The Inspector General's report

on Nuclear Safety and Radiation Protection

2021

edf

FOREWORD

Written specifically for the Chairman of EDF, this report gives my assessment of nuclear safety and radiation protection within the EDF Group.

The report also concerns all those working for the company, a subsidiary or contractor, who contribute in any way to nuclear safety and radiation protection, from design through to decommissioning.

In keeping with the spirit of public awareness and transparency expressed in my appointment letter, this report focuses specifically on the areas for improvement as its format does not allow me to highlight all the positives.

As emphasised in EDF's nuclear safety policy, our overriding priority is nuclear safety, which is the key to providing controllable, low-carbon energy. Achieving this priority is a task shared by all, every moment of the day; it is reflected in the excellence of the plants and the operational rigour of its motivated and skilled staff. My role as Inspector General is to detect any early warning signs that could compromise this priority, to encourage constructive discussions, and to recommend areas for improvement.

The quality and relevance of this report - a result of team effort - would not have been achieved without the invaluable discussions held with all those we met in France and the UK alike. The clarity of observations, the frankness of assessments, the sincerity of expectations and questions, all attest to the strong nuclear safety culture instilled in the Group. Our meetings with representatives from trade unions, local information commissions, industry partners, medical bodies, and independent nuclear safety organisations also proved extremely fruitful.

Much like 2020, the travel restrictions imposed by the Covid-19 pandemic somewhat impacted our programme of site visits, though the health and safety measures allowed us to conduct field visits without undermining the robust organisation in place.

In the first year of my term, I would like to pay tribute to my predecessor, François de Lastic, who headed IGSNR over the last seven years, driven by two convictions: rigour and transparency.

I would also like to thank Jean-Michel Fourment, Stephen Preece, Bertrand de L'Épinois and Jean-Paul Joly who have been relentless in their efforts and whose input has proved invaluable during the drafting of this report. I would particularly like to thank Jean-Michel and Stephen who are soon to reach the end of their respective terms at IGSNR. The chapter on Framatome has been written by its Inspector General, Alain Payement.

Both the French and the UK energy transition strategies pinpoint nuclear energy as a key technology for the future to fight climate change, with focus placed on further improving nuclear safety and reducing costs. Following in the footsteps of my predecessors, this annual report sets out to contribute in its own way to this daunting task facing our countries; a task which will motivate staff, open up new prospects, and attract the new talent needed to further enhance nuclear safety whether in operations, engineering, projects or innovation.

This document is available to the public in both French and English on the EDF website *(www.edf.fr)*.

EDF Group Inspector General
for Nuclear Safety and Radiation Protection

Admiral (retired) Jean Casabianca
Paris, 7 January 2022

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

Contents

EPR 2 project - Penly nuclear power plant

My view

2021 HAS BEEN AN ATYPICAL YEAR

Although the Covid-19 pandemic revealed structural weaknesses and vulnerabilities in our society, the French and UK nuclear power plants have continued to maintain the energy balance in both countries. On both sides of the English Channel, the EDF Group met the electricity demand in line with the highest nuclear safety standards, providing more than 70% of the French demand and 20% in the UK. It even exported part of its production to neighbouring countries. Although the circumstances were exceptional, low-carbon nuclear energy did not fail.

Maintenance outage schedules included outages postponed from 2020 due to the implementation of Covid-related health measures. Though there is always room for improvement, the number of unplanned reactor trips was limited. The organisations set up at the power plants and the Group's engineering centres, as well as in its subsidiaries or at its contract partners, have enabled production to continue, while adapting the working practices to comply with the national Covid-19 guidelines. After the good performance in 2020, the overall nuclear safety results tended to level off in 2021 though still in progression compared with previous years. Shortly after the summer period, both fleets had to deal with a series of operational events that called for increased vigilance and rigour *(see Chapter 1)*.

The economy seems to have picked up again, following a period of stagnation. The demand for energy, in particular electricity and gas, has outstripped forecasts and is growing faster than the capacity of producing countries to respond. Neither is the steady increase in the use of renewables sufficient to meet the global demand. In Europe, less wind during the summer resulted in reduced wind generation. In China, lower rainfall resulted in a decrease in hydroelectric generation.

Ranked third worldwide in the number of operable reactors (a tenfold increase over the last twenty years), China generated more nuclear energy than France did in 2021. Globally, the Chinese programme to build fourteen reactors - making them world leader - largely offsets the closing of plants in the West. The declarations by the Chinese at COP26 in November 2021 extend their targets further. China's fourteenth five-year plan provides an investment of $440 billion over 15 years to build 150 reactors.

In the US, EDF has sold its stake in Constellation Energy Nuclear Group's five reactors. I am committed to maintaining a close relationship with the US nuclear safety bodies and operators as the leading nuclear power generator in the world, as well as those in China and Russia.

In Europe, the Finnish Olkiluoto EPR - the first European Generation III reactor – achieved first criticality in December 2021. In the wake of the pandemic, the energy crisis is hindering Europe's economic recovery and forcing countries to make massive use of carbon-producing energies (coal and gas) to the detriment of their environmental targets. This once again demonstrates the soundness of France's historical decision to establish a nuclear industry. This energy system has one of the highest levels of surveillance, and it constantly meets three nuclear safety requirements, in both normal and off-normal circumstances:

- Controlling the nuclear chain reaction
- Cooling the reactor core, including the removal of decay heat after shutdown
- Containing radioactive material.

IMPROVEMENT OF NUCLEAR SAFETY TEN YEARS AFTER FUKUSHIMA

Two of the three nuclear safety functions failed at Fukushima: core cooling and containment. As with other accidents, the importance of human and organisational factors was demonstrated. The operators and emergency response teams were placed in an unforeseen, complex situation, with no real representation of the facilities and no appropriate procedures or training.

MAJOR IMPROVEMENTS IN DECAY HEAT REMOVAL

The Fukushima accident underlined the need to thoroughly assess the risks associated with natural hazards, particularly climatic events, flooding and earthquakes, and to provide protection with significant margins to take account of the uncertainties, which affect our knowledge of this type of phenomenon.

Provisions designed for very severe hazards strengthen the defence in depth when faced with the risk of a total loss of heat sink and power supplies (off-site and internal). At all French sites, the ultimate diesel generators and an additional emergency water source are now operational, providing at least three days of complete autonomy in water and electricity.

Contents My view 01 02 03 04 05 06 07 08 09 Appendices Abbreviations

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

In EPRs, two station blackout diesel generators in addition to the four emergency diesel generators and a second heat sink are part of the original design.

In France and the UK, protection of reactors against natural hazards has been strengthened. The engineering divisions have taken action and developed their expertise in response to the impacts of climate change. Like other risks, the risk of flooding is reassessed during each ten-yearly safety review and is also reassessed after every unusual event. This commitment must be continued.

THE FOURTH TEN-YEARLY SAFETY REVIEWS ARE A LEAP FORWARD FOR NUCLEAR SAFETY

In the case of a severe accident (core meltdown), the primary objective is to maintain containment integrity and limit radioactive releases.

In France, the strengthening of reactor protection is continuing during the fourth ten-yearly outages (VD4) of the 900 MWe fleet. All the improvements allow them to operate for 50 years, perhaps more. They also prevent early widespread radioactive releases in the event of a core meltdown. The design of this generation of reactors may now have reached a level of maturity where further substantial modifications would not improve nuclear safety due to the resulting complexity. Analysis of human factors must play a greater role in nuclear safety reviews, without making equipment changes the sole factor driving progress.

Work between containment walls - Nogent nuclear power plant

RAPID RESPONSE RESOURCES ARE OPERATIONAL

The Nuclear rapid reaction force (FARN) and the Deployable back-up equipment (DBUE) ensure the resilience of the organisations in France and the UK by providing sites with mobile units, which can restore nuclear safety functions autonomously, in all circumstances.

Mobile emergency equipment (FARN)

Regular scenario-based training including unexpected events has continued despite the pandemic. Interface management must remain a focus area: drills to practice deploying FARN and DBUE resources and equipment must be combined with the implementation of arrangements specific to each site. Solutions suitable for any situation, including extreme and unplanned events, will be based on all the resources and equipment dovetailing together. This must be validated more systematically and implemented during training, both for the site and for FARN and DBUE. The site management retains responsibility for the implementation of resources and equipment.

Emergency preparedness, in France and in the UK, is coordinated from national and local emergency support centres. At Flamanville, I visited the local emergency support centre (CCL); this bunker-like building is fitted with the most up-to-date information transmission and management equipment. Based on what has been learned from this first building, less oversized CCLs will be deployed in the rest of the fleet. This represents a significant step forward in emergency preparedness.

REACTIVITY CONTROL: A PRIORITY

Reactivity control must always be the main priority in a nuclear reactor and thus a major concern for management I am pleased to see that reactivity control is now one of the DPN's four nuclear safety indicators.

The increase in events, even minor ones, requires greater involvement of the site management teams, greater rigour, and better training of the operations teams *(see Chapter 5)*.

Design improvements should make more use of the engineering divisions and R&D with the aim of achieving more intrinsic nuclear safety for new reactors, by partially or completely dispensing with the active injection of boron during emergency cooling events.

ENSURING THE SAFETY OF THE REACTOR ENVIRONMENT

There are several vulnerabilities that may affect nuclear safety, I have decided to focus on fire, and on drug and alcohol abuse in this year's report. I am equally mindful of protecting the sovereignty of our energy resources, which is why I believe we should also focus on malicious acts.

FIRE-FIGHTING IS IMPROVING

In 2021, France and the UK unfortunately each suffered one significant fire event: a transformer fire *(see Chapter 1)*. Individual and collective training courses were certainly affected by the restrictions associated with the pandemic, but an effort must be made to rapidly catch up with the accumulated delays.

I am pleased with the organisation in place in the UK fleet, giving the first response team a fire-fighting capability before the arrival of the offsite fire and rescue service. This contributes to the nuclear safety of facilities and reinforces the feeling of ownership within the operations teams, who are keen to protect the assets. The implementation of such an organisation in the French plants is an idea that deserves further exploration. I also note that the principle of increasing the number of volunteer fire-fighters has not been put into operational practice. The number on each site is far from being uniform.

Fire drill at a nuclear power plant

With the forward planning of work for the 10-yearly outages (VD4s) whilst still at power, routes around the industrial areas are regularly obstructed by scaffolding, which must be managed rigorously. Regular fire and escape drills are particularly necessary during these complex periods in the life of the power plants.

PREVENTION OF DRUG AND ALCOHOL ABUSE MUST BE MORE STRICTLY ENFORCED IN FRANCE

The consumption of psychoactive substances is not compatible with jobs in the nuclear industry. Drug and alcohol tests were temporarily stopped during the pandemic. In France, the process to include drug testing in the internal rules was suspended, despite it being essential to conduct regular checks at the plants. It is necessary to inject fresh impetus into these measures since the successive lockdowns and the new pandemic-related requirements may have eroded some social regulations *(see Chapter 3)*.

SITE SECURITY IN FRANCE: COMPLEX CHANGES TO BE IMPLEMENTED WITH DETERMINATION

The aim is to ensure nuclear safety while protecting and controlling the nuclear material and minimising operating constraints. This involves preventing the actions of malicious individuals while maintaining smooth operation on a daily basis.

As no off-the-shelf security system solution corresponded exactly to its requirements, EDF SA designed its own security system and is the exclusive owner. The need to take into account the specific features of each reactor series and each site complicates the development of the system, making it difficult to keep to a schedule. A platform has been developed to simulate all the security measures. It will be necessary to maintain the appropriate skills not only to deal with obsolescence, but also to be able to incorporate changes as quickly as possible to keep up with rapidly evolving threats and the technologies developed to counter them.

The site security professions use increasingly complex systems that require specialised maintenance. They therefore have to adjust to this. The site security core skills handbook, produced and distributed more than three years ago, requires the security department to carry out this operation and maintenance work. However, I note that this principle, which is benefiting those sites having adopted it, is not widely implemented. Beyond a quantitative improvement, incorporating the time required to complete training in a new technical environment and the considerably heavier workload, I suggest that job and skills planning be developed in order to make the team more efficient and attractive.

CYBERSECURITY IS INEXTRICABLY LINKED TO THE DIGITAL TRANSFORMATION

The transmission of viral diseases can be limited by good personal hygiene combined with suitable protection measures. In the same way, good digital hygiene and technical data protection measures can counter the effects of an IT failure, whether or not it results from a malicious act. This growing risk in society, to which all industrial sectors are vulnerable, is taken into account by EDF as early as design and integrated into modifications.

During my visits, I therefore endeavoured to check how aware personnel are of this risk that could jeopardise the nuclear safety functions. Although the new generations are more aware of this, they are not always the most disciplined when it comes to applying restrictive rules ('clean' docking stations for USB sticks, file exchanges, mobile telephony, smart devices, Internet access, etc.).

In France, the National cybersecurity agency (ANSSI) draws up joint inventories with support from the Institute for radiation protection & nuclear safety (IRSN) and the departments of the Senior Defence & Security Official (HFDS). The situation at EDF SA is satisfactory in all the reactor series, which have different levels of digitisation.

Faced with the multiplicity of bodies, these scarce skills must be concentrated in an organisation that has clearly defined responsibilities. I also draw attention to the training and control of contract partners and outsourced functions, from engineering to maintenance and from design to operations. Cybersecurity is not an excuse to slow down the digital transformation. It supports this programme.

INNOVATION AND TRANSFORMATION ARE APPEALING FACTORS

HIGHLIGHTING THE PROFESSIONALS IN THE NUCLEAR INDUSTRY

This year again, those working in the nuclear industry have shown their commitment and reliability. In addition to the recognition of a job well done, changing opinion and more positive communication on nuclear energy and jobs in the sector will undoubtedly contribute to the attractiveness of the industry and help to increase staff retention. During my meetings, I noted how much the young generations are hurt by the lack of respect for the industry. The debate on the fleet renewal to combat climate change is improving the industry's reputation, and the Group's external communications could capitalise on this. The policy must therefore meet the expectations of personnel who lament a form of over-cautiousness while detractors have the benefit of an open forum to misrepresent things, particularly to the younger generations.

This must not overshadow a topic that is of high media, environmental and technical importance: the fuel cycle closure strategy. Investment in innovation and research and the communication effort are essential here. The different stakeholders (ANDRA, Orano, CEA, EDF and Framatome) must implement a determined, coordinated approach to waste treatment, particularly for high-level and/or long-lived waste (LL-HLW), and it must cover the recycling of spent fuel and future fast reactor models.

Welding of vessel head sleeves

THE STRENGTH OF INTEGRATED R&D

In France, the announcement of a €1 billion investment to "*develop breakthrough technologies, in particular small modular reactors, for improved waste management or hydrogen production*" is conducive to recruiting high-quality young engineers.

In the UK, within the scope of the ten-point plan for a green industrial revolution, the government intends to become carbon neutral by 2050 through the use of renewables and nuclear energy. The 'Advanced Nuclear Fund' has been allocated £385 million to invest in new-build projects, such as developing a small modular reactor (SMR), and supporting research on advanced modular reactors, a fourth-generation design. A major project will be approved before the next general election: the probable building of two EPRs at Sizewell.

Nuclear energy is inextricably linked to science, high technology, research and innovation. France, a pioneer of the industry, cannot dissociate itself from the rapid development in the US and the considerable resources deployed in China and Russia. Innovation is key to the appeal of the industry, while R&D is the cornerstone of the skills on which it is based.

I am pleased that R&D work and initiatives are fully in line with the strategy of improving the nuclear safety of the fleet and nuclear projects; they are helping to extend the service life of reactors and improve fleet performance. Digital simulation tools, together with facilities for carrying out tests and processing huge volumes of data, are bearing fruit. The Group's R&D focuses mainly on the "customer" (fleet or projects underway), which is a positive approach, however it could focus more on the longer term, more specifically to achieve the ambitious targets of the France 2030 plan and its prospects. New technologies such as artificial intelligence, quantum computing, virtual reality, will be of benefit to the Group, its professions and nuclear safety.

DIGITAL TRANSFORMATION, A VEHICLE FOR IMPROVING PERFORMANCE

The development of digital technology is a major catalyst for the redesign of tools and the revision of working methods. It is an integral part of modern engineering and shapes organisations. It also helps to simplify processes and improve efficiency.

This transformation concerns both internal operation and relations with contract partners, subsidiaries and customers. I note that the digital transformation is struggling to be taken on board and in particular to produce the expected results in the Group. It is important to keep the objective in mind: digital transformation must simplify tasks and not lead to additional restrictions or an increased workload. It must only replace people if its benefit and the absence of any increased risk have been demonstrated, especially in nuclear safety *(see Chapter 8)*. I would go even further by saying that reducing the differences between private and professional digital environments would help retain young engineers.

OPPORTUNITIES TO BE TAKEN AND CHALLENGES TO BE MET

Though the European Commission has yet to include nuclear energy on its list of sustainable investments, the resilience of the Group's production model puts the countries in which the Group has interests in a good position with regard to their environmental commitments and has spared them an energy crisis.

The health measures taken over the past two years of the pandemic are going to radically change our society as we know it and there will be no going back. During a difficult time, the Group has been efficient because this was what the situation demanded and because its culture predisposed it to do so. The pandemic will set in motion more disruptions over the coming decade; we must take advantage of this rather than simply compensating for the effects.

IMPROVEMENT PLANS: QUANTITY OR EFFICIENCY?

The plans and initiatives launched by the Group set out to meet the challenges of simplification, efficiency and performance in an environment with a continuously heavy industrial workload. With initiatives such CAP 2030, START 2025, the Excell plan, TAMA (working differently, managing differently), Ambition Leadership, Dual Mission, *Osons la confiance* (dare to trust), or EVOLEAN, it must feel like there is too much on the proverbial plate. The sites, plants and engineering units only see the increased workload they bring (reports, indicator dashboards, etc.) without necessarily providing the expected results in nuclear safety.

Though all these plans are a step in the right direction, there are delays in implementing them collectively in a coherent way. There is no contradiction between the need to impose some directives on all within a tight schedule, and the need to maintain the autonomy of each power plant or engineering unit. It is important to capitalise on the post-pandemic period to speed up their implementation and to capture the positive effects they produce.

Most of these plans and initiatives, which are supported by new technologies, must not sideline employees and first-line management, nor must they bank on the further growth of working from home.

FLEET RENEWAL AND DECOMMISSIONING: INTERRELATED CHALLENGES

Over the coming decades, the EDF Group will have to demonstrate its ability to manage these two issues, which are very different in terms of their nature and their time-sensitivity.

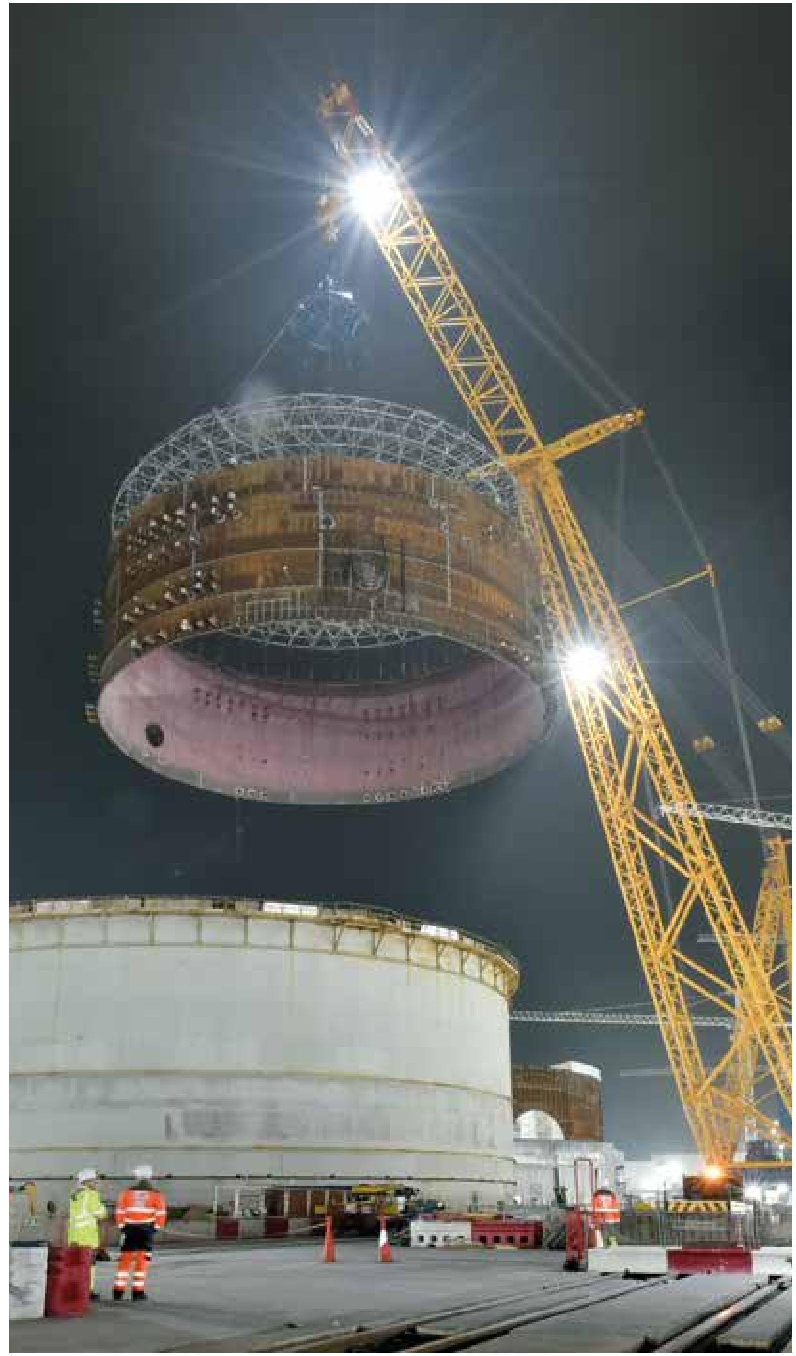
The fleet renewal plan may be subject to time constraints, which must not impair nuclear safety. There will be increasing demands on the power grids in France and the UK because of the reduced use of controllable carbon-producing energies. It will therefore be important to converge the lifetime extension and decommissioning programme with the renewal programme, and be consistent with the capacities offered by renewables. Given that periods of rain, wind and sun cannot be made to keep to a schedule, the Group itself has a duty to honour its own commitments.

Decommissioning, in both France and the UK, is a long-term process. It seems to be well-prepared and organised to address this challenge in a way that ensures nuclear safety. Following the end of operation of the two pressurised water reactors (PWR) at Fessenheim in 2020, preparation for their dismantling is on schedule. The decision to permanently withdraw the first advanced gas reactors (AGR) from service was made with a great sense of responsibility and based on criteria that fully respect the nuclear safety principles.

In late 2020, the first radioactive waste package was received at the new facility for the packaging and storage of activated waste (ICEDA). This licensed nuclear facility (INB) is used for the interim storage of waste from French reactors being decommissioned, and material from the in-service fleet, before it is accepted by ANDRA for final disposal.

Two points require attention:

- Acquiring and safeguarding skills specific to decommissioning worksites and the ramping up of the workload schedules
- Optimising experience sharing on both sides of the English Channel, and synergies within the Group, or with external entities (Orano).



Installation of reactor liner Unit 2 - Hinkley Point C

GUIDING PRINCIPLES FOR UNDERSTANDING

I will end this introductory overview by advising readers to immerse themselves in the following chapters. They have been written in line with the IGSNR approach, which intends to be critical, creative and responsible based on the three criteria that define complex thought according to Edgar Morin.

REMAINING EXEMPLARY

The nuclear industry is required to meet increasingly more demanding requirements and checks. It must remain both exemplary and transparent with regard to nuclear safety.

