highlights

2012

SCK•CEN

STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

2012

“ In tune with society ”

According to our mission SCK•CEN works on issues that are important to society, today and in the future: safety and efficiency of nuclear installations, solutions for the disposal of radioactive waste, protection of mankind and the environment against ionising radiation, and sustainable development. In this way we contribute to a viable society, for ourselves and for the generations te come.

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Dear reader

The Belgian Nuclear Research Centre celebrated its 60th anniversary in 2012. Together with the municipality of Mol, we looked back on these wonderful years in the exhibition ‘The countryside in the fifties: from green field to atom’. The establishment of SCK•CEN rapidly catapulted the region into ‘modern times’ for which Expo 58 later served as a model. We were true pioneers in those days. Looking back on 60 years of research and development, I can only conclude that we have succeeded in passing this spirit on from generation to generation.

The VKW Employers’ Association selected SCK•CEN as winner of ‘De Kempenaar 2012’. This is a highly prized recognition of our contribution to the prosperity of the region, and of our ambition to also remain a sustainable source of innovation in the future.

It goes without saying that we celebrated 60 years of SCK•CEN extensively; including an academic session in the presence of Prince Filip and a series of events for and by our staff. In addition, we had busy and well-attended open days for the general public, and a unique cultural event in the buildings of the BR3 reactor.

Moreover, BR3 celebrated a double anniversary in 2012. The reactor was connected to the electricity network 50 years ago, and was taken out of service again exactly 25 years ago. But BR3 remains a source of knowledge, even today. In fact, the experience that was gained by decommissioning this reactor is currently being put to good use in the decommissioning of the Thetis reactor at Ghent University.

In these *2012 Highlights*, we have compiled a number of striking examples of new developments in the areas in which SCK•CEN operates, including safety, health and sustainable industrial applications of nuclear energy. SCK•CEN plays a major role, for example, in a large-scale European investigation into the radiosensitivity of children subjected to CT scanning. Another example is the use of the BR1 reactor for the irradiation of new types of silicon rods. In the past year, tests have revealed that, in addition to BR2, BR1 is also able to respond to the latest developments in the semiconductor industry.

Science is all about acquiring new insights, although safeguarding and sharing knowledge are also fundamental aspects. In 2012, the Belgian Nuclear Research Centre launched the *Academy for Nuclear Science and Technology* with the aim of highlighting our function as a training centre.

In the previous edition of this publication, you could already read about the stress tests and the analyses we conducted into the robustness of our facilities. Our analyses have now confirmed that, in general, SCK•CEN facilities are also robust under extreme conditions. There are, of course, areas for improvement. And we have immediately taken action on those. Without waiting for the final report from the safety authorities, we have already undertaken a number of measures.

Finally, there is MYRRHA. The future major research infrastructure at SCK•CEN is becoming more tangible every day. The number of test configurations was extended significantly in 2012. The academic world is meanwhile eagerly looking forward to the unique research opportunities that the MYRRHA particle accelerator will be able to offer for fundamental research in various fields.

As you can see, the Belgian Nuclear Research Centre is 60 years young, and ready for the future.

Enjoy your reading!

Eric van Walle

Director-General


content

01

Ground-breaking research

into the optimal protection of people and environment

Large-scale research into radiation susceptibility in children

Drive to awareness and standardisation

At face value, Computerised Tomography may mean little to you, but you must be quite familiar with the abbreviation. Thanks to their high quality, CT scans are of immense value in making correct diagnoses. This technique is therefore applied increasingly in medical imaging. Nevertheless, in young children in particular, CT scans do not appear to be entirely without risk. A large-scale European research project, in which SCK•CEN is also participating, should give us the definitive answer. More precisely, EPI-CT is trying to show the connection between exposure of young children to CT scanning and a potentially enhanced risk of cancer.

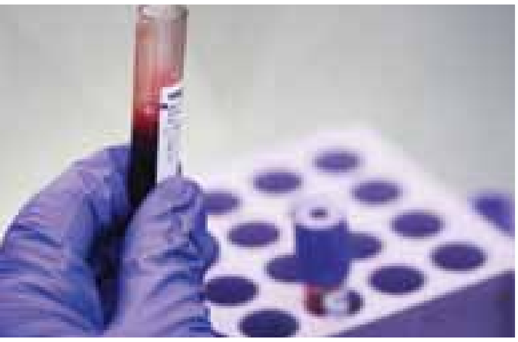
> *Children's sensitivity to radiation is much greater than that of adults because the cells still have to grow.*

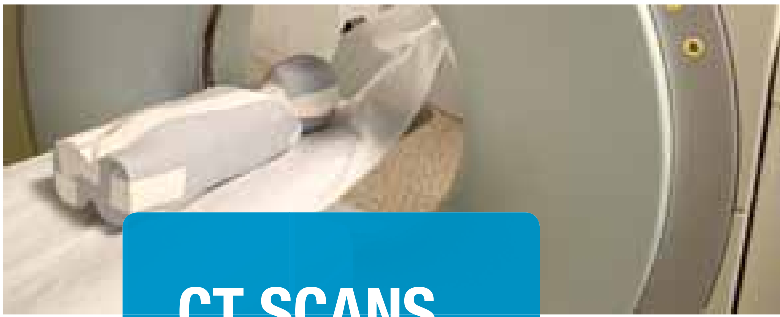
Interview with **Sarah Baatout,** head of Radiobiology and **Lara Struelens,** scientific collaborator

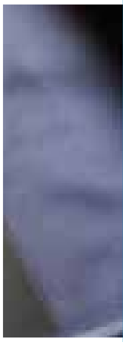
What role does SCK•CEN play in EPI-CT?

Lara Struelens: EPI-CT stands for the 'International Pediatric CT Scan Study'. Our group is helping with data collection in hospitals. At the moment there are two large hospitals taking part: the UZ Gasthuisberg Hospital in Leuven and the Oost-Limburg Hospital in Genk. Thanks to this joint project, we will have a database of about 30,000 patients. We will archive all the data of every single patient in great detail: which CT scanner, where the scan was taken and what the exposure parameters were and also (in anonymized form) some personal details.

We will go back as far as 1999 and request the CT data of patients who were under age at that time and who underwent a CT scan. In this way we can collect all the data we need in order to calculate the exposure dose individually for each patient. We will then check these doses against the cancer register to find out which patients from this group have in the meantime been diagnosed with cancer. Epidemiologists will then carry out the statistical analysis to show the potential link between a CT scan on children and a possible increased risk of cancer. The entire European database, which is built up from a combination of databases from nine different countries, will be used in this analysis. Obtaining all the necessary consents and permissions has taken a long time, but we can finally make a start with collecting the data in Belgium.







CT SCANS

CT scans or Computerised Tomography was developed in the 1970's and is used more and more. The results are much more detailed than in traditional radiography and the procedure takes very little time. Computerised Tomography is also often used for children. But in comparison with traditional x-ray radiography, the radiation dose from a CT scan is considerably higher. For a traditional x-ray photograph of the breast, for example, the effective dose is typically 0.02 milliSieverts, whereas it is 8 milliSieverts for a CT scan, and therefore 400 times higher.

Sarah Baatout: SCK•CEN is leading the biology section in this research. We are implementing a pilot study in which we monitor the change in a number of biological markers in the blood of 60 paediatric patients, just before and after the CT scan. The dose to which the patient is exposed, has a biological, molecular effect. Within a few minutes to a few hours after a CT scan, we hope that we will be able to see from these markers which patients are most susceptible. Our sensitivity to radiation is partly determined by genetics and therefore can differ between two children of the same age. We want to see if we can identify the more susceptible individuals. We have already shown in 2012 that blood cells exposed to a low radiation dose exhibit a different profile to those subjected to a high dose. When we analyse the entire genome (about 30,000 genes) with the low dose, we see that cell-to-cell communication develops, but that repair of the damage does not always take place. If, in contrast, a high radiation dose is applied, there will be a lot of DNA damage, but also a lot of DNA repair. If the cells are not able to recover, they will usually die off. This is the safest option for the organism. These differences in response patterns between high and low doses have provided us with a breakthrough because they point to a fundamental difference.

Why are children more susceptible to radiation?

Sarah Baatout: Children's sensitivity to radiation is much greater than that of adults because the cells still have to grow. The body still has to develop and so there is a risk in the long term of contracting cancer or another disease. Prompted by an epidemiological study in the United Kingdom, an article was published in 2012 claiming that there was an increased risk of brain tumours in children who had undergone a CT scan of the head.

Lara Struelens: This study shows that there is an increased risk, but it is very difficult to find a genuine link between the level of the dose and the risk of becoming ill. We assume that there is a linear relationship but there is not sufficient scientific evidence for that. We hope that the new large-scale European study will provide more information about this.

A significant upside of the EPI-CT project is that awareness of the problem is growing. Hopefully this will also result in a degree of standardisation. We have noticed that there is a huge variation between hospitals in the doses used in quite a lot of medical exposures. In general, doctors and nurses just look at the end result, the images. They do not always know exactly what dose is given to the patient and sometimes no special protocols are used for children. Yet a child is so much smaller and therefore needs so much less radiation than an adult does.

Does EPI-CT have any connection with earlier research projects within SCK•CEN?

Sarah Baatout: We have a unique and long experience over more than 30 years at the Belgian Nuclear Research Centre regarding radiation susceptibility at the various stages of development of the human being; from fertilization to the embryo and the foetus. This research on paediatric patients is an extension of that. It enables us to gain a better insight into the specific radiation susceptibilities of newly born babies and children up to the age of 12.

Lara Struelens: We also completed the PreDos project in 2012. PreDos is a national research project aimed at dosimetry for prematurely born babies. The problems of CT scanning are not relevant here because it is seldom used on such small patients, but a lot of x-ray photographs of the thorax, for example, are taken to monitor the development of their lungs. We had no idea what doses were used for this. We visited 17 post-natal intensive care units (NICUs) to learn which doses were being used and found that there was a great variation in the doses used for a simple lung image. In order to standardise the doses and to keep these as low as is reasonably possible, we have formulated guidelines which recommend the exposure parameters best used to take these photographs. The hospitals now know where they are in comparison with other hospitals and what they should aim at. We have presented our results at staff courses and they have incorporated the guidelines. We rely on the goodwill of hospital staff to follow these guidelines.

How does radioactive material disperse in the air?

Advanced technology and additional data make forecasts even more accurate

Thanks to the ever-improving performance of computers and the integration of weather data, the experts at the *Crisis Management and Policy Support* unit have been able to optimise the reliability of existing atmospheric dispersion models even further in 2012. These models calculate the dispersion of radioactive materials in different situations. This is important for the normal operation of nuclear facilities but even more so in the event of an incident or accident. Models have also been designed for MYRRHA taking into account the unique features of this research infrastructure.

Are the dispersion models developed for MYRRHA entirely new?

Tim Vidmar: We use atmospheric dispersion models for MYRRHA which were developed in the 1970's here at SCK•CEN. They can still be applied because they are based on parameters specific to the site. At the time these models were tested extensively and compared with realistic data. But now we have had to adapt them to the accident scenarios which are specific to MYRRHA. That's why the existing atmospheric dispersion models have been coupled to a mathematical description of all that takes place in the installation. We successfully completed this process in 2012.

What makes the atmospheric dispersion models for MYRRHA so special?

Tim Vidmar: MYRRHA is a new type of reactor. Insofar as permits are concerned, this is virgin territory. MYRRHA has specific features which are not found in existing nuclear power plants. So we have to investigate how radioactive material could find its way into the atmosphere in the event of anything going wrong. This is done using accident scenarios: assumptions of what could go wrong in the installation. The ultimate goal is to produce an estimate of the impact of potential accidents on the environment and the population.

The models for the other SCK•CEN installations were also improved in 2012. What does that mean?

Johan Camps: Technology doesn't stand still. We are now making new simulations with a very recent technique, called 'Computational Fluid Dynamics' (CFD). This makes it possible to calculate extremely complex air streams close to the installations, where structures such as buildings, trees in the vicinity and so on play an important role. In order to perform these calculations, technologies with a lot of computational power are needed. We now have these and these simulations are done by our PhD student Lieven Vervecken in collaboration with the Catholic University of Leuven (KU Leuven).

Johan Camps, head of Crisis Management and Policy Support
Geert Olyslaegers, scientific collaborator
Lieven Vervecken, PhD student
Tim Vidmar, scientific collaborator (not in the picture)

Why is this update so significant?

Johan Camps: This is important for the people who happen to be on site in an emergency, for one thing. We can examine which route is best for an evacuation. The modified models are also needed for making a correlation between what is measured and what is actually discharged. By using the CFD technique we are able to work much more accurately than with the previously available techniques.

How do you deal with the impact of variable factors such as weather conditions?

Johan Camps: In addition to the development of models, we also conduct research on the implementation of new data in existing models. An example of this is the improved meteorological information available these days. We can use these in our models to improve forecasts even further. In that context we have set up a joint project in 2012 with the KMI, the Belgian Royal Meteorological Institute, to implement their weather data in our systems. This continues something that we have been doing for quite a while, namely incorporating data from the precipitation radar. This is, for example, important in more accurately forecasting the deposition of radioactive material on the ground.

The Crisis Management and Policy Support unit also provides support for the emergency plan models. What are these used for?

Johan Camps: Atmospheric dispersion models are used first and foremost in the context of granting permits to nuclear installations. In addition they play a role in the federal nuclear emergency plan. In the event that an accident occurs, or in an emergency planning exercise, the operators themselves have to perform model calculations and pass these on. SCK•CEN is a Government partner within the framework of the emergency plan, verifying and interpreting these calculations and making recommendations about protective measures for the population.

Will these emergency plan models for accident situations be refined any further?

Geert Olyslaegers: The models that have already been developed by the Belgian Nuclear Research Centre are also used in many other places, for instance in the Doel and Tihange nuclear power plants. These models are certainly good, but in the meantime, better technology has come along. Whilst with slow computers we had to keep things simple, now that the computers perform the calculations much faster, we can develop much more realistic models. For this reason we have opted to upgrade the older emergency models to a newer platform, where we can calculate the impact in the event of accidental discharges. We have as good as completed the mathematical development of the updated dispersion model, but for the time being it only calculates the concentrations of radioactive material in the atmosphere. But we need to know more. We also need to know the impact on the population, the environment, on plants and animals and on the food people will eat. That's where the next stage starts.

“Radiation is used on a daily basis in medical practice: X-rays, radiotherapy, radioactive products. This radiation saves many lives. But this should not blind us to the risks of incorrect use: too many examinations, methods that are too sophisticated, inadequate parameters. SCK•CEN supports optimal use: as little radiation as possible, with as much result as possible, particularly in the case of children.”

Frank Hardeman

Institute Manager Environment, Health and Safety

How do radionuclides disperse in clay?

Impact of organic remains examined

Does the presence of organic deposits from plants and animals in Boom clay have any impact on the dispersal behaviour of radionuclides? This is one of the crucial questions which the *R&D Disposal* unit of SCK•CEN has been looking at.

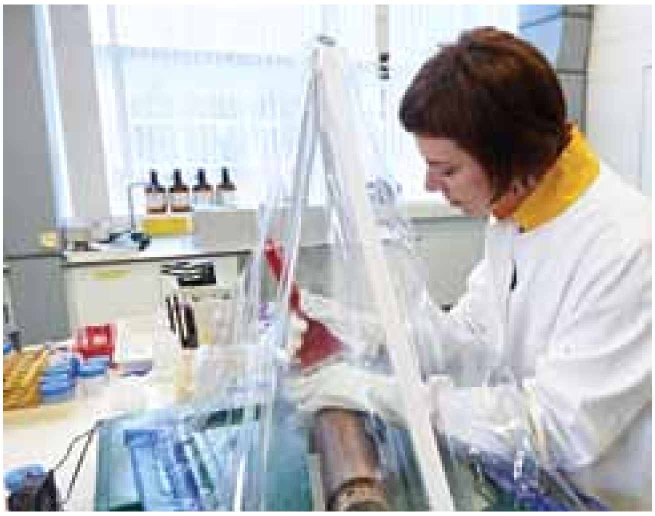
The research into disposal of this waste is coordinated by the Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS), in which SCK•CEN is the main research partner. For the underground laboratory, both have concentrated their efforts in the joint Economic Interest Grouping EURIDICE.

