ANNUAL REPORT | 2015

BELV

Contents

Message from the Chairman

Bel V is a private foundation established by the Federal Agency for Nuclear Control (FANC) as a subsidiary to which the agency delegates activities in the field of nuclear safety and radiation protection. It contributes towards protecting people and the environment against the danger of ionising radiation on the basis of experience built up over 50 years. Bel V has in fact inherited nuclear expertise dating back to 1965. Its predecessors were CORAPRO, established in 1965, and the Vinçotte SNV department (Sûreté Nucléaire – Nukleaire Veiligheid), established in 1969.

Didier MALHERBE
Chairman of the Board of Directors

CORAPRO was an accredited body which monitored Class I nuclear facilities (except for nuclear power plants and FBFC), as well as a series of Class II and III facilities. The Vinçotte SNV department was responsible for assessing the safety analysis report on nuclear power plants under construction and, after the publication of the Royal Decree of Authorisation, carrying out regulatory supervision of the Doel and Tihange nuclear power plants. These two entities were merged in 1996 under the name Association Vinçotte Nucléaire (AVN). In 2008, most of the AVN staff were transferred to Bel V.

Fifty years of developing expertise in nuclear and radiological safety with a view to monitoring the nuclear facilities were celebrated during an academic session organised on 8 December. Around 200 guests heard the speakers explain the history and role of Bel V, while the responsible Minister, Jan Jambon, also attended the event.

The quality of the technical expertise at Bel V is also acknowledged beyond our national borders. For example, the Bel V general manager was elected president of ETSON, the network of European organisations that provide technical support for their national safety authorities. In November Bel V also organised the EUROSAFE Forum, which brought together over 200 delegates from Europe and beyond to share their experience in the field of nuclear safety.

Bel V's mission of monitoring the safety of Belgian nuclear facilities is part of the overall inspection and control strategy developed in close collaboration with the FANC. As is the case every year, special attention was paid to the safety management policy of the management at the various nuclear facilities. The annual safety evaluation of the various facilities was carried out according to the standards of our quality system. This evaluation is presented by Bel V to each operator and discussed with its management in the presence of the FANC. The results of the annual evaluation are used for drawing up the control programme for the following year.

Using the financial resources available to the foundation, initiatives were taken to provide financial support for the work of researchers at Belgian universities in areas of interest for nuclear safety and to participate actively in international research programmes.

Finally, I would like to congratulate and thank the management team and the entire workforce for the results they have achieved and for the professionalism with which they carry out their tasks.

Didier MALHERBE
Chairman of the Board of Directors

Preface

Bel V, an incorporated foundation, was established on 7 September 2007 by the Federal Agency for Nuclear Control (FANC).

It is governed by the Belgian Act of 27 June 1921 on non-profit associations, international non-profit associations and foundations, and by its own Articles of Association as filed at the registry of the Brussels Court of First Instance.

Not intended for any pursuit of profit, it aims to contribute technically and scientifically to the protection of the population and the environment against the dangers of ionizing radiation.

At year-end 2015, the Board of Directors of Bel V was composed of:
D. Malherbe - President
Ph. De Sadeleer - Chairman of the Board of the FANC
J. Bens, Ir - General Manager of the FANC
J. Hens - member of the Board of the FANC
J. Germis - member of the Board of the FANC
S. Vaneycken - member of the Board of the FANC
M. Jurisse, Ir - membre

The management team of Bel V is composed of:
Benoît De Boeck - General Manager
Pieter De Gelder - Head of Department NRA (Nuclear safety & Radiation protection Assessment)
Marc Dubois - Head of Department NRP (Nuclear safety & Radiation protection Projects)
Marika Roobaert - Head of Service Support, Administration & IT
Vincent Standaert - Head of Service Finance
Michel Van haesendonck - Head of Department NRI (Nuclear safety & Radiation protection Inspections)

Editorial

2012 had been marked by the detection of flaw indications in the steel material of the reactor pressure vessels at Doel 3 and Tihange 2. In May 2013 the two units were authorized to restart, provided an action plan was implemented in view of the refuelling outage planned for 2014. One of these actions was to conduct a series of tests designed to assess how radiation affects the mechanical properties of hydrogen-flaked steel. For these tests, test pieces of hydrogen-flaked steel were submitted to irradiation in the BR2 reactor of the Nuclear Research Centre in Mol.

Benoît DE BOECK, Ir
General Manager

Preliminary test results showed that fracture toughness was more affected than predicted by theoretical models. The licensee decided to pre-emptively shut down both units and to initiate a new series of tests in order to explain these unexpected results. The results of these new tests were published in July 2015. They were independently analysed by various Belgian and foreign organisations, including Bel V, of course. The reports were finalised in November and led to the same conclusions, that is that the safety demonstration presented by the licensee was convincing. The FANC then gave the go-ahead for the units affected to be restarted.

While Electrabel had been preparing for almost three years for the final shut-down of Doel 1/2 in 2015, the new government decided to change the nuclear power phase-out law and to extend the operating lifetime of Doel 1/2 by 10 years. This required the establishment of a Long-Term Operation (LTO) project for Doel 1/2, which is a real challenge given the limited timeframe. The time lost had to be made up, the stress tests and ten-year reviews dossiers reopened and all the decisions taken in the context of a reduced operating period revisited. The impact on the Bel V workload in 2015 was considerable as the measures required by the FANC had to be put in place before operation in excess of 40 years could be authorised. A positive opinion was given at the end of December 2015, enabling Doel 1 to be started up again (shut down in February after 40 years of operation) and Doel 2 to remain in operation.

In early 2013 ONDRAF/NIRAS submitted its formal licence application concerning the future facility for the disposal of category A waste (low and intermediate level short-lived radioactive waste) in Dessel. Since then Bel V has been deeply involved, in collaboration with the FANC, in analysing the facility's safety report. An initial analysis, carried out in 2014, led to many questions being submitted to ONDRAF/NIRAS. The answers to these questions are still being examined. At the same time, we continued our long-term safety assessments using digital models.

In summary, Bel V continues to face many challenges. With our dynamic and multidisciplinary team, we are ready to take on these challenges and to prepare for the future serenely.

Benoît DE BOECK, Ir
General Manager

1 Introduction

Michel VAN HAESENDONCK

Nuclear power plants

On 17 November 2015, approval was given for the restart of the Doel 3 and Tihange 2 nuclear reactors. This decision was based on an analysis by the Regulatory Body – i.e. the Federal Agency for Nuclear Control (FANC) and Bel V – of the new safety case report submitted by the licensee and on advice from a large team of independent international experts (including the American Oak Ridge National Laboratory) and experts of the Belgian Regulatory Body.

It was deemed that Electrabel was able to demonstrate that the unexpected test results of March 2014 were likely due to the specific material properties of the sample used. Tests carried out on another material specimen with hydrogen flakes and the material of the reactor vessels themselves indicate that long-term radiation does not have an abnormal effect on the mechanical properties of the reactor vessels of Doel 3 and Tihange 2.

The structural integrity of the reactor vessels of Doel 3 and Tihange 2 falls within the requisite safety standards and the presence of hydrogen flakes has had no harmful effect on reactor safety. The Doel 3 and Tihange 2 reactors were therefore approved for continued operation until the time when they are definitively decommissioned.

After this approval, the licensee took all the necessary measures to prepare for and implement the restart of both units. Bel V inspected both units during the preparatory and start-up phases, closely following the specific inspection programme that had been set out.

The Long-Term Operation (LTO) project is still ongoing for Tihange 1, in view of the decision to authorise operation for another 10-year period, i.e. until 2025. An action plan was drawn up for the improvements to Tihange 1, based on the safety evaluation report prepared by the licensee and reviewed by the regulatory body. Specific files were examined and inspections were carried out in the context of the follow-up of this action plan.

During the summer months in 2015, a number of events took place at Tihange 1 and Tihange 3 that constituted a breach of the regulatory provisions in the technical specifications or the operating conditions as specified for these units. Since a number of similar deviations occurred over a period of 6 weeks, the FANC decided to issue a court summons and impose a series of corrective measures. These corrective measures must result in an enhancement of the safety culture at the Tihange nuclear power plant and ensure

that, among other things, the safety procedures are once again implemented with due care. Specific inspections were carried out in the context of the follow-up of the proposed corrective measures.

Electrabel developed an action plan for the end of operation and future dismantling of Doel 1/2 since – from a legal point of view – both the Doel 1 and Doel 2 nuclear power plants reached the end of their lifetimes in 2015. Discussions about this subject between Electrabel and the FANC / Bel V continued in 2015. As the year went on, this action plan became less relevant as new discussions were started regarding a potential extension of the lifetime of Doel 1/2. Action plans were drawn up for this purpose. After the government announced on 1 December 2015 that it had reached an agreement with Electrabel, the necessary priority actions were completed. After specific follow-up on site by Bel V and confirmation that all requisite actions had been implemented, the FANC was able on 23 December to give its consent to the start-up of both units.

In mid-2013 a gel-like substance was discovered in a number of drums containing conditioned waste, both at Belgoprocess and at the Doel site. As a result of this discovery, a close collaboration was initiated and is still ongoing by the Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS), the FANC and Bel V to thoroughly investigate and remediate this problem.

In the wake of the Fukushima accident, the licensees were asked to conduct stress tests and develop action plans that were reviewed by the Regulatory Body. Various modifications were made to the facilities or are in the process of implementation. Specific inspections were carried out by Bel V in the context of the follow-up of the proposed corrective measures.

Other nuclear facilities

Following the Fukushima accident, stress tests were conducted for all Class I nuclear facilities in operation. Safety evaluation reports and action plans were drawn up by the operators and reviewed by the Regulatory Body. The implementation phase of each plan is closely monitored by Bel V.

Various projects are ongoing at BR2 with a view to continuing operation after 2016.

At Belgonucléaire, dismantling work is ongoing. No contamination incidents of note were reported.

The challenges for the management of the National Institute for Radioelements (IRE) remain numerous. A number of different projects are under study: conversion from highly enriched uranium (HEU) to low-enriched uranium (LEU) for the targets, design study of a new facility, etc. Various action plans are being implemented, including for the disposal of historic waste.

Dismantling of the Thetis research reactor was completed in 2015.

Dismantling of the Franco-Belgian Fuel Fabrication (FBFC) facilities continued in 2015 and required close monitoring by Bel V.

Integrated strategy for control

The integrated strategy for inspection (by the FANC) and control (by Bel V) was applied in 2015.

The 2015 inspection programme was sent to the facilities at the end of 2014. Specific attention was paid to human factors and human performance, safety management and the development of a safety culture when implementing the programme, which was monitored against key performance indicators.

In 2015, our valued inspection teams faced many and varied challenges. Bel V also constantly seeks to learn lessons from the events and incidents that occur and to aim for even better inspections in the future. An action plan was therefore set up in 2015 to further strengthen and optimise the inspection activities.

1

Regulatory activities in Belgium

Regulatory activities in Belgium

1.1 Overview of inspections at nuclear power plants

1.1.1 Doel 1/2

The opening of an incorrect flange on 2 February led to flooding in a basement with safety-related equipment. Ultimately, three of the four raw water cooling systems were briefly unavailable.

Doel 1 was running at nominal power at the beginning of 2015, until on 15 February the unit was shut down as provided for in the legislation. From that time on, Doel 1 was kept in a safe shutdown state. At the beginning of October, the preparations were launched for a (then) potential restart.

During this period, Doel 2 was operating at nominal power, except for:

- from 2 May to 18 May, when the unit was stopped for refuelling;
- on 14 September, when 40 MW less power was generated because of the disconnection of a pump in the non-nuclear part of the unit as a result of a defective gaugeglass. After the unit was repaired, about 12 hours later, the unit was back to nominal power;
- from 23 October to 24 December, for a number of inspections that needed to be conducted as part of a potential restart. These involved an inspection of the pressure vessel and of the lower and upper internal parts. These inspections were also carried out at Doel 1. The results of the inspections did not bring to light any elements that could hinder the start-up.

On 31 October, there was an explosion with fire in one phase of the main transformer of Doel 1. All safety equipment worked properly. The defective transformer was replaced by the reserve transformer. The two other phases were replaced by transformers intended for Tihange 1.

All priority actions laid down in the LTO action plan and that had to be carried out before a restart were implemented. Bel V confirmed the completion of these actions with an acceptance report, after which the FANC approved the restart on 23 December.

