Introduction

The BR2 reactor is still SCK•CEN's most important nuclear facility. After an extensive refurbishment of 22 months to compensate for the ageing of the installation, to enhance the reliability of operation and to comply with modern safety standards, it was restarted in April 1997.

Routine maintenance activities and inspections guarantee the continued safe and reliable operation of the facility and provide the basis for a secure long-term future.

The annual operating regime is still restricted to 5 standard cycles of 21 days at power. This rather low utilisation of such a large facility is necessarily imposed by budgetary constraints. Nevertheless, we promote an extended operating availability by offering well-adapted services for internal and external scientific users and by developing new capabilities for commercial productions. In March 2001, the Board of Directors confirmed that the present operating regime would continue with the same budgetary constraints at least until 2006. However the possibility of a 6^{th} cycle was left open as an option subject to obtaining the necessary scientific and economic justification.

As before, we used extensively the CALLISTO loop, which is a high temperature, high pressure water loop in BR2, to simulate PWR conditions for various programmes involving LWR (Light Water Reactors), pressure vessel materials, IASCC (Irradiation Assisted Stress Corrosion Cracking) of LWR structural materials, fusion reactor materials and martensitic steels for use in ADS (Accelerator Driven System). We also started short irradiations for fusion materials in support of modelling work by RisØ scientists. This first collaboration will be continued in 2002 and followed by the design and development of a new irradiation rig for the dynamic testing of materials.

We still focussed the development of our new irradiation devices on emerging needs. Most of this work concerned multipurpose reusable rigs for materials irradiation under high fast neutron fluxes, a dedicated irradiation rig for the qualification of advanced MTR (Materials Testing Reactor) fuels, the detailed study of a new irradiation basket with instrumented LWR-advanced fuel pins to be loaded in one in pile section of CALLISTO and the concept study of a new capsule for irradiation of materials in a lead-bismuth environment.

An internal R&D programme currently aims at improving the BR2 utilisation. This is focussed on the improvement of the online in-core instrumentation (i.e. self powered neutron detectors, fission chambers, gamma thermometers integrated in the DOLMEN and FICTIONS irradiation rigs), data acquisition (system BIDASSE for BR2 nuclear and process data and for instrumented experiments), and the development of adapted neutronic computer models.

BR2's commercial programmes are of prime importance because they help to finance the reactor. The income from radioisotopes increased in 2001 by 33% with the recent expansion in capacity for ^{99}Mo production and the extended production of radioisotopes with high added value. We are expecting our market share to continue to grow in the future. A strategic alliance with a main competitor is now being implemented and this will certainly consolidate the position of BR2. 2001 was again a great year for the production of NTD-silicon in BR2. After years of stagnation since 1997, the market exploded in 2000 and the results for 2001 increased by nearly 55%. In close collaboration with CEA, all potential customers were approached and long term contracts were signed. We made adequate resources available which now enables the SIDONIE (Silicon Doping by Neutron Irradiation) facility to return to its maximum production capacity. We also started a new project to evaluate the expansion of silicon production capacity with enhanced characteristics.

In December 2001, BR2 successfully obtained QA certification for ISO 9002 for its radioisotope production and silicon irradiation commercial activities. This will enable BR2 to continue providing these services as a major international supplier whilst confidently meeting the ever increasing demand for thighter process controls.

Reactor Operation

Operation journal

The reactor was operated in 2001 for a total of 123 days at a mean power of 59 MW in order to satisfy the irradiation conditions of the internal and external programmes using mainly the CALLISTO PWR loop.

The availability of the installation reached an acceptable level of 96,25 % during operation (97,30 % averaged over the last 4 years). The continuous operation of the reactor was only affected three times. The first of these was due to equipment failure which initiated the fail-safe operation of the reactor control rods followed by a reactor-scram due to a low pressure in the reactor primary cooling circuit. The second was due to an operational decision to unload the CORONA experiment from one of the in-pile sections of the CALLISTO loop and, thirdly, an extraneous perturbation on the external electrical distribution network prompted a scram and a reactor poison-out one day before the programmed shutdown.

We effectively transferred the management and operation of the CALLISTO loop to BR2's Operation Section. A member of BR2's staff is dedicated to coordinating the Maintenance Group and the Reactor Experiments Department to help with this work. Also in 2001, all reactor operators followed a three-day refresher course on CALLISTO.

An ageing population of staff will again be a critical factor in the coming years. At the end of 2001, we started the procedure to recruit 6 new reactor operators, two engineers and a technical assistant.

