Research Reactors at the French Atomic Energy Commission
past, present and future

P. RAYMOND
CEA
Nuclear Energy Division
Reactors and hot laboratories operation and refurbishing programs manager

Research reactors are important tools for a Nuclear Energy Research Organisation like CEA. These facilities, linked with other R&D tool like hot laboratories or simulation software development will provides a lot of experimental results required for the industrial plants design, safety and operation or fundamental research
This paper will describe the CEA strategy to maintain and develop the Nuclear facilities dedicated to Research and Development programs as research reactors in use in our organisation for various purposes:

- Critical mock-up : EOLE, MINERVE, MASURCA, ISIS
- Material testing reactors : OSIRIS then the Jules Horowitz Reactor
- Safety related experimental reactors : CABRI, PHEBUS
- Neutron sources : ORPHEE

The main principles for the management of these facilities are the following

- to provide the highest quality of experimentation and measurement for the industry and Research
- to maintain a high level of safety and improve it according to the evolution of national and international standards
- to provide a high level of availability and adaptability for the experimentation with the lowest cost as possible.

A large part of scientific investments can be directly funded by to R&D programs. Nevertheless, for such large facilities which can be used for different purposes, there is a necessity to have specific investments which are necessary to maintain a
This paper will deal of the necessary evolution of CEA facilities and the policy of investment in order to offer to researchers the tools necessary for their R&D works, in framework of Periodic Safety Review, development of experimental tools and minimisation of the operating cost.
In the first part of the paper we will discuss of the necessary evolutions linked to the legal and technical regulation evolution, the second part of the paper will be dedicated to the some examples of reactor refurbishment operations actually performed by CEA/DEN

Evolution of the legal and technical regulation framework

Most of the CEA research nuclear facilities were constructed in the sixties or seventies (Tab 1). At this time regulatory framework and standards: safety regulations, industrial norms and practices, security requirements, were not so developed than now. New safety and security requirements, ageing and/or obsolescence of components and materials are generally treated in the framework of Periodic Safety Review.

Reactor	Reactor type		First operation
OSIRIS	Material Testing Reactor	Saclay	1966
ISIS	Critical Mock-up	Saclay	1966
ORPHE	High Flux Neutron source	Saclay	1980
PHENIX	Fast Neutron Reactor	Marcoule	1973
MINERVE	Critical Mock-up	Cadarache	1959
EOLE	Critical Mock-up	Cadarache	1965
MASURCA	Critical Mock-up	Cadarache	1966
CABRI	Safety dedicated RR	Cadarache	1964
PHEBUS	Safety dedicated RR	Cadarache	1977

Tab 1 :Reactors operated by CEA DEN in 2009

Periodic Safety Review

The June 13th, 2006 law on transparency and safety in nuclear field is the new legal framework which regulates nuclear activities according to the Environment Code. It gives the legal basic for licensing, operation, modification and dismantling of nuclear facilities. According to this law, the November 2nd., 2007 decree describes the process for the different steps of the Nuclear Facility lifetime. A basic principles is that main safety features of a plant has to keep a constant quality during the lifetime of a plant and improvement of safety has to be taken into account according to the evolution of technical regulatory framework and operating feedback coming from the plants and other similar facilites.
The Technical regulatory framework in France in mainly based on Fundamental Safety Regulations which gives the technical requirements which can be applied in order to satisfy objectives for various safety cases. Recent Fundamental Safety Regulations, mainly dedicated to the plant design as the seismic FSR (2001-01), have to be taken into account and will conduct to large modifications in our nuclear facilities.

Best technical practices are generally given by norms and technical codes. Main evolutions in the codifications which have been taken into account in our plants are those related to mechanical design

- RCC– M for nuclear pressurised facilities
- RCC- MR : for sodium fast neutron reactors
- RCC-MX : for Research Reactors using specific materials as Aluminium and Zircaloy

Evolution of Normalisation (ISO, AFNOR…) is also be taken into account to define the new technical reference framework of the plants

The Periodic Safety review is made of three different steps:

- Conformity Checking of the facility with its Safety and Technical reference framework;
- Re-assessment of the plant which take into account new regulations, technical best practices and operating feed-back in order to improved the facility, in order to define a new safety and technical reference framework for the plant;
- The compliance with this new framework will lead to facility's modifications and/or new plant operation procedures which have to be designed, implemented and assessed by the Nuclear Safety Authority.

