

BEL ✓ 2017
ANNUAL REPORT



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MESSAGE FROM THE CHAIRMAN

Bel V is a private foundation established by the FANC (Federal Agency for Nuclear Control) 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.

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.

To carry out its mission of monitoring and analysing the safety of nuclear facilities, Bel V needs to draw on a multidisciplinary team of experts who have a high level of knowledge and skills. Maintaining and developing the necessary skills is, moreover, part of the essential values upheld within Bel V. To this end, Bel V implements an effective knowledge management system, a focused research and development programme, and a programme for initial training and continuous learning. Tools that make it possible to generate, capture, use, transfer and store useful knowledge are also put in place.

Given the retirement of several experts with many years of experience, particular attention is devoted to the transfer of knowledge. New hires are assigned a mentor who guides them and helps with their integration. The transfer of knowledge from senior to new staff takes place by means of an appropriate form that allows for the systematization and documentation of relevant information. Moreover, a critical knowledge grid has been developed to identify and reduce the risk of knowledge loss. Lastly, an electronic document management system has been in use and fed for several years and is one of the key elements facilitating access to information and to the organisation's 'institutional memory'.

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 2017, the Board of Directors was composed of:

D. Malherbe  President

J. Annane  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

2016 was marked by an unusual event: following civil engineering works at Tihange 1 implementing a technique of jet grouting, 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 beginning of 2017, the licensee provided a justification that sought to demonstrate that the existing situation was acceptable. Bel V determined, after an in-depth analysis, that this demonstration was not sufficiently convincing. The licensee then proceeded to inject cement into the poor-quality backfill. After the cement set, soil samples showed that the stability of the subsoil had been significantly reinforced. A green light could thus be given for the restart of Tihange 1.

For several years now, Bel V has been developing its emergency preparedness and response capacity. This capacity was put to the test during a genuine activation of the Nuclear and Radiological Emergency Plan for the Belgian Territory in January 2017. There has been no such genuine activation since 2008. The response structures were mobilised in accordance with the provisions in place, and Bel V representatives were thus dispatched to the federal crisis centre's evaluation unit, to the joint internal crisis centre of the FANC/Bel V and to the site in question (Doel 4). This genuine activation of the Emergency Plan demonstrated that Bel V has sufficient response capacity to fulfil the tasks assigned to it in this regard.

Of course the crisis organisation is tested not only during genuine activations, but is the subject of frequent and regular exercises. In 2017, four such 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). 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 exercise carried out in November for the Doel nuclear power plant. In addition to the above-mentioned exercises in Belgium, Bel V participated in three international exercises organised respectively by the International Atomic Energy Agency (IAEA), the European Commission and France. Lastly, we implemented actions for the continuous improvement of our organisation. They are summed up in the body of this report.

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





**Regulatory
activities in
Belgium**



**Safety assessments
and national
projects**



**International
activities and
projects**



**Expertise
management**





INTRODUCTION

MICHEL VAN HAESENDONCK

Nuclear power plants

Since observations were made in the past few years that raised questions regarding the safety culture in the Belgian nuclear plants, ENGIE Electrabel is implementing an extensive action plan. As part of the follow-up to the agreed actions, a considerable number of specific inspections were held by Bel V in order to gain a sense of the progress made in terms of nuclear safety and safety culture.

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. For Tihange 1 in particular, the follow-up of work required a number of specific initiatives after the annex housing nuclear safety equipment was damaged during work and reinforcement work had to be carried out.

In the autumn, in the course of the refuelling of Doel 3, a planned renovation in the bunker revealed more severe deterioration of the concrete and reinforcement than expected. Since the analysis of the structural integrity of the bunker building showed that there was insufficient structural strength to guarantee integrity in the event of a plane crash, Bel V is monitoring the planning and progress of the repairs closely during its inspections.

In mid-2013 a gel-like substance was discovered in a number of drums containing conditioned waste, both at Belgoprocess and at the Doel site. As a result of this discovery, a close collaboration was initiated and is still ongoing by the Belgian Agency for Radioactive Waste and Enriched Fissile Materials

(ONDRAF/NIRAS), the FANC and Bel V to thoroughly investigate and remedy this problem.

In 2017 too, Bel V devoted particular attention to the storage conditions and capacity for the various waste streams at the Doel and Tihange sites. This was necessary since, after an audit conducted by ONDRAF/NIRAS, the authorisations for various sorts of waste were still withheld.

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.

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

The management of the National Institute for Radioelements (IRE) continues to face important challenges. 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.

In view of the various problems experienced with NTP Europe at the Fleurus site, Bel V together with the FANC monitored that site intensively during part of 2017.

Integrated strategy for control

The integrated strategy for inspection (by the FANC) and control (by Bel V) was applied in 2017.

The 2017 inspection programme was sent to the facilities at the end of 2016. 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.





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 shutdown for refuelling between 18 June and 22 July;
- four days at the end of December in order to repair a feedwater pump.

Doel 2 operated at nominal power throughout the year, except during the shutdown for refuelling, which began on 19 May. On 19 June, Doel 2 was operating at nominal power again.

Special efforts were undertaken to prepare for the various shutdown modifications (for the outages of 2017 and especially for the outages of 2018 and 2019, during which the largest amount of modifications for Long-Term Operation will be carried out).

1.1.2 Doel 3

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

- On 23 May, an automatic reactor trip occurred due to a turbine trip.
- The annual refuelling and maintenance outage started on 22 September with completion scheduled in November. However, due to the identification of severe concrete and armature damage in steam discharge rooms of a bunkerised building, restart has been postponed until June 2018.

Analysis of the structural integrity of the bunkerised building mentioned above showed that there is insufficient structural strength to withstand an airplane crash. This event has been classified at Level 1 of the International Nuclear and Radiological Event Scale (INES).

1.1.3 Doel 4

Doel 4 operated at nominal power without interruption throughout the year, except for:

- an unplanned outage from 10 to 13 August as a result of an automatic reactor trip due to loss of the 380 kV connection with the grid;
- a planned outage from 24 March to 5 May for 18-monthly refuelling and maintenance;
- an unplanned outage from 26 May to 2 June as a result of a manual reactor trip due to a major water leak in the condenser (tertiary circuit);
- a planned outage from 9 to 15 August for the repair of a leak in the safety injection circuit in the reactor building;
- an unplanned outage from 20 to 21 August as a result of an automatic reactor trip during a test of the main steam isolation valves;
- a temporary power reduction to 80% from 2 to 5 November for the repair of a limited water leak in the condenser (tertiary circuit).

During the events in January and August in particular, Bel V devoted careful attention to analysing the incident and the corrective measures proposed by the licensee.

1.1.4 Doel common (WAB, SCG)

WAB: Pursuant to an audit by the Belgian Agency for Radioactive Waste and Enriched Fissile Materials (NIRAS/ONDRAF), the authorisation for various types of waste was blocked. Bel V has closely monitored the storage conditions and capacity for the various waste streams (both on the units and in the WAB), as well as the actions undertaken by the licensee to anticipate potential problems with waste storage. Since then, all waste flows have been unblocked, with the exception of those for resins and concentrates. For resins and concentrates, an expansion of the storage capacity is in progress, in addition to the development of new procedures in collaboration with the French Alternative Energies and Atomic Energy Commission (Commissariat à l'énergie atomique et aux énergies alternatives, CEA). Bel V will continue to closely monitor this in the future.

In its 2017 evaluation report, Bel V indicated that improvements to the organisation and condition of the installations of the WAB were necessary. The licensee will draw up an action plan for this purpose, and Bel V will closely monitor it.

SCG: In the past, quality problems were identified with the containers for spent fuel that were delivered. On this basis, the quality control of the production of the containers by the manufacturer and the independent inspection by the licensee and the consultancy firm were strengthened. The reception of these containers is now also processed more thoroughly. Bel V follows up on the results of the various inspections very closely. Despite these additional inspections of the production, problems were still identified in the delivery of a few new containers (of an existing approved type), as a result of which



another investigation into the causes was carried out by the licensee and its consulting firm. Bel V monitored the results very closely. Due to delays in the delivery of the containers, Bel V has also devoted more attention to fuel management in general (capacity of the docks, load plans for the containers, etc.).

