

BEL ✓

ANNUAL REPORT  
2016



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# 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 FANC delegates activities in the field of nuclear safety and radiation protection. It contributes to the protection of people and the environment against the danger of ionising radiation on the basis of experience built up over more than 50 years. It is financed exclusively by its clients, which are essentially the facilities which it monitors. The operating income has been rising for several years, reaching more than €700,000 in 2016.**

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.

Bel V has for several years been strengthening its capacity for evaluating licensees' safety culture and, in particular, the human and organisational aspects. This expertise has been very useful for monitoring the problems at Tihange. Following the court summons drawn up by the FANC in August 2015, the licensee carried out an analysis of the underlying causes which led to this situation, in view of establishing a structural action plan. Bel V also provided technical support to the FANC for monitoring the development and implementation of this action plan.

In 2016, special attention was paid to the issue of radioactive waste management by the various nuclear licensees. Here are some examples:

- Authorisation of the evacuation of radioactive waste at the Doel and Tihange sites was not extended by ONDRAF/NIRAS after an audit that ended in an unsatisfactory result. This led to an accumulation of waste in the facilities. Bel V verified that this accumulation did not pose any threat to the safety of the operation.
- The activities relating to the problem of the gel drums from the Doel nuclear power plant that are currently stored at the Belgoprocess site are closely supervised by Bel V. Logistical works relating to the transfer and inspections of the drums were continued in the storage building. The preliminary consultation on the new storage building for non-compliant packages is under way.
- In collaboration with the FANC, Bel V has been involved in analysing the licence application concerning the future facility for the disposal of low and intermediate level short-lived radioactive waste in Dessel. Within the framework of the long-term safety evaluations, Bel V continued its activities (using its own modelling capacity) of independent safety verification.

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 2016, the Board of Directors 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** | member



# EDITORIAL

**Over the years, Bel V's operating method has evolved, with greater emphasis placed on processes and less on the hierarchical structure. Bel V's management system is made up of around ten different processes, covering activities such as: inspection, safety analyses, project management and developing expertise, as well as support processes (human resources, finance, logistics, IT). This system meets the requirements of the International Atomic Energy Agency (IAEA) standards and the ISO 9001 standard.**

A process-based working method is intended to make everyone aware of his or her role in the organisation and his or her contribution to the achievement of the company's objectives, as opposed to a working method that gives pride of place to the hierarchical structure and obedience to the head. At the end of 2016, the decision was therefore taken to redraw the organisation chart to bring it in line with the process-based operating method as developed within Bel V. The new organisation chart is available on our website.

The year was marked by an unusual event: following civil engineering works at Tihange 1 implementing a technique of cement injection into the ground, damage was observed in an adjacent building. In particular, the plant had to be shut down because the base of a safety-related pump had shifted. The investigations of the causes of the event showed, on the one hand, that the contractor did not respect the specifications imposed, and on the other hand that the subsoil was not as expected. The backfill, which dates back to the time when the plant was built, is not as described in the safety report. It is made up of inadequate materials, raising doubts as to the capacity of the buildings erected on it to resist earthquakes. At the end of 2016, the problem had still not been resolved. This event, like the discovery of hydrogen flakes in the Doel 3 and Tihange 2 reactor pressure vessels, brought to light non-compliances that were present from the outset but never detected.

Improving the safety of nuclear facilities is an ongoing concern. The lessons learned from the incidents and accidents (in Belgium and abroad) are a major source for identifying improvements aimed at preventing a recurrence of potentially dangerous situations. The BEST project (described in § 2.5), launched following the accident at Fukushima-Daiichi, gave rise to the implementation of substantial improvements that will help deal with extreme situations such as total loss of electric supply and cooling, and to significantly limit the radiological consequences of any serious accident. Moreover, the periodic safety reviews and Long-Term Operation (LTO) projects (described in § 2.2, 2.3 and 2.4) intended to achieve a safety level that allows for the continued operation of the plants also provide an opportunity to improve safety in order to come as close as possible to the level of modern plants. All of Bel V's expertise is needed to analyse these files and promote the ongoing improvement of safety. The result is that the Belgian nuclear plants, even the oldest among them, now achieve a much higher safety level than originally.

In sum, Bel V continues to develop its expertise, in breadth and depth, and draws on this expertise in the context of the missions delegated to it by the FANC.

**Benoît DE BOECK, Ir**  
General Manager

1

REGULATORY  
ACTIVITIES  
IN BELGIUM

2

SAFETY ASSESSMENTS  
AND NATIONAL  
PROJECTS

3

INTERNATIONAL  
ACTIVITIES AND  
PROJECTS

4

EXPERTISE  
MANAGEMENT





# 1

## INTRODUCTION

MICHEL VAN HAESENDONCK

## Nuclear power plants

Given that in 2016 a number of observations were once again made that elicited questions about the safety culture at the Belgian nuclear power plants, last summer the Federal Agency For Nuclear Control (FANC) addressed a number of letters to the general management of ENGIE Electrabel. These letters led to additional initiatives above and beyond the series of corrective measures that were introduced mid 2015 following the court summons that the FANC had drawn up. Bel V carried out many specific inspections in the context of the follow-up of the proposed initiatives and corrective measures.

For both Doel 1/2 and for Tihange 1, Long-Term Operation (LTO) projects are under way. Extensive action plans were developed for those units. Specific files were examined and inspections were carried out in the context of the follow-up of these action plans.

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 has been initiated 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 2016, Bel V devoted particular attention to the storage conditions and capacity for the various waste streams at the Doel and Tihange sites. After an audit conducted by ONDRAF/NIRAS, authorisation was withdrawn for various sorts of waste.

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. In 2016, specific inspections were carried out at Doel and Tihange to monitor the implementation of these modifications.

## 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 still closely monitored by Bel V.

As regards the BR2 research reactor, the various projects concerning the extension of operation beyond 2016 were

closely monitored. Given that the projects were running very successfully, Bel V was able, in mid-2016, to give the green light for the restart of BR2.

At Belgonucleaire, 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 ongoing: 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 Franco-Belgian Fuel Fabrication (FBFC) facilities continued in 2016 and required close monitoring by Bel V.

In view of the various problems experienced by NTP Europe at the Fleurus site, Bel V together with the FANC monitored that site intensively during most of 2016.

## Integrated strategy for control

The integrated strategy for inspection (by the FANC) and control (by Bel V) was applied in 2016.

The 2016 inspection programme was sent to the facilities at the end of 2015. In the course of the programme, which was monitored against key performance indicators, special attention was paid to the numerous action plans, waste management, human factors and human performance, safety management and the safety culture.

Bel V constantly seeks to learn lessons from the events and incidents that occur in order to further improve its inspections in the future. Our inspections were further reinforced by means of an action plan.



# 1

## REGULATORY ACTIVITIES IN BELGIUM

### 1.1 Overview of inspections at nuclear power plants

#### 1.1.1 Doel 1/2

Doel 1 operated at nominal power throughout the year, except for the following periods:

- On 2 January, the unit scrammed as a result of the tripping of an alternator safety mechanism. When Doel 1 started up again on 3 January, the transition from using an off-site power supply to the unit's internal power supply failed. In accordance with the procedures, the reactor was scrammed manually.
- Over the weekend of 12 and 13 February, the unit underwent a planned shutdown for the repair of the grounding of the main transformers.
- On 6 April, the unit scrammed due to a rapid decrease in neutron flux as a result of a fallen control rod. The unit was reconnected to the network on 8 April.
- On 12 April, the unit was shut down voluntarily for the repair of a primary leak. During the shutdown, it was determined that the drive mechanism of the control rod that fell down on 6 April needed replacing. The unit could therefore be reconnected to the network only on 20 May.
- From 23 September to 24 October, the unit was stopped for refuelling. When it was restarted, a test generated a scram that was noticed late, as a result of which

the technical specifications actions were also carried out late.

- On 11 and 12 November, the unit was shut down voluntarily for the repair of a primary leak.

Doel 2 operated at nominal power throughout the year, except for the following periods:

- From 8 April to 22 June, the unit was stopped for refuelling. During the refuelling, a few people were externally contaminated when cleaning a tank at Doel 2. This was noticed only when the persons concerned entered the controlled area of Doel 4.

In July 2016, a shortcoming was identified in the environmental qualification of a number of safety-related transmitters. Continued operation was temporarily justified for Doel 1 and Doel 2 and the necessary corrections for Doel 1 were carried out during the outage. The necessary corrections for Doel 2 will be carried out in 2017.

On 9 August, it was noticed that the control valves of the steam generators' safety-related auxiliary feedwater circuit were closed, as a result of which the technical specifications of the circuit were not met.

### 1.1.2 Doel 3

Doel 3 operated at nominal power throughout the year, except for the following periods:

- 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. Nominal power was again reached on 6 January 2016.
- On 21 April, an automatic reactor trip occurred due to a turbine trip. After this reactor trip, a rupture appeared in two classified instrument pipes in the secondary circuit. This caused the unit to remain in hot shutdown for maintenance until 23 April.
- The annual refuelling and maintenance outage took place between 14 October and 10 December.

In July 2016, a shortcoming was identified in the environmental qualification of a number of safety-related transmitters. Continued operation was temporarily justified and the necessary corrections were carried out during the outage.

During the outage, a follow-up inspection of the reactor pressure vessel was carried out. This did not show any change in the hydrogen flakes. The safety authority then issued a favourable opinion regarding the restart of the new cycle.