KEEPING IN TOUCH WITH REALITY

Everyone must be given enough time to carry out the essential and added-value tasks, such as knowledge of the plant and its human environment, practising one's profession, or interpersonal interactions (education, training, management, mentoring, social dialogue, analysis and OPEX, etc.). With regard to nuclear safety, taking a step back does not mean creating distance, but staying in contact with reality.

The industry can use plans for change that develop the results-driven culture and leave more space for autonomy of the divisions and individual accountability. The digital transformation must improve performance by supporting people rather than replacing them.

RECOGNISE THE ROLE OF PEOPLE

I believe it is important to not focus solely on technical matters, modifications, documentation, or procedures and processes in order to deal with all possible, probable or conceivable malfunctions or non-conformities. Endlessly improving a complex system will not replace human intelligence, which can quickly adapt to unforeseen events. We must accept that people, like machines, are fallible, and above all be aware that people can also improve. Yet this can only be achieved if they have the humility to admit to their weaknesses, and the determination to overcome them through learning and hard work. The words of the French sociologist, Michel Crozier, are still relevant today, when he recommended focusing on professionalising staff rather than endlessly refining structures and procedures.

Thus, it is necessary to restore meaning to actions and go back to the fundamentals, whether this is about behaviour, good practice or the quality of work performed. The level of individual and collective requirements must be stated, even reinforced, with tenacity. Education and training should be promoted, and time systematically set aside for them. Personnel from both the Group and contract partners alike should make better use of the remarkable resources that are available (simulators and mock-up facilities).

BEING A RESPONSIBLE OPERATOR

The industry must develop further its ability to anticipate problems, rather than having to experience and react to them. Every cause can therefore be considered as a consequence. This questioning approach should be considered to be a nuclear safety objective rather than a response to the requests of the oversight authorities. The complementary nature of roles should be recognised, rather than allowing antagonism to flourish.

SIMPLIFYING THE ORGANISATIONS

The EDF Group's long history and its organisational structure mean that it has all the skills of an integrated group. As both architect and Operator of reactors that exploit different technologies, not to mention being a designer of innovative systems, the Group has defined nuclear safety as its overriding priority. Each field benefits from staff with a high degree of expertise. Skills are often shared between several departments.

This massive organisation may prove to be a source of complexity and become unwieldy, which could undermine nuclear safety. There must be a clearly identified leader responsible for each subject. Better integration of the engineering divisions, with one another and with Operators, will enable new facilities, modifications and standards to be designed that are appropriate for the technical and operational realities. This will also help provide sites with swift operational support. The Group can benefit from the synergies offered by the operation of two fleets. Likewise, experience sharing between industrial operators and peer assessments are a key pillar in achieving high levels of reliability and performance.

ENSURING MARGINS FOR NUCLEAR SAFETY

As in any company, the EDF Group's fleets, engineering divisions and industrial partners have to control costs and keep to schedules. They must try to reconcile the safety of personnel, production needs, and nuclear safety, which must remain the overriding priority. In the future, environmental pressure, the economic crisis and the energy balance are all factors that could adversely affect the management of priorities and decision-making.

The design of the future generation capacity needs must incorporate sufficient margins to deal with any technical issues that could result in the temporary shutdown of several reactors *(see Chapter 1)*.

Everyone must strive to establish financial margins and timescales to ensure that the required level of nuclear safety can be maintained. At all times, the independent nuclear safety oversight teams must inform senior management constantly in relation to compliance with this imperative.

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

Maintenance work - Golfech nuclear power plant

The operational safety results have been improving over the past few years, although 2021 did not reach the levels achieved last year. Yet nuclear safety should not be assessed by indicators alone.

Despite a concerted effort to implement action plans in both fleets, the number of automatic and manual reactor trips has risen. Once again this year, the number of technical specification non-compliances is still too high.

In France, reactivity control events have become more frequent.

Operational safety: mixed results 01

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

THE INDICATORS

IN FRANCE

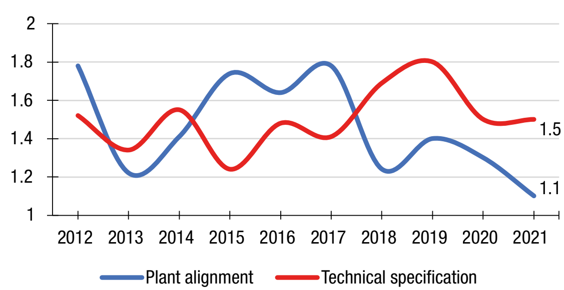
There were no significant nuclear safety events graded Level 2 on the INES scale in 2021. The number of Level 1 events reduced slightly (1.34 per reactor). The total number of Level 0 and 1 significant nuclear safety events (726) continues to reflect a good level of detection and transparency.

After a record performance in 2020, the number of automatic reactor trips has increased to 27, compared with 14 in 2020 and 31 in 2019).

The number of non-conformances relating to reactivity control, which stabilised in 2020, has started to rise again, reaching 57, compared with 33 in 2020 and 52 in 2019 *(see Chapter 5)*.

The number of technical specification non-compliances is still too high, highlighting major disparities between plants for a second year running.

Safety system availability remains excellent.

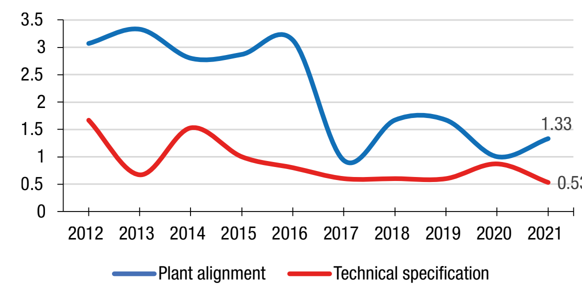


Plant alignment errors and non-compliance with technical specifications in France

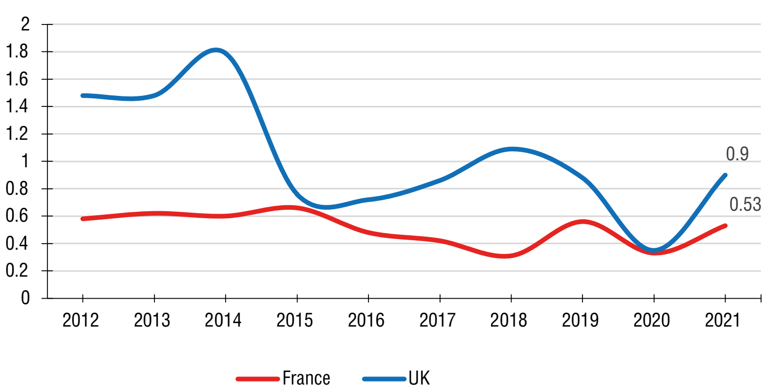
IN THE UK

One Level 2 event on the INES scale *(see Chapter 7)* and six Level 1 events (after just one in 2020) were declared, equating to 0.47 per reactor. However, as has been pointed out before, the British and French nuclear safety authorities apply slightly different declaration practices, hence it is not possible to make direct comparisons between the numbers of Level 1 events in each country. The number of Level 0 significant nuclear safety events per reactor remains stable and reflects a good level of transparency.

The number of automatic and manual reactor trips rose in 2021, whilst the number of technical specification non-compliances achieved the best performance in over 10 years. Safety system equipment reliability is good and continues to improve in the AGR fleet. Sizewell B PWR achieved 100% safety system availability for the fourteenth consecutive year.



Plant alignment errors and non-compliance with technical specifications in the UK



Combined automatic and manual reactor trip rates in France and the UK

THE COVID-19 PANDEMIC: ANTICIPATING THE FUTURE EFFECTS

Although the pandemic is far from over, it has not had a significant impact on nuclear safety in either fleet in 2021. In France and the UK, production has been impacted by the schedule delays or deferred maintenance outages decided in 2020. The engineering teams have adapted to the 'new normal' and achieved most of their deliverables. In France, the TAMA experiment (working differently, managing differently) has focused predominantly on rebuilding team spirit and on arrangements for working from home.

The introduction of additional health and safety measures during the pandemic has evoked a certain weariness in teams in both countries. It is imperative that this does not lead to a lapse in rigour and transgression of the industrial safety, radiation protection and nuclear safety rules.

Work to develop numerical tools and e-learning mentioned in the 2020 IGSNR report has continued this year. Efforts should focus on developing discussion opportunities and integrating new employees more effectively, as onboarding and training have suffered somewhat from the effects of the pandemic. I will be monitoring the actions taken in response to the recommendations in the 2020 IGSNR report regarding the key OPEX takeaways from the pandemic - simplification, training in the key professions and working-from-home arrangements - throughout 2022.

FIRE SAFETY: MAINTAINING VIGILANCE

The DPN is now using an event classification method based on the extent of fire propagation similar to that used by Nuclear Generation. The 2021 indicators show an improving picture: just one notable event (compared with 8 in 2020 calculated with the new method).

In the UK, there was one notable event - the first since 2018.

There is still scope for improvement in fire load management in both fleets and reducing the number of oil leaks remains an area for concern in the UK. Considering that the majority of fires are caused by electrical faults, Nuclear Generation now uses thermal cameras to detect hot spots, which tend to be around terminal boxes and connectors; I urge the DPN to widely implement a similar approach, as already adopted on some French sites.

Fire drills are organised regularly in both fleets. All plants must invest fully in this practice and make sure that the scope of such drills is representative of actual conditions. For instance, it would be a good idea to practice drills with pressurised water systems. Despite having developed virtual learning capabilities, a significant amount of time should still be dedicated to real-life practice sessions for all.

In the UK fleet, the operations teams have been given a fire-fighting capability that can be mobilised before the arrival of the offsite fire and rescue service. This further strengthens nuclear safety on sites. In France, response times of local fire and rescue services depend on the plants and the circumstances of the fire. I encourage the DPN to consolidate its fire-fighting response before the first vehicles arrive on the scene, and to increase the number of volunteer fire-fighters on hand.

Two transformer fires

A fire on the main transformer at one reactor - the tenth such event in the French fleet since 1988 - caused an automatic reactor trip and significant damage to neighbouring equipment, cables and engineered structures. Thanks to the rapid response of plant teams, the fire was contained before the local fire services arrived. An electrical penetration that had recently been installed was found to be the cause of the fire.
A transformer fire in an in-service AGR in the UK resulted in an automatic reactor trip and an oil leak into the environment. The fire was extinguished by the automatic fire suppression system without causing any further damage. The source of the fire was a short circuit due to insulation failure between two electrical devices. Both these devices had an estimated 20-year service life. They were installed in 2016 and inspected in 2019, at which time no non-conformity was detected.

NUCLEAR FUEL: SATISFACTORY PERFORMANCE OVERALL WITH SOME WEAK POINTS

Fuel assembly cladding forms the first barrier between the radioactive material and the environment, hence it must remain leaktight.

In France, the fuel assembly failure rate in PWRs remained at a satisfactory level: 0.07% (3 fuel rod leaks, making it the best performance for a number of years). Stakeholders from corporate divisions (DCN, UNIE-GECC, DT, DI[1]), sites and R&D all collaborate effectively; staff demonstrate a good level of expertise, and the field offers attractive career opportunities. I applaud the actions taken by the DCN to secure the supply chain by identifying critical suppliers.

A corrosion and spalling issue has arisen on some M5 fuel cladding in three reactors, but has had no impact on nuclear safety. Appropriate inspection and refuelling criteria were established quickly and

[1] *Nuclear fuel division; Operations engineering unit – Core design and engineering group; Technical division; Industrial division*

successfully. However, I am disappointed that OPEX from similar events in other countries did not prevent these problems from occurring.

Various other issues with fuel assemblies have arisen, i.e. deterioration of some grids (P-grid) and CRUD *(see Chapter 6)*. Additionally, mixed uranium and oxide (MOX) production issues experienced at Orano's MELOX facility meant that some plants had to be refuelled with uranium oxide only, thereby modifying the scheduling of MOX-based fuel reactor cycles.

These issues erode safety margins and impose additional operational requirements. The necessary human resources must be available in the relevant units to carry out all the changes to refuelling plans, the substantial number of design studies, and the consolidated surveillance of manufacturing.

In the UK, no fuel cladding failures were reported in the AGR fleet in 2021 for the second year running. The Sizewell B PWR has now had no in-core fuel cladding failures for over 12 years.

ROOM FOR IMPROVEMENT IN INDUSTRIAL PRACTICES

BETTER INTEGRATION OF CONTRACTORS IN FRANCE

Industrial practices rely to a large extent on the contractors who conduct the bulk of maintenance activities.

I commend the efforts made by EDF SA to improve the industrial fabric through the "regional hubs", GIFEN (the French nuclear industry association) and the *Excell* plan. However, I have noticed tensions in some Operator-contractor relationships. It is vital that contractors are integrated fully into all aspects of plant life. Some plants have taken steps to address this by involving contractors in project teams, for example.

In the UK, relationships with contractors are more inclusive. More improvements are needed in work management in terms of schedule stability and resource availability to improve the quality of maintenance work.

SATISFACTORY HOUSEKEEPING

In France, housekeeping is generally satisfactory, but there are a few persistent weaknesses:

- Corrosion, which is not being treated soon enough; although internal corrosion is usually only discovered belatedly, external corrosion is visible and should be treated promptly.
- The defect backlog is still too high and there are considerable variations between sites. The multi-disciplinary rapid maintenance response teams (EIR) deal with the most urgent defects but suffer at times from limited availability of resources from the relevant departments. In my view, the aim of the defect backlog reduction programme needs to be more closely aligned with international standards.

Another concern relates to the in-service preparations for the modifications planned for the ten-yearly outages. Amongst other things, these require a large amount of scaffolding which causes access problems for staff on site. It is important to make sure that this impaired working environment does not become the norm over time.

Housekeeping in the UK remains at a good level despite the impending plant closures. At all the plants I visited, I saw that storage areas were well managed. Corrosion is visible although in the process of being treated. The Diagnostic and Repair Teams (DART) are most effective when there is good collaboration between departments. Lastly, the Operations department needs to make sure it sets the right priorities. The defect backlog has risen compared with 2020; this needs to be addressed without delay.

SPARE PARTS: COOPERATION NEEDED TO OVERCOME OBSTACLES IN FRANCE

I was pleased to see that the UTO[2], now the only designated spare parts management centre, has made this one of its main strategic objectives. The plan to develop a spare parts repair programme is another step in the right direction, and is currently taking shape with the construction of purpose-built premises near the Velaines logistics centre.

However, there are opposing opinions regarding spare parts management: plant staff still claim they face an uphill struggle to obtain spares and mention the same recurring issues (obsolete part numbers, incorrect or faulty parts received and sometimes even no parts received), whereas UTO staff believe that the orders they receive from the plants are the source of the problems (lack of forward planning, incorrectly completed orders, etc.). This issue needs to be addressed as a matter of urgency.

A GENERIC DEFECT IN AN N4 PLANT SYSTEM

In December 2021, in-service inspections (ultrasounds) detected stress corrosion defects on the elbows of the safety injection system in one of the reactors. The Operator rapidly shut down the reactor and checked the three other N4 reactors. The ongoing analysis of the conditions causing these defects – unexpected in this area - will determine the repair techniques and will support the definition of additional areas of inspection. The manner in which this event was handled underlines the Operator's responsible reaction to the situation.

[2] *The DPN's Central technical support department*

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

Nuclear safety is, first and foremost, the responsibility of operations staff. It relies on their expertise and sense of individual and collective responsibility, as well as the quality of their first-line management.

Nuclear safety requires organisational structures, processes, and documentation, but primarily it depends on technical competency, knowledge of the field and rigour during operation. It engages all five senses and the judgement of everyone involved.

Top priorities: skills, responsibility and supervision in the field

02

NUCLEAR SAFETY EMBODIED BY THE OPERATOR

The IAEA's first fundamental safety principle states that "*the prime responsibility for nuclear safety must rest with the person or organisation responsible for facilities and activities that give rise to radiation risks*". At EDF, this responsibility first lies with the operational chain of command. Independent nuclear safety oversight has an additional monitoring responsibility, but this is no substitute for operational responsibility.

The Group's nuclear safety policy is in accordance with this principle. The latest policy update was signed by Jean-Bernard Lévy on 12 February 2021.

There are strong messages from the heads of both fleets, where productive discussions and freedom of expression are evident. Expertise, conscientiousness and good intentions are apparent, but overall efficiency is suffering because of the proliferation of bodies, organisational layers, documentation, and performance indicators. Direction, priorities and responsibilities are all being diluted.

At the plants, nuclear safety is ensured by all functions (operations, maintenance, chemistry, engineering, etc.), while the daily operational priorities are defined by shift managers. Operations leadership needs to be further supported and developed. In France, the deputy shift manager (CED) role needs to be more firmly embedded in reactor maintenance management when units are in service *(see Chapter 5)*.

Some good nuclear safety culture initiatives are continuing at the sites on both sides of the Channel and are being developed in engineering. However, safety culture surveys should not become yet another formality among so many others: it is more important to prompt an in-depth reflection. Some plants are working on this with support from corporate services. I also encourage them to share learning from past accidents - nuclear or conventional - supported by findings from accident studies and analyses, similar to the exemplary work conducted by R&D following the Fukushima-Daiichi accident.

In the French engineering departments and corporate services, and sometimes even at the plants, nuclear safety is too often perceived as solely meeting the ASN's requirements, despite several positive changes being implemented to rectify this. This attitude runs the risk of an insidious transfer of responsibility. The ASN and IRSN have compounded this with their proliferation of questions (though many are well-founded, they could be prioritised), requirements and legislation: they are *de facto* controlling the workload of engineering and corporate services, with the risk of overloading them.

The priority of nuclear safety according to WANO

"For the commercial nuclear power industry, nuclear safety remains the overriding priority. Although the same traits apply to radiological safety, industrial safety, security and environmental safety, nuclear safety is the first value adopted at a nuclear station and is never abandoned. [….]
... the special characteristics and unique hazards associated with nuclear technology – radioactive by-products, concentration of energy in the reactor core and decay heat – mean each station needs a healthy safety culture."
(Ten traits of a healthy nuclear safety culture)

REALITY BEFORE PROCESS

A relatively serious imbalance is evident, particularly in France, between what actually needs to be controlled through technical practices and what is believed to be ensured by documentation; between "regulated nuclear safety" and "managed nuclear safety". Issues such as overly detailed processes, the mass of rules and regulations, the burden of "nuclear safety on paper" and the difficulties in getting anything done are raised with alarming regularity in my meetings. Providing evidence seems to take precedence over the task itself (see the 2020 IGSNR report).

Following procedures to the letter should not be a substitute for knowledge and technical know-how, no more than coordinating processes should erode the sense of personal responsibility.

Is it necessary to have dozens of pages of documentation, risk analyses for every action required and several signatures, just to decant a tank? Does a criticality procedure really need to be more than 100 pages long? Is it realistic to expect someone to read such a document from cover to cover and follow it to the letter in the middle of controlling a

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

transient? I recommend that significant efforts be devoted to revising all operational documentation. Existing documents seem to be more of a demonstration that writers have identified all the risks, summarised all the requirements and included all the standards of excellence. Yet operational documentation should not be a training manual, a set of guidelines, or a "safety case". It must be focused on the needs of those in the field.

In France and the UK, significant event reports of some low-key incidents are often too long, and the tendency is to add processes, checks and signatures to prevent them from happening again. In the event of non-compliance with the basic rules, follow-up actions should focus on skills and behaviours.

Complexity is an issue in the UK too, as reflected in the intensive use of multiple indicators. However, one of the plants I visited proves that it is possible to achieve the right set-up: managerial presence in the field; intimate knowledge of plant operations; description of operational issues rather than monitoring processes; sense of ownership accompanied by a sense of pride.

USING THE RIGHT WORDS TO DESCRIBE REALITY

Language shapes minds. Yet there is a tendency in the French fleet to use a lot of jargon and legalese, which runs the risk of losing meaning. I urge people to revert to using unambiguous vocabulary that mirrors reality.

For instance, it is far better to say "nuclear safety" rather than "macro-process 3", "reactivity control" rather than "reactivity control sub-process", or "fire" instead of "fire sub-process". This does not preclude processes from shaping control and continuous improvement actions. If the fire doors need to be closed, it is to prevent the spread of fire, not because they are "highlighted in the safety case". The term "safety demonstration" is also frequently misused, which not only raises questions about doctrine but also risks causing confusion about the primary objective: nuclear safety is the overriding priority; demonstrations are a means of showing that nuclear safety is assured.

Additionally, the "core skills handbooks" should be a compilation of a small set of essential rules that must be applied systematically, rather than describing the vast array of best practices, to the extent that the desired expectations become lost *(see Chapters 5 and 6)*.

Expressions or behaviours, which primarily seek to prove compliance with ASN requirements in the event of a potential legal dispute, should also be avoided at all costs, as this can detract from the Operator's sense of primary responsibility. It once again accentuates the legislative environment that all the stakeholders exacerbate in their application of the INB ministerial order, which could be detrimental to nuclear safety.

PRIORITY TO THE 'MACHINE' AND THOSE WHO OPERATE IT

STRENGTHENING THE PRESENCE OF MANAGERS IN THE FIELD

Presence in the field must be standard practice for managers, whether for supervising teams, managing activities, enforcing the rules, teaching through experience or shaping behaviours.

The DPN's determination to develop managerial presence in the field and personal responsibility is good to see but there is still a long way to go. I also applaud the 'Manager in the Field' initiative in the British fleet; it is estimated that managers spend 20 to 25% of their time in the field, the target being 40%. At one plant, meetings are banned at certain times of the day and instead the time is dedicated to field activities. For leaders who have worked their way up through the apprenticeship programme, of which there are many, this comes as second nature; they have already been in their team's shoes.

Working in a radiation-controlled area - Chinon nuclear power plant

Both fleets developed databases for logging managerial field reports as a means of monitoring manager presence in the field and collating their observations. However, these extremely convoluted systems appear to have found their own purpose. It seems that they are used to provide evidence to WANO or the ASN. I suggest that this approach be reviewed and that supervision in the field be left to managers, without constant scrutiny from Paris or Barnwood.

Within engineering, first-line managers should focus on technical supervision, engineering judgement, physical senses and orders of magnitude. Not everything can be substantiated using 3D modelling.

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

SKILLS: JOB TRAINING AND SUPERVISION IN THE FIELD

As highlighted in the 2020 IGSNR report, managers in France need to engage more in developing and assessing the competences within their teams, paying much closer attention to training outcomes, organising practical and vocational training, and providing support in the field.

I am pleased to see that skill development is at the heart of the START 2025 and *Excell* initiatives, as well as being included in the nuclear industry's strategy. It is also an integral part of the Nuclear Generation's transformation project.

At the DPN, "discipline leaders" work on processes, attitudes and methods. It is disappointing that due consideration is not given to technical content, operating experience and how jobs are evolving.

Training provided by the UFPI[3] is of a good standard, but I note there is a drift towards focusing on the theory of rules and regulations; this needs to shift to technical principles and know-how.

Skills also affect emergency preparedness. The effectiveness of the 'last-resort' post-Fukushima emergency equipment relies on field operators to connect it up and operate it correctly. Operability requires enhanced training for all plant teams, from field operators right up to local emergency controllers, including the Nuclear rapid reaction force (FARN) or the deployable back-up equipment (DBUE).

In the UK, apprenticeships are becoming the norm *(see Chapter 5)* and together with in-house maintenance programmes, are helping to develop technical knowledge and a sense of ownership: I met many technicians who are happy in their job.

I support the strategy in France to bring some maintenance activities back in-house to ensure that core practical skills are not lost. The apprenticeship programme offered by a diesel generator manufacturer is a welcome practice: it includes technical certificate training, work-study learning, and initial workshop experience before progressing to on-site maintenance.

REFOCUSING ON SKILLS AND RESPONSIBILITIES

Advanced technologies, the multitude of technical domains, and the cross-functional link between design, construction and operation mean that organisational structures tend to be matrix-type and inherently complex.