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 emergency preparedness and response, transport, release etc., having in mind the importance for improvement actions to be permanent.
- Specific inspections were carried out in order to discuss particular topics that apply to various units (ventilation, monitoring of the construction of the 'Filtered Containment Ventilation System', etc.).

Bel V provided support to the FANC within the framework of its inspections, especially the management inspection and the inspections relating to 'ageing status preparation for the SALTO mission February 2017', stress tests, fire, waste ('Waste management: follow-up' and 'Long-Term Safety') and 'NV-Pro Action plan'. Support was also provided to the FANC for the implementation of the common action plan for the two sites and Corporate, in the wake of the events at the Tihange nuclear power plant that led to a court summons in 2015. The FANC was also provided with support for the evaluation of the progress in nuclear safety and safety culture.

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 was shut down in September 2016 due to soil heave in a building (after civil engineering work) rendering a pump unavailable. Electrabel carried out work to reinforce the stability of the subsoil. After verification that the reinforcement met the criteria, the unit was restarted on 20 May.

For the rest of the year, the unit operated at nominal power, except for the following periods:

- a loss of around 30% of power on 26 June due to a pump trip in the secondary circuit (non-safety-related);
- from 12 September to 24 November, in order to commission additional safety equipment, in line with the commitments made to the safety authorities under the terms of the extension of operation.

It should be noted that, by way of precaution, this shutdown had been moved forward by around 6 weeks following the detection of vibrations in the motor of one of the primary pumps.

1.1.7 Tihange 2

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

- a voluntary power reduction of one day, between 4 and 5 February, in view of a planned maintenance of the condenser (non-safety-related);
- the refuelling outage from 31 March until 29 May.

It should be noted that as a result of the unavailability of one of the two pumps of the tertiary circuit (non-safety-related), the unit operated at medium power (around 60%) until 22 June.

1.1.8 Tihange 3

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

- on 10 November, following an automatic reactor trip due to the spurious closure of a valve in the water supply circuit of the steam generators;

- on the night of 2 to 3 December, when a voluntary power reduction was undertaken in order to repair a valve in the steam supply circuit of the turbine.

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, amongst others, topics that apply to several units (qualification of specific materials, ventilation, etc.).

After an analysis of the underlying causes that led the FANC to issue a court summons in 2015, the licensee implemented an action plan aimed at structurally strengthening its safety and enhancing its safety culture. The actions planned for 2017 (organisational changes, training, etc.) were completed in line with their schedule. Bel V also provided technical support to the FANC for monitoring the implementation of this action plan and for evaluating the progress made in terms of safety and the safety culture of the licensee.

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.). The licensee undertook actions that enabled him to recover some of those licences. The fact that NIRAS/ONDRAF has taken charge of waste has led to a significant reduction in the volume of waste stored on site.

1.2 Overview of inspections at other nuclear facilities

1.2.1 Nuclear Research Centre (SCK•CEN)

The operating regime of the BR2 reactor in 2017 consisted of 3 cycles of 3 weeks and 3 cycles of 4 weeks.

During the 03/2017 cycle, there were two scrams of the reactor with the same cause. Due to a lightning strike to the electric grid, the vital grid was disconnected from the normal grid. The takeover by the diesels failed, as a result of which the vital grid was no longer supplied. The reactor scrammed and the evacuation signal was activated. During the first scram, the safety valves of the primary circuit moved, and hence the reactor was cooled by the natural circulation. After around one hour, the vital grid was reconnected to the normal grid.

During the second scram, the safety valves did not move and the vital grid was reconnected to the normal grid after some twenty minutes. No fission products were detected in the primary water. The fuel elements were thus adequately cooled at all times in both incidents.

During the 03/2017 cycle, there was another scram and a slow setback in the reactor due to faulty signals of 'flow too low in the primary circuit' and 'low water level in the reactor basin'.



REGULATORY ACTIVITIES IN BELGIUM

Upon the start-up of the primary circuit before the 06/2017 cycle, it was determined that the hydraulic link of the primary main pump J4-404 was defective. A derogation from the technical specifications was approved by the Health Physics department and by Bel V in order to start the 06/2017 cycle without a primary pump on standby.

The VENUS reactor was loaded with fuel assemblies with bismuth and with lead around the assemblies. The lead reflector assemblies were replaced by graphite reflector assemblies. The experimental programme continued with the study of the disturbances of this core configuration. Starting in September, the accelerator was thus in operation, but without being linked to the reactor.

No significant events occurred in the other facilities in 2017.

1.2.2 Belgoprocess

Periodic 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 continued in building 151X. Upon identifying gel outflows during the sorting process, the drums were packed in plastic and stored separately for additional follow-up.

The project for a new building for storage of these non-compliant packages was put on hold. Alternative concepts were developed, and the authorisation process will have to be started from zero.

On 16 January, there was a loss of electric power on site 2, due to the failure of the diesel to start up because of the faulty design of a new interlock for the diesel's fire safety.

On 20 February, liquid entered the pulsator room of building 234B during a transfer of B05 waste water from the SCK•CEN. Dismantling work had taken place in that room, in the course of which the operators had opened a pipe that was still in operation. The fluid was pumped into a storage tank and the pulsator room's drip tray was decontaminated.

On 2 June, a battery exploded in building 280X. This explosion was the consequence of sparks hitting a closed battery case, from which hydrogen gas diffused. There was material damage, but fortunately no persons were harmed. No nuclear contamination as a result of the incident was identified.

During the sandblasting of the O₂ tank during the renovation works, a small leak in the tank was identified on 14 June. Measurements showed that there was no contamination of the tank's drip tray. The leak was temporarily sealed with an epoxy resin, while awaiting the replacement of the tanks.

The Cilva supercompactor was turned off at the request of NIRAS/ONDRAF after some final storage drums were discovered to have a deformed bottom. The investigation to identify the cause of the problem is in progress.

During the preparations for unloading a transport container with liquid waste from the National Institute for Radioelements (IRE), a removable contamination was identified on the truck's walk ramp. After decontamination, the unloading of the transport container continued without any problem. Following this incident, transport between the IRE and Belgoprocess was temporarily suspended until a thorough causal analysis had been carried out by the IRE and corrective measures had been adopted. A problem also occurred with the pumping facility of building 108X when the fifth transport was being unloaded. The transport container was disconnected and the unloading will take place in early 2018.

1.2.3 Belgonucleaire

The rooms in building A were prepared for the final release measurements of the rooms and the building. At the same time, the underground pipe network in building A was dismantled and prepared for release. The release methodology for building A was further refined and approved by Bel V and the FANC.

Belgonucleaire also began a 'Historical Site Assessment' in preparation for the release of the site.

Because the dismantling of building A is already well advanced, the radiological risk is very limited.

Belgonucleaire continues to focus on retaining the necessary qualified persons on site and on thoroughly keeping track of the release measurements for final traceability.

1.2.4 National Institute for Radioelements (IRE)

The inspections carried out by Bel V in 2017 were related to various topics. The IRE is involved in the complex development of a new production line using low-enriched uranium (LEU) instead of highly enriched uranium (HEU). The licensee has obtained a new licence for the LEU-based production from the FANC.

The second periodic safety review (PSR) by the IRE was started and will in particular have to take into account conceptual margins in order to reinforce the design of the installation. Studies have been launched to build, replace or reinforce strategic components such as the reservoirs, the emergency installation (IUS - installation d'ultime secours) etc.

IRE-Elit, a subsidiary of the IRE, continues to develop new activities and is strongly involved in the development of new radio-pharmaceutical products.

1.2.5 JRC-Geel

Operation of the GELINA facility, the mass spectrometry department, the main building, the waste building and the X-ray devices occurred without any significant issues.

In 2017, one significant event was reported by the licensee. A total loss of power on site occurred when a main power supply cable was cut. Back-up power supply took over the safety-related SSC (systems, structures and components).

