The Inspector General's report

on Nuclear Safety and Radiation Protection 2022

Group's nuclear safety policy

FOREWORD

Written specifically for the Chairman of EDF, this report gives my assessment of nuclear safety and radiation protection within the EDF Group for the year 2022.

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 be exhaustive. It does make a number of recommendations, which are followed up by the Council for Nuclear Safety (CSN).

The EDF Group's policies place nuclear safety as the overriding priority. The quality of design of the facilities and the rigour of their operation by motivated and competent staff make it a continuous shared objective. Resolution of the unexpected stress corrosion issue is a perfect example of this. 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 would not have been achieved without the invaluable discussions held with all the staff 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, medical bodies, and independent nuclear safety organisations also proved extremely fruitful.

The year 2022 was rather atypical due to the lingering turbulence of the Covid-19 pandemic and the geopolitical turmoil caused by Russia's invasion of Ukraine. The choice of nuclear energy, which is both controllable and low-carbon, guarantees strategic independence and a smooth ecological transition; it is clearly demonstrating its relevance. Margins are a prerequisite to ensuring that nuclear safety is never compromised as a result of production demands. This is the price to pay if we wish to reconcile sovereignty and nuclear safety, while controlling costs.

This report is a result of considerable team effort from Bertrand de L'Épinois, Jean-Paul Joly, Jean-Baptiste Dutto and Paul Wolfenden. I would also like to give a special mention to Jean-Paul who is reaching the end of his long and successful career in nuclear operations. The chapter on Framatome has been written by its Inspector General, Alain Payement.

IGSNR was created 40 years ago. The change in the Group's status should not affect the principles guiding the production of its annual report. Following in the footsteps of my predecessors, inevitably marked by the experience of those having written it, this report sets out to provide an independent and unconstrained perspective of the Group. It must be widely distributed to foster a questioning attitude and critical thinking, which are key to continuous improvement in nuclear safety.

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

The Inspector General for Nuclear Safety and Radiation Protection of the EDF Group

Admiral (retired) Jean Casabianca
Paris, 18 January 2023

Introduction to the report

Contents

Saint-Laurent-des-Eaux plant

The year 2022 illustrates the strategic aspect of nuclear energy and its role in international diplomacy.

To enhance nuclear safety, it is important to consolidate management presence, maintenance of skills, technical competency and the level of requirements.

Preserving and valuing relationships and collective aspects, exemplary behaviour and empowerment, transferring knowledge and mentoring will all enable the Group to meet its challenges.

Retrospective and perspectives 01

A COMPLEX INTERNATIONAL CONTEXT

For the third consecutive year, many countries have been faced with an unprecedented situation. After the global shock of the pandemic and the effects of the war at the gateway to Europe, the consequences of strategic decisions made in recent decades are now being sharply felt, particularly in terms of energy dependence.

The "special operation" in Ukraine led to the abandonment of Russian fossil fuels in Europe, it advanced the development of renewables, which are intermittent and combined with gas, and it confirmed the need to renew the nuclear power fleet. Paradoxically, the use of German or Polish coal and lignite, and the import of US shale gas, have resumed. Nuclear power, which provides an efficient low-carbon and controllable energy source, is back in favour, and rigorous nuclear safety, from design through to operation, is more necessary than ever.

NUCLEAR ENERGY: A STRATEGIC DIMENSION AND A DIPLOMATIC TOOL

"Nuclear diplomacy" is most active. Against a backdrop of technological and economic war, Russia, the United States and China are moving their pieces around the international chessboard, trying to impose their technologies not only on those who are new to the industry but also on historic operators, in Europe and elsewhere. These three "empires" support their national industries and use energy as a weapon to develop their geopolitical hold. Mastery of nuclear technologies provides an alternative to the dominance of those who have fossil-fuel-based energies, and sometimes even increases their strength.

In 2030, China will become the world's leading nuclear electricity producer. It has been the world's leading polluter in terms of volume for many years, with close to 30% of global carbon dioxide emissions associated with energy. It is also confirming its status as a driving force for nuclear energy, with a national target of 150 reactors by 2035. However, it will still be mainly coal-driven because nuclear energy will account for less than 10% of its national electricity demand.

Despite the conflict in Ukraine, Russia is carrying out sustained diplomatic activity to maintain its position as a leader in the nuclear energy export market by signing cooperation agreements with African and Asian countries and maintaining a strong presence in Eastern Europe.

The US, which has returned to the Paris climate agreement, is gambling on the benefits of offensive climate diplomacy with the "Green New Deal". This spectacular change, to regain its historical leadership, is confirmed by the strengthening of the strategic alliance with South Korea, a strong presence in Brussels and Vienna, and investments worth billions of dollars. In Central Europe, it is offering energy coverage in addition to its military umbrella.

NEWCOMERS: THE CHALLENGE OF NUCLEAR SAFETY

As well as its undeniable low-carbon properties, the strategic aspect of the civil nuclear industry is indisputable. Its high-tech nature is a driving force for industry, research and education in the countries where it is developed.

Today, thirty or so countries are looking into the possibility of following the civil nuclear industry route. The challenge of nuclear safety is considerable for these newcomers. In addition to a high-quality industrial base and a reliable logistics chain, these countries must develop the proficiency and nuclear safety culture of the operators, establish a strong, independent nuclear safety authority and provide easy access for external oversight. This is the price to be paid for joining the nuclear operators' club.

ZAPORIZHZHIA: BLACKMAIL USING NUCLEAR SAFETY

The capture of the Zaporizhzhia nuclear power plant, one of Ukraine's five national nuclear electricity production sites, has deprived the country of a major source of power. This has been followed by blackmail using nuclear safety. This is a first in the history of conflicts, as unexpected as it is dangerous. In September 2022, an on-site mission by the International Atomic Energy Agency (IAEA) assessed the industrial and nuclear safety of the plant. It examined the physical integrity of the plant, the security of the electricity supply, essential for cooling the reactors, the condition of the transmission systems, the absence of any damage in the spent fuel storage pools, and the human and organisational operating conditions.

It is not for me to judge the truthfulness of the accusations made regarding the respective responsibilities and the reality of the bombings and sabotage of the plant, but the human factor is certainly the main issue to be considered in terms of nuclear safety. Physical exhaustion, the lack of freedom of action for management, and the psychological distress of the operations teams are aggravating factors in the face of a complex technical situation.

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

IN FRANCE, DIFFICULTY GETTING BACK TO NORMAL AFTER TWO ATYPICAL YEARS

Despite a significant decrease in production, 2022 will end up being a good year for the nuclear industry. The French now have a positive image of the sector and are in agreement with it keeping its rightful place in the energy mix. I note that the nuclear safety results have slightly improved, but they are too mixed for there to be any room for complacency. There is tangible progress in radiation protection, but radiography and contamination control require particular attention *(see Chapter 3)*.

Turbine rotor at Fessenheim

Education and training guidelines still need to be put into practice in the field. Management presence, the level of requirements and technical competency must be increased. Non-compliances and rework are all too often the result of a lack of rigour in both operations and maintenance. Thankfully, nuclear safety has not been adversely affected by a very restrictive work schedule, and I can confirm that the continuous improvement of nuclear safety remains the Group's priority.

THE ANNOUNCEMENT AT BELFORT: CONDITIONS FOR ITS IMPLEMENTATION

In addition to reducing our energy consumption and speeding up the development of renewables, on 10 February 2022 in Belfort, the French president said that he considered it necessary to "extend the service life of all nuclear reactors for which it is possible […] and launch a new reactor programme right away".

Continuing to operate nuclear reactors after 50 years will require a fifth ten-yearly safety review by EDF and its examination by the nuclear safety authority (ASN). The fourth ten-yearly outages (VD4), associated with post-Fukushima modifications, significantly improve defence-in-depth: this design safety upgrade should be sufficient to cover the remaining service life of the plants. In addition to the necessary compliance inspections, the priority of studies and modifications should now be given to climate change. As the 900 MWe series VD4s have also been affected by complexity, I urge the teams to avoid repeating this during the scheduling of the ten-yearly outages (VD) of all reactor series. I recommend that a discussion with the ASN be initiated straight away on determining the nuclear safety risks/benefits of the proposed modifications *(see Chapter 2)*, and that the capacity of the operations and maintenance teams to take on board all the hardware modifications is confirmed.

The project for six (then optionally eight) future EPR2 reactors is organised using a series-based approach, with the intention of replicating the same reactor on all the sites, apart from specific features associated with the heat sink. I note the increased involvement of the Operator in the project and the incorporation of initial lessons learned from Flamanville 3 (FLA 3). The DPN management must define the operations strategy for the EPR2 fleet. Together with the DIPNN, it must also promptly deal with the excessive complexity of the general operating rules, which has already been identified at FLA 3 *(see Chapter 7)*.

It is too soon to be able to measure the efficiency of the recently created cross-disciplinary technical function at the DIPNN. It will be measured over time by its ability to manage standardisation and to ensure that operating experience between Group projects is taken into account.

To complete this overview of the nuclear industry, I note there has been considerable investment in decommissioning, with good cooperation between the Group's directorates. The dynamic Fessenheim site was keen to maintain the spent fuel shipment schedule for its two reactors *(see Chapter 9)*. The centralised fuel storage pool at La Hague, which is essential for the downstream balance of the fuel cycle, has completed the preliminary consultation phase. Its tendering and construction schedule is increasingly constrained. I commend the classification of the Cigéo deep geological disposal project at Bure as an operation of national interest. Switzerland, Sweden and Finland have also chosen this solution for dealing with nuclear waste.

STRESS CORROSION: AN INDUSTRIAL ISSUE THAT HAS BEEN MANAGED WELL

While the effects of the pandemic have meant that EDF is subject to an already tight schedule to complete the postponed heavy maintenance, an unexpected issue occurred, affecting the generation capacity *(see Chapter 5)*.

In 2021, when I set out my guiding principles, I did not imagine that such a sensitive item of news would so quickly illustrate them. EDF acted in an exemplary way, as a responsible operator in the face of a significant issue. Luc Rémont, when he appeared before the French Committee on Economic Affairs on 26 October 2022, stated "that the company, in conjunction with the nuclear safety authority, immediately applied measures making nuclear safety the number one priority, which to my mind is an essential condition for the trust between EDF and the country on the nuclear fleet".

During periodic inspections, a conservative, questioning attitude led to the identification, analysis and then treatment of an unexpected stress corrosion issue on an N4 series reactor. All four reactors in this series were shut down. To protect the fleet against a generic effect, EDF decided to carry out representative checks on the entire fleet. Difficult decisions were taken to shut down reactors in the middle of winter without ever compromising the principle of the overriding priority of nuclear safety.

The way EDF dealt with this technical issue demonstrated its strength as an integrated group with design and operations skills, scientific expertise and practical know-how.

Its relationship as an operator with the nuclear safety authority, based on trust, communication and absolute transparency, enabled it to organise the review of the safety case within a short period, with the timescale and degree of oversight required by nuclear safety. This is essential for the smooth operation and credibility of the French nuclear industry.

As all the national capacity was mobilised between the corrective treatment of CCS and the preventive maintenance of the park, it was necessary to solicit a European smelter for the supply of pipes. And even if it remained limited, the recourse to foreign players once again highlights the lack of resources in welders and pipe fitters. Hence the importance of the opening of an advanced welding school in Cherbourg in 2021, on the instigation of EDF, with Orano and Naval Group. The first apprentices will not be available for several years, but they will be ready for the construction of the EPR2 reactors.

This industrial issue reminds us that nuclear safety is difficult without a controllable production capacity margin. In 1988, the subject was already being discussed by the head of the SCSIN, the predecessor of the ASN, and it has again been mentioned and repeated by those who came after him, clearly without any success...

Michel Lavérie, head of the SCSIN in 1988

"Given the place occupied by the standardised nuclear electricity fleet, it is essential to anticipate technical problems which would result in either prolonged outages for repair or the end of life for some plants. It would therefore not be acceptable to prolong the operation of a set of plants, which have become less safe, because of a lack of back-up capacity organised early enough. It is also important to provide production capacity margins so that unplanned outages can be managed correctly.
Discussions, which must include the safety authority from 1989, have also started to define the replacement design [...]. Given the lead times, the construction of the first units should doubtless be started before 2000."

A LONG FINAL STRAIGHT FOR THE EPR

Following on from those in China and Finland, Flamanville 3 will be the fourth EPR to enter commercial operation.

A significant amount of high-quality work has been carried out, in particular in the weld repair worksites. The necessary resources are being mobilised to deal with the technical topics that are still being examined. The on-site teams must be fully involved in the commissioning tests to perfect their knowledge of the plant, particularly since the teams consist mainly of people for whom this is their first job in the nuclear industry.

The schedule for the first major inspection outage (VC1) should be reviewed with the nuclear safety authority to ensure the industrial workload is achievable. I believe that, in the absence of any nuclear safety need, it would be preferable to replace the reactor vessel head during a ten-yearly inspection outage, rather than by the current fixed deadline, which is close to grid synchronisation *(see Chapter 6).*

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

NUWARD™ IS ON THE STARTING LINE

The hundred or so small modular reactor (SMR) projects worldwide include fast reactors, molten salt reactors, boiling water reactors and pressurised water reactors (PWR), with power levels ranging from a few MW to several hundred MW.

Simplification of design, low power, modularity and standardisation all favour the nuclear safety of these reactors, while controlling their cost and construction time. Nuclear power is thus becoming accessible to new stakeholders, and several countries that are new to the nuclear industry are including SMRs in their roadmaps. The OECD Nuclear Energy Agency estimates that SMRs will account for up to 10% of nuclear generation by 2040.

Torness reactor building

Developed by the CEA, EDF, Naval Group and TechnicAtome, and joined by Tractebel, Nuward™ is at the stage of confirming its main technical characteristics and the preliminary design. Its construction could start in the early 2030s subject to an ambitious test and technological validation programme. I am interested to see the approach of the French, Finnish and Czech nuclear safety authorities who have initiated a joint certification study. This should make it easier to obtain licences internationally.

A FIRM COMMITMENT TO NUCLEAR IN THE UK'S ENERGY POLICY

The year 2022 saw an increase in nuclear generation that was achieved by mobilising resources effectively to meet plant needs.

After five years of constant improvement, nuclear safety performance has plateaued. Nevertheless, equipment configuration, compliance with technical specifications, and operator compliance with process safety standards have been challenged. Action plans and nuclear safety initiatives have been reassessed and updated. Managerial presence and coaching, both of which are essential for sustainable performance improvement, have been consolidated through corporate site visits supporting the site's improvement plans. Tragically, Hinkley Point C, which previously had a very good safety record, is mourning the death of a worker involved in a construction plant accident.

RENEWAL OF THE FLEET

The UK government is putting nuclear at the centre of its strategy to boost energy independence and reach net zero carbon emissions by 2050. Nuclear power currently accounts for 13% of the country's electricity generation.

All the UK's Magnox reactors are permanently shut down and the first of the EDF NG AGR reactors are currently transitioning to defuelling after more than 40 years of service. The Hunterston B and Hinkley Point B power plants have both been permanently shut down and moved into the defuelling phase. Maintaining competences and knowledge, preserving a nuclear safety and industrial safety approach in a very different operational environment, are challenges for which the UK fleet is well prepared.

In addition to announcements on renewables and North Sea oil and gas exploration, the UK government is targeting to increase nuclear capacity from 7 GWe to 24 GWe by 2050. This will involve the construction of eight new reactors, including the twin 1600 MWe EPRs planned at Sizewell C.

The aim is to benefit from synergies and shared experience within the British EPR programme through a "one operator" model, regardless of the funding mechanisms or the legal structures of the operating companies.

SMR projects

Technician at Hartlepool

EXTENDING OPERATIONAL LIFE

The graphite inspections at the Hartlepool and Heysham 1 AGRs revealed no further deterioration of the cores, allowing for a potential short extension to their announced closure dates. This decision must be taken and implemented to avoid any inherent nuclear safety risks associated with deferral of end-of-life programmes (maintenance, motivation, etc.).

EDF NG is looking to extend the operating lifespan of the UK's only pressurised water reactor (PWR), Sizewell B, by 20 years, i.e. from 2035 to 2055. It has undertaken the necessary studies and planned the preparatory work. First connected to the grid in 1995, this 1200 MWe PWR is Britain's most powerful reactor. Once the remainder of the AGR fleet has been shut down, the only reactors left in service will be PWRs, and cooperation with the French fleet will become more invaluable than ever.

NUCLEAR, A KEY ASSET FOR THE FUTURE

CONTROLLABLE LOW-CARBON ENERGY

Decarbonised energy

France has safely deployed a programme with no major incidents that could call the technology into question. The fleet has been ensuring the overall reliability of the nation's power transmission system and security of supply for almost 50 years, as well as making a significant contribution to balancing the European electrical grid under the terms of the Euratom Treaty. It generates low-carbon energy, in contrast to other European countries that favour "greener" options.

The rise in uncontrollable renewable energies like solar and wind power cannot satisfy demand. The variability of renewables means that they alone cannot ensure the security of the electrical grid, and the resulting risk of widespread blackouts has significant safety implications.

Water security is another key challenge. Now an even more precious resource due to population growth, water is essential for life but also as a source of energy for hydroelectric power plants and a source of cooling for nuclear power plants. Sharing water resources is becoming a source of tension. Although conflicts over water use have historically been the exception rather than the norm, continued cooperation is not necessarily guaranteed.

The threat of "wars over water", aggravated by climate change, demonstrates the need for nuclear operators to control their hydropower networks effectively. At EDF, many technical aspects of hydropower are critical to nuclear safety, such as dyke maintenance, civil structures, geology, cooling water security and flood risk management. EDF Hydro is responsible for regulating water flows from rivers and for providing a back-up electricity supply for the reactors should the need arise.

EU TAXONOMY: A WORD OF CAUTION ON THE TERMS OF APPLICATION

In the EU, nuclear power continues to play a vital, albeit controversial, role in the energy mix. Despite offering numerous economic, environmental and climate-related advantages, it still faces strong political opposition based on ideological principles or incorrect perceptions of nuclear safety and radioactive waste management.

The inclusion of nuclear power in the EU taxonomy after long negotiations recognises the importance of its role in the transition towards climate neutrality. However, the regulation does not apply to the fuel cycle or waste management, both of which are critical to the safety of the production system.

In addition, EU taxonomy defines some restrictive procedures and conditions for obtaining a "green" investment label for nuclear projects. This introduces the potential risk of European institutions interfering in the technical assessment of nuclear safety, but this must remain the sole domain of independent nuclear safety authorities.

The energy mix

THE CHALLENGES FOR INNOVATION

Nuclear power clearly has a future on a global, European and national level. The advancements in innovation and new prospects, particularly with new modular systems, offer an economically competitive option that is compatible with environmental constraints. Innovation is key to the sector's appeal, and R&D is the cornerstone of its expertise. There are numerous technical, financial and human resource challenges.

Fast reactors, thorium reactors, molten salt reactors, nuclear fusion reactors, building new-generation reactors and dismantling older ones, treating long-lived radioactive waste: these are all projects for which funding needs to be found, industrial capacity needs to be developed, and the skills and expertise necessary to design, build and safely operate need to be acquired and maintained.

THE CHALLENGE OF HUMAN RESOURCES

The nuclear industry demands a robust nuclear safety culture; whilst this can be taught initially in the classroom, it can only be developed and cemented through experience.

Nuclear safety can either be imposed dogmatically or implemented through a rational, rigorous approach that is reflected through actions. Whilst it may be an implicit part of an administrative and procedural approach, putting it into practice requires individual effort, practice in the field, group discussions and full consideration of the human factors.

When handing over to the next generation, realising our ambitions will require a mass recruitment drive: 50% of engineers working in the nuclear industry by 2030 are not yet employed in the sector. Recruiting motivated staff, developing skills through appropriate forward planning, and retaining these skills in the long term is the greatest challenge for nuclear safety and the nuclear industry overall.

THE CHALLENGES FOR WORKING PRACTICES AND STRUCTURES

As a low-carbon form of energy offering plenty of innovation opportunities, nuclear power is drawing genuine interest among younger generations concerned about sustainable development. However, it seems that this alone is not enough. Working from home is reported to be a condition for attracting and retaining talent. Going back to what I said in last year's report, the pandemic may well have led to the adoption of new working practices, but it may also have allowed bad habits to take root.

Although working from home offers undeniable advantages, these tend to be highly individual (like saving commuting time, especially in the Paris region) and offer little collective benefit. Have all the human and organisational factors been fully considered before making this change to our working practices? Have new employees who need to be immersed in the nuclear safety culture and first-line managers who need to champion it, been adequately equipped to do so?

Is it possible to keep in touch with reality when working from home? How can we build relationships with co-workers? How will corporate cultures or group projects survive this radical shift in human relations? Breaking down silo mentalities, promoting teamwork, creating co-working opportunities to encourage discussion. All these mantras have suddenly been cast aside!

Can working from home truly offer the same informal opportunities for passing on knowledge and expertise that post-meeting chats and catch-ups at the coffee machine have traditionally provided? Does it not risk killing the spontaneity of discussion and brainstorming, thereby hindering creativity and innovation?

In the face of ever-increasing workloads, it is important to create time to get to know our social environment better, nurture interpersonal interaction, provide comprehensive on-the-job training through mentoring wherever possible, pay attention to working conditions, and share experiences. Lastly, we need to develop confidence, autonomy, initiative, accountability, rigour, and meaning, while still demanding high standards and being visible.