However, fragmentation of skills and responsibilities is quite striking. Trying to resolve the problem by adding yet more processes, committees and discussions only increases the complexity, often making it difficult to establish where responsibility lies. This is true in many areas, like diesel generators *(see Chapter 7)*, hazards (see the 2019 report), equipment knowledge and maintenance, the Hinkley Point C project and the Technical Client Organisation (TCO) *(see Chapter 8)*.

I encourage all to refocus on skills, to define the responsibilities for each topic and to ensure that they are internalised.

SPANNER TIME[4]: A KEY FACTOR IN NUCLEAR SAFETY

Aside from productivity, hands-on time (known as 'spanner time' in the industry) enhances job satisfaction (welders, valve fitters, electricians, etc. all want to practice their profession), not to mention skill retention, morale and quality, all of which have a knock-on effect on nuclear safety. At some sites, I was told that the actual spanner time was very low. Delays to schedules have a detrimental effect; unexpected delays lead to a demotivated, weary and stressed workforce.

It is therefore imperative to prevent situations where maintenance technicians find it impossible to perform their job due to circumstances beyond their control. At the DPN, START 2025 focuses on realistic, robust schedules that are shared and observed by all, which is vital.

AGR pile cap

[3] *Operations & engineering training department, which reports to the DTEAM and is responsible for training provision*
[4] *Amount of time per day that each maintenance technician spends at the worksite with tools in hand*

Nuclear Generation has launched a similar approach in the shape of the Maintenance Improvement Plan. Even though progress has been made at some plants, there is still a considerable amount of work to be done.

Enduring principles

In light of the potential consequences for nuclear safety and the complexity of working methods (see the 2019 and 2020 IGSNR reports), the EDF Group - as nuclear operator - must seek to re-establish the balance between "regulated nuclear safety" and "managed nuclear safety" in line with the following principles:

- Reduce the volume of processes and documentation
- Prioritise technical practices, skills and training in the field
- Instil personal and collective accountability
- Simplify and realign a fragmented organisational structure
- Revise operational documentation from a technician's perspective, removing any generic content; the nuclear safety systems would be an appropriate starting point.

This implies reaching an agreement with the nuclear safety authorities as far as they are concerned.

INDEPENDENT OVERSIGHT KEEPING UP THE PRESSURE

INDEPENDENT NUCLEAR SAFETY OVERSIGHT AT THE SITES

In France, safety engineers (IS) are highly skilled, work openly and transparently, and raise their concerns collectively. Although the advanced planning of jobs and skills is robust and improving at most plants, it remains critical at some, where the lack of planning or appeal for certain jobs is evident: this needs to be addressed as soon as possible.

Safety engineers still complain of the onerous workload regarding documentation, such as updating the general operating rules (RGE). Redefining their tasks would be a more effective solution than increasing their number. They are often required to spend too much time on the administrative aspects associated with declaring incidents and managing the unavailability of nuclear safety equipment. Instead, more of their time should be spent in the field assessing the site strengths and weaknesses in nuclear safety, including the skills.

In France, the annual safety reports (DAS), which are now slightly shorter thanks to a concerted simplification effort, contain many useful facts and analyses: this is a constructive practice that needs to continue. I recommend that they focus more on know-how and behaviour and less on processes. Above all, safety reports should summarise the state of the plant's nuclear safety and its future prospects.

In the UK, the Independent Nuclear Assurance (INA) benefits from a diverse talent pool and provides sound advice on site operations. It also has the confidence of the UK regulator, the Office of Nuclear Regulation (ONR). It is heavily involved in preparing for defuelling at one plant that is approaching the end of its operating life. To make sure it keeps up the pressure on plants, I urge the INA to assume more of a daily role in challenging practices, such as in the form of 'cross-examinations' *(see Chapter 5)*. I reiterate the need for vigilance regarding future jobs and skill requirements.

Nuclear safety culture

INDEPENDENT NUCLEAR SAFETY OVERSIGHT AT CORPORATE AND ENGINEERING LEVEL

I am pleased at the level of cooperation between the fleets and WANO. The in-depth analysis of Areas For Improvement (AFI) shared by several sites, which has been launched by the DPN and Nuclear Generation, is looking promising.

I am pleased to see that the role of nuclear safety director has been fully integrated into senior management teams in both fleets.

The DPN Nuclear Inspectorate (IN) is continuing to develop self-mandating and the role of independent nuclear safety oversight at corporate level, both of which are positive steps. The overall nuclear safety evaluations[5] are still too centred on process compliance and would benefit from being more performance-oriented. Uptake of the IN's recommendations must be better, though I note that there has been some improvement in this direction in 2021 after a period of poor uptake. I support the move in the French fleet to organise the overall nuclear safety evaluations jointly with WANO peer reviews, which both have complementary aspects and approaches. The initial joint evaluations have been encouraging.

In France, independent nuclear safety oversight is set up in new-build projects, as well as in the engineering departments at the DIPNN and the DPNT. However, their positioning and influence still vary across departments. Documentation audits and checks are being tackled as a matter of priority since they offer the greatest added value. I recommend that these new independent nuclear safety oversight teams maximise their role in challenging decisions and issuing warnings. At the DIPNN, the Independent nuclear safety and quality oversight department (DFISQ) is conducting robust audits.

In the UK, the INA's recommendations are being implemented effectively. I encourage the INA to write their twice-yearly reports in a more critical spirit to keep up the pressure on the plants. The independent nuclear safety oversight body for Hinkley Point C plays an important, recognised role in the project.

THE FRENCH OIU[6]

Like my predecessor in previous years, I met with OIU staff to assess their independence, which is unequivocal in my opinion. The organisation needs to pay greater attention to advanced job and skill planning. It has strong relationships with its clients.

INTERNAL AUTHORISATION

The internal authorisation system - delegation of ASN authority - is firmly established and is having a positive impact on internal rigour and responsibility. There is a good balance between workload and resources in routine operation activities (e.g. exemptions to the general operating rules, temporary modifications), which reflects efficient planning. However, the sharp rise in the number of technical changes is expected to upset the balance and place increasing strain on engineering teams across the fleet. I would also like to stress the need to prepare for the inclusion of Flamanville 3 in this system.

MY RECOMMENDATIONS

In order to achieve the degree of simplification needed in nuclear safety, I make the following recommendations to the Directors of the DPN and Nuclear Generation:

- **Launch a comprehensive review of the reporting processes so only information that is strictly necessary is reported at the appropriate level**
- **Increase the presence of managers in the field and, in France, reduce the systematic online reporting required after formal management field visits (VMT).**

The defence-in-depth improvements achieved through post-Fukushima modifications and the ten-yearly inspection outages (VD) imply effective operational management: I recommend that the Director of the DPNT ensure that all local modifications are fully tested and that training in operational conditions is increased from field operators to emergency controllers (PCD1), including the FARN.

[5] *Évaluations globales d'excellence (EGE): inspections conducted by the IN*
[6] *Attached to the DIPNN's Industrial Division (DI) with delegated responsibility to assess the conformity of some pressure equipment*

Personal contamination monitoring - Chinon nuclear power plant

Industrial safety is about taking into account critical risks, whether individual or collective. The results are improving in France and remain good in the UK.

In radiation protection, the UK fleet has experienced some minor events, while in France, the number of non-conformities concerning radiography work, access into red radiation-controlled areas, and entries into controlled radiation areas, has dropped. Cases of contamination remain too high, including an incident classified level 2.

Drug and alcohol abuse could not be more incompatible with the nuclear industry. Though testing for drug use is a common practice in the UK, it is rarely employed in France.

Industrial safety and radiation protection: exemplary behaviour is required

03

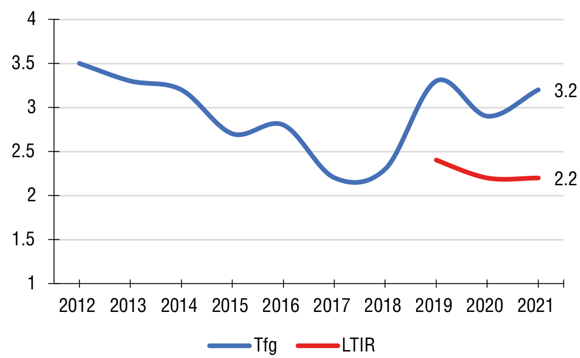
INDUSTRIAL SAFETY

The EDF Group reported seven fatalities in 2021. This shows just how crucial it is to respect the critical safety rules at all times.

The industrial safety results of both nuclear fleets are stable overall. Nevertheless, the number of accidents without lost time or significant consequences has risen. This indicates that vigilance is flagging and the rules are not being followed rigorously; this may be because staff are feeling overloaded by the additional rules to implement during the pandemic *(see Chapter 1)*.

IN FRANCE, RESULTS ARE STABLE

At the DPN, the lost-time injury rate (LTIR)[7] reached 2.2 as in 2020 and the overall accident rate (Tfg) of 3.2 (2.9 in 2020).



Overall accident rate (Tfg) and the lost-time injury rate (LTIR) at the DPN

The number of slips, trips and falls, together with the number of manual handling accidents, has increased.

The number of accidents due to critical risks (work at height, load handling, electrical work) has dropped : 4 accidents with lost time (5 in 2020, 5 in 2019) and 6 accidents without lost time (7 in 2020, 11 in 2019).

In the engineering functions, the DIPNN results (excluding Flamanville 3) are stable with an LTIR of 1.0 as in 2020, and an overall accident rate of 2.2 (1.7 in 2020). At the DIPDE, the results are also stable with an LTIR of 1.5 as in 2020.

At Flamanville 3, the accident rate has remained high but is improving, with an LTIR of 4.9 (8.3 in 2020) and an overall accident rate of 7.4 (8.9 in 2020).

On decommissioning sites, the LTIR is stable at 1.5 (1.1 in 2020).

Making progress in industrial safety requires:

- Exemplary managers and their presence in the field
- Individual and collective accountability
- Strictly respecting the requirements.

IN THE UNITED KINGDOM, THE RESULTS ARE STILL GOOD

The industrial safety results have remained good, with an LTIR of 0.3 in 2021 (0.3 in 2020 and 2019).

More often than not workers know the rules, but I note a certain erosion in how risks are perceived and an increased level of weariness. This is perhaps linked with the pandemic when faced with a multitude of rules and expectations.

Nuclear Generation rolled out the TAKE 5 initiative to improve the identification of risks before carrying out any work. This will be all the more important at those sites reaching the end of generation as the risk profile will change during the defuelling phase.

Spraying of sodium hypochlorite solution

An experienced field operator was in the process of restarting the sodium hypochlorite dosing system. In compliance with the procedure, he was preparing to operate the outlet valve on the tank located outside the plant room. However, the drain valve on the tank was not closed and pure hypochlorite was spraying out. Puzzled by the smell, the operator opened the door to where the tank was located to investigate. In doing so, his whole body was sprayed with concentrated hypochlorite. Several shortfalls were identified: previous system alignment performed incorrectly, no suitable pre-job briefing, and poor use of procedures or written instructions. Thankfully, the operator escaped unharmed as he was wearing suitable personal protective equipment.

[7] *The lost-time injury rate (LTIR) refers to the number of industrial accidents requiring sick leave per million hours worked, and is the most commonly used indicator in the world.*

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

The results for the Hinkley Point C construction site continue to improve. With an LTIR of 0.79 (0.89 in 2020, 0.92 in 2019), they are among the best results for such construction sites worldwide. As the construction work progresses, the types of risks will change and the site is adapting to this accordingly. For instance, work at height or in confined spaces will increase considerably.

EPR construction site - Hinkley Point C

PREVENTION OF DRUG AND ALCOHOL ABUSE: TESTING MUST BE DEVELOPED IN FRANCE

The nuclear industry dictates zero tolerance to drug and alcohol abuse in the workplace. The risks are multiple; they range from a work accident, impaired vigilance or an incorrect calculation, to making a plant operation error or being more susceptible to pressure from others to commit a malicious act. Behavioural changes can be detected and treated swiftly, with support from either a family member or a professional, by local management or the occupational health team. The relationship between these two latter parties is not always clearly established.

Drug and alcohol testing is a routine practice at sites in the UK: weekly random tests (about 20% of the workforce is tested every year), systematic testing following any event involving human factors, and any testing called for by a concerned manager. Whether working for EDF Energy or a contract partner, anyone who discloses their own drug or alcohol problem will be given help and support. Conversely, a positive drug or alcohol test can result in dismissal. The low number of positive tests, well below the national average, attests to the effectiveness of this testing policy.

In France, the pandemic either interrupted or completely slowed down the planned amendment of the internal rules, which is prerequisite to implementing routine testing. I reiterate my recommendation to set up a regular testing system at each plant. This should include targeted testing in the case of suspicion or after an event implicating human factors. It also seems necessary to strengthen relations between the managers and the medical staff, without violating the rules of medical confidentiality.

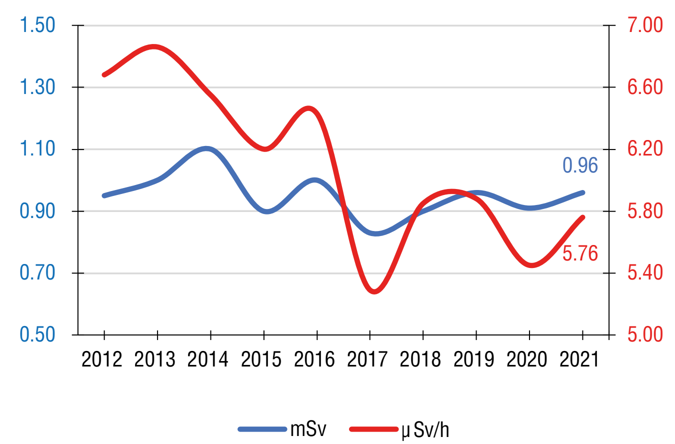
RADIATION PROTECTION

IN FRANCE: THE RESULTS ARE ACCEPTABLE BUT AN UNDERLYING WEAKNESS PERSISTS

In 2021, the collective dose was 0.71 Man.Sv per reactor which is consistent with the target defined by the DPN, albeit a less ambitious one than those set by other operators worldwide.

The average individual dose for workers (EDF and contractors) is stable: 0.96 milliSievert (mSv) compared with 0.91 in 2020. A total of 189 operatives received an annual dose exceeding 10 mSv (73 in 2020). No operative exceeded 14 mSv. The regulatory limit is 20 mSv.

The hourly dose per worker (EDF and contractors) reached the third best performance ever recorded. The CADOR software is a good decision support tool that helps define and optimise the biological shielding that needs to be set up before starting work. This allowed Tricastin 2 to save 0.261 Man.Sievert during its fourth ten-yearly outage.



Mean individual dose and hourly dose (EDF and contractors)

The DPN introduced its radiation protection recovery plan in late 2020. Following a slow start and varied levels of ownership, it is now delivering some preliminary results regarding the management of red controlled areas and compliance with entry/exit rules for controlled areas. The lack of rigour on some worksites, however, is giving rise to numerous cases of contamination, as evidenced by the significant level 2 event. The industrial safety indicators for radiography are improving, though I suggest reinforcing the routine work monitoring to make sure the fundamentals are being followed systemically.

In order to make further progress, radiation protection – like industrial safety - requires greater exemplary managerial conduct and presence in the field, more individual and collective accountability, and stronger action in enforcing the rules and expectations. Radiation protection must be everybody's business, not just that of the radiation protection department.

Training does not always include sufficient hands-on practice in the field; I am particularly surprised that you can be authorised to access the radiation-controlled areas without ever having gone there during training. I was told that assessments can be performed as a group rather than individually, which is unacceptable in my eyes. These training programmes seem to need updating. This action has been included in the radiation protection recovery plan, and I look forward to seeing the positive effects.

A significant radiation protection event

In the reactor building of a PWR, a worker was contaminated by a radioactive particle, which settled on his neck. The particle was immediately removed by the medical staff. This incident was classified as a level 2 significant radiation protection event because the received dose exceeded the yearly regulatory limit according to the conservative calculations performed. The whole-body dose, however, remained well below the regulatory limit. The suspected cause was due to the poor housekeeping in a neighbouring maintenance worksite.

The relevance of the Everest initiative is undeniable, as attested by the progress and rigorous level of radiological cleanliness it demands. It is necessary to maintain the level of discipline that it imposes so access into radiation-controlled areas does not become trivialised.

In the field of decommissioning, vigilance against the spread of contamination is crucial, in particular the alpha radiation risk.

IN THE UK: SATISFACTORY RESULTS...

Owing to specific design features, the collective doses in advanced gas reactors (AGR) are inherently lower than those in pressurised water reactors (PWR). The rules for operating in an environment concerned by radiation protection are still well understood. In 2021, the AGR collective dose remained low at 0.012 man.Sv per reactor (0.013 in 2020, 0.032 in 2019). The number of cases of contamination also decreased. These improvements may be partly due to the postponement of unit outages.

The collective dose for the Sizewell B PWR reached 0.383 man.Sv (0.031 in 2020, 0.26 in 2019). This increase can be explained by the extended reactor outage to repair some of the thermal sleeves on the reactor vessel head. This maintenance work was completed successfully and I commend the close cooperation between Nuclear Generation and the DPN.

The maximum individual dose in the UK fleet remains low at 5.9 mSv, compared with 2.2 mSv in 2020 and 4.37 mSv in 2019.

... BUT SOME ISSUES REQUIRE ATTENTION

As for industrial safety, some instances of unsuitable behaviour were observed in radiation protection. Even though staff clearly know the rules, some demonstrated a lack of rigour when applying them.

For the first time in five years, the demarcated area set up around radiography work was not respected, thankfully without any radiological impact.

Though these irregularities and other non-compliances with contamination checks in controlled areas had no significant impact, I suggest that the plant radiation protection ALARP committees take action to reinforce the expected behaviours.

MY RECOMMENDATIONS

The additional Covid health and safety measures put in place may have overshadowed the need to systematically respect other rules. I recommend that the Directors of the DPNT, the DIPNN and EDF Energy ensure strict compliance with the critical safety rules. In France, I reiterate my recommendation with respect to drug and alcohol abuse.

I recommend that the Director of the DPN ensure that all managers are in the field enforcing the expected behaviours, in support of the radiation protection recovery plan.

An Olympic champion

The integrated EDF Group has the means to support plants in need of improving their performance.

Nuclear Generation and the DPN are working to better predict, detect and then support those plants whose performance is showing signs of a downturn.

Internationally proven methods are available, such as INPO 12-011 and WANO Guideline 2015-01.

Better support the plants showing declining performance 04

In the past, downturns in plant performance have often been due to the delayed response in acknowledging the root causes, such as losing a sense of ownership of the plant and a disconnect between senior management and field staff. Pressure from external sources can make it even more difficult to adopt the perspective required to address the situation. Action plans are often overly ambitious and inadequately prioritised, calling for regular revision. Support missions are not always well-coordinated.

And yet after what is often a long period of acceptance, some plants have succeeded in reversing the negative trend by reinstating a collective response from plant staff, strengthening their leaders in the field programme, and sustaining a culture of prioritised actions over time. Targeted support missions have helped plants engage in corrective actions.

Management at Nuclear Generation and the DPN recently resolved to be better prepared in identifying and supporting low-performing plants in a timely manner. Both operators have support resources available on a national and local level, and access to ample performance data, though they are insufficiently well integrated. They intend to make better use of international operating experience with help from WANO.

BETTER ASSESSING THE REALITIES IN THE FIELD

ORGANISING A MORE QUALITY-BASED MONITORING SYSTEM

Both fleets recently introduced changes to monitor performance more frequently.

In 2020, Nuclear Generation initiated its COontinuous MOnitoring (COMO) process based on INPO methodology. Every three months the Fleet Managers (FMs) assess the performance of each site using a mix of quantitative and qualitative data and enter this into a common document known as the Area Monitoring Insight report (AMI). The AMI is shared with the relevant plants and discussed at the Collegial Review Meeting (CRM) chaired by the Chief Nuclear Officer (CNO). Additionally, the FMs each provide an assessment of their disciplines' performance trajectory for the following six-month period based on: organisational effectiveness, proficiency and future workload.

Following an experimental phase and having overcome initial reticence in the field, this approach is now well received by stakeholders. Its success relies on the FMs and their station counterparts working closely and transparently together. It has been rolled out across all Region 2 sites. I have noted, however, that there has been some difficulty in keeping track of decisions and mobilising support at the right moment.

DPN management conducts monthly performance reviews with plant directors using a set of 120 management indicators and 20 performance indicators to provide plant comparisons.

The DPN leadership team completes its overall picture of plant performance at the half-yearly reviews. The directors of operations (DDOs[8]) present an overview of each site based on a combination of indicators and more qualitative data. These constructive discussions undoubtedly aim to provide an uncompromising assessment of performance. However, if the DDO site visits focused more on the realities in the field, this could help avert declines in performance and engage improvement actions well in advance.

MAKING GOOD USE OF INTERNAL AND EXTERNAL OVERSIGHT

In the UK, the onsite INA teams, using their own field data and site indicators, conduct regular performance assessments. They share their findings with plant managers on a weekly basis. Every six months, they identify the three main areas for improvement and monitor the progress made.

The INA conducts a full audit of each site, staggered over a period of four years. WANO peer reviews are monitored closely to ensure that the Areas For Improvement (AFIs) are addressed within the desired time frames, with 88% being addressed satisfactorily within two years. Between reviews, WANO representatives are in regular contact with the plants and can issue warnings if necessary. In the last few years, these have not always been taken into account in a timely manner.

The role of the Nuclear Safety Review Board (NSRB) was revised recently to provide targeted support missions rather than conducting regular nuclear safety assessments. In light of this loss of one of the methods for detecting declining performance, I urge Nuclear Generation to focus future missions on plants in difficulty.

In France, the overall nuclear safety assessments (EGEs) conducted every four years by the DPN's Nuclear Inspectorate provide a full assessment of plant compliance with the standards. However, these assessments tend to focus on the internal process and consequently

[8] *Similar to Chief Nuclear Officers in the UK*

may fall short of painting a more rounded picture of actual performance. The Nuclear Inspectorate does not pay enough consideration to less formal aspects, though they are essential to assess nuclear safety and detect early warning signs.

WANO peer reviews are undertaken every four years. The results from the WANO follow-up reviews, conducted two years later, show that on average only 65% of AFIs are addressed satisfactorily. The experiences from the combined Nuclear Inspectorate/WANO reviews should help deliver efficiencies in both these oversight mechanisms. I will be monitoring this situation with interest.

HAVING REALISTIC EXPECTATIONS OF INDICATORS

To complement their peer review system, WANO recently asked the plants to submit a quarterly report of 53 performance indicators. Events must be reported and analysed meticulously. Visits aimed at tackling specific issues are organised by WANO representatives. The situation at each plant is assessed as part of a quarterly performance review.

I question the effectiveness of this indicator-only process, which seems to be redundant in light of the mechanisms implemented by both Operators. Peer reviews are WANO's main core strength: peers provide a credible and uncompromising snapshot of plant operations based on their observations, their field facts and their operating experience and insights. This underlines the importance of paying greater consideration to the tangible, first-hand information available to the senior management in each fleet.

I am pleased to see that the leadership teams in both fleets share, on a regular basis, their overall perspectives with their national nuclear safety authorities. These exchanges provide an additional opportunity to identify difficulties. In France, the ASN will introduce a new system to check the plants based on a set of around one hundred indicators provided by the Operator; this will mirror the Operator's own oversight process and increase the reporting workload without additional benefit.

Gold medallist

EXPLOITING THE AVAILABLE DETECTION CRITERIA

In addition to performance and management indicators, other early warning signals are available to the corporate staff of both fleets. These types of warning signals are described in international guidelines and methods, and their relevance is corroborated by operating experience. However, I regret to say that they have not been incorporated systematically into the assessment framework.

