accidents, using the TRANSV2[13] code, which allows to simulate both flow and reactivity transients.

The source terms thus obtained, the hourly meteorological data collected during more than two years and the demographic data of the area where the reactor is located, constitute the input data for the calculation of radiological consequences, which are accomplished with the code COSYMA-PC[14], which will allow to close the analysis with an estimate of the dose to the population and other usefull results at the time of assessing the risk and deciding whether the reactors operation authorization is to be granted or not.

QUALIFICATION OF THE FUEL ELEMENTS MANUFACTURING PROCESS

According to the technical specifications, the manufacture of the fuel elements would be done in two stages: the first, of processes qualification, and the second, of normal manufacture.

The qualification stage includes the evaluation of each one of the manufacturing and control procedures included in the Procedures Manual, under the point of view of Quality Assurance; the manufacture of four "lead fuel elements", with application of a rigurous sampling plan for the quality controls; and a quality audits program in different phases of the manufacturing process.

In the procedures evaluation special care was taken in order to assure that:

a) there was explicit written statements of:
   - the scope of the procedure
   - the participants and their responsibilities
   - the equipments and materials to be used
   - the special working conditions or applicable operational restrictions
   - the data to be registered
   - the format of the records
   - the definition of special terms
   - the references to other documents

b) the document was self-sufficient, this is, that there was no need of additional information for the complete comprehension of the described procedure

c) the actions description was detailed, sequential and complete

d) it did not exist any ambiguity in the actions description or in the set values of process variables or other parameters associated with the procedure

e) there were explicit mention of the data to be registered and of the instant, in the actions sequence, in which those records should be made

The manufacture of the four lead elements was submitted to the Quality Assurance Area of the Fuel Elements Plant for permanent quality control, complemented by audits on the part of an independent Quality Assurance Group, whose members came from the manufacturer proper, from the reactors operation unit and from the regulatory body. These audits were accomplished: during the synthesis of uranium silicide, at the completion of the manufacture of the fuel plates for the first fuel element, at the end of the manufacture of the fuel plates for all four lead fuel elements, at the end of the assembly of the fuel elements bodies and at the completion of the final assembly of the fuel elements.

Successful results, with the rejection of only two fuel plates at the beginning of the manufacturing process, one for dimensional defects and for poor homogeneity, the other, problems that were later surpassed, demonstrated that the equipment, as well as the personnel in charge of the manufacture, are perfectly qualified to face the following stage, of normal production.

FOLLOW-UP OF THE NEW FUEL ELEMENTS DURING THEIR IRRADIATION

It has been established, as an operational condition, that no LEU fuel elements would be loaded until the last HEU fuel element was discharged from the reactor core, after completion of its final burn-up. It has been thus anticipated that the loading of the four lead fuel elements to observe their performance under irradiation conditions will take place during the fourth trimester of the current year. The loading of the full low enrichment core will not be made until the lead elements reach a burn-up level that allows to have a reasonable certainty of their good behaviour. Later, their relative advantage in terms of burn-up level will permit to continue using them as a prognostication tool on the behaviour of the remaining LEU fuel elements.

The evaluation methods for the lead fuel elements conditions are currently under study:

a) measurement, in dry conditions, of the coolant channel gaps: this requires to modify the design and recondition the internals of the high activity cell in order to accomodate the gaps measurement equipment

b) observation, in dry conditions, of the coolant channels: either directly or by means of a video camera, a borescope or other optical device not yet given; this might require to recondition the high activity cell

it must be realized that the high activity cell will be able to be used only until the lead fuel elements reach an activity that prevents their manipulation and safe transportation between the reactor pool and the cell, according to the characteristics of the available transportation device. Anticipating that this will occur at an early stage, it has been considered:

c) measurement, under water, of the coolant channel gaps: this require the design and implementation of a device capable of performing the said measurements in dip conditions

d) observation, under water, of the coolant channels: this requires an optical device with remote control and distant images transmission, based on optical fiber, not yet given

In either case, the measurement of the gaps as well as their observation are aimed at verifying that the blistering process has not taken place; swelling measurement has been discarded since it was demonstrated that the said effect would be imperceptible at low burn-up levels, based on calculations made at the Argonne National Lab., using the code DART[15].

Metallographic examination and other destructive tests have also been discarded given that the uranium silicide loading is well below the maximum value licensed by the US-NRC and recommended by the IAEA, whose irradiation behaviour has been extensively studied and proven to be faultless[16].

CURRENT STATUS

Currently, the progress of the different safety related stages described above are as follows:

Fuel elements specifications assessment — Completed

RECH-1 relicensing:
- Risk assessment — Completed
- Accidents analysis (deterministic) — Completed
- Accidents analysis (probabilistic) — Postponed until 1999 (2nd stage)
- Safety related documents evaluation — To be completed in November, 1998
- LEU core license — To be issued in November, 1998

Completed

Manufacturing process qualification

Follow-up of new fuel elements: — Completed
- Lead elements manufacture — Programmed for November, 1998
- Lead elements loading — Programmed for March, 1999
- First lead elements control

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