The CEA scientific and technical offer as a designated ICERR

(International Center based on Research Reactor) by the IAEA: first feedback with the prime Affiliates

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The IAEA Director General has approved on September 2014 a new initiative, namely the IAEA designated **International Centre based on Research Reactors (ICERR)**, which will help Member States to gain access to international research reactor infrastructures. In fact, for the agency, one of the main goals of this ICERR scheme is to help Member States, mainly without research reactors, to gain timely access to research reactor infrastructure to carry out nuclear research and development and build capacity among their scientists.
CEA has decided to be candidate to its designation as an ICERR and consequently has established a candidacy report following criteria given by the IAEA in the Terms of Reference (logistical, technical and sustainability criteria). The CEA offer is covering a broad scope of activities on the 3 following topics:

- Education & Training
- Hands-On Training
- R&D Projects.

The perimeter (facilities and associated scientific and technical skills) proposed by CEA on this ICERR is centered on JHR project; its future international Material Testing Reactor under construction in Cadarache. Ancillary facilities in operation proposed in this offer include:

- ORPHÉE research reactor in Saclay, neutron beams reactor used for science, academic and industrial research, training and education to the use of neutrons scattering,
- ISIS EOLE and MINERVE zero/low power reactors located in Saclay and in Cadarache, dedicated to Core Physic and Education & Training in nuclear engineering,
- LECA-STAR and LECI hot laboratories for fuel and Material Post Irradiated Examination, located in Cadarache and in Saclay.

The designation was the result of a rigorous process, including the review of the application and support documentation, an audit mission performed at the CEA sites, as well as a comprehensive evaluation and recommendation by an international selection committee made up of representatives from the global research reactor community and IAEA staff.

CEA Cadarache and Saclay centers are the first designated ICERR by the agency; this has become official during the last General Conference on the 14th September 2015. The Director General of the agency indicated the agency motivations at a ceremony during which he awarded the designation to CEA: *"Such centers will enable researchers from IAEA Member States, especially developing states, to gain access to research reactor capabilities and develop human resources efficiently, effectively, and, probably, at a lower cost. The ICERR scheme will also contribute to enhanced utilization of existing research reactor facilities and, by fostering cooperation, to the development and deployment of innovative nuclear technologies".*

Following this designation, CEA has established a generic template as an agreement to be signed between CEA and any institutes, organization from Member State wishing to become Affiliate to CEA through this ICERR Scheme (it is question here of a bilateral agreement, the IAEA being only a facilitator).This template indicates rights and duties of both parties willing to collaborate through this ICERR scheme.

The 3 first Affiliates to CEA signed this agreement in September 2016 (JSI from Slovenia, CNSTN from Tunisia and CNESTEN from Morocco) followed by 3 others Affiliates during the first semester of 2017 (BATAN from Indonesia, COMENA from Algeria and JAEC from Jordan).

Some first scientific and technical topics are now going-on giving some concrete examples of collaboration.

This paper presents in detail the CEA offer as an ICERR, the template agreement and describes, as examples, some first scientific and technical actions recently launched with the Affiliates.

Introduction

The “IAEA” designated International Centre based on Research Reactor (ICERR) scheme was approved by IAEA Director General on 9th September 2014 and officially presented to the IAEA Board of Governors during the meeting held on 15th September 2014.

The ICERR scheme is intended to help IAEA Members States gain timely access to relevant nuclear infrastructure based on RRs and their ancillary facilities. ICERRs will make available their RRs and ancillary facilities and resources to organizations/institutions of IAEA Member States seeking access to such nuclear infrastructure (named Affiliates). For Affiliates, ICERRs will provide an opportunity to access RR capabilities much sooner and, probably, at a lower cost.

The implementation of the ICERR scheme will also contribute to enhance the utilization of some existing RR facilities (e.g. those that, in order to meet the criteria for designation would be stimulated to enhance their utilization and to foster their accessibility to attract potential Affiliates). On the other hand, an ICERR could benefit, for example, from additional scientific and/or technical resources made available by the Affiliate (e.g. Secondees) and by the increase of its international visibility.