The following criteria are commonly acknowledged early warning signals of a plant in decline, although this is by no means an exhaustive list:

- Inward-looking approach, implicit and convoluted organisational structures, lack of collective vision amongst senior management, lack of cooperation between departments or divisions (silo mentality), disconnect between management and teams in the field
- Poor advance planning of roles and skills (including the leadership team), inadequate consideration of vocational training and practice drills
- Denial from management and plant staff alike of declining performance (even if they are still at an acceptable level) and the need to question oneself
- Prioritising production over safety and loss of leadership by shift managers
- Less attention paid to independent nuclear safety oversight
- Degraded condition of equipment and difficulties in repairing defects, delays in preventive maintenance, poor housekeeping and budget overruns
- Frequent derogation requests
- Inadequate accounting of human factors in event analysis
- Absenteeism and a rising number of occupational accidents.

It is equally important to focus on the criteria for success, as it is to observe the signs of weaknesses. The following behaviours are those exhibited by consistently high-performing plants:

- Openness and dialogue with external parties
- Interdepartmental collaboration
- Staff with a sense of ownership and pride in achieving good results
- Continuous focus on behaviours, skills and the fundamentals rather than on continuous adjustment of processes and procedures
- Partner relationships with contractors.

ORGANISING SUPPORT AT THE RIGHT TIME

Both fleets present similar pictures. The expertise exists at both senior management and plant level. The will to succeed is evident during all my visits. Yet management is struggling to engage structured support at the right time and resources are not sufficiently well organised.

DIRECTORS OF OPERATIONS: A PIVOTAL ROLE

The respective roles of Director of Operations (DDO) at the DPN and Chief Nuclear Officer (CNO) at Nuclear Generation are performed in both fleets by highly experienced individuals with a sound understanding of the issues encountered on site gained through a long career in nuclear plant operation. They have access to all plant data and complete their overall picture through site visits which, in my view, should be conducted more frequently and on a more granular level.

London 2012 Paralympic Games

I urge the DDOs and CNOs alike to maintain their efforts to help site management better understand the support needed in good time. They also need to create the right conditions for collaboration between sites to mobilise support whenever it is needed. My final thought on this matter is to heed the findings and insights from the independent nuclear safety oversight and audit teams.

METHODOLOGY MUST BE STABILISED AND DOCUMENTED

Rigorous recovery action plans[9] implemented on both sides of the English Channel have helped sites restore performance, drawing on methods derived from past practice and tailored to each plant in their

[9] *Known as "plans de rigueur d'exploitation" (PRE) at the DPN and "Recovery Plans" at Nuclear Generation*

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

application. Although this empirical approach does achieve positive results, it needs to be more closely aligned with the following four phases of recovery defined by WANO.

The diagnosis phase is an essential part of the recovery process to raise awareness of the issues among senior management and plant staff, but it requires time, an outside-in perspective and external impetus. Disappointingly, it seems that rarely enough time is dedicated to sharing this diagnosis with relevant parties.

The identification phase determines the areas for improvement, and must prioritise the corrective actions needed and engage all levels of management. The sites have high ambitions, but this can often make it difficult to prioritise and limit the scope of action.

The action plan phase relies on the culture in both fleets to draw up detailed action plans with indicator-based monitoring and time-bound deadlines. More often than not, some of the actions defined also relate to corporate services.

The exit phase must be underpinned by clearly defined criteria. As performance improves, progress and successes must be celebrated.

Both fleets have achieved results, yet the overall picture is still mixed. Some plants have encountered difficulties associated with delayed implementation of recovery plans, poor prioritisation or siloing of actions, as well as an all too frequent lack of engagement from front-line management. Continuity of managers in their jobs is paramount in all cases, and must be consistent with the timeline of the recovery plan.

BUILDING SUPPORT METHODS THAT CAN BE REPLICATED

The French and British fleets have demonstrated their readiness and capability to provide support to the plants:

- Experts have helped restore equipment to good working order by updating preventive maintenance programmes and addressing recurring technical issues
- Operations resources from several plants have bolstered skills
- Nuclear safety culture assessments have aided diagnosis
- DDOs and CNOs have increased the frequency of their site visits and have provided personalised support to the respective site management teams
- Internal peer reviews organised to target specific issues have provided corrective actions.

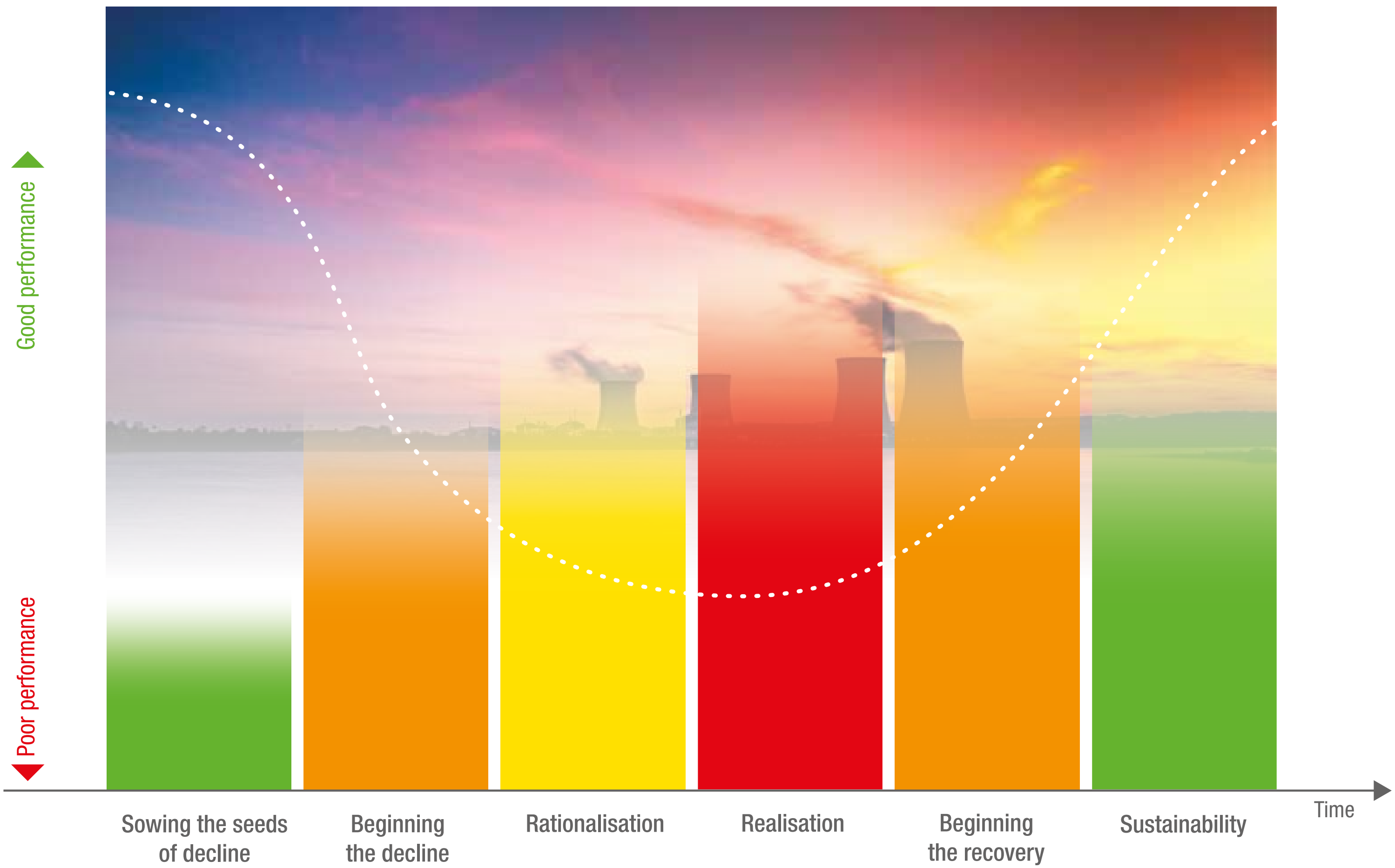
External support continues to be sought from WANO.

I suggest that the DPN and Nuclear Generation leadership teams better coordinate their own support resources, use the established support methods, and follow a more intrusive approach when necessary.

MY RECOMMENDATION

In order to improve detection of plants in difficulty and help them regain their good performance levels, I recommend the following to the Directors of Nuclear Generation and the DPN:

- **Complement the analysis of indicators with qualitative criteria**
- **Initiate recovery plans at the earliest opportunity, ensuring they are closely aligned with the four phases**
- **Launch support actions, adopting an intrusive approach if necessary**
- **Analyse the responsibility of the corporate level so it can establish its own improvement plan.**



Performance cycle

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

SURVEILLANCE DE L'INSTALLATION
MONITOR PLANT INDICATIONS

MAÎTRISE DES CHANGEMENTS D'ÉTAT
CONTROL PLANT EVOLUTIONS

ATTITUDE PRUDENTE ET CONSERVATIVE
CONSERVATIVE BIAS

TRAVAIL EN ÉQUIPE
TEAMWORK

COMPÉTENCES
KNOWLEDGE

The five operator fundamentals

Operations teams have a specific responsibility for nuclear safety and production. In many respects, the Operations department is like the conductor of an orchestra, directing plant operations.

The role of management is to ensure that the right conditions and talents prevail. Operating staff, for their part, must have exemplary skills and behaviours.

In accordance with international standards, the operator fundamentals are detailed in the *Noyau de cohérence conduite* (NCC) in France and in an Integrated Company Procedure (ICP) in the UK.

Operator fundamentals: a standard to be reinforced 05

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

The operator fundamentals explain the practices and behaviours expected of all shift and non-shift operations staff. They are applicable across all methods, processes and positions. They are based on an internationally proven standard of excellence adopted by both the French and the British fleets.

OPERATIONS DEFINES THE DAILY PRIORITIES

A plant's performance relies on an Operations department, which applies and enforces the nuclear safety standards on a daily basis. Shift managers (SM) and the *chefs d'exploitation* (CE) have to be operational leaders. Both fleets have been through a long period of stable operation. In the UK, preparations for defuelling before dismantling the AGR fleet are now upsetting the balance. In France, compliance with standards has been affected by the extensive maintenance work underway on units in service ahead of the ten-yearly inspections. This is placing extra demands on control rooms and involves an enormous amount of scaffolding and work in sensitive facilities. It is important that these conditions do not affect nuclear safety and that standards and situational awareness are not compromised. I will be monitoring these situations closely.

In France, the CE leads the daily operational focus meeting and explains the nuclear safety priorities clearly, which are generally taken into account. In the UK, the deputy operations manager runs the daily operational focus meeting. This ensures consistency in the station priorities across the different shift managers and greater continuity in terms of managing maintenance requests. The shift manager reinforces the station priorities during this meeting. Operations is also responsible for housekeeping and its role is consolidated when it uses this strength to ensure its requirements are met.

The excessive number of plant isolation and alignment events in both fleets, as well as the rise in non-compliances with technical specifications, tarnishes the authority of shift managers and CEs, undermining their leadership.

'CROSS-EXAMINATION' BETWEEN SHIFT MANAGERS AND SAFETY ENGINEERS - A PRACTICE SPECIFIC TO FRANCE

In France, the Operations department and independent nuclear safety oversight (FIS) hold a daily safety review (*confrontation*); this is a much needed and highly useful practice and one that is unique throughout the world. Though these review meetings are mature, too much formality in the proceedings can negate their benefit, especially if they focus solely on equipment unavailability classifications or involve protracted wranglings about event declaration criteria.

In the UK, a more informal meeting takes place between the shift manager and an INA representative, although not on such a regular basis, especially when the INA team is lacking its full complement. I suggest that this type of meeting becomes a daily occurrence, and it should be conducted routinely in the UK's EPRs.

Field operators - Hinkley Point B nuclear power plant

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

MONITORING: ONE OF THE FIVE OPERATOR FUNDAMENTALS

Field operators are the 'eyes and ears' of the shift team. They know the plant and ensure monitoring at a local level. The majority are highly motivated individuals who find their work rewarding. In France, field operators appear to be somewhat isolated, not least because they report to the plant safety officer (*délégue sécurité en exploitation*, DSE), who focuses more on managing plant isolations.

At the DPN, the full rollout of the control room supervisor (*pilote de tranche*, PT) role will improve monitoring in the control room: operators at the control desk will be able concentrate on the indicators and alarms on the control panels, while supervisors provide effective oversight when they have a proven track record in plant operations.

In the UK, the operational set-up for the AGRs has been stable for several years: the control room supervisor (CRS) faces the two reactor desks and each reactor desk engineer (RDE), and oversees all actions in the central control room (CCR).

SERENITY IN THE CONTROL ROOM CONDUCIVE TO RIGOROUS MONITORING

Worldwide, a serene control room environment is considered to be vital to plant operations and monitoring in both normal and off-normal conditions. Physical access and telephone communications are restricted and filtered. The DPN and Nuclear Generation both share this principle.

In the UK, the CRS upholds serenity rigorously in the control room, while the Work Execution Centre (WEC) provides the outside link to it, fielding any unnecessary requests. However, there seems to be a need for greater vigilance in the AGR fuel route control room; I note that they are receiving an increasing number of telephone requests as the sites prepare for the end of generation and subsequent final defuelling.

In France, control room access is controlled by entry badges issued to authorised personnel only. Further, the control room supervisor filters all in-person requests. Strict control room protocols were introduced to limit access during lockdown to protect operators from Covid-19. This shows that it is feasible to maintain serenity in the control room. This is already one of the targets of the DPN's START 2025 project. I have noticed that there are still far too many phone interruptions during working hours, as well as many requests to inhibit fire detection sensors. There is, therefore, still some way to go to define, approve and implement control room standards more uniformly across all sites.

This area could be an opportunity for the two fleets to share and exchange practices.

Central control room of a 1300 MWe unit

MANAGING CHANGES IN REACTOR STATE: VULNERABILITIES STILL EXIST IN REACTIVITY CONTROL IN FRANCE

Reactivity control is the number one priority in nuclear safety. It does not always seem to be given the importance it deserves, which is why the DPN's drive to restore the level of rigour is timely: a new plan for reactivity control is being drawn up and it is now one of the four key safety indicators.

In 2021, 57 non-conformities relating to reactivity control were reported. Among these, the following two events stand out: the inaccurate dilution of the primary circuit during maintenance work; a boron injection unavailable due to an alignment error.

I am convinced that the necessary improvements will come not from adapting processes or procedures, but from constantly focusing on the fundamentals:

- Monitoring the plants
- Controlling plant evolutions and configurations
- Establishing a conservative approach
- Working effectively as a team
- Solid understanding of plant design and operation though continuous practical training.

This will help to simplify procedures (a criticality procedure is currently more than 100 pages long!).

A CAREFUL, CONSERVATIVE APPROACH: MAINTAIN THE EFFORT

There is a similar picture on both sides of the Channel. Although the tools exist, are widely accepted and effective, they are not always implemented rigorously and are not covered adequately in the vocational training programmes. Perhaps this neglect is borne of overconfidence.

There are clear and structured methods describing the principles of operational decision-making (ODM) and conservative decision-making (CDM). Yet they are not always sufficiently well adapted to actual conditions, especially when analysing specific events. This could weaken the conservative decision-making process. I encourage INA to conduct more *post hoc* analyses into the way in which decisions have been made.

Human performance tools (HPT) are still not being used consistently, mainly due to a lack of continuity in the approach. More mentoring and training are required. It is not enough to simply appoint a human performance champion. It is a commitment that everyone should uphold at all times.

TEAM WORK: A MIXED PICTURE

IN FRANCE, SOME INTERACTIONS NEED TO BE CLARIFIED

The division of roles in the shift team in France has evolved for the better.

CEs are now more available to be present in the field, this being one of their main tasks. It is disappointing that the programme of management field visits (VMT) is overly formalised with strictly imposed themes.

Deputy shift managers (CED) must be the voice of operations when it comes to plant maintenance, either during operation or outages, which is something they struggle with at times. I urge the DPN to review the career development path of deputy shift managers as part of the START 2025 Operations project, as it should not be restricted to just managing during accident conditions.

In the control room, the supervisor maintains a sense of order and calm, and oversees in real time the quality of monitoring performed by the desk operators. Analysis of near-miss reactor trips shows that operations teams were able to respond promptly and appropriately, and that the presence of a supervisor in the control room is beginning to reap rewards. Robust advance planning of roles and skills for the 300-strong cohort of control room supervisors is essential to maintaining the respect and value of this new role.

In their capacity as head of the plant isolation offices (one or two depending on the site), plant safety officers (DSE) have to focus on isolation expertise, an area in which there is still room for improvement. They now also manage the field operators. This means their remit is far wider than that of their predecessors' role, hence their skill set needs to be developed accordingly.

The operations departments are struggling to implement the new organisation and are not always achieving the expected nuclear safety performance levels. The roles of deputy shift manager (CED) and plant safety officer (DSE) need some adjustment and support, the role of control room supervisor (PT) needs to be reinforced, and time needs to be made available for shift managers (CE) so they can impose their authority and consolidate their leadership.

Teamwork within a central control room

In 2017, IGSNR highlighted the relevance of crew performance observations (CPOs) in assessing the collective performance of shift teams on the simulator. This tool, developed by WANO, is used routinely during peer reviews, which are conducted every four years. In the 2020 report, IGSNR recommended that this practice be introduced in all shift teams, using internal resources. I reiterate this recommendation.

STABILISED CONDITIONS IN THE UK

In the AGRs, the control room set-up has been stable for a number of years. It consists of a control room supervisor (CRS) and two reactor desk engineers (RDE), one for each reactor. At Sizewell B, one control room supervisor, one reactor operator and one assistant operator control the plant. The operators monitor and control the reactor and the conventional plant. The control room supervisor (AGRs and PWRs) has an overview of all operations and bears ultimate responsibility for all common plant systems. Additional support is provided by the operations engineer if needed. A similar set-up is planned for Hinkley Point C.

Contents My view 01 02 03 04 05 06 07 08 09 Appendices Abbreviations

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

Before any sensitive activity, an additional operator will join the control room team. All these planned activities will have been rehearsed by the team on the simulator prior to carrying out the work. However, recent events prove just how difficult it is for shift managers and control room supervisors to maintain an overall view at all times. This is an area for improvement.

Crew performance observations are now conducted at Nuclear Generation. The feedback is positive. I am satisfied that some elements of the CPO approach are now part of normal business and have been incorporated into simulator training sessions.

UNDERSTANDING HOW PLANTS OPERATE: TRAINING AND COACHING

Operations teams work on the front line of nuclear power plants and therefore need to maintain their high level of knowledge and proficiency.

Both France and the UK have a structured, comprehensive training provision. A local programme is developed for each plant based on a national standard of excellence. After their initial qualifying training, all operators must complete 10 days per year on the simulator, at the end of which individual areas for improvement can be identified. Every two years, simulator-based assessment is used to renew their authorisation. The number of failures is negligible. It is disappointing that several sensitive transients (criticality, change in reactor state, primary circuit draining, etc.) are insufficiently covered in refresher training courses.

A NEED TO BOOST MENTORING AND SELF-STUDY IN FRANCE

The availability of experienced staff for mentoring has been impacted as the average age of staff is now much younger, making mentoring all the more necessary. There is some reticence to exploit opportunities to train as a team and improve understanding of how plant systems work. Utilising night shifts, dedicating non-shift days to training, encouraging independent simulator training, revising plant system descriptions, and taking ownership of significant events are just some such opportunities.

The INES level 2 event that occurred at one plant in 2019 involving the drainage of a primary cooling system has been widely discussed in all teams. However, I often notice a lack of ownership during my visits, compounded by a failure to incorporate the lessons learned into department training programmes.

A STRONG COMMITMENT TO TRAINING FROM OPERATIONS IN THE UK

The high turnover of operations staff in the UK has led to a loss of experience and know-how. Training has been consolidated as a consequence, with particular emphasis on behavioural skills. This drive needs to continue, as recruiting and retaining operations personnel will remain an ongoing challenge.

Operations department leaders are highly involved in the training process. Shift managers observe their own teams during training sessions and then lead the training debrief. Two experienced operators are normally seconded to the on-site training department; this is seen as an added value for professional development.

Nuclear Generation has invested heavily in apprenticeship training as one of its priorities. This training seems to be valued highly by the apprentices themselves despite the length of the programme and the mobility required: two years of preliminary training at a Royal Navy base is followed by two years on-site with mentoring. Apprentice field operators often complete an initial stint with maintenance before joining operations, which gives them a solid grounding and sound understanding of how plant systems operate.

EMBEDDING THE FUNDAMENTALS IN EVERYDAY PRACTICES

In 2017, IGSNR recommended that the leadership teams in both fleets apply the five operator fundamentals more effectively. There is still some way to go in this respect.

Even though both fleets have a different approach, working together with support from WANO should help them make further progress.

The choice

IN FRANCE: WORKING ON BEHAVIOURS BEFORE PROCESSES

Operator fundamentals are defined in terms of core processes rather than expected behaviours in all activities. Some plants have developed a base of 150 criteria to describe the operator fundamentals. This overwhelming profusion is apparent in the appendix of the French operations core skills handbook (NCC).

Every shift manager (CE) is responsible for periodically assessing one of the five fundamentals. This approach is perceived positively by Operations department managers. Field operators are also involved with this assessment but their engagement is variable. A 6-12 month action plan is then drawn up on the basis of this assessment. More often than not though, these plans revolve around putting various tools, working groups or coordinators in place. Too few of the numerous actions relate specifically to those staff in the field.

There appears to be a distinct failure to seize opportunities such as analyses of non-conformities and events, briefings at the start and end of a shift, and training assessments to discuss how the fundamentals should be applied correctly.

The work undertaken as part of the START 2025 Operations project is encouraging and substantiates the need for cultural change. I note the positive initiative implemented in five pilot plants, with support from WANO.

IN THE UK: CONTRIBUTIONS NEED TO BE MORE TANGIBLE

A structured approach was set up five years ago based on the INPO standards. For every member of the operations team (from the field operator to the shift manager), the expected behaviours are described for each of the five fundamentals. This allows every team member to understand the expectations and therefore their own accountability. The operator fundamentals are frequently examined by all members of the team: during briefings and debriefs, after an event, during training, and when sharing successes. This approach is accepted and supported by all teams.

Nevertheless, there is still a high number of alignment events and non-compliance with technical specifications. The main causes for these were inappropriate behaviours across the board, rather than incomplete processes or a lack of technical expertise. This highlights the need to reinforce the fundamentals to ensure that changes in behaviours are effective.

Use of operator fundamentals questioned in three events

A defective nuclear-safety-related pressure transmitter was declared unavailable during a periodic test. It was later discovered that it had been found to be defective during the previous monthly test, but not reported to the control room as required, thereby exceeding the acceptable unavailability time.

Operators check the correct operation of safety-related equipment daily to ensure compliance with technical specifications. During one of these checks, one of the channels on the high neutron flux protection system was out of tolerance, but it was not recognised by the control room staff. Compliance was restored the following day, but this was not within the prescribed period as it should have been repaired immediately.

A reactor was in hot shutdown mode. The desk operator, performing this for the first time, achieved sub-criticality by performing a boration and moving the control rods at the same time, despite the fact that the simultaneous use of two reactivity control methods is prohibited.

MY RECOMMENDATIONS

Considering that improvements in nuclear safety are more likely to be achieved through rigorous behaviours than the continuous adaptation of processes, procedures and action plans, the Director of the DPN should assess how the operator fundamentals are embedded into the day-to-day activities of the Operations departments.

In the UK, the organisation of the operator fundamentals has been implemented, but it is not fully achieving the expected results. I recommend that the Director of Nuclear Generation make sure the operator fundamentals are applied in such a way as to reduce the number of plant alignment errors and non-compliances with technical specifications.