As Henry Ford once said, *"Coming together is a beginning, staying together is progress, and working together is success".*

© Nicolas WAECKEL

**No sooner had Robin finished his TEAMS meeting than he was overcome with loneliness*

IN CONCLUSION

The next generation of men and women to work for the EDF Group in the French and UK nuclear fleets will have to face three major challenges:

- Continue operating in-service reactors beyond fifty or sixty years by establishing and substantiating the conditions for their continued safe operation
- Build a new series of reactors guaranteeing a high level of nuclear safety with a high-performance infrastructure capable of meeting deadlines and managing costs whilst ensuring industrial safety
- Dismantle the UNGGs, AGRs and PWRs that have reached the end of their service life and continue to develop a sustainable solution for the treatment and disposal of long-lived radioactive waste.

I can only encourage those entering the industry to follow the advice of French Admiral François Dupont, the first commanding officer of the nuclear submarine *Le Triomphant*, who said that *"going back to the fundamentals and maintaining a thirst for learning is how we make sure that we're not only constantly improving, but also breaking the routine".*

Contents 01 02 03 04 05 06 07 08 09 10 Appendices Abbreviations

This year has been marked by stress corrosion in France and the start of AGR defuelling in the UK, both of which have been well managed.

Some operations events call for greater rigour and a better grasp of basic skills.

Presence in the field is improving and competences have been identified as a key focus area, but real simplification is proving slow to implement.

*© Nicolas WAECKEL *Manager in the field – "Hello, do you have any low-level signals to declare for my action plan reporting dashboard?"*

Competences and simplification: a challenge for nuclear safety

02

The year 2022 has been challenging for the French fleet, with stress corrosion *(see Chapter 5)* on stainless steel pipework adding to an already demanding workload of the fourth ten-yearly outages (VD4) and the resumption of work post-Covid. Studies have started to assess the fleet's lifetime beyond fifty years.

In the UK, defuelling in the AGR fleet has started, whilst Torness and Heysham 2 must now carry out refuelling with the reactors shut down and depressurised. This requires more intensive and frequent plant operations. The results of the graphite inspections at Hartlepool and Heysham 1 proved favourable, which may allow for a possible extension to the service life of both plants. Sizewell B, the only UK PWR, is preparing to extend operation beyond its original 40-year lifespan, which will involve substantial unit outages over the next few years.

A WEALTH OF NEWS TO REPORT

HEAT WAVES: NO IMPACT ON NUCLEAR SAFETY BUT FOOD FOR THOUGHT

Neither the French nor the UK fleet came up against any nuclear-safety-related issues during the summer heat waves. Ambient temperatures of facilities and equipment remained normal at all sites. The DPN's mitigation plan introduced following the 2003 heat wave in Europe has proved effective, for example, increasing the capacity of heat exchangers. There were, however, issues relating to the regulatory environmental temperature limits governing cooling water discharges into rivers. The French nuclear safety authority (ASN) granted temporary exemptions in an effort to keep certain reactors running and maintain the balance of the national grid. This process proved effective thanks to the procedures in place, thermal plume modelling, and knowledge of the impact on aquatic ecosystems gained over decades of operation.

The record rainfall in southwest France and severe flooding in Germany and Belgium in 2021, as well as the heat waves in 2022, illustrate that the severity of natural hazards can be unforeseen, making them one of the main nuclear safety risks. It is important to continue working on local climate change projections and, more specifically, to model phenomena changes in addition to using the current statistical methods that are based on past data.

I am pleased to note the Group's commitment to predicting climate change resilience and water resource planning (an issue mainly for production). This relies on R&D initiatives, which I shall be I shall be watching with interest. For instance, designing future reactors will have to incorporate potential water shortages.

VD4: A LARGE INDUSTRIAL PROGRAMME TO MANAGE

In 2022, the VD4 campaign on the 900 MWe series proceeded at a sustained pace, in four reactors during outage and in seven during operation. The in-service preparatory work presents unusual conditions from a nuclear-safety perspective (enormous amounts of scaffolding, working in sensitive areas, etc.), and the key challenge will be to ensure that such conditions do not become the norm. Familiarity should not lead to acceptance, and vigilance should be maintained throughout these sensitive phases (see the 2020 and 2021 reports). Risk assessments alone are not enough; the Operator must have greater and more regular presence in the field to oversee these operations and confirm compliance with the nuclear safety conditions. Operating experience from the 900 MWe VD4 campaign should also be incorporated with the goal of optimising the management of activities, between those performed with the reactor in sevice and those performed with the reactor in outage.

Taking ownership of the modifications, the ultimate back-up diesel generators (DUS), and the new general operating rules is still proving challenging, despite an intense programme of training. A concerted effort is needed throughout the fleet, as ownership is a critical factor in nuclear safety.

The lessons learned need to be leveraged for the 1300 MWe VD4s and the N4 series VD3s. Although the original objective was to align these with the 900 MWe VD4s to avoid further increasing the workload, I fear this may not be the case now. I believe it is necessary to be more ambitious. To reduce operational complexification due to the cumulative effect of modifications, and without compromising genuine defence-in-depth improvements, I suggest dispensing with any modifications that only marginally enhance nuclear safety.

The VD5s for the 900 MWe fleet, preparations for which will soon be under way, should, in my opinion, focus on plant compliance and equipment qualification at least up to sixty years. The nuclear safety

Contents 01 02 03 04 05 06 07 08 09 10 Appendices Abbreviations

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

reassessment should prioritise external hazards, more specifically climate-related, and the potential resulting modifications.

FUEL: ROBUST TECHNICAL MANAGEMENT

In the UK, no fuel cladding failures were reported in 2022 as in 2021. In France, there were 4 in 2022 (5 in 2021).

The corrosion issue on M5 cladding alloy (see my 2021 report) affects all reactor series, although the 900 MWe fleet is less impacted. A new specification is being defined for the iron content, which is the key factor in this phenomenon. This issue does not affect nuclear safety since M5 corrosion does not cause hydriding, which would weaken the cladding in accident conditions.

Review of fuel OPEX for the period 2010-2019 showed that the technical issues encountered during this time have been resolved satisfactorily. It also confirmed the need to leverage international OPEX more effectively.

In nuclear safety studies, the Odyssée computer code is already proving its operational worth.

The MOX fuel assembly delivery issues experienced at the Melox plant are still ongoing, although production improved in 2022.

The EPR and EPR 2 projects have integrated the lessons learned for the fuel events at Taishan *(see Chapter 6)*.

FIRE SAFETY: ROLE OF THE FIRST RESPONSE TEAMS IN FRANCE

Despite the proposed reform to establish professional on-duty fire-fighters at some French plants, I encourage that the first response capability of shift teams be developed further.

Fire response requires operational judgement. The Belleville shift team should be commended for their pragmatic handling of the fire in a gas storage area in 2020. This is a prime example of good judgement based on the experience of the team members (including several volunteer fire-fighters), collective analysis of the situation, and clarity of response. The correct management of this event confirms the relevance of encouraging the vocation to become a voluntary fire-fighter within EDF and contractor staff.

I am pleased to see strong relations between plants and local fire and rescue services, thanks to having professional fire-fighting officers as on-site secondees. However, in-house fire safety supervisors sometimes appear to be relatively isolated, despite the fact that fire safety is everyone's responsibility.

Augmented reality is being increasingly used for refresher training courses. I urge caution here, as not all needs can be met using virtual reality and it is no substitute for real-life drills.

On sites, more work is needed regarding fire load management in France, and in the UK, maintaining electrical equipment, and fire detection and suppression systems.

EMERGENCY PREPAREDNESS: ENSURING EVERYONE IS TRAINED

Currently in France, the nuclear rapid reaction force (FARN) performs training exercises on sites without the latter using this as an opportunity to carry out training on their own in-field response arrangements, and without necessarily involving the onsite emergency response organisation (PUI). I acknowledge that the national emergency response organisation (ONC) and the FARN are merging, which should help achieve a more coordinated approach.

As mentioned in my 2021 report, greater emphasis should be placed on professional development in the field, on completing all the training, and ensuring that, when the time comes, everyone knows how to connect equipment, to operate valves, to configure electrical panels, and to coordinate operations in the correct order.

FARN exercise at Belleville

Predicting jobs and skills needs is not always a priority for the FARN, and some weaknesses are emerging that require attention.

In the UK, due to staff turnover, some on-call roles for the on-site emergency plan, such as emergency controllers and radiation protection advisors, are proving difficult to fill, and creating knowledge and competence gaps. One training exercise had to be rerun because of gaps in emergency procedure knowledge, managing the exercise and the time taken to muster personnel.

I suggest that training exercise and drill requirements are reviewed for on-call and shift staff in both fleets, as I believe that their frequency is insufficient at present.

OPERATIONS: AT THE HEART OF EVERYTHING

IN FRANCE: TOO MUCH DISPARITY IN PRACTICES AND COMPETENCES

Some events that occurred this year (e.g. moving control rods at the same time as performing a boration operation; non-compliance with the minimum neutron flux counting rate; isolation of a heat exchanger with the shutdown cooling system in service) have raised concerns about operator skills and compliance with basic rules.

I have noted a lack of consistency in operations between sites and even between shift teams working at the same site, whether in relation to control room serenity and monitoring activities, the role of the lead operator or shift-team training. Although there is evidence of some extremely good practices, these need to be implemented fleet-wide.

The issue of maintaining competencies after a comprehensive and robust initial training programme also needs addressing. This is primarily a matter for management, specifically shift managers.

Just-in-time simulator training is continuing to develop. This is particularly beneficial and should become a widespread practice. Training within the shift-teams must become common practice again, through studying reactor physics and systems in greater depth, preparing presentations, and giving the shift teams free access to the simulator, etc. Refresher training also requires greater managerial commitment: e.g. shift managers or deputy shift managers should be present at training sessions, operators should be suspended from duty if they fail a test, etc. I will be watching this closely next year.

Although a deputy director from the DPN is now responsible for the "operations performance" project, which is a positive step, the corporate stakeholders are still too widely dispersed, which hinders consistency and effectiveness. Furthermore, multiple action plans have been set up to tackle related issues, such as technical specification non-compliances, sensitive transients, reactivity management and automatic reactor trips, which confuses matters. Technical specification non-compliances remain too high, the DPN has provided dedicated support to the four plants that experienced over half of them in the summer of 2022.

I believe that more rigour is required in operations, with a permanent focus on competencies and a stronger managerial presence, as they have a major responsibility and must set an example for all to follow (see my 2021 report).

IN THE UK: WELL EMBEDDED OPERATOR FUNDAMENTALS BUT ROOM FOR IMPROVEMENT

In the main control room, I have observed a serene environment and effective supervision. The fuel route operators are sometimes quite remote from the control room team but actions are in progress to reintegrate them. The main weaknesses relate to the number of technical specification non-compliances (of which over 50% occurred at a single site), alignment errors and plant isolation events, therefore improvements are expected in these areas.

I have seen concrete examples of how operator fundamentals have been embedded: in simulator training and incident analysis, successes and weaknesses are all clearly traceable back to each of the five fundamentals. I was also interested to see the roll-out of the "line of sight to the reactor core" initiative promoted by INPO in the aftermath of operations events in the US, which was introduced to strengthen individual and collective capabilities in operations teams.

NUCLEAR SAFETY AT THE CORE OF MANAGEMENT

The Group published a new version of its nuclear safety policy in 2021, although it is not easy to find on the intranet. There seems to be a proliferation of nuclear safety policies relating to either "protected interests" or "integrated policies". Only one nuclear safety policy is needed, the Group nuclear safety policy. It must be visible, accessible, referenced and defined in the documentation of every entity.

THE NUCLEAR SAFETY PRIORITY: A MATTER OF LEADERSHIP

This year, the priority accorded to nuclear safety by leadership teams has been clear, as demonstrated by the handling of stress corrosion and the transition to decommissioning of the AGR fleet. Nuclear safety is a daily reality at all nuclear power plants, deeply embedded in mindsets and practices. Considering the current tensions in the energy market and the resulting pressure on production, we must always remain vigilant.

In France, nuclear safety is too often perceived as being required to answer the ASN's questions correctly. I hear this less now, which demonstrates progress. However, where work is validated by an authorisation from the ASN or a judgement from the French institute for radiation protection and nuclear safety (IRSN), some corporate services and engineering departments tend to make this their primary objective when under pressure.

Despite it being primarily an operational responsibility, nuclear safety leadership is still often perceived to be the responsibility of independent oversight teams or owners of the nuclear safety processes. I have been highlighting this issue for several years now and am regret the lack of more significant progress in this area.

NUCLEAR SAFETY CULTURE: FOCUS ON THE FIELD

The Group is demonstrating a high overall standard. Freedom of expression is evident. Some opportunities are opening up for technical dialogue, which need to be developed. Transparency also seems to be well established.

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

In my opinion, risk perception is an area that needs to be improved in engineering, where there is a lack of consistency. It is not enough to define specifications, there needs to be an understanding of the why.

Additionally, meaning is often lost in the sheer volume and obscurity of documentation. For example, lifting activities over the open reactor vessel are considered to be a matter for technical specifications (the number permitted and the alignment of the extraction and ventilation system), yet the association with the physical considerations, i.e. making sure the fuel is not damaged, seems to have been weakened.

Safety culture surveys are now common practice. It is important not to focus on overall quantitative results, however flattering these may be, but to concentrate instead on what they reveal about the teams and departments. I commend the initiatives undertaken in both fleets to examine the areas of disparity, rather than the overall ratings, through discussions with teams on-site. I will be following developments in this area with interest.

The finding from one survey was that “words have lost their meaning”; this insight is invaluable and steps must be taken to address it (see the 2021 report). Still on the subject of language, the DPN’s annual safety reports, which are being modified, are confusing matters by including process health assessments in the section on nuclear safety culture *(see Chapter 8)*.

“PROFESSIONALISE STAFF INSTEAD OF REFINING STRUCTURES AND PROCEDURES”

EDF has a vast skills base and is clearly able to leverage it. There is, however, not enough consistency, and preservation of this asset is crucial.

Although this has been recognised, the transformation still needs to be completed, especially in France. I note that this one of the key pillars of the DPN’s START 2025 project. All levels of management need to change their mindset that skills are a matter for training departments and committees, and must take ownership in this area.

Immersive site training sessions are being set up in engineering. However, initial technical training is often delayed or incomplete. A comprehensive programme is needed to meet the needs of the planned recruitment drive and I acknowledge the direction defined by the UFPI in this respect. It would be worth extending a similar policy to site engineering teams as initial technical training, professional development and handover arrangements are not addressed systematically.

The UFPI is a great resource and has close links with the sites. Some work is needed to strengthen its management of jobs and skills needs by bringing in experienced instructors, especially given the chronic shortage of operations instructors. The role of instructor should be a rewarding job and represent a natural progression in a career in operations. At corporate level, the UFPI is seen too much as just a service provider.

Preparing for the future with apprentices at Heysham 2

In France, the challenges associated with the skills base extend beyond the company. Joint initiatives set up by the French nuclear industry association (GIFEN), like the welding school, are positive. The links with the French Ministry of Education are important to promote technical professions and vocational courses (technical colleges, vocational qualifications and courses in electrical and mechanical engineering) and encourage careers in manual disciplines. This framework will have to adapt rapidly to the meet the future significant demand.

The expansion of apprenticeship programmes is helping to reindustrialise France. The rules and practices of such programmes need to be reviewed because apprentices are currently rarely able to work at nuclear power plants. This practice is already firmly established at EDF NG, and is paying dividends. One way to improve this would be to better take into account previous external experience.

THE CURSE OF COMPLEXITY

The Group demonstrates a robust capability to provide an effective response to unforeseen technical challenges. Yet effectiveness in daily activities remains elusive.

As mentioned in my 2021 report, effectiveness also concerns nuclear safety; the meaning of actions can be lost when staff are shackled by unwieldy processes, overly detailed documentation, a constant pressure to provide evidence, the overriding importance of demonstrating safety, abstract jargon and struggling to get things done. Not to mention their commitment, initiative and a sense of accountability. It seems that countermeasures in the form of processes and documentation, and the desire to write down everything that needs to be known in the hope that everything that is written down will be done, seems to prevail, with the loss of basic skills.

Three main causes of complexity compound the problem: fragmented organisations; the natural tendency of corporate services to dictate requirements; and an over-demonstration of safety.

Fragmented organisations lead to fragmented skills and responsibilities, and are characterised by silos and long decision-making processes. The more interfaces there are, the greater the number of processes and committees. A considerable amount of energy is spent navigating complexity.

Excessive levels of administration, a natural tendency within corporate services, stems from wanting to justify everything related to nuclear safety from Paris. However, this means that accountability is not assumed at the correct level and is systematically pushed up the management chain, resulting in a proliferation of directives, action plans, requirements, standards and reporting, etc.

Complexity also originates from an intellectual and regulatory trend according to which every single topic requires a safety demonstration and traceable evidence. The emphasis is therefore on documentation rather than being in the field, on standards rather competences, on organisational processes rather than techniques, and on compliance with processes rather than responsibilities.

The result is a multitude of scenarios in the general operating rules, an abundance of equipment in the technical specifications, and a veritable maze of nuclear pressure equipment regulations, and OPEX that is bureaucratic rather than practised in reality *(see Chapter 7)*. Similarly, the massive incorporation of the FARN's resources in the safety demonstration that consider increasingly more demanding scenarios, could impact its capability to act in the face of unplanned events. This would be contrary to the lessons learned from Fukushima and Three Mile Island.[1]

I can see little evidence of a move towards simplification even though this view is shared by senior management at the DPN and the ASN. Action is needed now. I approve the fact that EDF NG and DPN leadership teams are focusing on professionalism and behaviours rather than on adding new processes.

I am pleased to see that field presence is a guiding principle in both fleets. I see signs of progress, albeit inconsistent. Field presence must become standard practice again for first-line management and for this reason, I suggest that the bureaucracy associated with manager field visits be scrapped. There are some good practices in evidence, including assessments of field presence with line managers, sharing observations between peers, a monthly brief on observation themes, and updates in department meetings. For team leaders in the UK fleet, the target is to spend 40% of time in the field, with recording methods being simplified.

In France, engineering staff are too often far from the sites. Engineers involved in modifications should visit the locations for these modifications before designing them, and should find out how well they work once they have been implemented. There also seems to be a constant stream of sophisticated calculations, often developed at IRSN's request. The intellectual reassurance they are supposed to provide often overrides the engineer's judgement and experience.

GOOD RELATIONS WITH THE NUCLEAR SAFETY AUTHORITIES

Relations between the French fleet and the ASN appear to be built on trust and are characterised by open dialogue, unequivocal decision-making by the Operator (e.g. stress corrosion) and converging opinions. The working relationship between the sites and the ASN regional offices remains good.

I have noticed a certain degree of self-censorship with regard to the ASN: the Group may be convinced that practices, certain equipment, technical specifications, etc. should be modified, but is content with the status quo for fear of examination by the IRSN and the ASN. All the more so as the three-way game (ASN, IRSN, EDF) can lead to unnecessary escalations. It is up to the Operator to assert their convictions. The redraft of the INB regulation must be seized to resolve these complexities.

Relations in the UK between EDF Energy and the ONR remain strong and are particularly close with the INA and the INR (HPC). There seems to be general agreement regarding the difficulties encountered at the sites. Some issues come under intense scrutiny from the ONR, such as the pressure equipment regulations (process safety), certain defuelling safety cases (e.g. the plug unit), loss of grid, and operational decision-making. The safety authority's requirements relating to new designs (HPC and SZC) are, however, overcomplicating some matters.

RECOMMENDATION

In order to take greater account of the realities of operation related to the ten-yearly outage, I recommend that the Directors of the DPNT and the DIPNN:

- **Reduce, in agreement with the ASN, the list of modifications considered for the 1300 MWe VD4s and the N4 VD3s, weighing up the expected benefits for nuclear safety**
- **Focus the fifth ten-yearly outages for the 900 MWe series on compliance and climate-related hazards.**

[1] *TMI followed a condition-based approach in contrast to a normal events-based approach*

Contents 01 02 03 04 05 06 07 08 09 10 Appendices Abbreviations

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

Peer-to-peer support at Saint-Laurent

The quantitative indicators for industrial safety have improved in France and remain stable in the UK. Nevertheless, the Hinkley Point C construction site sadly experienced a fatality, reminding us of how important it is to remain vigilant.

The French fleet's outage programme and AGR defuelling activities in the UK require exemplary radiation protection practices and behaviours.

The alcohol and drug testing programme in the UK has proved its worth, protecting operators and ensuring nuclear and industrial safety. In France, there remain obstacles to this becoming systematic.

Industrial safety and radiation protection: first and foremost in the field

03

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

INDUSTRIAL SAFETY: MAINTAIN THE EFFORT

Ensuring the health and safety of workers is a moral and legal obligation for the organisations, management and all workers.

The industrial safety requirements are communicated well in both fleets. The 2022 performance indicators are improving slightly, confirming that the requirements must be systematically reinforced and applied in the field. The accident leading to the death of a contract partner supervisor at the Hinkley Point C (HPC) construction site is a stark example of this.