On 24 December, Doel 2 was connected to the grid. On 30 December, it was the turn of Doel 1.

1.1.2 Doel 3

In March 2014, Doel 3 was shut down again by Electrabel due to unexpected results of mechanical tests at SCK•CEN for the reactor vessel. While awaiting justification, the unit was in a state of extended outage until 16 November.

After receiving a favourable opinion from the safety authorities with regard to start-up, the unit was brought back into service on 17 November. Refuelling of the core took place from 30 November to 2 December. Sufficient time was allocated to making the systems operational and for the requalification of the equipment after changes had been made during the extended outage. After successful reactor tests, Doel 3 increased in power after 23 December.

Before reaching nominal power, the unit was stopped from 25 December 2015 to 3 January 2016 for repairs to a mechanical and electrical problem in the non-nuclear part of the reactor.

1.1.3 Doel 4

The reactor was at nominal power throughout the year, except for a planned outage (28 August to 14 October) for refuelling and maintenance. During the scheduled outage, the reactor pressure vessel head was replaced and the reactor wall was tested for flaws.

1.1.4 KCD common (WAB, SCG, GSG)

WAB: The upgrade of the WAB installation is in progress. Both floorwater evaporators were replaced and one of them is now ready for use. Because no procedures were at hand for conditioning concentrates or resins, Bel V focused on following up on the expansion of the buffer capacity of both concentrates and resins. A limited buffer for storage of concentrates has always been present, but a considerable extension was close to completion at the end of 2015. In 2016, this buffer was further expanded. There is a project under way for resins as well, with a view to extending storage capacity. Going forward, in collaboration with the French Commissariat à l'énergie atomique et aux énergies alternatives (CEA), it will become clear from new resin and concentrate procedures whether the operation needs further adjustment. The operation of the WAB facility has not hitherto experienced any problems (apart from a few technical defects), but the available buffer for storage of just about every sort of waste is relatively low and allows only a limited margin for failures and maintenance.

SCG: For more information on the introduction of a new type of storage container (HOLTEC), please refer to Section 2.6. The development of a solution for the storage of leaking fuel rods is under way. In preparing the loading of a container at Doel 3 in 2014 (TN24DH24), particles of foreign origin were detected. An investigation of the cause is still in progress for certain aspects. Quality control of the containers delivered was enhanced. The delivery of new containers (of the existing approved type) with the accompanying equipment (seal pressure monitoring) has hit some difficulties.

GSG/R: The GSR is also used to store the old reactor vessel head from Doel 4 and accompanying parts (besides the steam generators of Doel 1).

1.1.5 Doel site

The Bel V inspection programme at the site was further implemented as follows:

- Meetings were held with the heads of various departments (Maintenance, Operations, Care, Engineering) and services, in order to evaluate their organisation and the management of different processes relating to nuclear safety or radiation protection.
- More attention is being paid to human factors and human performance, housekeeping, experience management, training qualified staff, emergency preparedness and response, etc., having in mind the importance for improvement actions to be permanent.

Bel V provided support to the FANC within the framework of its inspections, especially the management inspection, the inspection of subcontractors, the inspection relating to 'waste' and the inspection in the context of the follow-up of the stress tests. In addition, Bel V also provided support to the FANC in the area of physical protection.

The monitoring of the implementation of the action plan resulting from the common periodic safety review is worth mentioning as well, which was completed at the end of 2011 and resulted in changes to facilities, procedures and the safety analysis report.

Regulatory activities in Belgium

1.1.6 Tihange 1

The unit operated at nominal power throughout the year, except for:

- a reactor trip on 20 January, due to the spurious closure of a (non-safety-related) main feedwater valve;
- a power reduction to 75% on 12 March, in order to repair a pump (non-safety-related);
- a power reduction to 50% on 9 April, in order to repair a steam leak in the non-nuclear part of the facility;
- house-load operation by turbine group South on 4 May, following an operating error;
- the LTO outage from 20 June until 15 September. Around half of the safety equipment has been replaced. The rest will be replaced in 2016;
- a reactor trip on 18 September, due to the rupture of a pump shaft in the non-nuclear part of the facility. The unit remained shut down until 28 September, as Electrabel took advantage of the opportunity to replace a valve of the fire protection circuit in the reactor building;
- a reactor trip on 18 December, due to a low level in one of the steam generators following a starting fire in a 220 V electrical board (non-safety-related).

1.1.7 Tihange 2

After obtaining unexpected and unfavourable mechanical test results (related to one of the Long-Term Operation actions set out in the context of the reactor pressure vessel issue), Electrabel decided on 25 March 2014 to shut down Tihange 2 and Doel 3. The unit has since remained offline.

On 17 November 2015, the FANC authorised Electrabel to restart the Doel 3 and Tihange 2 reactors. The licensee then carried out the work necessary for restarting both units. They were operating at full power again on 18 December.

1.1.8 Tihange 3

The unit operated at nominal power throughout the year, except for:

- a unit outage between 24 March and 10 May, in order to replace the reactor pressure vessel head;
- a reactor trip on 6 May, due to a low level in a steam generator while the unit was in the warm-up phase;
- a power reduction to 50% of nominal power, initiated on 8 April, after a purge recycling pump trip (in the non-nuclear part of the facilities);
- an accidental trip: in the night of 12 to 13 August, a reactor trip occurred following a failure in the power supply of the command unit of the control rods. On 27 August, the unit was restored to nominal power.

Having observed an accumulation of events linked to human and organisational factors during the unit outage, Bel V asked the licensee to conduct an analysis to identify any underlying trends and causes. See also the paragraph concerning the Tihange site.

1.1.9 Tihange site

The Bel V inspection programme at the site was further implemented as follows:

- Meetings were held with the management and the heads of various departments (Maintenance, Operations, Care, Engineering) and services in order to evaluate their organisation and the management of various processes relating to nuclear safety or radiation protection.
- Particular attention was devoted to human and organisational factors (see below).
- Specific inspections were carried out to address topics that apply to several units (conditioning of solid waste, taking account of extreme temperatures of the Meuse, etc.).

After the repetition of events relating to non-compliance with the Technical Operational Specifications and the observation of recurring deficiencies in terms of human and organisational factors affecting the entire site to varying degrees, the FANC issued a decree on 3 August (on the temporary suspension of the operating license of four persons) and drew up a court summons. Bel V provided technical support to the FANC, in particular in respect of conducting reactive inspections, preparing hearings (held subsequent to the court summons issued) and evaluating the immediate corrective action plan developed by the licensee. The licensee also carried out an 'analysis of the underlying causes' which led to this situation, in view of establishing a more structural action plan. Bel V also provided technical support to the FANC for monitoring the development of this action plan.

Bel V was again closely involved in the BEST project, which resulted in changes to facilities and procedures and the construction of new buildings.

1.2 Overview of inspections in other nuclear facilities

1.2.1 Nuclear Research Centre (SCK•CEN) (including Guinevere)

The operating regime of the BR2 reactor in 2015 consisted of 1 cycle of 4 weeks.

Since 25 February, the BR2 reactor has been stopped for refurbishment. The status of the refurbishment is as follows:

- Unloading of the current beryllium matrix from the reactor and cleaning of the reactor vessel have been completed.
- Inspection of the reactor pressure vessel has been carried out and the results are satisfactory.
- Loading of the new beryllium channels into the reactor pressure vessel has begun.
- Assembly of the new beryllium channels and the test assembly in building TCH were successful.
- Dismantling of the experimental CALLISTO loop has begun following decontamination.
- Replacement of the underground secondary pipes is in progress.

The VENUS reactor was loaded with 'type 13' fuel assemblies (instead of 'type 9'). The experimental programme is proceeding with the study of the disturbances of this core configuration.

Historical contamination was identified in the culvert of the waste water discharge pipe behind the BR1 reactor. The historical contamination is probably due to a leak in the connection between two waste pipes. The contaminated soil was removed and the existing B02 pipe and culvert were restored.

There were no events of note in the other facilities of SCK•CEN in 2015.

Regulatory activities in Belgium

1.2.2 Belgoprocess

Leaks were once again identified in the boiler of the Cilva installation in 2015. The boiler was replaced at the end of 2015. The restart of the installation is scheduled for mid-February 2016. During the unavailability of the Cilva installation, combustible waste will temporarily be stored in 40 ft containers.

In the second quarter, increased radioactivity was observed in the silt samples from the Molse Nete. This increase is probably due to the residual contamination released from the Nete pipe due to road works on the streets under which the Nete pipe is located. The results of the measurements in the third quarter indicate that the radioactivity in silt samples from the Molse Nete had fallen.

As a result of the safety audit carried out in October 2010, Belgoprocess initiated the Strategic Safety Program (SSP). This action plan was formally closed in 2015. The activities relating to the problem of formation of gel in drums from KCD were reported monthly to Bel V. Logistical works are under way in building 151X in order to free up a separate zone for the KCD drums. Work on developing a concept for a new storage building for non-compliant packages has started.

In 2015, the Scientific Council issued a provisional, reasoned favourable opinion concerning the extension of the license for the dismantling of site 2.

1.2.3 Belgonucleaire

The release of building H was approved by the FANC and Bel V, and the building was demolished in a conventional manner during the first few months of 2015.

At the same time, the dismantling of the components from building A continued, in particular of the remaining glove compartments and boxes.

In the summer, a detailed radiological characterisation of building A was started.

The spaces in building A were emptied out in the course of 2015 in preparation for their release.

The release methodology for building A was further developed and refined on the basis of the results of the radiological survey in test areas.

There were no incidents. The safety culture and necessary knowledge were retained thanks to a lease-back system of former employees, in consultation with their new employers.

1.2.4 National Institute for Radioelements (IRE)

The checks carried out by Bel V in 2015 were related to different projects:

- The challenging IRE program to eliminate historic waste accumulating on site is slowly reaching its main objective. The level of waste stored in Fleurus has been considerably diminished.
- The IRE is also involved (through a pre-licensing project) in the development of a new production line using low-enriched uranium (LEU) instead of highly enriched uranium (HEU).
- The dossier submitted by the IRE to increase production capacity has been accepted by the FANC.
- The stress test program, the periodic safety review and the checks performed by the Regulatory Body have highlighted margin for conceptual improvement for a facility that was designed in the 1970s and 1980s. The second periodic safety review by the IRE at the end of 2015 will have to take into account these conceptual margins in order to reinforce the design of the installation.
- The supervision and control of the production and the maintenance department of the IRE have been reinforced.

1.2.5 Thetis

In 2015, no incidents of note occurred.

Dismantling of the Thetis research reactor was completed in 2015.

The final dismantling file, the documents for the mapping of the reactor vessel concrete and the final mapping of the Thetis building were approved by the FANC and Bel V in 2015.

The Thetis building (with the exception of the activated floor plate) was released.

The Class I license was lifted in December 2015 and the reactor vessel was included in the existing Class II license for the INW site.

1.2.6 Institute for Reference Materials and Measurements (IRMM)

In 2015, no incidents of note occurred.

The operation of the LINAC, the Van de Graaff installation, the mass spectrometry department, the main building, the waste building and the three X-ray devices in the CRM 130 building ran smoothly.

The commissioning of a fourth X-ray device for experimental research was carried out in January 2015.

Much progress was made in the follow-up of the implementation of the PSR and BESTA actions.

1.2.7 Franco-Belgian Fuel Fabrication (FBFC)

The dismantling of buildings 1, 2, 3 and 5 continued in 2015.

The dismantling of building 1 (lab) was completed in 2015.

In building 2 (GADO), most of the dismantling was completed in 2015 and the majority of the release measurements were carried out.

Building 3 was demolished down to the foundations. Removing and measuring the foundations began in December 2015.

The dismantling of building 5 continued in 2015.

The approval of the methodology and release files for buildings 1, 2, 5 and 5M and the FBFC site is scheduled for 2016.

The last MOX campaign in building 5M was completed in April 2015. The last elements (except for 45 back-up canisters) were removed from the site in June 2015.

In August 2015, a fire broke out in the decontamination room in building 5 when carrying out work in a plasma cutting facility. That incident as well as the delays observed in the dismantling work led Bel V to inspect this installation more closely.

Regulatory activities in Belgium

1.2.8 Other (Class II and III) facilities

About 100 inspections of health physics services in Class IIA, II and III facilities were carried out.