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

Turbine blade corrosion

Compliance with the chemical and radiochemical parameters helps to ensure the integrity of the first and second containment barriers.

Chemistry management is an integral part of reactor control in all operating phases.

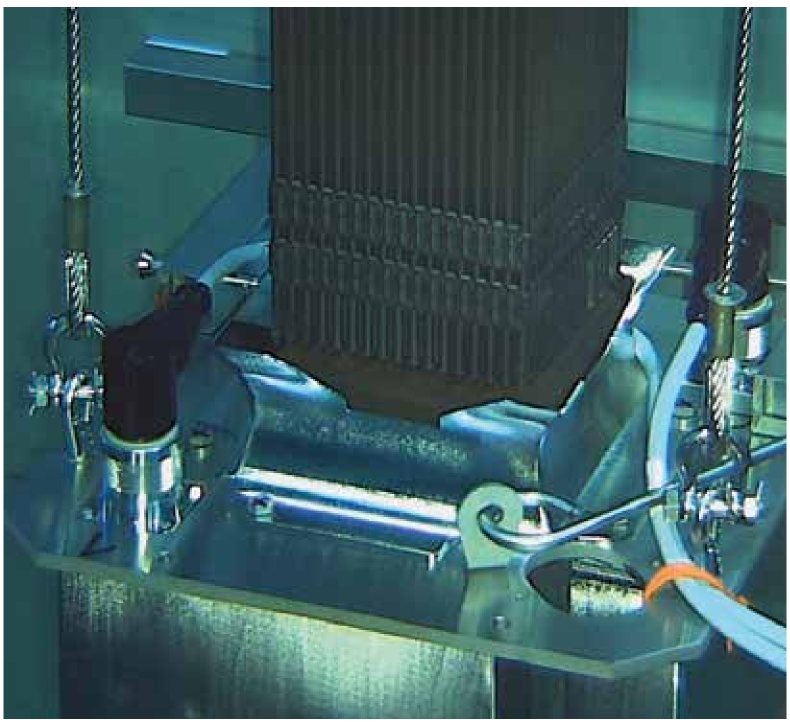
The role of the chemistry departments is defined in the environmental chemistry core skills handbook (*Noyau de cohérence chimie-environnement, NCCE*) in France and in an Integrated Company Procedure (ICP) in the UK.

Chemistry skills should be better utilised 06

The lifetime of a metal or an alloy is dependent on the fluid it carries or in which it is immersed, which may cause corrosion or damage. Controlling the chemical parameters helps to ensure the integrity of the first and second containment barriers[10] (primary and secondary chemistry). In PWRs, chemistry also plays an important role in radiation protection as it determines the extent of the radioactive deposits.

Any non-compliance with the chemical specifications, even briefly, can have a long-term effect. It is therefore essential to listen to the plant chemistry teams when making day-to-day decisions.

The chemistry departments in PWRs, unlike those in AGRs, deal with both monitoring the plants, which is the subject of this chapter, and monitoring the environment.



CRUD cleaning machine

CRUD *(Chalk River unidentified deposits)*

CRUD is a generic term describing corrosion or wear products (rust particles, etc.) in suspension in the primary system that may be deposited, under certain physical and chemical conditions, in particular on fuel rods. In 2019, CRUD affected a 1300 MWe reactor following the replacement of the steam generators (see IGSNR report 2019). As expected, passivation of the pipe material released corrosion products into the primary system. The primary system chemistry was too acidic for a few weeks, which led to these corrosion products being deposited on the hottest part of a large number of fuel assemblies. CRUD can affect the resistance of the fuel rod cladding due to the chemical and thermal conditions they cause. In this particular case, a few rods were perforated and several dozen assemblies had to be replaced.

IN FRANCE

IMPROVED RESULTS

There is generally a good degree of compliance with the limit values of the chemical and radiochemical parameters in the technical specifications[11] of the primary and secondary systems. In the French fleet, the monthly chemistry performance indicator combines various data. The required values are more stringent than those in the technical specifications. The chemistry performance indicator (IPC) results improved steadily but have since stabilised over the past two years. To improve further, “small” non-compliances must be corrected more quickly, and any drift anticipated more effectively so it can be prevented.

There are repeated examples of non-compliance with some chemical parameters during reactor start-up, load following or shutdown phases. In addition, some secondary system and auxiliary system conditioning parameters, which are not included in the French chemistry performance indicator (IPC), are not optimised enough.

Closer communication between the operations and chemistry departments would prevent these issues. The weekly presence of a chemical engineer at a face-to-face meeting between the shift manager (CE) and the nuclear safety engineer is a good practice, which I have

[10] *Fuel rod cladding and primary system*
[11] *Known as Spécifications Techniques d’Exploitation (STE) in France*

seen at some plants. It encourages collective awareness and ensures that action is taken in response to weak signals.

The DPN specifies rules for protecting steam generators during maintenance outages. However, water is not always maintained to the correct quality in the steam generator feedwater supply systems. Furthermore, less attention seems to be paid to protecting the other systems, in particular if outages overrun. The use of unauthorised products or the inadequate cleaning of worksites also regularly lead to pollution during reactor restart. I recommend better consideration and integration of the preservation strategies needed to protect all equipment during the outage preparation phase. These strategies must define what actions are needed during the outage and, where necessary, how they should be modified if there is an overrun.

CHEMISTRY EXPERTISE TO INTERFACE MORE WITH OPERATIONS

The French environmental chemistry core skills handbook (NCCE), which was published in 2015, describes the role of the chemistry department and the required behaviours for each role. It lists six fundamental requirements.

Surprisingly, these six fundamentals do not match the five operator fundamentals outlined in the WANO standard of excellence *(see Chapter 5)*.

The chemistry and environment core skills handbook (NCCE) has clarified the roles, the chemistry culture, training, and communication with operations. However, its rollout is slow and incomplete: there are still some shortcomings, such as a poor understanding of the effects of the chemical parameters on the condition of the plant. In addition to completing the analysis requirements, chemistry personnel should always have a questioning attitude and investigate any unexpected changes in the chemistry parameters.

Comprehensive training programmes have been introduced, often supported by the use of mock-ups in laboratories. Training combines theoretical teaching and practice in the field, which is supported by experienced managers in the subject; this combination seems to be very effective. I also observed good sampling practices by technicians who, often carrying out sampling rounds on their own, demonstrate a good sense of personal responsibility.

I note that the career paths open to chemists are generally limited to their own field. There should be more opportunities for them to broaden their experience, for example through secondments to other departments.

Relations between the Operations and Chemistry departments are generally good. However, chemistry is considered more as a service provider rather than contributing to good operational performance. Chemistry is rarely discussed during daily operational focus meetings, and responses to chemists' requests for maintenance or modifications are often slow.

HIGH-PERFORMANCE FACILITIES THAT NEED MODERNISING

Although the on-site chemistry laboratories are often old, they are well-maintained, with a good standard of cleanliness.

The purpose of the Renolab project is to either refurbish or build a new laboratory in each nuclear power plant. In this way, reactor unit chemistry, effluent chemistry and environmental measurements can be grouped together in a single laboratory. This project will lead to closer collaboration between the teams and make it easier to have the latest-generation equipment. I am disappointed that this project has fallen behind schedule.

A chemist working in a laboratory

The reliability of the demineralisation facility and its ability to produce the necessary volume of water of the required quality is too often affected by poor maintenance and obsolescence problems. Renovations are being carried out in the fleet, but at an unsatisfactory pace.

The MERLIN software, developed in-house several years ago, is used to manage all the sampling, analysis requirements and results. Although this system fulfils its purpose, it is not considered user-friendly by the chemists I have met, and some basic functions are unavailable, e.g. detection of trends, and direct connection to the instruments and meters to avoid having to re-enter data manually. Although workarounds have been used, this ageing system should be modernised or replaced.

CORPORATE SERVICES APPRECIATED, BUT A COMPLEX ORGANISATION

The DIPNN's Industrial Division demonstrates solid technical expertise to which on-site staff readily turn for short-term advice, medium-term help or the longer-term development of software. However, site staff consider that it issues numerous requirements, which are not always fully understood or easy to apply.

The scarcity of plant and environmental chemistry expertise is difficult to reconcile with the multiplicity of divisions and functions involved: the Industrial Division (DIPNN), the Operations engineering department (DPN), the Central technical support department (DPN), the Nuclear fleet engineering, decommissioning & environment division (DPNT), and R&D. This multiplicity makes it difficult to integrate the technical, regulatory and administrative aspects, and the plants perceive few signs of overall coordination between these different functions. I believe it is necessary to take better account of the Operator's constraints. I urge those involved to focus expertise more effectively in order to improve the responsiveness of support to nuclear power plants. In particular, it would be helpful to clarify the division of responsibilities and interfaces between the Industrial Division (DI), which has the technical skills, and the Central technical support department (UNIE) which leads the chemistry discipline.

The Industrial Division's chemical analysis laboratory (YAC) at Chinon performs full-scale testing of new online chemistry measurement equipment (sodium, oxygen, pH, etc.). This unique facility is a real asset. Only those instruments having passed the tests are approved and can be purchased by the nuclear power plants. It is regrettable that there is such a long delay between the qualification of an item of equipment and its installation onsite.

YAC laboratory

I also want to stress the rigour, which is necessary in the management of labelling and storage of chemicals, and in the use of fume cabinets in the central laboratories. The same rigour must be applied in these laboratories as at those onsite.

BRT-CICERO™

Corrosion-erosion (flow-accelerated corrosion, FAC) affects non-alloy steels in the secondary system. The damage causes thinning of the inner surface of components, which can lead to sudden failure.
The BRT-CICERO™ simulation tool, developed and qualified by EDF, predicts the thinning of pipes based on their characteristics (geometry, conditions of use, type of metal/alloy and chemistry of the system).
Using this software has led to better targeting of inspections, thus helping to improve the safety of personnel.

EDF R&D has substantial resources (equipment, laboratories and numerical models) to support the plants and the design of new reactors. Many of these research topics are also applicable to the UK fleet and I suggest there be closer cooperation.

IN THE UK

At the AGRs, the chemistry manager reports to the Operations department manager. At corporate level, a single chemistry team advises the plants, on both short- and medium-term matters. The Chemistry Fleet manager (FM) ensures that procedures are consistent and manages continuous improvement initiatives in this field.

Role of Fleet Managers

Each discipline or field on which nuclear safety and operational reliability depend is managed by a Fleet Manager (FM). The FMs are responsible for ensuring the governance, oversight, support and good performance of their respective fields.
They lead their peer groups in defining methods, training and standards to be adopted across the fleet, and they drive performance improvement initiatives. During site visits, they review performance levels in relation to these standards in order to identify and correct any non-conformities quickly. The FMs provide periodic updates and insights on individual or fleet performance. These summaries indicate any shortcomings that need to be addressed.
The FMs are the main contacts with external organisations and authorities on matters concerning their own fields.

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

GOOD RESULTS, BUT CHLORINATION IS STILL A WEAKNESS

The chemistry health indicator (CHI) assesses the compliance of the chemical parameters against requirements within the company standards. The values are generally good for the primary and secondary systems.

The poor availability of the chlorination systems on the seawater intakes at some plants is causing heat exchanger fouling (condenser and safety system coolants) by mussels. Efforts must be redoubled to solve these problems once and for all.

Investments have been made to upgrade the ageing demineralisation units. They will thus be operational until the end of generation.

NEED FOR CLARIFICATION OF THE SPECIFICATIONS FOR PLANT PRESERVATION DURING OUTAGES

Measures to protect all systems during unit outages are described in a guideline. Protection or preservation measures are generally carried out correctly, due to the considerable involvement of the chemistry function in the outage project team. However, this field is sometimes neglected when short outages overrun. At one plant, inadequate protection measures were planned during what was initially scheduled to be a short outage, but was subsequently extended. This resulted in widespread corrosion, most notably on the turbine. I recommend that the measures in these guidelines be made compulsory for all systems.

Sample analysis - Golfech nuclear power plant

FUNDAMENTALS IN PLACE

The chemistry fundamentals were officially adopted in 2019, using the same approach as for the other disciplines *(see Chapter 5)*. The required behaviour for each function, from technicians through to the group head, is defined for each of the five fundamentals based on international standards.

These have been accepted by everyone and incorporated in all activities, including training, pre-job briefing and debriefing, event analysis, etc. Each site could benefit from carrying out a self-assessment, which would identify which fundamental should be strengthened as a priority.

The fleet boasts an effective training programme comprising initial and refresher modules. The contents are constantly being adapted by each site according to its specific needs. Nuclear Generation has decided to end the training accreditation system undertaken by a committee of independent experts (Training Standards Accreditation Board, TSAB). It will be essential to have another way of ensuring that training continues to be of high quality, in particular in niche specialist areas such as chemistry.

Chemist in a radiation-controlled area - Chinon nuclear power plant

Some years ago, Nuclear Generation replaced the previous chemistry systems used to manage all the sampling, analysis requirements and results with a new single laboratory information management system (LIMS). This system, which is updated regularly and enhanced with the support of the supplier, continues to work well.

SPECIAL RELATIONSHIPS WITH OPERATIONS

There are generally good relations between the operations and chemistry services, given that they are in the same department. The chemistry group head is involved in all the daily operational focus meetings. However, a recent event has shown that there is still room for improvement. Inadequate control and awareness of the non-compliance of some chemical parameters, together with poor communication between departments led to the damage of boiler tubes. In light of this event, I urge Nuclear Generation to make sure that chemistry control is constantly integrated into all plant operations.

Damaged boiler tubes in an AGR

Problems were encountered with the management of the feedwater chemistry on a plant during a test period with the primary system at 190°C. Despite several chemical parameters being outside their specified ranges on several occasions over a two-week period, the mitigating actions that should have been applied immediately as defined in the operating instructions, were not implemented. The predicted corrosion damage from the event resulted in a reduction of around 25% of the remaining corrosion allowance for the boiler tubes.

In AGRs, the number of systems requiring regular chemical monitoring and analysis will decrease significantly following the end of generation and the beginning of defuelling. I urge Nuclear Generation to redefine the role of the Chemistry department in this phase.

CHEMISTRY PREPARATION AT HINKLEY POINT C

Hinkley Point C (HPC), like Flamanville 3 (FA3), is aware of the importance of effective equipment protection and preservation during the construction and commissioning phases. Robust equipment preservation practices, largely derived from supplier recommendations, have been formalised. I urge the two projects to share their experience, which should also benefit other EPRs.

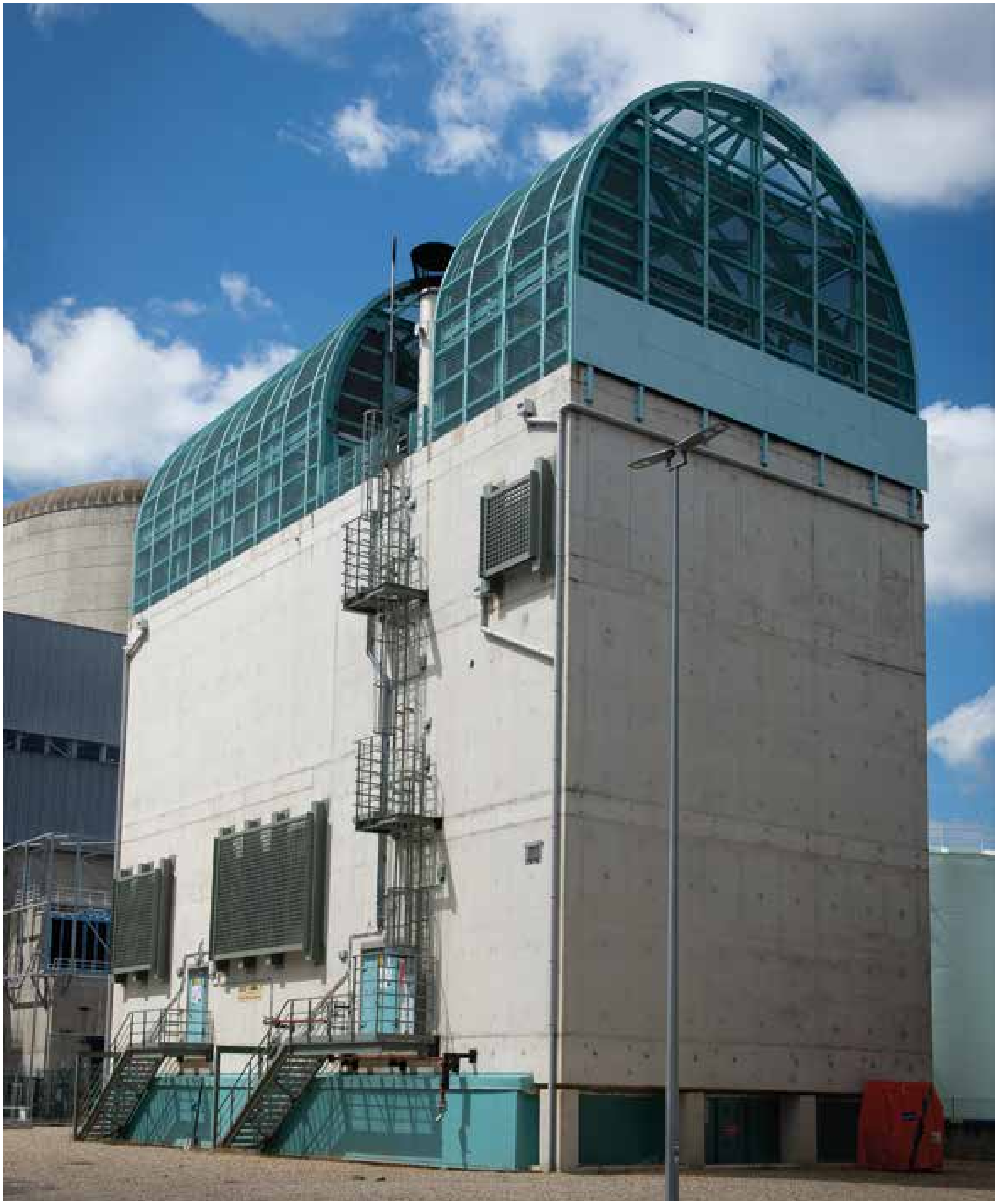
The chemistry team, which is already well integrated into the pre-operation department, is starting to take shape. The Flamanville 3 chemistry documents need to be adapted for HPC to take into account the specific features of UK operation. As such, all the chemical specifications and associated documents need to be rewritten. I urge those involved to ensure there is a thorough inventory of all the documents to be prepared and to allocate adequate and timely resources to this important work.

HPC's chemistry training programme is being developed, ready for the arrival of the first laboratory technicians. This programme, based on the same principles as that for the existing fleet, will have to be adapted to the new documentation.

MY RECOMMENDATIONS

Variations in the chemical parameters can have long-term consequences on the plant equipment. To limit these consequences, I recommend that the directors of the DPN and Nuclear Generation better integrate the control of circuit chemistry into the daily operation of reactors.

The plant preservations conditions during outages have a direct effect on equipment lifetime, especially if the outages overrun. I recommend that the Directors of the DPN and Nuclear Generation draw up and systematically implement suitable outage preservation measures, covering all relevant systems.



The electrical power supply to reactor backup systems and reactor auxiliary systems plays an important role in nuclear safety.

Operating experience, including that from the Fukushima accident, the development of probabilistic safety assessments and the increasingly comprehensive analysis of the risks associated with natural hazards have continued to confirm this.

Ultimate diesel generator (DUS) building - Paluel nuclear power plant

Power supplies: the central nervous system of the reactor 07

CENTRAL ROLE OF ELECTRICAL POWER SUPPLIES

During normal operation in a PWR, all the reactor's auxiliary systems must be supplied with power, which represents approximately 5% of its power production. In accident conditions, only systems that perform nuclear safety functions (reactivity control, decay heat removal from the core and from the spent fuel, and containment) or that support those functions (ventilation, air conditioning, lighting and the I&C system) are supplied with power. The primary pumps and most of the secondary system equipment, for example, are shut down.

The situation is similar in AGRs with gas turbines/diesel generators providing a back-up power supply to the gas circulators (the equivalent of the primary pumps) to ensure that the carbon dioxide cooling the core continues to circulate. AGRs have greater inertia if there is a loss of power, due to their lower power density and the very large size of the graphite core.

ROBUST, VARIED POWER SUPPLIES

The current PWRs have two physically separated electrical supply trains. They each correspond to one of two backup systems[12]; a single one is sufficient in the event of an accident.

Each reactor in the French fleet has the following power supplies:

- Main off-site power supply (400 kV power offtake line)
- Auxiliary off-site power supply (often a 225 kV line)
- Two standby emergency diesel generators (6.6 kV), one for each train
- One ultimate generator set per site (groupe d'ultime secours par site, GUS), either a diesel generator or a gas turbine (combustion turbine, eventually replaced by several low-power diesel generators)
- One ultimate diesel generator per reactor (diesel d'ultime secours, DUS)
- Batteries capable of supplying the I&C system, certain valves and the control room ventilation and lighting for several hours
- One ultimate turboalternator that supplies the vital I&C system and the injection at the primary pump seals.

If there is a station blackout, the alternator can isolate itself from the grid and supply the reactor only; this is referred to as 'house load operation'.

The architecture of Sizewell B is similar to that of French PWRs, but with four safety trains and six diesel generators.

The Flamanville 3 and Hinkley Point C EPRs have four safety trains, each of which has a standby diesel generator. They also have two station blackout (SBO) diesel generators.

Nuclear safety must be assured during all fault conditions by power from internal power sources only, until the off-site sources are restored. This requirement concerns the sources themselves and the power distribution equipment (cables, panels, contactors, etc.). Once the primary pumps have been shut down, a supply that is external to the reactor is necessary to restart it. In France, if there is a total station blackout, electricity supply to the site will be prioritised by the grid from a nearby power plant (hydro or another nuclear power plant) *via* specific arrangements already in place.

The general safety principles for AGRs are similar. As they are not all the same model, their electrical architectures have different numbers of trains and internal sources of generation (diesels or gas turbines). One problem area is the physical separation of the electrical trains, which is more or less acute depending on the site. This has been partially solved through the installation of physical means (fire walls and diversified cooling systems) and prevention measures (improved fire detection systems).

A mini power plant

Commonly referred to as a "diesel", it actually describes the engine, the alternator, the electrical panels and their environment, i.e. the building and the auxiliaries (diesel fuel supply, oil systems, compressed air for start-up, exhaust, cooling, ventilation, I&C system, etc.).

The robustness of the national grids, which has been good up to now across Europe, contributes to the overall reliability of the plants' power supply, and therefore to nuclear safety. Availability of the grid is not taken into account in the deterministic nuclear safety analysis. However, the probability of total loss of available power sources would

[12] *The main safety systems are organised into sub-systems or trains*

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

be increased if the frequency of grid failure increased. The Group must therefore pay attention to grid reliability, on both sides of the English Channel, as the European electricity mix changes. A controllable supply capacity will remain essential.

Maintenance work on electrical cabinets

HAZARDS: MAIN RISK OF LOSS OF POWER SOURCES

Electrical systems are flexible and reliable, as demonstrated by their widespread use in industry, transport, naval propulsion and aeronautics.

However, they must still be protected against hazards, principally flooding and fire. Fukushima was fundamentally an accident that resulted in the loss of all electrical backup systems (supplies, distribution, pumps and actuators) due to flooding. As fire can spread *via* cables, controlling the fire risk must also remain a priority *(see Chapter 1)*. Experience has shown that half of all fires are caused by electrical faults. Probabilistic nuclear safety studies estimate that total loss of power accounts for around half of the probability of a PWR core meltdown.

Excessively high temperatures, during a severe heatwave or if there is failure of the heating, ventilation or air conditioning (HVAC) system, are being studied and modifications made, the principle of which I believe to be satisfactory. However, the modification of the nuclear safety air conditioning chillers on the 1300 MWe fleet is continuing to pose some recurring problems.