### 1.1.3 Doel 4

The reactor operated at nominal power throughout the year except during a scheduled hot shutdown from 20 to 22 March and on 20 and 21 August because of work on the 380 kV post as part of the Brabo project aimed at reinforcing the external 380 kV network around the Doel site and the port of Antwerp. The unit has been experiencing (manageable) problems with the control rod drive mechanism since the reactor vessel head was replaced during the previous outage. However, the problems noted have not had any impact on the safety function of the control rods (the ability to fall by gravity in the core).

### 1.1.4 Doel common (WAB, SCG)

**WAB:** The radiological authorisation of the waste disposal was not extended by ONDRAF/NIRAS after an audit that ended in an unsatisfactory result. This led to an accumulation of waste in the WAB facility. Despite the necessary efforts, the radiological authorisation has not yet been extended. Given the absence of radiological authorisation, and because no processes are available for the conditioning of concentrates and resins, Bel V is focusing on the monitoring and extension of the waste storage capacity and buffer capacity for both concentrates and resins. A limited buffer for the storage of concentrates has always been present and a considerable extension was completed in 2015-2016. Additional efforts have to be made in 2017. The buffer for resins is very limited, and the project on extending this capacity has experienced considerable delays (due in part to the death of the project manager at ENGIE Electrabel). In order to bridge the period until the project is completed, ENGIE Electrabel suggests an interim solution for 2017, which entails a few risks. Bel V will provide the necessary monitoring for this (including formalisation).

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.

To date, the operation of the WAB facility has not been affected. The buffer available for storage of almost all types of waste is more or less completely used up, and allows for no margin within the standard limits for breakdowns and maintenance. Such a situation would be sustainable only on a temporary basis.

**SCG:** The introduction of a new type of storage container (HOLTEC) is under way, but has made little progress. Quality control of the containers delivered has been enhanced. The delivery of new containers (of the existing approved type) with the accompanying equipment and certificates (seal pressure monitoring) is still experiencing difficulties.

### 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, releases, ASME, 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 and the inspections relating to 'waste', 'radiation protection' and 'maintenance and ageing'. Support was also provided to the FANC for monitoring the drawing up and implementation of the action plans for the two sites and Corporate, in the wake of the events at the Tihange nuclear power plant that led to a court summons. These action plans have been further grouped into a single action plan.

It is also worth mentioning the monitoring of the action plan resulting from the common decennial review completed at the end of 2011 and the action plan in the context of the periodic safety reassessment for Doel 3 and Doel 4 (and Doel 1/2, included in the LTO action plan), which resulted in changes to facilities, procedures and the safety analysis report.

### 1.1.6 Tihange 1

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

- an outage from 7 February to 13 March, due to the rupture of a pump shaft;

- an outage for refuelling and LTO from 30 April to 13 August; around half of the safety equipment was replaced, the first half having already been replaced in 2015;
- a reactor trip on 13 August, due to a flaw in an electronic card;
- an outage from 7 September to 31 December at least, due to soil heave in one building (after civil engineering work) rendering one pump unavailable.

One event is worth mentioning:

- a maintenance operation on a faulty valve, rendering one diesel unavailable.

### 1.1.7 Tihange 2

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

- a brief power transient of up to 60 MW on 24 January following a problem in a system of secondary circuits;
- a brief power transient (of the order of 50 MWe) on 10 April;
- a reactor trip on 10 June following the loss of a lubricant pump from the turbine bearings (non-safety related circuit) after an electrical flaw; nominal power was restored on 18 June;
- a voluntary power reduction on 30 June, with a view to carrying out a vibration diagnosis on a primary pump; after the diagnosis, the unit was reconnected to the grid on 2 July;
- a hot shutdown on 8 July following a problem in a system of secondary circuits;
- a reactor trip on 9 September following the spurious closure of a valve in the water supply circuit of the steam generators; the unit was reconnected to the electric grid on 10 September.

### 1.1.8 Tihange 3

The 2016 unit outage for refueling began on 11 September - preceded by a stretch-out period of five days - and ended on 31 October.

The unit operated at nominal power for the rest of the year.

A new court summons was served by the FANC in June 2016 following an event (unavailability of a radioactivity chain) whose impact on safety was insignificant but for which human and organisational implications were identified (see also the 'Tihange site' section for the establishment of a structural action plan).

### 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 (qualification of specific materials, ventilation, etc.).

Following the court summons drawn up by the FANC in August 2015, the licensee carried out an 'analysis of the underlying causes' which led to this situation, in view of establishing a structural action plan. Bel V also provided technical support to the FANC for monitoring the development and implementation of this action plan. It should be noted that the action plans, initially drawn up separately for Tihange, Doel and the Corporate, have since autumn 2016 been integrated into a single action plan.

An audit conducted by ONDRAF/NIRAS has produced a negative result, which prompted this organisation to suspend all licences issued for unconditioned waste. Licensing for transporting conditioned waste was also suspended. Bel V carefully verified that these suspensions would not threaten the safety of the operation as a result of an accumulation of waste at the facilities (due to increased risk of fire, etc.).

## 1.2 Overview of inspections at other nuclear facilities

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

The refurbishment of the BR2 reactor was successfully completed in June 2016. The following important operations took place during this refurbishment:

- The beryllium matrix was unloaded from the reactor and the reactor pressure vessel was cleaned.
- An inspection of the reactor pressure vessel was carried out and the results were satisfactory.
- New beryllium channels were loaded into the reactor pressure vessel.
- The reactor measurement chains and the control rods were all checked.
- The underground secondary pipes were replaced.
- The ventilation pipes were checked.
- The experimental CALLISTO loop was dismantled following decontamination.
- A new diesel tank was installed.

During the refurbishment, there was a release of basin water into a well on the site outside the control zone. The water and soil samples in the well were all beneath the limits for release. The release was caused largely by an inadequate application of the procedure for works on pipes.

After the refurbishment, the BR2 reactor was started up on 1 July for a successful five-day 00/2016 test cycle. The operating regime of the BR2 reactor in 2016 then consisted of 2 cycles of 3 weeks and 1 cycle of 4 weeks.

During the 03/2016 cycle, the BR2 reactor was shut down due to a defect in a primary pump. After starting up the backup pump, the reactor was restarted and the rest of the cycle proceeded without any problem.

On 25 November, a takeover of the diesels took place as a result of the interruption of the connection with the external electrical grid.

The VENUS reactor was loaded with fuel assemblies with bismuth (instead of lead). The experimental programme is proceeding with the study of the disturbances of this core configuration.

In April 2016, a contamination incident took place in the cutting workshop and the adjacent control area of BR3. The contaminations were removed and the cutting workshop was once again operational on 18 May.

No significant events occurred in the other SCK•CEN facilities in 2016.

### 1.2.2 Belgoprocess

Monthly reports on the activities relating to the problem of the gel drums from the Doel nuclear power plant were made to Bel V. Logistical works relating to the transfer and inspections of the drums were continued in building 151X. The preliminary consultation on the new storage building for non-compliant packages is under way.

In 2016, the Scientific Council issued a provisional, reasoned favourable opinion concerning the extension of the license for the dismantling of site 1.

At the beginning of February, the Cilva oven was successfully restarted after the replacement of the boiler. Between June and October, the Cilva supercompactor was successfully replaced. The NCP (Nuclear Chemical Plant Ltd) evaporator in building 108X was restarted for a test campaign which ran until the end of 2016.

Upon the transfer of fluids from the SCK•CEN to Belgoprocess on 3 February, a leak was identified in the transfer pipe in the basement of building 234A (BRE). The leak was repaired and additional measures were drawn up for future transfers of waste water.

During works on the pipe for transporting B01 waste water between site 1 and site 2, on 8 April a contamination of historical origin was noticed in a well.

On 10 May, a tritium release above the concentration limits was identified from building 250B. Contamination measurements in the building indicated that the release originated from a box of broken H3 ampoules.

On 22 June, an operator sustained an external contamination with radon gas when removing the cover of a 400-liter drum with sources in the Stelcon hall.

In October, well corrosion was identified on the welds of the liquid tanks in building 280X. The processing in building 280X is currently shut down and the tanks will be replaced.

On 8 November, during the rinsing of a UF6 cylinder, a joint of the water supply came loose, as a result of which a limited amount of rinse water was released.

### 1.2.3 Belgonucleaire

The rooms in building A were further emptied out and stripped in preparation for measuring the releases in those spaces. At the same time, dismantling of the underground pipe network in building A began. The release methodology for building A (described in an operational procedure with underlying technical notes and working instructions) was discussed with the FANC and further refined based on the

measurement results and findings in the selected test areas, taking account of the remarks and questions of the FANC and Bel V. This led to an approval of the methodology in August 2016. A gradual, controlled dismantling of the room extraction in building A was started, in accordance with the progress on the dismantling activities in the various rooms and the associated ventilation requirements.

Major efforts were made to keep detailed records of all release measurements in the specific data management system, with a view to compiling a dossier on releases for each room.

Belgonucleaire also began the preparations for the release of the site.

There were no radiological incidents. Belgonucleaire continues to focus on retaining the necessary qualified persons on site.

### 1.2.4 National Institute for Radioelements (IRE)

The checks carried out by Bel V in 2016 were related to different projects:

- The level of waste (including historical waste) stored in Fleurus was considerably reduced and the situation is close to normal.
- The IRE is also involved in the development of a new production line using low-enriched uranium (LEU) instead of highly enriched uranium (HEU).
- The second periodic safety review by the IRE was started and will have to take into account conceptual margins in order to reinforce the design of the installation.
- A new director was appointed for the maintenance department of the IRE.