It is important to notice that a great care have to be taken in the second phase in order to decide if the investment necessary for modifications to comply with the new framework is acceptable or not according to a technical and economical analysis which can conclude to perform the refurbishing or to shutdown the plant.

Main evolutions of the technical regulatory frameworks

Fundamental Safety Rules or, now, Safety Guides, are emitted by the Safety Authority, These documents are generally adapted to specific plants as Power Reactors or Fuel cycle facilities, but some of them are generic. They address many safety cases like aircraft crash, seism, flooding or extreme weather hazards or safety related software for instance**.**
The new regulation for seismic design of reactors (FSR 2001-01) has a large impact on our facilities and leads to a large quantity of modification for both Civil Works and components. At the original design phase of our facilities the seismic load taken into account was generally defined from the "Maximum Historical Probable Earthquake", new rules requires to take into account a larger load " Safe Shutdown Earthquake", other aspects of seismic loading as site specific effects and the acceptability of consequences in case of a "paleo-seism" have also to be taken into account in the safety demonstration. The FSR defines also new level of loading for the frequency spectrum. The methodology to be applied is more accurate and requires, for instance, an evaluation of the floor response spectrum to design or analyse the behaviour of civil works and components. The new regulation has a large impact on our facilities and leads to important and expensive modifications

Norms and codification of practices are mainly coming from the industry, the compliance to these documents generally insure the compliance with regulation requirements. Generally, the design perform with a given code doesn't have to comply with an other one, we have only to verify that the

compliance with the design code. Nevertheless, in the practice, we have to analyse the effects on the design of the new practices and, if possible to perform modifications to comply.

A last important point with our facilities is to analyse the obsolescence of components. Mos of then has more than 40 years and a part of safety related components are not avalaible. Even if they still comply to the original requirements, it is asked to show that the operator may maintain this compliance for the future (time to the next Periodic Safety Review). This implies to look carefully at the maintenance program and spare part stock. But, in some cases, generally for I & C and venting systems, it implies to re-design the re-build the system with new technologies.

The other items which have taken into account in the refurbishing of our facilities are the following

- Criticallity margins
- Fire hazards and compliance with new regulations
- Power supply
- Human and Organisational factors
- External hazards : flooding, extreme weather

CEA/DEN research reactors refurbishing

The following table gives the main perspectives for the research reactors operated by the CEA/DEN

Reactor	Periodic Safety Review	Date of End operation	Remark
OSIRIS	2009	2015	Replace by JHR
ISIS	2009	2015	
ORPHEE	2010	> 2020	
PHENIX		2009	
MINERVE	2010	2020	Transfer of the function in PHEBUS
EOLE	2010	2020	Transfer of the function in PHEBUS
MASURCA	2008		Under discussion – GEN 4 research program planned in 2014
CABRI	2008	> 2018	
PHEBUS		2008	

Tab 2: Perspectives for research reactors at CEA DEN in 2009

The CABRI refurbishing

CABRI has an important role in the definition of technical limitations of fuel elements during Reactivity Insertion Transients. It was used in the past for Experimental reactors and Sodium cooled fast reactors. At the end of the fast breeder program, CABRI was used for Water Reactors reactivity transients.
In 2000 The Institute for nuclear Radiation protection and Safety (IRSN) has decided to run an International Program in a Pressurised Loop for Power Reactors mainly dedicated to MOX and UOx high burn-up fuel: the CIP Program (Cabri International Program). IRSN will fund the major part of the CABRI refurbishing.
The modification of the plant (introduction of a Pressurised Water loop in the reactor) necessitates modifying the Licensing decree of the facility. In addition to this important modification of the facility a complete safety reassessment of the facility is performed.