The Belgian Nuclear Research Centre has been engaged for many decades in research into the underground disposal of radioactive waste in the Boom clay layer. Clay is quite an impervious material that is well suited to this purpose because of its physical and chemical properties. These ensure that any dispersion of radionuclides is drastically limited. The long-term impact of humic acids (organic residues or compost) on the behaviour of radionuclides in the clay could not be accurately estimated, however. That is, up to now. Because what do we know now? Humic acids do bind with radionuclides, but this is not stable in the long term. This means that the clay can do its job in limiting the dispersion of radionuclides. At the basis of these findings lie the long-running experiments with radionuclides.

The *R&D Disposal* unit studies the migration behaviour of these radionuclides through the Boom clay layer. The researchers have a unique infrastructure available for this project: the underground HADES laboratory. The construction of this laboratory, at a depth of 225 metres below ground level, started in 1980. SCK•CEN is therefore a pioneer in research into geological disposal in clay beds as a potential long-term solution for highly radioactive waste.

Behaviour of radionuclides in clay

Clay layers are in general very suitable for storing radioactive waste disposal. Because there is no moving groundwater, radionuclides can only disperse by means of diffusion. Moreover, clay layers hold back radionuclides by virtue of the strong attractions to their surfaces, thereby reducing mobility. However, the water in the pores of the Boom clay also contains humic acids. These organic remains of animal or vegetable matter are studied because, amongst other things, they are able to bond strongly with radionuclides (and heavy metals), so they are less attracted and impeded by the clay surface. The presence of humic acids can therefore increase the mobility of radionuclides and hence make disposal less efficient.



However, the researchers at the *R&D Disposal* unit suspected that the bonding of humic acids to radionuclides would not be stable over an extended period. This would mean that they do not play a negative role in the dispersion of radionuclides. But there was insufficient data available to develop a complete picture of this phenomenon. Consequently, eight years ago, some long-term experiments were set up in order to obtain more data and information on the underlying processes. Sufficient data have now been collected to give a comprehensive picture of the bonding between humic acids and radionuclides. This has now been translated into a mathematical model that describes the experimental findings very well indeed.

Long-term experiments

There are two types of experiments in progress for developing a correct insight into the issues. On the one hand there are the typical migration experiments. These measure how fast the radionuclides disperse through the clay layers. The researchers take core samples from the clay and place a drop of radionuclide solution on the sample. They then observe the dispersion process. These migration experiments take place both on a small scale in the laboratory and on a large scale in HADES. They take a long time because the processes occur so slowly.

On the other hand, research is taking place into the binding of radionuclides with minerals and humic acids in the clay. The chemical conditions of a deep clay layer, such as the absence of oxygen, are simulated as closely as possible in 'glove boxes'. Every radionuclide has its own specific characteristics and therefore reacts differently as well. The behaviour of each radionuclide must therefore be examined separately. Among other things, the researchers monitor how strongly a radionuclide interacts with clay minerals (adsorption), to what extent a radionuclide bonds with the humic acid, and also study how this organic material behaves in the clay. These measurements are performed in separate experiments, without radionuclides, and subsequently in combined experiments as well.

> *"From previous experiments, we suspected that the bonding of organic materials with radionuclides was not stable. Now we have proof as well."*

A significant step forward

The experiments have shown that many radionuclides form a bond with humic acids, which results in a reduction of the attractive power for clay minerals. However, sustained migration experiments prove that these bonds are not stable. The radionuclide and humic acid complexes fall apart, after which the radionuclides are once again adsorbed by the clay minerals. As diffusion is a very slow process, the clay minerals have all the time they need to adsorb the radionuclides and therefore the bonding between the radionuclides and the humic acids is not an obstacle.

On the basis of the collected experimental data, a conceptual model has been developed which includes all the underlying fundamental processes such as adsorption, diffusion behaviour and the instability of the radionuclide-humic acid bonds. With the help of this mathematical model, it is now possible to simulate long-term migration experiments. This also represents a significant step forward for the implementation of safety analyses.

New techniques permit more accurate waste analysis

Solutions for problematic samples

The requirements for categorising waste are becoming increasingly stringent. The result is that even more advanced techniques are needed for detecting and identifying the presence of radionuclides. The *Radio-chemical Analysis* expert group optimized a number of methods in 2012 and also prepared for MYRRHA. The future large research infrastructure at SCK•CEN will also generate new and specific types of waste.

The acceptance criteria for radioactive waste have become ever more stringent in recent years, not only in Belgium, but around the world. This is meant to result in safer and more effective treatment and storage. These stricter criteria also require analyses of (radio)nuclides that are only present in the waste in very low concentrations and of (radio)nuclides that are difficult to identify. The *Radiochemical Analysis* expert group is tackling this challenge at the Belgian Nuclear Research Centre. This group specialises in the chemical and radiochemical analysis of various forms of radioactive waste produced at the SCK•CEN site as well as by the wider nuclear industry. The results of these analyses help to determine how the waste can be further processed and stored in a safe way.

Difficult solutions

Radioactive waste can be extremely diverse, ranging from homogenous liquids or solids to very heterogeneous mixtures. There are different analytical methods for each type of sample. Some radionuclides, such as prominent gamma emitters, can be measured directly in the waste. Other radionuclides, such as pure alpha and beta emitters, can only be measured in a dissolved sample and only after thorough purification. An additional problem is that some radionuclides, such as chlorine-36 and carbon-14, evaporate during the preparatory chemical treatment.

In 2012, the researchers worked intensively on the analysis of these radionuclides in various types of waste. Until recently, graphite samples used to be more problematic because the correct treatment techniques were not available to dissolve the graphite and simultaneously capture the volatile radionuclides. It was possible to dissolve graphite in a high-pressure bomb, but this method did not allow for the capture of radionuclides. The research team has been able to solve this problem by analysing the graphite samples in two steps. The non-volatile radionuclides are analysed after dissolution in the high-pressure bomb. In order to capture and analyse the volatile radionuclides, the graphite is incinerated.

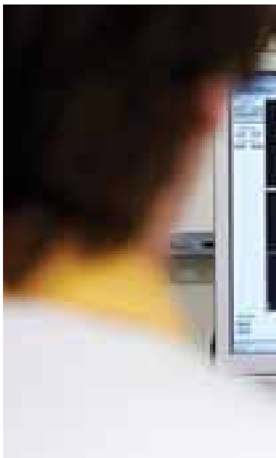
Resin samples are also difficult to dissolve. The *Radiochemical Analysis* expert group succeeded in developing a specific dissolution procedure for two types of resin in 2012. It is now possible to capture the volatile radionuclides in an alkaline solution which can then be analysed.

Even lower detection limits

The expert group is already capable of reaching detection limits as low as 6 Becquerels per gram of graphite for the volatile radionuclide chlorine-36. The intention is to reduce this limit even further. Chlorine-36, in particular, is a radionuclide for which the demand for its determination in waste has increased. Because it is only present in very low concentrations 6 Becquerels per gram is not always sufficient. Research is needed to ascertain how chlorine-36 can best be separated, or pre-concentrated, in order to obtain even lower detection limits, in graphite as well as in other types of waste.

MYRRHA ensures new challenges

A considerable proportion of our research was devoted to MYRRHA in 2012. There is of course no waste from the yet to be built reactor, but it is important to develop the procedures now so that samples deriving from scientific experiments can be analysed. The biggest challenge with the MYRRHA samples is that lead and bismuth from the coolant are present in high concentrations and may interfere with the analyses. That is why it was necessary to optimize a number of separations. There are two methods for this: separate the lead and bismuth, or isolate the radionuclides to be analysed. The analysis strategies are developed partly within the framework of postgraduate doctoral research.



In 2012, the *Radiochemical Analysis* expert group concentrated particularly on volatile radionuclides such as chlorine-36 and carbon-14. These are pure beta emitters. Every beta emitter has a continuous energy spectrum. This means that for a complex mixture containing several beta emitters, the spectrum is complicated and often provides little usable information. The various radionuclides first have to be separated from each other before they can be analysed. This is the reason why so much effort is put into the optimisation of separation methods used for research into waste categorisation.

25 years out of service and still a source of knowledge

Dismantling UGent reactor using BR3 know-how

The Belgian Reactor 3 had a double birthday to celebrate in 2012: it was commissioned and decommissioned 50 and 25 years ago, respectively. The Belgian Nuclear Research Centre has built up a unique body of knowledge around the planning, practical implementation and follow-up of a decommissioning process based on the dismantling of the BR3 reactor. This knowledge is now being actively used for the dismantling of other nuclear installations both within and outside SCK•CEN. One of these is Thetis, the research reactor at Ghent University. At BR3 itself, a new phase in the decommissioning process has just started.

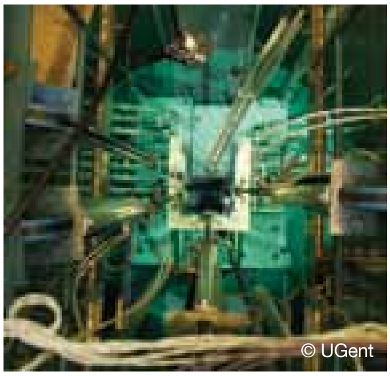
The last medium-active waste was removed from BR3 in 2012. This means that only low-radioactive material is left. In order to dismantle and remove this, robots are no longer needed and the *Dismantling, Decontamination and Waste* expert group can work manually. The team is now focusing on the decontamination of the concrete walls, floors and ceilings. So, we've already come a long way. In 1989, BR3 was one of the four dismantling pilot projects in Europe. At the time there was no legal framework at all in Belgium for drawing up decommissioning plans and the associated applications for permits. BR3 is a test case on which basis the Federal Agency for Nuclear Control (AFCN/FANC) developed the current law and regulatory system.

The BR3 experience applied to remediation of the hot cell

More than being just a test case for the authorities, BR3 is also at the basis of the knowledge and expertise built up within SCK•CEN about dismantling nuclear installations. In 2012, the *Dismantling, and Decontamination* unit put this knowledge into practice for the remediation of hot cell M2. This was not a genuine dismantling procedure, but rather a thorough clean-up with a view to reuse. After a long preparatory process, it was possible to start using the intervention room in 2012 and the remediation of hot cell M2 could be directed from there. Because there is no access to the hot cell, all manipulations have to be carried out remotely. This is proceeding successfully as, since the intervention room became operational, one and a half tonnes of waste have already been removed.

Dismantling Thetis

The knowledge accumulated from the BR3 project is now being actively applied, amongst others to Thetis, the shutdown research



reactor at Ghent University. The dismantling permit was granted in May 2012. Thetis is a different type of reactor from BR3 and easier to dismantle, yet the methodology and the approach remain the same. Ghent University lacked the experience to lead the dismantling project. At the time when Thetis was definitively shut down, the staff who had been running the reactor were reassigned and the reactor was left under minimum supervision. Because of its broad experience – including other reactor types – the *Dismantling, Decontamination and Waste* expert group at SCK•CEN was the logical partner for this project.

Radioactivity of Thetis now charted

A significant step in the dismantling process was completed in 2012: the radiological mapping of the installation in which all radioactivity was mapped out. The measurement results confirmed the pre-calculated model of the activated reactor components, the dismantling method and the removal scenario for the radioactive waste. The waste management plan can also be finalised on the basis of this mapping, as well as the methodologies for categorising this waste and releasing the remaining materials.

An important tool for managing a dismantling project is software developed in-house. This was optimized during the dismantling of BR3 and can be modified to suit the circumstances. In the case of Thetis, the *Dismantling, Decontamination and Waste* team used a simplified version. The tool enables the accurate tracking of what has actually been dismantled, which treatments have been applied, what the status is of the various measuring procedures and where all the materials go. It also provides the statutory reporting to the National Institute for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS) and the Federal Agency for Nuclear Control (AFCN/FANC).

In 2013, the expert group will continue on the chosen path with the actual dismantling of Thetis. This will take place in different stages, starting with the heavily activated part of the reactor and ending with the non-radioactive but toxic asbestos containing materials. If the activities proceed according to plan, Thetis will be completely dismantled by 2014 and the site can be released.

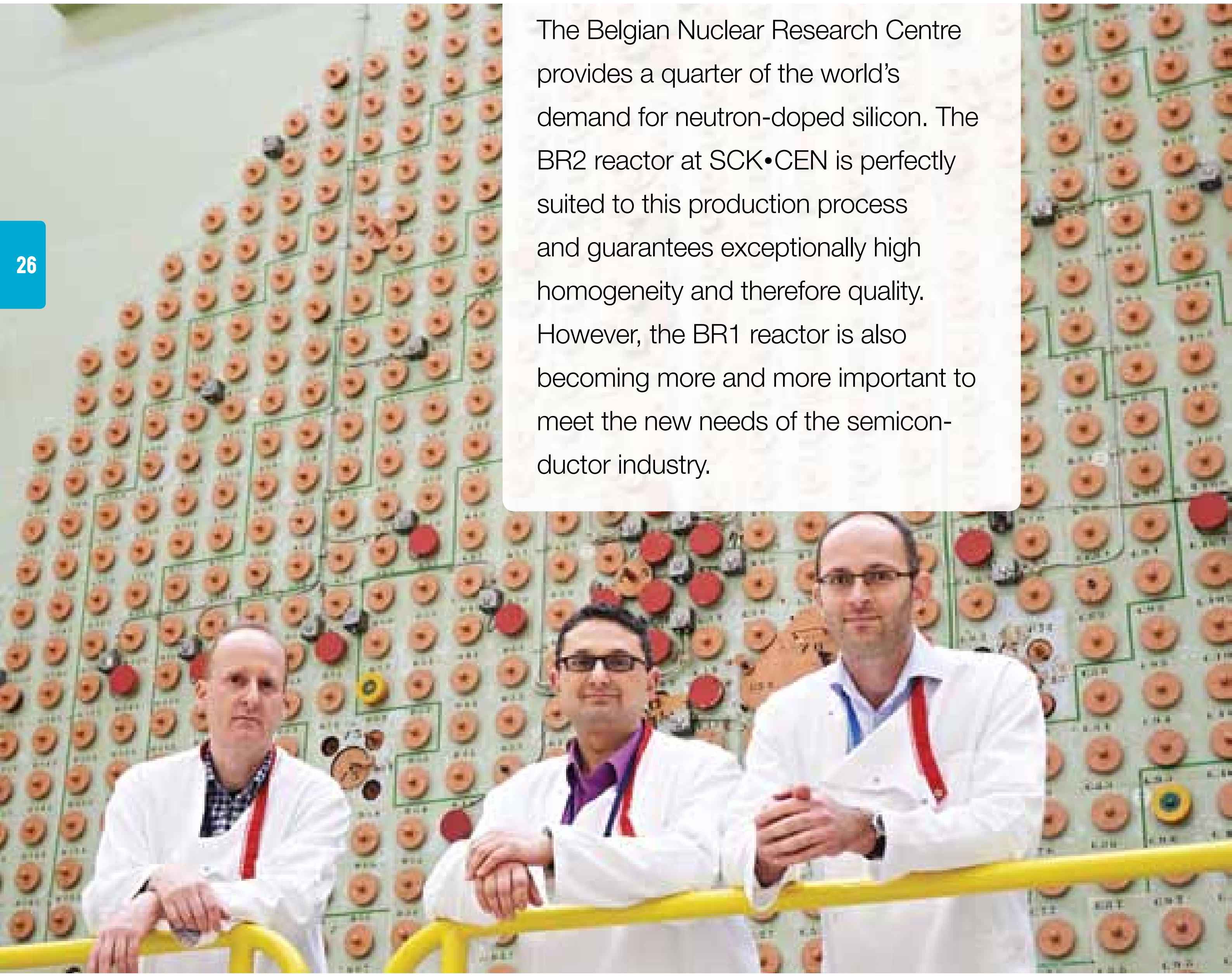
02

BR1 & BR2:

high-performance and multifunctional

Semi-conductor industry counts on the BR1 reactor

Silicon doping test phase successfully completed



The Belgian Nuclear Research Centre provides a quarter of the world's demand for neutron-doped silicon. The BR2 reactor at SCK•CEN is perfectly suited to this production process and guarantees exceptionally high homogeneity and therefore quality. However, the BR1 reactor is also becoming more and more important to meet the new needs of the semiconductor industry.