### 1.2.5 JRC-Geel

In July 2016, the Institute for Reference Materials and Measurements (IRMM) changed its name to JRC-Geel as part of a global reorganisation of the Joint Research Centre (JRC) (treated as a non-important modification still going through the approval process).

In 2016, no significant events were reported by the licensee.

Operation of the LINAC, the mass spectrometry department, the main building, the waste building and the five X-ray devices in the CRM 130 building ran smoothly.

During the summer, the Van de Graaff machine was replaced by a new Tandem accelerator (treated as a non-important modification), which should be commissioned in the course of 2017.

The first drafts of the JRC-Geel Safety Analysis Report (SAR) were received and general comments were submitted by Bel V. A revised consolidated version is due to be received in the first half of 2017.

The follow-up of the implementation of the PSR and BESTA (Belgian Stress Test) actions showed slow progress on some of the remaining open actions. This is monitored closely by the regulatory body.

### 1.2.6 Franco-Belgian Fuel Fabrication (FBFC)

The dismantling of buildings 1, 2 and 5 continued in 2016.

Further to an unannounced inspection by the FANC and Bel V, the FANC drew up a FANC decision on 29 January ordering the immediate halt to the activities relating to the release of radioactive materials. After all the actions

imposed by the FANC had been carried out, the decision was lifted on 12 May and the release activities could be restarted.

In building 1 (lab) and building 2 (GADO), most of the dismantling activities were completed in 2016 and release measurements were carried out.

Removing and measuring the foundations of building 3 continued in December 2016.

The dismantling of building 5 continued in 2016.

The approval of the methodology and release files for buildings 1, 2, 5 and 5M and the FBFC site is scheduled for 2017.

On 17 October, a tank (T4) overflowed, and as a result, slightly contaminated water ended up in the brick containment basin.

The adjustment to the organisation was discussed in consultation with the FANC, with particular attention to the Health Physics department and the associated safety functions. A modified organisation, to be applied as from 1 January 2017, was approved.

The development of a sorting facility for monitoring contaminated soil as part of the soil decontamination of the site is ongoing.

### 1.2.7 Other (Class II and III) facilities

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

No accidents were recorded in 2016.

Due to an unstable situation at NTP Europe, Bel V has considerably increased the frequency of its inspections.

Radioactive waste stored on site, and sometimes in public institutions such as universities, remained a point of attention for Bel V.

The radioactive waste characterization and 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 license.

### 1.3 Emergency preparedness and response

#### 1.3.1 Emergency response exercises

In 2016, 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 IRE nuclear facility: partial exercise limited to the interaction between the emergency crisis cell of the licensee (on-site) and the evaluation cell CELEVAL (off-site);
- in November for the Tihange nuclear power plant: 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).

All these exercises were prepared, conducted and evaluated according to the current 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 Tihange exercise (a Bel V representative was appointed as member of the exercise management team). A Bel V representative was also involved in a workshop for first responders, a dedicated Table-top 'Information flows' and an 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) organised by the FANC.

#### 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 emergency 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. After consultation of various stakeholders, it is expected to deliver a consolidated proposal for a revised version of this plan in the course of 2017.

### 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).
- A Bel V representative participated as Trainer in a Train-the-Trainer session regarding the emergency response arrangements for first responders (Brussels, April 2016).
- A Bel V representative participated as Trainer in a dedicated workshop for first responders of the Province of Namur (Jambes, April 2016).
- Bel V is involved in a 'Horizon 2020 Framework Programme for Research and Innovation' project coordinated by the French Institut de Radioprotection et de Sûreté Nucléaire (IRSN) (FASTNET project: FAST Nuclear Emergency Tools). This project started in 2016 and will 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 (Fontenay-Aux-Roses, June 2016);
- Exchange meetings between German, Dutch and Belgian authorities (Brussel, April and July 2016 and Düsseldorf, November 2016).

2

# INTRODUCTION

MARC DUBOIS



The year 2016 yielded the usual significant number of projects and safety assessments in the Belgian and international contexts. Bel V is continuing its activities of supervising safety dossiers resulting from major projects (PSRs, LTO, stress tests, waste storage facilities, PSAs, Myrrha, etc.) at the various Belgian facilities, which concern, as the case may be, the relevant action plans, the prelicensing phase, the licensing phase, etc. In order to handle the safety dossiers in a useful and satisfactory manner, it is essential to simultaneously render the organisation of Bel V even more efficient, improve our specific operating processes and maintain and develop a high level of expertise.

Thus, the organisation of Bel V was revised in order to place greater emphasis on its operating processes than on its structure. The employees of Bel V are thus integrated into each process more in terms of the role they are to play in the latter than by virtue of their position within the hierarchical organisation.

In the same vein, the processes are regularly revised and improved thanks to the quality management system. Moreover, more effective management tools are developed in order to usefully manage the growing workload and to set priorities.

The level of expertise is monitored and assessed in a specific process which considers especially the management and transfer of knowledge as well as active participation in working groups and international projects. In addition, a graded approach to safety is being developed so as to be used correctly and to be properly documented.

These various axes of continuous improvement are translated into the Bel V operating plan, while bearing in mind the evolving context of the nuclear safety sector, namely, regulation, the management of ageing and of waste, peer review, and the demands of the authorities and of the licensees.



# 2

## 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, and as required by the Royal Decree of 30 November 2011, ENGIE Electrabel and Tractebel Engineering continued their efforts to develop Internal Fire and Internal Flooding PSA models for the Belgian nuclear power plants. These PSA models include a plant-specific PSA Level 1 for each Belgian unit (including Doel 1/2, for which the development of Fire and Flooding PSA models was first cancelled due to the permanent shut-down originally scheduled for 2015, but then re-started in 2016 due to the lifetime extension of both units) and a PSA Level 2 for a representative unit (Doel 3). All plant operating states are covered. In 2016, Bel V continued the review of the development of the Flooding PSA for all units and drafted its evaluation report on this project. For the Internal Fire Level 1 PSA, Bel V focused on the analysis of the results obtained at the end of 2015 for the first phase of the project (which consisted in obtaining initial raw results based on a bounding plant response, i.e. by taking into account conservative modelling and hypotheses, e.g. related to the assessment of the impact of the fire on cables or the calculation of fire propagation through the

different plant compartments). Bel V also began the review of the approach proposed by the utility company for the second phase of the Level 1 Fire PSA project with a view to obtaining more realistic and usable results. In 2016, Bel V also monitored the Fire and Flooding PSA Level 2 project and drafted its evaluation report on this project.

At the same time, Bel V reviewed the update (incorporation of recent data and plant modifications) and the upgrade (improvements of certain methodological aspects) of the existing internal event Level 1 and Level 2 PSA models. In 2016, the synthesis report on the incorporation of the recent Belgian Operational Experience Feedback into the Level 1 PSA model for Doel 3 and the documentation of the interface to the internal event Level 2 PSA model for Doel 3 (which also includes the incorporation of the modifications performed during the upgrade of the Level 1 PSA model for Doel 3) were delivered to Bel V. Nevertheless, these projects were later suspended due to the considerable high-priority workload on the refinement of the Level 1 Fire PSA models. These projects will be continued at the beginning of 2018.

In 2016, within the context of the 4th Periodic Safety Review of Doel 1/2, Bel V assessed the analysis of the utility company related to Safety Factor 6 (following Specific Safety SSG-25 of the International Atomic Energy Agency (IAEA)). This resulted in an action plan that will be implemented during the upgrade of the Level 1 and Level 2 PSA models of Doel 1/2.

Through the annual meeting with the PSA Standing Committee of ENGIE Electrabel and Tractebel Engineering, Bel V monitored the use of the PSA models by ENGIE Electrabel for various PSA applications. In particular, Bel V checked 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, as well as the use of the PSA results as input for the training programme of the licensees on both sites). In 2016, Bel V also discussed the revised policy of the utility company for PSA developments and the use of PSA as a tool for the global safety assessment within the framework of the Periodic Safety Reviews.

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 the '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  
All assessment reports for Doel 1/2, 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 the assessments were discussed with the licensee. The resulting action plans were approved by the FANC; their implementation by the licensee has begun.
- The preparatory phase of the second Periodic Safety Review of the IRE was completed. The documents describing the methodology for evaluating the 15 safety factors were reviewed and approved by Bel V at the end of December 2016. The evaluation of the 15 safety factors will start in January 2017 and is scheduled to be completed by the end of 2018. The progress of the evaluation phase will be monitored by Bel V.

- The 2016 periodic safety reassessment (PSR) by SCK•CEN was conducted by the licensee in line with the previously determined schedule, and was completed on 1 July. Next, Bel V carried out its analysis of the overall assessment and submitted it to the FANC. The results of the analysis were presented to the FANC's Scientific Council for an opinion during its session of 9 December. The Council issued a favourable opinion on the decisions submitted and the associated action plan for their implementation.
- As part of the decennial safety review at Belgoprocess Site 2, the evaluation reports for the 14 individual safety factors were received on 30 June, as was the overall evaluation report, including an action plan. In the following months, these documents were analysed by Bel V. The analysis resulted in 15 safety evaluation reports which were submitted to the FANC and the licensee. After this, various discussion meetings were held between Bel V and Belgoprocess, in order to discuss the numerous remarks made by Bel V.