No accidents were recorded in 2015.

Accumulation of radioactive waste on site, and sometimes stored in public institutions such as universities, remained a point of attention for Bel V. Subcontracting the radioactive waste characterization or the unconditional release of waste after characterization by another licensee are also points of concern.

The number of accelerators in Belgium that have not been used for years continues to rise. Until now, none of them have applied officially to the FANC for a dismantling licence despite the fact that a sanitization process is on-going, as monitored by Bel V's regular inspections.

1.3 Emergency preparedness and response

1.3.1 Emergency response exercises

In 2015, three emergency preparedness and response exercises were held under the supervision of the Directorate-General Crisis Centre of the Federal Public Service Interior (DG Crisis Centre):

- in March for the Doel nuclear power plant: partial exercise limited to the interaction between the emergency crisis cell of the licensee (on-site) and the evaluation cell CELEVAL (off-site);
- in October for the Mol-Dessel area with the SCK•CEN (BR2 research reactor) and Belgoprocess nuclear facilities: methodological controlled exercise with the participation of local authorities and emergency services in addition to federal cells and committees (coordination committee, evaluation/information/measurement cells). A support team assisted the participating bodies at all stages of the exercise (development, preparation, execution and evaluation);
- in November for the Tihange nuclear power plant: partial exercise limited to the interaction between the emergency crisis cell of the licensee (on-site) and the evaluation cell CELEVAL (off-site);

All these exercises were prepared, conducted and evaluated according to a new Belgian methodology for the preparation, execution and evaluation of emergency preparedness and response exercises. Bel V was heavily involved in these exercises, as a stakeholder but also as 'controller' and 'evaluator' for the Mol-Dessel exercise (a Bel V representative was appointed as member of the exercise management team). A Bel V representative was also involved in the workshop for first responders, the Table-top 'Information flows' and the information session that were held in the context of this exercise.

In addition to the exercises mentioned above, Bel V participated in two internal exercises (at the common FANC /Bel V crisis centre) organized by the FANC and for which a Bel V representative simulated the role of the EDA/ coordination committee.

1.3.2 Other related activities

Bel V participated in the continuation of projects that have been initiated in previous years (such as the implementation, within the various Emergency Planning Zones concerned, of the principles and guidelines as defined in 2009-2010 or the development of improvements regarding the protection of first responders in case of a radiological emergency).

Bel V, together with the FANC, has been involved by the DG Crisis Centre in the process of reviewing the Royal Decree on the nuclear and radiological emergency plan for the Belgian territory. It is expected to deliver a consolidated proposal for a revised version of this plan in the course of 2016.

1.3.3 Improvement of Bel V's role

In order to improve the Belgian emergency preparedness and response in case of a nuclear emergency and especially the role of Bel V herein:

- Bel V staff participated in the Belgian emergency preparedness and response exercises, which, besides the response activities, required a lot of preparation, observation and evaluation of the response by the Bel V crisis team, by the licensee and by other parties involved (evaluation cell of the DG Crisis Centre).
- Two Bel V representatives participated as Trainers in a training module on emergency preparedness and response provided by the European Nuclear Safety Training and Tutoring Institute (ENSTTI) at the ENSTTI offices late June/early July 2015 (Fontenay-Aux-Roses).
- A Bel V representative participated as Trainer in a training module 'Advisor dangerous products' organized by the University of Mons (Jurbise, January 2015).
- A Bel V representative participated in the sub-working group 'Emergency planning zones' of the Scientific Council of the FANC.
- Bel V participated in R&D activities in the domain of emergency preparedness and response, in the context of a research program with the Vrije Universiteit Brussel (VUB) in view of developing cognitive radio for nuclear power plants (4-year program connected with a Doctorate).
- Bel V was involved in a proposal coordinated by IRSN within the Horizon 2020 Framework Programme for Research and Innovation (FASTNET project: FAST Nuclear Emergency Tools). This project is scheduled to start in 2016 and is expected to last 4 years.

1.3.4 International collaboration

Bel V took part, partly in support of the Belgian competent authorities, in the following working groups:

- WG Emergencies of HERCA (Heads of European Radiological Protection Competent Authorities);
- Exchange meeting between IRSN, the FANC and Bel V on emergency preparedness and response (Brussels, June 2015);
- Exchange meetings between German, Dutch and Belgian authorities (The Hague, September 2015 and Trier, October 2015).

2

Introduction

Marc DUBOIS

Since its creation in 2008, Bel V has managed an increasing number of diverse and major safety issues within the framework of projects launched in the various Belgian nuclear facilities. The diversity of the projects (e.g. PSR, LTO, stress tests, flaw indications in the reactor vessels of Doel 3 and Tihange 2, waste storage facilities, PSA, Myrrha, etc.) requires us to maintain and develop existing expertise and to build new expertise.

In 2015, the workload rose sharply in the national projects for all the stakeholders (licensees, the FANC and Bel V) after the Belgian government decided at the end of 2014 not to shut down Doel 1/2 after all and to allow long-term operation instead.

In this particular context, special thanks have to go to all the Bel V project teams for their much appreciated efforts to maintain the highest quality of safety evaluation while still meeting the schedule as much as possible.

At international level, Bel V actively participates in the cooperation programme launched by the European Union. The competence of the Bel V experts is well acknowledged and much appreciated by the Regulatory Authorities in many countries around the world. Participation in these international projects allows Bel V to promote its image internationally and to broaden the technical knowledge of its Technical Responsibility Centres (TRC).

2

Safety assessments and national projects

Safety assessments and national projects

2.1 Probabilistic Safety Assessment (PSA)

In the context of the implementation of the WENRA Reference Levels (version 2008) for all existing nuclear power plants (as required by the Royal Decree of 30 November 2011) Electrabel and Tractebel Engineering continued their efforts to develop an Internal Fire PSA and an Internal Flooding PSA for the Belgian nuclear power plants. These PSA models include a plant-specific PSA Level 1 for each of the units (except Doel 1/2, for which the development of Fire and Flooding PSA models has been delayed due to the permanent shut-down originally scheduled for 2015) and a PSA Level 2 for a representative unit (Doel 3). All plant operating states will be covered. In 2015, Bel V reviewed the development of the Flooding PSA study for all units. For the Internal Fire PSA, focus was on the first iteration of the projects which consisted in obtaining initial raw results (e.g. not taking into account the detailed circuit analysis yet). Bel V also monitored the Fire and Flooding PSA level 2 project and reviewed several notes (e.g. HRA methodology, Plant Damage States) within the context of this project.

Bel V also monitored the on-site implementation of PSA recommendations (i.e. plant modifications, procedural changes, etc.) made in 2011 after a global upgrade of the PSA models for internal events, which took place during the previous Periodic Safety Reviews (PSR). In addition, these plant-specific PSA models were further updated in 2012/2013 by taking into account all plant modifications up to 2010. Future updates of these PSA models are planned to take into account the Belgian Operational Experience Feedback since previous updates. In 2015, Bel V discussed with Electrabel its proposed methodology to take into account the Belgian Operational Experience Feedback for determining the data that will be used for the PSA update (e.g. initiating event frequencies).

In 2015, Bel V was also involved in monitoring the upgrade of the PSA models (taking into account a revised scope and methodology) for internal events. The main inputs of this upgrade are the recommendations of an external peer review of the Doel 3 PSA against the American Society of Mechanical Engineers (ASME) Standard for PSA. In 2015, Bel V reviewed and discussed with Electrabel several methodological documents (e.g. adaptation of the HRA methodology) and study documents within the context of this project.

Through the annual meeting with the PSA Standing Committee of Electrabel and Tractebel Engineering, Bel V monitored the gradually increasing use of the PSA models by Electrabel for various PSA applications. In particular, Bel V monitored compliance with the requirements of the Royal Decree of 30 November 2011 in terms of PSA applications (e.g. the use of PSA for verifying the adequacy of procedures and plant modifications and for evaluating the significance of operational events). The possibility of the establishment of a more comprehensive process of collection of data which could be used for PSA development was also envisaged and discussed with Electrabel within this framework.

Bel V's international and R&D activities on PSA methodology and PSA applications are presented in Section 4.4 on research and development.

2.2 Periodic Safety Reviews (PSR)

A Periodic Safety Review consists in an assessment by the licensee of 14 'safety factors' as defined in the IAEA Safety Guide NS-G-2.10 (recently replaced by SSG-25), the use of which is required by the FANC for all Class I nuclear facilities.

- Nuclear power plants – 2nd Common PSRs
  Scope and methodology documents according to the guidelines of the FANC were issued for all the units. All assessment reports for Doel 4, Tihange 1 and Tihange 3 (one per safety factor and one for the overall safety assessment) were reviewed by Bel V. The conclusions of this review were submitted to the FANC and the licensee.
- The second Periodic Safety Review of the IRE started in November 2015. A meeting was organized by the FANC with Bel V and the IRE to initiate the discussion on the scope and methodology documents.
- The PSR 2016 periodic safety review of SCK•CEN is ongoing. SCK•CEN issues a number of deliverables every month for analysis by Bel V, in accordance with the schedule found in the methodology document. Bel V analyses the documents and submits the results thereof to SCK•CEN. If necessary, meetings are held to facilitate discussions and address any points that could hinder progress.
  On 31 December, 86% of the deliverables had been submitted to Bel V. 33% of these could be closed.
- As part of the ten-year review at Belgoprocess Site 2, the first deliverables in support of the assessment reports were analysed by Bel V in 2015.

2.3 Long-Term Operation (LTO) – Tihange 1

The implementation at Tihange 1 of the detailed action plan resulting from the final summary LTO reports as approved by the safety authority (June 2012) continued in 2015 for each area covered by the 'FANC Strategy Note on Long-Term Operation':

- Development of an Ageing Management Programme;
- Re-evaluation of the design (Agreed Design Upgrade);
- Pre-conditions to be fulfilled before the start of the Tihange 1 life extension period;
- Knowledge Management.

In accordance with the timetable for the approved LTO action plan, all commitments related to 'Preconditions' and 'Knowledge Management' were concluded before the start of the long-term operating period of this unit, i.e. 30 September. The requests by the licensee to close the LTO projects relating to these topics, accompanied by a summary dossier containing the supporting documents, were all approved by Bel V before that date.

The work and the modification files relating to 'Ageing Management' in the LTO programme (partly completed on the S1 safety train during the unit outage in 2014) were finalized during a special outage from 20 June to 15 September. The completion of the work on the S1 train in 2015 (in accordance with the action plan's schedule) and the partial acceptance of the relevant modification files were favourably assessed during a joint FANC/Bel V inspection carried out in early December 2015. Work on the S2 safety train, scheduled for the unit outage of April-July 2016, is under preparation. The relevant modification files are being submitted progressively to Bel V for analysis, commentary and approval.

As regards the 'Agreed Design Update', progress is being made on the two main projects, i.e. the extension of the Emergency System (SUR) at Tihange 1 and the construction of a full-scale simulator representing that unit (to optimise operator training). The start-up of the new Tihange 1 simulator is scheduled for the first quarter of 2016.

In application of Article 13 of the general regulations for the protection of the population, workers and the environment against the danger of ionizing radiation (RGPRI – Royal Decree of 20/07/2001) by the FANC, a Royal Decree was

issued on 27 September according to which the licensing conditions for Tihange 1 have been fulfilled for long-term operation. These conditions apply to the terms of the LTO action plan approved by the safety authority in June 2012. In particular, any delay in this action plan's schedule or any divergence from its content must be submitted to the FANC for approval.

As regards 'Ageing Management' and 'Agreed Design Upgrade', the licensee has filed a request to the FANC to update the action plan. The FANC approved this request on 30 September. The modifications requested do not affect the main milestones of the initial action plan or the nuclear safety of the installation.

The SALTO (Safety Aspects of LTO) mission of the International Atomic Energy Agency (IAEA), organised at the request of the FANC (in its strategic note), was held from 13 to 22 January.

The mission gave rise to 7 suggestions and 3 recommendations, and identified one 'good practice'. The IAEA published its report in March 2015. The FANC and Bel V will monitor the implementation of these actions.

The mission also examined the follow-up on the 13 suggestions and recommendations made by the IAEA during the preparatory 'pre-SALTO' (limited scope) held in November 2012 at the initiative of the licensee. Of the 13 issues, six were declared resolved and seven showed good progress.