In 2001, we started and finalised the first quinquennial safety re-evaluation after the extensive 1995-1997 refurbishment of the installation. The main points concerned a reissue of the Safety Analysis Report, the refinement of technical specifications, the execution of the actions remaining after refurbishment and the implementation of the recommendations and suggestions made during the INSARR (INtegrated Safety Assessment for Research Reactors) that was conducted in 1999.

Fuel Cycle

The mean consumption of fresh fuel elements was 5.26 per 1000 MWd in 2001. This figure is comparable to those obtained in previous years. Due to the larger number of operating days the global consumption of fresh fuel elements was however higher in 2001.

Standard UAlx 93% ^{235}U fuel elements are still used and will continue to be fabricated from available feed stocks until the new LEU (Low Enriched Uranium) UMo high density fuels have been completely qualified for use in BR2.

Three shipments of 68 spent elements each were transported to La Hague for reprocessing with the new TN-MTR cask. At the end of 2001, a total of 646 fuel elements will have been transferred under the contract signed with COGEMA. Four shipments of 68 fuel elements each are planned for 2002.

Refurbishment

Phase 5 of the refurbishment programme was continued:

- the recuperation of effluents from the monitoring system: we installed a new system to collect the effluents from the primary coolant radiation monitors for re-injection into the primary loop; this produces an important saving of waste water;
- mitigation of consequences of an earthquake: we designed the reinforcement of the ventilation pipe-bridge with additional I-beams (installation is foreseen early 2002);
- automatic regeneration of the Pool Ion Exchangers: we continued the study for automating the regeneration process using a PLC (Programme Logical Controller).

Maintenance

The complete maintenance (preventive, adaptive and corrective) of the irradiation device CALLISTO is now organised and executed by the Technical Services of BR2. Further,

- we modified the system for rinsing the primary filters which is now equipped with interlock devices to guarantee a safe operation; we also installed a new synoptic panel;
- we started a study of the emergency diesel groups to guarantee a safe and reliable operation for the next ten years; we will procure the necessary spare parts and plan the modernisation of the electric cabinets;
- we renewed and upgraded a hoisting device in the BR2 "hot-cell".

Scientific staff

Thierry Aoust, André Beeckmans de West-Meerbeeck, Willy Beets, Philippe Benoit, Gilbert Bergmans, Henry Blowfield, Guido Bossi, Simon Claes, Willy Claes, Jozef Cools, Jean-Marie Corbisier, Willy Corthouts, Bernard Coupé, Luc De Laet, Charles De Raedt, Stefan Declercq, Camiel Decloedt, Jean Dekeyser, Jan Dierckx, Ludo Eysermans, Freddy Geenen, Eduard Geysen, Philippe Gouat, Pol Gubel, Patrice Jacquet, Frank Joppen, Edgar Koonen, Vadim Kouzminov, Richard Liesenborgs, Fernand Mallants, Steven Mellemans, Frank Mertens, Marcel Noël, Hans Ooms, Temenouga Petrova, Bernard Ponsard, Yvan Pouleur, Felix Put, Filip Ramaekers, Frans Schelles, Bart Smolders, Roger Stynen, Jef Valenberghs, Jan Van der Auwera, Karel Van Eyndhoven, Marc Van Hoof, Marcel Van Hoolst, Constant Van Ierschot, Dirk Vanleeuw, Walter Vennekens, Bernard Verboomen, Ludo Vermeeren, Alfons Verwimp, Marcel Wéber, Stefan Wirix

Supporting staff
Walter Aarts,
Armand Aerts,
Monique Alen,
Willy Andries,
David Bastiaensen,
Tom Berghmans,
Filip Borgers,
Geert Broeckx,
Kris Bruns,
Leo Caeyers,
Werner Cauwenberghs,
Gert Cools,
Sita Cornelissen,
Ferdi Daemen,
Louis De Jonge,
Chris De Wandeleer,
Ludo Dekien,
Willy Dierckx,
Luc Drooghmans,
Edmond Essers,
Eugeen Essers,
Johan Fransen,
André Gastmans,
Patrik Geboers,
Peter Gerinckx,
Freddy Gevers,
Hektor Gevers,
Gerard Groenen,
Stefan Huysmans,
Valère Jacobs,
Dirk Jansen,
Eric Jennen,
Gudrun Joyeux,
Guido Lievens,
Rudy Linden,
Herman Lodewyckx,
Stephan Lodewyckx,
Henri Meeus,
Wim Minnen,
Bert Moons,
Didier Mortiers,
Victor Oeyen,
Luc Overath,
François Poorters,
Alois Renders,
Patrick Smeyers,
Richard Stappers,
Kamiel Swinnen,
Kris Thys,
Guido Van Clemen,
Bart Van de Venne,
Godefridus Van Diepenbeek,
Gerard Van Esch,
Jan Van Gompel,
Dirk Van Gestel,
Hendrik Van Gestel,
Alois Van Hoolst,
Herman Van Houdt,
Steven Van Loven,
Luc Van Roy,