## 2.3 Long-Term Operation (LTO) - Tihange 1

The implementation of the action plan at Tihange 1 continued in 2016:

- Development of an Ageing Management Programme;
- Re-evaluation of the design (Agreed Design Upgrade);

Work on the topic of 'Ageing' was completed at the time of the 2016 unit outage. The effective finalisation of the work on 'Ageing' was verified by Bel V in accordance with the Royal Decree of 27 September 2015 on the long-term operation of Tihange 1.

The next three major projects on the topic of 'Design' advanced as follows in 2016:

- Construction of the new buildings (BUR-D and BUR-E) and of the technical galleries within the framework of the extension of the Emergency System (SUR) at Tihange 1 continued, and is in accordance with the schedule for the LTO action plan. This was the case despite an event that occurred on 7 September, during the civil engineering works relating to the construction of one of the new galleries, which resulted in the involuntary injection of jet grouting under the floor slab of a neighbouring building housing safety equipment. This incident has led to a unit outage since that date, in order to investigate

the causes, carry out repairs and confirm restart.

- The new full-scope simulator representing Tihange 1 was installed in an extension to the Nuclear Training Centre (CFN) built for the purpose, and went into service in March 2016 in accordance with the schedule for the LTO - Design projects.
- Improvements to fire detection and protection are made in 4 phases, between 2015 and the end of 2019. The works are advancing in line with the schedule.

The IAEA's follow-up to the SALTO (Safety Aspects of Long-Term Operation) mission, carried out in January 2015 upon request by the FANC (in its strategic note) took place between 6 and 9 December.

- The preliminary report on the follow-up, presented to the authorities by the IAEA, concluded that of the 10 'issues' (suggestions and recommendations) identified by the experts during the SALTO of January 2015, 8 have been resolved and 2 were advancing satisfactorily. The final SALTO report is expected to be published in early February 2017.
- This follow-up marks the end of the entire SALTO mission by the IAEA to Tihange 1. Bel V and the FANC will follow up on the 2 actions that have yet to be completed.

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

In 2015, the licensee had set up an integrated action plan. The completeness of the various work packages and the documents underlying the integrated action plan, and compliance of said action plan with the requirements laid down in the FANC policy note of September 2014, were assessed and confirmed in 2015. 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 'TO date'). All priority actions that had to be completed before the start of long-term operation (cycle 41), while the LTO pre-

conditions had to be met as well, were certified by Bel V at the end of 2015. Other changes may be spread over a period of 3 years (and at most 5 years) after the approval of the LTO file.

Preparations for the implementation of the various LTO actions planned during nominal power operations and during the refuellings in 2016 and 2017, and especially during the long common stops planned for 2018 and 2019, are continuing. Bel V is closely monitoring these preparations and the implementations of the changes. The ongoing

recruitment exercise and the alternatives proposed when it was found impossible to recruit and train sufficient staff in time, were closely followed up and evaluated.

During the 2016 refuellings, pursuant to the Royal Decree of 27 September 2015 on the supplement to the licensing requirements for the Doel 1 and Doel 2 nuclear reactors under long-term operation, the acceptance of the various LTO actions carried out during these refuellings, prior to the startup after the refuelling, was certified.

An IAEA expert mission relating to LTO was also conducted in 2016. The expert mission is part of the preparation for the final SALTO mission, which will take place in February 2017. During the expert mission, a team of seven international IAEA experts examined the LTO approach of the Doel nuclear reactor in order to determine the terms of reference for the actual SALTO mission scheduled for February 2017.

The four following domains were part of the scope of this expert mission:

- organisation, licensing, changes;
- scoping and screening programmes for LTO;
- approach in the electrical and instrumentation domain;
- human resources and skill and knowledge management.

The overall conclusion of the IAEA team was that the LTO project for Doel 1/2 is in line with the IAEA standards. The experts acknowledged that they were impressed by the work done in the previous year on the site of the Doel nuclear reactor as part of the LTO project. The openness of the reactor staff and their willingness to work on

continuous improvement were praised repeatedly. The smooth cooperation and exchange of experiences with the Tihange reactor and the Nuclear Corporate services were also noted. In addition, they remarked that the facilities at Doel 1/2 were in good condition.

At the end of the mission, the team indicated that they considered the entire set of quality measures in the In-Service Inspection programme (ISI) at the Doel nuclear reactor to constitute good practices.

In addition to 8 other positive findings (good performances), the Doel reactor was also the subject of 6 recommendations and 4 suggestions with a view to further strengthening the LTO project. The team recommended, among other things, to reinforce the existing organisation for 'ageing management' as planned, to further compare the nuclear reactor programmes with the IAEA standards, to further strengthen the housekeeping and maintenance practices when work is done on electrical and instrument signs, to examine the long-term staffing of the site, to guarantee effective training programmes for all those involved in the lifespan extension of Doel 1/2 and to ensure that knowledge is transferred from the LTO project to the rest of the organisation at the Doel nuclear reactor.

These recommendations were incorporated into the LTO action plan and included in the further lifespan of Doel 1/2. The FANC is monitoring the implementation of the corrective actions accompanying the recommendations. These recommendations must be implemented by the SALTO mission of 2017.

## 2.5 BEST project

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 ENGIE Electrabel (2011);
2. national report of the safety authority (2011);
3. peer review, country visit and final ENSREG (European Nuclear Safety Regulators Group) overall report, in accordance with the ENSREG methodology (2012);
4. action plan of ENGIE 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 ENGIE 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.

Since 2011, the Doel and Tihange sites have been the subject of various works, such as: reinforcement of structures, systems and components for withstanding

a major earthquake, construction of protection against flooding and additional mobile equipment (pumps, diesel generators). The two sites are now adequately protected against natural risks such as flooding or earthquakes.

At the end of 2016, the strategies intended to deal with loss of electrical power or heat sinks were well defined on both sites; the works were completed at Doel and nearly completed at Tihange. The latter work, along with those concerning the filtered vents at the Doel and Tihange units, and those of a new backup of the current crisis operating centre at Tihange, are among the most important actions to be finalized within the action plan that was drawn up following the stress tests.

In sum, by the end of 2016, ENGIE Electrabel had completed more than 85% of the action plans, and estimates that a substantial part of the remaining actions should be completed in 2017.

In 2016, as in previous years, ENGIE 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.

## 2.6 Spent fuel and 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. In 2016, Bel V was still deeply involved in the analysis of the ONDRAF/NIRAS answers on the more than 200 questions that were submitted to ONDRAF/NIRAS. Within the framework of the long-term safety evaluations, Bel V also continued its activities (using its own modelling capacity) of independent safety verification.

In 2014, the FANC and Bel V initiated a collaboration under the terms of the Belgian programme for the disposal of B & C waste in deep geological formations. In this regard, Bel V contributed in 2016 to the development of the Strategic Research Needs (SRN) to structure the needs of the regulatory body for research and development associated with the geological disposal of radioactive waste and spent fuel. At this stage of the project, the emphasis of the Strategic Research Needs is on key issues that are critically important for the review of Safety & Feasibility Case 1 (SFC 1) planned in 2020 by ONDRAF/NIRAS (i.e. issues relevant to host rock and site selection). A Deployment Plan (currently developed for the period 2017-2019) has been developed for investigating the Key Questions identified in the Strategic Research Needs in terms of priorities,

actions foreseen, required human and financial resources, deliverables and timeline.

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 2016.

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, a prelicensing phase was started in 2016 for a new building on the site of Belgoprocess dedicated to the storage of these drums. Bel V performed a safety analysis of the documents received from Belgoprocess in the framework of this prelicensing phase.

## 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 2016. This pre-licensing phase has been extended until 2019.

In this context, 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 2016, less than half of the deliverables had been provided by SCK•CEN. Technical meetings took place to discuss focus points with SCK•CEN. Given the constant evolution

of the MYRRHA design, many deliverables are anticipated in 2017 and beyond.

But since it will not be possible to deal with all the focus points by Q3 2017, the aim of the centre in Mol is to give priority 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.

### 2.8 SF<sup>2</sup> - spent fuel storage facilities

ENGIE Electrabel is carrying out a process of prelicensing of two on-site interim spent fuel storage facilities, one on the site of Doel and one on the site of Tihange. The current interim spent nuclear fuel storage facilities at Doel and Tihange will be saturated by 2023.

To support the design and its justification, a strategic note was drafted by the safety authority with its expectations with respect to safety, security and safeguards. Radiation protection and transport aspects are also included.

The SF<sup>2</sup> safety demonstration is based on the new FANC guidance on safety demonstration for new class I nuclear facilities taking into account the WENRA statement on safety objectives for new nuclear power plants.

In 2017, 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).

For both facilities the dry storage concept with dual purpose casks (transport and storage) was selected.

The prelicensing phase resulted in a Design Options and Provisions File, in which the potential license applicant (ENGIE Electrabel) presented the selected nuclear safety and nuclear security provisions, taking into account the nuclear safeguards obligations, in a way that meets the expectations by the nuclear regulator as set out in the strategic note. The Design Options and Provisions File is currently being analysed by Bel V.

Both SF<sup>2</sup> spent fuel storage facilities are expected to be operational in 2023.



# 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 Organisational 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).

In April 2016, the FANC and Bel V hosted the 13th International Nuclear Regulatory Inspection Workshop of OECD/NEA/CNRA/WGIP in Bruges. This successful workshop was attended by 58 participants from 18 countries.