WORK ON BEHAVIOURS AND PERSONAL ACCOUNTABILITY

In France, the effort to strengthen management presence in the field needs to be continued to improve behaviours, perception of risks, wearing of personal protective equipment (PPE) and compliance with critical safety rules. There must be greater focus on the critical risks associated with lifting operations, electrical work, and working at height. In my previous reports, I have already stressed that there is insufficient presence in the field, sometimes accompanied by less than exemplary conduct by managers.

Wearing personal protective equipment at Hartlepool

The daily safety message is rarely followed by a discussion, which would ensure that its meaning is taken on board and personal commitment encouraged. It is often reduced to a bland statement, and I regret the lack of progress. In the UK, I note greater ownership of the safety message and more engaged discussions.

The Group's industrial safety day takes place in October each year with managers spending time in the field providing information on the industrial safety requirements. In the UK, this industrial safety day is extended to a week, entitled "Zero Harm Week". Other weeks are also devoted to industrial safety and promoting correct behaviours. For example, "Safe start" weeks, scheduled at the beginning of the year and after the summer holiday period, provide a reminder of required behaviours by increased manager presence in the field, briefings and interactive demonstrations.

I have seen that there is a strong desire to improve performance levels, and to share and transpose best practices through benchmarking between both fleets. I urge the continuation of these cross-fleet comparisons.

At the Flamanville 3 construction site, the improvements observed since 2020 are continuing in 2022, with no accidents associated with critical risks. I urge the on-site teams (DPN and DIPNN) to continue concentrating on industrial safety and workers' behaviours while preparing for start-up.

In the UK, after a period of stable, solid performance at EDF NG, I note that the lost-time injury rate (LTIR) has almost doubled in 2022, at 0.5 compared with 0.3 in 2021. As observed in France, inappropriate behaviours of EDF NG staff or contract partners illustrate a lack of personal accountability and risk perception. The requirements and expectations are known, but workers do not apply them. This weakness could be due to the new operational context of the advanced gas-cooled reactor (AGR) fleet. The transition to permanent shut down and defuelling may have diverted attention from the implementation of safety improvement plans. The leadership community have been more focused on these social aspects. The nuclear excellence and industrial safety leadership programmes, started in 2022, will help to bring about a change in behaviours. I expect to see the impact of these programmes in 2023.

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

Identifying the risks in any situation

During the maintenance of a valve, the reassembly sequence was modified following the unavailability of a spare part. The procedure was adapted without any independent approval process. As a result, the valve counterweight was not correctly restrained.
After the maintenance team had left the worksite, believing to have left it in a safe state, scaffolding was built next to the valve. As the scaffolding was being erected, the valve counterweight suddenly turned and trapped a scaffolder's foot, seriously injuring him. The main causes of this event are shortcomings in worksite supervision, failure to comply with the expectations for procedural use and adherence, together with a lack of knowledge and perception of risks.

At Hinkley Point C, the industrial safety performance had been good for such a complex construction site, until the fatal accident in November. This accident reminds us that nothing should ever be taken for granted in industrial safety.

With the installation of the mechanical, electrical and ventilation systems (MEH), the types of safety risks will become significantly more diverse. With the HPC workforce comprising 84 nationalities on-site, speaking twelve different languages, this diversity gives rise to communication challenges and industrial safety culture shocks. "The HPC way" initiative provides a framework of requirements and helps to inspire staff alignment with the project's safety objectives. Different supervisory levels are identified by the colour of their hardhats.

DRUG AND ALCOHOL TESTING: LABORIOUS IMPLEMENTATION IN FRANCE

Once again, I cannot but notice the difference in the situation between the two countries. The UK fleet has been carrying out drug and alcohol testing for a number of years, both routinely and in the case of suspicion. Positive tests remain significantly below the national average (1.5% as against a national average of 7%), confirming the effectiveness of preventive testing, which acts as a deterrent.

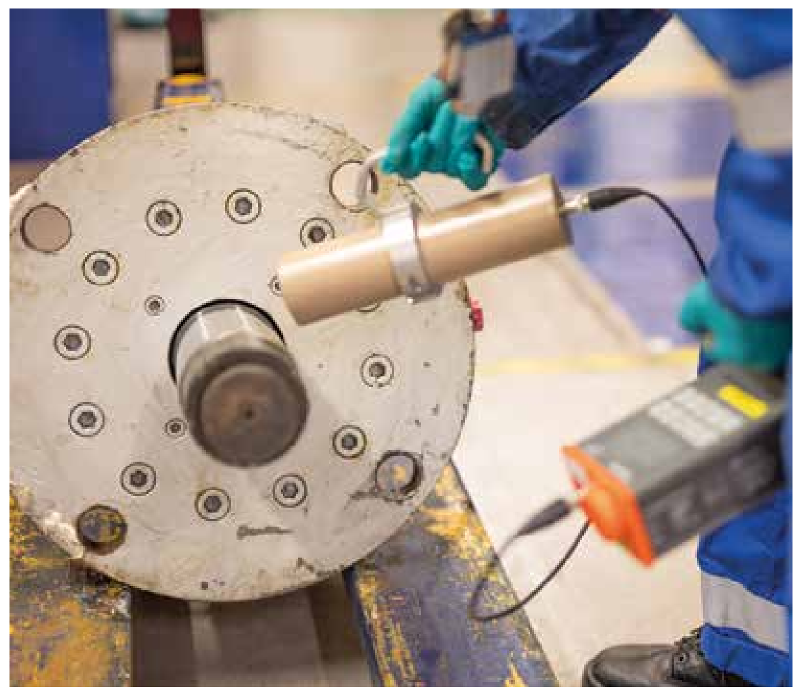
In France, although systematic testing for psychoactive substances is an essential part of protecting workers, I am disappointed that it has not always been done. The establishment of testing methods and their integration in the internal rules are proving laborious. To achieve this, all those involved must be fully committed, whether the labour inspectorate, the occupational health service, social partners, management and staff.

RADIATION PROTECTION: TAKING ACTION ON BEHAVIOURS AND PRACTICES

IN FRANCE, THERE IS A RECOVERY PLAN BUT IT IS NOT GAINING ENOUGH GROUND

The radiation protection recovery plan is showing some tangible results at certain sites, particularly in the management of red and orange controlled areas. However, in 2022, its implementation has been inconsistent and is not hitting the target. I note that some workers still have a poor understanding of the requirements and behaviours associated with radiography, checking dose rates, individual monitoring, and the prevention of contamination (even if the number of C2 monitor alarms at the exit to the controlled area is historically low). The number of events reported (significant radiation protection events (ESR) and interesting radiation protection events (EIR)) remains high, and they are mainly associated with incorrect worker behaviours and practices

There is sometimes insufficient rigour in preparing for and carrying out radiography. For example, non-compliances include insufficient demarcation of areas, incorrect use of gamma radiography equipment and failure to comply with demarcation barriers, all of which could lead to dangerous levels of radiation exposure.



Contamination check at Hartlepool

The initial and refresher training programmes have been reviewed. However, I have noticed that these programmes do not always result in workers clearly understanding the requirements and the basic rules of radiation protection. The reduction in the amount of time devoted to refresher training, the absence of any individual evaluation of what has been learned and the incorrect use of e-learning are affecting the degree to which the fundamentals are taken on board. Furthermore, training should not be a substitute for the presence of management in the field and its exemplary attitude.

Incorporating operating experience (OPEX) at the right time is another mechanism for improvement. It is important to ensure that essential OPEX is at the right level without it getting lost in the background noise. Too often, it does not reach workers as it is diluted by other, less relevant OPEX, and leads to events being repeated *(see Chapter 7)*.

The outage programmes and treatment of stress corrosion constitute an additional radiation protection issue. The DPN has taken account of the impact of the stress corrosion programme on individual and collective radiation exposure levels and has successfully implemented measures to minimise them.

Radiological cleanness: a requirement to be shared by all

The contents of an extractor (used for dust and cutting chips) at a worksite in a reactor building were not emptied correctly. Significant contamination was dispersed into the workspace and adjoining rooms. Nine workers (EDF and contract partners) received internal contamination. The received dose for three of the workers was estimated to be more than 0.5 mSv. The legal dose limit is 20 mSv a year.

IN THE UK: A NEW CONTEXT TO CONSIDER

Some AGR sites are preparing for the end of production and complete defuelling. This new situation is creating uncertainty and leading to the loss of experienced staff across all professions. Radiation protection is particularly affected and suffering from a shortage of engineers and technicians who cannot be replaced quickly.

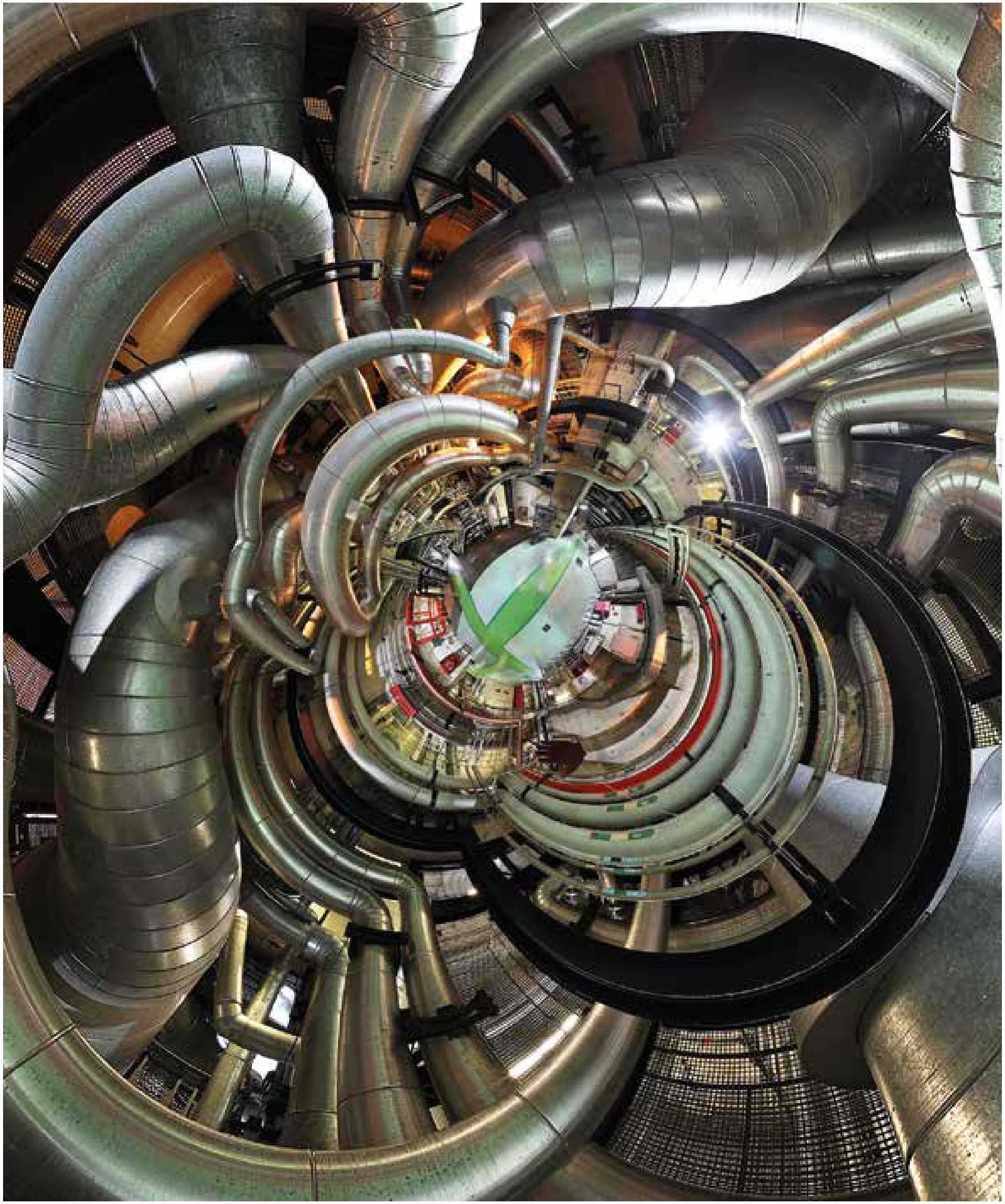
After several years of good results, I have noticed a drift in behaviours and a decrease in competence. The industrial transition is contributing to this. The indicators in 2022 nonetheless remain satisfactory. I reiterate my suggestion that the plant radiological protection (ALARP) committees concentrate on reinforcing the radiation protection culture.

Given that each AGR unit contains around 300 fuel assemblies, defuelling will become a repetitive activity, leading to a risk of it becoming trivialised and lead to a decrease in operator vigilance. I have been pleased to see that this risk has been clearly identified: the field presence and Independent Nuclear Assurance (INA) programmes include monitoring the activities of the fuel handling route and worker behaviours.

CONCLUSION

I can only insist on the effective implementation of the recommendations from previous reports. I feel it is necessary to recall the fundamental principle of personal accountability, as well as the importance of a strong field presence and exemplary managerial behaviour, in order to improve industrial safety and radiation protection behaviours in the field.

I must also reiterate the need to quickly implement testing for psychotropic substances in France and to remove the obstacles through greater collaboration between all stakeholders.



Turbine hall at Belleville

Effective maintenance carried out to a high standard is key to plant performance.

The industrial environments in both the French and the UK fleets are unique and place great demands on maintenance teams.

A large proportion of maintenance activity has traditionally been outsourced in both fleets due to the seasonal nature of outages and the level of specialisation required for certain activities.

Maintenance that maximises equipment availability 04

Reliable operation of our power plants depends on a high standard of maintenance, which is carried out as a preventive measure to avoid equipment failure, and as a corrective measure to restore equipment availability.

To successfully perform their role, maintenance engineers must work closely with the operations teams, by sharing their knowledge of equipment behaviour and associated availability requirements. Everyone must work together towards the same goal of full equipment availability in complete safety.

The fleet upgrade programme in France (known as the "Grand Carénage"), preparations for dismantling the advanced gas-cooled reactor (AGR) fleet in the UK and the loss of skills associated with staff turnover, are all placing further demands on maintenance teams and limiting maintenance improvement actions.

APPLYING THE BASIC PRINCIPLES

MAINTENANCE TRAINING TAILORED TO PLANT REQUIREMENTS

High-quality maintenance relies first and foremost on technical skills and practices.

In France, maintenance training is deemed to be of a high standard and is meeting plant needs. Most of it is outsourced and the training provided by manufacturers is particularly well received. EDF has allocated limited internal resources to maintenance training, assigning just 60 instructors to maintenance compared with 450 in Operations. Furthermore, training courses are not being fully exploited: the average absence rate is around 30% and it is apparent that there is a lack of self-learning by participants between sessions. Dedicated maintenance academies are organised at plant level. The capability of these academies needs to be monitored closely to ensure they can meet the demands of future recruitment campaigns, particularly in relation to bringing certain maintenance activities back in-house.

Site maintenance teams generally have senior maintenance specialists available for in-field support. They provide extensive technical expertise, which is effective and highly valued in the majority of cases. However, their lack of availability to deliver training is sometimes an issue.

Every plant has well equipped mock-up facilities, which are invaluable when it comes to training staff prior to carrying out complex tasks. Some plants provide this training systematically and require contractors to take part as well. Despite this, these facilities remain under-utilised.

I note that in both France and the UK, competence for the maintenance of specific nuclear safety significant equipment (EIPS) is not systematically assessed to support nuclear accreditation. In France, the control and instrumentation specialism, which covers the more sensitive safety equipment, has introduced this competence assessment into the management of such activities. Yet accreditation is rarely called into question, even though the person's level of competency has not been confirmed. Similarly, ensuring maintenance team abilities are kept up to date is not covered by a national guidance note, which is the standard reference document used for Operations.

Mock-up facility at Saint-Alban

In the UK, the loss of skills associated with the number of staff leaving EDF Nuclear Generation (EDF NG) and its contractors, due to the final

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

shutdown of the AGR fleet, will be difficult to mitigate in a timely manner. The apprenticeship programme is robust and mature, and provides a valuable source of recruitment. However, the training programme for new employees could take greater account of previous external experience by effective use of task performance evaluations.

SIMPLIFY AND INTEGRATE THE FUNDAMENTALS

Maintenance fundamentals set out the expected behaviours for everyone involved in maintenance activities.

In the UK, these fundamentals have been defined on the same basis as the operator fundamentals (monitoring, control, conservatism, teamwork, knowledge). They are simple, realistic and appreciated by workers in the field. EDF NG then continued this process, by producing 67 “What Excellence Looks Like” sheets (WELL) to provide an overview and describe the standards and expectations for all activities. I regret that this development has created a new complexity, and, in the case of the 20 sheets specific to maintenance, the connection with the maintenance fundamentals is now far less evident.

In France, several different local initiatives have been set up to define the maintenance fundamentals: one plant has defined 10 criteria, whereas another lists 31. This inconsistent approach dilutes the message and causes confusion in the field, especially when engineers and technicians work at more than one site.

I hope that the approach, described in my 2021 report, undertaken by Operations to reinforce the fundamentals be followed through into maintenance.

INSOURCING MAINTENANCE ACTIVITIES IN FRANCE, ESTABLISH CONSISTENCY BETWEEN SITES

One of the strategic goals defined in the DPN’s START 2025 project is to bring maintenance operations back in-house to build the skills base. Reclaiming some of these activities, and thereby strengthening technical capabilities, will make supervising sub-contractors, monitoring their work and maintaining relationships with specialist contractors inherently more effective and meaningful. It also offers the added benefit of ensuring that the sites are able to handle any unforeseen complex maintenance operations in-house.

The right conditions are in place:

- There is the necessary skills base to perform some of the major maintenance activities in-house (Maintenance & Logistics Unit (ULM), Dalkia, etc.).
- There is a recognised apprenticeship programme that is expanding year on year.

Technician at the Maintenance & Logistics Unit (ULM)

- There is a desire from maintenance staff to reclaim technical capabilities and re-establish confidence in the field.

Without intending to be too prescriptive in the approach, it would be worth:

- Defining a national and local insourcing strategy that provides a consistent yet complementary target across professions, reactor series, and regional hubs, etc.
- Resisting the tendency to poach talent from the limited pool of contractor staff, which is already a common practice among contractors
- Setting aside the necessary time for change management and assimilation of work practices.

The formula for success: performance = motivation x competence

An experienced EDF mechanical technician was carrying out routine maintenance on a site's turbine-driven pumps, an activity he is accustomed to doing. He was in the process of replacing an intake valve actuator on a pump, when a work coordinator arrived, dressed in overalls, armed with plans and a spare part, and started to discuss the plans with the technician. This is something the coordinator would like to be able to do more often, but the complex processes involved mean that his workload does not always allow time for this kind of working relationship. Both expressed that they found this kind of cooperation very motivating.

Insourcing requires a commitment from all plants to follow a coordinated approach compatible with the industrial infrastructure. It involves defining which maintenance activities are sufficiently repetitive to be handled at plant level or that can be pooled across several plants in the same regional hub or reactor series. The key stage in the process is evaluating the impact on the skills base to scale the training provision accordingly and consolidate it at a national level. Finally, it will also be necessary to offer appealing career advancement opportunities to ensure that field expertise is not lost due to staff turnover.

INVOLVEMENT OF CONTRACTORS TO ACHIEVE COLLECTIVE SUCCESS

I have already mentioned in my previous report how well contractors are integrated into teams in the UK. Although this is facilitated by the legal framework, this factor should not be overstated. Permanent contract partners are fully immersed in plant activities and management. They receive the same training as EDF NG staff, including courses on leadership and human performance. They are involved in field visits and are fully integrated in the 'Leaders in the field' programme.

In France, that there are good practices at some sites, but these need to be consolidated and implemented fleet-wide. For instance, contractors are involved in plant-related matters and take part in the daily operational focus meetings; joint field visits are organised between EDF staff, contractors and representatives from the regional coordination centres. I am pleased to see how effective the regional nuclear contractor associations are, particularly in terms of training and maintaining competence. Some training sessions are also open to EDF staff.

The concept of the extended enterprise is evolving along similar lines within the EDF Group. It aims to integrate contract partners into EDF entities to be able to share data more effectively.

Provided that the quality of services is met, I am convinced that improvements will be achieved by increasing contractor loyalty in this way, rather than by constantly pitting them against each other. Early contractor involvement in modular planning, designed to coordinate unit outage projects, is crucial. This helps to ensure adequate forward planning of orders and provides the best visibility of future workload.

PRESERVING THE GROUP'S ASSETS - MORE AMBITIOUS TARGETS NEEDED

MINIMISING THE DEFECT BACKLOG

In the UK, the Operator's ambition is in line with international standards, i.e. to have fewer than 150 open work requests in the defect backlog per unit. I am disappointed to see that this number has been far exceeded and is still rising at all plants. The key here is not to minimise the backlog artificially by reclassifying the category or priority of the work requests, but to actually complete the work.

In France, the target is set with respect to its impact on plant availability. The threshold is therefore far greater and is set at 350 outstanding requests, despite an improving positive trend, a value which is nonetheless frequently exceeded.

In my view, it is preferable to set this target as low as possible. This is undoubtedly an ambitious target, but I have seen examples of good practices at some sites that can help achieve success:

- Some plants have been able to reduce their backlog by prioritising operational requests through constructive discussions between operations and maintenance.
- Fix-it-now teams (EIR in France and DART in the UK), which protect scheduled maintenance activities, are a success story that can be replicated elsewhere; it is vitally important that these teams are not diverted to other tasks.
- Work management rapid intervention support visits have already been conducted at two plants in the UK, and have been favourably received, although the recommendations need to be more targeted. Three more missions have already been scheduled.