Production of radioisotopes

Radioisotopes are produced in BR2 for various applications in the nuclear medicine (diagnostic, therapy, palliation of metastatic bone pain), industry (radiography of welds, ...), agriculture (radiotracers, ...) and basic research. Due to the availability of high neutron fluxes (thermal neutron flux up to 10^{15} n/cm^2.s), the reactor is considered as a major facility through its contribution to a continuous supply of various products.

Since BR2 was restarted after refurbishment in 1995-1997, the income from radioisotopes has increased considerably as shown by the relative units in the figure below.

The loading of an additional PRF irradiation device in the reactor in 2000 enhanced the position of BR2 in the European market for the production of **^{99}Mo** ($T_{1/2}$=66 h), which is also a major isotope produced in the BR2 for the manufacture of **^{99}Mo/^{99m}Tc** ($T_{1/2}$=6 h) generators. Five irradiation devices are available in reflector channels, providing a total capacity for the simultaneous irradiation of 36 high enriched ^{235}U targets, i.e. 108 targets per reactor cycle.

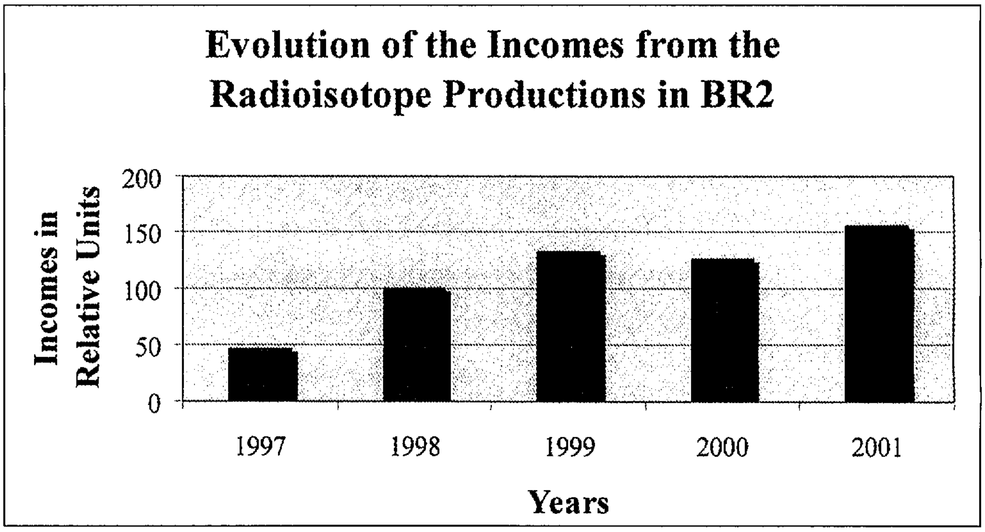
A successful collaboration has been established with the Oak Ridge National Laboratory to supply ^{188}W ($T_{1/2}$=69.4 d) during the refurbishment of the HFIR reactor in 2000-2001. The high enriched ^{186}W targets were irradiated in the central channel of the BR2 reactor and shipped to ORNL for processing and manufacture of **^{188}W/^{188}Re** generators. Furthermore, negotiations with various partners are ongoing in order to start a very promising research project related to **^{188}Re** ($T_{1/2}$=16.9 h) and its applications. This will include the enrichment of natural W in ^{186}W, the target irradiation and the production of an optimal generator for the users.

Production of NTD-Silicon

BR2 is ideally suited to the volume production of Neutron Transmutation Doped (NTD) silicon for the semiconductor industry. This is carried out in a dedicated facility called SIDONIE (Silicon Doping by Neutron Irradiation Experiment). SIDONIE is located within BR2's beryllium reflector and is designed to continuously rotate and traverse the silicon through its neutron flux. The speed at which the silicon is traversed through the reactor is computer controlled to ensure that the correct neutron dose is received. The effect of continuously rotating and traversing the silicon produces exceptional dopant homogeneity. SIDONIE can accommodate batches of silicon measuring 4-inch and 5-inches (max.) in diameter by up to 750 mm in length. For n-type silicon, the average axial and radial resistivity variation can be controlled within about 3% whilst the resistivities produced are normally within ± 5 % of the specified (target) value.