By fostering wider utilization in cooperative manner of RR(s) and ancillary facilities capabilities, ICERRs could also effectively contribute to the development and deployment of innovative nuclear technologies.

Description of CEA Facilities proposed in the ICERR

CEA has decided to be candidate to its designation as an ICERR and has prepared a candidacy report indicating its motivation and answers to the Terms of Reference criteria’s as being designated an ICERR-See Terms of Reference in (1). This report has been sent to the Agency in January 2015 for examination.

CEA has a few decades-long experiences in operating and using research reactors for various purposes, Zero Power Reactors for Core physics, Material Testing Reactors, safety-dedicated Reactors, neutron beams reactors for science and Low Power Reactor for Education & Training.

CEA maintains a long tradition of international collaboration agreements in the field of peaceful uses of Nuclear Energy both with Member States or organizations having extensive nuclear programs, but also with new comers (potential or existing ones) or countries with no or limited nuclear power experience.

The perimeter (facilities and associated scientific and technical skills) proposed by CEA to be include in this ICERR is centered on its future international Material Testing Reactor; the Jules Horowitz Reactor under construction in Cadarache. Ancillary facilities will also be a very important part of the ICERR; they include:

- ORPHEE research reactor in Saclay, neutron beams reactor used for science, academic and industrial research, training and education to the use of neutrons scattering,

- ISIS EOLE and MINERVE zero/low power reactors located in Saclay and in Cadarache, dedicated to Core Physics and Education & Training in nuclear engineering,
- LECA-STAR and LECI hot laboratories for fuel and Material Post Irradiated Examination, located in Cadarache and in Saclay.

1) The Jules Horowitz Reactor

The Jules Horowitz Reactor (JHR) is a new Material Testing Reactor (MTR) currently under construction at CEA Cadarache research centre in the South of France. It will represent a major research infrastructure for scientific studies dealing with material and fuel behavior under irradiation (and is consequently identified for this purpose within various European road maps and forums: ESFRI, SNETP…). The reactor will also contribute to medical isotope production.

The reactor will perform R&D programs for the optimization of the present generation of Nuclear Power Plans (NPPs), will support the development of the next generation of NPPs (mainly LWRs) and also offer irradiation capabilities for future reactor materials and fuels.

JHR is fully optimized for testing material and fuel under irradiation, in normal and off-conditions:

- With modern irradiation loops producing the operational condition of the different power reactor technologies,

- With major innovative embarked in-pile instrumentation and out-pile analysis to perform high-quality R&D experiments

- With high thermal and fast flux capacity to address existing and future NPP needs.

  JHR is designed, built and will be operated as an international user-facility open to international collaboration. This results in several aspects:

- A partnership with the funding organizations gathered within an international consortium,
- Setting-up of an international scientific community around JHR through seminars, working groups to optimize the experimental capacity versus future R&D needs.
- Preparation of the first JHR International Program potentially open to non-members of the JHR consortium.

Consequently, the JHR facility will become a major scientific hub for cutting edge research and material investigations (multilateral support to complete cost effective studies avoiding fragmentation of scientific effort, access to developing countries to such state of the art research reactor facilities, supra national approach…). Many publications (2,3,4) described in detail the JHR project. It will answer needs expressed by the scientific community (R&D institutes, TSO…) and the industrial companies (utilities, fuel vendors…).