Neutron Transmutation Doping or NTD has been used for decades at the BR2 reactor at SCK•CEN (see box). The longer a silicon crystal is irradiated or the higher the neutron flux, the lower the final resistivity. Resistivity or specific resistance is the degree to which a material resists an electric current. Thanks to its high neutron flux the BR2 reactor is ideal for producing crystals with low resistivity. The demand for doped silicon with higher resistivity for a number of new applications has been growing recently. This implies that the crystals need to be irradiated for a shorter time or with a lower neutron flux. It is less easy to obtain higher resistivity in the BR2 reactor, which is where the BR1 reactor comes into the picture.

BR1 offers additional capacity and flexibility

BR1 is a reactor with a significantly lower neutron flux, therefore making it easier to create silicon crystals with a higher resistivity. An additional advantage is that BR1 is a large reactor, which means that the neutron flux is virtually constant over a relatively large distance. It is therefore possible to irradiate large volumes of silicon with more or less the same neutron flux, without needing to rotate or move the crystals during the irradiation, something which is necessary in BR2. SCK•CEN is now able to meet the new market demand thanks to the BR1 reactor.

Due to its design, BR2 can only irradiate crystals with certain very specific dimensions. Furthermore, this also has to be done under water. If the crystals are too large they will not fit into the irradiation channels. If they are too small, the surrounding water will absorb too many neutrons, which makes the NTD process too imprecise. However, in the BR1 reactor the irradiation takes place in air, which means that the process is much less dependent on the dimensions of the crystals being irradiated. This allows

NTD SILICON: AN EXCELLENT SEMICONDUCTOR

Silicon is one of the most widely used materials in the electronics industry. It can be made into an excellent semiconductor by creating impurities in the crystalline structure. One way to do this is to irradiate silicon in a research reactor, a process known as Neutron Transmutation Doping or NTD.

The process works as follows. Silicon consists of three natural isotopes: silicon-28 (92.2%), silicon-29 (4.7%) and silicon-30 (3.1%). When silicon is irradiated in a reactor, part of the silicon-30 interacts with the neutrons and so forms the unstable silicon-31. The latter will decay into the stable isotope phosphorus-31. The creation of phosphorus isotopes as impurities in the silicon changes the electrical properties of the irradiated crystal and thus turns it into a semiconductor.

The advantage of NTD in comparison with other methods is that the process required for this ensures that the impurities are spread very homogeneously throughout the crystal. This makes doped silicon exceptionally suitable for use in applications with high electrical loads.

BR1 to respond more flexibly to the demand to irradiate silicon crystals with specific dimensions, but with high resistivity.

Another important point is that the NTD process works with so-called thermal or low-energy neutrons. There are always both low- and high-energy neutrons present in a reactor. But high-energy neutrons damage the silicon crystal structure, requiring an additional treatment by the customer. The BR1 reactor is exceptionally suitable for irradiation with thermal neutrons.

Ready to start

A feasibility study into doping silicon in the BR1 reactor was carried out in 2012. Firstly, the most suitable position in the reactor for this irradiation was investigated. Afterwards, the first test irradiations were performed for two potential customers. The results of these tests were positive. BR1 is now ready to switch over to production.

A TIMELESS DESIGN

The Belgian Reactor 1 has been operational since 1956, which makes it the oldest research reactor in Belgium. BR1 is air-cooled, uses graphite as a moderator and natural uranium as fuel. It is striking that this is still the same fuel as when it was first started up. BR1 has a thermal capacity of 4 MW and consists of 829 channels of which 569 are loaded with fuel. Some 70 channels of various dimensions are intended for experimental purposes.

Following the start-up phase, BR1 was mainly used for research into reactor and neutron physics. Until the BR2 reactor started up in 1964, BR1 was also used to produce radioisotopes.

At the moment BR1 is no longer in continuous use. The reactor is started up when needed and then switched off again. In the current operating scheme the maximum capacity has been reduced to 700 kW. Among other things, this flexible test reactor is now used to calibrate measurement equipment and for various irradiations for in-house research, but also for other study centres, universities and industry. BR1 also plays an important part in the training of scientists and engineers.

POLLUX controles silicon quality

A new star in the BR2 firmament

The BR2 reactor has two installations for the irradiation of silicon: SIDONIE for crystals with a diameter up to 5 inches and POSEIDON for diameters from 6 to 8 inches. Since the final product has to meet increasingly strict specifications, it is also necessary to monitor the irradiation of the silicon more and more accurately. This is the purpose of the newly developed measuring rig POLLUX.

The semiconductor market is continuously evolving. To maintain and guarantee the required product quality, the procedures which SCK•CEN has had in place in the SIDONIE installation (SIlicon DOping by Neutron Irradiation Experiment) since the early 1990's need to be improved. Besides the demand from the semiconductor industry, there are other factors which mean an upgrade is necessary. New experiments, previously absent, have since been loaded into the BR2 reactor, and the original control rods have been replaced. Lastly, the neutronic environment in the reactor core also changes depending on the age of the matrix in which the rig is placed. That is why it was necessary to develop a new instrument to improve the accuracy of the measurements. And so, POLLUX was born.

Sensors measure neutron flux

POLLUX will be installed near SIDONIE, which will result in the measuring equipment providing more accurate readings of the irradiation conditions to which the silicon is exposed. These conditions determine the quality of the irradiated product. At the start of the process the silicon has a certain electrical resistance. The resistivity must be modified to produce a semiconductor with the desired characteristics. This is achieved by irradiating the silicon with neutrons for a specific time in SIDONIE.

In order to achieve the desired resistivity, it is crucial to monitor as accurately as possible how the neutrons behave. This can now be done with POLLUX. The instrument is placed in an irradiation channel in BR2 and is equipped with sensors to measure the neutron flux. These sensors are called 'Self Powered Neutron Detectors' or SPNDs. They are located at the lower part of a 5-meter-long cylindrical rod that is placed in the reactor core. POLLUX measures the axial distribution of the neutron flux at 18 positions every single minute.

SCK•CEN's clients need the final product to be as homogeneous as possible. This is because this type of silicon is used principally in high power electrical applications, such as wind turbines, solar energy systems and hybrid vehicles. In order to obtain this homogeneity, the silicon is continually rotated during irradiation in SIDONIE and oscillated at two speeds.

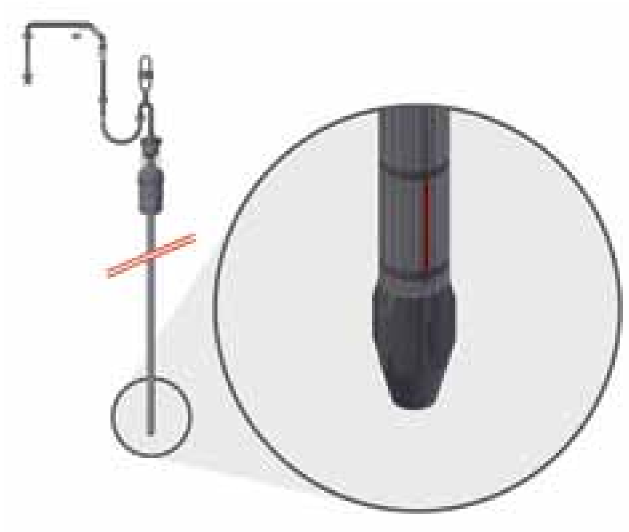
POLLUX collects first data

POLLUX was first deployed, for an irradiation cycle of three weeks, in the autumn of 2012. In a subsequent phase POLLUX will be used to measure the neutron flux in a different reactor configuration over a four week period. More measurement data will obviously result in a better insight into the working of BR2. The measurement results are not interpreted directly. Instead the data is compared with the neutronic models of the reactor in order to determine the correlation. The information generated by POLLUX must ultimately ensure that SCK•CEN can maintain and further develop its unique position in irradiating silicon for high-quality applications.

Extension anticipated

POLLUX was developed especially for BR2 and is at the moment unique. The measurement apparatus can be moved within the reactor and can even be duplicated so that it can be placed inside a different irradiation channel. At present, POLLUX is only used for SIDONIE, but the possible arrival of a new SIDONIE installation to irradiate 6 inch silicon crystals has already been anticipated. At a later stage the instrument could also prove its usefulness for the other silicon irradiation configuration in BR2, namely POSEIDON (POol Side Equipment for Irradiation and DOping of silicon by Neutrons).

> *"POLLUX measures the axial distribution of the neutron flux at 18 positions every single minute."*



POLLUX detail

“Only the positive cooperation of all scientific and technological disciplines, including nuclear research and development, will provide the innovative solutions needed for the major social challenges of tomorrow.”

Leo Sannen

Institute Manager Nuclear Materials Science

To have all research reactors operating with low-enriched uranium has been a global objective for several decades. For some reactors this was not within reach until now. But thanks to the SELENIUM programme at SCK•CEN, this might change soon.

Low-enriched uranium

soon for all research reactors?

Interview with **Sven Van den Berghe**,
head of Micro-structural and Non-destructive Analysis

Why is it so difficult to operate a high-performance research reactor such as BR2, on low-enriched uranium?

Sven Van den Berghe: Research reactors are built to produce the largest possible quantity of neutrons in the smallest possible space. That is why they operate with special fuel designs and often with highly enriched uranium (HEU). Naturally, if we want to switch to a fuel based on low-enriched uranium (LEU), we do not want to lose the performance of these reactors, and we do this by making the density of the fuel as high as possible. Many reactors have already made the switch from a fuel based on uranium-aluminium compounds where the uranium is highly enriched, to a fuel based on uranium-silicon compounds, which can be low-enriched because they inherently have a higher density. But there are five high-performance research reactors in Europe, including our BR2, for which this fuel will not suffice. Novel international programmes have been started with the aim of producing fuel with an even higher density especially for these reactors. This became the uranium-molybdenum alloy. The first high-capacity irradiation and research on this fuel took place here in the BR2 reactor in 2003 in an international joint project. We thought we would follow a relatively straightforward trajectory: irradiation, qualification, conversion. But the fuel did not perform very well. The reaction that occurs between the uranium-molybdenum granules and their surrounding aluminium matrix during irradiation, turned out to cause too many problems. Since that experiment in 2003, experts both in and outside SCK•CEN have been busy searching for a solution to this interaction, in the first place without success.

In spite of that setback you and your colleagues obviously did not give up.

Sven Van den Berghe: The first potential solution was to add silicon to the aluminium in the matrix. SCK•CEN has contributed to this development in the context of the international LEONIDAS programme (see also *Highlights 2010*). This enhances the behaviour of the fuel but the improvement proved insufficient. So we needed another solution. This is the reason why we started the SELENIUM programme at SCK•CEN in 2007. SELENIUM has nothing to do with the chemical element but stands for 'Surface Engineering of Low ENrIched Uranium Molybdenum'. The programme is therefore aimed at surface engineering or surface tuning of the uranium-molybdenum granules. Why are we doing this? Because the reaction occurs at the interface between the uranium-molybdenum granules and the aluminium. We wanted to place something at that interface which ensures that the reaction does not occur. So we have developed a

"We are cautiously hopeful, and the rest of the world is very positive. SCK•CEN is at this time the only institute which has successfully carried out such an irradiation programme."

coating: the deposition of a thin layer on the fuel granules before they are placed in the aluminium matrix. This could be a silicon coating as a continuation of the LEONIDAS programme where we added silicon to the matrix aluminium, or a barrier to the reaction, for example a zirconium nitride coating. We are also investigating other possibilities. In the meantime we have been working on these coatings for five years and have taken out a patent on the idea. Our SELENIUM fuel with these two coatings was placed in the BR2 reactor twice in 2012. Both plates appear to be in very good condition. They will come out of the cooling channel in 2013 and we will then start with the post-irradiation examination.

On what do you base this cautious optimism?

Sven Van den Berghe: We have inspected these fuel plates under water with a camera. But in the first instance we can't do any more than just look at them. Still, this tells us quite a lot. For example previous plates started to leak or were deformed. We could see this with the naked eye from the camera images. In contrast, the SELENIUM plates still appear to be in good condition. How good exactly we can only say when we can look at them inside the hot cell and when we can measure the end result. In the hot cell we can measure the expansion of the plate and the oxidation of the



surface. After that we perform gamma spectrometry on the plate, after which we will cut it up to examine the inside with microscopic and spectroscopic techniques, to see where the actual nuclear fuel is located. So then we can determine how effective the coating has been in inhibiting the reaction between the uranium-molybdenum granules and the surrounding aluminium matrix.

Is this the solution you have been waiting for with bated breath for years?

Sven Van den Berghe: We are cautiously hopeful, and the rest of the world is very positive. There is a lot of pressure. The Belgian Nuclear Research Centre is at this time the only institute which has carried out a successful irradiation programme with uranium-molybdenum dispersion fuel under the conditions required for operations in a high-performance research reactor like BR2, while all other solutions encountered problems. A parallel programme is running in the United States, but this opted for a different fuel system which is much more complex and expensive as well as more problematical as regards production and qualification. At the moment we have the eyes of Europe upon us.

Why does SCK•CEN attach so much value to this research?

Sven Van den Berghe: In the context of non-proliferation and our friendly relations with the United States, who are the driving force behind the elimination of non-military highly enriched uranium, Belgium opted to go full steam ahead with the development of low-enriched fuel for research reactors. We absolutely want to continue with this commitment, not only in the context of the conversion of our own BR2-research reactor, but also within the framework of non-proliferation in order to counter nuclear terrorism. In that sense SCK•CEN also intends to make the SELENIUM results available to the international community.

03

MYRRHA: source of innovation

MYRRHA

In full, MYRRHA is short for Multi-purpose hYbrid Research Reactor for High-tech Applications. This successor to the BR2 reactor represents a particularly innovative research infrastructure. MYRRHA operates with fast neutrons, and cooling takes place with liquid metal: a mixture of lead and bismuth. MYRRHA is the very first prototype of a nuclear reactor worldwide that is driven by a particle accelerator. We are referring to a subcritical reactor: the core does not contain enough fissile material to maintain the chain reaction spontaneously. It must be continuously fed by an external neutron source. This is the reason why the reactor is coupled to a particle accelerator. It is a technology that is particularly safe and easy to control. When the accelerator is switched off, the chain reaction stops literally within a fraction of a second, and the reactor stops.

The fast neutrons ensure that the uranium fuel in the reactor is used more efficiently, and, as a result, there is less residual radioactive waste. Moreover, MYRRHA should demonstrate that it is technically feasible to process the most radiotoxic elements (the minor actinides neptunium, americium and curium) by transmutation. This fission of long-lived elements into products that are radiotoxic for a considerably shorter period of time ensures the further reduction of the quantity and the life span of the waste. This reduces the required storage time from hundreds of thousands of years to a few hundred years.

In addition to research into transmutation, SCK•CEN will deploy MYRRHA for a wide range of applications, including material testing for current and future reactors, nuclear fusion technology and the development of innovative nuclear fuels. In addition, there is also the production of medical radioisotopes that are essential for the diagnosis and treatment of cancer, and the irradiation of silicon for electronics, which is used in wind turbines and hybrid vehicles, among other applications. SCK•CEN aims to put MYRRHA into use in 2023. The total cost has been estimated at € 960 million (2009).

“ It is said that ‘faith moves mountains’. But the mountains are sometimes too big, too high and too heavy. In this case, we should not try to climb straight up. It’s better to pick paths that lead around the most difficult passages. But, at any rate, reaching the top should be the clear and undisputed goal from the very start. ”

Hamid Aït Abderrahim

MYRRHA Director

MYRRHA particle accelerator boosts research

Exotic experiments with ISOL@MYRRHA

Can MYRRHA's particle accelerator also be used for other purposes? The answer is yes and the project already has a name: ISOL@MYRRHA. This initiative is still in its infancy but there is already great international interest in research communities. ISOL@MYRRHA is in fact a unique concept because it will make a whole new category of experiments possible.