The first phase of a programme to maintain the reliability of this device was implemented in 2001. This consisted of successfully upgrading the instrumentation that interfaces with the systems computer controller. The second phase of renewing the computer with state-of-the-art software and technology is scheduled for completion in March 2002.

In association with CEA, BR2 has established long-term agreements with the world's principal suppliers for NTD-silicon and this has provided the framework



for generating an increase in revenue of almost 55% above the income that was produced by the business in 2000.

In 2001, a study was began to identify the technical feasibility of a new scheme to increase BR2's NTD-silicon capability by more than 100% whilst also taking into account the industries increasing demand for 6-inch irradiation capacity.

Reactor BR2: R&D programme

Objectives

The aim of this programme is the ongoing improvement in the utilisation of BR2: the refined determination of the irradiation conditions, the development of new irradiation devices and the improvement of the in-core instrumentation and data acquisition systems.

Achievements

Reactor physics

This year's work was concentrated on the development of a three-dimensional full-scale model of the BR2 reactor for simulation and prediction of irradiation conditions for various experiments.

This newly developed reactor model consists of a full-scale three-dimensional description of the reactor core and of channels loaded by different irradiation devices. All reactor channels have a real orientation with their respective angles of inclination. Simulation of inclined orientation of channels may be important for irradiation experiments where the irradiation samples are located in the axial periphery of the core (not in the core mid-plane). This is because of the presence of triangular water gaps between the beryllium channels and additionally the angular shifting of neighbouring channels relative each other. The model includes a precise description of the fuel elements, control rods, regulation rods and all BR2 irradiation devicesMonte Carlo simulation of each irradiation cycle is performed by the MCNP-4C computer code taking into account the actual loading of the fuel elements with their respective burn-up and the positions of the control rods. The effect of beryllium poisoning is also taken into account.

Verification of the Monte Carlo model will be based on comparisons of calculated and measured axial distributions of thermal neutron fluxes in the various reactor channels, thermal and fast neutron fluxes in irradiation samples, fission activity in the irradiated fuel elements. These comparisons are in progress.

This Monte Carlo model has already been used for the following purposes:

- prediction of the BR2 power needed to fulfil the requested irradiation conditions of the individual fuel pins of the BACCHANAL program;
- optimisation calculations for the design of a proposed additional irradiation facility for Si doping, which should be located in the BR2 reactor pool;
- detailed 3D irradiation conditions and power distributions in the fuel plates, which have been irradiated in the FUTURE MTR irradiation device;
- evaluation of the irradiation conditions in a new arrangement of fissile targets for ^{99}Mo production in a newly proposed PRF irradiation device.

MTR fuel qualification – the FUTURE irradiation device

In order to enhance our capabilities in the field of MTR fuel testing and qualification, we designed in 2000 a dedicated irradiation device. The objective is to provide BR2 with a reusable device for the irradiation of fuel plates under representative conditions, that is geometry, neutron spectrum, heat flux and thermal-hydraulic conditions.

We built in 2001 the FUTURE-MTR device (FUel Test Utility for REsearch reactors) allowing the irradiation of up to 3 fuel plates. A fuel plate may be replaced by a dummy plate or a plate carrying dosimeters (in addition to the 4 dosimeter-carrying rods foreseen in the periphery of the device).

We performed a qualification irradiation campaign using 2 standard UAlx-Al plates with HEU. The objectives of this program are:

- qualification of the irradiation device including the thermal-hydraulic conditions and the fuel plates unloading and reloading after an irradiation cycle;
- qualification of the methods to determine the irradiation conditions of the fuel plates to be tested with the FUTURE device.

We performed the detailed neutronic calculations to predict the irradiation conditions (several codes have been used) and will check the outcome against the results of the evaluation of the dosimeters and the post-irradiation burn-up measurements as soon as the experimental results become available.

Jozef Vangheel,
Marc Vanrintel,
Frans Vansummeren,
Tom Verachtert,
Rachel Verboven,
Alfons Verheyden,
Benny Vullings,
Leo Verwimp,
Emiel Willekens,
Bart Wilms,
Gunter Wilmsen

Development of in-pile instrumentation

The aim of this program is to select and/or develop the most suitable sensors for physical, nuclear and electrochemical measurements in specific in-pile conditions. Our approach consists in a detailed modelling of all physical processes relevant to the sensor operation, combined with experimental irradiation campaigns.