There are some specific electrical hazards, such as over-voltages or disturbance from the grid. These can render protection equipment ineffective. We must draw all OPEX from the INES 2 event at a UK plant this year. It was similar to an event at the Forsmark nuclear power plant in Sweden in 2006.

Loss of off-site power supplies

At a UK site consisting of two nuclear power plants, a grid failure caused a total loss of off-site power resulting in the automatic tripping of the three in-service reactors and a significant local voltage fluctuation. This fluctuation damaged 5 of the 8 uninterruptible power supplies (UPS)[13] of one power plant, whose protection did not operate, similar to the Forsmark event. The operations teams in the other power plant, facing other malfunctions and a never-before experienced electrical configuration, met with some problems stabilising all the systems.

BEST PRACTICES TO ENSURE THE RELIABILITY OF STANDBY DIESEL GENERATORS

The availability of the diesel generators of both fleets is good, comparable to that of international fleets. Most of the failures that adversely affect reliability are the result of human or organisational errors during maintenance or operational activities.

Over the past few years, there have been a number of problems in the engine environment: corrosion of exhaust manifolds or heat exchanger support structures, incorrect assembly of hoses, incorrect tightening, etc. Some of these were latent errors that had not been discovered during requalification. Occasionally, it was the ASN that had to point out these problems. Greater attention is being paid to this and I urge sites to maintain this rigour.

THE PARADOX OF DIESEL ENGINES

The diesel generators used in nuclear power plants are extremely robust marine engines that propel vessels around the world.

Paradoxically, they have become a matter of concern, which erodes confidence in their reliability. The widely held perception that “we

[13] *The UPS supply certain equipment that is essential for nuclear safety. They are immediately backed up by batteries*

misuse them" is based on the fact that these engines are designed to operate regularly and for long periods, but are operated very little and only intermittently in the nuclear industry. In the event of a nuclear-safety-related incident, the standby diesel generators must start up immediately and take over the full load within a few tens of seconds, a requirement that is clearly very demanding. This does not discredit them in my eyes, provided they are run in and maintained for this purpose. There are also similar examples of the diesel engines being used in this way in a marine environment.

However, I do not believe that it is satisfactory, in France, to weaken these engines by carrying out short no-load tests (or at low load) as this is contrary to best practice. It also seems risky to refrain from using barring, which is a beneficial practice and is an industry standard. I am surprised that some calls for tender have specified several hours of no-load operation or the prohibition of barring. I am pleased that the periodic testing practices were revised ten years ago in the UK, and that barring the engines is now a common practice.

These conditions of use in the French fleet are the result of a set of real or contrived constraints, habits and unwillingness to change, and a reluctance to submit any engine or technical specification modifications to the ASN. While real skills exist, the fragmentation of expertise and responsibilities across the engineering divisions and corporate services is not conducive to achieving a coherent solution to these issues. There also seems to be a long-held, widespread belief that specifications used in calls for tender will enable everything to be obtained and that suppliers will adapt.

In the French plants, diesel engineering skills and the sense of ownership are generally insufficient. The lack of skills and clarity of responsibility can lead to inappropriate use of the engine. In the engineering, maintenance and operations functions, the need for specific skills has not always been identified. In addition, too little account is taken of the non-written, practical aspect of the mechanic's role. Conversely, in the UK, I have seen the advantages of apprenticeship learning and performing routine maintenance in-house.

For maintenance, despite a considerable volume of servicing work on diesel generators in relation to the number of hours they operate (e.g. less than 2,000 hours operating time over a 20-year lifespan), the "function and equipment reviews"[14] are not widely shared and do not include a sufficiently in-depth review of their operating history or health.

Maintenance on a emergency diesel generator

Scuffing of a diesel generator after a full inspection

A 20-year full inspection of a diesel generator in the French fleet had just been completed, during which the pistons were removed and the liner was remade by a contract partner. During the running-in phase, due to various problems on the auxiliaries, it was started up and stopped 11 times in a row with no reaction from the Operator. The 11 hours of non-load operation caused liner scuffing (wear by polishing and scratching the liner due to it being subjected to excessive temperature) and engine unavailability. The liner had to be remade a second time, resulting in several weeks of delay at the end of the ten-yearly outage.

I particularly urge that all the engine data and diagnostics information be brought together at each site, under a clearly defined responsibility. This should include observations (maintenance, tests and inspections), parameters recorded during tests, diesel fuel and oil characteristics, etc. There should also be a closer relationship with the manufacturer, whose experience and recommendations, gained from a much larger fleet of engines, could be better shared. From this perspective, the resumption of national technical seminars is a positive initiative.

[14] *Regular reviews, at each site, of the conditions of the main systems and their ability to perform their functions*

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

Finally, I recommend strong action to ensure that the diesel generators are operated in a condition consistent with industry best practices, by reviewing the ways the diesels are operated, technical specifications, maintenance and reliability as a whole.

Emergency diesel generator in an AGR

ULTIMATE DIESEL GENERATORS: OWNERSHIP AND RELIABILITY

Ten years after Fukushima, all ultimate diesel generators (*Diesels d'ultime secours*, DUS) are now operational. With a third diesel generator for each reactor offering a high level of protection against natural hazards, real progress is being made in defence in depth. The issues regarding their ownership and reliability will be resolved.

The ultimate diesel generators (DUS) are dedicated to extreme, post-Fukushima-type conditions to supply all identified essential nuclear safety systems when all other sources of backup power have been lost. In the event of total loss of the reactor's power supplies, and in the absence of extreme conditions, the site's ultimate generator set (*Groupe d'ultime secours*, GUS) would be used rather than the reactor's ultimate diesel generators (DUS). I urge consideration of the wider use of the DUS when the standby diesel generators are lost, in the spirit of improving defence in depth and emergency preparedness.

One type of engine is posing some problems, e.g. candle fires where the oil soaks into the exhaust insulation after shutdown and then subsequently ignites during the next start-up. The remedy is known as "barring" after each shutdown. More generally, this particular engine, which has been used by the US Navy for 70 years, is considered indestructible, which therefore presents a paradox in light of its current unavailability performance.

One of the two ultimate diesel generator (DUS) projects, like some other projects, has demonstrated the limitations of the industrial supply chain in which the diesel generator is not the core activity of the prime contractor. What is more, new diesel generator projects are carried out by different EDF engineering functions depending on whether the project involves a new-build or in-service reactor. The time it has taken to reach an agreement with IRSN on the seismic levels is questionable. Given the extreme robustness chosen from the outset and the design-basis margins, would this not have been grounds for a faster, inclusive approach? I therefore urge the engineering functions to learn from all the ultimate diesel generator (DUS) and other diesel generator projects.

As with many modifications, I am disappointed that, at the time, the Operator was not included and did not involve itself early enough: the handovers proved unsatisfactory and the familiarisation process was laborious. I urge the DIPDE, the DIPNN and the DPN to learn lessons from this for future modifications. I also note that the Operator - as project owner - is now included as early as the conceptual design phase for modifications.

A RELIABLE ELECTRICAL DISTRIBUTION SYSTEM THAT MUST BE MAINTAINED IN THE LONG TERM

During my visits to both fleets, batteries, cables, contactors, panels, transformers and inverters seemed well-maintained and in good condition. All this equipment is reliable and robust. Organic materials (e.g. insulation) and contactors are subject to ageing. I am pleased to see the considerable testing carried out in preparation for the VD4 outages (e.g. removing cables) and the replacement programmes (see 2020 report). Hot spots sometimes appear at the contactor or terminal blocks in electrical panels if the lugs are tightened incorrectly *(see Chapter 1)*.

International operating experience shows that common-mode failures have affected electrical distribution systems in the nuclear industry worldwide. They are caused by maintenance errors, protection adjustment errors, or mistakes during modifications. At a French plant in 2019, a problem with some replacement contactors resulted in the unavailability of several engineered safety features on both safety trains. Such events serve as a reminder of the rigour required when managing electrical distribution equipment.

In addition, I note shortages of some spare parts in both France and the UK. I was also informed of some examples of obsolescence in the medium term. Solutions need to be prepared and incorporated in the future replacement programmes.

THE FUTURE: REDUCING ENERGY CONSUMPTION THROUGH INNOVATION

The EPR 2 incorporates several enhancements, including:

- A bank of low-power diesel generators replacing a larger diesel generator in conditions where there is a total loss of off-site power and unavailability of the standby diesel generators
- The disconnection of the severe accident electrical distribution system during normal operation, thereby protecting these systems from grid disturbances (Forsmark OPEX)
- The intention to separate, as much as possible, any equipment that dissipates considerable heat from the temperature-sensitive I&C cabinets.

I am generally pleased with the structured work of the DIPNN's Technical Division on internal electrical architectures.

In the future, ways of reducing electrical consumption in accident conditions could be an area for innovation, for example by reducing:

- The need for air conditioning (heat dissipation, inertia and layout of areas, and permissible temperatures for equipment)
- The number of essential items of equipment requiring high power.

It would also be interesting to study reactor design approaches making it possible to adapt to a slower start-up of standby generators.

The eventual disappearance of the conventional fossil-fuel engine may have significant consequences on the diesel engine industry and skills. I believe it is necessary to anticipate this risk, both in terms of maintenance of existing equipment and choice of technologies for the future.

MY RECOMMENDATIONS

To ensure the long-term reliability of the current and future fleet of standby diesel generators by adopting best practices, I recommend that the Director of the DPNT review their standard operating conditions, specifically making sure to:

- **Clarify the responsibilities of designers, manufacturers, operators, and maintenance contract partners**
- **Define the local diesel engineering skills and develop a professional resource**
- **Improve the "health reports" and review the periodic test conditions.**

I recommend that the Directors of EDF Energy, the DPNT and the DIPNN learn from the station blackout that occurred at a UK plant with respect to:

- **Protection of the safety systems against over-voltage**
- **Preparation for managing an extended long-term loss of off-site power sources**
- **Relations with their transmission system operator in terms of grid maintenance and reliability.**

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

EPR construction site - Hinkley Point C

Commissioning the EPRs at Flamanville 3 and Hinkley Point C under the best nuclear safety conditions is a key priority for the Group.

EDF and partner companies are busy preparing to renew the French and UK nuclear fleets.

Improved quality and efficiency levels will determine the success of these projects. Skills, simplification and standardisation are the foundation of this success, as well as including operating experience from the Operator in the design phase.

Overcoming the challenges facing renewal of the fleets 08

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

This chapter focuses on the EPR and EPR 2 projects, although there are other lower-power reactors such as the EPR 1200 or the SMR Nuward™ that supplement the Group's proposals and reflect the sector's expansion.

FLAMANVILLE 3: PROGRESSING TOWARDS START-UP

CONSIDERABLE PROGRESS MADE...

Significant progress has been made in its project management and the integration of the DIPNN and DPN teams. Those I met remain motivated and devoted to their job.

Weld repairs on the main secondary system - a real technical feat – continues to progress.

To deal with the risk of the failure of three nozzles[15] on the primary system, EDF and Framatome developed a solution considered valid from a safety perspective, i.e. installation of a support clamp to limit the break to a size covered by the safety studies, even in the case of weld failure on a set-in nozzle. Substantiation of the robustness of this solution will need to be examined by the ASN.

Robotic weld repair of a main secondary system pipe - Flamanville 3

...BUT STILL A GREAT DEAL TO BE COMPLETED

There are still numerous non-conformities to be resolved, not to mention complex technical issues with major safety implications that need to be handled rigorously. This is the case both for the filtration capacity of the recirculation sump filters in the event of an accident, and for the defects on welds of some primary system equipment during the stress-relieving heat treatment process performed by Framatome. I must stress how important it is to take into account operating experience from other EPRs such as Olkiluoto 3 in Finland or the two reactors in Taishan, particularly for neutronic and fuel issues.

To complete the outstanding work to the expected level of quality, interactions between the Flamanville 3 project, engineering units and contractors must be perfected, the planning of activities needs to be made more reliable, spanner time at the construction site should be increased, and the mobilisation of EDF and contractor engineering teams needs to be pushed ahead.

The need to comply with a timetable that is now without any margin must not be allowed to affect the quality and nuclear safety of this project.

A MORE EXPERIENCED OPERATOR

The new fuel assemblies are now in the storage pond in the fuel building, operated by the DPN, where I found housekeeping to be of a good standard. With their manpower increased, these DPN teams are now maturing. They also need to assume ownership of all others buildings and operating standards. I will be paying close attention to how the general operating rules (RGE) and technical specifications (STE) are assimilated given their complex structure specific to this new reactor.

The corporate departments are becoming more involved and I recommend this be consolidated. For instance, the Central technical support department (UTO), Edvance, the Electromechanical & plant engineering support department (CNEPE), and the plant are working together to build up a spare parts stock. The necessary budget has been allocated, it is now a question of ensuring there will be enough spares available over the busy commissioning period and then up to the first outage.

[15] *These nozzles were not included in the original safety studies, nor considered within the scope of welds categorised under 'break preclusion'*

From an engineering perspective, Edvance and CNEPE plan to support the plant during the commissioning tests with, for example, an Edvance Test Team onsite. It would be worth maintaining this team during the 'troubleshooting' phase after reaching full power.

The level of housekeeping is satisfactory, and corrosion issues now seem to be more widely taken into consideration. The handover of systems and rooms to the Operator is still ongoing, but at a slower pace than expected. I must again draw attention to the fact that equipment maintenance programmes must be respected, whether handover has taken place or not.

The plant's fuel loading and pre-operation action plan must be pursued with determination, i.e.: inclusion of tighter control, an onsite testing commission, a nuclear safety start-up commission, and calls for external viewpoints (IAEA, WANO).

To ensure that the best nuclear safety and operational standards are met by this first EPR in France, as well as its successful integration into the existing operating fleet, I recommend undertaking an assessment, and then ongoing monitoring, of the state of readiness of all stakeholders, the plant and its support units.

HINKLEY POINT C: START OF MECHANICAL, ELECTRICAL AND HVAC WORK

THE PROJECT ADAPTS TO THE NEW CIRCUMSTANCES

The conditions on the construction site, its organisation and cleanliness are remarkable.

The impact of Brexit is beginning to bite: some contractors have withdrawn from the project due to the ever-increasing complexity of the rules or problems encountered with non-English speakers working in the UK. For HPC, this brings in the risk of increasing costs and being unable to find qualified manpower.

The project has shifted from a programme-based organisation (classified by disciplines) to an organisation based on geographic zones, bringing together the different trades for each zone, area or building. This is nonetheless complex and the decision-making process is still lengthy, which could lead to reduced performance.

In addition to the UK Design Centre and the Joint Design Office, several initiatives to pool resources between the current fleet and HPC are boosting the nuclear skill-building process:

- The Nuclear Skills Alliance (NSA) was formed in 2017 with training teams from Barnwood and HPC pre-operations staff; it is now responsible for training future EPR operators and giving general fleet-oriented training courses
- The Technical Client Organisation (TCO) brings together EDF Energy's AGR and EPR nuclear skills. It covers the skillsets required in both new-build projects and operations, and is progressively being deployed. Its organisation and interfaces with the many different engineering bodies seem complex
- The Bridgewater Welding Centre of Excellence is operational and all welders are now tested here.

Preparations are being made for operations: an experienced team is now in place to provide an operator's perspective, such as defining the standards to be implemented (e.g. protection of equipment) and managing the spare parts programme. I recommend paying particular attention to the general operating rules and technical specifications whose complex structure could lead to interpretation errors. Training of the first wave of operators is underway and I advocate for their strong involvement in the commissioning phase.

Pipe supports in a gallery - Hinkley Point C

QUALITY MUST CONTINUE TO IMPROVE

With 450 tier-1 partner companies and 5,500 tier-2 suppliers from about thirty countries, the surveillance of manufacturing requires more resources than initially estimated: there were over 4,000 factory inspections and 30,000 site inspections completed in 2021, reaching a "right first time" rate nearing 90% compared with the target of 95%. Tier-2 sub-contractor surveillance has been strengthened.

The number of non-conformities has remained stable, and the excessively long times needed to resolve them has reduced. The pace at which design changes are being made has not slowed despite initiatives to speed up the resolution of "open points". More specifically, some 'decoupling values' applied in the preliminary studies are not consistent with the final data issued by the contractors.

The clear intention to fully exploit operating experience from the first reactor to benefit the second is yielding results. For example, the quality and the pace of civil engineering work on the reactor building for unit 2 have improved significantly, with a 30% drop in construction irregularities and a 25% increase in productivity.

Concerning the qualification of HPC equipment under accident conditions: the direct transposition of Flamanville 3 data is very limited, even in the case of identical equipment. This can sometimes be explained by the need to meet a specific UK context. I suggest that the relevant lessons be drawn from such situations so as to standardise qualification processes for future projects as much as possible.

The mechanical, electrical and HVAC work - known as MEH - is the next challenge: a huge number of documents now need to be written, a very ambitious pace of work will need to be maintained, and large quantities of equipment will need to be supplied; all this within a complex organisation and working with a design not yet finalised.

The HPC Project Director's key words "Safety, Quality, Time and Cost" - in that order - have never been so important to the project's success.

SIZEWELL C PROJECT: REPLICATING HINKLEY POINT C

The two EPRs at Sizewell C (SZC) will most likely be financed *via* the Regulated Asset Base (RAB) model, which involves EDF participation, public funding and market finance.

The intention to replicate the HPC design, which is echoed by the ONR, should lead to improvements in efficiency, cost control and scheduling, while reducing the number of design changes required during construction. This replication will be beneficial to both construction and nuclear safety.

The main design changes have already been identified. They result from differences in site characteristics, i.e. ground structure, maritime features, dimensions, etc. Others will arise during the course of the project, such as suppliers deciding to withdraw from the project or HPC equipment becoming obsolescent.

Replication of the HPC reactors was only partially anticipated during the design and contracting phases: the engineering units will be in great demand when it comes to substantiating the design replication assumptions and updating the documentation. Nuclear New Build will have to make sure it has the necessary resources and that they are appropriately allocated between HPC and SZC. I recommend that the Group's future projects - especially the EPR 2 - start anticipating the replication of the first-in-series so that the following reactors can fully benefit from the process.

THE EPR 2 PROJECT: OFF TO A GOOD START

The preliminary safety report for the EPR 2 project was sent to the ASN in February 2021. The proposal compiled by EDF in concert with the industry on the construction of three EPR 2 pairs was submitted to the government in June the same year. Once the public authorities have reached a decision, the next stage will be to launch the public inquiry prior to submission of the licensing application.

The ASN has accepted in principle and subject to certain conditions, that EDF can apply the "break preclusion" concept for the main primary and secondary system pipes. The assumptions to be considered in the case of an aircraft crash have also been defined. The design of a set of six reactors can therefore continue on the basis of a stabilised nuclear safety standard.

The 'break preclusion'[16] concept

This approach is based on the precept that all the consequences resulting from the failure of certain pipes do not need to be studied because the event is deemed highly unlikely to occur. It is based on the assumption that the design, manufacturing and in-service monitoring requirements are stringent.
In the French fleet, it has already been applied to "protected pipe sections", known as superpipes, on the main steam lines outside the reactor building and up to a set point downstream of their isolation valves.
This approach differs from the leak-before-break (LBB) principle applied in some countries, though it is not accepted in France. It assumes that early warning signs will appear and that continuous monitoring will allow the operator to take the necessary measures before failure occurs.

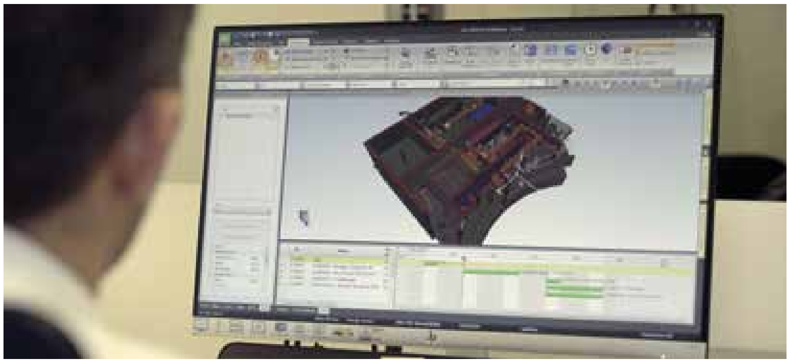
At Edvance and CNEPE, the deployment of integrated teams comprising design and project stakeholders is helping improve efficiency and gain a better understanding of the context associated with each project. It is nevertheless important to make sure both the silo mentalities between projects and the scattering of skills between units, do not undermine the technical coherence of the EPR design and the value of operating experience.

The main contracts, such as those for the NSSS[17], the civil works for the first site and the turbine-generator, are all being prepared. The level of design maturity of the EPR 2 at the start of the construction phase

[16] *Also known as 'incredibility of failure' (IOF)*
[17] *Nuclear steam supply system*

will have improved; in particular, the construction drawings for all the infrastructures will be available at the first concrete pour.

The EPR 2 system engineering has been in place since the beginning of the project and has greatly enhanced the quality of the design studies. The plant lifecycle management (PLM) tool chosen at the time was not the one finally chosen by the DIPNN within its digital transformation programme; the tool will have to be replaced and the data transferred to the new tool in 2022.



3D modelling of an electrical building

IGSNR repeatedly stressed how important it was to involve the Operator sufficiently early and at the right level in new-build projects. Real progress has been made when such an approach has been taken, for instance in operational flexibility or feedwater train design. However, some of the Operator's requests are now more difficult to implement owing to the advanced status of the project, such as increasing the available space during maintenance outages, improving accessibility into radiation-controlled areas, etc.

In light of the issues identified at Flamanville 3 and expected to arise at HPC, I recommend initiating the necessary actions to simplify the general operating rules (RGE) and technical specifications (STE) without delay.

TRANSFORMATION IS ESSENTIAL TO ENGINEERING

In order to bring the nuclear industry, new-build project management and engineering methods to the highest levels, the DIPNN is reshaping its engineering methods and tools, having enrolled the help of its partner companies to do so. Though most of the engineering stakeholders are aware of the pressing need to implement these changes, some are apprehensive about the disruptions they will cause to ongoing projects and their impact on routine operations. This sentiment may hamper the success of the DIPNN's transformation programme.

THE BENEFITS OF THE EXCELL PLAN

The advantages proposed in the Excell plan will have a positive effect on quality and nuclear safety, whether it be standardisation, development of skills, or welding quality improvements.

The standardisation of equipment is a real step forward that is reflected, for instance, in the first 13 catalogues (CADO) defined as being mandatory for use to limit the proliferation of multiple types of equipment. It must be made sure that these catalogues of standards are used as much as possible on all projects, that any changes made to them are strictly monitored, and that the authority of the "catalogue owners" is preserved, especially as they are spread across several engineering departments.

I commend the creation of the Cotentin-Normandie advanced welding school, which is a key milestone in the welding improvement plan.

Though its primary focus is not on nuclear safety, the major project control team (*controle des grands projets*) is helping to improve performance overall. IGSNR supports its observations and opinions on issues in correlation with nuclear safety.

HEFAÏS advanced welding school - Cherbourg

STIMULATING THE OPEX PROCESS

Event-based operating experience (OPEX) has been collected and analysed for many years now, and I was told that no repeat events were recorded in 2021. Nonetheless, it does seem that OPEX has been focusing more on technical issues rather than organisational shortcomings and the robustness of decision-making processes. Project divisions generally tend to devote little time to OPEX, any recommended actions are rarely questioned, and their implementation is seldom checked.

Operator OPEX provides a valuable source of information for integrated groups. I will be watching how OPEX is brought to the forefront and integrated more often, as it only further enhances reactor design.

BETTER HARMONISING THE EPR DESIGN

The EPR design has evolved with every different project, depending on the client, the nuclear safety requirements, optimisations and OPEX. Numerous project management organisations and technical teams cohabit within projects and engineering divisions.