The remaining Belgian Stress Test (BESTA) actions were formally closed by the regulatory body but several PSR

actions are still open. For instance, a draft of the JRC-Geel Safety Analysis Report (SAR) received mid-2017 could not be approved as such by the regulatory body. Detailed analysis is being provided to JRCGeel in order to improve its first version of the Safety Analysis Report.

In 2017, JRC-Geel launched several important projects, such as a safety culture action plan and the implementation of an Integrated Management System.

Several modifications are pending and/or have been progressing slowly. The replacement of the Van de Graaff machine by a new Tandem accelerator took place during the summer of 2016. The new accelerator is currently off until the modification file and related Preliminary Safety Analysis Report (PSAR) have been submitted to Bel V for approval.

ONDRAF/NIRAS has revoked the JRC-Geel certification for waste characterisation and evacuation. A revised file was submitted for approval to ONDRAF/NIRAS mid-2017. No waste evacuation may be performed until this approval has been obtained.



1.2.6 Franco-Belgian Fuel Fabrication (FBFC)

The dismantling of buildings 1, 2 and 5 continued in 2017. The demolition of building 1 and the controlled demolition of building 2 has started.

The approval of the methodology and release files for buildings 1, 2, and 5M took place in 2017. The approval of the methodology and release files for building 5 and the ditches and lands of Franco-Belgian Fuel Fabrication is scheduled for 2018.

The completion of a sorting facility (FREMES) that will be used for monitoring contaminated soil as part of the soil decontamination of the site is planned for early 2018.

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.

Due to an unstable situation at NTP Europe, Bel V has maintained the high 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.

1.3 Emergency preparedness and response

1.3.1 Genuine activation of the external emergency plan

In the early afternoon of 10 January 2017, a genuine activation of the Nuclear and Radiological Emergency Plan for the Belgian Territory and the associated response structures took place following an event that occurred in unit 4 of the Doel nuclear power plant. This event, first attributed to a rupture in the steam pipes, was reported by the licensee as an N1 notification. In response to this initial notification,

the activation and mobilisation of the emergency response structures took place in accordance with the provisions of the Emergency Plan. Bel V representatives were dispatched to the federal crisis centre's evaluation unit, to the joint internal crisis centre of the FANC/Bel V and to the site in question. After the situation returned to normal and a closer investigation had been carried out, the emergency situation was lifted around 6:30 p.m. without any protective action having to be taken. This event therefore had no impact on the population or the environment.

After an activation in response to an incident that occurred in 2008 at the IRE, this was only the second activation of the Emergency Plan. Alongside regular exercises in which Bel V takes part (see below), this genuine activation of the Emergency Plan demonstrated that Bel V has sufficient response capacity to fulfil the tasks assigned to it in this regard.

1.3.2 Emergency response exercises

In 2017, four 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 May for the Belgoprocess site: partial exercise limited to the interaction between the emergency crisis cell of the licensee (on-site) and the evaluation cell CELEVAL (off-site);
- in June for the SCK•CEN site: 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: 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 Doel 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). This exercise had the particularity of combining a 'safety' dimension with a 'security' dimension.

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 a 'controller' and 'evaluator' for the Doel exercise (a Bel V representative was appointed as member of the exercise management team and another as 'evaluator' of the evaluation unit). A Bel V representative was also involved in a workshop for first responders and an information session that was held in the context of this exercise. These exercises, which allow the relevant persons at Bel V to regularly put into practice the provisions of the operational plans and procedures, also allowed for a number of observations to be made that will, after analysis, be subject to specific action (for example, in terms of training).

In addition to the above-mentioned exercises, Bel V participated, albeit to a limited extent, in three international exercises organised respectively by the International Atomic Energy Agency (IAEA), the European Commission and France (Cattenom nuclear power plant).

1.3.3 Other related activities

Bel V took part in further work on projects launched in the previous years (such as the development of improvements regarding the protection of first responders in case of a radiological emergency and related training sessions).

Bel V, together with the FANC, has also been involved by the DG Crisis Centre in the continued process of reviewing the Royal Decree on the nuclear and radiological emergency plan for the Belgian territory. After taking account of the consultation of various stakeholders, a consolidated proposal for a revised version of this plan was submitted to the Minister of the Interior at the end of 2017. An official publication of the revised plan is expected in the first months of 2018. It should be noted that an information campaign on nuclear risk and on the distribution of stable-iodine tablets, in which Bel V will be involved, should be launched in March 2018.

1.3.4 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). It should also be noted that meetings for information exchange among Bel V participants were organised after most of these exercises in order to reinforce the feedback from the Bel V staff involved.
- Limited communication and availability exercises and tests were organised throughout the year. A total of 21 tests of that type took place in 2017.
- A Bel V representative took part, as 'EP&R Reviewer', in an OSART (Operational Safety Review Team) mission at the Taishan nuclear power plant (China, January 2017).
- A Bel V representative participated as Trainer in two Train-the-Trainer sessions dedicated to the protection of first responders (Seraing and Ranst, October 2017).
- A Bel V representative took part in a workshop organized by the IAEA on the implementation of internal emergency plans (Vienna, May 2017).
- A Bel V representative participated as Trainer in a 'National System for Emergency Preparedness and Response' training offered by the European Nuclear Safety Training and Tutoring Institute (ENSTTI) (Fontenay-aux-Roses, May 2017).



REGULATORY ACTIVITIES IN BELGIUM

- 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. In this context, two representatives of Bel V took part in a two-day workshop in Paris (Paris, October 2017).

1.3.5 International collaboration

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

- WG Emergencies of HERCA (Heads of European Radiological Protection Competent Authorities) (Madrid in February 2017, Oxford in March 2017 and Oslo in September 2017);
- exchange meeting between IRSN, the FANC and Bel V on emergency preparedness and response (Brussels, June 2017);
- seminar organised by the Grand Duchy of Luxembourg on the application of the HERCA-WENRA approach (Luxembourg, July 2017);
- information exchange meetings among the Belgian and Dutch authorities.

2

INTRODUCTION

MARC DUBOIS

2017 was a year in which, once again, several challenges were met as part of the major regulatory projects, including: decennial reviews, lifetime extensions of the Belgian units, probabilistic assessments, temporary storage of spent fuel, action plans relating to stress tests conducted following the accident at Fukushima-Daiichi, the surface disposal of category A waste, and the future MYRRHA research reactor.

In this context, Bel V has demonstrated its highly developed and diversified skills and organisational capacity, to the benefit respectively of bringing the requisite level of quality to its technical analysis and of abiding with the project timetables. To illustrate this point, let us evoke a few examples of important ongoing safety evaluation dossiers at the Belgian nuclear facilities.

For a few years now, the monitoring of the 'Long-Term Operation' action plans has continued at the two oldest units, with the plans including an Ageing Management Programme and a re-evaluation of the design. At Tihange 1, the approval by Bel V of the requests for closure of the LTO ageing projects advanced significantly in 2017. The partial commissioning of the Emergency System (SUR) was also announced.

The timetable approved by the FANC has been followed without significant delay. For Doel 1/2, Bel V is continuing its efforts to evaluate all the changes to be made during the extended unit outages planned in 2018 and 2019.

As regards the BEST action plans, an in-depth re-evaluation of the Doel and Tihange sites was carried out by the licensee and submitted to the safety authorities for analysis. The sites are now adequately reinforced to withstand external attacks (flood, earthquake). A backup of the crisis operating centre has yet to be established at Tihange.

The SF² prelicensing project has, moreover, made it possible for Bel V's experts to make a significant contribution to verifying the correct application of the recent FANC guidance regarding the safety demonstration at Class I nuclear facilities.





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 PSAs for the Belgian nuclear power plants.

These PSAs include a plant-specific Level 1 PSA for each Belgian unit (including Doel 1/2, for which the development of Fire and Flooding PSAs 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 Level 2 PSA for a representative unit (Doel 3). All plant operating states are covered.

In 2017, Bel V continued the review of the development of the Flooding PSA for Doel 1/2. The final results of the Doel 1/2 Flooding PSA were delivered by the licensee

in June 2017, and Bel V then performed its final evaluation of this PSA project (the review of the Flooding PSA for the other units had already been completed in 2016).