Tool pouch - a simple approach for simple maintenance operations

Tool pouch is a methodology employed in the UK to perform minor or low-risk maintenance tasks (e.g. repairing leaks, replacing air filters, lubrication, etc.) without the need for maintenance documentation, isolation or a specific procedure. This approach takes advantage of the technical competency of the technician and reduces the amount of time needed to perform low-risk, non-intrusive operations.

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

Spanner time (i.e. the actual time spent working on equipment) is still too low. As identified in my 2021 report, improving this measure involves making sure that realistic and reliable schedules are in place and, more generally, improving working conditions in the field. The Minor maintenance approach adopted in the UK allows low-risk maintenance activities to be completed using simplified documentation. Similarly, the tool pouch method allows simple, non-intrusive maintenance to be performed with no procedure or document. However, this initiative has not been widely adopted and is seldom encouraged for contractors for fear of non-conformities. From a different perspective, what is more excusable? A significant non-conformity resulting from an operation carried out with a procedure, or a minor non-conformity resulting from an operation carried out without a procedure?

MAINTENANCE OPTIMISATION: VARIABLE RESULTS PROVE THAT MORE WORK IS NEEDED

Maintenance optimisation (referred to as MVM in France) has been in place for a number of years now and aims to optimise routine, preventive and predictive maintenance. Despite this, it appears that some equipment is still subject to excessive maintenance, whereas other equipment could benefit from more, especially considering the conditions of the operating environment (corrosion, cooling water, etc.).

Plants in the French fleet have some leeway when it comes to adapting maintenance programmes. However, the unwieldy nature of the process and a lack of time mean that maintenance teams are rarely able to take advantage of this. Maintenance optimisation targets essentially boil down to not exceeding a specific number of maintenance hours per outage. Activities tend to be postponed from one outage to the next rather than being truly optimised. There is still some way to go before outage project managers and maintenance planners strike the right balance, which is improving under the START 2025 project.

In the UK, and at Torness in particular, an "as-found condition code" strategy (condition-based maintenance) is being used as evidence to support maintenance optimisation. This allows a dedicated team of engineers, the ERAT (Equipment Reliability Acceleration Team), to reschedule intervals between maintenance operations. This strategy should be implemented fleet-wide to help other plants struggling to optimise their maintenance catalogue.

At Hinkley Point B, now shut down and defuelling, fuel handling equipment maintenance has been increased, whilst maintenance of other equipment has been optimised based on its operational demands.

C&I system technician at Torness

In France, predictive maintenance is difficult to implement. Diagnostics of the electric valve actuators is a case in point: a level 2 analysis of "Quicklook[2]" parameters is proving difficult as planners are no longer allocating sufficient time to the task. Planners, on the whole, do not take adequate account of the feedback given in the maintenance reports, tending instead to focus on updating the databases. Whilst this is a legitimate priority for optimising unit outages, it should not compromise a planner's technical advisory role. However, finding hotspots in transformers for example, demonstrates the relevance of this approach.

I note that good maintenance optimisation clearly relies on 100% ownership at plant level, driven by the site's Technical Director. Regular functional health reviews are representative of the operational condition of equipment, but engagement in this process varies between sites.

A good relationship between engineering teams and maintenance planners is critical for robust risk analysis and the effective optimisation of maintenance. The time taken to accept changes to preventive maintenance programmes at a national level must be reduced to maintain motivation at a local level.

DATA QUALITY - A BACKBONE TO BE STRENGTHENED

In France, the changeover from SYGMA to the SDIN nuclear technical information system introduced a temporary problem resulting in a data quality issue, where historical plant data was overwritten by reactor series data. The reinstatement of data has been initiated at all sites and needs to be continued. Despite this commitment and varying levels of success, everyone recognises the importance of the data recovery work and its beneficial effects.

The timely procurement of spare parts has deteriorated in the UK. The difficulties encountered have been caused primarily by late or incomplete demands at the work preparation stage and obsolescence management issues.

Procurement of spare parts, as well as general consumables, are still a cause for concern in France. I note that stakeholders do not seem to be fully aligned on what remains to done to return to a more stable situation. It is my belief that:

- The referencing of industrial models (MI) and the link with installed equipment needs to be completed as part of a concerted joint approach by the Central technical support entity (UTO) and the plants.
- Site leadership teams should focus on realising the full potential of collective effort.
- The efforts of those working hard behind the scenes on data sub-projects must be recognised and their frequent isolation from the project corrected.

RECOMMENDATION

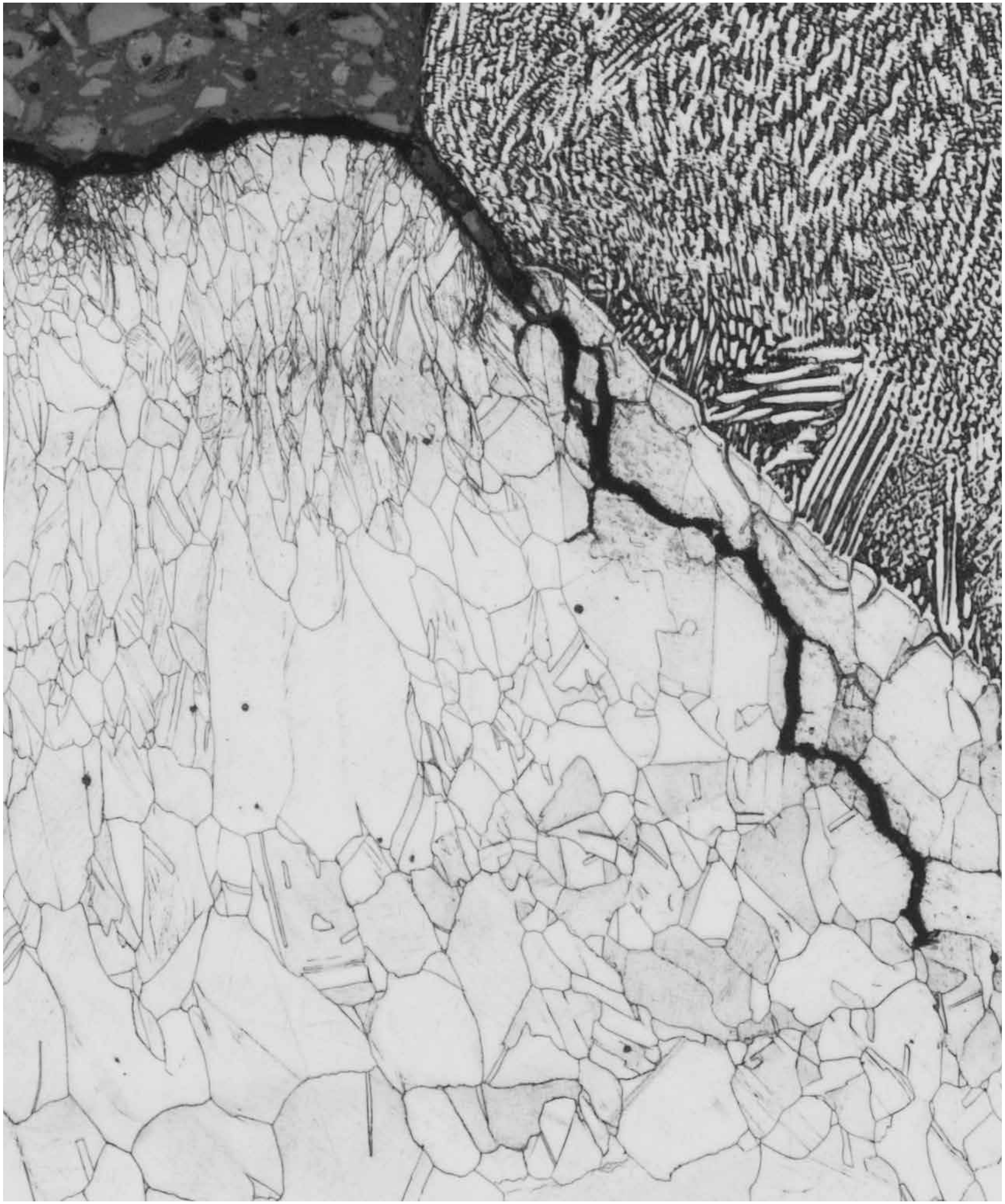
Maintenance activities are vital to the safety of nuclear facilities and demand a high level of technical expertise. Insourcing maintenance operations will enhance this expertise.

I recommend that the Director of the DPN continue the approach launched as part of the START 2025 initiative by:

- **Drawing inspiration from the successes achieved by the DPNT**
- **Fostering consistency between local initiatives and guaranteeing repeatability of the selected maintenance actions**
- **Involving all EDF Group stakeholders to establish the necessary training actions and offer attractive career prospects.**

[2] *An integrated system for online monitoring of valve actuator performance*

Contents 01 02 03 04 05 06 07 08 09 10 Appendices Abbreviations



Stress corrosion phenomenom

The year 2022 was marked by stress corrosion of stainless-steel safety injection pipes. The Operator made it clear that nuclear safety was its overriding priority regardless of the energy crisis.

Thanks to the unprecedented technical mobilisation, the understanding of this phenomenon has progressed considerably and solutions have been developed within a year.

What we know today gives us the time to carry out the necessary inspections and repairs aligned with a wide-reaching, multi-year industrial work schedule.

A year marked by stress corrosion 05

In autumn 2021, the ten yearly outage (VD) inspections on the Civaux 1 reactor (N4 series) revealed stress corrosion (SC) defects on the pipes of the safety injection system (RIS), situated between the main primary cooling system and the first isolating valve.

These stainless steel pipes are 30 cm in diameter, 30 mm thick and approximately 10 m long. They play a key role in nuclear safety because the failure of one of them would lead to a break in the primary system and affect safety injection.

AN UNEXPECTED PHENOMENON

Until now, the VD inspections were not designed to detect stress corrosion but rather thermal fatigue cracking. Though stress corrosion is a well-known phenomenon, it was not expected to occur in this material and in this location. Stress corrosion in the primary system environment is known, for example, to affect Inconel 600, which was historically used to make steam generator tubes, nozzles, vessel head adapters, etc., which led to the replacement of many steam generators.

Stress corrosion: a multifactorial phenomenon

Stress corrosion can be described as thin, branching cracks that creep between the grain boundaries. In no case is it a question of rust. It needs three conditions to occur: a sensitive material, a conducive chemical environment, and tensile stress in the material.
The 316L stainless steel in question is not known to be prone to stress corrosion in PWR primary water, unless it has been cold-worked (cold working plastically deforms the material during manufacturing). Cold-work hardening may have occurred in certain welding conditions onsite, thereby rendering the material prone to stress corrosion.
The water chemistry in the primary system is checked very regularly, and so far has not revealed any anomalies that could provoke stress corrosion without the material sensitivity having first been altered.
Sources of stress may have come from welding (residual stress), installation or in-service conditions. It seems that the combination of several of these factors is necessary.

This time, the material concerned by stress corrosion is an austenitic stainless steel that is widely used in the industry. The stress corrosion phenomena known to affect this steel grade are well documented. However, this steel grade is not reputed for being susceptible to stress corrosion in the primary cooling water of pressurised water reactors (PWR). Though cases of stress corrosion have been regularly detected in boiling water reactors (BWR), owing to their more aggressive chemistry, only a few cases have occurred in PWRs around the world. The few cases detected in France, e.g., at Bugey in 1983, were shown to be caused by chemical pollution or repairs.

SHUTDOWN OF N4 PLANTS: AN IRREPROACHABLE NUCLEAR SAFETY DECISION

Identified in Civaux 1, the first crack measured almost 6 mm in depth and covered the entire circumference of the pipe. Other welds were also affected but not to the same extent. As a precautionary measure, the Civaux 2 reactor was also shut down for inspection during which stress corrosion was also detected.

The other N4 reactors, Chooz B1 and B2, had already undergone the same VD inspections, without any stress corrosion having been detected. Analysis of the inspection results had highlighted some indications, but as it did not resemble thermal fatigue, it was classified as an artefact.

A special nuclear safety review committee meeting was held on 14 December 2021 during which it was decided to shut down both Chooz B units. This decision, in my opinion, is irreproachable. It was necessary given the size of one of the defects identified in Civaux and the similarities between the signals. It was a clear-cut decision showing that nuclear safety is the overriding priority.

BROADER INSPECTIONS AND LABORATORY EXAMINATIONS

Over the same period, inspections during the third ten yearly outage (VD3) at Penly 1 (1300 MWe P'4) detected the same type of signals. Metallurgical assessments once again revealed stress corrosion but with smaller defect sizes, between 1 to 3 mm in depth.

The DPN then reviewed all the inspection reports from previous VDs in search of signals that may have been classified as artefacts at the time, but could be indicative of stress corrosion. It was decided that all reactors under suspicion of being affected by these defects would be inspected during their outage when this was programmed for the first six months of 2022. Otherwise, an inspection would be organised

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

during a specific shutdown. A "control" reactor was also defined for each reactor series.

The main concern was that there was no non-destructive examination means, in France or elsewhere, capable of easily identifying the exact nature of this type of defect and of characterising it, particularly in terms of its depth. With the defects being located inside the pipes, it was not possible to perform dye penetration tests, magnetic particle inspections, or replica examinations, etc.

When stress corrosion was suspected, the only solution was to cut the pipe section in question and have it analysed in a hot lab[3]. Each inspection that revealed a signal led to cutting part of the line, with the reactor remaining shut down for an unknown period since the industrial and regulatory framework of these repairs had yet to be defined. In total, 157 welds were inspected on twelve different reactors.

In most cases, defects of moderate depth

Defects were all detected inside the piping and close to welds. None of the defects had started or developed in the weld itself. The material systematically revealed significant cold work hardening and the models showed that the areas in question were affected by tensile stress.
Even though some defects were between 5 to 6 mm in depth and covered all, or practically all, of the pipe circumference, most of them were between 1 to 3 mm, with limited angular extension of the cracks.

A GENERIC ISSUE

The inspections and analyses completed to date show that the N4 and 1300 MWe P'4 plants are either sensitive or very sensitive to stress corrosion, while the 1300 MWe P4 and 900 MWe plants show little or hardly any sensitivity. The only defects detected in the 900 MWe plants are located in areas that had been repaired. No defects were detected in the 1300 MWe P4 plants.

Other than in the safety injection systems, stress corrosion has been found in PWR shutdown cooling systems (RRA). Inspections will be progressively extended to other areas such as the pressuriser expansion line.

I commend the unprecedented scale of studies carried out to identify the causes of stress corrosion and to establish the priority reactors. Numerous assumptions were examined in terms of the material, the chemistry and the stresses present. The primary system's chemistry logs were reviewed and revealed no anomalies.

It also seems that residual welding stress alone would not be enough to provoke this phenomenon, as computer codes developed by R&D now allow us to model stresses accurately. The most plausible cause is the addition of this residual welding stress with thermal stresses due to vortex and stratification phenomena in dead legs. The differing pipe geometries, which determine the position and extent of thermal stress, would explain the different sensitivities between reactor series.

I note that in situ measurements are being collected to consolidate this assumption and that studies are still ongoing, such as those on the mechanism explaining the circumferential spread of some cracks or on the effect of oxygen. I believe such studies are important.

THE TRIANGLE OF NON-DESTRUCTIVE TESTING, SAFETY ANALYSIS AND REPAIRS

Plane defects, such as cracks, must normally be removed. Some can be temporarily tolerated, or left indefinitely in very exceptional circumstances provided that a strong safety case is submitted and supported by in-service inspections. Substantiation must be based on:

- Size of the defects
- Propagation kinetics
- Conservatively determined critical defect size, i.e., likely to provoke pipe failure in the case of a maximum load as calculated in accident studies.

A justification for leaving a defect for another cycle before its repair at the next outage must demonstrate that the measured size of the defect together with its estimated propagation during the next cycle, will remain below the critical defect size, taking into account uncertainties.

Non-destructive tests (NDT) able to characterise stress corrosion have been developed in under a year, which is a remarkable achievement. I also note that an extensive number of mechanical calculations (several hundred configurations investigated) have been conducted, none of which have questioned the nuclear safety of the fleet.

The kinetic assessment is a complex task when there is no precise NDT inspection history. It seems that the results of analysis, so far, lean towards slow kinetics. Studies will need to continue to consolidate this assumption; in the meantime, reasonable margins must be applied. Modelling has also shown that residual stress becomes compressive towards the middle of the pipe wall and is likely to slow down or even stop the development of stress corrosion.

Studies on the simultaneous failure of two safety injection lines have also shown that core cooling would be ensured (heating is even

[3] Hot laboratories, e.g. the LIDEC at EDF's Chinon plant or Framatome's hot facility in Erlangen (Germany), are specialised in the metallurgical analysis of radioactive components

expected to be much lower than the temperature criterion), which attests to the robustness of the PWR design.

The first repairs were completed in the second half of 2022 using the originally qualified methods and optimising the welding parameters to limit cold-work hardening. Weld grinding inside pipes significantly reduces the risk of stress corrosion; this technique is used in reactors currently under construction such as Flamanville 3, and it is expected to be implemented across the fleet.

NDT development at the Industrial Division (DI)

EXTENSIVE KNOWLEDGE AMASSED IN A RECORD TIME

An in-depth understanding of the phenomenon was reached in under a year thanks to the remarkable mobilisation of the technical, scientific and industrial means at EDF. The 157 laboratory examinations conducted on the removed pipe sections were of excellent quality, and they have been used to compile an incredibly strong database. Up until now, no anomaly of this magnitude had ever benefited from such a collection of knowledge in such a short space of time.

The development of NDT in an astonishingly short time is a key element to resolving the problem. Even if periodic inspections inevitably focus on predictable types of defects, we must keep our eyes open and a questioning attitude to avoid classifying unexpected signals as artefacts (e.g. stress corrosion), while remaining capable of detecting the problems that we most fear finding (e.g. thermal fatigue).

I am pleased to hear that a group of twelve international experts was formed who all had access to the database and were able to share their opinion on the issue.

A LONG-TERM INDUSTRIAL PROGRAMME

The many inspections and laboratory examinations, together with root-cause analyses, have provided a comprehensive enough picture to enable the implementation of a multi-year strategy. The industrial programme of inspections and repairs will be long, and as the situation evolves, it will need to be adjusted, so caution is in order.

This is not the first time that the fleet has dealt with generic defects; they are part of any technical and industrial environment, and may call for the shutdown of several reactors, which is why controllable production margins are indispensable (see IGSNR report 2021). Once this large scale issue has been definitively dealt with, it will be beneficial to perform a cold-eye review to gather the lessons learned, and in particular, how to prepare a standard optimised response for generic defects that could affect a well replicated fleet in the future.

The Sizewell B reactor in the UK will be inspected during its next outage using the same procedure. I commend the openness and quality discussions ongoing between the two fleets.

In the international arena, EDF, as a member of WANO, has informed its counterparts of the issue. I have every confidence that other operators will address this issue with the importance it deserves.

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

Flamanville 3

The EPR at Flamanville 3 constitutes a reactor series on its own. It has the benefit of the operating experience from the start-up of Taishan in China, for which it is the reference plant, and that of Olkiluoto in Finland. Their designs are different as a result of the national regulatory contexts.

Once the final system performance tests have been completed, authorisation will be given for fuel loading, criticality and raising load through the various power levels, based on the advice of the on-site testing committee (CES) and the start-up nuclear safety committee (COMSAD).

FLA3

Guaranteeing the safe start-up of Flamanville 3 06

Over the past few years a great deal of high-quality work has been carried out across a number of areas: bringing welds back into compliance, the equipment qualification task force, resolving the remaining technical issues, including taking into account operating experience from Taishan, and implementation of the site security standards.

Preparation for the operation of Flamanville 3 is managed through a comprehensive “fuel loading” project, consisting of eleven work streams. The on-site testing committee (CES) and the start-up nuclear safety committee (COMSAD) are validating equipment handover and changes in reactor operating mode.

The goal of the project organisation, ONE Fla3, is to bring the operational teams and the construction project closer together. This also meets staff expectations and has increased the Operator’s sense of ownership. In addition, the DPNT and the DIPNN have created a coordination committee to support the project director and ensure the safe commissioning of the reactor.

It will only be possible to complete the outstanding work and resolve the non-conformances with a stable schedule that is shared by all those involved. Changes from engineering or from nuclear safety authority (ASN) requests need to be strictly limited to enable plant configuration to be finalised.

The various start-up phases will contain a high number of activities. Experience from the start-ups at Taishan and Olkiluoto 3 has identified that plant adjustments will be necessary, all the way through to commercial operation, particularly on the secondary system. The equipment designers and manufacturers will have to provide solutions quickly with the expected levels of nuclear safety and quality.

The complexity of the general operating rules could result in numerous safety-significant events, which must be anticipated.

GOOD PROGRESS ON TECHNICAL ISSUES

EXEMPLARY ENGAGEMENT

The important subject of incorporating operating experience from Taishan has been managed well. I would like to recognise the excellent collaboration on the fuel issue between Framatome, EDF and the Chinese Operator TNPJVC, and also the benefit of sharing experience between the Operators and the designer. The reactor instrumentation reliability problems and the control of neutron flux variations (slight oscillation of the fuel assemblies caused by hydraulic phenomena) have been analysed and compensatory measures have been defined for the first few years’ operation of Flamanville 3; thereafter, it will be necessary to develop long-term solutions.