During 2001, we irradiated the DOLMEN experimental device, containing several types of SPNDs (Self-Powered Neutron Detectors) and gamma thermometers, in 4 different BR2 channels with various total neutron and gamma fluxes and various spectra. The recorded detector data, combined with neutron flux data from activation dosimetry, led to a validation of the global SPND sensitivity calculations using a Monte Carlo model and also provided evidence for the validity of detailed spatial neutron flux distributions of the BR2 core, also from Monte Carlo calculations. From data recorded after fast movements of DOLMEN, we extracted several detector current contributions with distinct time constants; all contributions turned out to be in perfect agreement with detailed model calculations taking into account the underlying physical processes.

For the testing of sub-miniature fission chambers we initiated the FICTIONS program (collaboration with CEA-Cadarache). We built an experimental rig with 4 fission chambers, 2 SPND's, a gamma thermometer and activation dosimeters and irradiated it in three BR2 channels. We found a good agreement between the thermal neutron fluxes deduced from the SPND's, the fission chambers and the activation dosimeters, which again confirms the validity of the sensitivity calculations and of the detailed neutronic calculations. The saturation behaviour of the fission chamber signal as a function of the applied polarisation voltage was investigated, as well as the influence of the gas pressure inside the fission chamber and the contributions of gamma induced currents and currents induced in the signal cable. FICTIONS was irradiated up to $2 \cdot 10^{21}$ n/cm^2; the sensitivity evolved according to the predictions and the saturation behaviour remained remarkably constant.

For several applications (irradiation damage of materials, research in the framework of ADS systems), the fast neutron flux is a much more relevant parameter than the thermal neutron flux. Therefore we started investigating the feasibility of using especially designed sub-miniature fission chambers or SPND's for on-line in-pile fast neutron flux detection. On the fission chamber option, we are setting up a collaboration with CEA-Cadarache; on the other hand, we are extensively investigating candidate emitter materials and geometries of SPND's for maximising the fast flux sensitivity.

Development of data acquisition systems

We further upgraded the BR2 integrated data acquisition system for survey and experiments (BIDASSE). The system allows us to follow all operation parameters of the reactor and is also used for experiments. The BIDASSE system has its own fully independent network, which is running with Novell Netware and has its own dedicated server (the BIDASSE server). One PC is used to make a bridge between the BIBASSE network and the SCK•CEN network. This PC sends every second a copy of updated information to a server on the SCK•CEN network. In this way this network is only seen by BIDASSE as one user.

In 2001 we connected new experiments to the BIDASSE system, in particular the FICTIONS and COFUMA experiments and the CALOR measuring devices.

This year's novelty is that BIDASSE allows for direct command/control on experiments; it can therefore be used as an active system by an authorised operator to trigger non-safety related actions. In the near future these new functionalities will be used to control the CALOR measuring devices for local thermal neutron flux measurements in the BR2 core.

Scientific irradiations programmes

Objectives

The principal mission of the Department Reactor Experiments is to successfully achieve the practical realisation of scientific irradiation experiments in BR2 on behalf of its clients.

This work is mainly undertaken for external customers and/or R&D projects that are sponsored by SCK•CEN. We also provide technical support to produce irradiation devices for commercial productions.

Our Department is specialised in the design, engineering, construction, instrumentation and operation of dedicated irradiation facilities. In these facilities experiments are currently undertaken for testing LWR fuels, LWR materials, fusion-reactor materials, ADS materials, special-purpose targets and even safety oriented tests.

Achievements

Experiments performed in CALLISTO PWR loop

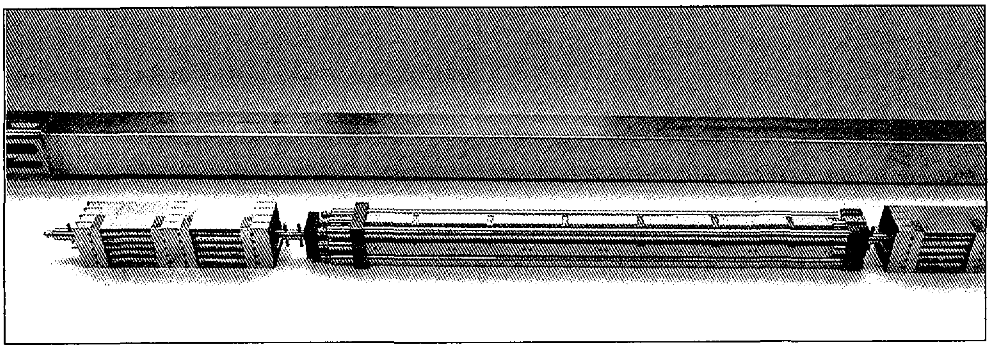
The CALLISTO facility provides a purpose-made environment for the irradiation of LWR fuel and/or materials under realistic PWR conditions (flowing coolant water, 155 bar, 300°C, PWR water chemistry). Appropriate irradiation conditions are also offered for different fusion reactor materials. The loop comprises three in-pile sections in the BR2 reactor, occupying different channels with distinct neutron flux characteristics.