For the Internal Fire Level 1 PSA, Bel V monitored two specific projects defined by the licensee. The first project consisted in the development of distinct Fire PSAs for Doel 3, Doel 4, Tihange 1, Tihange 2 and Tihange 3 (a global upgrade of the preliminary Fire PSA studies performed for these units at the end of 2015, which led to over-conservative results). The second project concerned the development of a specific Fire Level 1 PSA for Doel 1/2, which was required in the context of the lifetime extension of these twin units. The review of these projects by Bel V also included audits of the databases (for the cables and the spatial localisation of the components in the plants used as input in the Fire PSA studies). By the end of 2017, the final results obtained within the context of these Fire PSA projects were delivered by the licensee, and Bel V then started its final evaluations.

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.

- At the end of 2016, the FANC approved the methodology to assess the 15 safety factors that provide the framework of the PSR of the IRE. In 2017, the IRE submitted assessments for several safety factors to be reviewed by Bel V. The assessment phase of the IRE has to be completed by the end of March 2018. The results will be summarised and presented to the Scientific Council at the end of 2018.
- In the context of the decennial safety review at Belgoprocess Site 1, Bel V received an important document from Belgoprocess in June, namely the classification into SSCs (systems, structures and components) of the buildings of site 1. After analysing the document, a letter was sent to Belgoprocess with comments by Bel V. No items that

could hinder progress were identified. After a consultation meeting between Bel V and Belgoprocess, an updated version of the memo was provided to Bel V. Bel V also received the first documents relating to a number of safety factors, and is currently engaged in their analysis.

- The decennial safety review at Belgoprocess Site 2 was submitted to the FANC's Scientific Council on 24 February. No objections were made by that body, and the action plan was thus approved, meaning that the implementation phase could begin. At the moment Belgoprocess is implementing the action plan.

2.3 Long-Term Operation (LTO) - Tihange 1

The implementation of the LTO action plan at Tihange 1 continued in 2017:

- development of an Ageing Management Programme;
- re-evaluation of the design (Agreed Design Upgrade).

Work relating to the topic of 'Ageing' (in the domains of Electricity, Instrumentation and command and control, Mechanical systems and structures, Civil engineering) was completed during the 2016 unit outage (with a few very rare exceptions, duly justified to the FANC and Bel V).

The examination and approval of requests for closure of the LTO projects submitted by the licensee with regard to this topic formed the bulk of Bel V's workload in 2017. The total number of 'Ageing' projects finalised by Bel V stood, at the end of 2017, at 72 projects out of 86 requests submitted (the total number of 'Ageing' projects being 93).



The following major projects on the topic of 'Design' advanced as follows in 2017:

- 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 was completed in 2017. The modification files relating to the installation of internal equipment (electric panels, diesel generator groups, pumps, tanks, pipes, ventilation systems, etc.) are under examination at Bel V, or already in the process of implementation (preparatory work). In line with the LTO schedule, the partial commissioning of the extended SUR (involving the connection of a new, higher-capacity safety-related auxiliary feedwater tank for the steam generators) took place in November 2017 after the scheduled unit outage. The complete commissioning of the SUR extension is planned for the end of 2019.
- Improvements to fire detection and protection are made in 4 phases, between 2015 and the end of 2019. The first two phases are in the process of completion.

The vast majority of the commitments and projects of the LTO action plans for Tihange 1 are progressing in line with the schedule approved by the FANC and without any significant delays.

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 continued for the implementation of the various LTO actions planned during nominal power operations

and during refuelling in 2017, and especially during the long common stops scheduled for 2018 and 2019. 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 2017 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 start-up after the refuelling, was certified.

In February 2017, a SALTO mission was conducted by the International Atomic Energy Agency (IAEA). Based on the SALTO report, the IAEA deemed that ENGIE Electrabel is managing the LTO programme well, in line with the international standards in this regard, but that there is also room for improvement.

Twelve international IAEA experts prepared an evaluation of the various projects that ENGIE Electrabel has carried out as part of the LTO. This was done by means of a few clearly defined areas such as human resources and knowledge management, ageing management for mechanical and electric components, civil engineering, internal organisation and the management of modifications to the facilities.

Based on these areas, the international experts analysed a substantial number of actions. They provided various recommendations and suggestions for reinforcing the LTO management by ENGIE Electrabel.

In addition, they also identified several good practices and achievements on the part of the licensee:

- integrated risk management for LTO at various levels;
- a comprehensive scoping methodology for selecting the systems, structures and components for the analysis regarding ageing during the ten-year LTO period;
- measures to address staff turnover to ensure that knowledge is not lost when staff members leave.

The team also provided a few recommendations for improvement:

- The licensee must ensure that all required systems, structures and components for ageing management are followed up during the LTO period.
- The licensee must ensure the consistency and completeness of data regarding structures and components in the context of the LTO.
- The licensee must complete the review and update of the ageing management programmes for civil structures and components relating to the LTO.

A follow-up mission is provisionally scheduled for 2019. That mission will evaluate the actions taken by ENGIE Electrabel to implement the recommendations and suggestions made by IAEA during the SALTO mission.

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 2017, the strategies intended to deal with loss of electrical power or heat sinks were well defined on both sites and had been the subject of additional work, previously completed at Doel and now also at Tihange. Similarly, filtered vents were installed at the Doel and Tihange units and are now operational (with the exception of Doel 1/2 where this equipment, installed as part of the LTO project, will be operational in 2019). The installation of a new backup of the current crisis operating centre at Tihange is the last of the most important actions to be finalised within the action plan that was drawn up following the stress tests.

In sum, by the end of 2017, ENGIE Electrabel had completed more than 92% of the action plan, and estimates that most of the remaining actions should be completed in 2018.



In 2017, 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 were sometimes significant (estimated at one or even two years) for the most ambitious safety improvements, and affected 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 2017, 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. In December 2017, all the ONDRAF/NIRAS answers had been approved by the FANC and Bel V. In 2018, Bel V will verify whether these answers have been taken into account in the revision of the safety case.

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. At this stage of the programme, the emphasis for Bel V is on the development of its knowledge and expertise, which is critically important for the review of Safety & Feasibility Case 1 (SFC 1), which will be submitted by ONDRAF/NIRAS in 2020. In 2017, Bel V mainly contributed to the deployment of the Strategic Research Needs (SRN) to structure the needs of the regulatory body in the development of its knowledge and expertise through research and development associated with the geological disposal of radioactive waste and spent fuel.

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 the storage of spent fuel on the Doel site, the Q&A

process between the different stakeholders continued in 2017. In the course of 2017, discussions have been initiated for other new types of dual-purpose casks for the storage of spent fuel at the Doel and Tihange sites. Those discussions take place in the context of the SF² project (Spent Fuel Storage Facility) scheduled at both sites. The analysis of the Safety Assessment Report (SAR) for a new cask for the wet transfer of spent fuel on the Tihange site is also ongoing, in collaboration with the FANC.

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 affected by this gel formation issue. An action plan was developed by ONDRAF/NIRAS and Belgoprocess to address this issue. One of these actions is the construction of a new facility on the site of Belgoprocess dedicated to the storage of these drums. A pre-licensing phase for this project was initiated in 2016, followed by a license application in 2017. Bel V performed the safety analysis of the documents received from Belgoprocess in this regard.

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 2017. This pre-licensing phase will continue in 2018.

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 2017, around half of the deliverables had been provided by the SCK•CEN. Technical meetings took place to discuss focus points with SCK•CEN. Given the constant evolution of the MYRRHA design, more deliverables can be expected beyond 2017.

But since it was not possible to deal with all the focus points by Q3 of 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.

In Q3 of 2017, the SCK•CEN submitted a file to its supervisory authority with a view to obtaining the subsidies required to continue the project.

In 2017, the SCK•CEN launched a licensing process for the creation and operation of a 100 MeV accelerator, to be completed in 2019, with the construction works planned for 2020-2025 and commissioning scheduled for 2024-2025 (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 another design with relatively important modifications (reactor loop-type design instead of reactor pool-type design).

2.8 SF² – spent fuel storage facilities

ENGIE Electrabel is carrying out a process of pre-licensing 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 SF² 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.