In a renewed climate of trust, technical discussions with the ASN are proceeding in a satisfactory manner. Sump recirculation and filtration substantiations continue, and a reliability improvement programme is taking into account the operating experience of the Sempell primary relief valves from Olkiluoto 3 and Taishan.

VVP weld repairs: an industrial success

The reactor secondary system steam lines (VVP) have been designed according to the break preclusion standard. This presupposes that their high integrity precludes the need for the safety case to take into account the possibility of their failure. As this standard was not fully complied with during their manufacture, the welds have had to be repaired in situ.
The repairs have necessitated the development and qualification of special tools, including welding robots, to work inside the VVP penetration pipes. The best qualification testing techniques have been used to validate the materials, qualify the methods and substantiate the quality of the welds.

Operations and engineering are working together to improve the reliability of certain items of equipment and extending their qualification periods, which are currently incompatible with the plant service life. Conservation measures to protect equipment to keep it in working order have been adapted for the extended construction phase. The same cannot be said for their preventive maintenance, for which the Operator has defined a recovery programme. A dedicated programme of periodic tests must be implemented to check the correct operation of equipment. I attach great importance to the effective implementation of these two programmes that contribute to the nuclear safety of the facility and will require considerable resources.

Preparation for the first major inspection outage (VC1) must now recommence to define a realistic scope and provide programme margins to deal with unexpected additional work. To enable a realistic outage programme to be defined, I suggest that some deadlines be re-examined with the ASN. In the absence of any nuclear safety need, I believe it would be preferable to replace the reactor vessel head during a ten-yearly inspection outage rather than by the current regulatory deadline.

Secondary circuit weld repairs

DIFFICULTIES SHARING GOOD PRACTICES AND OPERATING EXPERIENCE

Although necessary, sharing operating experience between EPRs remains difficult. The EPR Owner-Operator Group (EPROOG) meets once a year and provides a platform for Operators to share information. However, members find it difficult to keep in touch between meetings to raise new subjects. The most effective way of facilitating information exchange remains the reciprocal secondment of plant engineers. To support the efficient start-up of reactors, Framatome has implemented the Power UP project, and as the nuclear island designer, it provides a cross-functional link between the various EPRs when design adjustments are necessary.

Exchanging information with Taishan is becoming more complex, and sharing information with Olkiluoto 3 remains difficult for contractual reasons. *"When those involved adapt successfully despite the contractual framework and they focus on the core activities, relationships are easier and benefit the nuclear safety of the facilities."*

FAMILIARISATION WITH THE FACILITY AND DEVELOPING COMPETENCE

OPERATIONS AND MAINTENANCE COMPETENCIES

Most operations staff have been recruited to meet the specific needs of Flamanville 3. Their proficiency in the operation and knowledge of the facilities, as well as carrying out plant alignment activities, has greatly improved. The organisation of the shifts into six supplemented teams will ensure the safety of the start-up. The training courses provided by the operations and engineering training department (UFPI) meet the site needs. Operations staff are trained in accordance with the standards of the existing fleet. There are difficulties in the management of forward planning for trainer jobs and skills needs.

The number of maintenance training courses specific to EPRs is high, 64 in total. Given the small number of people to be trained each year and the limited possibilities for pooling with other nuclear power plants, this training will require special attention over time. As many training courses are sub-contracted, this dependence will also have to be managed. The maintenance teams are mainly competent on the equipment transferred to the Operator. The fix-it-now teams (EIR), which are currently sub-contracted, should be brought back in-house as their activity is one of the Operator's core responsibilities *(see Chapter 4).*

Work planners must be given the time to carry out a full update of the databases and to provide operating documentation. However, they are still too busy dealing with the outstanding work.

Together with the periodic tests and preventive maintenance, the final test phases provide a unique opportunity to become familiar with the specific features of the facility. It is only by adjusting the control systems that you become familiar with their logic. It is only by adjusting the valves that you understand how they work. It is only by starting up rotating equipment that you learn how it is controlled, and it is only by carrying out system performance tests that you fully grasp how the systems actually operate. I recommend that these tests be used to perfect the operational competences of staff. The plant's operational teams need to be involved in the testing and commissioning phases, and this needs to be anticipated when planning these activities.

SIMPLIFY THE OPERATING STANDARDS

There is still outstanding work to be completed on documentation and updating the nuclear information system (SDIN). Some engineering studies are still being finalised and some test procedures have yet to be written. In addition, the standard configuration and plant isolation procedures remain to be developed.

Tests in the main control room

I reiterate my observation that the general operating rules are too complex. The operations team, when faced with equipment unavailability, may find it difficult to define the correct actions to be taken within a reasonable timeframe. I believe initiatives to develop artificial intelligence tools are misguided. In addition, during plant start-up there is the risk of an “avalanche” of safety-significant events and of exception requests, which will not be truly representative of the nuclear safety status of the reactor.

I believe it is essential to benefit from the lessons learned through applying the general operating rules once the plant has started up, so that they can be simplified.

ENGINEERING AND CORPORATE SERVICES SUPPORTING OPERATION

ORGANISED AND ENGAGED ENGINEERING AT THE DIPNN

Edvance is organised to provide engineering support for the start-up and during first operating cycle, including the first major inspection outage (VC1). This organisation, structured at both contractual and managerial level, inspires confidence.

Handover to the in-service fleet engineering division (DIPDE) has also been planned, and is divided into three sub-projects: start-up, first major inspection outage and replacement of the reactor vessel head.

Fuel operating experience from Taishan, China

The failure of some friction springs caused by stress corrosion resulted in fretting of the cladding on some fuel rods at the base of the assembly. The increased activity in the primary fluid led the Operator to shut down the Taishan 1 reactor in July 2021 for investigation. The thresholds in the technical specifications for operation were always met.
The solution for Flamanville 3 has been defined. Only assemblies with heat-treated springs, to prevent stress corrosion, will be loaded at the periphery of the core where this phenomenon originated. New models of assembly grids will be used in the future.

The technical division (DT) and the nuclear fuel division (DCN), together with Framatome’s engineering, technical and fuel directorates, have taken decisive action to draw and apply all the lessons learned from Taishan. I acknowledge the organisational arrangements developed by the technical division to support core physics tests, which take account of the operating experience from the start-ups of previous EPRs.

The engagement from the DIPNN will have to be maintained to ensure continued responsive support of any unforeseen events, the collection of operating experience and its use to the benefit of new projects.

REMOBILISATION OF THE DPNT

In the summer of 2019, during the repair of the VVP penetration welds, the nuclear fleet adapted its support of Flamanville 3. Since summer 2021, preparation work by the DPN’s central functions has once again been accelerated.

The operations engineering unit (UNIE) signed an agreement with Flamanville 3 and has defined its organisation. The internal authorisation process has been defined for exception requests to the general operating rules. Taking into account the complexity of these rules, I question the capacity of the system to deal with the volume of requests during the start-up phase.

UNIE has the responsibility for maintaining the operating standards for all reactors in the entire in-service fleet. The advanced planning of EPR jobs and skills, arrangements for document supervision and responsibilities for writing operating documents remain to be clarified. The VC1 is sometimes considered by UNIE as the reference milestone for their readiness, whereas it is preferable to keep the fuel loading milestone as the reference.

Approximately 95% of the spare parts, under the responsibility of the Central technical support entity (UTO), differ from those of the existing fleet, sometimes only in terms of the documentation. I am pleased to note the creation of a stock of spare parts for the first 36 months of

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

operation. However, since the maintenance programme and schedule have not yet been defined, there is no guarantee there will be suitable stock to meet the needs. The provision of documentation and completion of the spare parts databases must continue. Identification and acceptance test reports are missing, not all the industrial models have been defined, and some of the initial stock of spare parts has already been used without being subsequently replenished. The Operator is currently experiencing difficulties in carrying out certain work due to a lack of spare parts.

Last of all, the DIPDE is organising the EPR-FLA 3 design authority, which will be operational in time for the fuel loading activities, alongside the DPN.

HPC unit 1 - installation of the third reactor building liner

FROM FLAMANVILLE 3 TO THE OTHER EPRS

EPR PROJECTS IN THE UK: THE AIM TO REPLICATE

The Hinkley Point C (HPC) construction site remains impressive and busy, with more than 8000 workers in mid-2022.

I commend the intention of the HPC project to allow maintenance to be carried out when units are in service, making use of the redundancy provided by the four safety trains. As a result of specific UK regulatory requirements and supply chain selection, very few equipment qualifications that have already been obtained for Flamanville 3 are applicable to the HPC design (less than 50% would be applicable).

Now that Covid restrictions have been lifted, the HPC project could now work more closely with Edvance and Flamanville 3 in order to:

- Secure the necessary resources for resolving the remaining inconsistencies between the detailed design, (Edvance responsibility), and the production of construction drawings, (HPC responsibility)
- Acquire operating experience of the Flamanville 3 start-up phase by having future operators there on secondment.

HPC

The funding arrangements for the Hinkley Point C and Sizewell C projects result in separate licensees, and could lead to different operating models being chosen for the two sites. I advocate retaining an operating model that is as close to the "one operator" model as possible in order to benefit from synergies and shared experience. The seismic criteria and the geological nature differ between the two sites, and therefore studies are needed to justify the design duplication: 1.9 million hours of studies are planned for the potential modifications.

These two findings could lead to a situation where it is no longer possible to talk about an EPR series in the UK.

Prefabrication: an advantage for the HPC construction site

The Bylor partnership has opted for a high level of prefabrication, rather than *in situ* construction. With prefabrication, it is possible to enhance quality and industrial safety, and, at the same time, improve radiography inspection conditions. The reactor pool is entirely prefabricated. Its 1100-tonne weight determined the design of the world's largest land-based crane, "Big Carl", made by the manufacturer Sarens. The reactor buildings' steel liners and domes are also prefabricated. An innovative mechanisation and automation method is being used to prefabricate 30% of the wall rebars in an on-site workshop.

EPR2: CONSIDER ITS OPERATION

The EPR2 project is gathering momentum following President Macron's announcement at Belfort, France, in February 2022, and should see its implementation being made easier by a law to simplify permitting authorisations.

At Penly, the first concrete pour is expected in 2027. I am pleased to see that the design takes full account of a series-based approach: one reactor that can be replicated on all sites, apart from specific features associated with the heat sink.

The main social and organisational lessons learned from Flamanville 3 have been used for the EPR2 project: a realistic construction schedule, local presence of the project directorate, incorporation of operating experience, cooperation with suppliers in an "extended enterprise" set-up, inclusion of the future Operator and the advanced state of the safety studies required at the first concrete pour. With regard to competences, it is important to secure the transfer of key resources from ONE Fla3 to the EPR2 project.

We must not resign ourselves to the complexity of the general operating rules. The complexities relating to engineering must be tackled right now without waiting for the required changes that are planned for the in-service fleet. Operating experience from Flamanville 3 must be taken into account.

I have noticed that the DPN team seconded to the project is providing real added value, which means that others pay attention to them. For the EPR2 reactor series, the DPN management must also define:

- The operational structure, which may have an impact on the layout of the main control room and the man-machine interface
- Maintenance strategies to inform equipment choices, predictive maintenance and associated e-monitoring needs, standard exchanges, preventive maintenance periodicity for equipment selection, etc.

Similarly, the position of the DPN during the construction phase needs to be clarified.

Lastly, with regard to information systems, I noted that the changeover from Teamcenter to 3DX, in summer 2022, needs more time so user feedback can be incorporated and the new system can be fully assimilated. I believe it is important that Framatome's Plant Lifecycle Management (PLM) be implemented in coordination with that of the DIPNN's SWITCH programme.

RECOMMENDATIONS

The start-up tests and system commissioning phases represent a major opportunity for professional development of operational competences and ownership of Flamanville 3 plant operation. I recommend that the Directors of the DPNT and the DIPNN routinely involve operations and maintenance teams in these phases.

I recommend that the Director of the DPNT, together with the Director of the DIPNN, establish the operating model for the EPR2 reactor series and simplify the general operating rules.

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

Operating experience (OPEX) must benefit reliability in three areas, that of equipment, organisation and people. OPEX is used on a daily basis to share good practices and avoid repeat events.

Operators have also been able to draw OPEX from the major events in the nuclear industry: Three Mile Island, Chernobyl and Fukushima.

Operating experience, the key to continuous improvement 07

Operating experience (OPEX) is part of a continuous improvement cycle. Its use enables improvements; it transforms the analysis of incidents into a performance driver; it acts as a lever for success in the context of recurring activities; and it also improves the management of projects, organisations and, more broadly, industry tools.

OPEX is above all about nuclear safety. It must examine the root causes and early warnings of various types of failings and focuses on events that provide the most opportunity for learning, without being limited to major events.

The continuous improvement loop starts by the collection of events, which are then analysed to understand their origins and identify areas for improvement. Next, it must be passed on so that it can be put into practice. OPEX must not only include failures or errors, it must also capitalise on successes and good practices.

MULTI-FACETED OPERATING EXPERIENCE: CONTROL HOW IT IS COLLECTED

The DPNT and the DIPNN chose a shared tool for capitalising on and processing OPEX, i.e.: Caméléon. However, not enough people are using it and adopt other parallel, processing methods. Over time, this leads to duplication, an incomplete vision and less use of OPEX.

In the UK, OPEX is collected by submitting condition reports (CR) in Asset Suite. Positive OPEX is then shared via Learning briefs.

In both fleets, however, positive OPEX is still not collected or shared enough everywhere, or adequately exploited.

Available international OPEX is effectively collected and used by the relevant teams. However, its use could be improved, as in the area of fuel (e.g., the corrosion of M5 fuel cladding). International OPEX, in particular from the United States, is regrettably restricted by the Export Control Regulations (EAR).

Sizewell B, the only PWR in the UK fleet, has the benefit of OPEX and expertise from the French fleet. Seconded French staff, working on-site or at senior management level in EDF Nuclear Generation (EDF NG), are making an effective contribution.

Caméléon: OPEX database

In the early 2010s, a single event was processed by the Operator using a number of databases. In 2015, the DPN decided to develop a tool separate from the Nuclear technical information system (SDIN) to collect and process event-based OPEX in the fleet. Caméléon was launched in 2018. The hydraulic and new nuclear directorates adopted it quickly.
In Caméléon, various means of processing can be associated with an observation. Two or three times a year, the DPN upgrades the software using an agile mode, during which time groups of users make suggestions and vote on which proposals should be added to the database.

Installation of HPC anchor plates (OPEX from Flamanville 3)

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

The sharing of OPEX, in either direction, between EDF, its suppliers, its contract partners, and even its own subsidiaries, has progressed very little as it conflicts with the protection of know-how, intellectual property and user rights.

New nuclear projects remained siloed, focused too much on deliverables and planning, and have too few resources and time to devote to providing other projects with OPEX. The Project support and digital transformation division (DSPTN) ensures cross-functional coordination on behalf of the DIPNN. Its network of liaison engineers is essential to the success of the approach. I note a real increase in maturity since the creation of the project in 2019.

ANALYSIS OF OPERATING EXPERIENCE: TOWARDS A MORE QUALITATIVE APPROACH

ORGANISATION OF OPERATING EXPERIENCE

OPEX reporting slowed down during the pandemic, but has since returned to normal, in both France and the UK.

Sharing operating experience

The central technical support department (UNIE) controls cross-functional event-based OPEX in the DPN in two timeframes:

- "Hot" OPEX on the main events in the fleet, a selection of which is shared with the plants in the weekly OPEX bulletin
- "Cold" OPEX provides an in-depth analysis of around 10% of all events, recorded in OPEX sheets (FIREX).

The Caméléon tool is still sometimes used as a tracking system in order to provide proof. Trend analyses of low-level events recorded in the tool do not add much value, as the issues are often already known. It takes time to become proficient at using the tool, and it is not easy to use; it cannot be considered as a "Google" for OPEX.

The opinion of the DPN is that OPEX from modifications is sluggish and fragmented. I support the DPN in its desire to boost, organise and coordinate this aspect.

The DIPNN organises OPEX based on three main pillars: "short loop" OPEX, "high threat" OPEX at the request of new nuclear projects, and the Caméléon information system. The entities hold regular meetings known as: OPEX committees (COREX) to examine OPEX, an operational committee (COPIL) to deal with sharing of cross-functional OPEX, and a strategic committee (CoStrat) to bring together representatives of the DIPNN management to assess whether OPEX is operating correctly and decide on improvement actions. The cross-functional coordination of OPEX at the DIPNN is becoming more mature under the leadership of the DSPTN. However, the various projects are too frequently left with the responsibility of closing the OPEX loop.

Framatome's engineering directorate capitalises on its OPEX using the "DevonWay" tool. OPEX is shared with Edvance via the "Lessons Learned Event Committee".

In the UK, the OPEX committees involve a wide range of people. These committees sometimes receive too many low-level events, which are of limited use, leading to a "data rich, action poor" culture. Information in condition reports often lacks specific detail, and thus reduces the effectiveness of the process.

Within the EDF Group, the organisational measures are very comprehensive, even complex: OPEX is certainly not under-administered!

ANALYSIS OF OPERATING EXPERIENCE, LESS IS MORE

At the DPN, OPEX focuses on: production losses, significant nuclear safety events, radiological protection and environmental events, and industrial safety events. Directives DI 100 and DI 135 cover the first two categories. Considering the teams' current workload and the unwieldiness of the analysis system, some noteworthy events that are not covered by these two directives are not analysed and shared. This is the case with many maintenance events, on the basis that they have no impact on plant availability or nuclear safety.

Event analysis is highly structured. In France, EDF uses guidelines for in-depth analysis of an event and provides training for those using them. I find it disappointing that the analysis methodology focuses action plans mainly on organisations and equipment, and too little on behaviours and competences. In-depth analyses of significant nuclear safety, radiation protection and environmental events constitutes a significant workload. In France, the application of the INES rating to characterise events is different to that of other countries. The DPN declares an average of 13 significant events per unit each year, compared with 4 in the UK. Out of 700 significant nuclear safety events reported each year in France, approximately fifty are considered noteworthy by WANO. Additionally, the systematic application of Directive DI 100, which requires an in-depth analysis of all events, creates a considerable workload, the added value of which does not necessarily justify the time spent. For example, each significant nuclear safety event investigation report (CRESS), even for minor events, is several dozen pages long and requires at least fifty hours of work. Too many actions are identified, mainly centred on organisation and documentation.

I believe it is necessary to review Directive DI 100 and how it is applied so that the effort involved is proportionate to the event, and thus free up time. I recommend the causal analyses and the actions taken for all events covered by Directives DI 100 and DI 135 take better account of behaviours and competences.

In terms of openness, I commend the sharing of experience on their respective working practices organised in 2022 between UNIE and the French Institute for radiation protection and nuclear safety (IRSN), and the existence of a long-standing partnership between the DPN and STXN (a three-member organisation comprising MARINE-DGA-CEA).

The engineering divisions, which are rarely involved in the declaration of events, are less proactive in carrying out in-depth analyses and sometimes they are too defensive. In addition to the analyses carried out by engineering departments, the second-level analysis of ESSs and cumulative compliance non-conformities initiated by the DIPDE need to be developed.

In the UK, staff involved in root-cause event analyses are well-trained in the practice. However, there are still too many actions identified, which do not adequately target the root causes. Closing the OPEX loop could be improved. Completion of Significant Adverse Condition Investigation (SACI) and Adverse Condition Investigation (ACIN) analyses are sometimes delayed, as well as completion of the resulting actions. Although the effectiveness of the main actions resulting from the analyses is measured, these completion criteria are often poorly

R&D modelling at Saclay

defined and thus do not sufficiently measure the effectiveness of actions.

The DPN is looking to reduce the numbers of events to be analysed and the associated actions to do less and achieve more. EDF NG has a similar approach to reduce the number of actions in order to better target and deal with the root causes and to ensure that actions are better managed.

THE CHALLENGES OF OPEX: REACHING WORKERS

At a national level in the DPN, technical OPEX is shared in the professional networks and the communities of practice (COP). The COPs still lack visibility and even lack support. The effectiveness of the networks is mixed. The most active networks communicate technical OPEX efficiently, which is greatly appreciated. The digital communication networks used by the management teams have created an informal information exchange system, but they cannot be regarded as OPEX tools.

On the sites, first-line management and team leaders are responsible for communicating OPEX to workers, and in particular, they must discuss OPEX briefs included in work packages with them. It is regrettable that still too few of these reports are used. On their own, reports do not suffice; the essential point remains that managers, or specialists, must support workers so that they fully take on board the practical lessons from OPEX.

OPEX, to avoid repeat events

A steam generator supply valve was closed because its C&I cable was overheating, which triggered an automatic reactor trip. This reactor trip, due to a hardware fault, could have been avoided if the OPEX-related inspections identified after a previous similar trip had been correctly performed.

When the reactor was restarted, there was a second trip due to a large quantity of algae in the cooling tower pond.

During the second start-up of the same reactor, operations to drain the condenser resulted in the disconnection of a pipe that was important for nuclear safety.