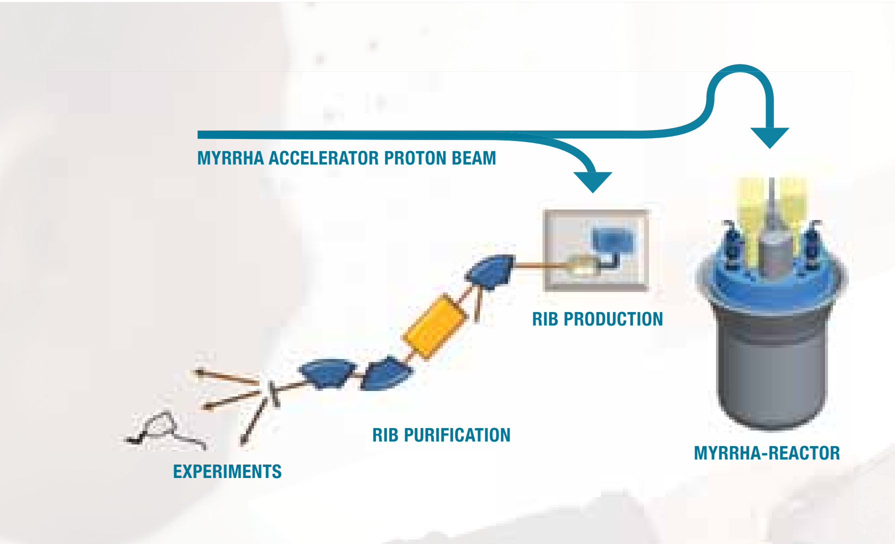
ISOL@MYRRHA will divert part of the proton beam from the MYRRHA particle accelerator and use this for the production of 'Radioactive Ion Beams' or RIBs. These RIBs consist of exotic ions which do not exist in the natural environment or at least in very limited quantities. In order to study these ions, they have to be artificially produced. The more exotic the radioisotope, the shorter its half-life and thus its lifetime. This implies that the intensity of the beams for these very short-lived isotopes decays drastically, which is exactly where ISOL@MYRRHA will prove its worth. Since the beams will be many times more intense than those which can be produced nowadays, for example with the ISOLDE facility at the European Organization for Nuclear Research CERN, physicists are able to study more exotic radioisotopes.

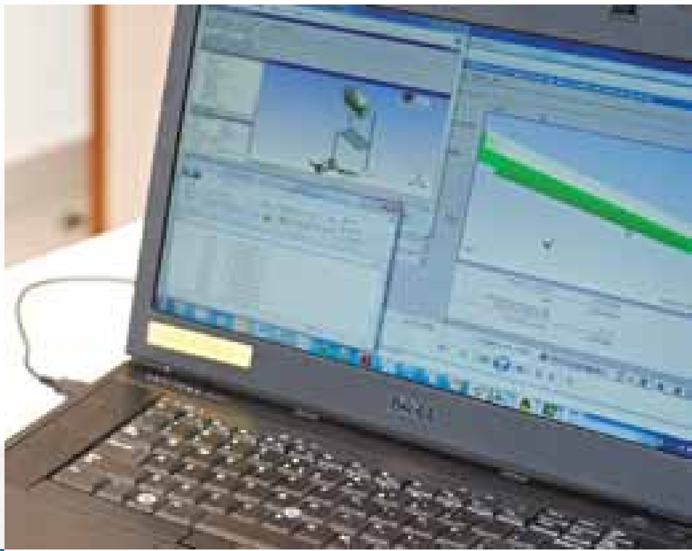
ISOL@MYRRHA focuses on experiments which require a long beam time without interruption. This will allow scientists to make precise measurements or to perform experiments about very rare phenomena which are extremely hard to detect. The first feasibility studies have been carried out jointly with the universities which are part of the BriX-network (Belgian research initiative on eXotic nuclei) while the research programme has also been defined.

Workshops and discussion opportunities

ISOL@MYRRHA wishes to build a users' community of researchers from the various specialised disciplines having an interest in using the new facility. The first steps in that direction were made in 2011 with a workshop on fundamental interactions. A sequel to that came in 2012 with the 'Detailed decay spectroscopy' workshop. The top players in the field were gathered together and made the meeting a success with their contributions.

The purpose of these workshops is twofold. For one thing it is the ideal opportunity to bring together a group of scientists with an interest in the same topic, which helps to better define the ISOL@MYRRHA research programme. In addition to the purely scientific input, the discussions also produced technical input. The latter is particularly important for the second objective of this initiative. Thanks to the input from experienced physicists





ISOL@MYRRHA: THE CONCEPT

MYRRHA and ISOL@MYRRHA are run in parallel. ISOL means Isotope Separator Online. Up to 5% of the proton beam of the MYRRHA accelerator is diverted and sent to the ISOL@MYRRHA target. This is where the radioisotopes are produced, then selectively ionised, accelerated and – after selection for their mass – sent to the various experimental installations.

the ultimate design of ISOL@MYRRHA can be optimised. Within this framework, four more workshops will follow with diverse subjects: RIB production, medical applications, atomic and solid state physics and biology.

The design takes shape

In 2012 the *Physics and Technology Innovation* unit defined the basic components of ISOL@MYRRHA. The first drawings of the building and the integration with MYRRHA have been developed and a technical report about the design has been drafted. This report will be continuously updated in the future according to how the design of ISOL@MYRRHA evolves. Moreover, the first steps have been taken in the development of a target based on liquid lead-bismuth. This is where the RIBs are produced. A prototype of this target will first be tested with the ISOLDE infrastructure within the framework of LIEBE (LIquid lEad Bismuth eutectic Experiment), a project headed up by CERN.

As pure as possible

The purity of the RIBs is of crucial importance. When a beam becomes more intense, more contaminants will appear. That is why it is essential to purify a beam. This process will be performed in ISOL@MYRRHA in two stages. In the first stage the purification is based on a selective ionisation of the desired radioisotopes. In the second stage an additional purification takes place by means of a mass separation with a magnetic separator. This selects the specific radioisotope which the scientists want to work with. Adding a radio-frequency beam cooler before the magnetic separator makes the array perform even better (see figure).

"MYRRHA has become tangible. The embryonic ideas with which we started years ago are taking shape through the different test settings that we use to perfect the new technology. To do what has never been done before – that's the ultimate motivation for everyone participating in this project. What makes it even more fascinating is the awareness that we are building a unique infrastructure here that, in turn, will be a source of innovation for decades."

Peter Baeten

Institute Manager Advanced Nuclear Systems

CRAFT tests moving parts in lead-bismuth

An impressive example of craftsmanship

You may have read about RHAPTER (Remote HAndling Proof of Principle TEst Rig) in *Highlights 2011*. This installation makes it possible to test the behaviour of moving parts in a vessel with lead-bismuth, the liquid metal that is used as coolant in MYRRHA. The new CRAFT loop goes one better. Materials that MYRRHA will use can now be exposed to flowing lead-bismuth.

CRAFT (Corrosion Research for Advanced Fast reactor Technologies) is the outcome of a fruitful collaboration between the *Nuclear Systems Design* expert group and the *Design and Engineering Office* at SCK•CEN. The circular loop is based on an existing design by the Karlsruhe Institut für Technologie in Stuttgart, but utilising more advanced techniques. The construction of CRAFT was completed in 2012 so that experiments can start in the middle of 2013.

Propulsion without contact

CRAFT is a circular-shaped, channelled loop in which liquid lead-bismuth circulates. It is different from the traditional rig arrangement in that the drive comes from a pump consisting of an internal liquid channel in an omega (Ω) shape and two discs with magnets which rotate on the outside of the pump. The magnetic effect propels the lead-bismuth through the channel. This makes CRAFT a totally contactless system. A traditional pump, where lead-bismuth flows through the pump chamber and comes into contact with moving parts, can cause problems. First of all it will not be known whether the material the pump is made from, will actually be adequate. The rotor is a component that rotates quickly and could suffer erosion from contact with lead-bismuth. A second risk is that the materials in a traditional pump may contaminate the lead-bismuth, which will give false measurement readings. A contactless drive was therefore necessary and its realisation in the CRAFT loop is an important step forward in materials research.

A long-running task

The CRAFT loop will be used for long-running tests. SCK•CEN has developed a rig installation which is entirely separated from the ambient air in order to eliminate the effect of oxygen on the test samples. This arrangement allows the test samples to be introduced into the channel loop where lead-bismuth is circulating at a very high temperature and at high speed. After a given time, the test samples are examined to see to what degree they have been affected. These experiments may last from months to a few years. The conditions in the CRAFT loop are deliberately more

> *The CRAFT loop is an important step forward in materials research.*

extreme than the conditions in the final MYRRHA reactor. This applies to both the flow rate and the temperature of the lead-bismuth. The underlying philosophy is that materials which can withstand the extreme conditions of the experiments will definitely be sufficient for MYRRHA.

There is no data in the literature for the conditions that will prevail in MYRRHA, so it is important that the selected materials will perform and last for many years. The lead-bismuth that cools MYRRHA is a liquid metal that is more corrosive than water. The Federal Agency for Nuclear Control (AFCN/FANC), demands empirical evidence that the materials used will withstand this. The results which CRAFT will give us can be extrapolated into a lifetime of several decades.

Test case for engineers

The CRAFT loop is not only a good instrument for materials tests, it is also a test in itself. This is the first time that SCK•CEN has worked with such a complex installation filled with lead-bismuth. So CRAFT is therefore also a test case for the engineers who will experience how a looped channel full of lead-bismuth behaves, how the characteristics of the valves, temperature gauges and oxygen sensors evolve, which types of sealants and materials are best between the flanged joints, how much torque should be applied to the bolts, etc. This is highly valuable information, both for the construction of MYRRHA and for the construction of future loops.

The ideal steel for MYRRHA

Which material offers a lifetime guarantee?

The future MYRRHA research reactor must function optimally throughout its entire lifetime. This can only be guaranteed for many decades if the best possible materials are selected for the design. The *Structural Materials Research* unit has made a significant step forward in 2012 in the evaluation of the performance of steel types which are suitable for MYRRHA. Thanks to a few newly constructed rig installations, the tests can now also be performed under realistic conditions.

LIMETS4

The *Structural Materials Research* unit put another test station into service in 2012. LIMETS4 is a mechanical rig for testing materials in an environment comparable to that in which they will later be used in MYRRHA. In addition to the effects of corrosion, the mechanical properties of materials could change because of the specific environment. That is why the materials are immersed in lead-bismuth after they have been tested in air. LIMETS4 is globally one of the few experimental sites where these types of test can be carried out in a controlled lead-bismuth environment.

The first milestone in 2012 was the construction of LIMETS3. LIMETS stands for 'LIquid MEtal Testing Station'. This third version is a unique arrangement for investigating metal fatigue. A similar arrangement already existed but it could not control the oxygen concentration in the lead-bismuth, the liquid metal used as the coolant in MYRRHA. In other words: the existing test rig was able to show whether metal fatigue occurred in the tested steel alloys or not. With the help of LIMETS3 it is now possible to perform experiments with different and well-defined oxygen concentrations in the lead-bismuth. Because of this the materials experts are able to determine with even greater certainty whether the required lifespan will be achieved.

A new method for determining the thickness of the oxide layer

The team also developed a new method for characterising oxidation of materials on their first contact with the environment. Traditional corrosion research methods submerge the material in the environment, leave it there for a given time and cut a slice through it to analyse the oxide layer which has formed on the surface. This type of testing requires a long series of tests in order to gain a comprehensive picture.

SCK•CEN can now use a new method which does not measure the thickness of the oxide layer but instead measures the amount of oxygen in the environment of the steel components and the speed with which this is used up. The thickness of the oxide layer can be based on these measurements. Many of the components in the MYRRHA reactor will be metal alloys which come in to contact with liquid lead-bismuth. To minimise the negative effects of corrosion, it is important that the oxygen concentration is kept within certain limits. That means that the oxygen supply must be monitored at every moment of the MYRRHA's entire lifespan. Oxygen consumption, for instance, increases enormously every time new fuel is loaded into the reactor. The new test method should give us more clarity as regards the speed at which oxygen needs to be added at each stage of the reactor's life.

THE RIGHT CHOICE

Not just any material can be used for the construction of a new type of nuclear reactor like MYRRHA. The options are limited to the types for which there already exists a proper basis for the issue of a licence to use the material. Taking this into account, a shortlist of potential construction materials for MYRRHA has been compiled. Tests will have to demonstrate which provide the best results. But there is always a small risk that none of the selected materials will turn out to be satisfactory for the specific environment of the reactor. This applies in particular to the materials in the reactor core. In that event there are two possible solutions. The first option is to modify the operational conditions very slightly, for example by working with a lower temperature or by changing the amount of oxygen. The second option consists of shortening the fuel cycles. In parallel, the *Structural Materials Research* unit is also working on innovative materials concepts which may possibly provide better results. But even if these perform perfectly, there will still be a long licensing and approval process ahead.

Abroad as well

The *Structural Materials Research* unit is conducting part of the irradiation programme in the Russian research reactor BOR60. This is currently one of the few installations in the world where experiments can take place in which the materials are simultaneously exposed to radiation and lead-bismuth. These long-term tests were started five years ago and have in the meantime yielded important information which enables the materials selection for MYRRHA to be optimised even further.

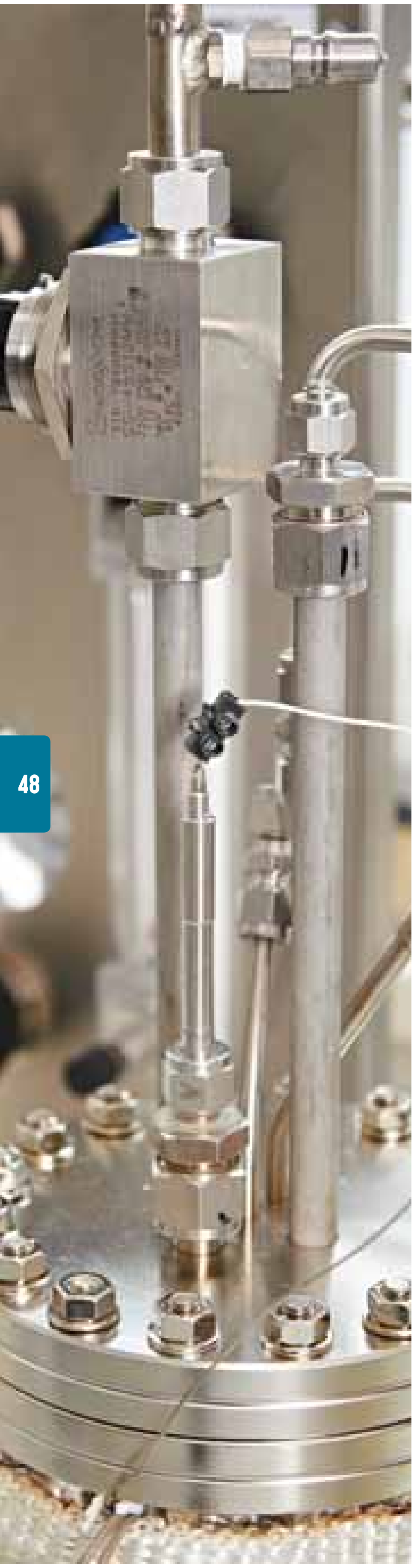
New pyrochemical laboratory for MYRRHA

Exclusively for heavy metals

It will not come as a surprise to anyone that SCK•CEN is doing research into the chemistry of heavy metals. But it is news that, for the first time, this is happening in a laboratory exclusively dedicated to this research. Given that MYRRHA will be cooled with lead-bismuth, research into heavy metals will become more and more important. For this reason the Belgian Nuclear Research Centre has invested in a specialist heavy metals laboratory which was officially opened in November 2012.