To prepare the future JHR scientific community, CEA has started five years ago a “Secondee program” welcoming scientists, engineers in the CEA team to prepare the first experimental capacity. Up to now more than 20 Secondees from various countries have participated to this program. **This hosting possibility within JHR team will be enhanced using the recent ICERR designation.**

JHR Building site- Mid 2017

2) The ORPHEE Research Reactor

ORPHEE is a pool-type reactor specifically designed to produce thermal neutron beams primarily used by the French user community of academic and industrial researchers working on neutron scattering instruments. **ORPHEE Research Reactor has a long tradition of welcoming foreign visiting professors, scientists but also post-doctoral students and such hosting capacity is proposed here through this ICERR designation.** This reactor of 14 MW power uses light water as coolant and heavy water as reflector reaching maximum thermal flux in the reflector of 3.10^{14} $n.cm^{-2}.s^{-1}$. It has 2 CNS-Cold Neutron Sources- (20K) and 1 hot source (1400 K), 9 horizontal channels, 20 neutrons beams, 9 vertical irradiation channels and 26 experimental areas. The various devices (neutron radiography, imaging station…) around the neutron guides of the ORPHEE reactor are used for several industrial and research applications.

 ORPHEE neutron beam research reactor.

3) ISIS Research Reactor

The ISIS reactor is the neutron mock-up of the OSIRIS Material Testing Reactor. Both reactors are located in the same facility on the CEA Saclay Research Centre. The ISIS reactor has a maximal rated power of 700 Kw. Although OSIRIS has been shut down last December 2015, ISIS will at least continue being in operation until the end of this decade. The reactor is now mainly used for Education and Training in the frame of academic programs. An extensive panel of experiments covering the reactor operation and related activities has been developed. They are addressed to trainees from different fields and education levels, i.e. bachelor and master students, technicians, engineers and staff from various organizations including the French regulatory body. About 50% of the teaching is carried out in english for foreign trainees. Since 2007, ISIS is typically operated 350 hours per year for education and training and about 400 trainees attend the courses every year (Master students, engineers, ASN staff, future operators of research reactors, etc.). The typical duration of a course is 3 hours, the courses being spread over 60 operating days. Concerning Education and Training, it is worth quoting that ISIS reactor has been designated as an Internet Reactor Laboratory (IRL) by the IAEA for Europe and Africa since 2013. This project is partially funded by the IAEA and aims at providing countries with access to the ISIS practical work sessions by means of live video-conferences. Video signals and graphs, including all the parameters relevant to reactor operation, will be transmitted while ensuring the strictest conditions of safety and security.

Thus, further development of the education and training activity could easily be achieved within the ICERR.

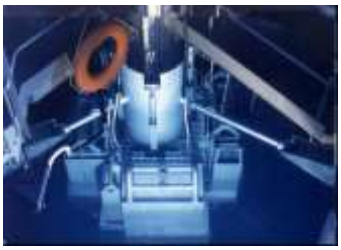
 **ISIs Education & Training Research Reactor**

4) EOLE & MINERVE Reactor

The EOLE critical mock-up is a very low power experimental reactor (ZPR) designed to study the neutron behavior of moderated lattices, in particular those of pressurised water reactors (PWR) and boiling water reactors (BWR). The first studies specifically dedicated to the French PWRs and the qualification of core calculation tools were launched in the early eighties. EOLE provides fluxes up to 10^9 n.cm^{-2}.s^{-1}. Thanks to the high level of flexibility of the reactor, it is possible to implement complex experimental set-ups representing various core configurations to be studied. The physical measurements recorded during the experimental programmes are used to fully characterize the configurations (critical sizes, absorber weights, refined power distributions, spectral indices, material buckling, reactivity effects – boron and/or temperature, kinetic parameters, etc.) thanks to proven experimental techniques:

- Gamma spectrometry
- Measurements using miniature fission chambers
- Thermo-luminescent detectors (TLD)
- Neutron activation dosimeters.