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 the autumn meeting. He is also Vice-Chairman of the Steering Committee of the Technical and Scientific Support Organization Forum (TSOF) of the IAEA and participated in two meetings in 2016. The General Manager of Bel V is also the Belgian representative in the Nuclear Safety Standards Committee (NUSSC) of the IAEA.

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

- severe accident phenomena (in-vessel melt retention; ex-vessel corium cooling);
- cyber threats and computer security at nuclear facilities;
- fatigue assessment for long term operation;
- operating experience feedback for nuclear power plants and other facilities;
- safety of radioactive waste management and disposal;
- safety and control features of radiation processing facilities;
- human and organisational factors and safety culture;
- knowledge management;
- effective nuclear regulatory systems.

A Bel V representative is a member of the Steering Committee on Regulatory Capacity Building and Knowledge Management (coordinated by the IAEA). He attended the eighth meeting of this committee.

## 3.2 Cooperation with safety authorities

### 3.2.1 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, HERCA and ENSRA (European Nuclear Security Regulators Association)) were also discussed at these meetings. In 2016, further 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, timely implementation of reasonably practicable safety improvements to existing nuclear power plants, the current status on reactor pressure vessel issues, and the Vienna declaration on nuclear safety.

### Reactor Harmonization Working Group (RHWG)

Bel V participated in the three RHWG meetings held in 2016. The main publications of the RHWG in 2016 were related to the specific guidances for natural hazards (extreme weather conditions, seismic events and external flooding) that complement the 'Guidance Document - Issue T: Natural Hazards' (published in 2015) and the Reference Levels on Issue T (published in 2014). The RHWG has continued discussions on the benchmarking of the implementation of the 2014 Reference Levels in national regulations. The RHWG also finalised its work on a proposal for the Technical Specifications for the first Topical Peer Review on ageing management (see above).

### Working Group on Waste and Decommissioning (WGWD)

In 2016, Bel V participated in the development of a new report gathering Safety Reference Levels (SRL) on waste processing facilities. In February, Bel V participated in the 36th WGWD meeting (held in Liverpool, United Kingdom), during which the development of this SRL report on 'Waste Processing' was further discussed within the plenary group. In June Bel V participated in a sub-group of the WGWD (working meeting held in Brugg, Switzerland) in order to finalise the text of this SRL report. The SRL report on 'Waste Processing' was then endorsed by the WGWD during its 37th plenary meeting (held in September in The Hague, The Netherlands). The WENRA-WGWD report on 'Waste Processing' was eventually approved by the WENRA Board of Directors in October.

### 3.2.2 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.

In 2016, exceptionally only one meeting was held, hosted by Bel V. The main topics at this meeting were: new regulatory initiatives in both countries, status of the Chooz and Gravelines nuclear power plants, cross-inspections, feedback on emergency response exercises, operating experience feedback in Belgian Class IIA facilities, and issues related to important mechanical components such as reactor pressure vessels and steam generators.

### 3.2.3 Belgian-Swiss Working Group

This working group is composed of the regulatory organisations of Switzerland and Belgium (respectively ENSI, and the FANC and Bel V). One meeting is held each year, alternately in Brugg and in Brussels.

In 2016, the following topics were discussed, amongst others: long-term safety of waste management and siting of a geological disposal facility, exploring a possible collaboration on definitive shutdown and dismantling of nuclear power plants, long term operation of nuclear power plants, reactor pressure vessel issues and ageing of dual purpose casks.

In November 2016 an exchange meeting on decommissioning was held between ENSI and Bel V/FANC. The first day a visit to Zwiilag was organised, including visits to various facilities, i.e. the conditioning plant, the plasma plant, the storage building for medium-level waste and the hot cell. The second day a workshop about decommissioning was organised, where several topics were discussed, such as the legal decommissioning framework in both countries, the transition phase and organisational factors in decommissioning. At the end, all participants agreed with the idea of a follow-up meeting.

### 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 safety-critical digital instrumentation and control systems implemented in nuclear facilities. The task force is composed of experts from regulators and technical safety organisations (TSO). 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 was the founder of this task force and has taken an active part in it since its inception in 1994, assuming the chairmanship until 2007. Eight countries are currently members. Two plenary meetings took place in 2016 (invited by the Enlarged Halden Programme Group meeting in Sandefjord, Norway, 11-13 May, and by STUK in Helsinki, Sweden, 11-13 October). The Chinese technical safety organisation, the Nuclear and Radiation Safety Centre (NSC), participated in the first 2016 meeting, the purpose being to investigate the possibilities and mutual benefits of their future participation as full members. These aspects are currently under examination.

A full revision of the Common Position report on licensing practices - dated December 2015 - was made available to the public at large on all member websites at the beginning

of 2016. At the same time, the US Nuclear Regulatory Commission (USNRC) issued a NUREG/IA report, which includes the task force position report as well as USNRC commentaries to assist USNRC staff in using this information in its licensing review and regulatory framework.

Meanwhile, the TFSCS also revisited a number of topics like the licensing of pre-existing software, and worked on new licensing concerns raised by cyber security problems, the qualification of new build and software platforms, third party certification, software hazard analysis and software implications in the validation of programmable logic devices recently introduced, such as Field-Programmable Gate Arrays (FPGA). Cyber security and programmable logic devices in particular raise licensing issues found to be amongst the hardest to come to grips with.

### 3.3 Cooperation with technical safety organisations

#### 3.3.1 EUROS SAFE

In November 2016, the German technical safety organisation *Gesellschaft für Anlagen- und Reaktorsicherheit* (GRS) hosted the EUROS SAFE Forum in Munich. The EUROS SAFE Forum, which is a co-organisation with the *Institut de Radioprotection et de Sûreté Nucléaire* (IRSN, France), the GRS, Bel V and the other EUROS SAFE 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 its involvement in the EUROS SAFE Programme Committee, by co-chairing technical seminars and by presenting several papers.

In April 2016, EUROS SAFE Tribune 29 ('2014 nuclear safety directive: a driver for convergence') was published for the last time in its well-known paper format. This

Tribune presents a number of highlights of the EUROS SAFE Forum 2015 (hosted by Bel V). EUROS SAFE Tribune is now published as a monthly electronic newsletter. Bel V took the lead for the issue published in July 2016 (available at <http://www.eurosafeforum.org/node/258>). In this newsletter Bel V's and other Belgian and ETSON activities in nuclear safety and radiation protection are highlighted.

#### 3.3.2 European Technical Safety Organisations Network (ETSON)

ETSON contributes substantially to all activities within the framework of the EUROS SAFE 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.

Since 2015, the General Manager of Bel V is President of ETSO. The ETSO General Assembly and/or Board met in Manchester (June) and Munich (November, at the occasion of the EUROSAFE Forum).

In 2016, the extension of the network was further explored and a new member organisation of Italy (ENEA) joined ETSO.

A Bel V representative continued chairing the ETSO Technical Board for Reactor Safety (TBRS) to oversee the technical activities of ETSO, such as the functioning of the ETSO Expert Groups and the publication of Technical Safety Assessment Guides (available at <http://www.etso.eu/reports-and-publications>). In 2016, a document was published concerning the 2015 ETSO 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 Fukushima accident'.

Bel V representatives took an active part in the ETSO 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.

From 4 until 9 September, several junior Bel V members of staff participated actively in the ninth ETSO Summer Workshop in Warrington (United Kingdom). The workshop was devoted to 'Structural Integrity Aspects in Nuclear Safety'. Bel V representatives participated by giving several presentations.

### 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.

In 2016, Bel V members of staff lectured in the courses on 'Oversight of safety culture and management system' (April) 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 (see Section 4.4 on R&D).

The collaboration with IRSN in the field of radioactive waste management was pursued in 2016.

Three PhDs co-funded by Bel V and IRSN were followed: a first PhD thesis devoted to the understanding and modelling of perturbations induced by a plume of salts (that could be induced by bitumen waste degradation) on the transport of radionuclides in clay; a second PhD thesis devoted to the study of radionuclide diffusion in concrete and at 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); and a third PhD thesis devoted to 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 (based on a detailed experimental programme performed at IRSN). The latter two PhD theses were successfully defended in 2016.

Also in 2016, 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 modelling of cement degradation phenomena.

The SCANAIR software, developed by the IRSN, makes it possible to model the thermomechanical behaviour of fuel during accidental reactivity insertion following the ejection of a control rod from the nuclear reactor. The IRSN asked Bel V for an independent verification of the validation of version 6.7 of the SCANAIR software. This involves, more

specifically, a contribution to expertise in the use of the SCANAIR v 6.7 software in the safety demonstration vis-à-vis accidental ejections of a rod and uncontrolled group withdrawal at zero power. In the course of 2016, Bel V prepared a technical questionnaire, and discussed the answers received.

### 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 of INSC projects covers 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. Bel V participated 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'.

This project was completed in 2016.

#### 3.4.2 Vietnam

Bel V has participated in the second INSC project, which started in 2016: 'Enhancing the capacity and effectiveness of VARANS and its TSO'.

This project is a follow-up to the previous INSC project in Vietnam, which was completed in 2015.

Bel V is involved in 2 tasks:

- Task 3: Further development of capabilities within VARANS for undertaking and/or commissioning independent reviews and assessments of safety submissions;
- Task 4: Human resources development plan and sustainable training programme for VARANS and its TSO.

#### 3.4.3 China

Bel V participated 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'.

Bel V was 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 was completed at the end of 2016.