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

A Design Options and Provisions File (DOPF) presenting the selected nuclear safety and nuclear security provisions of SF² was issued by ENGIE Electrabel and reviewed by the FANC / Bel V. A number of technical meetings were held between the FANC, Bel V, ENGIE Electrabel and Tractebel Engineering to discuss the main licensee answers to comments made by the FANC / Bel V. Formal answers to all FANC / Bel V comments were given by ENGIE Electrabel in October 2017. The FANC and Bel V are now preparing their final opinion on the SF² pre-licensing, to be presented to the Scientific Council in February 2018.

ENGIE Electrabel will now submit a license application for SF² to the FANC. For this purpose, the Preliminary Safety Assessment Report (PSAR) for the Tihange nuclear power plant taking into account all FANC / Bel V comments on the DOPF, which was initially scheduled for June 2017, has been postponed to the end of March 2018. The PSAR for the Doel nuclear power plant should follow a few months later.

Both SF² spent fuel storage facilities are expected to be operational in 2023. However, Bel V would like to stress that it believes the SF² planning to be very ambitious.



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 CNRA Working Group on Safety Culture (WGSC);
- the CSNI Working Group on Fuel Cycle Safety (WGFCFS);
- 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 (WGHOFF);
- the CSNI Working Group on Fuel Safety (WGFS);
- the CSNI Working Group on Electrical Power Systems (WGELEC);
- the CSNI Working Group on External Events (WGEV);
- the RWMC Integration Group for the Safety Case (IGSC);
- the RWMC Working Party on Management of Materials from Decommissioning and Dismantling (WPDD);
- the Incident Reporting System Coordinators' activities (IRS, IRSRR, FINAS);
- various OECD projects (see also Section 4.4 on research and development).

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 spring and autumn meetings. He is also Vice-Chairman of the Steering Committee of the Technical and Scientific Support Organization Forum (TSOF) of the IAEA and Bel V participated in two meetings of the TSOF in 2017. The General Manager of Bel V is also the Belgian representative in the Nuclear Safety Standards Committee (NUSSC) of the IAEA.

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 ninth meeting of this committee.

At the International Conference on Topical Issues in Nuclear Installation Safety: Safety Demonstration of Advanced Water Cooled Nuclear Power Plants held by the IAEA (Vienna, June 2017), Bel V presented a keynote lecture on behalf of the European Technical Safety Organisations Network (ETSON) and presented a technical paper on the Belgian regulatory guidance documents for safety demonstration and external hazards.

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

- cyber threats and computer security at nuclear facilities;
- external hazard risk assessment;
- operating experience feedback for nuclear power plants and other facilities;
- safety of radioactive waste management and disposal;
- human reliability assessment;
- decommissioning, release of sites and clearance of materials;
- emergency preparedness.

In close collaboration with the IAEA, Bel V has started preparations for hosting the 'International Conference on Challenges Faced by Technical and Scientific Support Organizations (TSOs) in Enhancing Nuclear Safety and Security: Ensuring Effective and Sustainable Expertise' in October 2018. Bel V also participated in two programme committee meetings to prepare for this conference.



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. In 2017, special attention was given to the publication on timely implementation of reasonably practicable safety improvements to existing nuclear power plants (in accordance with Article 8a of the EU Nuclear Safety Directive), WENRA's input for the IAEA Safety Strategy, the ad-hoc working group on reference levels for research reactors, the current status of reactor pressure vessel issues and carbon segregation in large steel components, challenges with regard to supply chain control, and the IAEA Convention on Nuclear Safety.

Reactor Harmonization Working Group (RHWG)

Bel V participated in the three RHWG meetings held in 2017. Concerning the WENRA Reference Levels, the RHWG continued discussions on the benchmarking of the implementation of the 2014 Reference Levels in national regulations, the benchmarking of the implementation of the 2014 Reference Levels in the nuclear power plants, and the development of reference levels on internal hazards and on external hazards (for natural and man-induced hazards). The RHWG also worked on a future publication on the 'practical elimination' of accident scenarios and a future publication on the safety of passive systems.

Working Group on Waste and Decommissioning (WGWD)

In 2017, the report 'Radioactive Waste Treatment and Conditioning Safety Reference Levels' was reviewed by different stakeholders (such as the European Nuclear Installations Safety Standards Initiative (ENISS) and the Club

of Agencies). As a result, Bel V's activities in 2017 were much more limited than in 2016, focusing mainly on the analysis of stakeholder comments. In preparation of the 39th WENRA-WGWD meeting in September 2017, Bel V submitted the position of the Belgian regulatory body on those comments to the WGWD.

3.2.2 Franco-Belgian Working Group on the safety of nuclear facilities

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

In 2017, only one meeting was held. The main topics at this meeting were: new regulatory initiatives in both countries, status of the Chooz and Gravelines nuclear power plants, cross-inspections, decommissioning and waste management, feedback on emergency response exercises, 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 2017, the following topics were discussed, amongst others: reactor vessel issues and issues related to large mechanical components, operational experience feedback concerning a number of specific events that occurred in Swiss and Belgian nuclear facilities, the safety assessment of steam generator tube rupture events, and decommissioning of nuclear facilities.

3.2.4 Task Force on Safety Critical Software (TFSCS)

The 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 in nuclear digital instrumentation 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. Eleven institutes from ten countries are currently participating members. Two plenary meetings took place in 2017 (hosted by SSM, Sweden, 25-27 April, and by CSN, Spain, 19-21 September).

The last edition of the Common Position report on licensing practices 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 (NRC), which had participated in the meetings of the task force from 2009 to early 2016, issued a NUREG/IA report, which includes the task force position report as well as NRC commentaries to assist NRC staff in using this information in its licensing review and regulatory framework.

Since then, and in particular in the course of 2017, the TFSCS has continued work by revisiting a number of topics, and by working on new licensing concerns raised by the challenges brought by digital technology. Cyber security issues cause specific problems and require measures to protect software against unauthorised access and malicious interactions. Technological developments in circuit design result in the

production of components with programmable integrated logic, such as programmable logic devices and field gate arrays. The verifiability of their conception and performance poses new issues as well.

The results of these recent activities will be included in a new edition of the Common Position report, which is scheduled for early 2018.



3.3 Cooperation with technical safety organisations

3.3.1 EUROS SAFE

In November 2017, the French technical safety organisation *Institut de Radioprotection et de Sûreté Nucléaire* (IRSN) hosted the EUROS SAFE Forum in Paris. The EUROS SAFE Forum, which is a co-organisation with the *Gesellschaft für Anlagen- und Reaktorsicherheit* (GRS, Germany), 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.

EUROS SAFE Tribune is now published as a monthly electronic newsletter. Bel V took the lead for the issue published in October 2017 (available at <https://www.eurosafe-forum.org/node/406>). 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 has been President of ETSON. The ETSON General Assembly and/or Board met in Frascati (June), Bled (September) and Paris (November,

on the occasion of the EUROS SAFE Forum). One of the outcomes was the publication of the new ETSON Strategy for the Future on the ETSON website.

In 2017, the extension of the network was further explored and a new member organisation of Romania (RATEN ICN) joined ETSON.

A Bel V representative continued chairing the ETSON Technical Board for Reactor Safety (TBRS) to oversee the technical activities of ETSON, such as the functioning of the ETSON Expert Groups and the publication of Technical Safety Assessment Guides (available at <http://www.etson.eu/reports-and-publications>).

Bel V representatives took an active part in the ETSON Expert Groups, aimed at sharing views and experiences with colleagues of other technical safety organisations. Bel V is chairing the Expert Group on Ageing Management and in 2017 Bel V took the lead to relaunch the ETSON Expert Group on Human and Organisational Factors.

From 10 until 14 July, three junior Bel V members of staff participated actively in the ETSON Summer Workshop in Ljubljana (Slovenia). The workshop was devoted to 'Uncertainty and sensitivity in safety analysis'. Bel V representatives participated by giving several presentations and by chairing a session.