All the investigations taking place in the heavy metals laboratory are related to MYRRHA. The investigations are first of all important for the licensing procedure. Almost one third of the issues for the Federal Agency for Nuclear Control (AFCN/FANC) relate directly or indirectly to this. Specific risks have to be taken into account in a pyrochemical laboratory like the heavy metals lab. Heavy metals are toxic, require raised temperatures, modified ventilation and the necessary personal protection equipment. The rigs installed in the new laboratory are adapted to these exceptional circumstances, which makes it possible to provide the maximum guarantee of health and safety regarding people and the environment. The waste flows are also strictly monitored.

Most research laboratories combine the activities around the chemistry of heavy metals with their other activities. The heavy metals laboratory at SCK•CEN forms an exception because it is solely and exclusively used for research in connection with heavy metals. The infrastructure is extremely well suited to corrosion testing under various conditions, the conditioning of oxygen in lead-bismuth and for decontamination testing. The new laboratory also produces, calibrates and



tests oxygen sensors. Finally, there is room for quantifying the evaporation of impurities from lead-bismuth under various conditions, as well as for the testing and optimisation of filters for these volatile elements, such as mercury and iodine.

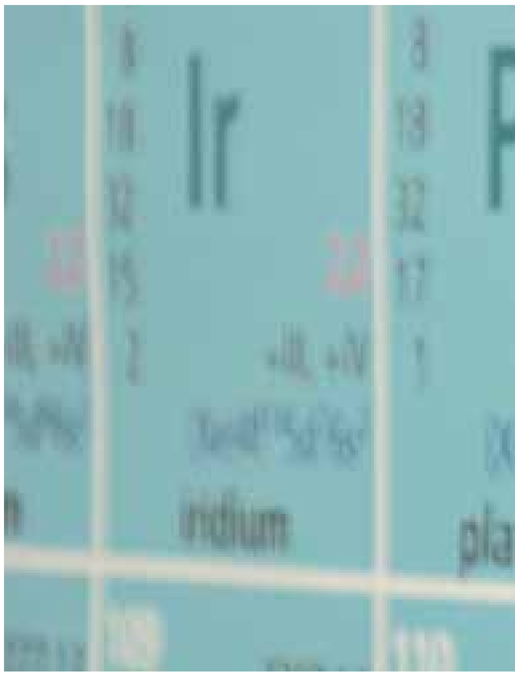
Research into mercury

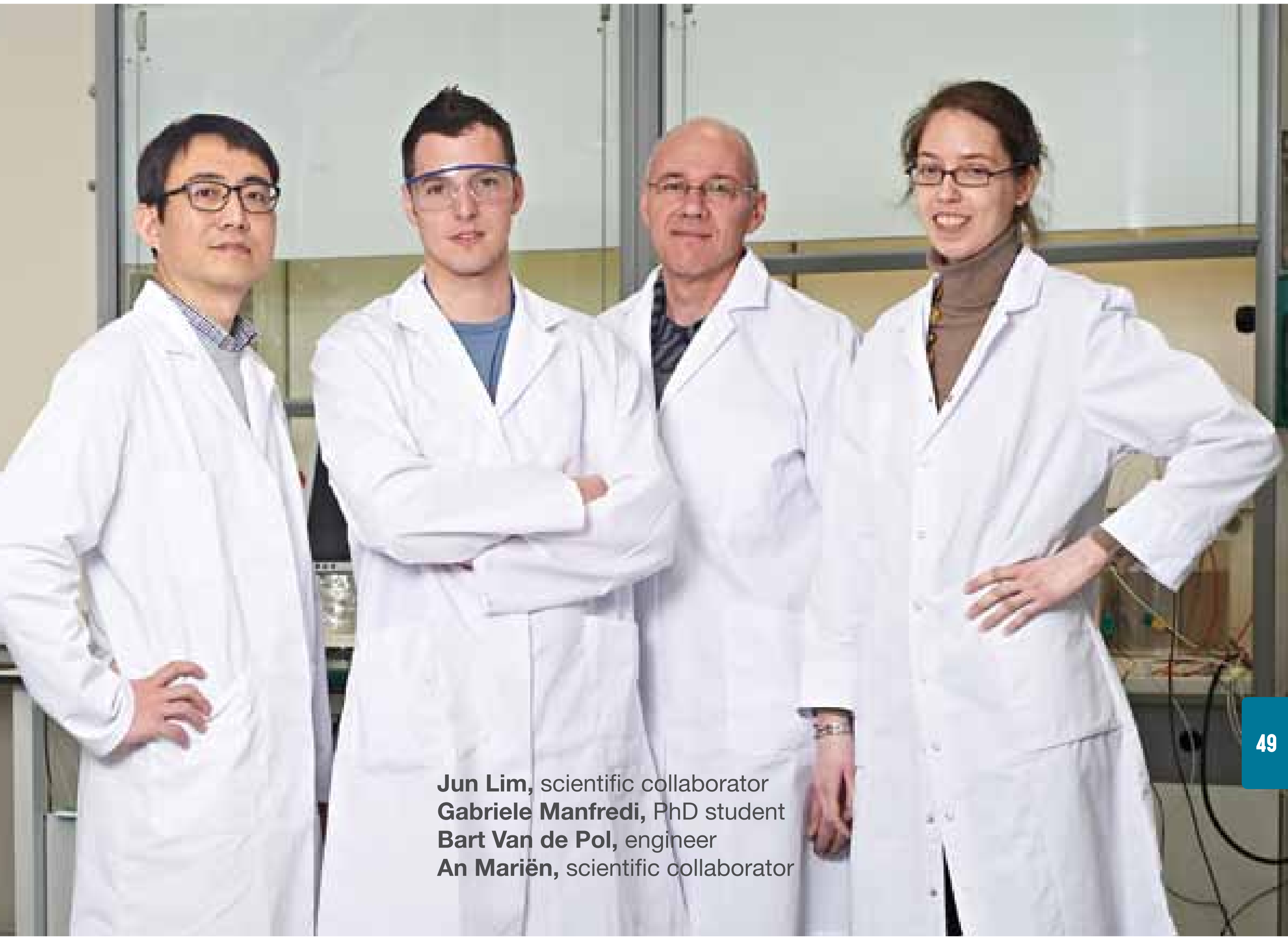
Research into mercury is one of the most significant applications for which SCK•CEN uses the heavy metals laboratory. The experts are particularly interested in the vaporisation and condensation of mercury from lead-bismuth, the MYRRHA coolant. When this cooling agent circulates within the reactor, the nuclear reaction will create mercury. Mercury is volatile, therefore it can be released at certain temperatures. The heavy metals laboratory investigates how this vaporisation process develops and how much mercury is released, in both normal and accidental circumstances.

Another point of interest is qualifying and optimising the filtration systems. Of course, a lot is already known about capturing mercury from industrial applications. This new research is designed to obtain a more robust filter with a longer lifespan which is resistant to extreme factors such as fire.

Adaptable to changing needs

Staff in the *Conditioning and Chemistry Programme* unit, as well as in the *Structural Materials Research* unit, officially put into use the heavy metals laboratory in November 2012. However, this does not mean that the composition is finally complete. The needs of scientific research are extremely variable. The laboratory is prepared for this and offers the possibility of adapting the composition depending on the needs at the time.





Jun Lim, scientific collaborator
Gabriele Manfredi, PhD student
Bart Van de Pol, engineer
An Mariën, scientific collaborator

04 Safety as the top priority

"Constant attention to internal and external experiences, and drawing the necessary lessons from them in order to make both technical and organisational improvements, is an important aspect of the safety culture of an organisation."

Fernand Vermeersch

Head of the Internal Service for Prevention and Protection at Work (ISPPW)

Robust under extreme conditions

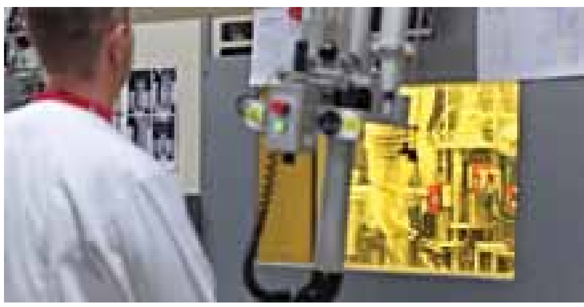
SCK•CEN completes analyses on stress tests

After the accident at the Fukushima Dai-ichi nuclear power plant in March 2011, the European safety authorities formulated a series of specific requirements in the context of compulsory stress tests for nuclear plants. Safety and resistance is analysed under various extreme conditions. One year later, in June 2012, SCK•CEN was able to submit a full report.

Stress tests include a theoretical investigation of the existing protective measures that are in force in nuclear installations. As an initial step, the European safety authorities and the heads of government have drafted a series of requirements for nuclear power plants in Europe. Specific requirements for the other nuclear installations were formulated in a second phase. The safety evaluation considers various extreme conditions, such as floods, tornadoes, earthquakes and fire. The Belgian government and safety authorities have added a number of man-made trigger events to these scenarios, such as an explosion, toxic gases and an airplane crash.

A detailed analysis

The operators themselves were responsible for the analyses. The Belgian Nuclear Research Centre did not limit their investigation to research reactors BR1 and BR2, but also took an in-depth look at all nuclear facilities, including those with a very limited radiation risk. To a large extent, SCK•CEN was able to rely on a wide range of internally available skills to carry out these analyses. External companies were approached for a number of specific aspects, however. This concerned, for example, the impact of seismic events or an aircraft crash. The complete report on the stress tests could be submitted on time in June 2012, thanks to the major efforts of numerous SCK•CEN employees. The Federal Agency for Nuclear Control (AFCN/FANC), and its technical subsidiary Bel V subjected the report to an in-depth analysis. This resulted in a number of additional questions, which were answered by SCK•CEN within a very short time.



Initial findings and actions

The analyses show that the installations that were investigated are, in general, robust were the extreme conditions defined in the stress tests to occur. There are obviously a number of factors where improvement is possible. New studies provide new insights, and these studies indicate that certain risks were assessed differently in the past, or have not been studied in appropriate detail. Additional measures are therefore required in this context. As an example, the possible effects of a forest fire have been better identified, and actions for a more adequate management of this risk have been implemented. A series of improvements in the area of fire fighting were made in 2012, including the removal of a number of trees surrounding the buildings in order to reduce the fire load (see page 55).

The internal SCK•CEN emergency plan will also be revised. The focus there is mainly on communication, education, training and prolonged emergency situations. There are also advanced plans for a mobile emergency room that could be set up off-site within a short time in the event that the on-site infrastructure would not be available. The renewal of the internal emergency room is also planned as part of the systematic renovation of the buildings. Experience gathered from previous emergency plan exercises and the additional requirements for robustness serve as guidelines. In consultation with local companies, SCK•CEN carries out evaluations with the aim of further streamlining fire brigade and civil protection interventions.

A consolidated action plan

Based on the analysis made by the Belgian Nuclear Research Centre, safety authorities will formulate additional recommendations and requirements in the spring of 2013. A consolidated action plan will be drawn up to facilitate this process. This will contain all the measures necessary to further optimise the solidity of the installations in the event that extreme conditions occur.

Conifers cut down in the name of fire prevention

Fresh vegetation increases biodiversity

Fire prevention became very obvious in 2012 on the Belgian Nuclear Research Centre's site in Mol. As part of the periodic regulatory safety review, trees standing within a relatively short distance of buildings have been removed.

To avoid the spread of fire, a minimum distance of 16 metres between trees and buildings has been imposed. Three important risks are involved in forest fires: fire spread, wind-driven fire, and smoke emission. The purpose of the perimeter is to prevent a forest fire from spreading to the buildings. Furthermore, the fire-fighting services must have sufficient room for vehicles, equipment and personnel to be able to bring the fire under control, especially in the case of a large forest fire. Once the permit was granted in November 2012, *Forest Management* personnel started to cut down those trees standing within 16 metres of the most 'sensitive' buildings. Just over 400 trees will be cut down during this first phase, of which the majority are coniferous trees. From 2013 onwards, trees in the vicinity of other buildings will be removed in several stages. The work should be completed by 2016.

The Belgian Nuclear Research Centre has always been surrounded by nature and it is the intention that this remains the case in the future, despite the compulsory chopping down of trees. A large part (approx. 3 000 m^2) of the space that has been cleared will be planted with fresh vegetation. The plants have been judiciously chosen according to height: the closer to the buildings, the lower their maximum height. Lower flames mean less risk of fire spreading. In the autumn of 2013 you will see broom, hazel, rowan, holly and alder buckthorn sprouting. This local broadleaf vegetation has all sorts of advantages. It is less liable to catch fire, and if it does, it burns more slowly and less aggressively than the existing conifers. Furthermore, these plants and shrubs are easier to tend, and they make a positive contribution to biodiversity in the area.

Innovative maintenance method for BR2 reactor

A workhorse in excellent condition

The Belgian Reactor 2 was officially commissioned in Mol on 6 July 1961. At that time, probably only few people believed that BR2 would still be considered to be one of the most powerful research reactors in the world more than half a century later. This has only been possible because the installation has been maintained in an excellent manner throughout those years, and has been renovated thoroughly several times. The *Belgian Reactor 2* expert group developed an innovative management method in 2012 in order to maintain BR2 in excellent condition and to continue to ensure maximum safety over the long term.

An approach that is used mainly in electricity plants and industries with continuous production processes, such as the chemical and paper sector, was applied to a research reactor for the first time. The risk of ageing and failure is thereby systematically mapped for all components of the installation. The essential evaluation points are, in the first place, the security of the installation, followed by its reliability and efficiency. Depending on the importance of the component under consideration, proactive, preventive or curative measures are implemented. This 'graded approach' means that the scope of the measures is in relation to the risk. If, for example, one pump in a group of four fails, the risk is lower than if there was only one pump that could fail.

Risk is always the product of the likelihood and the consequences of the failure of one or several components. This is examined through the 'failure mode effect and criticality assessment method'. Typically, the effect of the failure of a component depends on the design of the system, while the probability of this happening is (usually) a function of time. In order to determine the maintenance, replacement and adjustment measures with the aim of minimizing the risk; the maintenance, ageing and modernisation of the design must all be considered. This approach to the management of the BR2 reactor is a break with the prevailing practice, which is based on expertise and experience.

Reactor in good condition

In the course of its 50-year operating history, BR2 has been subjected to two large-scale upgrades, resulting in the reactor being in excellent condition today. The analyses carried out in the context of the stress tests have demonstrated clearly that the installation is safe, even in extreme circumstances. BR2 holds a crucial position within the research and production activities of the Belgian

"This approach to the management of the BR2 reactor is a break with the prevailing practice, which is based on expertise and experience."

Nuclear Research Centre. It is, therefore, extremely important that this reactor remains reliable, and that its operation is as efficient as possible. To ensure its continued safety, the *Belgian Reactor 2* expert group makes significant investments in the continuous evaluation of the condition of the installation and the preventive approach to possible ageing issues. In practice, this is done by systematically mapping out all risks that are related to the ageing of components, by evaluating their impact and by taking preventive measures that are in line with the actual risk.

The analysis described above began for BR2 in 2012. When the ageing of the various components is reviewed, this is not limited to only the technical aspects. Economic obsolescence is also a feasible risk. This means, for example, that spare parts may no longer be available at some point in the future. In this case, it is necessary to consider whether additional spare parts should be purchased now, while still possible, or whether it is better to choose another option. In addition, it is also possible that the regulations might change, and that the use of certain components would no longer be permitted.

Preventive measures

The *BR2* expert group has finalised the classification of the systems, structures and components of the complete installation. The risks associated with a potential failure have been analysed thoroughly. On the basis of this, the components have been classified according to importance, and an appropriate approach with regard to maintenance or replacement has been established. The preventive measures for each component class will be developed further from a technical point of view in the next phase. This information will form the basis of the future investment programme, in which activities undertaken as part of the ten-yearly safety review scheduled for 2016 are also included.

SCK•CEN aims to share its experience of this innovative analysis method at an international level. The nuclear sector is paying increased attention to obsolescence and maintenance management worldwide. The number of research reactors is decreasing, while the number of applications is increasing or changing. In this type of environment, it is particularly instructive to look for the latest insights and the best possible solutions in terms of safety and maintenance, including from areas outside the nuclear sector.