2.4 Long-Term Operation (LTO) – Doel 1/2

At the end of December 2014, the government revoked the decision to close Doel 1/2 and opened the door to a potential long-term operation. The 'definitive shutdown' (DSD) project is being run down. The (provisional) final status of the DSD project is clearly described, so that if in future the project should be reopened, there will be a clear starting point.

In September 2014, the FANC prepared a policy note in relation to a possible political decision to once again authorise long-term operation for Doel 1/2. The policy note was presented to the Scientific Council during its session of 12 September 2014. The note requires Electrabel to submit an integrated action plan to the safety authorities for approval. The action plan contains the proposed schedule and prioritised list of actions in relation to the principal milestone of this project, i.e. the start-up in long-term operation (the so-called 'T0 date'). The priority actions must be completed before the start of long-term operation (cycle 41), while the LTO pre-conditions must likewise be met. Other changes may be spread over a period of 3 years (and at most 5 years) after the approval of the LTO file.

Bel V has first assessed the completeness of the various work packages and the underlying documents of the integrated action plan. Afterwards, Bel V assessed whether Electrabel's integrated action plan meets the requirements as set out in the FANC policy note of September 2014. This was presented to the Scientific Council at its meeting on 22 May 2015. The Scientific Council determined at that meeting that the action plan was complete and that an agreement had been reached regarding the prioritisation principles.

At the Scientific Council meeting of 11 September 2015, Bel V presented the following:

- The integrated action plan is complete.
- The list of priority actions is complete and implementation will be monitored by Bel V as a condition for the restart.
- An evaluation of the schedule and feasibility of the action list for non-priority actions.
- An evaluation of the project organisation, with the necessary staffing needs and the current recruitment process.

In the last quarter, the priority actions were carried out (which have to be done before the restart under LTO). The completion of the individual actions was approved by the Health Physics Department, and that approval was confirmed by Bel V. On 21 December 2015, KCD submitted a status report to the FANC and Bel V confirming that all priority actions had been carried out. On 23 December, Bel V drew up a report that, pursuant to Royal Decree ANPP-0011847 of 27 September 2015 'Supplement to the licensing requirements for the Doel 1 and Doel 2 nuclear reactors under Long-Term Operation', attests to the acceptance of the priority actions of the LTO project. Doel 2 and then Doel 1 were restarted in the following days.

In conclusion, it can be stated that this project, given the high volume of work, short deadlines and uncertainty as a result of delays in government decisions, represented a major challenge both to the licensee and to Bel V.

2.5 BEST (A) project

2.5.1 Nuclear power plants

In the wake of the accident that occurred on 11 March 2011 at the Japanese Fukushima-Daiichi nuclear power plant, a wide-scale targeted safety reassessment programme was set up among the Member States of the European Union that operate nuclear power plants on their soil. This stress test programme was designed to re-evaluate the safety margins of the European nuclear power plants when faced with extreme natural events, and to take relevant action wherever needed.

The stress tests of the Belgian nuclear power plants included the following main steps:

1. reports of Electrabel (2011);
2. national report of the safety authority (2011);
3. peer review, country visit and final ENSREG overall report, in accordance with the ENSREG methodology (2012);
4. action plan of Electrabel based on findings from the previous steps, and approval by the safety authority (2012).

Bel V was involved in steps 2 to 4.

Bel V is now in charge of the technical and organisational follow-up of the implementation of the actions by Electrabel. This follow-up includes the assessment of studies and implementations, regular follow-up meetings and on-site inspections, sometimes with the contribution of the FANC.

In 2015, as in 2013 and 2014, Electrabel indicated to Bel V and the FANC reasons to postpone or modify certain actions, including the complexity of studies and implementations, additional actions resulting from conclusions of studies, issues with suppliers (compliance with the specifications, bankruptcies, etc.) or the need to organise these activities during the outages. Analysis of the causes of the delays resulted in modifications to the action plan. These delays are sometimes significant (estimated at one or even two years) for the most ambitious safety improvements, and affect the overall progress on the BEST project.

2.5.2 Other nuclear facilities

Following the Fukushima accident, stress tests were also conducted at all other Class I nuclear facilities in operation (BESTA project). Safety evaluation reports were drawn up by the operators and reviewed by the FANC / Bel V. On 16 April 2013 the FANC published the national report of these stress tests on its website. The required action plans for the respective licensees were finalised by 1 July 2013, after which the implementation phase started.

The technical and organisational follow-up of the implementation of the actions by the different licensees is the responsibility of the operational control of each facility (Bel V inspector). As is also the case for the BEST project, this follow-up includes the assessment of studies and implementations, regular follow-up meetings and on-site inspections, sometimes with the contribution of the FANC.

Progress on action plans is generally satisfactory. However, Bel V has noted that some licensees (Belgoprocess, IRE) are experiencing difficulties meeting the deadlines despite the additional resources allocated in 2015 to try to catch up.

2.6 Radioactive waste management

In collaboration with the FANC, Bel V has been involved in the licensing discussions (since the license application by ONDRAF/NIRAS on 31 January 2013) concerning the future facility for the disposal of low and intermediate level short-lived radioactive waste (category A waste) in Dessel.

After the completion of the detailed analysis of the safety case by the FANC and Bel V, more than 200 questions were submitted to ONDRAF/NIRAS, which ONDRAF/NIRAS then started answering. Bel V is deeply involved in the analysis of the ONDRAF/NIRAS answers in collaboration with the FANC. Furthermore, within the framework of the long-term safety evaluations, Bel V continued its activities (using its own modelling capacity) of independent safety verification (already started in February 2012).

In 2014, the FANC and Bel V initiated a collaboration under the terms of the Belgian program for the disposal of B & C waste in deep geological formations. In this regard, Bel V contributed in 2015 to the development of a Strategic Research Agenda defining the needs of the regulatory body in terms of the expertise required for reviewing the SFC1 safety case (scheduled for 2020). Bel V also participated in discussions between the regulatory body and ONDRAF/NIRAS regarding a number of important subjects for the storage programme (security aspects, biosphere modelling, monitoring, reversibility, etc.). Lastly, Bel V contributed to the FANC's review of the R&D plan published by ONDRAF/NIRAS and of the draft national programme for managing spent fuel and radioactive waste.

In the framework of the approval by Bel V of the Topical Safety Assessment Report (TSAR) for a new type of dual-purpose cask for storage of spent fuel on the Doel site, the Q&A process between the different stakeholders continued in 2015.

In 2013 a gel-like substance was discovered in a number of waste drums from the Doel nuclear power plant stored at Belgoprocess. Further investigations revealed that thousands of drums stored at Belgoprocess were potentially concerned by this gel formation issue. Since the discovery of this issue, Bel V has verified that Belgoprocess is taking the necessary actions to ensure the safety of their storage buildings. In addition, Bel V has verified that the Doel nuclear power plant develops new and safe conditioning processes for the waste streams concerned by the gel formation issue and that the temporary on-site storage of unconditioned radioactive waste remains safe. In the context of this gel formation issue, in 2014 Bel V participated in a new working group allowing the FANC, Bel V and ONDRAF/NIRAS to consult each other about the measures to be taken to manage this issue and to avoid such a problem in the future.

2.7 MYRRHA

MYRRHA is a multi-purpose irradiation facility coupling a 600 MeV proton accelerator with a fast spectrum reactor of 100 MWth cooled with Lead-Bismuth eutectic, through spallation reactions. The pre-licensing phase of the MYRRHA project, initiated in 2011 in order to analyse the 'licensibility' of the facility, continued in 2015. This pre-licensing phase has been extended by at least one year and is expected to run until at least late 2017.

In the context of this pre-licensing, Bel V evaluates the SCK•CEN deliverables in response to focus points (technical issues that are new or not yet mature enough, that are specific to MYRRHA and that have an impact on the safety of the facility) identified by the Regulatory Body (the FANC and Bel V). At the end of 2015, more than a third of the deliverables had been provided by SCK•CEN. Technical meetings took place to discuss focus points with SCK•CEN. As the MYRRHA design still evolves, many deliverables are anticipated in 2016 and 2017.

But since it will not be possible to deal with all the focus points by the end of 2017, the aim of the centre in Mol is to give priority during the 2016-2017 period to the first three volumes of the Design Options and Provisions File (DOPF), a document prepared by the designer detailing, in a top-down approach, the objectives, options, design and operational specifications, as well as the safety provisions. The aim is to present to its supervisory authority, in the third quarter of 2017, a file that is sufficiently well documented for the purpose of obtaining the subsidies required to continue the project.

In 2016, the SCK•CEN also plans to launch a licensing process for the creation and operation of a 100 MeV accelerator, to be completed in 2018, with the construction works planned for 2019-2022 and commissioning scheduled for 2024 (phase 1 of MYRRHA). This accelerator will later be upgraded to 600 MeV (phase 2 of MYRRHA) and, finally, a reactor will be built (phase 3 of MYRRHA).

Lastly, the centre in Mol is maintaining the option of an additional design with relatively important modifications (loop-type design instead of pool-type design).

2.8 Reactor vessel flaws

In June 2012, in addition to the inspection of the Doel 3 reactor pressure vessel welds as required by the regulatory programme for in-service inspection for the closure of the third inspection interval, an ultrasonic inspection of the base metal of the shell forgings of the reactor pressure vessel was carried out. This inspection was part of the inspection programme decided for all the Belgian units in the framework of the operational feedback from Tricastin 1, where underclad defects (planar defects perpendicular to the internal wall of the reactor pressure vessel) were identified. No underclad defects were detected, but several thousand quasi-laminar flaw indications were identified in the upper and lower core shell forgings. Similar inspections were then carried out in September 2012 at Tihange 2, which has a reactor pressure vessel of identical design and construction. Similar quasi-laminar flaw indications were also detected, but to a lesser extent.

The licensee decided to keep both Doel 3 and Tihange 2 in cold shutdown state with the core unloaded and initiated analyses in support of a request for restart of operation.

The safety demonstration by the licensee was documented in two safety cases, one for each unit, as submitted to the FANC and Bel V in December 2012. The safety cases, backed by a number of technical documents, allowed the licensee to conclude that the safe operation of both units was guaranteed and that the units could be restarted immediately.

Safety assessments and national projects

Taking into account the views of different groups of Belgian and foreign experts and conclusions of both Bel V and AIB-Vinçotte assessments, the FANC issued a provisional evaluation report in January 2013. This report concluded that some issues remained open that impaired the level of confidence in the safe operation of the units, but also that these issues, in the current state of knowledge and given the available data, did not represent conditions that required final shutdown of Doel 3 and Tihange 2. As a consequence, the FANC decided that, in the current state of events, Doel 3 and Tihange 2 could only restart once the requirements listed in its provisional evaluation report had been met by the licensee. These requirements include short-term and medium-term actions. In response, the licensee developed an action plan to meet these requirements.

Once the licensee had completed its short-term action plan, the FANC evaluated whether all the safety concerns at the origin of these requirements had been resolved and whether the related reservations could be lifted. On this basis, on 17 May 2013, the FANC considered that Doel 3 and Tihange 2 could be restarted safely. Consequently Doel 3 and Tihange 2 resumed operation in June 2013.

Since then the licensee has continued to implement its action plan by carrying out the medium-term actions. Some of the main medium-term actions include those relating to the specific qualification of the ultrasonic inspection method, and experimental confirmation of the conservatism of the margins considered in safety cases to reflect the additional influence of hydrogen flakes on irradiation embrittlement of the steel in reactor pressure vessels. For these two actions in particular, the licensee was able to use an existing forged part affected by hydrogen flakes. This part is a recently scrapped steam generator shell manufactured by AREVA.

First, the aim of the inspection method qualification is to confirm the ability to detect hydrogen flakes using ultrasound inspection techniques, and to locate and characterize them to the required confidence level. The qualification of the inspection method by the licensee has essentially been monitored by AIB-Vinçotte, and resulted in an adjustment of the inspection procedure, consisting essentially of an improved dimensioning method and a lowering of the notation threshold. On the basis thereof, the number of defects detected in the Tihange 2 and Doel 3 shells was revised up considerably. The zone affected by the phenomenon being unchanged, this has led to the need to consider a higher defect density in the calculations for the justification of the structural integrity of the reactor pressure vessels.