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 2017, Bel V members of staff gave the following lectures:

- 'Emergency Preparedness and Response in Belgium - Current situation and perspectives' in the training module on 'Nuclear safety - Emergency preparedness and response';
- 'The meaning of Safety Culture for the Operator and its sub-contractors' in the training module 'Safety Aspects and Regulatory Requirements related to Fusion Reactors';
- 'Examples of national approaches in Europe - Belgium' in the training module 'Lessons Learned from the Fukushima Daiichi Accident and EU Stress Tests'.

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 2017. For instance, a PhD thesis co-funded by Bel V and IRSN 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 was followed.

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. IRSN asked Bel V for an independent verification of the validation of version 6.7 of the SCANAIR software. More specifically, this involves a contribution to expertise in the use of the SCANAIR version 6.7 software in the safety demonstration with regard to accidental ejections of a rod and uncontrolled group withdrawal at zero power. In 2017, Bel V finalised its assessment of the SCANAIR software and submitted its conclusion to IRSN.

3.3.5 Collaboration with technical safety organisations on waste management

In 2017, Bel V closely collaborated with other technical safety organisations in European projects related to waste management, such as JOPRAD and SITEX-II.

Within the framework of SITEX-II the establishment of the SITEX_ Network association was prepared, aiming at strengthening TSO expertise in the field of waste management.

Since 2017, Bel V has also actively collaborated as TSO representative within the Core Group facilitating and coordinating the preparation of a proposal for a first European Joint Programme on Radioactive Waste Management and Disposal, based on the results of the JOPRAD project.



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 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.

The project is scheduled for completion in 2019.

3.4.2 Egypt

Bel V 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. Bel V was 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 was 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.

The final meeting was held in Brussels in May 2017.

3.4.3 Thailand

Bel V 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 lasted for three years. Bel V was 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.

The final meeting was held in Brussels in November 2017.

3.4.4 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.

3.4.5 Council Directive 2013/59/EURATOM

Bel V 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. Bel V was responsible for task 5 on summarizing and evaluating Member States' strategies and plans to implement the Basic Safety Standards Directive.

The project was completed in 2017.

3.4.6 Lithuania

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

Task 2 related 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.

The project was completed in 2017.





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 2017, 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 3 IRS reports, 1 IRSRR report and 1 FINAS report.

2017 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:

- reactor trip and safety injection signal following a 380 kV circuit breaker trip at Doel 4;
- significant contaminations in a reactor building and a nuclear auxiliary building as a result of several interventions during the refuelling outage at Doel 4;
- emergency boration and safety injection during cold shutdown at Tihange 2;
- 2 events of loss of vital electrical power following a lightning strike at the BR2 reactor;

- manual scram following a flooding of the turbine building due to significant leakage in the circulation water system at Doel 4;
- removed valve internals causing a potential leak path between the reactor building and the atmosphere during the refuelling outage at Doel 1;
- reactor trip and safety injection signal as a result of the closing of main steam isolation valves (MSIV) during a periodic functional test of the MSIV closing signal at Doel 4;
- degradation of concrete walls of main steam blow-down rooms resulting in a reduced resistance of the emergency systems building to the impact of external events at Doel 3;
- leak at a socket weld of a vent line of the safety injection system within the reactor building at Doel 4.

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 2017 Bel V performed an applicability review of the following generic issue in France: risk of loss of heat sink for 29 reactors operated by EDF. Bel V also requested a similar review from the licensee ENGIE Electrabel. This review concluded that the risk of flooding of emergency service water system related safety equipment due to corrosion issues in safety and/or non-safety related systems is adequately managed by design and/or surveillance measures at all Belgian nuclear power plants.

In addition the Belgian nuclear power plant licensee was invited to provide answers to specific questions after analysis of the following reports:

- IRS 8567 and IN 2017-05 'Potential binding of Schneider Electric/Square-D Masterpact NT and NW 480-Vac circuit breaker anti-pump system';
- NRC IN 2016-05 'Operating experience regarding complications from a loss of instrument air';
- IRS 8591 'Various Electroswitch products sold as safety class 1E not properly qualified';
- IRS 8617 'Arc flash in emergency distribution board resulting in reactor shutdown'.

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

- IRS 8178 'Calibration of high head safety injection to RCS cold legs', initiated in 2011, was closed after review of the utility company's responses and of the modified test procedures;
- NRC RIS 2013-09 and IRS 8381 'System gas accumulation - prevention and management' progressed with the review of responses from the licensees.

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 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 2017, several new engineers were recruited. This requires considerable efforts on the part of the more experienced engineers to ensure an adequate transfer of knowledge. A coach is assigned to every newly recruited person, to facilitate their integration. This knowledge transfer approach is combined with, among other things, on-the-job training and cross-functional activities. The recruitment of a high number of new people also requires customised training (see Section 4.5).

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

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

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

4.4 Research and development

4.4.1 Introduction

The 2017 research and development (R&D) programme was set out in February 2017. This section provides a summary of the main R&D activities carried out in 2017.

The total effort in R&D activities in 2017 amounted to 7,742.25 hours, which represents about 7% of the total working time for the technical staff.

The involvement in R&D activities remains a key pillar for the continuous development and sustainability of Bel V's expertise.

4.4.2 R&D on nuclear installation safety

Thermal-hydraulic phenomena

Bel V participated in the OECD/NEA experimental thermal-hydraulic PKL-4 and ATLAS projects, allowing Bel V to develop an ATLAS model for CATHARE code in collaboration with a trainee from EDF. The Bel V representative was also elected as a Chair of the Program Review Group of the ATLAS2 project, and vice-Chair of the Programme Review Group of the PKL-4 project.

In the context of the RELAP5-3D activities, Bel V simulated heat conduction in axial direction in a column of low-velocity Pb-Bi eutectic alloy coolant, as well as heat conduction from Pb-Bi coolant to cover gas inside the MYRRHA reactor by using conduction enclosures and special heat structures. Bel V also simulated heating of the fuel pins of an irradiated MYRRHA assembly that is accidentally dropped and left without cooling inside the containment.

Bel V participated in the OECD Working Group on Analysis and Management of Accidents (WGAMA) related to the drafting of the 3DSYSTH State-of-the-Art Report. Bel V was in charge of writing a dedicated chapter §2.2.5 on the use of the 3D System-Scale Thermal-Hydraulic Codes (3DSYSTH) for Feed Water Line Break (FWLB)-related scenarios.

Bel V continued its cooperation with IRSN for the DENOPI project, aimed at acquiring experimental data on the physical phenomena associated with a spent fuel pool loss-of-cooling and loss-of-coolant accidents. In this context, Bel V developed a CATHARE model for simulating the small-scale pool test rig, and performed CATHARE simulations of the experimental tests.

Finally, Bel V contributed to several communications. Firstly, a common publication by Bel V, the *Gesellschaft für Anlagen- und Reaktorsicherheit* (GRS) and the Paul Scherrer Institute (PSI) related to calculations on mixing under natural circulation flow conditions using 3D thermal-hydraulic system code and Computational Fluid Dynamics (CFD) codes was presented at the NURETH17 conference. Secondly, a common publication by Bel V, GRS, the *Helmholtz-Zentrum Dresden-Rossendorf* (HZDR) and PSI related to mixing under natural circulation flow calculations using 3D thermal-hydraulic system code and CFD codes was submitted to the American Nuclear Society (ANS) for publication in Nuclear Technology. This paper is currently under review. Thirdly, a report related to the comparison of the results of the CATHARE and MELCOR code calculations in simulating the natural circulation interruption phenomenon in a 3-loop pressurised water reactor was issued internally. A NUREG/IA version of this report will be issued in 2018.

Severe accidents progression

With the objective of strengthening Bel V’s capabilities with regard to independent severe accident safety assessment for the Belgian nuclear facilities, the effort in developing and improving MELCOR simulation capabilities at Bel V continued in 2017. A MELCOR 2.2 model of a 3-loop pressurised water reactor is now available to Bel V for its safety assessments. The main effort was focused on completing the containment modelling, in particular converting the plant data into code input data and the selection of the most suitable modelling assumptions. Lessons learned and feedback were shared within the MELCOR community in the context of review meetings in which Bel V participates.