A large number of safety issues was re-examined and have conducted to a large number of modifications of the facility.

- fire regulation : compliance with the new regulation
- seismic loading : compliance with the FSR 2001-01

    - major civil works reinforcement on the containment and auxiliary buildings
    - Reinforcement of the le pool vessel, main water tanks, piping.
- Venting : new venting system
- Transportation : new container for the transfer of the test section between CABRI and hot labs

The conformity checking has implied to rebuild a new core envelop due to corrosion of the previous one. The analysis of the reactor core fuel rods has shown some unexpected deformation, the analysis of these anomalies has shown than for some reactivity transient, the criteria for a good cooling of the rods have been exceeded. A new analysis of all the operational and accidental reactivity transients has been performed, the analysis of the mechanical limitations of the cladding material was made and a new criteria showing that the cladding will keep its integrity during power transients will be proposed and accepted by the Safety Authority.

Fig 1 : CABRI main seismic reinforcement (in red)

Fig 2 : CABRI introduction of the new pressurised test section

The authorisation for the reactor restart is planned for mid 2010 after the end of all the refurbishment works.

PHEBUS

was only dedicated to the study of Loss of Coolant Accident and fuel behaviour under Severe Accident conditions for Water Reactors. The 20 years of experimental programs in PHEBUS are now finished and The French Atomic Energy High Committee has decided in 2007 to close the reactor. The experimental facility and the reactor core will be dismantled; the containment building will be cleaned, in order to have the possibility to integrate the future critical mock-up to replace EOLE – MINERVE.

OSIRIS

The OSIRIS reactor is planned to shutdown in 2015, nevertheless a Periodic Safety review performed in 2009 has lead to some modifications to perform in the reactor.
An detailed analysis of transportation, and the operating feedback analysis has shown the necessity to improve the safety the handling in the reactor containment and in the hot cells building.
An access hatch will be constructed to reinforce the leak-tightness of the building.
A Safety venting system was added to reduced the environmental impact of accidental situations.
A large program of verifications on the reactor core cooling system was performed as the verification of the corrosion status of the de-activation tank.
At least the leak-tightness of the control rod mechanism room will be improved bu adding a specific coating on the wall of the room located at the bottom part of containment.
The program of OSIRIS safety improvement was presented to the safety authority and accepted in 2008. Works are planed to be realized in two period in 2009 and 2010 in order to preserve availability for irradiation programs and medical radioisotope production;

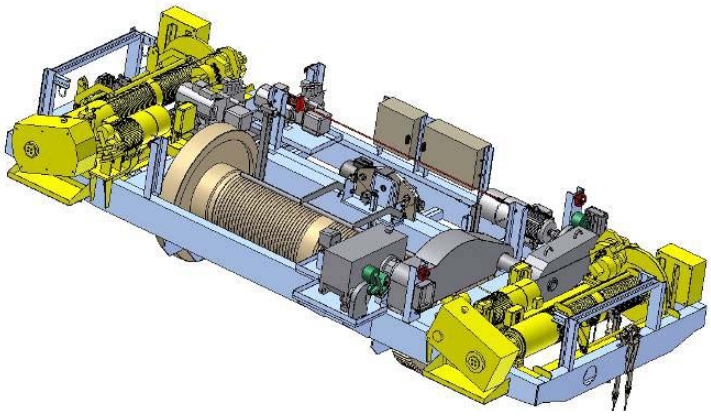

Fig 3 : High reliability lifting equipment for the OSIRIS polar crane

CRITICAL MOCK-UP

There is four critical mock-ups in operation at CEA-DEN: MASURCA, EOLE, MINERVE and ISIS

MASURCA is a critical mock-up for fast neutron reactor cores, the last Periodic Safety Review (PSR) held in 2006 has show a necessity to make a large refurbishment of the facility to satisfy different requirement as the containment leak tightness, the seismic behaviour of the auxiliary building for fuel storage, protection against hazards like internal fire. The obsolescence of various components as the I&C system, or components of the venting systems is also a part of the works to be done.
The works are planned according two phases:

- phase 1 : before 2013 refurbishment of the reactor containment
- phase 2 : after 2015 : refurbishment of the fuel storage building

EOLE – MINERVE: These two critical mock-ups are in the same building for which the civil works doesn't fulfil the new requirements for the seismic loads of the Cadarache centre. This two reactor are implemented in a hall which.
The application of new technical regulations may lead to large modifications in order to satisfy seismic, external hazards and security requirements. The function performed by this two reactors is important for the analysis of neutronics parameters of reactors and for the adjustment of nuclear data files.
A study was launched in 2008, the main hypothesis is a facility shut-down after the 10 years following a last PSR in 2010. These two reactors will be replaced by a new one with new possibilities as for instance the possibility of measuring integral cross sections in a fast neutron spectrum. This new facility will be integrated in the containment of the PHEBUS reactor.
A detailed analysis of the conclusion of this feasibility phase will be performed at the end of the year 2009.

In order to obtain the authorisation to operate the facility for the next ten years, the periodic safety review was realized. A new safety analysis based on the definition of operating situations was performed and modifications were proposed to handle fire hazards, to improve criticality margins in the fuel storage room and to ameliorate operational procedures in order to reduce risks due to human errors.

Fig 4 : EOLE – MINERVE hall

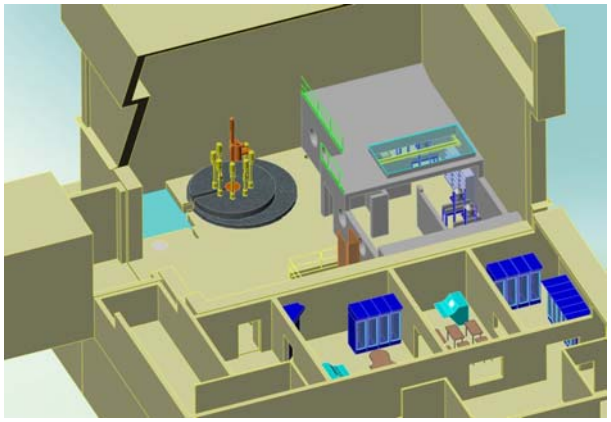

Fig 5 : New implantation in the PHEBUS Building

ISIS: ISIS is the critical mock-up of the OSIRIS reactor, the mock-up will be essentially used for Nuclear Engineering Education, the reactor is linked to the lifetime of OSIRIS, actually, in the framework of the last OSIRIS PSR, some works are made reinforce the safety of handling and the reactor building leak-tightness.

ORPHEE Neutron Source Reactor

The ORPHEE Neutron source reactor is under the realisation of its Periodic Safety Review. Some works have been identified to maintain a high level of safety of the reactor. The Periodic Safety Review includes a complete Conformity Checking of the plant; the conformity is also evaluated according to new regulations. The safety analysis of the reactor was reassessed according to a new methodology including all operating conditions for normal operation to severe accident situations. The new safety report is under the analysis of the Safety Authority and some reinforcement works have been proposed which will be performed from 2010.

Conclusion

A large effort is performed by CEA/DEN to maintain the operability of its Nuclear Research Facility, new needs of the R&D, new regulations, improvement of the safety and security leads to large modifications of these plants to maintain the possibility to perform these programs.

To perform such an investment program on reactors and hot labs, CEA/DEN has dedicated a large Engineering Department to manage these complex projects which are stressed by strong funding and planning objectives and have to manage with sometimes the necessity to manage both normal operating conditions with experimental programs and modifications works. The necessity to conduct such works in an existing building which, even if the facility is not in operation still is a nuclear facility with radioactive materials and contaminated zones will induce other large constraints.

A deep study of technical and economical issues has to be performed in order to decide of the future of the plants. It has to be performed in the preliminary phase of the refurbishment project.