MINERVE is also a ZPR designed for neutron studies mainly aiming to improve the nuclear database for fuel systems representative of various nuclear reactor technologies. The thermal neutron flux in the vessel is 10^9 n.cm^{-2}.s^{-1} (maximal power of 100 Watt). Physical measurements (spectral index, conversion rates, axial and radial fission rate distributions, neutron activation) are also performed to characterize the neutron behavior of both the core and the samples under investigation. MINERVE is also used to test the performance of mini fission chamber prototypes developed by CEA and its partners. It is clearly identified as a reference facility for international collaborations on various aspects of experimental physics. MINERVE is also a key-tool for Education & Training either for Nuclear Engineering Students or for Reactor Operators. **Both these 2 Zero Power Reactors have a long tradition to host foreign scientists, PhD, Post-Doc students for E&T and R&D projects.**



MINERVE Research Reactor for core physic studies

5) LECA-STAR Hot Laboratory

The LECA-STAR, located on the Cadarache nuclear centre, is the CEA hot laboratory in charge of the characterization of irradiated fuel for various types of nuclear industrial and/or research reactor.

The LECA-STAR was extensively refurbished between 2001 and 2011 to extend its operation. It represents a reference hot laboratory in support to the fuel experiments performed in any MTR. That means that refabricated short fuel rods to be irradiated in JHR will be manufactured there, and that fuel materials will be sent to LECA-STAR after their irradiation in JHR.

The LECA-STAR includes about 20 hot cells (up to 9 m long), with all the equipment for a wide range of irradiated fuel rod examinations, namely: non-destructive examination (visual inspection, confocal, radionuclide distribution by gamma-spectrometry, diameter measurement, eddy current testing for cladding integrity and zirconia thickness, X-rays), puncturing and fission gas release measurements, cutting, macro- and microscopy examinations. A special area is devoted to micro-analysis, with fully-shielded SEM/FIB, EPMA, SIMS and XRD, all these equipment being adapted to irradiated-fuel or material examination.

The LECA-STAR facility is mainly devoted to R&D development within French joint programs with industrial partners as EDF and AREVA. Nevertheless this laboratory is able to welcome foreign scientists and engineers in other scientific and technical areas, such as the development of new hot cell equipment, fundamental or academic research topics and safety tests required to perform PIE conducted within the framework of International collaboration.


Post Irradiation Examns of fuel at LECA Hot-Laboratory

6) LECI Hot Laboratory

The LECI, located on the Saclay nuclear centre, is the CEA reference hot laboratory in support to JHR for Material testing. This laboratory is in charge of the characterization of irradiated non fissile materials for:

- Water cooled reactors (PWR and Material Testing Reacors): Pressure Vessel life extension (embrittlement, mechanical properties), Internals (swelling, creep, stress corrosion cracking of 304 or 316 stainless steels), Zirconium alloys for fuel pin cladding and assembly (evolution of metallurgical and mechanical properties in incidental, accidental or in service reactor conditions, in storage or retrieving after

interim storage conditions of spent fuel pins-corrosion-interaction between fuel pellets and cladding), and Aluminium alloys for Material Testing Reactors: vessel and cladding materials,

- Generation IV reactors: Characterization of materials for fuel pin cladding and assembly for sodium or gas-cooled reactors (steels, ODS, ceramics, refractory materials, graphite).

The LECI includes about 50 hot cells, with up-to-date scientific equipment: metallography & optical microscopy, micro-hardness, SEM, TEM, EPMA, XRD, density, Raman spectroscopy, thermoelectric power, H_2 measurements, Eddy currents, metrology, 4 autoclaves (360°C, 220 bar, 1 coupled to slow tensile testing), machining (conventional, ram and wire spark erosion machining) and welding (TIG and Laser).

The LECI was the hot laboratory in support to OSIRIS-CEA MTR- for structural materials investigation (guide tube, fuel cladding, pressure vessel steel…) when this reactor was in operation. That means that refabricated short fuel rods to be irradiated in Osiris were manufactured there or in the LECA, and that materials were and are still sent to LECI after their irradiation in Osiris. It will also be the reference non-fissile material hot laboratory for JHR.

The LECI facility is mainly devoted to R&D development within French joint programs with industrial partners as EDF and AREVA. Nevertheless this laboratory is able to welcome foreign scientists and engineers in other scientific and technical areas, such as the development of new hot cell equipment, fundamental or academic research topics and experimental devices required to perform PIE on material.