Bel V is creating a database of MELCOR models which includes not only Belgian nuclear facilities, such as nuclear power

plants (mentioned above), spent fuel pools and MYRRHA¹, but others as well, such as experimental facilities, generic models and Fukushima Daiichi units, which are suitable for performing steady-state and transient analyses.

Thanks to the availability of suitable calculation results from this database, Bel V was able to perform its first independent assessment of an issue related to the containment filtered venting system (CFVS) installation in Belgian nuclear power plants (with the aim of identifying priority questions and supporting interpretation of the licensee’s MELCOR results).

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

Bel V attended the 9th European MELCOR User Group (EMUG) meeting, the Cooperative Severe Accident Research Programme (CSARP) meeting, the MELCOR Code Assessment Programme (MCAP) meeting, the final workshop of the Passive and Active Systems on Severe Accident source term Mitigation (PASSAM) project, the European Review Meeting on Severe Accident Research (ERMSAR) conference, the workshop of the In Vessel Melt Retention (IVMR) project and the Severe Accident Research NETwork (SARNET) course on severe accident phenomenology.

¹ MELCOR cannot be used for lead-bismuth cooled reactors. However, the code can provide useful information about containment performance and fission product behaviour during design-basis and severe accidents.



Bel V contributed to the CSNI Working Group on Analysis and Management of Accidents (WGAMA) documents 'Phenomena Identification and Ranking Table (PIRT) on Spent Fuel Pools under Loss-of-Cooling and Loss-of-Coolant Accident Conditions' (NEA/CSNI/R(2017)18), 'Informing Severe Accident Management Guidance and Actions through Analytical Simulation report on the WGAMA WG' (NEA/CSNI/R(2017)16) and 'Status Report on Ex-Vessel Steam Explosion: EVSE' (NEA/CSNI/R(2017)15).

Bel V has actively participated in the OECD/NEA Thermal-hydraulics, Hydrogen, Aerosols, Iodine (THAI-3) project, thanks to the cooperation with the von Karman institute for fluid dynamics (VKI). Any useful results will be used in the evaluation of the licensees' nuclear safety assessments.

Finally, Bel V has contributed to the DENOPI project of IRSN by performing analyses of the aerualics of the spent fuel pool building during accident conditions by means of MELCOR code, in support of the interpretation of future experimental results.

Fission product and aerosol behaviour

In 2017, Bel V continued its participation in the BIP-3 project (aiming to investigate the behaviour of fission products (iodine in particular) and aerosols in the containment after core melt accidents) and attended two Programme Review Group meetings.

PSA methodology and its applications

In 2017, Bel V attended the 20th Technical Meeting on Experiences with Risk-Based Precursor Analysis (Petten, 19-20 October). PSA-based event analyses performed by ENGIE Electrabel for Belgian nuclear power plants and by foreign organisations (utility companies, technical safety organisations) for nuclear power plants abroad were presented and discussed.

In 2017, Bel V participated in several international activities in order to maintain adequate expertise in PSA methodologies.

Within the framework of the follow-up of the development of human reliability assessment (HRA) methods, Bel V attended the PSAM conference on human reliability assessments in Munich (7-9 June) and the IAEA Technical Meeting

on the Development of the Safety Report on Human Reliability Assessment for Nuclear Installations (Vienna, 13-17 November). As part of its participation in the IAEA Technical Meeting, Bel V actively contributed to the review of an IAEA guidance in preparation (i.e. 'Safety report on Human Reliability Assessment for Nuclear Installations').

Bel V also participated in the ETSON Workshop on 'PSA from a TSO Perspective' (IRSN, Fontenay-aux-Roses, 8 November) and gave a presentation entitled 'Experience of the Belgian TSO with review of PSA models and PSA applications'.

Fire protection

The 3rd phase of the OECD/NEA PRISME project started in 2017. The project partners agreed on the experimental programme and the first campaign started at the end of the year. This campaign (called S3 - 'Smoke Stratification and Spreading') studies fire behaviour and in particular smoke propagation in a large-scale multi-room configuration, possible using multiple fire sources.

Bel V continued to be involved in the OECD/NEA FIRE database, the first release of which since Bel V/Belgium joined was published in August 2017. This database collects fire event experience (through international exchange) in an appropriate, quality-assured and consistent format. The information generated and published in this context can be used, for example, in Fire PSA activities.

In collaboration with GRS, Bel V organised and hosted the 15th International SMiRT Post-Conference Seminar on Fire Safety in Nuclear Power Plants and Installations (in Bruges). This seminar was a unique opportunity to gather more than 60 international experts from Europe, the United States and Asia to present and discuss current issues on fire safety in nuclear facilities and varied topics such as regulation, design, operating experience, experimental research, and deterministic and probabilistic risk assessment.

The last research report from the PhD thesis funded by Bel V at Ghent University was published, and the work is now entering its final phase. The high-quality work performed should allow to improve the capabilities of numerical fire modelling codes, especially the reproduction of transient phenomena, such

as pressure effects that could severely affect the dynamic confinement of a nuclear facility.

Regulatory approaches and practices

ETSON collaboration and expert groups

In 2017, 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 two meetings of the TBRS and Bel V representatives participated in meetings of the Expert Groups. The most active Expert Groups in 2017 were related to mechanical systems and probabilistic safety assessments (PSA). Within the framework of the latter Expert Group, Bel V representatives participated in an ETSON workshop on 'PSA from a TSO perspective – Experts from TSOs provide lessons learned through PSA application and review' (Paris, 8 November) and Bel V presented a paper on experiences with the review of probabilistic safety assessments.

Bel V also took the initiative to re-launch and take the leadership of the ETSON Expert Group on 'Human and Organisational Factors'. Bel V will be organising a kick-off meeting on 18 January 2018.

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

Ageing

Bel V participated in the ODOBA project, an experimental study on ageing and degradation mechanisms in concrete conducted by IRSN in Cadarache, France. This international R&D activity will enable Bel V and the FANC to develop their expertise in ageing mechanisms in concrete components.

A number of technical meetings were held with all stakeholders in 2017 to develop and confirm the practical details of the experimental programme. Specific concrete compositions for Belgium were proposed in this project.

4.4.3 R&D on waste and decommissioning

Geological disposal of category B&C waste

In 2017, Bel V initiated implementing actions to develop and strengthen the expertise of the FANC and Bel V in the field of the geological disposal of category B&C waste. The development of this expertise is required for the review by the FANC and Bel V of the 'safety and feasibility case' regarding geological disposal that will be submitted to the FANC in 2019 by ONDRAF/NIRAS. Bel V also actively contributed in international activities. For instance, Bel V participates in the Core Group facilitating and coordinating the proposal development for a first European Joint Programme on radioactive waste management and disposal. Bel V also leads the development of a networking work package on 'Understanding of Uncertainties, Risks and Safety by the different actors', in which more than 50 organisations across Europe have expressed an interest. Together with IRSN and other technical safety organisations, Bel V also helped to prepare the establishment of the SITEX_Network association in January 2018, aimed at promoting the development of a strong expertise function at international level. These activities have contributed to increasing the visibility of Bel V at international level and to ensuring that Bel V will be involved in future strategic R&D and networking activities in the field of radioactive waste management.



4.4.4 R&D on radiation protection

Bel V set up a collaboration with the *Rijksinstituut voor Volksgezondheid en Milieu* (RIVM) in the Netherlands in order to develop criteria and screening levels for surface contamination with a view to clearance. A thorough study was performed on 4 typical objects for different isotopes and isotopic vectors. Benchmarking with other international references was performed and showed satisfactory results. A report was edited by Bel V and reviewed by the RIVM on the preliminary results of the use of the SuDoQu methodology for the calculation of effective dose related to specific exposure scenarios for re-use of objects from a controlled area.

Two 2-day workshops were held (in April and June) to present the first results of the SuDoQu methodology to the RIVM, the *Autoriteit Nucleaire Veiligheid en Stralingsbescherming* (ANVS), Bel V and the FANC.

At the Workshop on Low Doses (11-12 September) organised by the Scientific Council of the FANC, Bel V was invited to participate and briefly present the SuDoQu project.