The experimental verification of the effect of radiation on the mechanical properties of a material affected by hydrogen flakes, and in particular fracture toughness, is to ensure that irradiation embrittlement of such material conforms to what is expected of a healthy material, but taking into account the higher content of embrittling factors in localised segregations in which hydrogen flakes are present. Samples from the affected AREVA shell were irradiated in the BR2 reactor of SCK•CEN before undergoing a series of various mechanical tests. These tests have demonstrated unexpected behaviour, indicating a greater effect of the irradiation than expected on the toughness of the material. The existence of this phenomenon of embrittlement was confirmed through repeated trials. A research programme was developed by the licensee in order to gain more insight into this phenomenon, and to check whether it is specific to the AREVA shell material, or typical to all materials affected by hydrogen flakes, in particular the material of the Tihange 2 and Doel 3 reactor pressure vessels. Note that following the discovery of this phenomenon, the FANC has created a group of international experts that is responsible for contributing to the evaluation of the issue on behalf of the safety authority.

In the course of its investigations, the licensee was able to find another part affected by hydrogen flakes. This part had been the subject of a German research programme in the 1980s. The results obtained by the German research programme, as well as from new destructive tests after irradiation of an available sample of this material allowed the licensee to underpin the conclusions of its analysis of the primary cause, according to which the damage

from hydrogen flakes could be ruled out as a cause of the unexpected behaviour observed on the AREVA shell. The licensee concluded that hydrogen flakes would not lead, as a result of their presence, to heightened embrittlement of the material under the effects of neutronic irradiation. The international expert group set up by the FANC endorsed this conclusion. Nevertheless, the licensee considered that, for conservatism purposes, the atypical behaviour of the AREVA shell should be considered in the analysis of the pressure vessels at Doel 3 and Tihange 2 by taking into account a term of non-hardening embrittlement in the rules for predicting embrittlement under irradiation.

An expert group was also set up by the FANC to respond to concerns raised by a number of university professors. The latter speculated that the hydrogen flakes in the reactor pressure vessels could increase while in service due to hydrogen-induced cracking. This phenomenon involves hydrogen accumulation in the flakes, coming from different potential sources. This accumulation would lead to a significant pressure increase in the existing flakes, liable to lead to their propagation. The expert group concluded that this hypothesis was not applicable to the Doel 3 and Tihange 2 reactor pressure vessels.

After the methodology had been accepted by the safety authorities, the licensee submitted the new Safety Cases to the FANC on 17 July 2015. The Safety Cases were subjected to independent analysis by different bodies, i.e. AIB Vinçotte, Oak Ridge National Laboratory (ORNL) and Bel V. These bodies finalised their reports in November 2015 and arrived at the same conclusions, i.e. that the licensee had provided adequate proof relating to this issue. In particular, the Safety Evaluation Report by Bel V concluded that "*Considering the information made available, in particular the Electrabel assessment reports and the supporting analysis reports, but also the current understanding of the involved phenomena, Bel V concludes that the flaking damage has been demonstrated satisfactorily to have an acceptable impact on the serviceability of the Doel 3 and Tihange 2 RPVs during normal, abnormal and accidental service conditions.*"

On 17 November 2015, the FANC granted permission to the licensee to start up the Doel 3 and Tihange 2 units. Tihange 2 restarted on 14 December and Doel 3 on 8 January 2016.

2.9 Reactor pressure vessel head replacement – Tihange 3 and Doel 4

Preventive replacement (in response to international experience feedback) of the Tihange 3 and Doel 4 reactor vessel heads represents a 'significant modification' within the meaning of Article 12 of the Royal Decree of 20 July 2001 on general regulations for the protection of the population, workers and the environment against the danger of ionizing radiation (RGPRI).

By way of reminder, the preliminary and final assessments by Bel V of the license applications submitted to the FANC in October 2013 by Electrabel for the two sites, as well as the documents submitted later in support of those applications, were presented to the FANC Scientific Council during the sessions held on 28 February 2014 and 12 December 2014 respectively.

Based on the provisional, reasoned favourable opinion issued by the Scientific Council on 12 December 2014 regarding the applications submitted by Electrabel to replace the reactor pressure vessel heads at Tihange 3 and Doel 4, the Royal Decrees authorising these replacements were issued on 26 February 2015. These Royal Decrees included conditions to be fulfilled before the reactor pressure vessel fitted with its new head could be placed under pressure, with a view to the issuance of the confirmation decrees for each of those units.

The Tihange 3 reactor pressure vessel head was replaced during the 2015 unit outage (March-April). After Bel V had examined compliance with the conditions laid down in the authorising Royal Decree (update of the safety analysis report, submission to the authorities of the on-site test programme for inserting hold points and stop points, etc.), Bel V issued the acceptance report on 30 April 2015. The Royal Decree confirming the authorisation of the said replacement was issued and entered into force on 7 May 2015. The project for Tihange 3 has been completed.

The new Doel 4 reactor pressure vessel head was installed during the 2015 outage of this unit. After verifying compliance with the conditions of the authorising Royal Decree and follow-up of the on-site qualification tests, Bel V issued the acceptance report on 12 October 2015. The Royal Decree confirming this important modification was issued on 15 October 2015. The Royal Decree authorising the storage of the old head in the storage building for the site's used steam generators had already been issued (on 11 September 2015). The project for Doel 4 has also been completed.

3-4 Introduction

Pieter DE GELDER

For Bel V, as the technical safety organisation of the FANC, expertise is of the utmost importance. That is why Bel V is continuing its efforts to participate in activities of international organisations, to exchange information with counterpart organisations, and to be involved in research and development (R&D) activities.

Concerning international organisations, Bel V participates in many activities of well-known institutions such as the International Atomic Energy Agency (IAEA) and the Organisation for Economic Co-operation and Development (OECD).

WENRA and a number of bilateral agreements play an important role in the exchange of information with counterpart organisations. ETSON, EUROSAFE and ENSTTI provide interesting networking opportunities for Bel V. An important event in that respect was the organisation of the EUROSAFE Forum 2015 in Brussels. Assistance projects under the umbrella of the European Union also allow Bel V to share its expertise and experience with other countries, while being able to learn from partner organisations at the same time.

Research and development is essential for maintaining and developing our expertise. That is why Bel V participates in numerous R&D activities and sponsors research projects at universities and research institutes.

3

International activities and projects

3.1 OECD and IAEA activities

Bel V participated in the activities of the following committees, working groups and meetings of the Organisation for Economic Co-operation and Development (OECD):

- the Committee on Nuclear Regulatory Activities (CNRA);
- the Committee on the Safety of Nuclear Installations (CSNI);
- the Nuclear Science Committee (NSC);
- the CNRA Working Group on Inspection Practices (WGIP);
- the CNRA Working Group on Operating Experience (WGOE);
- the CSNI Working Group on Fuel Cycle Safety (WGFCS);
- the CSNI Working Group on Risk Assessment (WGRISK);
- the CSNI Working Group on Analysis and Management of Accidents (WGAMA);
- the CSNI Working Group on the Integrity and Ageing of Components and Structures (IAGE), and its subgroups on the integrity of metal components and structures and on the ageing of concrete structures;
- the CSNI Working Group on Human and Organizational Factors (WGHOF);
- the CSNI Working Group on Fuel Safety Margins (WGFSM);
- the Senior Level Task Group on Safety Culture of the Regulatory Body;
- the RWMC Integration Group for the Safety Case (IGSC);
- the RWMC Working Party on Decommissioning and Dismantling (WPDD);
- various OECD projects (see also Section 4.4 on R&D);
- the Incident Reporting System Coordinators' activities (IRS, IRSRR, FINAS).

The General Manager of Bel V is a member of the International Nuclear Safety Group (INSAG) of the International Atomic Energy Agency (IAEA), and attended two meetings in 2015.

Bel V participated in the Nuclear Safety Standards Committee (NUSSC) of the International Atomic Energy Agency (IAEA).

Bel V experts participated in several IAEA conferences, workshops and technical committee meetings, mainly on the following subjects:

- emergency preparedness;
- severe accident mitigation through filtered containment venting;
- computer security for Instrumentation & Control;
- operational experience feedback;
- electrical power systems;
- safety of radioactive waste disposal and spent fuel management;
- safety of fuel cycle facilities;
- decommissioning safety and risk management;
- radiation protection;
- the interface of safety and security for research reactors.

The General Manager of Bel V is Vice-Chairman of the Steering Committee of the Technical and Scientific Support Organization Forum (TSOF) of IAEA. He participated in two meetings in 2015.

A Bel V representative is member of the Steering Committee on Regulatory Competence and Knowledge Management (coordinated by the IAEA). Together with another Bel V colleague, he attended the seventh meeting of this committee.

A Bel V representative participated (as member of the Belgian delegation) to the fifth review meeting (May 2015) of the contracting parties to the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management.

International activities and projects

3.2 Cooperation with safety authorities

3.2.1 Franco-Belgian Working Group on nuclear safety

This working group is composed of the regulatory organisations of France and Belgium (ASN, IRSN, FANC, Bel V). Two meetings are held each year, one in Paris and the other in Brussels (the latter chaired by Bel V). The working group covers a large range of topics on nuclear safety.

The main topics at the 2015 meetings were: new initiatives on regulations, status of the Chooz and Gravelines nuclear power plants, cross-inspections, feedback on emergency response exercises, decommissioning and dismantling projects, and the status of the safety case related to the flaw indications in the reactor pressure vessels of Doel 3 and Tihange 2.

3.2.2 Western European Nuclear Regulators Association (WENRA)

Bel V representatives participated, in support of the FANC representatives, in the spring and autumn meetings of WENRA. At these meetings, the work progress of the subgroups (see below) was discussed. Interfaces with other international forums (especially ENSREG and HERCA) were also discussed at these meetings. In 2015, special attention was devoted to the preparation of the first Topical Peer Review (on ageing management) to be organised within the framework of the Nuclear Safety Directive of the European Commission, the interface between safety and security, the indications observed in the reactor pressure vessels of Beznau (CH) and Famanville-3 (F), and the Vienna declaration on nuclear safety.

Reactor Harmonization Working Group (RHWG)

Bel V participated in the three RHWG meetings held in 2015. The main publication of RHWG in 2015 was 'Guidance Document Issue T: Natural Hazards', which complements the Reference Levels on Issue T published in 2014. The RHWG has continued discussions on the benchmarking of the implementation of these revised Reference Levels in regulations and in the nuclear power plants. The RHWG also worked on a proposal for the Terms of Reference for the first Topical Peer Review (see above).

Working Group on Waste and Decommissioning (WGWD)

The action plans of the Belgian licensees (Electrabel and Belgoprocess) with respect to the implementation of the WENRA Reference Levels for the facilities to store radioactive waste and spent nuclear fuel were closed in 2015 by the FANC on a proposal of Bel V.

In 2015 the WENRA-WGWD started the development of a new report gathering Safety Reference Levels (SRL) on waste processing facilities. In March Bel V participated in the 34th WGWD meeting (held in Paris), during which the development of this SRL report on 'Waste Processing' was launched. At the end of 2015 Bel V contributed to the review of the first draft version of this report.

3.2.3 Dutch Safety Authority ANVS

Recently, the Dutch safety authorities were restructured by the creation of Autoriteit Nucleaire Veiligheid en Stralingsbescherming (ANVS). Bel V participated, in support of the FANC, in the information exchange meeting (to be held annually) between the FANC and ANVS.

As a result of that meeting, a meeting was held between ANVS and Bel V to examine to which extent Bel V could provide support to ANVS in the field of nuclear safety. Some topics were identified and a first specific meeting with ANVS has meanwhile taken place. Bel V also presented to ANVS its R&D activities and R&D management process.

3.2.4 Belgian-Swiss Working Group

This working group is composed of the regulatory organisations of Switzerland and Belgium (ENSI, the FANC, Bel V). One meeting is held each year, alternately in Brugg and in Brussels. The group initially also included the regulatory organisations of France (ASN, IRSN) and treated mainly issues related to long-term operation and the action plans following the stress tests. But in 2014, it was decided to create a bilateral Swiss-Belgian group covering more diverse subjects on nuclear safety, like the Franco-Belgian group. If needed, specific technical meetings can be organised between the three regulatory organisations.