The maintenance and logistics unit (ULM) incorporates short-loop OPEX efficiently. OPEX reviews are organised systematically after each project, and these are supplemented by annual reviews. In addition, event-based OPEX from the DPN is periodically analysed by a centralised body that implements it in the ULM regional branches.

In the UK, EDF NG communicates OPEX briefs via the Organisational Learning Portal (OLP) information system. These OPEX briefs are not pragmatic enough and are difficult for front-line workers to understand. The sites currently being defuelled remain part of the EDF NG fleet and continue to use the same working practices. Defuelling is carried out in the British fleet in a timeframe that is short enough to ensure that the know-how and OPEX are transferred. The “Lead and Learn” approach is used to share information specific to defuelling.

The Knowledge Management system used by Framatome’s engineering directorate is based on the coordination of sixty or so communities of practice networks. Experts must be involved in these networks to share their knowledge and operating experience. Even within Edvance, sharing OPEX between Framatome and EDF is still complex, as access rights vary according to its four staff profiles (EDF, Framatome, staff employed under separate agreements and contractors). The protocol on the use of intellectual property rights (IPR) is the main obstacle. I would like the current renegotiation of this protocol to be used as an opportunity to simplify the daily work of those involved and to make sharing OPEX easier.

I note that, in both EDF NG and at the DPN, in-field practices have struggled to change. Issues reappear after having disappeared. Reaching workers, whether they are contract partners or not, and changing work practices in the field over time remain the most difficult. Beyond databases, a collective memory must be built up by training, using mock-ups, practice drills, mentoring, supervision in the field and practice on a daily basis. Whilst the engineering functions use their own internal OPEX within the boundaries of their organisational silos, they struggle to fully integrate operations-based OPEX.

In both fleets, and within the engineering functions, regardless of the administered systems, I believe that knowing, passing on and using OPEX is, above all, is a responsibility of the engineering, maintenance and operations departments.

KEEP THE MEMORY ALIVE

OPEX is a support for the collective memory and must be preserved over time. Ultimately, its performance is measured by the absence of repeat or similar events.

The contents of the DPN’s previous event-based operating experience databases have been successfully loaded into the Caméléon tool. Likewise, the DIPNN has transferred the OPEX log into Caméléon, which was used in previous operating experience databases.

OPEX from WANO: SOERs

WANO helps to share experience between nuclear operators by publishing reports on significant events or series of significant events similar in nature. Each Significant Operating Experience Report (SOER) includes recommendations, the implementation of which is assessed during the peer reviews. Each SOER provides the members with detailed information; a description and in-depth analysis of the events, recommendations, training courses and "How to Guides".

The engineering functions (EDF and Framatome) traditionally record their knowledge and operating experience in very comprehensive, stand-alone documents; summary reports, design documents, etc. The subject of break preclusion for the steam penetration welds at Flamanville 3 has been covered in several OPEX reports written by EDF's Industrial Division (DI) and translated into English so they can be used on UK projects. It is essential that beyond this written knowledge, the engineering entities can enable other projects to benefit from its experience.

Two British plants are currently trialling the use of an artificial intelligence tool to analyse the trends in very low-level events. I will be monitoring its effectiveness and the improvements this brings.

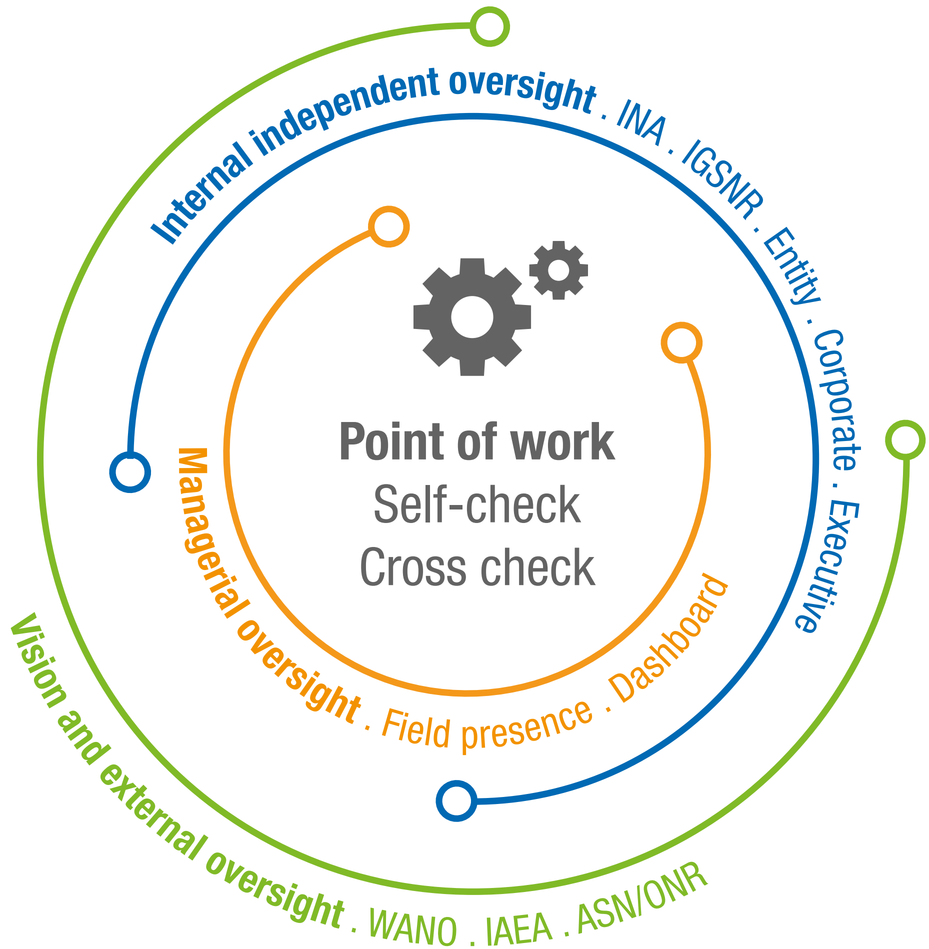
RECOMMENDATION

To make OPEX more effective by changing in-field practices and focusing on competences rather than making organisations more complex, I recommend that the Directors of the DPNT and EDF NG:

- **Simplify the in-depth analyses of certain significant nuclear safety, radiation protection and environmental events and make them proportionate to the issues**
- **Where necessary, focus actions more on competences and behaviours**
- **Re-balance resources devoted to OPEX, from upstream processes (collection and analysis) to downstream processes (communication and changes to in-field practices).**

Contents 01 02 03 04 05 06 07 08 09 10 Appendices Abbreviations

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations



The existence of an independent nuclear safety oversight team is one of the seven requirements of the Group's nuclear safety policy and an international standard of the IAEA and WANO.

Established at various levels within the EDF Group, it must be able to carry out its assessments independently of the operational teams. It constitutes an additional level of monitoring and internal oversight that does not take the place of each worker's responsibility (self-checking) and that of management (presence in the field).

WANO provides an external view, and the French nuclear safety authority and the IAEA carry out external oversight.

Independent nuclear safety oversight: recovering its agility 08

The EDF Group has established independent nuclear safety oversight teams in all the divisions and functions associated with nuclear activities: power plants, engineering departments, maintenance entities, new reactor construction projects and decommissioning entities.

Independent nuclear safety oversight is organised differently between the nuclear power plants in France and the UK. It is firmly established and complies with international standards.

In the UK, independent nuclear safety assessments are conducted by the Independent Nuclear Assurance (INA) teams. Local teams report directly to the corporate organisation and not to the site management. The corporate team carries out topic-based inspections, based on a four-year programme on behalf of the corporate level of EDF Nuclear Generation's (EDF NG) executive team. The corporate INA and the local teams each produce a twice-yearly report on nuclear safety, industrial safety, radiation protection and the environment, which they share with the management of each site or the EDF NG executive team. Each site also has a Technical and Safety Support Department (TSSD) consisting of a nuclear safety engineering team, the Nuclear Safety Group (NSG), and a quality audit team, from the Quality Management Group (QMG). The manager of this department, the Technical and Safety Support Manager (TSSM), reports directly to the Station Director.

Sixth requirement of the Group's nuclear safety policy

An independent nuclear-safety assessment function, often taking the form of an independent safety oversight organisation, operates within each entity, especially on each nuclear site, and at Group level. Independent from the line management, it verifies that the governing principles and standards of this policy are properly implemented. It reports to the manager of the entity and escalates concerns if it deems this necessary. Managers ensure that these functions possess the requisite resources, skills and level of authority, and that they effectively fulfil their oversight role.

In France, independent assessment, inspection, audit and nuclear engineering skills are combined in a nuclear safety and quality department (SSQ). The Nuclear Safety Director or the Safety & Quality Manager (CMSQ), who is a member of the site's leadership team, coordinates the nuclear safety activities of the team. The Nuclear Inspectorate (IN), the national audit and inspection unit, carries out assessments on-site and in the DPN's engineering units, as well as in the stakeholder entities of the DPNT, including the DIPDE. It produces in particular an annual report on the status of nuclear safety in the French fleet.

This chapter looks at the activities of the independent nuclear safety oversight team, but does not cover audit and inspection activities carried out both locally and at a corporate level. These activities are based on a long-term programme and lead to recommendations, the added value of which is acknowledged. Likewise, this chapter does not cover the activities of the Nuclear Safety Review Board (NSRB), which deals with EDF NG sites.

INDEPENDENT TEAMS THAT OPERATE THROUGHOUT THE WHOLE GROUP

ON THE SITES: A MATURE ORGANISATION BUT WITH FRAGILE RESOURCES

Operational management teams on both sides of the English Channel clearly demonstrate their reliance on the independent nuclear safety oversight team and seek its critical view.

Routine practices are in place, including the daily "cross-examinations" between the shift manager (CE) and the nuclear safety engineer (IS) in France, and regular meetings between the INA and Shift Manager (SM), the Operations Manager, or Station Director, in the UK.

The independent nuclear safety oversight teams are dynamic and motivated. Their assessments and interactions with the operations teams are very structured. Nuclear safety engineers and operations or maintenance teams frequently work closely together. In addition to the assessments, there are regular analyses of any non-compliances to determine any issues requiring attention and weaknesses that need to be taken into account.

Early outage safety review

At the beginning of any major outage, a willingness to start work as quickly as possible could compromise compliance with the nuclear safety, industrial safety and quality standards. During the first five days of the outage, an INA team carries out an independent examination of the standards and behaviours, through in-field observations and discussions with workers. This assessment is used to confirm whether those involved in the outage understand and are complying with the nuclear safety, industrial safety, and quality standards.

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

In France, the nuclear safety engineers have a good level of operations expertise as they need to be qualified in accident management. Their involvement in nuclear safety engineering, which is frequently sought during the constant changes to operating standards, increases their knowledge of reactor operation.

In the UK, the clear separation between the INA and nuclear safety engineering ensures there is a wider diversity of skills and knowledge. This makes it is easier to perform independent assessments across a wide range of activities. However, maintaining a high level of knowledge of the nuclear safety principles in relation to design is more difficult and remains the prerogative of the Nuclear Safety Group (NSG).

I regret that in both France and the UK, the independent nuclear safety oversight teams do not always achieve their head-count complement. There are numerous reasons for this: a succession and development strategy that does not fully take into account staff movements and examination panel failures, and the fact that the role is not very attractive as a result of the lack of professional opportunities available when leaving the oversight function.

In France, given the required qualification in accident management, it is difficult to easily broaden recruitment to include profiles other than those from operations. In the UK, the restriction on transferring to the INA from an operations role at the same site makes it difficult to have operations experience, and may affect the credibility of INA assessors with operations staff, including the Shift Manager.

Penly plant

INDEPENDENT OVERSIGHT IS ESTABLISHED IN THE ENGINEERING DIVISIONS, BUT NEEDS TO BE REINFORCED

Independent nuclear safety oversight teams are in place in all the engineering and project divisions and functions. More often than not, they have recognised skills. However, their position within the organisations varies depending on the entity. Some are integrated in independent oversight bodies, such as DACI at Edvance, while others are integrated in nuclear safety engineering departments, such as the DESA (design authority) at the DIPDE, which also assumes the role of design authority for the DPNT.

The Independent Nuclear Regulator (INR) is operational at the Hinkley Point C construction site, with an organisation similar to that at operational sites. At Flamanville, the One FLA3 project emulates the independent nuclear safety oversight arrangements of the DPN operational sites for all assembly and testing activities.

The independent nuclear safety and quality oversight department (DFISQ) carries out assessments in the divisions and functions of the engineering and new-build projects directorate (DIPNN). Some evaluations are carried out with the support of the DPN's Nuclear Inspectorate. Others incorporate independent nuclear safety oversight managers from engineering and project functions.

I note that management consults the independent oversight teams for their opinions, notably in their regular meetings, and tries to take into account the recommendations they are given. This approach strengthens the authority of the independent nuclear safety oversight teams, bearing in mind that they do not yet have the maturity of those working in the power plants. The independent nuclear safety oversight teams are now regularly invited to technical decision-making meetings and give an independent opinion. I was able to note some examples of this during my visits and I believe this is essential for future progress. I expect an independent oversight team in an engineering entity to talk about nuclear safety objectives, design safety cases and margins, rather than focusing only on the quality control of documents.

I support the ambition, adopted by the DFISQ, to move towards a challenge-based approach, in the spirit of a responsible operator's nuclear safety mindset, rather than solely managing compliance with regulatory requirements. I believe that the different viewpoint of independent nuclear safety oversight must also be applied to behaviours and skills and, more broadly, to the nuclear safety culture.

Progress is needed to improve efficiency. Independent oversight teams must ensure there is a balance between the nuclear safety engineering activities that they must do, and targeted reviews that they independently decide to perform.

I am pleased to see the efforts made to share independent oversight practices between all the Group's divisions and functions. The DFISQ coordinates the DIPNN's independent oversight teams. Links between the DPNT and DIPNN independent oversight teams have been strengthened. The organisation of the first EDF Group seminar for independent oversight teams in December 2022 is evidence of this.

THINKING OUT OF THE BOX, THE KEY TO SUCCESS

DAILY NUCLEAR SAFETY ASSESSMENT: A VALUABLE ROUTINE PRACTICE

Every day, the on-call safety engineers (IS) and the duty shift managers (CE) carry out a nuclear safety assessment of the plant status across the site. During their field visits, the IS carry out an in-depth assessment of the main control rooms and plant indications, and often have discussions with the operators and the control room supervisors. They also carry out systematic inspections of the electrical facilities and the permit issuing office. A procedure is used to guide them through this data collection. However, they could be more challenging regarding main control room serenity or the application of operator fundamentals. In addition, maintenance activities are rarely assessed. At the end of each morning, the CE and the IS meet to share their nuclear safety assessments in a face-to-face "cross-examination" style meeting.

I regret that this independent nuclear safety assessment is part of a large routine that does not leave enough time for initiatives outside of the procedures, some parts of which may be identical to that already carried out by operations personnel. It is more difficult to detect unusual situations if there is no thinking outside the box or looking at things from another angle. Thus, the IS do not notice the scaffolding that has not been used for two months and is blocking an evacuation or fire access route in an electrical room.

In the UK, the "cross-examination" of daily nuclear safety assessments is left to the initiative of both parties: the INA and the shift managers. The INA attends the daily review of condition reports. They may also ask the shift manager to carry out additional analyses.

The INA satisfactorily covers the areas of maintenance (including contract partners), radiation protection, and engineering. However, it must improve its understanding of operations issues, covered more broadly by NSG engineers. These engineers have proven expertise on operating safety cases and reactor physics. NSG provide the SM with advice on the assessment of non-compliances, interpretation of the technical specifications, and reactivity control.

INDEPENDENT OVERSIGHT IN FRANCE: INCREASE THE AREA OF ANALYSIS AND PROVIDE A FORWARD-LOOKING VIEW

A significant amount of time is spent on recording the detection of all operational non-compliances and on assigning a significant event classification, which are declared to the nuclear safety authority (ASN). The same amount of effort is spent on minor non-compliances and other more sensitive issues, which can be subject to differences in analysis between the CE and the IS. A better balance needs to be found between the excessive procedural formality and the added value of an independent analysis *(see Chapter 7).*

Discussion between a shift manager and safety engineer at Belleville

Contents | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | Appendices | Abbreviations

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

The IS have developed an in-depth knowledge of the general operating rules and the safety cases as a result of their nuclear safety engineering activities. This is a valuable asset for providing operations staff with advice and assistance and identifying any non-compliances. However, the increasingly detailed classification of non-compliances into categories must not divert the IS from the priority of developing a better understanding of non-compliances, and thus help prevent repeat events.

The time saved could be better employed to broaden their scope to challenge issues and, for example, expand their assessments to cover:

- Maintenance activities in the field
- Competence (quality of training and refresher courses)
- Sharing lessons learned from major events
- Embodiment of the nuclear safety culture
- Radiation protection behaviours (particularly in the context of the recovery plan)
- Management of organisational changes
- Integration of modifications and assessment of actual improvements in nuclear safety
- A more forward-looking view of the nuclear safety situation at the sites.

The oversight teams contribute to the annual safety report (DAS). This involvement is essential, considering their independent view. However, I am disappointed that these annual safety reports do not take better account of employee behaviours, and do not truly analyse the nuclear safety culture beyond the effectiveness of the supporting sub-processes. Additionally, they also tend to be activity reports, which are cumbersome, administrative and without any real forward-looking view, which is the guarantee of continuous improvement in nuclear safety *(see Chapter 2)*. I acknowledge the content changes that will be made to the future reports.

IN is gradually positioning itself as the DPN management's independent oversight body. They challenge the DPN management's views, and they select their own topics for investigation. For instance, the incorporation of significant events in operations training courses has been assessed and criticality reports have also been analysed. I encourage the continuation of these initiatives.

INDEPENDENT OVERSIGHT EFFECTIVENESS: MORE QUALITATIVE ASSESSMENT

The performance of the independent oversight teams must be assessed regularly, as stated in the Group's nuclear safety policy.

Quantitative assessment is currently carried out via indicators:

- Rate of integration of recommendations, with each site setting its own target
- Employee and competence status
- Rate of accepting advice.

This last indicator measures the proportion of decisions given in favour of the independent oversight team's suggestions regarding the declaration of significant events. I believe there is too much importance attached to this indicator, given that its interpretation may be difficult, or even convoluted. Does a low value mean there is a weakness in the independent oversight team or there is a conservative attitude in the operational departments? Does a high value indicate an inability in the departments to detect issues or an overly administrative interpretation of the general operating rules?

Discussion with the ONR at Torness

Beyond these indicators, management should develop a more qualitative assessment of the independent oversight teams' efficiency, including:

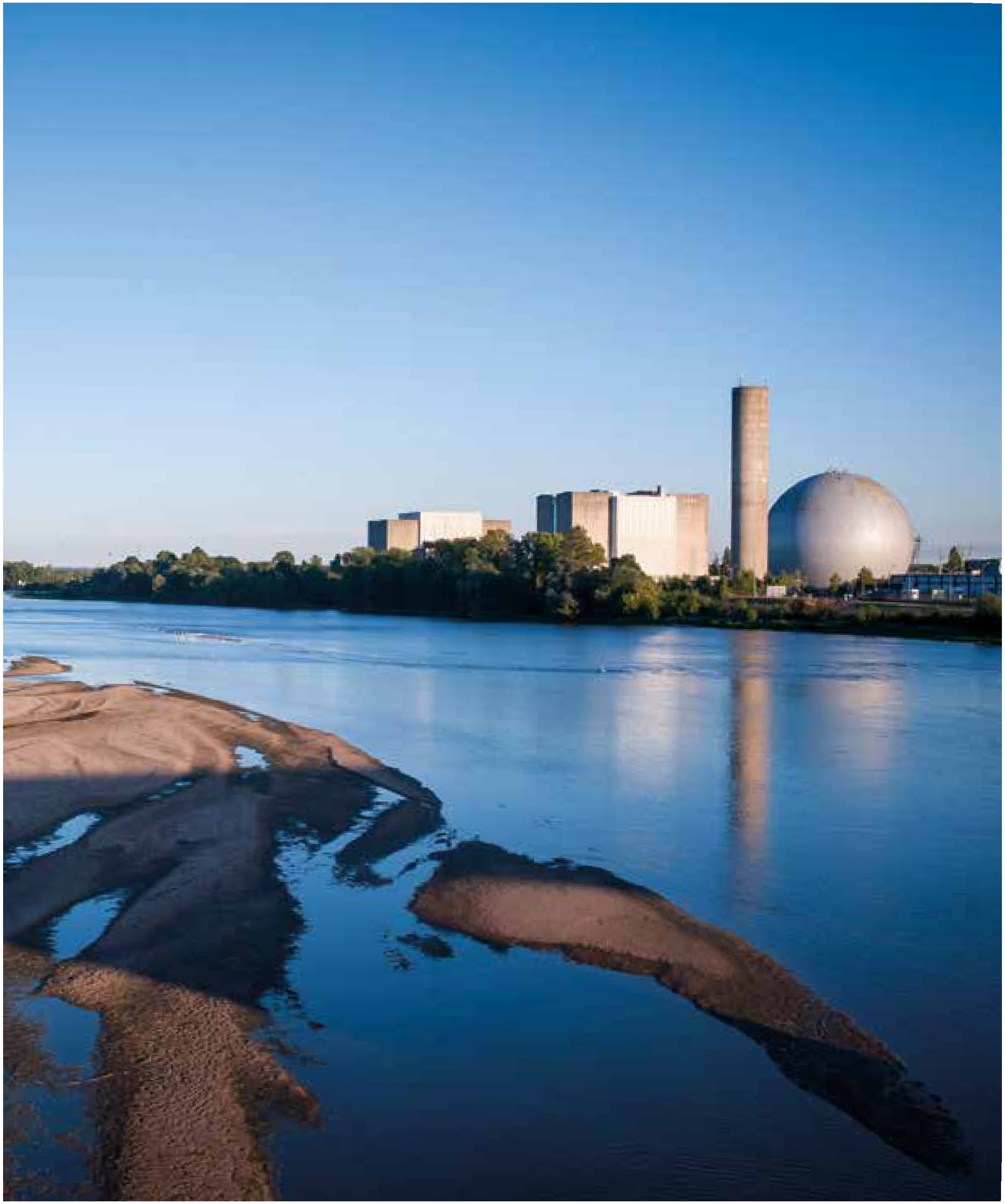
- Assessment of the areas covered and the departments assessed
- Assessment of behaviour in the field and nuclear safety performance, rather than just looking for compliance with the rules
- A more forward-looking view of trends and not simply adopting a position in response to events
- Critical nature of the assessment reports
- Participation in operational meetings and analysis of decisions made
- Quality of analysis of nuclear safety culture surveys, and challenge of the associated action plans
- Participation in the various independent oversight networks.