 Post-Irradiation Exams on Materials at LECI Hot-Laboratory

Both these 2 Hot Laboratories have a long tradition to perform R&D programs within an international framework and consequently are ready to welcome scientists for Hands-On Training, R&D projects through this ICERR designation.

First Affiliates to CEA: examples of utilization of this ICERR scheme

CEA is now ready to welcome scientists, engineers within its facilities described above in the framework of this ICERR designation.

In a practical point of view, for welcoming scientists from Member States at CEA through this ICERR designation, a bilateral agreement has to be signed between the assigning party (organization from which the scientist belongs to) and CEA. Such agreement will indicate the scientific/technical topic of collaboration, and rights and duties of both parties including the financial issues. The IAEA is here a “facilitator” creating the network between its Member States and the CEA and having eventually the possibility to partially sponsor some part on a “case by case” basis (through potential TC projects).

The 3 first Affiliates to CEA signed this agreement in September 2016 (JSI from Slovenia, CNSTN from Tunisia and CNESTEN from Morocco) followed by 3 others Affiliates during the first semester of 2017 (BATAN from Indonesia, COMENA from Algeria and JAEC from Jordan).

Here are some first scientific and technical illustrations which are on-going with these Affiliates:

Slovenia: Secondment in 2017 of a scientist from JSI to Cadarache and Saclay to perform experiments on gamma sensors (in MINERVE reactor) and to be trained on CEA Monte-Carlo core-physic code (TRIPOLI) in order to enhance future experiments in the JSI TRIGA Research Reactor.

Morocco: Expert mission of Safety Engineer from CEA to CNESTEN for analyzing safety aspects for installation of a neutron beam in the TRIGA research reactor. Review by CEA staff of the Safety report performed by CNESTEN and foreseen secondment of Safety Engineer to ORPHEE reactor team (hands-on training on safety approach when operating a neutron beam RR)

Tunisia: Secondment of 3 scientists from CNSTN (2 times in 2017) on MINERVE research reactor to perform dosimetry measurement- support from CEA to perform core-physic calculation for dimensioning a sub-critical mock-up to be established at CNSTN.

Algeria: support to COMENA on the on-going actions for refurbishment of their 2 Research Reactors (NUR and Sallaam) especially on appropriation of new Safety report and establishment of operating procedures. Secondment of a scientist to COMENA foreseen on instrumentation for research reactor (Cadarache-1st semester 2018)

Jordan: Secondment of a Safety Engineer from JAEC to Saclay for hands-on Training on thermo-hydraulic and Core-Physic CEA codes to perform complementary Safety Analysis of the JRTR core. Later on it is foreseen a secondment in ORPHEE research reactor for enhancing utilization of the JRTR neutron beams.

Indonesia: Support from ISIS reactor team to BATAN to establish their own Internet Reactor Laboratory (in collaboration with the IAEA). A secondment of scientist/engineers from BATAN to Saclay is foreseen in 2018 in ISIS reactor for hands-On Training.

References

(1) http:/www.iaea.org/OURWORK/ST/NE/NEFW/Technical-Areas/RRS/documents/ICERR Concept ToR Final.pdf

(2) “Sustaining Material Testing Capacity in France: From OSIRIS to JHR”, G.Bignan, D.Iracane, S.Loubière, C.Blandin, CEA (France) IGORR 2009 Conference (Beijing)

(3) “The Jules Horowitz Reactor: A new European MTR open to International collaboration” Gilles Bignan et al, IGORR 2010 (Knoxville TN-ORNL-September 2010)

(4) “The Jules Horowitz Reactor: A new European MTR (Material Testing Reactor) open to International collaboration: Description and Status” , G.Bignan, J.Estrade – IGORR 2013 – Daejeong Korea (October 2013)

(5) “The Jules Horowitz Reactor: A new high performance MTR (Material Testing Reactor) working as an International User Facility in support to Nuclear Industry, Public Bodies and Research Institutes”, X.Bravo, G.Bignan, Journal of Nuclear Energy International – December 2014.