In 2001 we operated the loop for the following irradiation programmes.

1. The **BACCHANAL** programme consists of increasing the burn-up of nine MOX fuel rods that had been pre-irradiated in BR3. This was carried out in the in-pile section IPS 1 of CALLISTO, where the rods were irradiated during the first three BR2 cycles in 2001; each rod accumulated about 3000 MWd/t.
   The BACCHANAL programme will continue in 2002. It will also support the qualification of CALLISTO loop for the OMICO and THOMOX projects.
2. In the framework of IASCC of LWR materials we continued the CORONA irradiation in IPS 2 of CALLISTO. The aim is to study on-line crack initiation in pressurised tube specimens. After reaching a fast neutron fluence of 7.8 10^{20} n.cm^{-2}, we moved the experimental rig to IPS 3 for another 4 irradiation cycles where the neutron flux is about 3 times lower. Although the tube specimens were further pressurised to 680 bar during the last irradiation cycle 05/2001, they did not fail.
3. After the successful completion of the IRFUMA I (IRradiation of FUsion MAterials) experiment, we continued with the **IRFUMA II** project. Conducted at a temperature of 300°C, the specimens of IRFUMA II were irradiated in CALLISTO IPS 2 during 4 BR2 cycles in 2001. The neutron dose was more than 1.1 dpa in the specimens located on the reactor mid-plane. The experimental loading consisted of 38 Charpy specimens and 50 tensile specimens made of chromium alloys (denominated DUCROPUR and DUCROLLOY) and of RAFM steel with denomination EUROFER97. Due to the presence of the REVE specimens at the hot plane, we assembled these Charpy and tensile specimens to form 2 bundles of each 8 rod-like positions above and below the hot-plane.

Part of the IRFUMA II specimens will continue their irradiation together with additional samples during the year 2002 in a new project, called IRFUMA III. The expected final dose after the latter campaign should lie in the range of 2 to 2.5 dpa (iron).

4. The **REVE** (REacteur Virtuel d'Etude) project is an international effort aiming at developing computational tools, based on well grounded techniques such as Molecular Dynamics, Monte Carlo methods, Dislocation Dynamics methods, and so on, capable of predicting the behaviour of materials (in particular LWR pressure vessel steel) under irradiation. The materials irradiated within the REVE experimental programme are essentially (except one case) model alloys. Not less than 2000 mini specimens from 10 different materials were loaded. Moreover, we succeeded in encapsulating these specimens, avoiding them to react with the CALLISTO coolant, but keeping a close control of their irradiation temperature (300°C). Taking advantage of the flexibility of BR2 and of the CALLISTO facility we overcame the challenge of reaching material damages of 0.2, 0.1, 0.05 and 0.025 dpa with fast neutron fluxes of 1.10^{14} n.cm^{-2}.s^{-1} and 3.10^{12} n.cm^{-2}.s^{-1} during short reactor cycles in 2001, specially dedi-



Detail of the REVE & IRFUMA II experimental devices

cated for this purpose. The post-irradiation characterisation will range from atom-probe examinations to tensile tests and will allow the study of the modifications induced by radiation in the different materials on microscopic, macroscopic and intermediate scales.

5. In contrast to the REVE project, where most of the specimen materials are model alloys with trace elements of well-controlled chemistry, the **RADAMO** project (<u>RA</u>diation <u>DA</u>mage <u>MO</u>delling) addressed "real" pressure vessel steels selected for their nature (plate versus weld), chemical composition (mainly %Cu, %Ni and %P) and their origin (US, J, F, D and B). Hence, we tested a broad variety of steels used for RPV fabrication.

   All the irradiations performed to date with these materials deal with high neutron exposures, usually between 3.10^{19} and 7.10^{19} $n.cm^{-2}$ (E> MeV), i.e. 0.05 to 0.1 dpa. However, irradiation effects are known to saturate in this range of fluences and large effects are observed in the range below 1.10^{19} $n.cm^{-2}$. In addition, some damage mechanisms are operative only above some incubation fluence.

   Therefore, we irradiated 4 x 8 (material types) x 7 (fluences) = 224 small tensile specimens (D=2.4 mm; L=24 mm) in IPS 2 and IPS 1 of CALLISTO to reach 0.003, 0.005, 0.008, 0.01, 0.025, 0.05 and 0.1 dpa damages in the material. These irradiations were combined with the REVE and IRFUMA II campaigns in 2001.