RECOMMENDATION

The independent oversight teams must have sufficient competent staff with a wide range of profiles.

I recommend that all the Group's entities with an independent oversight team adapt their advanced planning of jobs and skills to cover all their activities and thus ensure that all new recruits fully adopt the nuclear safety culture.

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations



Chinon A reactors

Decommissioning is an integral part of the nuclear industry and a condition for its sustainability: the Group truly has taken up the challenge and its commitment is clear.

In the UK, a new page was turned in EDF Energy's history with the start of defuelling of the first reactors in the AGR fleet.

In France, dismantling of its UNGG reactors has now begun, while Fessenheim will represent the first-in-series in dismantling PWRs.

Decommissioning: a strong profession in the nuclear industry

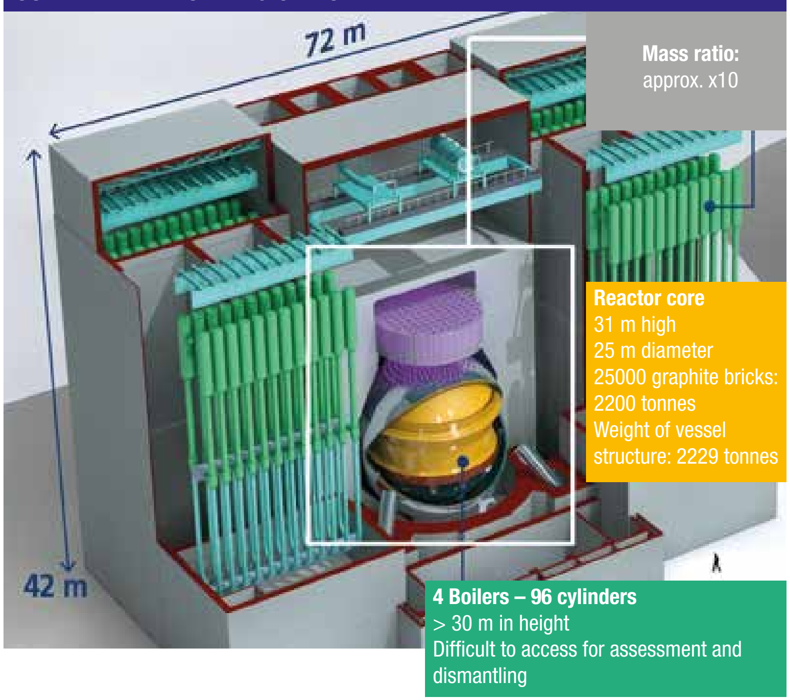
09

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

At the end of a reactor's service life, the Operator must proceed with defuelling and transfer of the irradiated fuel to either La Hague or Sellafield. The next step is dismantling, which is governed by legislation that is very different between France and the UK.

EDF has a very diverse range of licensed nuclear facilities (INB) to dismantle. In France, there are gas-cooled graphite-moderated reactors (UNGG), the first PWRs (Chooz A and Fessenheim), and some unique facilities such as Brennilis, the Superphénix fast reactor and the irradiated material workshop (AMI). In the UK, the first of the advanced gas-cooled reactors (AGR) have been shut down.

CONTAINMENT BUILDING CHINON A2



Comparison of an UNGG and a PWR

Once the irradiated fuel has been removed from the site, most of the nuclear risks disappear; there is no longer a risk of criticality, there is no decay heat, and the source term has been reduced by 99.9%. Containment remains the only nuclear safety function and hazards generally concern environmental aspects (radioactive liquids, sludges and gases), fire risks, radiological protection, asbestos and industrial safety. The risk of contamination by alpha particles is a specific concern in the field of radiation protection.

The availability of interim storage and disposal facilities for spent fuels and nuclear waste is a prerequisite for decommissioning. In France, the national plan for radioactive materials and waste (PNGMDR) now updates the waste management plan every five years. The most recent version was published on 10 December 2022.

Very unique nuclear facilities

The AMI irradiated material workshop located on the Chinon A site was specifically tasked with analysing irradiated fuel samples.
The Brennilis heavy water reactor, shut down in 1986, was the subject of a public enquiry at the start of 2022 regarding the official decree for complete dismantling, which is expected to come out in 2023 and will authorise dismantling of the reactor block.
The monitoring and dismantling of the Superphénix fast reactor requires significant resources. The sodium has been removed from the reactor vessel and cutting operations on the diagrid will start soon. The reactor fuel, whose decay heat is very low, is currently being stored in an onsite facility (APEC).

A STRONG IMPETUS

The Group's commitment to decommissioning and defuelling is clearly visible. Industrial functions are growing in size and showing great initiative. The dismantling projects are well-coordinated. Cost control is a very important aspect considering that dismantling projects are long term and financed by public money in the UK or via legal provisions in France.

At the French sites, I have met many people motivated by the broad range of subjects, greater independence and interesting career opportunities. Two-way job transfer channels established between the DPN and the DP2D should be further encouraged. The DP2D is the nuclear operator of licensed nuclear facilities undergoing decommissioning, and protocols have been agreed with the relative plants for site security, fire services, emergency preparedness, etc., which are working well. At the UK sites, I noticed that staff found defuelling jobs appealing and have shown an interest in transferring to Magnox, since they can offer long-term job prospects to some locally based staff.

Since their transfer from the DIPDE to the DP2D, the Lyon-based engineering functions seem to be better incorporated into decommissioning projects. The matrix organisational structure between projects and disciplines is functioning well enough despite a few persistent silos. Engineers must spend more time doing site visits so they can be sure that their proposals always reflect the realities of the facilities.

Decommissioning projects have several characteristics:

- A very comprehensive and precise inventory of the site must first be established, especially its radionuclide inventory, which can prove complex in legacy facilities
- The facility is constantly undergoing transformation
- The end products of this process are radioactive waste packages.

The field is also driven by innovation, for example, in robotics and diagnostic methods.
In France, the complex administrative procedures and lengthy document review schedules are shocking (usually between 5 to 10 years), whereas the reduced number of risks should help to reduce documents and procedures. Simplification of nuclear safety reports and the general operating rules is essential, for example, regulatory tests for lifts have been classified as periodic safety tests. I also question the principle of periodic safety reviews for facilities that are in the process of being dismantled. These reviews should at least correspond to milestones where the facility's physical characteristics have changed, rather than following a fixed 10-year calendar.
In the UK, before the site licence can be transferred to Magnox, it must be proved that there is no fuel remaining on site, and the handover of site operations must be precisely organised. EDF NG and Magnox are in the process of jointly defining the transfer arrangements.

Different legislation

In France, the Operator is responsible for dismantling, who remains both the owner and final entity responsible for spent fuel and waste, even after its acceptance by Orano or ANDRA.
In the UK, the ownership and responsibility for spent fuel, facilities and nuclear waste are transferred to a public organisation called the Nuclear Decommissioning Authority (NDA). Spent fuel belongs to Sellafield (NDA) as soon as it arrives at their storage facilities. The AGR site operating license is transferred to Magnox (NDA) at the end of defuelling after fuel-free verification.

Sites under decommissioning are assigned their own independent nuclear safety oversight team. As priorities have shifted from nuclear safety to radiation protection, industrial safety and environmental protection, is it necessary to retain the same organisational arrangements? In the UK, Independent Nuclear Assurance (INA) has adapted its means of assessment to better reflect the activity of defuelling, which has its own specific safety issues.

SPENT FUEL REMOVAL - AN OPERATIONAL ACTIVITY

Defuelling a PWR is a radically different operation to defuelling an AGR. While in service, a PWR core is completely unloaded and then reloaded during each unit outage, with either a third or a quarter of the fuel assemblies being replaced. Each of these operations takes two days to complete. In AGRs, refuelling and defuelling operations are carried out frequently (every two months), with only partial replacement of the fuel while the reactor is at power. Such operations usually last about ten days.

Fuel route at Hartlepool

The spent fuel stored in the cooling ponds of the two reactors at Fessenheim was completely transferred to La Hague in August 2022. It was completed in 15 months without any problems, which I believe is a commendable performance. The sense of injustice felt by the staff at having to shut down the reactors transformed into pride at being able to finish operations on a high note by successfully completing the final unloading operation. The plant was very thorough in its review of the spent fuel removal procedures. A hot debriefing after each operation made it possible to fine tune the process for the next operation. I believe it would be worth sharing this OPEX with all the sites, as spent fuel removal is a frequent operation. At the end of a reactor's service life, spent fuel removal is a continuous activity, and to maintain a high level of quality, it is therefore important to avoid this becoming a routine activity. I am pleased to see that Fessenheim is chair of a WANO working group on this topic and that its staff were able to visit La Hague plant.

The two reactors at Hunterston B were shut down in November 2021 and January 2022 respectively, with defuelling commencing in April 2022, once the Office of Nuclear Regulation (ONR) had validated the last remaining safety cases. The Hinkley Point B reactors were shut down in July and August 2022, with defuelling activities commencing in September this year. I am pleased to hear that site staff were able to visit Sellafield. Having been shut down since 2018, it was decided in June 2021 that Dungerness B would not be restarted, and its defuelling would start in mid-2023.

Owing to the sheer size of the core and the complexity of operations, the complete defuelling of two reactors is expected to last at least three years. The type of activities will be the same as those carried out during reactor operation, but they will be continuous. Teams will have to remain vigilant for the entire duration to ensure the reliability and safety of the fuel route. Maintaining competence and staff motivation will be a key focus point, making sure there is no sense of falling into a routine or being under excessive pressure.

Fuel route

Designed to operate with slightly enriched uranium, AGRs, contrary to PWRs, have very large cores with a lot more and longer fuel assemblies that can be replaced during operation, known as online refuelling. The building and dismantling of fuel assemblies is carried out in this facility. The fuelling machine is a very complex item of plant as it handles plug units and fuel assemblies, not to mention acting as a containment barrier while the reactor is in service and pressurised at 40 bar. One refuelling machine is used for two units and is located in the same hall.
The fuel route refers to all the facilities involved in the delivery, transfer and disposal of fuel; the assembly and dismantling of fuel assemblies, their loading and unloading, interim cooling, and storage in fuel ponds. The fuel route is required to run continuously, which means its reliability is a key issue for AGR operation owing to the significant number of basic operations involved with complex kinematics.

Fuelling machine at Hinkley Point B

The complete defuelling of an AGR core was not integrated into its design, so specific safety cases had to be written to justify it. For example, in the case of a fault on the fuelling machine, dropping a fuel assembly the full length of the fuel channel was integrated into the design, but this was not considered for a plug unit. It therefore had to be demonstrated that the impact of a dropped plug unit would not damage the core support plate. It was also checked that the CO_2 flows were still able to guarantee cooling in a core with a mixture of empty channels and channels filled with fuel assemblies.

All AGR fuel is transferred to Sellafield for storage. The fuel 'dismantler'[4] at Sellafield is a potential bottleneck in the process; and its reliability has been improved. With the available buffer storage capacity estimated at one to two months, a technical issue with the dismantler could quickly lead to the suspension of defuelling operations. Sellafield and EDF Energy are acutely aware of this problem. There is close cooperation between the defuelling industry partners within the AGR Operating Programme (AGROP).

I was able to visit La Hague and Sellafield facilities and to observe the extensive investments.

UNGG REACTORS: DISMANTLING GATHERS MOMENTUM

After having been long deferred pending radioactive decay and the development of technical solutions, the dismantling of the UNGGs has

[4] *A unique, highly advanced machine that removes fuel rods from the fuel elements, and then places them into canisters which are optimised for long-term storage in a pond*

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

finally started, which is commendable. The standard of worksites and the positive attitude of the teams (see above) were clearly visible during my visits to Chinon A and Saint-Laurent A.

Boilers at Chinon A2

The dismantling of UNGG reactor vessels has not yet been performed at an industrial level anywhere in the world. Obviously not considered during design owing to the size of an UNGG (about ten times larger than a PWR), this large-scale operation is faced with difficulties such as cutting through 10 metres of containment concrete, and uncertainty surrounding the best method for cutting and recovering graphite blocks from the core.

The Group revised its strategy in 2016, switching from a graphite removal and metal structure cutting method performed underwater, to a method performed in air. The project is planned in three phases: an industrial demonstrator, followed by a first-in-series trial at Chinon A2, and finally the dismantling of the five other UNGG reactors. The first-in-series dismantling operations are expected to take about thirty years, while the others should continue to the end of century. The new applications requesting dismantling authorisation were submitted in late 2022.

The industrial demonstrator was introduced in 2022. It comprises an industrial test building in which the graphite cutting and handling robots will soon be trialled. I stress the importance of preparing for fire and dust explosion risk mitigation during UNGG graphite cutting operations.

Before the reactor vessels can be dismantled, the auxiliary systems must first be completely removed, and good progress is currently being made. Chinon A3 is an impressive cathedral of steel owing to its size and the installed handling equipment. Restoration work on the external structures has started, such as at Saint-Laurent A. The seismic qualification of the civil structures must be justified for their anticipated lifetime (a century); the concrete sample analysis results are very positive at this stage.

The main risks lie with highly contaminated sludges, liquids and legacy waste found at the bottom of ponds, silos, tanks, etc. The situation is improving significantly, with the decontamination of the reactor ponds and the ongoing removal of legacy waste from Saint-Laurent and from pits in the AMI irradiated material workshop. Several sensitive areas will remain for a few more years, notably at Saint-Laurent A and the AMI. I call for continued vigilance to ensure that their containment remains intact, especially with respect to natural hazards.

The risk of alpha particle contamination is common to all fuel cycle plants and facilities being dismantled. It is rarely found at plants in service, and calls for specific measures in terms of worksite cleanliness and radiological protection controls.

Lastly, I believe it is important to preserve Chinon A1 and its sphere-shaped reactor (now a museum), a technical and industrial legacy of which the region is very proud.

FESSENHEIM: THE FIRST-IN-SERIES FOR FRENCH PWRS

It is much easier to dismantle a PWR than it is an UNGG reactor. About ten have already been dismantled in the United States. Most of the equipment and systems except those in the reactor pit, remain accessible during operation. Steam generators, the largest items in the nuclear island, are regularly replaced.

In France, the dismantling of Chooz A, the first French PWR, has advanced well and is serving as the prototype. Underwater cutting of the reactor internals has been completed and will be followed by the vessel itself; it is a pilot for cutting techniques. Lessons have also been learned from pool monitoring (development and treatment of microalgae) and industrial organisations. As the reactor is in a cavern deep in the bedrock, the collection and management of infiltration water is a specific issue. The radioactivity level of this water is already nearing the threshold under which it may eventually be exempt from surveillance. Reactor dismantling will not be the end of the cavern, the CNRS plans to install a neutrino detector, as an older generator has already operated in an adjoining cavern.

At Fessenheim, the actual decommissioning process will only start after publication of the official decree authorising dismantling, which is based on meeting specific initial plant condition requirements. I approve the principle of a joint DPNT and DP2D pre-dismantling project team, which has been tasked with establishing these conditions. The project has been divided into twelve work-streams with clearly defined objectives and responsibilities. The deep decontamination of the primary system is one of its key activities. The pre-dismantling operations need more resources than originally anticipated. The handover of operator responsibilities from the DPN to the DP2D is programmed for September 2023, and the pre-conditions for this transfer must be carefully verified.

During this pre-dismantling period, significant parallel activities, and a multi-faceted organisation, mean that the site must continue to fully exercise its daily responsibilities as an operator regarding work authorisation, isolating equipment, dismantling other equipment, etc. The plant's organisation is evolving with each phase and with each successive wave of staff departures. At Fessenheim, I was able to witness first-hand the team's enthusiasm, proactive mindset and ability to adapt to a constantly evolving environment. This approach could serve as an inspiration to the plants in service. I support the priority given to ensuring the future of its staff and commend the site's determination to make a success story of its final shutdown.

Many years will separate the decommissioning of Fessenheim from the rest of the French PWRs, which is why its operating experience must be recorded precisely and meaningfully so we can capitalise on this know-how to improve all future decommissioning activities.

WASTE DISPOSAL FACILITIES: A PREREQUISITE

It is common to think about decommissioning in terms of the waste packages it will produce. Moreover, this waste must have an outlet. For this reason, the declaration of public utility for the Cigéo deep geological repository is welcome news, as is ANDRA's submission of its licensing application.

A project is being implemented, following very rigorous inspection procedures, to release very-low-level radioactive steel from disposal so it can be re-used, after melting, in conventional metallurgy sectors. This development would be beneficial for two reasons: being able to recycle raw materials that are free of risk and reducing the final waste volumes destined for ANDRA facilities, which are a rare commodity. At Fessenheim, the development of a Technocentre will be used to melt such metal resources. This is an excellent initiative, similar to other projects already existing in Europe.

Pending establishment of the Technocentre, and because authorisations for interim waste storage and transit facilities are restricted to 2 years, it seems that large quantities of dismantled steel will nonetheless end up in ANDRA's final disposal facilities. This would be regrettable considering the objective to avoid unnecessary storage at these facilities, and I believe an alternative solution should be identified.

In the same spirit, the management of dismantled concrete waste needs to be optimised. Transferring tonnes of clearly harmless concrete rubble to radioactive waste disposal facilities does not seem to be the best solution. Whether for the characterisation of waste inventories, or the application of procedures, excessively conservative measures generally have a negative impact on radioactive waste management.

Some specific types of waste are still without a suitable outlet, and in my opinion, planning for the final disposal of UNGG graphite waste is a top priority.

Finally, decommissioning must be incorporated into the design of all future reactors. For instance, materials should be selected, not only taking into account radiological protection during operation, but also the final waste that will be produced, e.g., the in-core reactor instrumentation materials.

RECOMMENDATIONS

Based on a logic reflecting the proportionality of the risks, I recommend that the Directors of the DPNT and the DP2D simplify the nuclear safety reports and general operating rules of the licensed nuclear facilities undergoing dismantling, and that they work with the ASN to simplify the administrative procedures and application review processes.

Extensive experience of graphite has been developed for the AGRs; I recommend that the Director of the DP2D foster cooperation with EDF NG and Magnox as regards the knowledge, anticipation and testing of graphite properties.

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

Visual inspection of a fuel assembly at Romans

Framatome's resources have been engaged in the global development of civil nuclear power, and in supporting the French fleet in resolving their difficulties. In this context, nuclear safety, industrial safety and quality are the core values underpinning all actions taken by Framatome's employees and contractors.

Standardisation of products and manufacturing, equipment conformity and the roll-out of human performance tools have all helped to strengthen these three core values.

Skills management, organisation of independent oversight, and analysis of weak signals (particularly in industrial safety) are areas that require specific attention.

Report by the Inspector General of Framatome 10

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

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

General Inspectorate of Framatome

The role of the General Inspectorate (IG) is to provide the Framatome CEO with an assessment of the health of nuclear safety in its operational entities, 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 nuclear safety, radiation protection, process safety5, industrial safety, and environment. Its activities are defined in a yearly programme, which is submitted 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.
The IG also conducts site visits to assess how nuclear safety and industrial safety are perceived by employees at all levels and across all disciplines, through informal interviews conducted without the presence of line managers.

NUCLEAR SAFETY CULTURE: PRESENCE IN THE FIELD AND COMPLIANCE WITH STANDARDS

The training programme launched in 2021 to train all Framatome employees over a four-year period is progressing well. The target for 2022 (to have 50% of all employees trained) has been exceeded. From my field observations, I note that there is now a far greater understanding of nuclear safety culture principles at all levels.

The IG assessed the nuclear safety culture at Framatome's Le Creusot plant, as well as at the Montbard plant, which was acquired in 2021. At each site, an assessment team of a dozen members, including two managers from other business units (BU), appointed by the executive committee, completed approximately sixty interviews and field visits. These assessments demonstrated effective communication at all levels of the organisation and a readiness to involve employees in making changes to their working environment. At Le Creusot, human performance tools are being implemented, and at Montbard, I was pleased to see how committed employees are to the company values and their awareness of the importance of product quality.