As each project is responsible for its design, the EPRs at Flamanville, Taishan and Hinkley Point C are all different, thereby depriving the EDF Group of a standardised series design, which would have enhanced both quality and efficiency.

The DIPNN explained the role of "Product owners" (see IGSNR report 2019) who bring together the numerous stakeholders involved to establish an in-depth understanding of a functional or geographic subset of the plant. It would seem relevant to redefine the balance between technical decisions common to all projects and those that remain within the remit of each separate one. To achieve this, I recommend appointing an entity responsible for ensuring the overall coherence of the EPR design assumptions and characteristics.

THE PROCESS-BASED APPROACH AND THE SWITCH PROGRAMME: CHANGES TO BE KEPT UNDER CONTROL

In 2019, the DIPNN identified 92 different engineering processes to cover the scope of EPCC services[18]. In the interest of simplification, this number was reduced to 48, with each process currently being defined. As already pointed out by IGSNR, there is a danger that an overly detailed approach could make it difficult for the parties involved to take ownership. Beyond the implementation of these changes, this process-based approach must be managed within a long-term perspective, relying on strong governance considering the many departments involved.

The Switch digital transformation programme is moving forward but is encountering difficulties that had been previously identified, i.e. there are not enough people available with required information system experience; the future system users within engineering teams are not sufficiently available; the programme is struggling to keep up in a context where information systems are rapidly evolving; and new threats have appeared (cyber-attacks). The actions launched to resolve these issues and drive change without disrupting the projects must be managed with a firm hand.

The decision to postpone the transition from the PLM tool used by the EPR 2 project to a tool chosen by the Switch programme, which is now scheduled for summer 2022, acutely reflects these problems. The decision to prioritise the integrity of the data to be transferred and the performance of the new tool is understandable. However, I regret that the measures taken to secure the data transfer were not jointly planned sufficiently in advance together by the Switch programme and the EPR 2 project staff.

On a more general level, ownership of the digital transformation by the teams is not evident in the engineering centres. It seems like two worlds - the engineering teams on one side and the information system teams on the other - continue to exist in parallel. The cultural shift has yet to happen!

MY RECOMMENDATIONS

Improved performance levels are key to the success of new-build projects. To move further in this direction, I recommend that the Director of the DIPNN together with the Director of the DPNT:

- **Implement a sustainable organisation to ensure the application of standards in the projects**
- **Assign the responsibility to a department to manage all the design characteristics common to all EPRs**
- **Simplify the organisations by grouping skills and relying on the digital transformation to do this, which must be endorsed by the engineering teams.**

To ensure the nuclear safety standards are met by the first French EPR at Flamanville 3, I recommend that the Director of the DPNT undertake an assessment, and then ongoing monitoring, of the state of readiness of the plant and its support units.

The general operating rules for the EPR and EPR 2 plants are complex. I recommend that the Directors of the DIPNN, the DPNT and EDF Energy initiate a simplification process without delay and in collaboration with the relevant safety authorities.

18 *Engineering, Procurement, Construction and Commissioning*

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

Visual inspection of PWR fuel rods

Nuclear safety is a core value at Framatome, as is industrial safety. They were the subject of major actions in 2021: more training in nuclear safety culture, and consolidated analysis and experience feedback from accidents and near-misses.

Some areas for improvement were identified: systematic analysis of weak signals, heightened involvement of the independent nuclear safety oversight, development of human performance tools, simplification of operating documentation, and technical and regulatory compliance of equipment.

Report by the General Inspectorate of Framatome 09

Framatome supplies equipment and services to many sectors, both in France and abroad, i.e. nuclear fuel, engineering, major projects, reactor components, nuclear instrumentation, safety I&C, and nuclear facility maintenance. Most of these activities have a significant impact on nuclear safety.

This chapter has been written by Alain Payement, the Inspector General of Framatome, who shares his views based on his inspections. Owing to the highly specific role of the General Inspectorate, the structure and level of detail provided in this chapter differ from the others.

General Inspectorate of Framatome

The role of the General Inspectorate (IG) is to provide the Framatome CEO with an assessment of the robustness of nuclear safety in its operational units, both in France and overseas. The IG is headed by an Inspector General who is assisted by four inspectors.

The IG also performs independent oversight of the organisation in the areas of nuclear safety, radiation protection, industrial safety[19], occupational safety, and the environment. Its activities are defined in a yearly programme that is presented to the Framatome executive committee.

During its inspections, the IG issues recommendations for the relevant business units to incorporate into their action plans. Progress is regularly checked by follow-up inspections.

Lastly, the IG conducts visits of its sites to detect any weak signals in nuclear safety and industrial safety through informal interviews with employees at all hierarchical levels and from all professions, but without their line manager present.

TRAINING: THE KEY TO SECURING NUCLEAR SAFETY CULTURE IN THE FIELD

The first phase of developing nuclear safety culture entails training its employees *via* a network comprising about one hundred instructors within the different business units (BU). Late 2021, more than 38% of all Framatome employees had been trained in the year, which is well above the annual target of 25%. Periodic self-assessments of sites or divisions were also completed.

I believe that these measures form a solid basis for a nuclear safety culture that can be relayed by managers on a daily basis so it is shared by all.

The IG assessed the nuclear safety culture at its Saint-Marcel, Paimboeuf and Ugine sites. Around sixty interviews and field visits were completed by an assessment team with a dozen members, including two managers from other BUs appointed by the executive committee. On the grounds of these assessments, I note the good quality of exchanges between the different levels of hierarchy, which only further promotes our nuclear safety culture. Improvements must focus on the presence of managers in the field, the quality of operating documentation, and the rollout of human performance tools.

INDEPENDENT NUCLEAR SAFETY OVERSIGHT TO BE FULLY DEPLOYED

The nuclear safety policy at Framatome clearly states the responsibility of the management line. The independent nuclear safety oversight ensures first-level oversight on each level of the organisation. The IG undertakes the second level of oversight.

I note progress in the field: the scope of the independent nuclear safety oversight is well known and representatives have been appointed in the different units. Except for the Romans-sur-Isère site and the Engineering and Technical Directorate (DTI), the inspection programmes and yearly self-assessments are insufficient. I believe these shortfalls must be resolved so the independent nuclear safety oversight can fulfil its role correctly.

NUCLEAR SAFETY

ANALYSIS APPRAISAL COMMITTEE TO CONSOLIDATE OPEX

The Analysis appraisal committee (*Comité d'évaluation des analyses*) was set up to help reinforce operating experience (OPEX) from significant events in the fields of nuclear safety, industrial safety and the environment. Including a representative from the General Inspectorate together with experts from the 3SEP[20] and the BUs, this committee examines whether the causes of events have been properly analysed and if the relevant actions plans are comprehensive enough. I will be paying close attention to its output in 2022.

[19] *The management of industrial risks such as chemical hazards*
[20] *Health, safety, environment and protection*

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

THE 'EXCELL IN QUALITY' PLAN: CONTRIBUTING TO SAFETY

The 'Excell in Quality' plan has led to many initiatives involving Framatome and its suppliers, such as:

- Creation of a 'Supplier quality development' team, with experts seconded from the supply chain to help improve supplier quality levels
- Creation of the Inspection Academy
- Rollout of a new industrial process to approve the qualification of manufacturing, such as within the scope of the EPR 2 project
- Significant investment in automating welding activities.

I acknowledge the resources allocated and expect to see improvements in the quality of production, to the benefit of nuclear safety.

The Inspection Academy dedicated to training quality inspectors

In line with EDF's Excell plan and Framatome's Excell in Quality plan, the training of quality inspectors needs to be done in-house in order to effectively manage supplier inspections. This is the objective of the Inspection Academy. Resulting from a partnership with the Metz national school of engineering, the course lasts two months on the sites of Le Creusot and Saint-Marcel (in close proximity to the plant's workshops, welding school and a non-destructive testing laboratory), which simplifies practical training. Trainees receive a university diploma upon successful completion of the course.

The theoretical content focuses on the design and construction rules, welding techniques and inspection methods. After having completed their theoretical classes, trainees are given two months of practical coaching before they are qualified.

In 2021, three different groups (27 employees from Framatome and 3 from EDF) completed the course. The aim is that the Inspection Academy will become the centre for all EDF and Framatome inspector training.

NUCLEAR SAFETY RESULTS

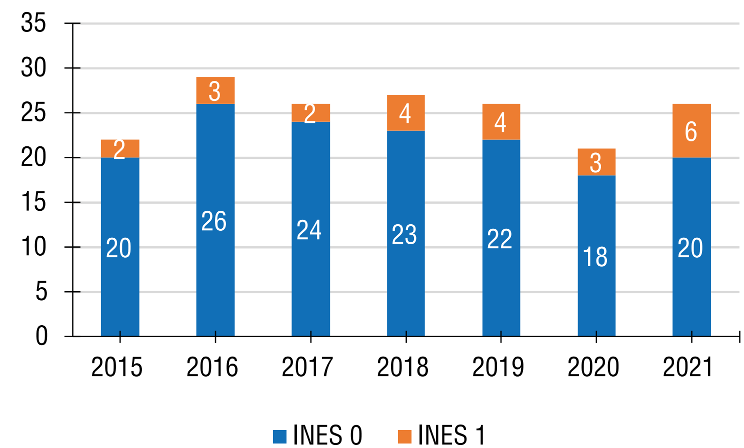
No INES Level 2 event or higher was declared in 2021. The number of significant nuclear safety events classified as level 1 (6) increased compared with previous years.

These six level 1 events were declared by the Romans-sur-Isère site, which is one of Framatome's three fuel fabrication plants. They were all due to a criticality risk management issue.

Worryingly, three of them involved operators not complying with the rules governing the management of uranium-based materials. The IG conducted an immediate inspection after the 19 April 2021 event relating to the non-compliant transfer and storage of containers holding uranium-based materials. I note that three of the causes identified are potentially common to other events at Romans-sur-Isère:

- Complexity of the safety standards, in which the multiple and often overlapping requirements for the same operation can generate ambiguity and possible misunderstandings
- Operational documentation, which is not really user-oriented and too focused on restating the nuclear safety standards
- Poor use of human performance tools during operation.

I will monitor the rollout of the action plan that the Romans-sur-Isère site presented to the executive committee and which agrees to simplify both the documentation and its operational scope. The IG will check its progress in 2022.



Variation in the number of INES events

The Romans-sur-Isère site: a criticality risk management event

The event occurred in their licensed nuclear facility used to manufacture PWR fuel elements employed in pressurised water reactors.
In this facility, there is a system designed to extract all the uranium-bearing dust that settles in the equipment. This dust is stored in cylinders that are padlocked to the floor in specific areas before being transferred to another location where it is sieved to separate out the uranium particles. These cylinders must be transported one at a time. However, the operators moved them together using a trolley that is prohibited for such material.
This event had no impact on the operators or the environment.
The IG ascertained that: the operating procedures were difficult to implement because they were based on a complex set of nuclear safety standards, no human performance tools were being used, and there were organisational weaknesses in work and team management.

RADIATION PROTECTION: STABLE RESULTS

In 2021, the mean occupational doses for Framatome employees and contract partners were the same as those recorded in 2020, reaching 1.1 mSv and 0.1 mSv respectively.

The number of workers having received a dose below the minimum recordable level (zero dose) was 28% (37% in 2020) for Framatome and 36% (23% in 2020) for contract partners.

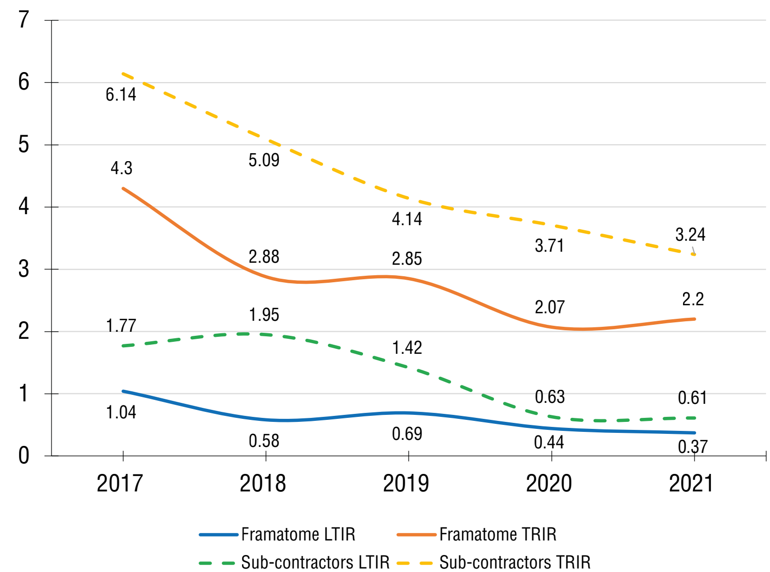
The sites with the highest mean doses belong to the Installed Base business unit and carry out plant inspection and maintenance activities, i.e. Lynchburg in the US, and Chalon, Intercontrôle and Maubeuge in France. Most of the 44 employees (57 in 2020) having received an annual dose exceeding 10 mSv worked at Lynchburg (29) or Chalon (13). It is also at these sites that the highest annual doses were recorded for Framatome staff (15.7 mSv in Lynchburg) and for sub-contractors (6.4 mSv in Maubeuge). These results highlight the importance of having a robust policy for estimating and managing doses that is capable of rapidly incorporating schedule changes for high-dose activities.

INDUSTRIAL SAFETY: MIXED RESULTS

Thanks to strong commitment and decisive action plans, the industrial safety results continued to improve for contractors in 2021: their lost-time injury rate (LTIR[21]) was 0.61, which is better than their target of 1, while their total recordable incident rate (TRIR[22]) with or without lost time, reached 3.24, which is below their target of 3.5.

At Framatome, the LTIR reached 0.37 to better its target of 1, though this indicator has varied little lately (0.44 in 2020). After having dropped for several consecutive years, the TRIR rose slightly to 2.2 in 2021 (2.07 in 2020) against the target of 2. I believe that the systematic analysis by the managers of hazardous situations and weak signals would help to reverse this trend.

I would like to mention that the executive committee asked that the analysis of the most significant near-misses be presented to it.



Variation in accident frequency indicator rates

The ‘5 TOP killers’ programme to eliminate fatal risks (work at height, lifting operations, managing energy sources, using mobile equipment, and confined spaces) underwent a corporate audit to assess how well the practices in each BU compared with each best industry practice. Among the areas for improvement identified was the need to better supervise work at height and lifting operations, which were responsible for numerous events.

I was pleased to learn that a network of ‘lifting operations’ specialists has been created, which meets my recommendation with respect to analysing the root causes of lifting accidents and to sharing the relevant operating experience.

[21] *Lost Time Injury Rate*
[22] *Total Recordable Injury Rate*

Network of 'lifting operations' specialists

Faced with the rise in events during lifting operations, Framatome's executive committee decided to set up a network of lifting specialists.

Its organisation takes inspiration from a similar network that exists at EDF plants. Its objective is to improve the professional competence of stakeholders and to foster the sharing of good practices and knowledge.

Each of Framatome's industrial sites has appointed a specialist and allocated the necessary means to supervise, support and monitor lifting operations. This specialist is also charged with giving training sessions and taking part in the analysis of events, in addition to having the authority to stop any lifting activities that do not comply with the standards, regulations, or best practices.

These lifting specialists are trained by an approved organisation, APAVE, in France.

Regular network meetings are held to share operating experience and good practices.

Several accidents or near-misses highlight the importance of equipment compliance. During inspections, I noticed a certain lack of rigour when conducting the regulatory checks. In 2022, the IG will conduct several inspections on this theme linked to human and industrial performance.

REVIEW OF INSPECTIONS

In 2021, the IG carried out 19 inspections on a specific subject, 1 immediate inspection, and 11 follow-up inspections on the uptake of its recommendations.

In light of the Covid-19 pandemic, three inspections planned for Richland were carried out remotely.

MANAGING CONFIGURATION CHANGES, CRITICALITY SAFETY AND RADIATION PROTECTION AT THE RICHLAND SITE

In the US, the IG carries out two inspections every year at the Richland fuel fabrication facility, as agreed with the US Nuclear Regulatory Commission (NRC). These inspections focus on a specific subject each time: emergency preparedness, radiation protection and the environment, fire safety, criticality safety management, chemical hazards, and staff education and training.

In 2021, criticality safety management and radiation protection were the subjects chosen for the inspections. In these disciplines, the rigorous organisations and robust processes rely on dedicated programmes that enable effective control over the improvement actions. I encourage the Richland site to:

- Reinforce the traceability of requirements issued by administrative authorities
- Arrange refresher courses for criticality safety experts
- Provide regulatory training, such as in environmental issues
- Formalise its off-site radiation monitoring programme.

The IG also reviewed how Richland managed configuration changes of the facilities. The inspected process was seen to provide rigorous control at a level appropriate to the nuclear safety risk at hand when configuration changes are made to industrial processes. Upstream identification of safety-important equipment and better integration of human and organisational factors would make it possible to further improve the effectiveness of this process.

CONTAINMENT OF NUCLEAR MATERIAL AT THE LINGEN AND ROMANS-SUR-ISÈRE SITES

At both sites, nuclear material containment has been the subject of several robust risk assessments; it is also well documented in a precise technical standard, and supported by an effective continuous improvement approach. Both sites also demonstrate good management of occupational exposure to radiation and the environmental impact of nuclear material.

At Romans-sur-Isère, the responsibilities of the operational units with respect to nuclear material containment must be clearly specified and annual dose targets must be given in the site's master plan.

At Lingen, the periodic reviews of operational documentation must align with Framatome's integrated management system to ensure greater coherence.

MANAGING SKILLS AND QUALIFICATIONS

In 2021, inspections at the Creusot, Saint-Marcel and Montreuil-Juigné sites focused on their capability to manage and forward plan the need for skills and qualifications.

At these three sites, the organisation, processes, practices, and numerous improvement initiatives all reflect how well the situation has been handled with respect to the nuclear safety and industrial safety risks. Methods to support the advanced planning of the required job and skills (GPEC) have been rolled out. The current training provision meets the regulatory requirements, and provides a solid base for building and sharing knowledge. The onboarding process aims at passing on knowledge and know-how.

Improvements must focus on ensuring the documentation standards complies with both the regulatory and Framatome requirements, and on effectively implementing the rules designed to manage skills and qualifications. On this point, I must stress that involvement of first-line managers is essential.

OCCUPATIONAL RISK MANAGEMENT

In 2021, the Jeumont site and a Framatome maintenance worksite at the Chinon plant were inspected.

The Jeumont site would benefit from developing its nuclear safety culture and implementing a zero-harm approach to encourage the reporting of weak signals. The main hazards are the subject of in-depth analyses and action plans that ask for the proactive involvement of staff. The management of chemical products, the monitoring of regulatory checks, and ensuring the safety of equipment, are all areas that call for improvement.

Framatome's maintenance teams at the Chinon plant are supported by the Installed Base business unit, which helps them with industrial safety and radiation protection issues. The regulatory and contractual standards are up to date, the responsibilities are defined (including the interfaces with the Operator), human performance tools are being implemented, and non-conformities are being processed, with EDF where necessary. It is imperative to formalise the delegations allowing the signing of regulatory authorisations and emergency protocols during operations that involve fatal risks (handling, work at height, etc.).

MANAGING SUB-CONTRACTED ACTIVITIES AT THE ROMANS-SUR-ISÈRE SITE

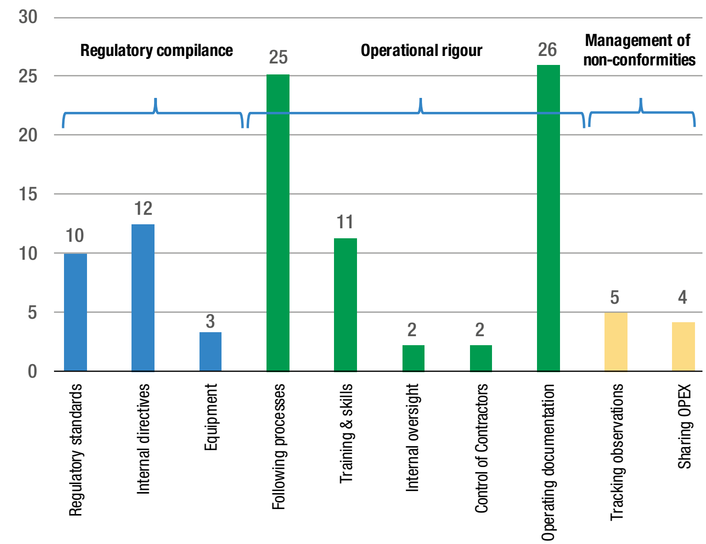
At Romans-sur-Isère, the control of all sub-contracted activities is assured through the organisation of responsibilities, regulatory monitoring, qualification and autonomy of staff in charge of supplier surveillance, and management of sub-contractor approvals.

Additional efforts must focus on: incorporating nuclear safety requirements into the service specifications; the quality of sub-contractor surveillance reports, which must be used to determine whether their contracts should be renewed in the future; the analysis of events related to sub-contractor activities; and reinforcement of independent oversight.

UPTAKE OF RECOMMENDATIONS

In 2021, the IG issued 65 recommendations of which 50 were implemented, including 17 that were more than two years old. A total of 100 recommendations are currently in the process of being implemented, 3 of these are more than two years old. The objective of reducing the number of recommendations older than two years to fewer than ten has been reached. This objective will be renewed in 2022.

Operational rigour (mainly compliance with processes, and quality of operational documentation) was the main subject of recommendations (66%) in 2021, followed by regulatory compliance (25%), and management of non-conformities (9%).



Classification of recommendations outstanding

MY RECOMMENDATIONS

The use of human performance tools only during the most hazardous operations is not sufficient. To significantly reduce the number of events caused by human factors, I recommend that these tools be used extensively, and the conditions for their application defined in Framatome standards.

The sites are at risk of experiencing considerable human and industrial losses if technical and regulatory non-conformities with equipment are left unresolved. I recommend doing an inventory of all the equipment and the practices with respect to regulatory checks, and taking the necessary measures to improve the overall situation.