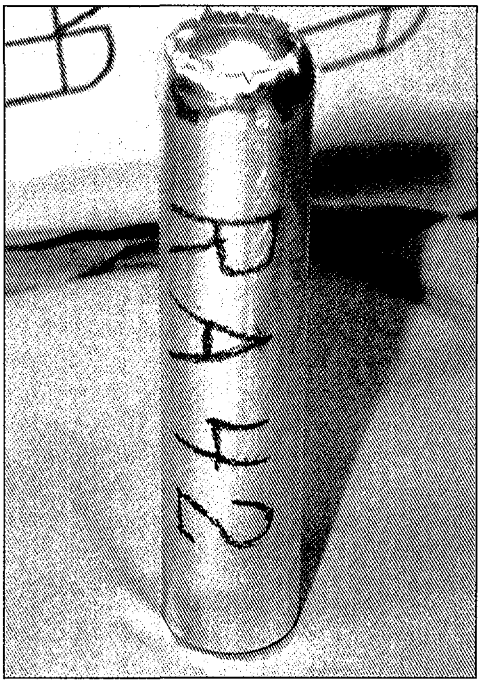
Experiments performed in dedicated facilities

SMIRNOF II project

A dedicated rig has been built and put into operation for the irradiation testing of optical fibres. This experiment provides quantitative data on the behaviour of optical fibres for diagnostics in fusion reactors in a mixed spectrum of neutron and gamma rays. The fibres have been irradiated in a fast neutron flux of 3.2 10^{13} $n.cm^{-2}s^{-1}$ (E>0.1 MeV) and a gamma heating of 1.5 $W.g^{-1}$. The temperature can be adjusted between 150°C and 290°C by regulating the flow rate of the cooling gas (air). Experimental results are commented on under Reactor Safety – Instrumentation.

CORSAIR 50 project

The purpose of CORSAIR 50 project (<u>CO</u>pper, <u>R</u>afm and alloys <u>SA</u>mples <u>IR</u>radiation) is to investigate the effect of neutron irradiation on copper and RAFM specimens at the temperature of 50°C, in the framework of fusion reactor development. Our partner, Risø National Laboratory (Denmark), supplies the specimens (tensile, fatigue and fracture toughness) loaded in aluminium capsules. These capsules are hermetically closed and filled with helium. Then they are mounted inside seven different open baskets, each loaded into a different standard channel of BR2. These baskets are simple rigs, allowing the specimen capsules to be directly cooled by the reactor primary water (at about 40°C).The required damage dose accumulation rate at the mid-plane of a basket is about 0.1 dpa per BR2 cycle. In order to achieve the target dose of 0.3 dpa we irradiated during three reactor cycles in 2001.



Capsule of CORSAIR

Experiments under preparation & development of irradiation rigs

GERONIMO project

Within the framework of the international fuel programme GERONIMO, we continued the preparatory work for the transient irradiation of BWR MOX fuel segments. Three such segments will be subject to power-transient testing in BR2 during 2002. Therefore, refurbishment of the dedicated facility

PWC/CCD has continued in 2001. A new control-command rack was built and new instrumentation lines between in-pile and out-of-pile equipment are under construction. Some gas circuits will also be renewed.

OMICO (THOMOX) project

Launched this year, the OMICO (Oxide fuels, MIcrostructure and COmposition variations) project is devoted to the study of a series of advanced nuclear fuels, all ceramic oxides: $(Th, Pu)O_2$, $(U,Pu)O_2$ and UO_2. In fact the extended programme, comprising 16 fuel segments, was first defined under the so-called THOMOX (THOrium MOX) project. Part of this programme has now become the OMICO project, with support of the 5th European Framework Programme.

We completed the design of the instrumented fuel rods, each equipped with a pressure transducer of LVDT type (Linear Variable Differential Transformer) to follow the fission gas release and with a high-temperature thermocouple to monitor the fuel central temperature. We also started the design of the in-pile section to be loaded in the CALLISTO facility: the upper part of the fuel basket contains the eight instrumented segments, while in the lower part there are eight segments that we can unload and reload for intermediate non-destructive examinations.

Fuel rods, instrumentation and rig components will be manufactured in 2002, so that the first two-year irradiation campaign can start at the end of 2002.

CORSAIR 300 project

The purpose of CORSAIR 300 project is to investigate the effect of neutron irradiation on copper and RAFM specimens at the temperature of 300°C, in the framework of fusion reactor development.