Bel V also presented the preliminary results at the 10th International Symposium on Release and Re-use of Materials of TÜV-Nord and at the annual Eurosafe Forum (in November 2017).

Bel V acquired the Mathematica platform for further probabilistic and sensitivity studies. It will be commissioned for SuDoQu in the presence of the RIVM expert in 2018.

4.4.5 R&D on cross-cutting issues

Experience with MCNPX

Within the framework of the Filtered Containment Venting System (FCVS) project, preparations were made for verifying the conservatism of the modelling of the dose rates. Different ways for gamma dose rate assessments in MCNPX (Monte Carlo N-Particle extended) were investigated to gain insight into the uncertainties of each assessment technique.

Simple models have been developed to assess the dose rate as a function of the location inside a rectangular corridor (2m x 2m cross-section, with concrete walls), taking into account a photon (1 MeV) and neutron source (1 MeV) in the centre of the entrance of the corridor. The aim was to determine if some locations allow to find higher dose rates than others. Dose rates close to the walls are greater after a certain distance (roughly > 2m) due to the interactions with the walls, whatever the source type. At very short distance one observes an expected geometrical effect due to the spherical shape of the source.

Safety culture assessment

The objective in 2017 was to develop an inspection methodology dedicated to safety culture on the basis of qualitative interview techniques. Therefore, Bel V now has a large set of monitoring tools covering safety culture issues within a nuclear facility, i.e. a Safety Culture Observation process, a thematic inspection methodology for the 'safety culture assessment' carried out by a licensee, and a specific cross-inspection methodology for the 'safety culture' regarding particular safety issues. All these methods provide input for Bel V's annual safety evaluations of the facilities.

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.

4.4.6 R&D collaboration with other institutes

R&D collaboration with Belgian universities

Vrije Universiteit Brussel (VUB)

Bel V has 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)

Four PhDs 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. This PhD thesis was successfully defended in 2017.
- A third PhD thesis, performed at the SCK•CEN in collaboration with UCL, is related to the complexation/colloid formation of U(VI) with Boom Clay dissolved organic matter.
- A fourth PhD thesis is sponsored at UCL in the context of the DENOPI project², aiming to develop closure relations required to simulate spent fuel pool LOCA type accidents with CATHARE. These closure relations are related to the modelling of natural convection at the free surface of the pool.

² See §4.4.3.1.



R&D collaboration with IRSN

- Bel V is a member of the *Pôle Géochimie Transport* (PGT), which groups several institutions (including IRSN) 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 (IAEA). 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 2015, 9 in 2016 and 11 in 2017:

- Q2-INST-2 Class 1 facilities other than nuclear power plants (Belgoprocess)
- Q2-INST-4 Research facilities (SCK•CEN)
- Q3-RB-9 Waste management
- Q2-NS-2 Deterministic safety analysis
- Q1-REG-4 Quality management system
- Q2-NS-3 Probabilistic safety analysis
- Q2-SPE-3 Fire protection
- Q1-REG-1 Bel V guidances
- Q2-RP-1 Radiation protection - basics
- Q2-SPE-3 Ventilation
- Q1-REG-3 International standards (ASME)

An example of an external training course with the participation of new members of staff at Bel V in 2017:

- Sûreté des centrales à eau sous pression (INSTN, 1 week)

In addition, Bel V set up so-called 'Internal Technical Sessions' aimed at disseminating the R&D results to the Technical Responsibility Centres. In 2017, 4 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 2017.



FINANCIAL REPORT

Balance sheet as at 31 December 2017

(amounts in €1,000)

	2016	2017
ASSETS	13,935	11,701
FIXED ASSETS	5,190	4,759
II. Intangible fixed assets	339	83
III. Tangible fixed assets	4,849	4,674
A. Land and buildings	4,629	4,467
B. Plant, machinery and equipment	177	153
C. Furniture and vehicles	43	54
IV. Financial fixed assets	2	2
CURRENT ASSETS	8,745	6,942
VII. Amounts receivable within one year	3,883	2,942
A. Trade receivables	3,818	2,890
B. Other amounts receivable	65	52
IX. Cash at bank and in hand	4,577	3,694
X. Deferred charges and accrued income	285	306

	2016	2017
LIABILITIES	13,935	11,701
EQUITY	10,224	10,112
I. Capital	4,732	4,732
IV. Reserves	2,868	2,868
V. Result carried forward	2,624	2,512
DEBTS	3,711	1,589
VII. Amounts payable after more than one year		
IX. Amounts payable within one year	3,710	1,589
A. Current portion of amounts	500	
C. Trade debts	338	265
D. Advances received on contracts in progress	1,500	
E. Taxes, remuneration and social security	1,372	1,324
F. Other amounts payable		
X. Deferred charges and accrued income	1	1



Profit and loss account as at 31 December 2017

(amounts in €1,000)

	2016	2017
Turnover	13,001	12,774
Other operating income	171	160
TOTAL OPERATING INCOME	13,172	12,934
Services and other goods	2,096	2,282
Wages and social security costs	750	10,175
Depreciation	488	491
Write-downs on trade receivables		
Other operating charges	96	93
TOTAL OPERATING CHARGES	12,430	13,041
Operating result	742	-107
Financial charges and income	-3	-6
Profit on ordinary activities	739	-113
Profit for the financial year	739	-113

Profit and loss account: notes

In 2017, activities were somewhat reduced, yielding a 1.75% decrease in our turnover.

Operating income

Turnover

The largest part of the turnover of Bel V (96%) 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 continued work on the 'Long-Term Operation' of Doel 1/2 and Tihange 1, the SF² project, the continuation of the MYRRHA project, and the intensification of the operational control of the units at the Tihange site.

A small part of the turnover derives from contracts with the European Commission for support to nuclear safety authorities in Eastern European and emerging countries, as well as from inspections 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 4.37% of our operating charges.

Wages and social security costs

Staff expenses represent 78% of our costs, including training expenses.

Operating result

The operating result for the financial year (a slight loss) has been allocated to result carried forward.



List of abbreviations

ANVS	Autoriteit Nucleaire Veiligheid en Stralingsbescherming (Netherlands)
ASN	Autorité de Sûreté Nucléaire (France)
BEST	Belgian Stress Tests
CEA	Commissariat à l'énergie atomique et aux énergies alternatives (France)
CNRA	Committee on Nuclear Regulatory Activities (OECD)
CSNI	Committee on the Safety of Nuclear Installations (OECD)
DG Crisis Centre	Directorate-General Crisis Centre of the Federal Public Service Interior
ENSREG	European Nuclear Safety Regulators Group
ENSTTI	European Nuclear Safety Training and Tutoring Institute (ETSON)
ETSON	European Technical Safety Organisations Network
FANC	Federal Agency for Nuclear Control
FBFC	Franco-Belgian Fuel Fabrication
FINAS	Fuel Incident Notification and Analysis System
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit (Germany)
HERCA	Heads of European Radiological Protection Competent Authorities
IAEA	International Atomic Energy Agency
INSC	Instrument for Nuclear Safety Cooperation (European Commission)
IRE	National Institute for Radioelements
IRS	Incident Reporting System
IRSN	Institut de Radioprotection et de Sûreté Nucléaire (France)
IRSRR	Incident Reporting System for Research Reactors
LTO	Long-Term Operation
NEA	Nuclear Energy Agency (OECD)
NRC	Nuclear Regulatory Commission (US)
NUSSC	Nuclear Safety Standards Committee (IAEA)
OECD	Organization for Economic Cooperation and Development
ONDRAF/NIRAS	Agency for Radioactive Waste and Enriched Fissile Materials
PSA	Probabilistic Safety Assessment
PSR	Periodic Safety Review

R&D	Research & Development
RIVM	Rijksinstituut voor Volksgezondheid en Milieu (the Netherlands)
SCK•CEN	Studie Centrum voor Kernenergie – Centre d'études d'Energie Nucléaire (MoI)
TBRS	Technical Board for Reactor Safety (ETSON)
TRC	Technical Responsibility Centre (Bel V)
TSO	Technical Safety Organisation
TSOF	Technical and Scientific Support Organization Forum (IAEA)
WENRA	Western European Nuclear Regulators Association



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