In 2015, amongst others the following topics were discussed: FANC guidance for new class I facilities; Swiss action plans after the Fukushima accident; residual operation and definitive shutdown of old units (Doel 1/2, Mühleberg); security (insider threat); and the status of the safety case related to the flaw indications in the reactor pressure vessels of Doel 3 and Tihange 2.

3.2.5 FRAmatome REGulators (FRAREG)

Since many years, Bel V has represented Belgium in the FRAmatome REGulators working group, which meets every 2 to 3 years.

In November 2015, Bel V hosted the eight meeting of this FRAREG working group. Participation was welcomed from all member countries (Belgium, China, France, South-Africa and South-Korea). The main topics on the agenda were: evolution of regulatory frameworks, implemented and planned safety improvements of pressurised water reactors following the Fukushima accident, lessons learned from the latest safety reassessments, long-term operation of the nuclear power plants, and other specific issues on hardware and operational conditions of the pressurised water reactors.

3.2.6 Task Force on Safety Critical Software (TFSCS)

The main objective of this international task force is to provide a public record of agreed regulatory expectations on the validation of the safety critical software implemented in nuclear facilities. The task force is composed of experts from regulators and TSO's. They maintain and update a consensus document on the basis of emerging experience, expertise and practice. Additional benefits are the exchange of information, and the sharing of licensing know-how on digital instrumentation in operating plants and new builds. Bel V has taken a prominent and active part in this task force since its inception in 1994.

Eight countries are now members. Two plenary meetings took place (CNSC, Ottawa and Bel V, Brussels). A full revision of the Common Position report on licensing practices was completed and published on member websites in December 2015. At the same time, the US Nuclear Regulatory Commission (NRC) published a NUREG/IA report, which includes the task force position report as well as NRC commentaries to assist NRC staff in using this information in its licensing review and regulatory framework.

At the end of 2015, the Chinese technical safety organisation, the Nuclear and Radiation Safety Center (NSC), showed interest in taking part in the task force activities, and was invited to the first 2016 meeting, the purpose being to investigate the possibilities and mutual benefits of their future participation as full members.

Meanwhile, work was continued on new licensing issues raised by cybersecurity problems, new build and software platform qualifications, third party certification and software implications in the validation of programmable logic devices recently introduced, such as Field-Programmable Gate Arrays (FPGA).

3.3 Cooperation with technical safety organisations

3.3.1 EUROSAFE

In November 2015, Bel V hosted the EUROSAFE Forum for the fourth time. The EUROSAFE Forum, which is a co-organisation with IRSN, the Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) and the other EUROSAFE partners, brings together representatives of organisations specialised in nuclear and radiological safety techniques, research institutes, power companies, industry, public authorities and non-governmental organisations. Bel V participated actively in this Forum by chairing the EUROSAFE Programme Committee, by chairing the plenary session, by providing Seminar Chairpersons and by presenting several papers.

The EUROSAFE Programme Committee met three times in Brussels (January, May and at the occasion of the Forum), under the chairmanship of Bel V.

The EUROSAFE Tribune 27 on 'Going global: ETSON inputs to the 2014 IAEA TSO Conference in Beijing' (available at http://www.eurosafe-forum.org/#Tribune) reflects the active participation of Bel V in this event, mainly via the chairmanship of the Conference by the General Manager of Bel V.

In the EUROSAFE Tribune 28 on 'Severe accident management: new directives, new questions, new research' (also available at http://www.eurosafe-forum.org/#Tribune) Bel V contributed with a short statement on transboundary cooperation in emergency preparedness.

3.3.2 European Technical Safety Organisations Network (ETSON)

ETSON contributes substantially to all activities within the framework of the EUROSAFE approach (i.e. the Forum, Tribune and the public website), as well as to the work of strengthening the scientific and technical partnership. This work area applies to general or specific issues directly linked to the convergence of scientific and technical safety practices in Europe.

In July 2015, the General Manager of Bel V was elected as president of ETSON. The ETSON General Assembly and/or

Board met in Munich (July) and Brussels (November, at the occasion of the EUROSAFE Forum).

In 2015 the extension of the network was further explored and a new member organisation of Hungary (MTA EK) joined ETSON.

A Bel V representative continued chairing the ETSON Technical Board for Reactor Safety (TBRS) to oversee the technical activities of ETSON, such as the functioning of the ETSON Expert Groups and the publication of Technical Safety Assessment Guides (available at http://www.etson.eu/InformationCenter/Pages/Reports-Publications.aspx). In 2015, a new TSAG on Safety Fluid Systems was published.

Bel V representatives took active part in the ETSON Expert Groups, aimed at sharing views and experiences with colleagues of other technical safety organisations. Bel V is chairing the Expert Group on Ageing management.

In May, ETSON organised a workshop on 'Overview on the assessments of Earthquake/Flood and Provisions in case of Station blackout (SBO) or Loss of ultimate heat sink (LUHS), in the light of the Fukushima accident'. Bel V contributed by chairing a session and by delivering several presentations. A report will be published on the ETSON website shortly.

From 24 August until 28 August, several junior Bel V members of staff participated actively in the eight ETSON Summer Workshop in Villigen (Switzerland). The workshop was devoted to 'Material properties aspects in nuclear safety'. Bel V representatives participated by giving presentations and by coordinating work sessions.

3.3.3 European Nuclear Safety Training and Tutoring Institute (ENSTTI)

ENSTTI is an initiative of the European Technical Safety Organisations Network (ETSON). ENSTTI provides vocational training and tutoring in methods and practices required to perform assessments in nuclear safety, nuclear security and radiation protection. ENSTTI calls on European TSO expertise to maximise the transfer of knowledge and proficiency based on practical experience and culture.

Bel V is a member of this network. The General Manager of Bel V was President of ENSTTI until the end of 2014.

In 2015, Bel V staff lectured in the courses on 'Emergency preparedness and response' (June-July) and 'Management of spent fuel and radioactive waste' (November-December).

3.3.4 Collaboration with IRSN

Under the terms of the Cooperation Agreement between IRSN and Bel V, activities were continued, in particular in relation to the use of computer codes developed by IRSN, such as the Cathare code for thermal hydraulic analyses.

The collaboration with IRSN in the field of radioactive waste management was pursued in 2015. Three PhDs co-funded by Bel V and IRSN were followed: a first PhD thesis devoted to the study of radionuclide diffusion in concrete and in clay-concrete interfaces, taking into account the effects of 'high' temperature (up to 70°C, laboratory and in situ experiments in the IRSN Tournemire Underground Research Laboratory were performed); a second PhD thesis aiming at modeling the transport of chemical species in simple porous materials (sand, ...) undergoing porosity clogging or porosity opening phenomena; and a third PhD thesis devoted to the development of a new feedback law for modeling the impact of a porosity change caused by cement degradation phenomena on the cement transport properties (based on a detailed experimental programme performed at IRSN).

A new PhD co-funded by Bel V and IRSN was initiated in 2015 on the understanding and modeling of the perturbation induced by a plume of salts (that could be induced by bitumen waste degradation) on the transport of radionuclides in clay. Finally, in 2015 Bel V continued using the HYTEC code, obtained in the context of the Pôle Géochimie Transport (PGT) in which among others Bel V and IRSN participate, for the modeling of cement degradation phenomena.

3.4 Assistance projects of the European Commission

After the PHARE and TACIS programmes, the European Union has launched a new cooperation programme financed by the Instrument for Nuclear Safety Cooperation (INSC). The main objective is to promote a high level of nuclear safety, radiation protection and the application of efficient and effective safeguards of nuclear materials in third countries.

The first phase of this programme started in 2007. The second phase will cover the period 2014-2020.

3.4.1 Armenia

Bel V has cooperated with the Armenian Nuclear Regulatory Agency (ANRA) for many years through TACIS/INSC-financed projects. At present, Bel V is participating in the project AR/TS/07: 'Enhancement of the safety assessment capabilities of ANRA for licensing of Medzamor 2 safety improvements and decommissioning activities' (follow-up of the AR/TS/06 project). The project started in July 2013 and the inception meeting took place in September 2014.

In 2015, Bel V participated in task 5 of this project: 'Pilot decommissioning project and licensing related documentation'.

3.4.2 Morocco

Bel V participated as Technical Project Leader and also in tasks 1 and 3 of the first INSC project (MO/RA/01) with Morocco, which started in April 2011.

During the first progress meeting in Rabat in January 2012, it was decided to freeze the activities due to the delay in the promulgation of the law creating the new regulatory authority. Therefore there were no activities in 2012 and 2013. The project restarted in January 2014 with a new Technical Project Leader, due to the retirement of the Bel V Technical Project Leader.

Bel V participated in tasks 1 and 3 of the project:

- Task 1: Update of the Strategy Plan, the Action Plan and the Cooperation Plan in the field of capacity building for the enhancement of the National Regulatory Authority including an overview of the present situation;
- Task 3: Assistance in the field of regulatory framework.

The project was completed in April 2015.

3.4.3 Vietnam

Bel V participated in the first cooperation project between the European Commission and Vietnam. This project was initiated in July 2012. The general purpose was to develop and strengthen the legal framework as well as the managerial and technical capabilities of the Vietnam Agency for Radiation and Nuclear Safety (VARANS) and the local technical safety organisation.

Bel V was involved in Task 2 of the project, i.e. the development of a quality assurance system for assessment and verification of safety and regulatory oversight (internal regulatory guides and procedures).

The project was completed in May 2015.

3.4.4 China

Bel V is participating in the first INSC project between the European Commission and China (CH3.01/11), i.e. 'Enhancing the capacity and regulatory capabilities of the Chinese national nuclear safety authority and its technical support organisation'.

The agreement with the European Commission was signed in early December 2013. The project will last for three years. Bel V is involved in three tasks:

- Task 2.3: Independent evaluation, validation and verification of the safety of digital instrument and control systems used in nuclear power plants;
- Task 3: Safety culture and safety management (Bel V is acting as key expert);
- Task 5: Assessment of flood hazards.

The project includes training Chinese experts in Belgium and in China.

3.4.5 Philippines

Bel V is participating in the first INSC project between the European and the Philippines (PH3.01.09), i.e. 'Technical assistance for improving the legal framework for nuclear and strengthening the capabilities of the Regulatory Authorities of the Philippines (PNRI) and its technical support organisation'.

The agreement with the European Commission was signed in November 2013. The project will last for three years. Bel V is involved in subtask 1.2, supporting PNRI in the development of safety regulations.

3.4.6 Egypt

Bel V is participating in the second INSC project between the European Commission and Egypt (EG.01.10), i.e. 'Provision of assistance related to developing and strengthening the capabilities of the Egyptian Nuclear and Radiological Regulatory Authority (ENRRA)'. This project has been frozen for two years because of the political turmoil in Egypt.

The kick-off meeting of the project took place in November 2013. The project will last for three years. Bel V is involved in training the new Egyptian authorities to review the Preliminary Safety Analysis Report (PSAR) and the Environmental Impact Assessment Report (EIAR) of a nuclear power plant.

3.4.7 Thailand

Bel V is participating in the first INSC project between the European Commission and Thailand (TH3.01/13), i.e. 'Enhancing the capacity and effectiveness of the regulatory body and developing a national waste strategy'.

The kick-off meeting of the project took place in January 2015. The project will last for three years. Bel V is involved in the following tasks:

- Task 2: Regulatory framework;
- Task 3: Assessing and verifying the safety of nuclear facilities;
- Task 4: Human Resources Development Plan;
- Task 5: National strategy and regulatory framework for radioactive waste management.

3.4.8 Ukraine

Bel V is participating in an INSC project between the European Commission and Ukraine (U3.01/12) to support the Ukrainian Regulatory Authority.

The kick-off meeting of the project took place in October 2015. The project will last for three years. Bel V is task leader for component B of the project dealing with the licensing of a new nuclear subcritical facility – neutron source based on an electron accelerator-driven subcritical assembly.

3.4.9 Council Directive 2013/59/EURATOM

Bel V is participating in a project of the European Commission entitled 'Evaluation of Member States' strategies and plans for the transposition of the Basic Safety Standards Directive (Council Directive 2013/59/EURATOM)'.

The kick-off meeting of the project took place in June 2015. The project will end in September 2017. Bel V is responsible for task 5 on summarizing and evaluating Member States' strategies and plans to implement the Basic Safety Standards Directive.