#### 3.4.4 Philippines

Bel V participated in the first INSC project between the European Commission and the Philippines (PH3.01.09), i.e. 'Technical assistance for improving the legal framework for nuclear safety and strengthening the capabilities of the Regulatory Authority of the Philippines and its TSO (PNRI)'.

Bel V was involved in subtask 1.2, supporting PNRI in the development of safety regulations.

The contribution of Bel V to this project was completed in 2016.

#### 3.4.5 Egypt

Bel V has participated in the second INSC project between the European Commission and Egypt, i.e. 'Provision of assistance related to developing and strengthening the capabilities of the Egyptian Nuclear and Radiological Regulatory Authority (ENRRA)'.

The kick-off meeting of the project took place in 2015. 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.

Bel V is involved in the following tasks:

- Task 1: Update of the Strategy Plan and Action Plan;
- Task 2: Training and support in safety assessment and licensing;
- Task 3: Strengthening professional skills of the Project Partner staff.

### 3.4.6 Thailand

Bel V has participated 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.

### 3.4.7 Ukraine

Bel V has participated in an INSC project in Ukraine 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.

### 3.4.8 Council Directive 2013/59/EURATOM

Bel V has participated 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.

### 3.4.9 Lithuania

Bel V has participated in task 2 of the project on 'Technical Assistance to VATESI in the Field of Decommissioning' (Phase 6).

Task 2 relates to the review of licensing documentation for facilities for the retrieval of solid radioactive waste from the existing storage facilities and new treatment and storage facilities for the Ignalina nuclear power plant.

# 4

## 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 2016, more than 50 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.

2016 was marked by the following events in particular, which were analysed in depth by Bel V and for which appropriate analysis, regulatory inspection and follow-up of corrective actions were carried out:

- failure of high pressure safety injection pump shaft at Tihange 1;
- common cause failure risk on auxiliary feedwater system due to replacement of floor grates by fire panels at Doel 3;
- unplanned inoperability of emergency diesel generator following human error during maintenance intervention at Tihange 1;
- rupture of feedwater instrumentation impulse lines resulting in auxiliary feedwater leakage in mode 3 at Doel 3;
- inoperability of reactor protection system instrumentation channel for 92 days following channel operational test at Tihange 3;
- radiation measurement instrumentation channel inoperable for 7 days after the performance of a check source test at Tihange 3;
- cold shutdown following the impact of jet grouting operations on auxiliary building W at Tihange 1;
- loss of environmental qualification of Rosemount transmitters caused by a broken neck seal due to rotation of the electronics housing at Doel 3.

## 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 analysis by Bel V of selected events may result in formal Operating Experience Examination Request Letters (OEERL) or Operating Experience Information Letters (OEIL), requests to provide clarification on the extent to which the operating experience was taken into consideration by licensees or in the conduct of specific inspections.

In 2016, together with the FANC, Bel V performed applicability reviews of the following operating experience in France:

- generic non-conformity issue with respect to the design of the component cooling systems of 900 MWe CPY nuclear power plants;
- irregularities in the fabrication of components at Creusot Forge;
- falsification of material test reports at SBS Forge;
- high carbon concentrations in central areas of the steam generator bottom hemispherical heads.

## 4.3 Knowledge management

For several reasons (one of them being that in the next 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

In addition the Belgian nuclear power plants licensee was invited to provide answers to specific questions after analysis of the IRS 8517 report 'Challenge of the EDG Safety Function during Safety Injection Followed by LOOP (at Almaraz-1)'.

Follow-up inspections have been scheduled after analysis of the following operating experience documents:

- NRC IN 2015-09 Mechanical Dynamic Restraint (Snubber) Lubricant Degradation Not Identified Due to Insufficient Service Life Monitoring;
- NRC RIS 2016-07 Containment Shell or Liner Moisture Barrier Inspection.

Finally a further follow-up was performed of OEERLs sent to the licensees in previous years:

- 'IRS 8289 Non-compliance of component cooling systems in France', initiated in 2013, was closed after final analysis of the utility company's responses;
- 'NRC RIS 2013-09/IRS 8381 System gas accumulation - prevention and management' progressed with the review of partial responses from the licensees;
- 'NRC GL 96-06 Equipment operability and containment integrity' was closed for Doel 3 after full implementation and approval of all the required design modifications.

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 2016, 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.

## 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 2016, special attention was again paid to the possibility of encouraging new R&D projects.

### 4.4.2 R&D on nuclear installation safety

#### Thermal-hydraulic phenomena

Safety topics related to thermal-hydraulic phenomena in light-water reactors and heavy-metal reactors are addressed within Bel V's thermal-hydraulic R&D programme. This includes numerical simulations by advanced computer codes, as well as experimental test proposals within dedicated OECD/NEA projects. The main objective of the thermal-hydraulic R&D programme is to keep expertise and competence up-to-date in order to respond to various and challenging licensing problems. The thermal-hydraulic R&D activities scheduled for 2016 were carried out successfully and on time. This concerns:

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.

- Participation in the OECD/NEA experimental thermal-hydraulic PKL-3 project and the follow-up projects PKL-4 and ATLAS;
- Participation in the PKL/ATLAS analytical workshop in Italy with a Bel V presentation entitled 'Bel V Analytical Activities within the PKL-3 Framework';
- Simulations of 3-loop nuclear power plant transients using CATHARE and RELAP5-3D codes. This mainly involved:
  - an advanced parametric study of the natural circulation interruption (NCI) phenomenon in a generic 3-loop pressurised water reactor using the CATHARE code;
  - natural circulation flow simulation of an operational primary pump trip transient using CATHARE code;
  - investigation of the primary pump dissipation heat using RELAP5 code;
- Agreement on R&D cooperation with IRSN for the DENOPI project; Bel V will finance a research project, which will be carried out by an UCL doctorate;
- A dissertation by an UCL student related to the simulation of a generic spent fuel pool using OpenFoam computer code, within the context of collaboration with UCL;
- Acceptance for publication in the Elsevier Nuclear Engineering and Technology Journal of a paper 'Unsteady

Single-Phase Natural Circulation Flow Mixing Prediction Using CATHARE Three-Dimensional Capabilities'; the paper is scheduled for publication in 2017;

- Agreement between Bel V, the Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) and the Paul Scherrer Institute (PSI) to prepare and carry out mixing under natural circulation flow calculations using a 3D thermal-hydraulic system and CFD codes, and to assess the results using ROCOM experimental data;
- Drafting and submission of the Bel V contribution to the OECD Working Group on Analysis and Management of Accidents (WGAMA) on the simulation capability of the 3D System-Scale Thermal-Hydraulic Codes (3DSYSTH).

### Severe accidents progression

In 2016, the development of MELCOR simulation capabilities at Bel V continued. A MELCOR 2.1 model of a 3-loop pressurised water reactor is now available to Bel V for its safety assessments. The main modelling efforts were focused on improving the decay heat and radionuclide parts of the plant input deck based on the results of ORIGEN calculations, thanks to the data provided by Tractebel Engineering. Lessons learned and feedback were shared within the MELCOR community in the framework of review meetings in which Bel V participates.

The MELCOR model developed by Bel V is suitable to perform steady-state and transient analyses. Transient analyses (after fuel failure) are ongoing on selected transients.

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

Bel V attended the 8th European MELCOR User Group (EMUG) meeting, the Cooperative Severe Accident Research Program (CSARP) meeting, the MELCOR Code Assessment

Program (MCAP) meeting, the International Workshop 'In-vessel corium retention strategy: status of knowledge and perspectives', and the IAEA technical meeting on phenomenology and technologies relevant to in-vessel melt retention and ex-vessel corium cooling.

Bel V has participated in the international panel of experts responsible for the OECD/NEA activities on 'Phenomena Identification and Ranking Table (PIRT) on Spent-Fuel Pools in Loss-of-Cooling/Coolant Accident Conditions'. In particular, Bel V is co-leader of the sub-task related to the preparation of table for the severe fuel damage phase and contributes to the ranking of such phase and the pre-uncovery and uncovery phases.

Bel V now also participates in the OECD/NEA 'Thermal-hydraulics, Hydrogen, Aerosols, Iodine (THAI-3) Project'. In this context, Bel V is sponsoring a doctoral activity at the von Karman institute for fluid dynamics (VKI). This cooperation is expected to support Bel V in the active participation in THAI-3, especially in areas where follow-up of the state-of-the-art is important.

### Fission product and aerosol behaviour

Bel V continued its participation in the OECD/NEA BIP-3 (Behaviour of Iodine Project), whose main objectives are to improve our ability to simulate iodine adsorption and desorption on containment surfaces, to predict CH3I behaviour (formation and degradation) under accident conditions, and to investigate the effect of paint ageing on these processes.

The first BIP-3 Programme Review Group meeting (4 and 5 April) was attended and a description of the co-operative sensitivity study based on a simple accident scenario for the BIP-3 Analytical Working Group was received.

## PSA methodology and its applications

In 2016, Bel V attended two meetings of the ETSON Expert Group on PSA (June and November). In particular, information was exchanged on lessons learned by technical safety organisations from PSA and a workshop on this topic has been scheduled for 2017.

Bel V reviewed and commented several draft deliverables of the ASAMPSA\_E project and replied to the 'End-User Questionnaire' about these draft deliverables. The comments on all ASAMPSA\_E draft deliverables, provided by various end-users, were discussed at the 'Final End User Workshop' (Vienna, 12-14 September 2016), which was attended by Bel V.