Criticality studies refined further

The difference lies in the details

Safety is an on-going concern. Within SCK•CEN, numerous procedures and systems are in place to ensure the protection of people and the environment. It is, for example, of key importance to determine correctly how much fissile material may be present in a particular area. So-called 'criticality analyses' are carried out for this purpose. In 2012, the *Nuclear Systems Physics* expert group further refined the existing approach with the introduction of an 'Upper Safety Limit'.

Gert Van den Eynde: We carry out criticality analyses internally for all rooms in which fissile material is stored or processed. This analysis involves determining how many grams at most of a specific substance may be present in that particular room in order to ensure that no uncontrolled chain reaction can take place. We also review the facilities that are required to safely store or process this material.

These procedures have been refined in 2012. Why was this necessary?

Gert Van den Eynde: We previously assumed a safety value. The threshold value for the multiplication factor with regard to criticality is 1, and this must never be reached. If this multiplication factor happens to be equal to 1, we have criticality: the number of neutrons in the system is constant, because it is always multiplied by 1. If the factor is greater than 1, the number of neutrons will increase very quickly, because the number is multiplied by a number greater than 1 at every time step. In this case, the system is over-critical. If the factor is less than 1, the number of neutrons will drop very quickly. This condition is called sub-critical.

Gert Van den Eynde, head of Nuclear Systems Physics
Alberto Ottonello, scientific collaborator

In order to take uncertainties into account, for example in the basic data or in the models, we introduced a safety margin, where the calculated multiplication factor was required to not exceed 0.98 or 0.95. In 2012, we established and validated a complete procedure, in which our code and our data can be confirmed on the basis of experiments, so-called benchmarks. This procedure provides us with the ‘Upper Safety Limit’ (see box).

Where did you obtain the reference values on which this Upper Safety Limit is based?

Gert Van den Eynde: This basic data is internationally available from the database of the Nuclear Energy Agency. This is based on results of experiments that took place in the United States, Russia and France, amongst other countries. It is, therefore, not raw data, but well-verified information, checked by evaluators who are experts in reviewing whether the experiment was carried out correctly. The reference values are therefore of very high quality. By testing our models against this data, they can only become safer.

We also used this type of criticality analysis for two external clients in 2012. At the National Institute for Radioelements in Fleurus (IRE), where radioisotopes are produced, there was a criticality analysis made of one of their production lines. This study has since been completed. At Belgoprocess in Dessel, which is specialized in the processing, conditioning and storage of radioactive substances, we have been analysing a new installation. This criticality analysis is still in progress. Belgoprocess deliberately opted for an external partner to carry out the studies, whereby their staff then perform a peer review of our work. At both the IRE and Belgoprocess, the analyses are part of the overall safety file that they must submit to the Federal

Agency for Nuclear Control (AFCN/FANC). On the basis of the criticality study, the operator can provide evidence that there are no criticality risks, both in normal situations and in situations involving an accident.

Is your group aiming to work with external customers even more in the future?

Gert Van den Eynde: Yes, that's the plan. We've had these skills for some time, and we have now refined and expanded them. We're aiming to start prospecting and to look for additional projects. But there's also always work internally, of course. After the stress tests in particular, several what-if scenarios emerged, and we need to look at them and make the appropriate calculations. These scenarios may seem far-fetched ideas, but it's very important to do this brainstorming. Very imaginative suggestions are sometimes made, but these provide food for thought, and lead to the development of safer procedures.

UPPER SAFETY LIMIT

In criticality, the materials, the process and the geometry of the storage are important. Is the fissile material stored in a jar or in a drum, for example? How large is this drum? What are its dimensions? Researchers collect all this information and establish mathematical models in a computer code. These codes then calculate the multiplication factor. But in order to be able to draw conclusions, it must first be ensured that the calculations that are made have been validated. For this purpose, benchmarks are available in which relatively simple experimental systems are constructed, and effective measurements are made to establish the conditions and composition under which criticality is reached. Many experiments are available with different materials, varying conditions and various geometries. This collected data is available. The *Nuclear Systems Physics* expert group re-calculates a number of these tests and checks how close the calculated result is to the result of the original experiment. From the calculation, the deviation between these models (code, nuclear data, approach) and the experimental reference values can be established. In this way, it is possible to integrate an additional margin, and to calculate the values that should never be exceeded. That is the 'Upper Safety Limit'.

05

2012: 60 years of know-how

2012: a busy anniversary year

60 years young and ready for the future

In 2012, the Belgian Nuclear Research Centre celebrated its 60th anniversary with a range of events for prominent guests, the general public and for staff. No fewer than 4,700 guests took part in the activities that were organised by SCK•CEN in the course of the year. The focus of attention centred around one particular theme: 60 years of research and development in the service of society.

SCK•CEN welcomes the general public

During the open days on 11, 12 and 13 May, the general public was invited to visit the technical site in Mol to learn more about the wide range of activities in which SCK•CEN is involved. Opening the gates of a nuclear site to the general public represents quite a logistical challenge, not the least with regard to registration and access. The Belgian Nuclear Research Centre nevertheless made these efforts in the context of its responsibility and openness towards society. At six locations, a total of 2,200 visitors discovered how a nuclear reactor works, exactly what MYRRHA is, how radioisotopes and silicon are produced, and what solutions SCK•CEN is investigating for radioactive waste. The site tours and the direct contact with scientists were especially popular.

"Our research is a unique source of new developments, products and services, with a key societal value, that can be valorized both internally and externally. This enormous potential is increasingly recognized and addressed. We are therefore very pleased that SCK•CEN has been chosen as the winner of 'De Kempenaar 2012' for the role we have been playing for many years in placing the region on the Belgian, European and world map in a lasting manner."

Dirk Ceuterick

Head of the Business Support Unit

Howard Guttman

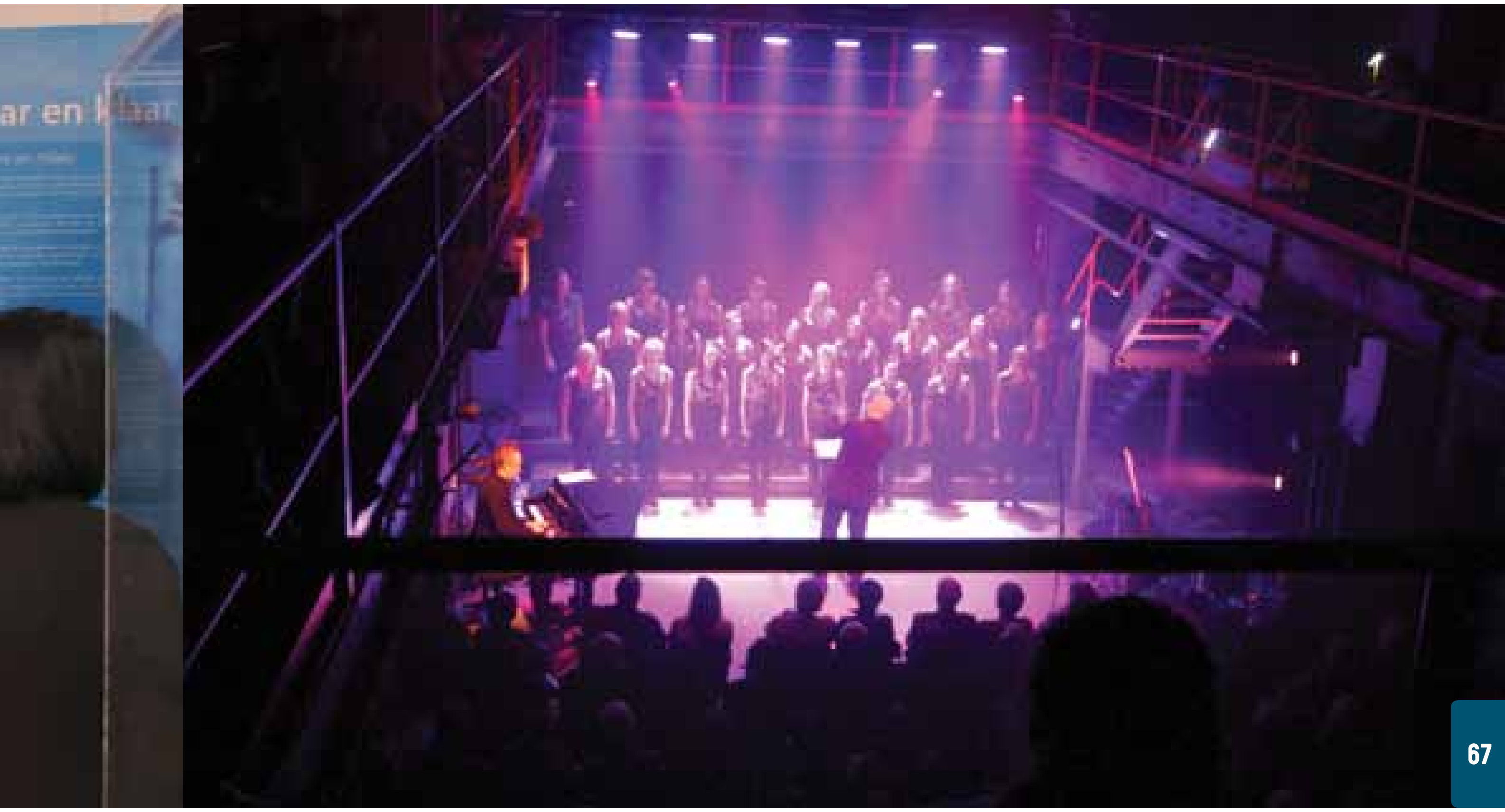
On sixty years of partnership in science and safety: "Today, at SCK•CEN, you are building a better, cleaner, more secure world. This is where a better tomorrow is emerging. And I am proud to say that the U.S. and Belgium continue to work together to get to that better tomorrow."

Melchior Wathelet

On the future of nuclear research in Belgium: "I am proud of the research that has been carried out in this institution, which has put Belgium on the global map in terms of 'centres of excellence' in civil nuclear science and technology ... Major challenges lie ahead, and I am proud to say that I am convinced that SCK•CEN has the know-how and the skills available to take on these challenges."

PRINCE FILIP GUEST OF HONOUR AT THE ACADEMIC SESSION

In June, SCK•CEN welcomed prominent guests from the political scene, the academic world and industry to an Academic Session under the auspices of Prince Filip. Other prominent visitors were Melchior Wathelet, Secretary of State for Energy, and the ambassadors of France, Japan and the United States. Several speakers reflected on the merits of SCK•CEN for Belgium and the international community over the years.



SCK•CEN has taken a cultural turn

SCK•CEN was able to celebrate two more anniversaries at the end of October 2012. The BR3 reactor was connected to the electricity network exactly 50 years ago, and was taken out of service 25 years ago. At that time, BR3 was a European-first, and the reactor was the model for the nuclear power plants that were to be built in Belgium. Later, BR3 was selected as the European pilot project for the decommissioning of this type of reactors. The Belgian Nuclear Research Centre opted to celebrate these anniversaries together with the local community. To this end, the BR3 reactor was renamed 'Culture Reactor' for one weekend. 600 visitors were able to acquire a ticket to one of two unique concerts by Scala & Kolacny brothers. The audience could admire the work of local and international artists before and after the performance. But there was also room for science and technology. BR3 staff expertly explained the history and the meaning of the reactor and its decommissioning.

The Culture Reactor was made possible thanks to intensive cooperation between the *Communication* and *Decommissioning, Decontamination and Waste* expert groups. The event enjoyed exceptional media attention, at both a local and a national level. When asked about the future, Director-General Eric van Walle replied that the success of the Culture Reactor was definitely a source of inspiration for a new destination for BR3. Meanwhile, the dismantling of the reactor building continues. Or, in the words of a BR3 colleague: "It was still the Culture Reactor yesterday, but today it's simply gone back to being our workshop."

From green field to atom

The establishment of the Belgian Nuclear Research Centre in Mol in the mid-fifties had a significant impact on life in Mol and the surrounding municipalities. Not only employment and commerce, but also social life underwent major changes in a short period of time. The municipality of Mol, the Molse kamer voor heemkunde (Mol chamber of regional geography and history) and SCK•CEN believed that this unique period in the history of the municipality should not pass by unnoticed. An exhibition on the topic of 'The countryside in the fifties: from green field to atom' was therefore organised. Thanks to a rich collection of historical photographs, films and typical objects, the Cultural Centre 't Getouw found itself immersed in the wonderful atmosphere of the fifties for one month. The exhibition was visited by 1,500 people.

Sports and music for and by our staff

In all the excitement about 60 years of SCK•CEN, our own staff was not forgotten. They were able to enjoy open air musical performances during three lunch breaks. These 'Sandwiches in the Wood' were very tasty indeed. It was an ideal opportunity to meet colleagues in a pleasant atmosphere. Besides the lunches, there were sporting challenges. The staff was encouraged to cycle, run and hike in groups, wearing SCK•CEN sports outfits. These teams were noticed every time! In Laakdal, for example, 143 cyclists appeared at the start of the 'Ludo Dierckxsens Classic'. 98 runners defended the SCK•CEN colours during the 'Tessenderlo Classic', and, in Bornem, 25 hikers joined the 100 kilometre 'Death March'. Ten go-getters, including the Director-General and his Deputy, even made it to the finish. Since these sporting and musical activities enrich our internal communication, they will certainly be continued in 2013.

Interview with
Michèle Coeck,
head of Education and Knowledge Management

Academy for Nuclear Science and Technology

SCK•CEN invests in training and knowledge transfer

The Belgian Nuclear Research Centre launched the 'Academy for Nuclear Science and Technology' in 2012. SCK•CEN is known and appreciated throughout the world as a research institute, but it is also a training centre. By establishing the Academy for Nuclear Science and Technology, SCK•CEN is putting the spotlight even more firmly on this activity. Retaining, and where necessary expanding, high-level nuclear competence, as well as transferring knowledge, are essential to using radioactivity in a safe and responsible manner, both now and in the future. The Academy brings together all SCK•CEN's training activities, in the broadest sense of the words, and, as such, can rely on more than 60 years of expertise.

What is the core business of the newly-founded Academy for Nuclear Science and Technology?

Michèle Coeck: The Academy concentrates on four major areas: we support young scientists, we organise courses, we provide policy support with regard to education and training, and we introduce what we call a 'transdisciplinary approach' to training and the transfer of knowledge. We are a pioneer when it comes to this fourth pillar. We are all too well aware that the use of nuclear technology is not just a complex subject at the technical and scientific level, but also from a societal point of view. This is why SCK•CEN carries out research into the transdisciplinary aspects of education, training and nuclear technology policies via the PISA research programme, which is short for 'Programme for the Integration of Societal Aspects in nuclear research'. Together with PISA researchers, the Academy is looking at what could be the best way to encourage critical reflection based on scientific and technical knowledge, but also based on awareness and analysis of the societal context.

What is the specific contribution of this transdisciplinary approach?

Michèle Coeck: We believe it is important that people who are dealing with the application of radioactivity, either in a professional or other context, should, in the first place, have the appropriate scientific and technical competence to do so. In addition to this, we also want to stimulate them to think critically about their acquired knowledge, and to confront them with a different, broader way of thinking. This provides them with a means and a voice to communicate differently, for example with policymakers. We provide pieces of a puzzle that somehow have to fit together, taking ethical, political and economic factors, or, in brief, the societal context, into account. By thinking critically about the justification for the use of nuclear technologies, we can contribute to an open and more thoughtful social debate in, for example, the fields of processing and storing radioactive waste, the further expansion or, alternatively, the dismantling of civil nuclear power production, the use of ionising radiation in medical applications, and so on.

What can the Academy offer its students?

Michèle Coeck: Our target public is very broad: from students in the final year of secondary school, with TSO (Technical Secondary Education) or ASO (General Secondary Education) orientations, through Bachelor and Master students to PhD students and postdoctoral researchers. For the youngest amongst these, we want to show them, through visits as well as other activities, what SCK•CEN is doing, and, above all, we try to give them a sense of

Michèle Coeck, head of Education and Knowledge Management
Tom Clarijs & Thomas Berkvens, scientific collaborators
Griet Vanderperren & Kris Pennemans, liaison officers

what it is like to work in a research centre. In case they might be considering a scientific or technical career, this would give them a taste of a potential professional environment.