Contents My view 01 02 03 04 05 06 07 08 09 Appendices Abbreviations

Cattenom nuclear power plant

Appendices

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

RESULTS FOR THE EDF SA FLEET

Nº	Indicators	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Number of significant nuclear safety events graded 1 or greater on INES per reactor[1]	1.55	1.19	1.14	1.16	0.98	1.12	1.28	1.45	1.4	1.34
2	Number of significant nuclear safety events (0 or greater on INES) per reactor[1]	11.90	11.60	10.8	10.03	9.78	11.59	12.6	12.7	12.4	12.9
3	Number of significant events per reactor • Non-compliance with technical specifications • Reactivity	 1.52 -	 1.34 -	 1.55 -	 1.24 -	 1.48 -	 1.41 0.9	 1.69 0.7	 1.8 0.9	 1.5 0.6	 1.5 1.0
4	Number of alignment errors[2] per reactor	1.78	1.22	1.41	1.74	1.64	1.78	1.24	1.4	1.3	1.1
5	Number of trips per reactor (for 7,000 hours of criticality[3]) • Automatic • Manual	 0.55 0.03	 0.59 0.03	 0.53 0.07	 0.66 0	 0.48 0	 0.38 0.04	 0.31 0	 0.53 0.03	 0.29 0.04	 0.53 0
6	Average operational collective dose per nuclear unit in service (in man-Sv)	0.67	0.79	0.72	0.71	0.76	0.61	0.67	0.74	0.61	0.71
7	Exposure of individuals: • Number of individuals with doses above 20 mSv • Number of individuals with doses between 16 and 20 mSv • Number of individuals with doses between 14 and 16 mSv	 0 2 22	 0 0 18	 0 0 5	 0 0 2	 0 0 1	 0 0 0	 0 0 1	 0 0 0	 0 0 0	 0 0 0
8	Number of significant radiation protection events	114	116	113	109	117	131	170	171	173	108
9	Availability (%)	79.7	78.0	80.9	80.8	79.6	77.1	76.5	74	71.9	72.9
10	Unplanned unavailability (%)	2.8	2.6	2.4	2.48	2.02	3.26	3.7	3.95	5	4.55
11	Occupational accident rate Tfg (per million hours worked)[4]	3.5	3.3	3.2	2.7	2.8	2.2	2.3	3.3	2.9	2.93
12	Occupational accident rate LTIR (per million hours worked)[4]	-	-	-	-	-	-	-	2.4	2.2	3.2

[1] *Excluding 'generic' events*
[2] *Any configuration of a system or its utilities that deviates from the expected situation and is a cause of a significant event (statistical data reviewed in 2018)*
[3] *Average value for all reactors, exclusing external causes, unlike the WANO parameter which is based on the median value*
[4] *Accident rate for EDF SA and its contractors*

RESULTS FOR THE EDF ENERGY FLEET

Nº	Indicators	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1	Number of significant nuclear safety events graded 1 or greater on INES per reactor[1]	0.80	0.80	0.33	0.47	0.27	0.47	0.53	0.27	0.07	0.47
2	Number of significant nuclear safety events (0 or greater on INES) per reactor[1]	4.60	5.13	4.47	7.40	10.00	6.13	5.93	6.73	5.47	6.20
3	Number of cases of non-compliance with technical specifications per reactor	1.67	0.67	1.53	1.00	0.80	0.60	0.60	0.67	0.87	0.53
4	Number of alignment errors[2] per reactor	3.07	3.33	2.80	2.87	3.13	0.93	1.67	1.67	1.00	1.33
5	Number of trips per reactor (per 7,000 hours of criticality[3]) • Automatic • Manual	0.64 0.84	0.45 1.03	1.17 0.62	0.57 0.19	0.3 0.42	0.49 0.37	0.89 0.20	0.56 0.32	0.35 0.00	0.63 0.27
6	Average operational collective dose per nuclear unit in service (in man-Sv) • PWR • AGR	0.037 0.063	0.386 0.034	0.365 0.074	0.048 0.067	0.544 0.021	0.296 0.020	0.096 0.050	0.255 0.032	0.031 0.013	0.383 0.012
7	Number of individuals with doses above 15 mSv	0	0	0	0	0	0	0	0	0	0
8	Number of significant radiation protection events	50	27	27	18	20	10	23	28	26	29
9	Availability (%): • EDF Energy fleet • PWR • AGR	78.0 89.2 76.3	78.9 83.0 78.2	72.1 84.1 70.2	77.3 100 73.7	83.0 82.0 83.1	81.6 83.8 81.2	76.1 89.4 74.0	65.8 80.6 63.5	61.7 99.4 55.9	60.4 64.2 59.7
10	Unplanned unavailability (%): • EDF Energy fleet • PWR • AGR	8.9 9.9 8.7	6.9 0.2 7.9	10.7 0.7 12.3	2.3 0 2.7	5.1 0.1 5.8	5.0 0.0 5.7	3.1 2.2 3.3	4.0 0.2 4.7	5.0 0.6 6.2	12.3 0.0 14.3
11	Occupational accident rate LTIR (per million hours worked)[4]	0.5	0.2	0.2	0.4	0.3	0.2	0.5	0.3	0.3	0.3
12	Occupational accident rate TRIR (per million hours worked)[4]	1.9	0.7	0.8	0.6	0.7	0.4	1.1	1.0	0.7	0.5

[1] *Excluding 'generic' events (ones due to shortfalls in design)*
[2] *Any configuration of a system or its utilities that deviates from the expected situation and is a cause of a significant event*
[3] *Average value for all reactors, unlike the WANO parameter which is based on the median value*
[4] *Accident rate for EDF Nuclear Generation and its contractors*

KEY DATES FOR THE EDF SA NUCLEAR UNITS

Year in service	Nuclear unit	Power in MWe*	VD1	VD2	VD3	VD4
1977	Fessenheim 1	880	1989	1999	2009	N/A
1977	Fessenheim 2	880	1990	2000	2011	N/A
1978	Bugey 2	910	1989	2000	2010	2020
1978	Bugey 3	910	1991	2002	2013	-
1979	Bugey 4	880	1990	2001	2011	2020
1979	Bugey 5	880	1991	2001	2011	2021
1980	Dampierre 1	890	1990	2000	2011	2021
1980	Dampierre 2	890	1991	2002	2012	2022
1980	Gravelines 1	910	1990	2001	2011	2021
1980	Gravelines 2	910	1991	2002	2013	-
1980	Gravelines 3	910	1992	2001	2012	2022
1980	Tricastin 1	915	1990	1998	2009	2019
1980	Tricastin 2	915	1991	2000	2011	2021
1980	Tricastin 3	915	1992	2001	2012	2022
1981	Blayais 1	910	1992	2002	2012	2022
1981	Dampierre 3	890	1992	2003	2013	-
1981	Dampierre 4	890	1993	2004	2014	-
1981	Gravelines 4	910	1992	2003	2014	-
1981	St-Laurent B1	915	1995	2005	2015	-
1981	St-Laurent B2	915	1993	2003	2013	2022
1981	Tricastin 4	915	1992	2004	2014	-
1982	Blayais 2	910	1993	2003	2013	-
1982	Chinon B1	905	1994	2003	2013	-
1983	Blayais 3	910	1994	2004	2015	-
1983	Blayais 4	910	1995	2005	2015	-
1983	Chinon B2	905	1996	2006	2016	-
1983	Cruas 1	915	1995	2005	2015	-
1984	Cruas 2	915	1997	2007	2018	-
1984	Cruas 3	915	1994	2004	2014	-

Year in service	Nuclear unit	Power in MWe*	VD1	VD2	VD3	VD4
1984	Cruas 4	915	1996	2006	2016	-
1984	Gravelines 5	910	1996	2006	2016	-
1984	Paluel 1	1330	1996	2006	2016	-
1984	Paluel 2	1330	1995	2005	2018	-
1985	Flamanville 1	1330	1997	2008	2018	-
1985	Gravelines 6	910	1997	2007	2018	-
1985	Paluel 3	1330	1997	2007	2017	-
1985	St-Alban 1	1335	1997	2007	2017	-
1986	Cattenom 1	1300	1997	2006	2016	-
1986	Chinon B3	905	1999	2009	2019	-
1986	Flamanville 2	1330	1998	2008	2019	-
1986	Paluel 4	1330	1998	2008	2019	-
1986	St-Alban 2	1335	1998	2008	2018	-
1987	Belleville 1	1310	1999	2010	2020	-
1987	Cattenom 2	1300	1998	2008	2018	-
1987	Chinon B4	905	2000	2010	2020	-
1987	Nogent 1	1310	1998	2009	2019	-
1988	Belleville 2	1310	1999	2009	2019	-
1988	Nogent 2	1310	1999	2010	2020	-
1990	Cattenom 3	1300	2001	2011	2021	-
1990	Golfech 1	1310	2001	2012	2022	-
1990	Penly 1	1330	2002	2011	2021	-
1991	Cattenom 4	1300	2003	2013	-	-
1992	Penly 2	1330	2004	2014	-	-
1993	Golfech 2	1310	2004	2014	-	-
1996	Chooz B1	1500	2010	2020	-	-
1997	Chooz B2	1500	2009	2019	-	-
1997	Civaux 1	1495	2011	2020	-	-
1999	Civaux 2	1495	2012	2022	-	-

VD1: First ten-yearly inspection outage
VD2: Second ten-yearly inspection outage
VD3: Third ten-yearly inspection outage
VD4: Fourth ten-yearly inspection outage

*Net continuous power

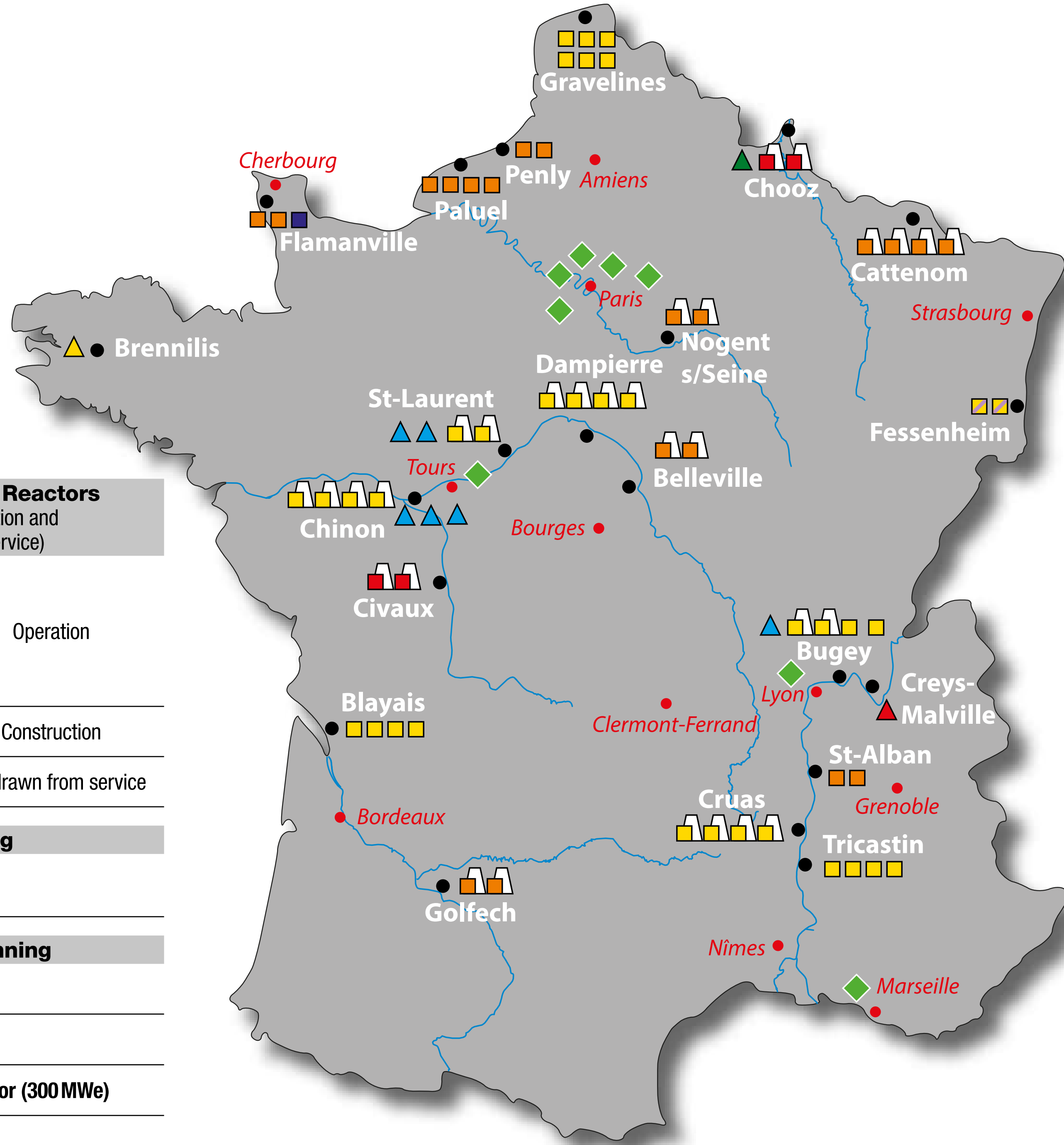
KEY DATES FOR THE EDF ENERGY NUCLEAR UNITS

Year in service	Nuclear unit	Reactor number	Power MWe	Planned date of withdrawal from service
1976	Hinkley Point B	R3	480	2022
1976	Hinkley Point B	R4	475	2022
1976	Hunterston B	R3	480	2021
1976	Hunterston B	R4	485	2022
1983	Dungeness B	R21	525	2021
1983	Dungeness B	R22	525	2021
1983	Heysham 1	R1	580	2024
1983	Heysham 1	R2	575	2024
1983	Hartlepool	R1	595	2024
1983	Hartlepool	R2	585	2024
1988	Heysham 2	R7	615	2030
1988	Heysham 2	R8	615	2030
1988	Torness	R1	590	2030
1988	Torness	R2	595	2030
1995	Sizewell B		1198	2035

EDF SA NUCLEAR SITES

Closed loop cooling

Open loop cooling



Pressurised Water Reactors (operation, construction and withdrawn from service)		
32	900 MWe	Operation
20	1 300 MWe	Operation
4	1 450 MWe	Operation
1	1 600 MWe (EPR)	Construction
2	900 MWe	Withdrawn from service

Engineering	
8	Engineering centre

Decommissionning	
6	Gas-Cooled Reactor
1	Heavy Water Reactor
1	Pressurised Water Reactor (300 MWe)
1	Fast Breeder Reactor

EDF ENERGY NUCLEAR SITES

Contents
My view
01
02
03
04
05
06
07
08
09
Appendices
Abbreviations

FRAMATOME NUCLEAR SITES

United States

1. Benecia
2. Charlotte
3. Cranberry
4. Jacksonville
5. Houston
6. Lynchburg
7. Richland

Rest of the world

8. Japan: Tokyo
9. South Korea: Séoul
10. Czech Republic: Prague
11. Russia: Moscow
12. Ukraine: Kiev
13. Bulgaria: Sofia
14. Slovakia: Bratislava
15. Hungary
16. Sweden: Helsingborg
17. Spain: Zaragoza, Tarragona, Madrid
18. UK: London
19. South Africa: Capetown
20. Argentina
21. Brazil: Rio de Janeiro / Angra dos Reis
22. Canada: Pickering / Kincardine

China

1. Beijing
2. Lianyungang
3. Fuqing
4. Shanghai
5. Taishan
6. Deyang
7. Haiyan
8. Daya Bay

France

1. Cadarache
2. Chalon-sur-Saône
3. Grenoble
4. Jarrie
5. Jeumont
6. Le Creusot
7. Lyon
8. Maubeuge
9. Montreuil-Juigné
10. Paimbœuf
11. Paris La Défense
12. Rugles
13. Romans-sur-Isère
14. Rungis
15. Saint-Marcel
16. Sully-sur-Loire
17. Ugine

Germany

1. Berlin
2. Erlangen
3. Karlstein
4. Lingen

TABLE OF ABBREVIATIONS

A

AFI	Areas For Improvement
AGR	Advanced Gas-cooled Reactor
ALARP	As Low As Reasonably Practicable
AMI	Area Monitoring Insight (UK)
AMT	EDF fleet maintenance agency
ANDRA	National Radioactive Waste Management Agency (F)
ANSS	National cybersecurity agency (F)
ARENH	Regulated access to incumbent nuclear electricity (F)
ASN	Nuclear Safety Authority (F)
ATEX	Explosive atmosphere

C

CADO	Approved equipment catalogues
CE	Shift manager (F)
CED	Deputy shift manager (F)
CCL	Local emergency response centre (F)
CCR	Central control room (UK)
CDM	Conservative decision-making (UK)
CEA	Alternative Energies and Atomic Energy Commission (F)
CEFRI	Committee for the certification of companies in training and monitoring radiation workers (F)
CESC	Central Emergency Support Centre (UK)
CGN	China Guangdong Nuclear Power Company (China)
CHI	Chemistry health indicator (UK)
CIC	EDF Group's national emergency response team
CNC	Civil Nuclear Constabulary (UK)
CNO	Chief Nuclear Officer (UK)
CNEPE	Electromechanical & plant engineering support department (DIPNN)
COMO	COontinuous MOnitoring process (UK)
CPO	Crew Performance Observation
CRM	Collegial Review Meeting (UK)
CRS	Control Room Supervisor (UK)
CRT	Technical standards committee
CRUD	Chalk River Unidentified Deposits
CSN	Council for Nuclear Safety
CSNE	DPN nuclear safety review meeting

D

DACI	Independent oversight directorate for EDVANCE
DART	Diagnostic And Repair Teams (UK)
DAS	Annual safety report
DBUE	Deployable Back-Up Equipment (UK)
DCC	Core-fuel directorate
DCN	Nuclear fuel division
DDO	Director of operations (F)
DFISQ	Independent nuclear safety and quality oversight department (DIPNN)
DI	Industrial division (DIPNN)
DIPDE	Nuclear fleet engineering, decommissioning & environment division
DIPNN	Engineering & new-build projects directorate
DOE	Department Of Energy (US)
DP2D	Decommissioning & waste directorate
DPN	Nuclear generation division
DPNT	Nuclear & conventional fleet directorate
DRS	Nuclear safety standards directorate
DSE	Plant safety officer (F)
DSPTN	Project support and digital transformation division at the DIPNN
DT	Technical division at the DIPNN
DTEAM	Conventional fleet multi-disciplinary expertise & industrial support division
DTEO	Transformation and operational efficiency directorate
DTG	General technical division
DTI	Engineering and technical directorate (Framatome)
DUS	Ultimate diesel generator per reactor (post-Fukushima)

E

EATF	Enhanced Accident-Tolerant Fuel
EDT	Dedicated field team
EDVANCE	Joint venture between EDF and Framatome (80% and 20% respectively)
EGE	Overall nuclear safety assessment
EIPS	Equipment protected for nuclear safety reasons
EIR	Rapid Maintenance Response Team (FR)
EPCC	Engineering, procurement, construction and commissioning
EPR	European Pressurised Reactor
EPRI	Electric Power Research Institute (US)
ESPN	Nuclear pressure equipment
ESR	Significant radiation protection event
ESS	Significant nuclear safety event
EVEREST	EDF project to allow workers to enter controlled areas wearing ordinary work clothes

F

FAC	Flow-accelerated corrosion
FARN	Nuclear rapid reaction force
FIN	Fix it Now Team (UK)
FIS	Independent nuclear safety oversight (F)
FM	Fleet manager (UK)
FME	Foreign Material Exclusion
FMECA	Failure Modes, Effects and Criticality Analysis

G

GDA	Generic Design Assessment (UK)
GECC	Core design and engineering group (F)
GIFEN	Nuclear Energy Industry Group (F)
GK	Fleet upgrade programme (F)
GPEC	Advanced planning of jobs and skills
GPSN	Nuclear safety performance group (UNIE)
GUS	Ultimate diesel generator per site (F)

H

HCTISN	High committee for transparency and information on nuclear matters
HFDS	Senior Defence & Security Official (F)
HOF	Human and organisational factors
HPC	Hinkley Point C (UK)
HPT	Human Performance Tools

I

IAEA	International Atomic Energy Agency
ICEDA	Facility for packaging and storage of activated waste (F)
ICP	Integrated Company Procedure (UK)
ICPE	Environmentally regulated facility
ICRP	International Commission on Radiological Protection
IG	Inspectorate General (Framatome)
IN	Nuclear inspectorate (DPN)
INA	Independent Nuclear Assurance (EDF Energy)
INB	Licensed nuclear facility (F)
INES	International Nuclear Event Scale
INPO	Institute of Nuclear Power Operators (US)
INSAG	International Safety Advisory Group (IAEA)
IOF	Incredibility of failure (break preclusion)
IPC	Chemistry performance indicator (F)
IPCC	Intergovernmental panel on climate change (UN)
IRSN	Institute for radiation protection and nuclear safety (F)
IS	Safety engineer (F)

J

JDO	Joint Design Office (UK)

L

LBB	Leak Before Break
LIMS	Laboratory Information Management System (UK)
LLS	Turbo-alternator last-resort power supply
LOCA	Loss-Of-Coolant Accident
LTIR	Lost-Time Injury Rate

M

MAAP	DPNT performance assessment and support team
MEEI	Campaign for maintaining exemplary housekeeping (DPN)
MEH	Mechanical, Electrical and HVAC (UK)
MME	Operations and maintenance methods
MQME	Campaign to raise the standards in maintenance and operation (DPN)

N

NCC	Operations core skills handbook (F)
NCCE	Environmental chemistry core skills handbook (F)
N3C	Plant alignment and circuit configuration errors
NC STE	Non-compliance with technical specifications
NDA	Nuclear Decommissioning Authority (UK)
NEA	Nuclear Energy Agency (OECD)
NEI	Nuclear Energy Institute (US)
NNB	Nuclear New Build (EDF Energy)
NNSA	National Nuclear Safety Administration (China)
NQME	Non-quality in maintenance and operations
NRC	Nuclear Regulatory Commission (US)
NSA	Nuclear Skills Alliance (UK)
NSRB	Nuclear Safety Review Board (UK)

O

ODM	Operational decision-making (UK)
OIU	Internal inspection organisation
ONC	National emergency response organisation (F)
ONR	Office for Nuclear Regulation (UK)
OPEX	Operating experience
OSART	Operational Safety Review Team (IAEA)
OST	Task observation focused on skills and competences (F)

P

PCC-EO	DPN skill advisory centre for organisational effectiveness (F)
PCD1	Emergency controller (F)
PIA	Protection-important activity
PIC	Protection-important component
PLM	Plant Lifecycle Management
PPI	Off-site emergency response plan (F)
PSPG	Police site protection unit (F)
PT	Control room supervisor (F)
PUI	Onsite emergency plan (F)
PWR	Pressurised Water Reactor

R

RAB	Regulated Asset Base (UK)
R&D	Research & Development directorate
RDE	Reactor Desk Engineer (UK)
RGE	General operating rules (F)
RIS	Emergency water injection system for reactor cooling
RTE	Transmission system operator (F)

S

SAT	Systematic Approach to Training
SBO	Station BlackOut (UK)
SDIN	Nuclear technical information system
SDIS	Local fire and rescue services (F)
SIR	Authorised internal inspection department
SM	Shift Manager (UK)
SMART	Digitalisation programme (DIPDE)
SMR	Small Modular Reactor
SOER	Significant Operating Experience Report (WANO)
SOH	Socio-organizational and human approach
SPR	Risk management department
SQEP	Suitably Qualified and Experienced Person
STE	Technical specifications
SWITCH	Digitalisation programme at the DIPNN
SZC	Sizewell C (UK)

T

TCO	Technical Client Organisation (UK)
Tfg	Occupational accident frequency factor (F)
TNP JVC	Joint venture between CGN (51%), Guangdong Yuedean Group Co. (19%) and EDF (30%)
TRIR	Total Recordable Injury Rate
TSAB	Training Standards Accreditation Board (UK)
TSM	Technical Support Mission (WANO)
TSN	Nuclear safety & transparency act (F)
TSSM	Technical Safety and Support Manager (UK)

U

UFPI	Operations & engineering training department (DTEAM)
UGM	EDF Group Management University
ULM	Maintenance & Logistics Unit (F)
UNGG	Gas-cooled graphite-moderated reactor (F)
UNIE	Operations engineering unit (DPN)
UTO	Central technical support department (DPN)

V

VD	Ten-yearly inspection outage
VMT	Management field visits (F)
VP	Partial inspection outage

W

WANO	World Association of Nuclear Operators
WEC	Work Execution Centre (UK)
WENRA	Western European Nuclear Regulators Association

Bertrand de L'EPINOIS, Jean-Paul JOLY, Jean-Michel FOURMENT, Jean CASABIANCA, Stephen PREECE

PHOTO CREDITS

BEAUMONT Romain - CARAVECO Marc - CNPE de Golfech - CNPE de Nogent - D'ARAM Thomas - DIPNN - DUPONT Cyrille - EDF - EDF Direction technique - EDF Energy - Framatome - Freepik - KMSP - LACOUR Richard - MORGANTI David - MORIN Alexis - MOURET Thierry - PEDRONO Emmanuel - RAMSES - VAN ELSLANDER - Sébastien - WAECKEL Nicolas - WALLACE Valery

E.D.F.
Présidence IGSNR
22-30, avenue de Wagram
75008 Paris
✆ : +33 (0)1 40 42 25 20

www.edf.com