Bel V attended the 13th International Conference on Probabilistic Safety Assessment and Management (PSAM13) in Seoul (3-7 October). Attending this conference allowed Bel V to keep its PSA knowledge up-to-date, to receive input for its review tasks for various PSA sub-domains (e.g. Fire PSA, Flooding PSA, PSA for external events, HRA, etc.), and to exchange knowledge and experiences with international contacts from the PSA community.

Bel V attended the 19th Technical Meeting on Experiences with Risk-based Precursor Analysis (Brussels, 26-28 October). PSA-based event analyses performed by ENGIE Electrabel for Belgian nuclear power plants and by foreign organisations (utility companies, TSOs) for nuclear power plants abroad were presented and discussed.

Bel V attended the International RiskSpectrum User Group meeting (London, 9-10 November). Several new features of the most recent code release were discussed with the software developers and users from several countries.

## Fire protection

In 2016, Bel V actively followed the activities of the OECD PRISME 2 project, which has produced a large amount of high-quality experimental data on fire behaviour in confined environments, along with extensive characterization of realistic fire loads such as cable trays.

Support to the PhD thesis at Ghent University was continued and developments made in this context should lead to an improvement of the capabilities of numerical fire modelling codes.

During this year, Bel V joined the OECD FIRE database project, whose aim is, among others, to collect fire event experience (by international exchange) in an appropriate format in a quality-assured and consistent database. The information generated and published in this context can be used, for example, in Fire PSA activities.

## ETSON collaboration and expert groups

In 2016, Bel V continued its active involvement in the activities of the ETSON Technical Board on Reactor Safety (TBRS), a committee that is chaired by Bel V, and the ETSON Expert Groups. In this respect, Bel V chaired a meeting of the TBRS and Bel V representatives participated in meetings of the Expert Groups. The most active Expert Groups in 2016 were related to mechanical systems, PSA (Probabilistic Safety Assessment) and radioactive waste management and decommissioning. On behalf of the latter Expert Group, a Bel V representative co-authored a paper that was presented at the IAEA International Conference on the Safety of Radioactive Waste Management (Vienna, 21-25 November).

As a result of an ETSON workshop organised in 2015, to which Bel V contributed actively, an ETSON report was published entitled '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 Fukushima accident' (available on the ETSO website: [www.etso.eu](http://www.etso.eu)).

Bel V also continued its contribution to the ETSO R&D Working Group and the Knowledge Management Working Group.

### Mechanical Safety

In order to enhance knowledge in the field of numerical simulation of fracture mechanics, a three-day course was organised at Bel V. The course focused on conventional finite element techniques (contour integrals, element- and surface-based cohesive behaviour, virtual crack closing technique) as well as the extended finite element technique (XFEM). The topics 'wear' and 'low cycle fatigue' were also treated.

A meeting was held between IRSN and Bel V to discuss a new collaboration which will be set up within the framework of new experiments conducted at the Commissariat à l'énergie atomique et aux énergies alternatives (CEA), whose objective is to analyse the effect of biaxiality on the stress state and fracture mechanics behaviour of steel containing hydrogen flakes. Bel V is expected to perform numerical simulations of these experiments and compare them with the experimental results.

### Ageing

To further develop its expertise in ageing and degradation mechanisms in concrete, Bel V, in collaboration with the FANC, has participated in the ODOBA project.

The ODOBA project aims to improve insight in concrete ageing pathologies within the context of extending the service life of nuclear facilities. The effect of these phenomena on the mechanical and containment properties of concrete structures, like reactor containments and waste disposal facilities, needs to be studied in depth to assess their durability.

The ODOBA project is international. It is led by IRSN in France and the other organisations involved are CNSC (Canadian regulator), NSC (Chinese technical support organisation), VTT (Finnish research centre), USNRC (US regulator), and several French academic partners.

In 2016, the research and development agreements between the parties were concluded and a first kick-off meeting was held in France.

### 4.4.3 R&D on waste and decommissioning

#### Waste disposal

Within the context of the cAt licensing process, ONDRAF/NIRAS and the regulatory body agreed in 2015 on a phenomenological expected evolution of the repository. In the autumn of 2015 ONDRAF/NIRAS started updating the near-field models supporting the long-term safety assessment initially submitted to the regulatory body, in order to make them consistent with this expected evolution. In 2016, Bel V performed independent modelling studies to verify (e.g. by comparing the radiological impact modelled by ONDRAF/NIRAS to the radiological impact modelled by Bel V for a similar model, but with a different code) and challenge (e.g. by performing specific uncertainty analyses to identify potential weaknesses in the ONDRAF/NIRAS models) the updated long-term safety assessment performed by ONDRAF/NIRAS. These activities provided a sound technical support for the review of the updated long-term safety assessment by the regulatory body.

Three PhDs theses, started before 2016 and co-funded by Bel V, were followed up: a first PhD thesis on the understanding and modelling of perturbations induced by a plume of salts (that could be induced by bitumen waste degradation) on the transport of radionuclides in clay; a second PhD thesis studying radionuclide diffusion in concrete and at 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); 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 (based on a detailed experimental programme performed at IRSN). The latter two PhD theses were successfully defended in 2016. These PhDs provided Bel V with relevant results and information 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 PhDs allow Bel V to strengthen its collaboration with other technical safety organisations (e.g. IRSN) and R&D organisations (e.g. ULB, CEA, École des Mines de Paris).

In the autumn of 2016, a new PhD funded by Bel V was started by the SCK•CEN and UCL on the impact of organic matter on uranium transport in clay (preliminary title: 'Complexation/colloid formation of U(VI) with Boom Clay dissolved organic matter').

In 2016, Bel V - in collaboration with the FANC - developed a 'Strategic Research Needs' (SRN) document structuring the needs for developing and strengthening the expertise of the FANC/Bel V in the field of the geological disposal of radioactive waste. The above-mentioned PhDs are related to these research needs. Based on this document, an R&D action plan was developed for 2017-2019 and will be implemented.

Finally, Bel V participates in two European projects (coordination and support actions) related to R&D for geological 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 regulatory authorities). In the latter project, Bel V leads the working group aimed at structuring the R&D activities of the network. Moreover, Bel V participated in NEA and IAEA working groups related to the safety of radioactive waste disposal (e.g. NEA-IGSC, IAEA-HIDRA 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

Regarding decommissioning, 2016 was marked by the drafting of the final DRiMa report. The methodology developed in this IAEA project at strategic level enables to define a structure allowing a systematic screening of the main issues of a large decommissioning project (cost, regulations, waste, technologies ...), to assess risk levels, and to manage risks by using the traditional techniques of risk management with the aim of reducing risk levels by minimising uncertainties on the key assumptions and by managing the residual risk.

#### 4.4.4 R&D on radiation protection

The *Rijksinstituut voor Volksgezondheid en Milieu* (RIVM) in the Netherlands has developed a methodology entitled SUDOQU (Surface Dose Quantification) to calculate the annual effective dose due to surface contamination for both consumers and non-radiological workers, addressing issues of removability of surface contamination. Within this collaboration project with Bel V, the potential of this methodology for deriving nuclide-specific surface clearance levels for the Belgian context was studied.

A kick-off meeting took place at RIVM in Bilthoven on 8 March. Introductory presentations of the RIVM activities and the Bel V expectations were given, followed by a discussion on defining a collaborative work programme for 2016.

On 2-3 May, a 2-day SUDOQU workshop was held at the Bel V premises. The aim was to introduce this RIVM methodology to Bel V experts and to set up a work environment for SUDOQU development and applications at

Bel V. A selected expert received specific training and the work environment for SUDOQU development at Bel V was successfully implemented.

A new method for deriving weighting factors for dose conversion coefficients was finalised, based on a proposal by RIVM.

A second workshop was organised at Bel V on 4 October. The results of the calculations performed by Bel V were discussed and validated by RIVM. Further developments were set out and the benchmarking of the SUDOQU results was discussed.

The next step is a summary and documentation of the studies that were carried out, which should lead to the publishing of papers in scientific magazines.

### 4.4.5 R&D on cross-cutting issues

#### Safety culture assessment

In order to comply with a set of IAEA standards (mainly GSR Part 2), Bel V developed and implemented an assessment model aimed at evaluating its safety culture maturity level. On the basis of this home-made model, self-assessment workshops (7 members) were conducted (April-June). Assessment results were analysed and presented to the steering committee and the entire staff. The results of the assessment will be integrated in the Bel V operational plan. A paper related to the model has been submitted for publication.

#### 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. In particular, Bel V is part of the consortium of the FASTNET project (FAST Nuclear Emergency Tool) launched within the framework of Horizon 2020. The project started in the second half of 2016 and will last 48 months.

#### Verification and validation

It has been shown how the Bel V methodology meets the challenges of the current practices for code calculation for the validation of safety properties and criteria. This has been done by means of the development of examples and tests cases. Based on this process and the experience gained, the methodology was clarified and improved.

The work on logical post-verification conditions, although in a preliminary stage, has already had an impact on the design of a classified software procedure designed by the licensee.

### 4.4.6 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 be useful for 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)**

A PhD thesis carried out at ULB and funded by IRSN and Bel V 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 was successfully defended in 2016. Most models representing this feedback are based on the Archie's law, which is not reliable for complex materials such as cement materials. In this PhD, an alternative law has been developed, based on experiments performed on 'simplified' cementitious materials. This PhD provided Bel V with a better knowledge of the limitations and weaknesses of current models linking cement degradations to its transport properties. It also provided Bel V with information on more reliable alternative laws. The results of this thesis thus contributed to strengthening Bel V's expertise in modelling radionuclide migration in degraded concrete materials (a key material in ONDRAF/NIRAS concepts for surface and geological disposal facilities).