Bachelor and Master students can make use of the laboratories and the unique and large-scale facilities at SCK•CEN. Our experts provide guidance within the context of an apprenticeship, or in the preparation of their thesis. We work together closely with the universities in this area. We have a list of available topics on our website, which is continuously updated. Every student can apply on line; the Academy then evaluates the files.

We have a similar approach for PhD students and post-doc researchers, but here we focus on a more long-term partnership of 4 and 2 years, respectively, and the number of places available is limited due to the financial cost. For this reason, we ask candidates to submit a detailed application package, which is then assessed rigorously for its quality. The Scientific Council of SCK•CEN also plays an important role in the selection of candidates. In all cases, close cooperation with the Belgian and foreign universities, and especially with the promoters, is essential. We then ensure that the student is supported in the best possible way by our top experts, in a dynamic research environment in which he or she can also make use of our facilities. Upon successful completion of the research project, it is still the university that grants the degree. For the time being, this cannot be done by the Academy for Nuclear Science and Technology itself, as, unlike the universities, we are not a legally recognized academic institution. We therefore play a complementary role.
And, of course, we also benefit from this cooperation. We offer the best students the opportunity to continue working with us. Because it is crucial that the immense nuclear knowledge that has been built up by SCK•CEN is maintained, and expanded with a view to the future.

The pillar that focuses on education is twofold?

Michèle Coeck: Indeed. On the one hand, we co-operate with universities, where we participate actively in a number of academic programmes. Several of our experts teach at universities, and SCK•CEN has been involved with the founding of BNEN (Belgian Nuclear higher Education Network), and the setting up of the radiation protection expert (RPE) course. Our target audience in this case consists of students or young professionals who are tackling a specialisation in a nuclear field. This is different for the second component of our training pillar. Here, we provide tailor-made training courses for professionals from the nuclear industry, the medical sector, or from research or government

> *“We are convinced of the importance of transferring nuclear knowledge in all its facets to the generations to come.”*

institutions. The content, duration, level and language of the training programme are flexible, and are determined during an interview with the applicant. Our team of lecturers comprises engineers, physicists, biologists, physicians, philosophers, technicians ... who all are experts in their specific areas on the basis of their positions as researchers or technicians. They are therefore firmly embedded in practical reality, and can impart the most up-to-date information. They also have excellent didactic skills, of course. Those who attend a training programme enjoy the added bonus of being able to expand their network. If students have a question later on, they know who they can contact.

What are the topics that are covered?

Michèle Coeck: The subjects that are most in demand are in the areas of radiation protection, reactor technology, materials science, emergency operations, and radiobiology and radio-ecology. But we can, in fact, develop a training programme in any field in which SCK•CEN carries out research. We are working on extending the range of subjects we offer. In the future, we would like to become more involved with training in the area of decommissioning, and we are also planning to offer new modules in the medical sector.

How can the Academy for Nuclear Science and Technology have an impact on educational policy?

Michèle Coeck: This is possible through our active participation in European training projects and by being represented on the steering committees of international institutions such as the International Atomic Energy Agency IAEA. For example, we are working on the development of European standards for the training of specific job profiles in the nuclear sector. A harmonised European approach and a transparent system for quality assurance can also create mutual confidence in the quality of various training programmes, and this facilitates the mobility of employees. In addition, we participate in advisory groups that are preparing the implementation of European standards into Belgian legislation. This means we are represented at the international centre of policy development. As a result, we can adapt our own training programmes perfectly to meet the most recent international requirements. This is an additional guarantee that we can offer our stakeholders.

Is the future of the SCK•CEN Academy assured?

Michèle Coeck: That is a question I'm asked quite often, especially in the light of Belgium's position on the use of nuclear energy for the production of electricity. But I am firmly convinced that the Academy is necessary, and has every chance of success. Whether new nuclear facilities are required or existing facilities need to be closed, nuclear knowledge will be necessary for both scenarios. In the first case this will be oriented more towards reactor technology, and in the latter more towards decommissioning and decontamination techniques. For both options, safe working practices and knowledge of radiation protection are absolute necessities. Our remit is broad, and we want to ensure the necessary competence is available for applications in the medical world, transport, radiobiology and radio-ecology etc., both at home and abroad. There are enough challenges, as you can see. The SCK•CEN Academy will make a valuable contribution to meeting these challenges. In terms of content, we can rely on more than 60 years of experience, as well as on the latest results of our research; we have large and unique facilities available that provide the necessary complement to theoretical education, and, last but not least: we can rely on motivated SCK•CEN staff, who are convinced of the importance of transferring nuclear knowledge in all its facets to the generations to come.

“On the occasion of our 60th anniversary, we participated as a group in various sports activities in the region. On the one hand, having hundreds of colleagues cycling, running and hiking in an SCK•CEN outfit shows the world that they are proud to work in a research centre with strong local roots, while, on the other hand, it is an international pole of attraction, with employees from 37 countries. We consider it a privilege to experience the richness of so many cultures on a daily basis.”

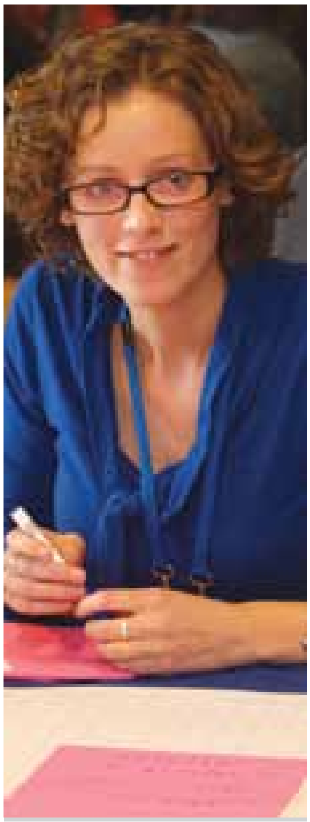
Christian Legrain

Secretary-General

Happy at work

Interactive feedback sessions form the basis of an action plan

Wouldn't we all sign up to work in a healthy working climate, based on good relationships with colleagues and bosses? Yet this should never be taken for granted. Well-being at work requires continuous effort. As one step towards an integrated policy, the SCK•CEN *Psychosocial Well-being* work group started in 2012 by focussing on improving the information flow and the relationships between managers and staff.



An SIMPH survey was conducted in 2011 in order to establish the basis of a sustainable policy for the prevention of undesirable and inappropriate conduct at work. This 'Short Inventory to Monitor Psychosocial Hazards' mapped out the psychosocial strain in the workplace and gave an idea of the risk of employees becoming victims of inappropriate behaviour, such as violence, bullying or sexual harassment. The results were processed with the help of external experts, and were presented to the staff in the spring of 2012.

Einstein cafe brings counsel

Overall, the results of the SCK•CEN staff survey were quite positive when compared to those of similar organisations and companies. It appears that staff generally enjoy their work, and that the strain is manageable. But there are, of course, areas that also need attention. For one, there is a demand to strengthen communication within SCK•CEN. Direct communication between employee and supervisor, as well as feedback and appreciation, could be improved. To examine these results in more detail, and to develop a solution in an interactive way, an 'Einstein cafe' was held in the autumn of 2012. The name of this interactive feedback and brainstorming session was inspired by the location where the sessions were held. A total of around 80 staff members started to work on the topics of communication, appreciation and feedback. Thanks to their contributions, it became clear exactly what is meant by these concepts, where the shortcomings are, and also how they could be remedied.

Informal communication and people management

The *Psychosocial Well-being* work group included the most recurring subjects in an action list, which is also supported by management. The intention is to keep one's eye on the ball, and, where possible, to take action immediately. Specifically, the company has already started working towards improving the flow of information and strengthening informal internal communication channels by continuing the social and sporting activities that were introduced as part of SCK•CEN's 60th anniversary. More fundamental aspects are being dealt with by focussing on so-called soft skills and on people management for managers. Targeted training courses are planned to address these. Another key element is top-down and bottom-up communication within the organisation. This involves, for example, the presence of the management on the workfloor and stimulation of informal communication. The exchange of information between colleagues can also be improved. The *Psychosocial Well-being* work group and the *Committee for Prevention and Protection at Work* are closely monitoring these efforts. Together, these all make an undeniable contribution to the overall prevention policy. And enjoying work reduces exposure to stress, to name but one example …

New communal house welcomes its first residents

The best of two worlds

Visiting **Mohamed Ahmed**, **Feyzan Ozgun Ersoy** and **Ellina Macaeva**

Living close to where you work; this is rarely as simple as at SCK•CEN. When the Belgian Nuclear Research Centre was established in Mol, a residential area incorporating dormitories, studios, apartments, houses and villas was also built. Accommodation on the site is still very popular, particularly amongst employees from abroad and students. SCK•CEN has a total of 86 rooms, 49 studios, 38 houses and 11 villas available. In order to better respond to the needs, the choice was extended by providing a new type of home in 2012: a communal house.

The villa was almost ready to move in, and the technical collaborators had to carry out some freshening-up work. They painted the external joinery and renewed the floor coverings in the bedrooms. In addition, fire doors and fire extinguishers, smoke detectors and emergency lighting have been installed. The entire villa has been repainted and refurnished inside. The work started in August 2012 and was completed last November. PhD students Ellina Macaeva, Feyzan Ozgun Ersoy and Mohamed Ahmed were among the first to move into the communal house.

Because the strain on the dormitories was becoming too great, and because there was an urgent need for more accommodation for couples, the *Central Technical Services* expert group converted one of the villas into a communal home. Eight people can now live there. There are three bedrooms for couples and two single bedrooms. The residents share two bathrooms, a kitchen and a living room.

Why did you opt for a communal house?

Mohamed: I was previously living in the dormitories. Living in this communal house is quite different for me. There is more privacy, and it is more personal. I'm getting to know the other people a lot better. It is not as 'public' as in the dormitories. I also find the facilities such as Internet and TV very good here.

Feyzan: I moved here from Antwerp. I used to commute to work by train, but that was very tiring. I was travelling a total of 3 to 4 hours every day, and always had to get up at 6 in the morning, because otherwise I would miss the bus connection between the railway station and SCK•CEN. Now I can sleep until 8 a.m.

RENOVATIONS IN A NEW PHASE

The *Central Technical Services* expert group completed a busy programme in 2012. A new road to the intervention building was built, and the work on the northern and southern wings of the BR1 building was completed. The construction of the new animal house, with a planned surface area of 450 m^2, was also started. This building will comply with all the requirements to ensure biological safety and optimal hygiene. The mice that are used to study the effects of ionizing radiation will be accommodated there from the end of 2013 onwards.

SCK•CEN launched a major project for the renovation of its buildings in 2008. The next phase is now in preparation. Plans for the telephony building and a new main entrance are currently on the drawing board. The GKD building, which accommodates laboratories and the medical department, will be renovated and extended with a new building.

> *“Living in this communal house is quite different. There is more privacy, and it is more personal.”*

But you do have to give up a little privacy for it …

Feyzan: It is, of course, true that we are sharing a house, but it’s only with a few residents. Up to eight people can live here, so everyone has their privacy. Moreover, we have the feeling that this is really our home. That we’re not merely guests, but really live here. This house was completely renovated before we moved in, and that is certainly a major benefit. Everything feels new and neat. The furniture is also very nice. We have absolutely nothing to complain about. All the friends who come to visit us are very impressed with our lovely place.

Mohamed: I didn’t always feel completely ‘at home’ in the dormitories, but I do have this feeling here. It’s also easier to invite friends over. It’s a nice place to live. As far as I am concerned, SCK•CEN could organise more communal houses of this type.

What are the advantages of living in a communal home?

Ellina: I will soon move to a studio, where I will be living with my partner. We will naturally have more privacy in a studio, but we will also be more isolated from other people. Here, there is always somebody to have a chat with. And there is also more than enough room to be by yourself, if you feel like it.

Feyzan: And when you run out of bread, you can eat someone else’s. Just kidding! Here, I have the feeling that I’m renting a house with a group of friends. We’re ‘housemates’.

Mohamed: I wonder whether this will still be the case when all the beds are occupied, though. With eight residents, the layout of the fridge will certainly be a challenge!

Feyzan: The living room with sitting and dining area is quite large. And, of course, there are more rooms, so there should be enough space. Moreover, everyone has a different rhythm: some leave early in the morning, others don’t come home until late at night. In other words, we are hardly ever all here at the same time. And we have a garden, which is certainly also a bonus. We’ll definitely organise a barbecue party when the weather is nice!

2012 in a few words

JANUARY

SCK•CEN and the Japan Atomic Energy Agency (JAEA) extend their cooperation agreement

SCK•CEN and its Japanese counterpart, JAEA, are going to work for the next five years in close cooperation regarding a number of specific projects. The collaboration includes the development of accelerator driven systems such as MYRRHA and the performance of material tests. This cooperation agreement was signed on Wednesday 4 January in the presence of H.E. the ambassador of Japan in Belgium, Mr. Jun Yokota.

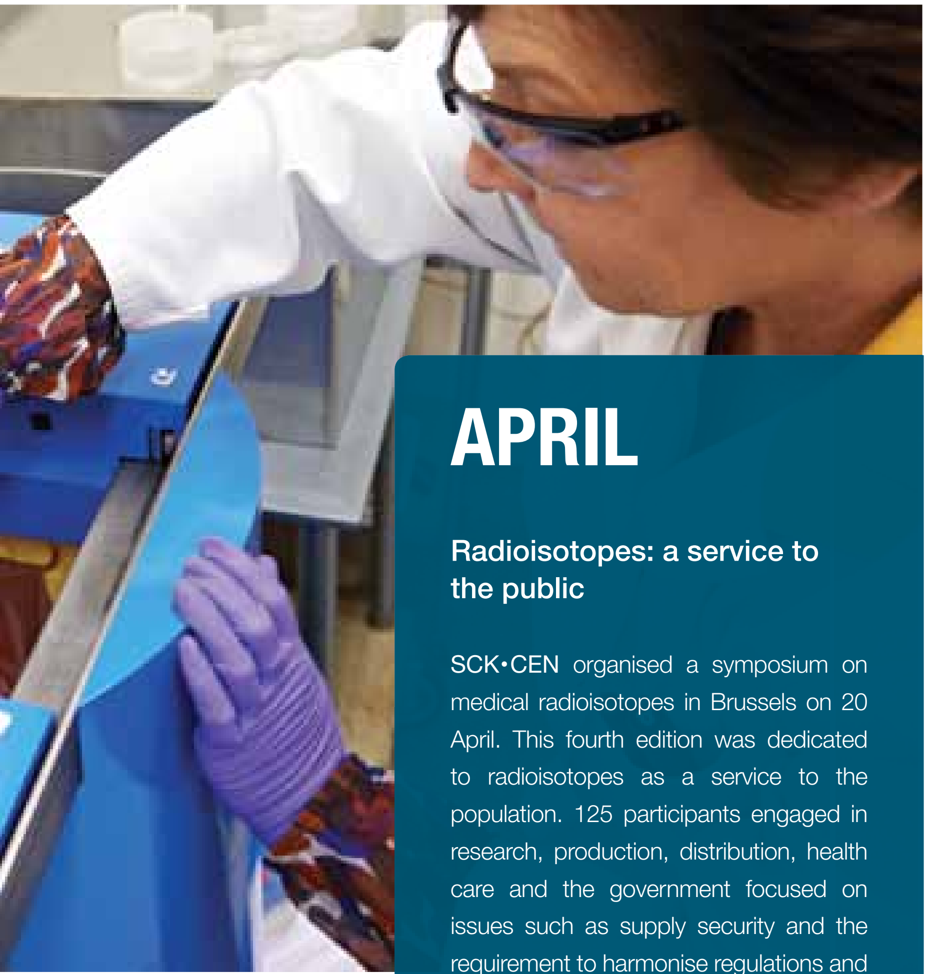
MARCH

Dr. Sebastien Couet (KUL) wins the SCK•CEN Prof. Roger Van Geen Scientific Award

On the initiative of the Belgian Nuclear Research Centre, the Fund for Scientific Research ('FWO' in Dutch) and the 'Fonds de la Recherche Scientifique' (FNRS) award the biennial SCK•CEN Prof. Roger Van Geen Scientific Award. This award, which has a value of € 12,500, honours a study that provides an original contribution in an area relevant to SCK•CEN. Dr. Couet has developed a special nuclear analysis technique that permits the study of a large number of phenomena in solid state physics.