Our partner, Risø National Laboratory (Denmark), supplies the same type of specimens (tensile, fatigue and fracture toughness) as those for the experiment CORSAIR 50. The specimens are precisely fitted in aluminium matrices, which are slid into stainless tubes (outer diameter 10 mm). These tubes are hermetically sealed and filled with helium. They are then loaded in a shroud tube of a CALLISTO in-pile-section, in the same way as originally used for loading a bundle of nine fuel rods. Therefore the tubes, carrying the specimens, are directly cooled by the CALLISTO loop water at PWR conditions (300°C, 150 bar).

The required damage dose accumulation rate is about 0.1 dpa per BR2 cycle. To achieve the target dose of 0.3 dpa, three cycles are thus needed. First irradiation started in cycle 5/2001.

SPIRE project

Different steel alloys are candidate materials for future Accelerator Driven System (ADS) core internal structures, spallation module and spallation target window. The purpose of the SPIRE project is to irradiate such steel samples (tensile and mini Charpy) under a fast neutron flux at 200°C in order to investigate the effect of irradiation damage on their mechanical behaviour.

In 2001 we built most of the MISTRAL facility (Multipurpose Irradiation System for Testing of Reactor ALloys), which is designed to irradiate metallic specimens in pressurised stagnant water in the temperature range of 150-350°C. The in-pile rigs are loaded inside BR2 fuel elements so as to obtain a damage dose of 0.5 dpa per reactor cycle at the hot-plane level. The facility comprises two instrumented and temperature regulated in-pile sections and associated out-of-pile control equipment. Both in-pile sections will be used for the SPIRE project at the operating temperature of 200°C. To reach the required damage doses of 3 and 6 dpa, these irradiations will take about 1 and 2 years respectively. The start of the first irradiation is foreseen in April 2002.

TECLA project

The influence of irradiation on the corrosion of ADS structural materials in Lead Bismuth Eutectic (LBE) liquid metal must be experimentally investigated. This is the aim of the TECLA project. The materials to be tested are SS316L, T91 and F82H; these are candidate materials for future ADS core internal structures and the spallation module. The irradiation will be conducted at a representative temperature of 450 ± 50°C. Results hereof will be compared with corrosion tests on non-irradiated specimens.

In 2001 we devoted much effort to define the appropriate operating conditions and the main design features of the irradiation device. The in-core part of the rig consists of a double-wall capsule with a He/Ne gas mixture between the walls to control the specimen temperature. Electrical heating is provided to melt the LBE before the start of irradiation. The specimens are in fact small tubes (dia. 5 mm) stressed by internal gas pressure as well as tensile samples. The rig is to be loaded in the central hole of a standard BR2 fuel element (i.e. with six concentric fuel plates); this offers a large flexibility to find the correct irradiation position in BR2.

In 2002 we will finalise the detailed design and construct two or three TECLA in-pile sections together with their associated out-of-pile equipment.

[illegible]

CEA	Commissariat à l'Energie Atomique (Saclay, France)
DEN	Direction de l'Energie Nucléaire
DRSN	Département des Réacteurs et Service Nucléaires
SIREN	Service d'Irradiations en Réacteurs et d'Etudes Nucléaires
LAPSI	Laboratoire de Support aux Programmes d'Irradiations.(Saclay, France)
DED	Département d'Etudes des Déchets
SCCD	Service de Caractérisation et de Contrôle des Déchets
LSMN	Laboratoire des Systèmes de Mesures Nucléaires. (Cadarache, France)
JAERI	Department of JMTR (Narita-cho, Japan)
HRP	Halden Reactor Project (Halden, Norway)
OECD	
RISØ	RisØ National Laboratory (RisØ, Denmark)
VTT	Technical Research Centre of Finland (Epoo, Finland)
EFDA-CSU -	European Fusion Development Agreement Close Support Unit (Garching, Germany)
WEDHOLM MEDICAL	(Nyköping, Sweden)

Scientific Output

L. Vermeeren, "Absolute on-line in-pile measurement of neutron and gamma fluxes using self-powered detectors: Monte Carlo sensitivity calculations", 29th EHPG meeting, Lillehammer, Norway, March 11-16, 2001.

L. Vermeeren, "Absolute on-line in-pile measurement of neutron fluxes using self-powered detectors: Monte Carlo sensitivity calculations", 5th International Topical Meeting on Research Reactor Fuel Management (RRFM), Aachen, Germany, April 1-4, 2001.

E. Koonen, "The qualification of a new Fuel. The Operator's Perspective", Research Reactor Fuel Management, 5th International Topical Meeting, Aachen, Germany, April 1 to 3, 2001.

P. Gubel, "The BR2 Refurbishment : from concept to achievements", 12th Annual Conference of the Nuclear Society of Russia, Dimitrovgrad, RIAR, Russia, 25-29 June 2001.