### **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).

### **von Karman Institute for Fluid Dynamics (VKI)**

Since 2016, Bel V has sponsored a PhD thesis within the context of Bel V's participation in the international THAI-3 project, which investigates hydrogen and fission product related issues in water-cooled reactor containment under accidental conditions.

### **Université catholique de Louvain (UCL)**

Two PhD theses are sponsored at UCL:

- A first PhD is related to numerical simulations of thermal fluctuations in the vicinity of a contact line between the free surface of a liquid and a solid wall. Such thermal fluctuations can have a significant impact on the fatigue of the wall material. The aim is to provide realistic models that can be implemented in conventional commercial codes, with application to the MYRRHA reactor.
- A second PhD 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 numerical simulation of PTS-related issues.

### R&D collaboration with IRSN

- A PhD thesis co-funded by IRSN and Bel V aimed at studying radionuclide diffusion in concrete and at clay/concrete interfaces was successfully defended in 2016. This PhD provided Bel V with a better understanding of the physico-chemical reactions which could occur in the cementitious engineered barriers of a geological repository and at their interfaces with a clay host-rock (a possible host-rock considered by ONDRAF/NIRAS for geological disposal in Belgium). In particular this PhD allowed to enhance the scientific knowledge on the impact of high temperature conditions (up to 70°C, in the order of temperatures that could occur in geological disposal conditions) on those reactions. The PhD thus contributed to strengthening the expertise at Bel V that will be required for the future review of a safety case for a geological disposal facility.
- Bel V is a member of the Pôle Géochimie Transport (PGT), which groups several organisations (including IRSN) and institutions having a common interest in the development of numerical simulations of reactive transport. Within the framework of its participation in PGT IV, Bel V strengthened its knowledge and expertise in the field of reactive transport in porous media. This was achieved by developing models linking radionuclide migration in cement and cement physicochemical degradations expected in the project for the near-surface disposal facility with the HYTEC code (developed within the framework of the Pôle Géochimie Transport). The exchanges that Bel V had with other PGT IV participants (during meetings and workshops) also contributed to the development of Bel V expertise.
- Since 2015, Bel V has co-financed (with CEA and IRSN) a PhD thesis entitled '*Capacité de prise en compte des perturbations chimiques par les codes couplés chimie-transport : une étude 'expérience vs simulation numérique' de l'impact des panaches salins*'.

## 4.5 Training

A structured training approach has been adopted on the basis of the Systematic Approach to Training (SAT) of the International Atomic Energy Agency. 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: 8 sessions took place in 2014, 8 in 2015 and 9 in 2016:

- Physical Protection
- INES
- Quality Management System
- Electrical Systems

- Environmental Impact Assessment
- Introduction to Safety Analysis Reports
- Radiation protection Art. 25
- Class I facilities other than nuclear power plants (IRE)
- Enforcement

An example of an external training course with the participation of new members of staff at Bel V in 2016:

- Induction to Nuclear Safety (ENSTTI, 3 weeks)

In addition, Bel V set up so-called 'Internal Technical Sessions' aimed at disseminating the R&D results to the Technical Responsibility Centres. In 2016, 3 Internal Technical Sessions were held.

Non-technical training was also offered as needed (languages, IT, etc.).

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 65 training activities took place in 2016.

# FINANCIAL REPORT

## Balance sheet as at 31 December 2016

(amounts in thousands of euros)

	2015	2016
<b>ASSETS</b>	<b>13,722</b>	<b>13,935</b>
<b>FIXED ASSETS</b>	<b>5,652</b>	<b>5,190</b>
II. Intangible fixed assets	602	339
III. Tangible fixed assets	5,048	4,849
A. Land and buildings	4,792	4,629
B. Plant, machinery and equipment	205	177
C. Furniture and vehicles	51	43
IV. Financial fixed assets	2	2
<b>CURRENT ASSETS</b>	<b>8,070</b>	<b>8,745</b>
VII. Amounts receivable within one year	3,136	3,883
A. Trade receivables	2,890	3,818
B. Other amounts receivable	246	65
IX. Cash at bank and in hand	4,700	4,577
X. Deferred charges and accrued income	234	285

	2015	2016
<b>LIABILITIES</b>	<b>13,722</b>	<b>13,935</b>
<b>EQUITY</b>	<b>9,485</b>	<b>10,224</b>
I. Capital	4,732	4,732
IV. Reserves	2,868	2,868
V. Profit carried forward	1,885	2,624
<b>DEBTS</b>	<b>4,237</b>	<b>3,711</b>
VII. Amounts payable after more than one year	500	
IX. Amounts payable within one year	3,736	3,710
A. Current portion of amounts payable within one year	500	500
C. Trade debts	500	338
D. Advances received on contracts in progress	1,500	1,500
E. Taxes, remuneration and social security	1,236	1,372
F. Other amounts payable		
X. Deferred charges and accrued income	1	1

## Profit and loss account as at 31 December 2016

(amounts in thousands of euros)

	2015	2016
Turnover	12,746	13,001
Other operating income	241	171
<b>TOTAL OPERATING INCOME</b>	<b>12,987</b>	<b>13,172</b>
Services and other goods	2,534	2,096
Wages and social security costs	9,201	9,750
Depreciation	494	488
Write-downs on trade receivables		
Other operating charges	95	96
<b>TOTAL OPERATING CHARGES</b>	<b>12,324</b>	<b>12,430</b>
<b>Operating result</b>	<b>663</b>	<b>742</b>
Financial charges and income	4	-3
<b>Profit on ordinary activities</b>	<b>667</b>	<b>739</b>
<b>Profit for the financial year</b>	<b>667</b>	<b>739</b>

## Profit and loss account: notes

In 2016, our activities continued apace, yielding a 7.6% increase in our turnover.

### Operating income

#### *Turnover*

The largest part of the turnover of Bel V (94%) 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 marked by the decennial reviews by Belgoprocess and the SCK•CEN, the continuation of the Myrrha project, an intensification of the operational control at the Tihange site, and the pursuit of works as part of the Long-Term Operation of Doel 1/2 and Tihange 1.

A small part of the turnover (3.79%) 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.

### Operating charges

#### *Services and other goods*

Services and other goods represent 17% of the charges. This year, our expenditures in research and development represent 3.38% of our operating charges.

#### *Wages and social security costs*

Staff expenses represent 78% 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

<b>ASN</b>	Autorité de Sûreté Nucléaire (France)
<b>BEST</b>	Belgian Stress Tests
<b>CEA</b>	Commissariat à l'énergie atomique et aux énergies alternatives (France)
<b>CNRA</b>	Committee on Nuclear Regulatory Activities (OECD)
<b>CSNI</b>	Committee on the Safety of Nuclear Installations (OECD)
<b>DG Crisis Centre</b>	Directorate-General Crisis Centre of the Federal Public Service Interior
<b>ENSREG</b>	European Nuclear Safety Regulators Group
<b>ENSTTI</b>	European Nuclear Safety Training and Tutoring Institute (ETSON)
<b>ETSON</b>	European Technical Safety Organisations Network
<b>FANC</b>	Federal Agency for Nuclear Control
<b>FBFC</b>	Franco-Belgian Fuel Fabrication
<b>FINAS</b>	Fuel Incident Notification and Analysis System
<b>HERCA</b>	Heads of European Radiological Protection Competent Authorities
<b>IAEA</b>	International Atomic Energy Agency
<b>INSC</b>	Instrument for Nuclear Safety Cooperation (European Commission)
<b>IRE</b>	National Institute for Radioelements
<b>IRS</b>	Incident Reporting System
<b>IRSN</b>	Institut de Radioprotection et de Sûreté Nucléaire (France)
<b>IRSRR</b>	Incident Reporting System for Research Reactors
<b>JRC</b>	Joint Research Centre
<b>LTO</b>	Long-Term Operation
<b>NEA</b>	Nuclear Energy Agency (OECD)
<b>NUSSC</b>	Nuclear Safety Standards Committee (IAEA)

<b>OECD</b>	Organisation for Economic Cooperation and Development
<b>ONDRAF/NIRAS</b>	Agency for Radioactive Waste and Enriched Fissile Materials
<b>PSA</b>	Probabilistic Safety Assessment
<b>PSR</b>	Periodic Safety Review
<b>R&amp;D</b>	Research & Development
<b>RIVM</b>	Rijksinstituut voor Volksgezondheid en Milieu (the Netherlands)
<b>SALTO</b>	Safety Aspects of Long-Term Operation
<b>SCK•CEN</b>	Studie Centrum voor Kernenergie - Centre d'études d'Énergie Nucléaire (Mol)
<b>SRL</b>	Safety Reference Levels
<b>TBRS</b>	Technical Board for Reactor Safety (ETSON)
<b>TRC</b>	Technical Responsibility Centre (Bel V)
<b>TSO</b>	Technical Safety Organisation
<b>TSOF</b>	Technical and Scientific Support Organization Forum (IAEA)
<b>USNRC</b>	Nuclear Regulatory Commission (US)
<b>WENRA</b>	Western European Nuclear Regulators Association

[www.belv.be](http://www.belv.be)