4

Expertise management

Expertise management

4.1 Domestic experience feedback

Each year, Bel V performs a systematic screening of events at all Belgian nuclear facilities, as well as an in-depth analysis of a number of events with emphasis on root causes, corrective actions and lessons learned. In 2015 more than 70 events were registered into the domestic experience feedback database.

For a number of events a more detailed event analysis was performed with a view to identifying lessons learned which are potentially applicable to a wider range of nuclear facilities. These analyses resulted in 2 IRS reports, 1 IRSRR report and 1 FINAS report.

2015 was marked by the following events which were analysed in depth by Bel V and for which appropriate analysis, regulatory inspection and follow-up of corrective actions were carried out:

- inoperability of several safety trains of the essential raw water cooling system (ERWCS) combined with flooding of the ERWCS pump room at Doel 1/2;
- violation of Technical Specifications due to blocking of a containment isolation valve in open position following a spurious closure of the valve at Tihange 3;
- violation of Technical Specifications following a failed periodical closure test of a containment isolation valve at Tihange 3;
- fire in a filter of the ventilation system of a plasma cutter installation during decommissioning activities at FBFC;
- reactor trip during maintenance intervention on power supply to control rod drive mechanism at Tihange 3;
- safety injection in hot zero power during periodical test of valves in steam supply to the turbine driven auxiliary feedwater pump at Tihange 1;
- explosion and fire of power transformer at Doel 1.

4.2 Foreign operating experience feedback

In addition to screening domestic events, Bel V also performs a screening of events at foreign nuclear facilities as well as potential generic issues that are safety significant, require technical resolution by licensees or require generic communication to the licensees.

In this context, the Bel V Operating Experience Feedback coordination committee selects events resulting in either formalised Operating Experience Examination Request Letters (OEERL), Operating Experience Information Letters (OEIL) or follow-up inspections.

In 2015, following an in-depth analysis of nuclear industry guidance for effective prevention and management of system gas accumulation which was endorsed in 2014 by the USNRC, an OEERL was sent to the nuclear power plant licensees, requiring information on how this guidance is applied in Belgium.

Following an in-depth review of an IRS report relating to the icing of ventilation systems of nuclear auxiliary buildings after a loss of the hot water heating system at Chinon in 2012, specific follow-up inspections at Belgian nuclear power plants are scheduled for early 2016.

Together with the FANC, Bel V also performed an applicability review of a manufacturing deficiency of the forged domes of the reactor pressure vessel of the EPR reactor at Flamanville and requested the Belgian nuclear power plant licensees to produce a formal demonstration of the absence of similar deficiencies in the new reactor pressure vessel heads of Tihange 3 and Doel 4, which were installed during the 2015 outages.

In addition, a follow-up of former OEERLs occurred:

- 'Design vulnerability in electric power systems', initiated in 2012, required further discussions with the licensees and their architect engineer on the analysis of the consequences of unbalanced voltage in external grid supplies and of proposed protection system improvements;
- 'Non-compliance of component cooling systems in France', initiated in 2013, progressed with the review of utility responses and requests for additional information and analysis.

4.3 Knowledge management

For several reasons (one of them being that in the next 5 to 10 years several experienced Bel V staff members will retire), Bel V is attaching great importance to knowledge management. Various tools are used in order to generate, capture, transfer, use and store knowledge.

The Technical Responsibility Centres (TRC) continue to play a key role in knowledge management within Bel V. There are about 20 Technical Responsibility Centres, acting as 'centres of competence' for all important fields of expertise of Bel V. In line with developments in nuclear issues, new Technical Responsibility Centres are regularly set up (i.e. concerning decommissioning issues). Moreover, TRC management and operation is fully embedded in Bel V's Quality System.

In 2015, several new engineers were recruited. This requires considerable efforts on the part of the more experienced engineers to ensure an adequate transfer of knowledge. A coach is assigned to every newly recruited person, to facilitate their integration. This knowledge transfer approach is combined with, among other things, on-the-job training and cross-functional activities. The recruitment of a high number of new people also requires customised training (see Section 4.5).

Mention should also be made of the Bel V focus on knowledge transfer from retiring experts to younger staff. A Knowledge Transfer Form is used for this purpose. In addition, we also use a Knowledge Critical Grid that aims to identify and reduce the risk of knowledge loss. Other knowledge transfer tools (such as the 'Knowledge Books') are currently in the implementation phase.

Knowledge management is also closely linked to the R&D programme aimed at generating new skills, better ideas or more efficient processes (see Section 4.4).

The continuous implementation of the Bel V adapted Electronic Documentation Management software (KOLIBRI, based on Hummingbird DM) is an important tool for efficient retrieval of information, good knowledge sharing and easier integration of new members of staff. To this end, a specific committee known as the DOCumentation USers group (DOCUS) focuses on user needs analysis and on improvements.

4.4 Research and development

4.4.1 Management activities

The involvement in research and development (R&D) activities remains an important pillar for the continuous development and sustainability of Bel V's expertise. In 2015 as well, special attention was paid to the possibility of encouraging new R&D projects.

4.4.2 R&D on nuclear installation safety

Thermal hydraulic phenomena

In 2015, the thermal-hydraulic R&D activities covered Bel V participation in the OECD/NEA PKL, ATLAS and PREMIUM projects, the CATHARE and RELAP5-3D applications to typical Belgian nuclear power plants and MYRRHA contexts, as well as two papers and presentations in international journals and conferences.

In 2015, Bel V successfully organized (for the first time) the 7th OECD/NEA PKL-3 meeting. During this meeting Bel V delivered three presentations, mainly on the CATHARE 3D simulations of natural circulation tests carried out in the PKL and ROCOM facilities.

For the experimental OECD/NEA PKL-3 and ATLAS projects, Bel V submitted test proposals related to the assessment of the natural circulation flows and the 3D effects on mixing in the reactor pressure vessel. The proposals for the PKL-3 project were carried out successfully in the ROCOM and PACTEL test facilities. The ROCOM outcome allowed to assess phenomena taking place under asymmetric natural circulation flows in the vessel downcomer. On the other hand, the PACTEL test results emphasized the flow reversal phenomenon in the steam generator U-tubes during single phase natural circulation flow regime.

The outcome shows, for different flow conditions, that 30% of the natural circulation flow is reversed in the U-tube of the active steam generator.

For the OECD/NEA PREMIUM project for the development, study, comparison and application of methods for quantification of the uncertainty of the physical models contained in thermal-hydraulic system codes used in nuclear safety, Bel V participated in the final phase (phase V) of the project. In this phase, the main conclusions and lessons learned from the benchmark were drawn, and lines of future work were proposed and reported in the Phase V and Final report of PREMIUM.

The R&D activities related to the MYRRHA project by means of the RELAP5-3D model were carried out by considering pre-licensing evaluations related to the simulation of reactivity insertion (RIA), loss of forced reactor coolant circulation (LOFC) and loss of heat sink (LOHS) transients.

Other applications using CATHARE and RELAP3D for pressurised water reactors were also studied. A CATHARE input deck for a 3-loop nuclear power plant was used to carry out assessment studies of the natural circulation interruption (NCI) phenomenon. On the other hand, a RELAP5-3D input deck of a 3-loop pressurised water reactor was built.

Finally, two papers were published in 2015. The first paper entitled 'Experimental and Analytical Assessment of Natural Circulation Interruption Phenomenon in the LSTF and PKL Test Facilities' was published in the ANS Nuclear Technology journal. The second paper entitled 'Assessment of CATHARE 3D model in predicting the mixing phenomenon in a PWR reactor pressure vessel downcomer' was presented at the EUROSAFE Forum 2015 in Brussels.

Severe accidents

In 2015, considerable progress was made in developing MELCOR simulation capabilities at Bel V. A MELCOR model for a 3-loop pressurised water reactor plant was initially developed for MELCOR 1.8.6 and then converted to MELCOR 2.1 by means of SNAP. The main modeling efforts were focused on the core package and achieving stabilisation at full-power (steady-state analysis).

Moreover, modeling now also includes containment (MELCOR 2.1 code version only).

Bel V also made progress in the simulation of accident scenarios and the analysis of results for the following aspects:

- Stabilisation at full power for both MELCOR code versions 1.8.6 and 2.1;
- Results of Intermediate Break-LOCA (Loss Of Coolant Accident) transient analysis for both MELCOR versions 1.8.6 and 2.1;
- Comparison of the results of MELCOR 2.1 and CATHARE for an asymmetric cooldown transient for a 3-loop pressurised water reactor;
- Results of Large Break-LOCA transient analysis with MELCOR 2.1.

The MELCOR model developed by Bel V is suitable for steady-state and transient calculations (before fuel failure). Transient analysis (after fuel failure) has started.

Together with Tractebel Engineering and SCK•CEN, Bel V organized the European MELCOR User Group (EMUG) 2015 meeting on 17-18 March in Brussels. In addition to the organisation, Bel V contributed to the technical sessions.

An annual meeting of the steering committee to supervise Belgian participation in the USNRC programme on severe accident research was organised by Bel V, who holds the implementing agreement with the USNRC.

Bel V also attended the JRC Workshop on Severe Accident Simulators for Nuclear Power Plants, the 7th ERMSAR conference, the OECD/NEA PKL3 7th PRG meeting, the IAEA Technical Meeting on Severe Accident Mitigation through Improvements in Filtered Containment Venting for Water Cooled Reactors, the Cooperative Severe Accident Research Program (CSARP) meeting and the MELCOR Code Assessment Program (MCAP) meeting.

PSA methodology and its applications

Bel V had the opportunity to exchange information with IRSN on the PSA methodology for internal flooding.

The PSA Event Analysis (PSAEA) activities are still ongoing at Bel V. In 2015, these mainly consisted of a screening of the studies performed by Electrabel in order to determine whether an additional analysis by Bel V would provide added value. Bel V attended the 18th Technical Meeting on Experiences with Risk-based Precursor Analysis (Brussels, 28-30 October 2015). PSA-based Event Analyses performed by Electrabel for Belgian nuclear power plants and foreign organisations (power utilities, technical safety organisations) for nuclear power plants abroad were discussed.

Bel V attended the International RiskSpectrum User Group meeting (London, 11-12 November 2015) organised by Lloyd's Register Consulting.

Bel V attended two meetings of the ETSON PSA expert group. In particular, information was also exchanged on issues related to spent fuel pool accidents and on lessons learned from PSA by technical safety organisations.

The SPAR-H, THERP, ASEP, ATHEANA and IDHEAS methodologies as well as the differences between these methodologies and the fields in which they are applicable were studied. In particular, the specificities needed to implement HRA for PSA Level 2 and to introduce dependencies between Level 1 and Level 2 PSA models were investigated.

Fire protection

The involvement of Bel V in the OECD/NEA PRISME2 project continued in 2015. The participation in this project is considered extremely important in acquiring proper knowledge on fire behaviour in nuclear facilities such as smoke and hot gases propagation through horizontal openings, fire spreading on real fire source such as cable trays and electrical cabinet and fire propagation from one fire source to another, and fire extinguishing. During this project, the improvement of the heat release rate prediction is still considered particularly important. Based on experimental results, code guidelines to simulate complex fires, such as cable trays or electrical cabinets, are another important objective as there is a lack of knowledge on these types of fire sources and, following the assumptions of simulation, there is a considerable discrepancy in the results.

In the framework of the Ph.D. thesis funded by Bel V, preliminary simulations were carried out at Ghent University using the ISIS CFD software from IRSN in order to reproduce complex behaviour of enclosure fires, and in particular the oscillatory behaviour that was observed in some of the PRISME2 experiments. The numerical prediction of such behaviour has indeed been identified as challenging, and in addition to more insight into the origins of this phenomenon, could lead to a better understanding of the codes' capabilities and possible improvements.

4.4.3 R&D on waste and decommissioning

Waste disposal

In 2015 Bel V pursued its R&D activities aiming at strengthening its expertise in near-field models supporting the long-term safety assessment of a near surface disposal facility. Among others, considerable efforts were made to develop 2D unsaturated models representing possible evolution scenarios of the near-surface disposal facility. Bel V also updated the 2D models representing the near-field of the repository developed these last years to account for the repository expected evolution developed by ONDRAF/NIRAS and assessed by the regulatory body.

In the context of its participation in the Pôle Géochimie Transport (PGT IV), Bel V pursued the development of expertise in the understanding and modelling of reactive transport in porous media. For instance, Bel V organised a workshop on modelling reactive transport in cement for researchers from the Pôle Géochimie Transport.