SCK•CEN becomes member of a new association for R&D promotion

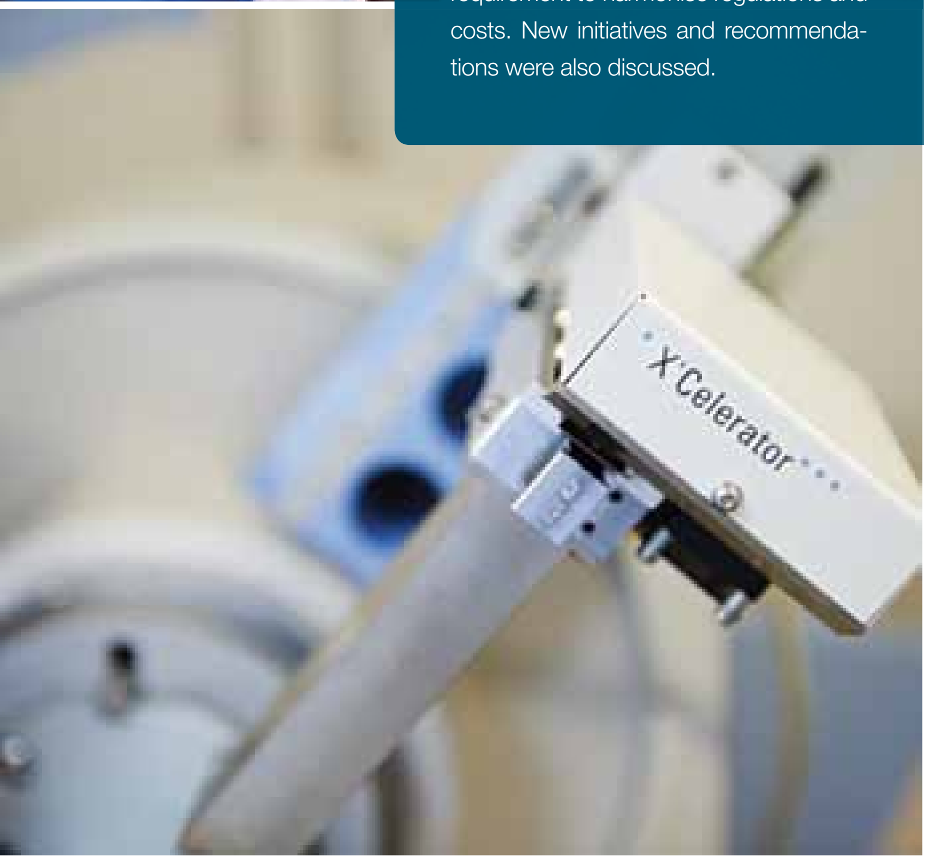
NUGENIA, a new European association for the stimulation of research and development, was launched in Brussels on March 20, 2012. The major stakeholders from industry, research, safety organisations and universities join their forces within NUGENIA. Also SCK•CEN participates in this initiative to support safe, reliable and competitive nuclear power plants. Through more co-operation and better co-ordination, NUGENIA aims to put the scientific and technical expertise to optimal use for research and development focused on reactors of the 2nd and 3rd generation.

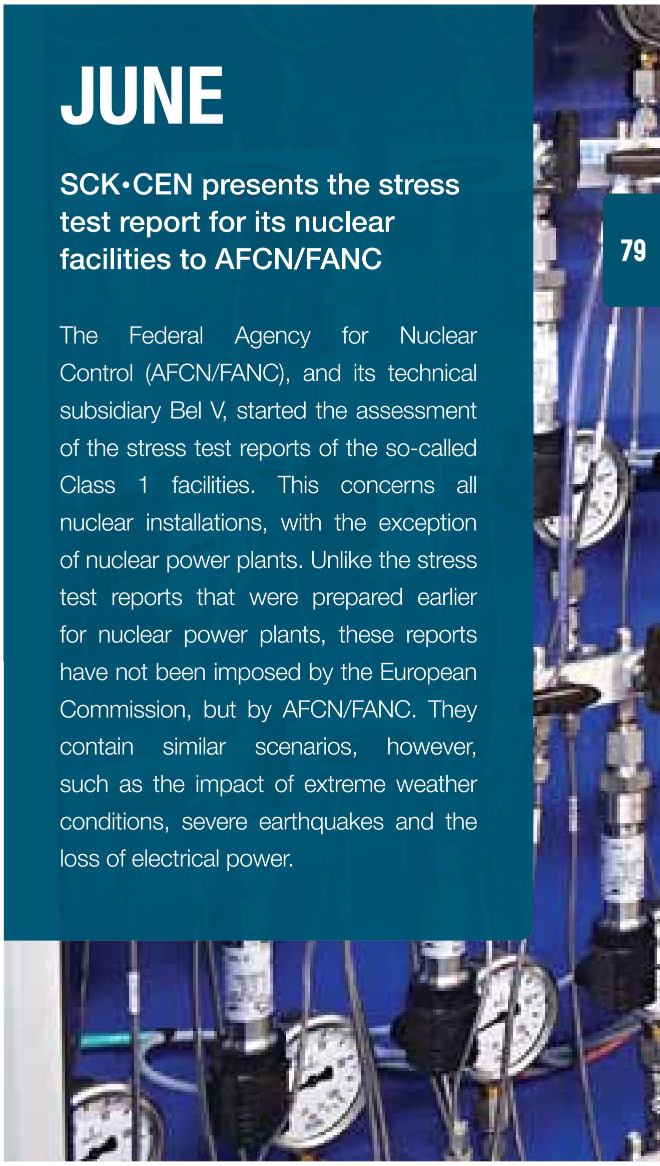


APRIL

Radioisotopes: a service to the public

SCK•CEN organised a symposium on medical radioisotopes in Brussels on 20 April. This fourth edition was dedicated to radioisotopes as a service to the population. 125 participants engaged in research, production, distribution, health care and the government focused on issues such as supply security and the requirement to harmonise regulations and costs. New initiatives and recommendations were also discussed.





JUNE

SCK•CEN presents the stress test report for its nuclear facilities to AFCN/FANC

The Federal Agency for Nuclear Control (AFCN/FANC), and its technical subsidiary Bel V, started the assessment of the stress test reports of the so-called Class 1 facilities. This concerns all nuclear installations, with the exception of nuclear power plants. Unlike the stress test reports that were prepared earlier for nuclear power plants, these reports have not been imposed by the European Commission, but by AFCN/FANC. They contain similar scenarios, however, such as the impact of extreme weather conditions, severe earthquakes and the loss of electrical power.

SEPTEMBER

First transport of cemented waste from Scotland to Belgium

On Monday evening, 3 September, the first return transport of cemented radioactive waste from Dounreay (Scotland) to Belgium took place. This was intermediate-level, long-lived waste originating from the reprocessing of spent nuclear fuel from the BR2 research reactor. Two transport containers, each loaded with three barrels of cemented waste, were transferred to a storage building on the Belgoprocess site in Dessel. A total of 21 shipments of cemented waste will be made from Scotland to Belgium in the period 2012-2014.

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SCK•CEN - winner of the VKW 'De Kempenaar 2012' award

The VKW Kempen Employers' Association has awarded the Belgian Nuclear Research Centre 'De Kempenaar 2012' prize. The jury opted for SCK•CEN because, as an independent research centre, it has been conducting research into the impact of a range of nuclear applications on human beings, the environment and materials for 60 years, independent of any political position. Furthermore, according to the jury, SCK•CEN has made a deliberate social commitment with regard to the region and the world that is reflected in the essential production of medical radioisotopes, and its efforts in the area of education. SCK•CEN succeeds Janssen Pharmaceutica on the roll of honour. In previous years Sibelco, MIKO, Soudal and Nike also received this prestigious award.

Laboratory for Nuclear Calibration recognized as a reference lab for ionising radiation metrology

On 3 September, the Laboratory for Nuclear Calibration received official recognition from BELMET, the Belgian Network of Metrological Laboratories. It is now the reference laboratory for the realisation and management of the national standards, and for ensuring the convertibility to these standards for ionising radiation metrology in the dosimetrics subsection for Gray and Sievert units. This recognition applies for both the SCK•CEN laboratory in Mol and the calibration set-up operated in co-operation with Ghent University.

Symposium on nuclear fusion technology

From 24 to 28 September, SCK•CEN organised the 27th ‘Symposium on Fusion Technology’ (SOFT) in cooperation with the ‘Trilateral Euregio Cluster of Fusion Associates’ (TEC). 1,030 scientists and engineers from around the world met in Liège to exchange information and experience regarding the latest developments and technologies in the area of nuclear fusion. The construction of the first ITER test fusion reactor in France was one of the central topics. The event was officially opened by H.R.H. Prince Filip.

Key figures

Summary of the social balance sheet for 2012
Number of employees as on 31 december 2012

	Full time	Part-time
Under a Contract of Employment for an indefinite duration	559	78
Males	505	49
Females	121	31
Number of employees joining service	88	0
Number of employees leaving service	64	8
Average number of employees	620	82
Total	626	80

Comparative balance sheets
(in thousands of Euros)

Assets	31/12/12	31/12/11
Intangible fixed assets	3 499	3 631
Tangible fixed assets	29 614	29 333
Financial fixed assets	6 182	6 182
Stocks, work in progress	19 842	20 074
Amounts receivable within one year	33 133	30 332
Current investments	31 039	78 277
Cash at bank and in hand	48 546	4 372
Deferred charges and accrued income	3 191	3 090
Total	175 046	175 291

Liabilities	31/12/12	31/12/11
Equity	45 367	49 100
Provisions for liabilities and charges	92 967	91 392
Amounts payable after more than one year	0	0
Financial debt	0	0
Trade debt	8 664	11 123
Advances received on contracts in progress	18 896	16 692
Taxes, remuneration and social security	7 145	6 905
Other debt	28	29
Accrued charges and deferred income	1 979	50
Total	175 046	175 291

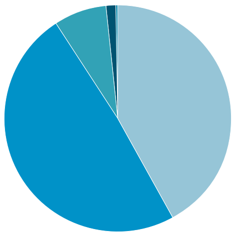
In 2012, the total costs of SCK•CEN amounted to € 118.6 million. Personnel costs rose by € 3.4 million, and still represent the largest cost item, i.e. 55.5%. The workforce increased from 690 to a record high of 706 at the end of 2012.

The ‘purchases and services’ package, accounting for 37% of spending, rose by € 7.3 million compared to 2011. In addition to recurrent waste costs for the nuclear facilities, this item also includes the external expenditure for the maintenance and repair of buildings and equipment, studies and expenses for nuclear fuel for reactor BR2. There were no expenses for this in 2011.

Each year, in the context of scientific research and the constant further development of new insights into the priority R&D topics, SCK•CEN concludes a number of four-year contracts for doctoral research with various Belgian universities. This currently involves more than 60 PhDs. The current commitments for this programme amount to € 3.4 million for the next two years. Most of this amount is financed by the Belgian Nuclear Research Centre, with the rest being provided by external financing sources such as industry, the Fund for Scientific Research (in Dutch, FWO) and European framework programmes. The number of PhDs is expected to rise to 70 in 2013.

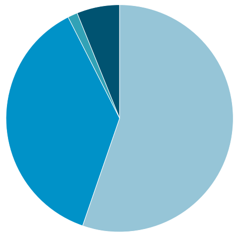
The federal government contributed 49% of the financing for SCK•CEN expenditure in 2012. Own income (42%) arising from

Income 2012
(in thousands of Euros)



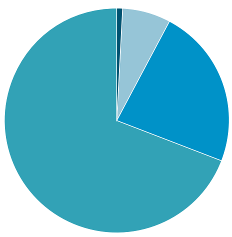
Turnover	48 008
Subsidies from government, grants	55 576
Other	8 608
Financial income	1 785
Extraordinary income	25
Total	**114 002**

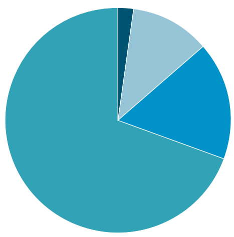
Charges 2012
(in thousands of Euros)



65 781	Personnel costs
43 941	Purchases, Services
1 848	Provisions
7 046	Depreciation
118 616	**Total**
0	Transfer to Allocated Funds
-4 614	**Net result**

Scientific output





	2011	2012
Books	7	13
In-proceedings papers	46	67
Journal articles	156	98
Presentations	467	403

Sharing and dissemination of scientific knowledge is one of the core tasks of SCK•CEN. For this reason, researchers present the work they are doing at numerous international conferences. In addition, many publications appear in magazines and other media.

scientific research contracts and specific services remained virtually constant. A major part of 'Other revenue' (€ 5 million) is due to the reduction in withholding tax for scientists.

The financial resources amounted to € 80.0 million at the end of 2012; this is a decline of € 3.1 million compared to 2011. This is due to a € 4.4 million decrease in cash flow (result plus depreciations) and to a slight net increase of € 0.8 million in operating capital (short-term assets and liabilities). The equity of € 45.4 million amounts to 26% of the balance sheet total of € 175 million.

The investments of € 7.2 million that were made in 2012 remain somewhat under the level of 2011, but are still significantly higher than the average level for the period up to 2007. In 2012, € 2.1 million of this amount went to the MYRRHA project. In the future, we will continue to invest in the renewal of the BR2 reactor, the renovation of buildings, the physical separation of VITO (the Flemish Institute for Technological Research) and the security of the site. The new Royal Decrees concerning the security of nuclear facilities stipulate stricter standards, which the Belgian Nuclear Research Centre is to implement within a period of four years.

The final word

As is clear from these *2012 Highlights*, the Belgian Nuclear Research Centre is more than ever a pioneer in the field of innovative nuclear research and its applications.

In a context and world in which
- science and technology are evolving faster than ever;
- the ability to adapt quickly to a new context and new developments is of vital importance;
- it is becoming increasingly difficult to obtain a share of the ever-shrinking cake in terms of financial support, especially within the research community;
- market-orientation is essential, even if it harbours a danger in the long term for ground-breaking research;
- education and training are the foundations on which we must build further,

a dynamic strategy is the key to a sustainable future. 2012 therefore provided the incentive for drawing up a new strategic statement.

The statement will be in line with and be based upon a preliminary study of the Belgian and international context, and will be prepared following an intensive participatory process led by SCK•CEN experts, and fuelled by internal interviews, external assessments and source analyses.

The Board of Directors is pleased that, in addition to ensuring the three main functions, i.e., the pursuit of excellence as a research centre, a technological centre and a knowledge centre, SCK•CEN will continue to give the highest priority to its safety culture, operational safety, security, the non-proliferation of nuclear weapons and the research in these areas.

The strategic statement will be completed in the spring of 2013. We will come back to this in detail in the next edition of this publication.

SCK•CEN
Belgian Nuclear Research Centre
SCK•CEN is a foundation of public utility, with a legal status according to private law, that operates under the tutorship of the Belgian State Secretary in charge of Energy.

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SCK•CEN

Belgian Nuclear Research Centre

60 years of experience in nuclear science and technology

As a research centre dealing with peaceful applications of radioactivity, SCK•CEN is an indispensable part of our society. We perform forward-looking research and develop sustainable technology. In addition, we organise training courses, we offer specialist services and we act as a consultancy. With more than 700 employees, SCK•CEN is one of the largest research centres in Belgium.

Throughout all of our work, there are three research topics that receive particular attention:

- Safety of nuclear installations
- Well-thought-out management of radioactive waste
- Human and environmental protection against ionising radiation

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