Three PhD theses co-funded by Bel V were also followed-up: a first PhD thesis on the study of radionuclide diffusion in concrete and in clay-concrete interfaces taking into account the effects of 'high' temperature, a second PhD thesis aimed at investigating and modelling the transport of chemical species in simple porous materials (sand, ...) undergoing porosity clogging or porosity opening phenomena, and a third PhD thesis on the development of a new feedback law for modelling the impact of a porosity change caused by cement degradation phenomena on the cement transport properties. These PhD theses provide Bel V with results and information relevant for its own R&D activities (e.g. modelling of transport and reactive transport of radionuclide migration) and, more generally, for the long-term safety of waste disposal. Moreover, these PhD theses allow Bel V to strengthen its collaboration with other technical safety organisations (e.g. IRSN) and R&D organisations (e.g. CEA).

Finally, Bel V participates in 2 European projects (coordination and support actions) related to R&D for waste disposal that were started in 2015: JOPRAD (EU project on the development of a joint R&D programme at EU level) and SITEX II (development of a network of technical safety organisations and nuclear regulation authorities). In the latter project, Bel V leads the working group aimed at structuring the possible R&D activities of the network. Moreover, Bel V participated in several NEA and IAEA working groups related to the safety of radioactive waste disposal (e.g. NEA-IGSC, IAEA-PRISMA, IAEA-HIDRA, IAEA-GEOSAF II...).

All these R&D activities of Bel V contributed to maintaining and strengthening knowledge in waste disposal safety assessment and the skills related to the review of these safety assessments.

Decommissioning and dismantling

R&D activities in decommissioning project DriMa were fruitful to collect and organise information and experience that will prove to be useful for Bel V in preparing and organising the assessment of a large decommissioning project.

4.4.4 R&D on cross-cutting issues

Safety culture assessment

Bel V participated in the CNRA Senior Task Group on regulatory body safety culture. The publication of an NEA 'green booklet' on that matter is planned.

In addition, a Bel V model aimed at capturing regulatory body safety culture was developed.

Emergency preparedness

In view of enhancing Bel V's expertise and competence in emergency preparedness and response, various R&D activities were initiated at both national and international level. These initiatives were mainly focused on gaining more insight into software tools to be used for estimating the consequences of an emergency situation occurring at a nuclear facility.

Verification and validation

Bel V maintained and updated the guidance recommendations to ensure the validity of models and calculation results used in safety analyses, and to document the verification and validation activities. This guidance is used more and more often in various national and international projects of Bel V.

The problem of evaluating the safety of commercial software platforms used to support digital I&C applications was investigated. Safety criteria for managing safety cases in the selection and acquisition of such platforms have been identified.

Contributions on regulatory requirements related to the two topics mentioned above were made to the international regulators' common position on safety-critical software.

4.4.5 R&D collaboration with other institutes

R&D collaboration with Belgian universities

Vrije Universiteit Brussel (VUB)

A research agreement was signed in October 2012 with the VUB, which will undertake studies in the field of cognitive radio for nuclear power plants. This project will make a contribution to the emergency support plan. The objective is to improve communication links during emergencies that might promote a stronger emergency management.

Bel V has also collaborated with the VUB on the R&D project entitled 'Experimental analysis of flow-induced vibrations and application to the fuel rod bundle of the MYRRHA reactor'.

Université libre de Bruxelles (ULB)

Since November 2012, Bel V has been sponsoring an R&D project at the ULB, in the area of long-term safety assessment of radioactive waste disposal. This project relates to the modeling of the evolution of diffusion coefficients during degradation of cement used for waste disposal.

Ghent University

Since 2014, Bel V has sponsored a PhD thesis at Ghent University on the numerical study of oscillatory fire behaviour in mechanically ventilated confined enclosures. The PhD thesis aims to provide more insight into the underlying phenomena, using computational fluid dynamics (CFD) with liquid pools as fire sources (as in the experiments carried out for the PRISME project).

Université catholique de Louvain (UCL)

Two PhDs are sponsored at UCL:

- A first PhD thesis is related to numerical simulations of thermal fluctuations in the vicinity of a contact line between a free surface and a solid wall. The aim is to provide realistic models that can be implemented in conventional commercial codes, with application to the MYRRHA reactor.
- A second PhD thesis involves the numerical study of impinging jet flows and turbulent heat transfer in mixing layers with application to pressurised thermal shock situations in nuclear reactors. The aim is to strengthen expertise in algorithm development, modelling and quantitative simulation of PTS-related issues.

R&D collaboration with IRSN

Several R&D agreements were signed with IRSN in 2013, on a number of topics:

- radionuclides migration in waste disposal facilities – this R&D project is carried out together with ARMINES (France);
- development of a quantitative simulation tool taking into account chemistry and hydrodynamic transport to be used within the framework of the assessment of waste disposal facilities – this R&D project is carried out together with ARMINES, AREVA, EDF, LAFARGE and CEA (all France);
- radionuclide diffusion in clay – this R&D project is carried out together with CEA (France).

4.5 Training

A structured training approach has been adopted on the basis of the IAEA Systematic Approach to Training (SAT). Training programmes are developed for all staff members, and in particular for new hires, on the basis of the job descriptions and the relevant competencies needed. In this respect, Bel V has implemented the IAEA SARCoN model in order to properly assess the competence level of new members of staff and therefore to fine-tune our competence needs analysis.

The training programmes are implemented using different methods, depending on the availability of training materials and the adequacy of external courses: self-study, internal training sessions, external courses or on-the-job training.

A key element of the initial training of new members of staff is the programme of internal training sessions conducted by the Technical Training Manager with the help of experienced experts (mainly from Bel V) as lecturers. This programme comprises 35 training modules: 9 sessions took place in 2013, 8 in 2014 and 8 in 2015:

- Operational Safety
- MYRRHA
- Quality Management System
- Accident analysis – scope and boundaries
- Belgian legal framework
- Basic radiation protection
- International regulatory framework
- Summary description of Class III facilities

An example of an external training course with the participation of new members of staff at Bel V in 2015:

- Sûreté des centrales à eau sous pression (Institut national des sciences et techniques nucléaires, 1 week

In addition, Bel V set up so-called 'Internal Technical Sessions' aimed at distributing the R&D results of the Technical Responsibility Centres. In 2015, 4 Internal Technical Sessions were held.

Non-technical training sessions are also held as needed (language, IT, etc.) and a training programme (Interpersonal Effectiveness Development Path) was systematically offered in 2014 and 2015 in order to improve the communication skills of all staff.

Also worth mentioning is the participation of Bel V staff members in numerous specialised or refresher training activities, and in several working groups, seminars and conferences at international level.

In total, more than 60 training activities took place in 2015.

Financial report

Balance sheet as at 31 December 2015

(amounts in thousands of EUR)

		2014		2015
ASSETS		**13,231**		**13,722**
FIXED ASSETS		**6,028**		**5,652**
II. Intangible fixed assets		872		602
III. Tangible fixed assets		5,154		5,048
A. Land and buildings	4,953		4,792	
B. Plant, machinery and equipment	139		205	
C. Furniture and vehicles	62		51	
IV. Financial fixed assets		2		2
CURRENT ASSETS		**7,203**		**8,070**
VII. Amounts receivable within one year		2,994		3,136
A. Trade receivables	2,929		2,890	
B. Other amounts receivable	65		246	
IX. Cash at bank and in hand		4,018		4,700
X. Deferred charges and accrued income		191		234

		2014		2015
LIABILITIES		**13,231**		**13,722**
EQUITY		**8,820**		**9,485**
I. Capital		4,732		4,732
IV. Reserves		2,868		2,868
V. Profit carried forward		1,220		1,885
DEBTS		**4,411**		**4,237**
VII. Amounts payable after more than one year		1,000		500
IX. Amounts payable within one year		3,410		3,736
A. Current portion of amounts payable within one year	500		500	
C. Trade debts	204		500	
D. Advances received on contracts in progress	1,541		1,500	
E. Taxes, remuneration and social security	1,165		1,236	
F. Other amounts payable				
X. Deferred charges and accrued income		1		1

Financial report

Profit and loss account as at 31 December 2015

(amounts in thousands of EUR)

	2014	2015
Turnover	11,608	12,746
Other operating income	142	241
TOTAL OPERATING INCOME	**11,750**	**12,987**
Services and other goods	1,983	2,534
Wages and social security costs	8,791	9,201
Depreciation	511	494
Write-downs on trade receivables		
Other operating charges	98	95
TOTAL OPERATING CHARGES	**11,383**	**12,324**
Operating result	**367**	**663**
Financial charges and income	5	4
Profit on ordinary activities	**372**	**667**
Profit for the financial year	**372**	**667**

Profit and loss account: notes

In 2015, our activities continued apace, yielding an 8% increase in our turnover.

Operating income

Turnover

In 2014, the largest part of the turnover of Bel V (95%) was again related to the regulatory inspections and safety assessments in Class I facilities, which are invoiced on the basis of a rate which has been agreed with the FANC and which covers the costs of our services. This year was once again marked by activities linked to the implementation of the action plans based on the stress tests, by continuing the analysis of the confirmation dossier on the flaw indications in the vessels of two reactors, as well as by the ten-year reviews at Doel 4 and Tihange 1 and 3. Moreover we observed an increase of our activities in the Doel 1/2 Long-Term Operation project.

A small part of the turnover (2.2%) derives from contracts with the European Commission for support to nuclear safety authorities in Eastern European and emerging countries. Regulatory inspections were also carried out in some Class II facilities (the future Class IIA).

Other operating income

Other operating income is not actual revenue, but consists principally of contributions by staff for the private use of company cars and for the provision of meal vouchers. This year we received a contribution for the organisation of the EUROSAFE Forum 2015 in Brussels.

Operating charges

Services and other goods

Services and other goods represent 21% of the charges. This year, our expenditures in research and development represent 4.7% of our operating charges.

Wages and social security costs

Staff expenses represent 75% of our costs, including training expenses.

Financial charges and income

Financial income comes from cash investments.

Operating result

Operating result for the financial year has been allocated to retained earnings.

List of abbreviations

ANVS	Autoriteit Nucleaire Veiligheid en Stralingsbescherming (Netherlands)
ASN	Autorité de Sûreté Nucléaire (France)
BEST	Belgian Stress Tests
CEA	Commissariat à l'énergie atomique et aux énergies alternatives (France)
CNRA	Committee on Nuclear Regulatory Activities (OECD)
CSNI	Committee on the Safety of Nuclear Installations (OECD)
DG Crisis Centre	Directorate-General Crisis Centre of the Federal Public Service Interior
ENSREG	European Nuclear Safety Regulators Group
ENSTTI	European Nuclear Safety Training and Tutoring Institute (ETSON)
ETSON	European Technical Safety Organisations Network
FANC	Federal Agency for Nuclear Control
FBFC	Franco-Belgian Fuel Fabrication
FINAS	Fuel Incident Notification and Analysis System
HERCA	Heads of European Radiological Protection Competent Authorities
IAEA	International Atomic Energy Agency
INSC	Instrument for Nuclear Safety Cooperation (European Commission)
IRE	National Institute for Radioelements
IRRS	Integrated Regulatory Review Service (IAEA)
IRS	Incident Reporting System
IRSN	Institut de Radioprotection et de Sûreté Nucléaire (France)
IRSRR	Incident Reporting System for Research Reactors
KCD	Kerncentrale Doel – Doel nuclear power plant
LTO	Long-Term Operation
NEA	Nuclear Energy Agency (OECD)
NRC	Nuclear Regulatory Commission (US)
NUSSC	Nuclear Safety Standards Committee (IAEA)
OECD	Organization for Economic Cooperation and Development
ONDRAF/NIRAS	Agency for Radioactive Waste and Enriched Fissile Materials
PSA	Probabilistic Safety Assessment
PSR	Periodic Safety Review
R&D	Research & Development
SCK•CEN	Studie Centrum voor Kernenergie – Centre d'études d'Energie Nucléaire (Mol)
TBRS	Technical Board for Reactor Safety (ETSON)
TRC	Technical Responsibility Centre (Bel V)
TSO	Technical Safety Organisation
TSOF	Technical and Scientific Support Organization Forum (IAEA)
WENRA	Western European Nuclear Regulators Association

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