I reiterate the need to improve the presence of managers in the field and the rigorous application of standards. Delivery of these actions needs to be improved. Critical skills must also be managed more effectively to predict future requirements and provide the necessary training to ensure qualifications are up to date.

CONSOLIDATING INDEPENDENT NUCLEAR SAFETY OVERSIGHT

The nuclear safety policy at Framatome clearly states the primary responsibility of line management in relation to nuclear safety. The independent nuclear safety oversight organisation verifies that first-level oversight is carried out at every level of the organisation. The IG constitutes the second level of oversight.

The first-level independent nuclear safety oversight team is gradually taking shape. Representatives have now been identified in all the BUs and other operating units (plants or projects) and they perform this role in tandem with their other duties. They have all received specific training on their oversight role. However, I note that this team is not actively pursuing this role. I believe an analysis needs to be performed, to understand exactly what is hampering independent nuclear safety oversight. At the very least, as stipulated in the independent oversight mission statement, all entities should have a surveillance programme in place.

NUCLEAR SAFETY

STANDARDISATION, A CONTRIBUTION TO NUCLEAR SAFETY

The quest for operational excellence in the BUs, as laid out in the 'Excell in Quality' plan, led to a commitment from Framatome in 2020 to standardise all mechanical components in the nuclear steam supply system (NSSS). Significant improvements are expected; structured manufacturing processes achieved through system engineering; more effective management of materials and equipment conformity; reproducible manufacturing processes; reducing equipment changes that are sources of non-compliance; operating experience (OPEX) that

[5] *The management of industrial risks such as chemical hazards*

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

offers a greater benefit to series production; and greater compliance with regulatory milestones.

In my view, this approach enhances nuclear safety in the construction of new reactors.

Standardising NSSS components

Introduced in 2020, the objectives of this approach are two-fold; firstly, to "do it right first time", by integrating the manufacturing conditions of mechanical components at the design stage, and secondly, to simplify by proposing a design standard that will be used for all future projects from 2023, including those intended for export. The initiative relies on two programmes.
The first investigates the standardisation of EPR2 equipment and is considered as the benchmark. Using previous manufacturing OPEX, the manufacturability of this equipment has been analysed, and the standardisation processes have been consolidated by integrating them into system engineering practices.
The second involves defining a design standard with two configurations: "EPR1", corresponding to EPRs already built or under construction, and "EPR2", corresponding to future projects.
This standardisation approach has also been extended to reactor safety C&I systems.

STRESS CORROSION TASK FORCE (CSC)

Since the announcement of the discovery of this issue, Framatome has mobilised teams and resources to support EDF. The objectives of this task force are as follows:

- Examine the samples collected from the fleet in Framatome's hot cell laboratories
- Contributing to the root-cause analysis of the issue
- Substantiate defect tolerances using mechanical calculations
- Develop a non-destructive testing process to characterise the defects according to the different circuit geometries
- Develop an automatic welding process to mitigate the stress corrosion risk
- Help to replace the systems impacted by stress corrosion (Bugey 4 and Chooz B1 in particular).

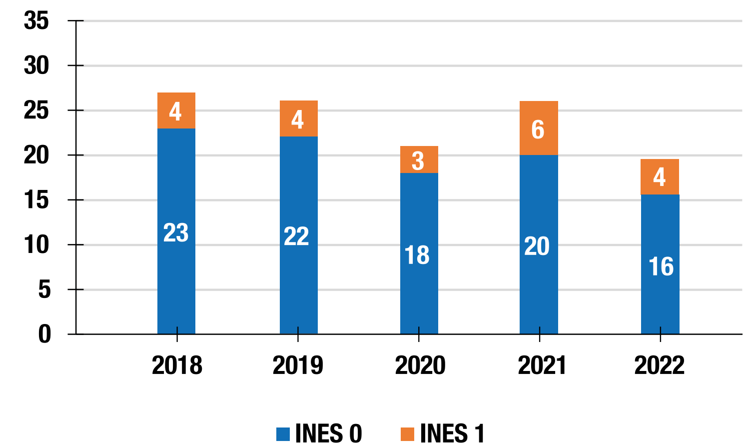
Given the radiological conditions and the heavy workload associated with these activities, with EDF's agreement, Framatome has drafted in support from their American and Canadian partners. Some 140 welders, machine tool operators, pipe fitters and worksite coordinators arrived in France in the summer of 2022 and have been trained by Framatome at their Chalon facility.

MORE IN-DEPTH ANALYSIS OF SIGNIFICANT EVENTS

The analysis appraisal committee reviewed 8 reports from significant events in the areas of nuclear safety, industrial safety and the environment. These appraisals lack depth and do not identify all the root causes. They also fail to consistently take account of the organisational and human factors, with very few field operators being involved in the preparation of these event reports.

NUCLEAR SAFETY RESULTS

No INES Level 2 event or higher was declared in 2022. The number of Level 1 events (4) fell this year with the reduction in the number of criticality events.



Trend in the number of INES events

This reflects the positive impact of the action plan launched in 2021 at the Romans-sur-Isère facility. The IG will continue to monitor this ongoing improvement closely throughout 2023.

There has been an increase (8 in 2022, 3 in 2021 and 2 in 2020) in the number of radiation protection events involving Framatome employees working at EDF facilities (in the BU Installed Base (IB)). Action with staff must be taken.

One of these INES Level 0 events involved a printer fire that broke out on 21 September 2022 in a workshop at the CERCA facility at Romans-sur-Isère. The site triggered its emergency response plan for the very first time and the fire was extinguished by the on-site fire safety teams. No radioactive material was affected by the fire. This emergency was handled extremely well, with no impact on operators or the environment.

RADIATION PROTECTION - LEVERAGING OPEX TO REDUCE OCCUPATIONAL DOSES

There was little change in the mean occupational dose figures for Framatome employees (0.8 milli-Sievert) and contract partners (0.1 mSv) in 2022. The same applies to the number of employees having received a dose below the minimum recordable level (zero dose), with the figures standing at 30% for Framatome employees (compared with 28% in 2021) and 34% for contract partners (compared with 36% in 2021).

The sites with the highest recorded annual doses (13.9 mSv) and for contractors (8.9 mSv) were Lynchburg in the US, and Chalon, Intercontrôle and Maubeuge in France. These sites are involved in maintenance and inspection operations at nuclear power plants. For Chalon and Intercontrôle, I recommend that a rigorous assessment of OPEX from the stress corrosion maintenance operations be conducted to help improve occupational dose estimation and reduction.

The ageing of the existing nuclear fleet has caused an increase in radiological activity of primary system pumps maintained at Maubeuge. As this plant already has an effective policy for monitoring individual exposure levels, my advice is to investigate new solutions to reduce the doses received.

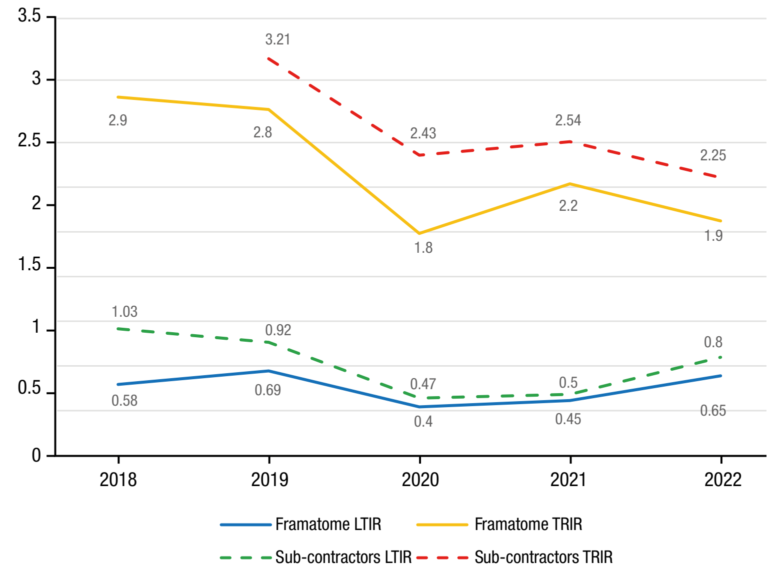
INDUSTRIAL SAFETY - A SHARED PRIORITY

The industrial safety performance objectives were consolidated in 2022. They are now consistent for Framatome staff and sub-contractors alike, with a global lost-time injury rate (LTIR) of less than 1 and a global total recordable injury rate (TRIR) of less than 2. At the end of the year, these indicators stood at 0.8 and 2.25 respectively, close to the target values.

The 2023 targets will be even more demanding, with a global LTIR of less than 0.5 and a global TRIR of less than 1.8.

Managers from the relevant BUs must present analyses of the most significant events to the CEO, demonstrating that the importance of industrial safety is exhibited at the highest level of Framatome.

I note, however, that the results for the BU Installed Base have deteriorated throughout the year. This is attributable to two factors: the integration of a new subsidiary (Framatome ARC, ex EFINOR) with far worse industrial safety results than the high standards demanded by Framatome (initial LTIR greater than 20); and an increase in the LTIR relating predominantly to on-site teams. This is a worrying trend given the high demands placed on BU Installed Base services and the causes need to be identified.



Trend in accident frequency indicator rates

On the subject of integrating new subsidiaries, the support offered by 3SEP[6] and the respective BU, through in-field visits in particular, is helping to raise awareness of the importance of nuclear safety and industrial safety among newly integrated staff. The IG will be inspecting Framatome ARC on the subject of industrial safety in 2023.

REVIEW OF INSPECTIONS AND VISITS

In 2022, the IG carried out 19 subject-specific inspections and 14 follow-up inspections to review progress against the uptake of its recommendations.

EMERGENCY PREPAREDNESS AND FIRE SAFETY AT THE RICHLAND SITE

As agreed with the US Nuclear Regulatory Commission (NRC), the IG carries out two inspections every year at the Richland fuel fabrication facility, with a focus on one of six specific subjects: emergency preparedness, radiation protection and the environment, fire safety, criticality management, chemical hazards, and staff education and training. In 2022, the inspections focused on emergency preparedness and fire safety.

[6] *Health, safety, environment and protection body*

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

The emergency preparedness plan is sound: responsibilities are clearly defined, all staff are well trained and drilled, and emergency response equipment is well maintained. I am pleased to note the effectiveness of the new headcount system for emergency evacuation procedures. I ask the site to update the agreement with the Richland Fire & Emergency Services Department to include the need for fire-fighters to be trained to fight fires in a radiological environment.

Fire risk management relies on standards strictly complying with the applicable regulations, appropriate training, robust drills and exercises, inspections and regular internal audits. Improvements are still needed in terms of preventing exothermic reactions, and paying attention to detail when preparing documents authorising hazardous work.

CRITICALITY MANAGEMENT AT LINGEN AND ROMANS-SUR-ISÈRE

The organisation and documentation at both these sites meet expectations. Periodic equipment testing is performed. The management of competences and training is consistent with their needs, and qualifications are monitored rigorously.

I advise Lingen to consolidate its exercise drills programme and to take better advantage of OPEX from Framatome's two other nuclear plants.

At Romans-sur-Isère, monitoring non-conformities and incorporating regulatory requirements in the documentation for the different facilities could both be improved. The programme launched to clarify operating rules in the aftermath of events that occurred in 2021 is ongoing. I recommend that operators play a greater role in drafting operations-related documentation, as per IAEA standards.

OPERATIONAL RIGOUR

In 2020, the compliance with the operational standards and the traceability of activities were inspected at: the CEDOS equipment maintenance and decontamination facility in Sully-sur-Loire, the CEMO equipment servicing and repair facility in Chalon-sur-Saône, the Karlstein and Erlangen facilities under the Engineering & Technical Directorate (DTI) in Germany, and the Erlangen facility under the BU IB. The nuclear safety, industrial safety and quality policies are all clearly set out in the standards inspected at these facilities. The different operational responsibilities and delegation of activities are also clearly defined.

However, coordination of improvement actions, monitoring of authorisations and qualifications, and operational management of chemical products at both the CEDOS and CEMO facilities could be more efficient.

Inspection of a steam generator spacer plate at Saint Marcel

Human performance tools are rarely used at the two DTI-run facilities. An action plan must be implemented swiftly to remove the accumulated waste at Erlangen.

The 5S continuous improvement strategy relating to the working environment and conditions remains to be implemented at the IB site.

Finally, independent nuclear safety oversight must be implemented at the German sites.

MANAGING EQUIPMENT CONFORMITY

Following several equipment-related events, Framatome launched a plan to validate and improve equipment conformity at the end of 2021. The IG inspected four sites on this subject.

I note that all four sites had the correct arrangements to monitor this issue. Responsibilities were clearly defined, regulatory training requirements were met, emergency evacuation procedures exist for staff working on machinery, and the necessary physical and organisational arrangements are in place.

The main areas for improvement relate to: the lack of operational safety instructions at workstations and equipment conformity documentation; overdue periodic checks; consideration of regulatory requirements when investing in new machinery.

Consolidating equipment conformity

Framatome introduced a programme to assess and restore equipment compliance after non-conformities were confirmed on several machines. This assessment defined the corrective actions to be implemented by the BUs and identified the required compensatory operational measures. Framatome has also started to assess the remaining service life of bridge cranes in the wake of a fatal accident that occurred at a Ugitech plant in January 2022. This assessment began in 2022 and will continue through 2023. It is based on OPEX from port facilities and covers all bridge cranes that have been in service for more than 19 years. Their remaining service life and any additional operating checks required will be defined.

MANAGING COMPETENCES AND QUALIFICATIONS AT RUGLES

The Rugles plant was inspected on its ability to manage and predict the competences and qualifications needed for its operations. I have seen evidence of close collaboration between managers and HR in this area. The needs are being predicted by appropriate systems and critical skills are being monitored very closely.

I advise Rugles to ensure that the roles, qualifications, authorisations and training that represent the greatest challenges to nuclear safety, industrial safety and quality are more clearly identified. Self-assessments of the nuclear safety culture must also be performed.

INDUSTRIAL RISK MANAGEMENT AT LYNCHBURG

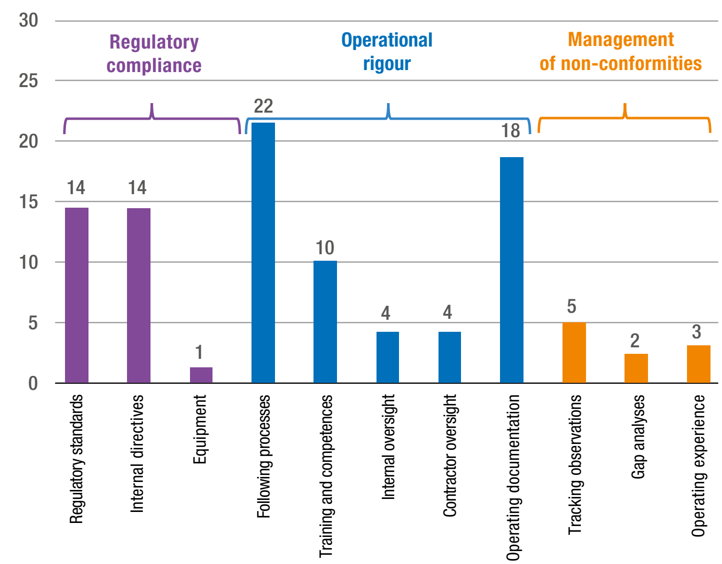
This American site, which comes under the BU IB, has satisfactory industrial safety and radiation protection results. Risk analyses are conducted for production and maintenance activities. Non-conformities are recorded, and improvement actions are monitored closely.

I note, however, that the independent oversight arrangements required by Framatome have not been implemented, and that chemical hazard management could be improved. Sub-contractors must be systematically informed of the risks involved with the operations assigned to them.

UPTAKE OF RECOMMENDATIONS

In 2022, IG issued 64 recommendations, 42 of which were implemented, including 18 that were more than two years old. A total of 97 recommendations are currently in the process of being implemented, with 2 of these being more than two years old. The same objective of keeping the number of recommendations of more than two years old below 10 will be reapplied in 2023.

Operational rigour (mainly the quality of operational documentation and compliance with processes) was the main subject of recommendations (60%), followed by regulatory compliance (30%), and management of non-conformities (10%).



Classification of outstanding recommendations

RECOMMENDATION

The effectiveness of independent nuclear safety oversight depends on being able to assess the practices of operational chains of command on a regular basis. I recommend that the surveillance programmes for first-level independent nuclear safety oversight be formalised and implemented systematically, and that their effectiveness be evaluated regularly.

Contents 01 02 03 04 05 06 07 08 09 10 Appendices Abbreviations

Belleville plant

Appendices

RESULTS FOR THE EDF SA FLEET

Nº	Indicators	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022[5]
1	Number of significant nuclear safety events graded 1 or greater on INES per reactor[1]	1.19	1.14	1.16	0.98	1.12	1.28	1.45	1.4	1.34	1.4
2	Number of significant nuclear safety events (0 or greater on INES) per reactor[1]	11.60	10.8	10.03	9.78	11.59	12.6	12.7	12.4	12.9	12.2
3	Number of significant events per reactor • Non-compliance with technical specifications • Reactivity	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	1.5 0.7
4	Number of alignment errors[2] per reactor	1.22	1.41	1.74	1.64	1.78	1.24	1.4	1.3	1.1	1.3
5	Number of trips per reactor (for 7,000 hours of criticality[3]) • Automatic • Manual	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	0.4 0
6	Average operational collective dose per nuclear unit in service (in man-Sv)	0.79	0.72	0.71	0.76	0.61	0.67	0.74	0.61	0.71	0.67
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 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	0 0 0
8	Number of significant radiation protection events	116	113	109	117	131	170	171	173	108	140
9	Availability (%)	78.0	80.9	80.8	79.6	77.1	76.5	74	71.9	72.9	58.07
10	Unplanned unavailability (%)	2.6	2.4	2.48	2.02	3.26	3.7	3.95	5	4.55	2.36
11	Occupational accident rate Tfg (per million hours worked)[4]	3.3	3.2	2.7	2.8	2.2	2.3	3.3	2.9	2.93	3.10
12	Occupational accident rate LTIR (per million hours worked)[4]	-	-	-	-	-	-	2.4	2.2	3.2	2.00

[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*
[5] *Data don't include CSC (8,3%, CSC included)*

RESULTS FOR THE EDF ENERGY FLEET

Nº	Indicators	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	Number of significant nuclear safety events graded 1 or greater on INES per reactor[1]	0.80	0.33	0.47	0.27	0.47	0.53	0.27	0.07	0.47	0.13
2	Number of significant nuclear safety events (0 or greater on INES) per reactor[1]	5.13	4.47	7.40	10.00	6.13	5.93	6.73	5.47	6.20	5.53
3	Number of cases of non-compliance with technical specifications per reactor	0.67	1.53	1.00	0.80	0.60	0.60	0.67	0.87	0.53	0.60
4	Number of alignment errors[2] per reactor	3.33	2.80	2.87	3.13	0.93	1.67	1.67	1.00	1.33	1.20
5	Number of trips per reactor (per 7,000 hours of criticality[3])										
	• Automatic	0.45	1.17	0.57	0.3	0.49	0.89	0.56	0.35	0.63	0.49
	• Manual	1.03	0.62	0.19	0.42	0.37	0.20	0.32	0.00	0.27	0.00
6	Average operational collective dose per nuclear unit in service (in man-Sv)										
	• PWR	0.386	0.365	0.048	0.544	0.296	0.096	0.255	0.031	0.383	0.028
	• AGR	0.034	0.074	0.067	0.021	0.020	0.050	0.032	0.013	0.012	0.015
7	Exposure of individuals:										
	• Number of individuals with doses above 20 mSv	0	0	0	0	0	0	0	0	0	0
	• Number of individuals with doses between 16 and 20 mSv	0	0	0	0	0	0	0	0	0	0
	• Number of individuals with doses between 14 and 16 mSv	18	5	2	1	0	1	0	0	0	0
8	Number of significant radiation protection events	27	27	18	20	10	23	28	26	29	18
9	Availability (%): • EDF Energy fleet	78.9	72.1	77.3	83.0	81.6	76.1	65.8	61.7	60.4	77.9
	• PWR	83.0	84.1	100	82.0	83.8	89.4	80.6	99.4	64.2	98.7
	• AGR	78.2	70.2	73.7	83.1	81.2	74.0	63.5	55.9	59.7	73.1
10	Unplanned unavailability (%): • EDF Energy fleet	6.9	10.7	2.3	5.1	5.0	3.1	4.0	5.0	12.3	4.8
	• PWR	0.2	0.7	0	0.1	0.0	2.2	0.2	0.6	0.0	1.3
	• AGR	7.9	12.3	2.7	5.8	5.7	3.3	4.7	6.2	14.3	5.9
11	Occupational accident rate LTIR (per million hours worked)[4]	0.2	0.2	0.4	0.3	0.2	0.5	0.3	0.3	0.3	0.5
12	Occupational accident rate TRIR (per million hours worked)[4]	0.7	0.8	0.6	0.7	0.4	1.1	1.0	0.7	0.5	0.8

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*

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

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	2023
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	2023
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	2023
1981	Dampierre 4	890	1993	2004	2014	-
1981	Gravelines 4	910	1992	2003	2014	-
1981	St-Laurent B1	915	1995	2005	2015	2023
1981	St-Laurent B2	915	1993	2003	2013	2023
1981	Tricastin 4	915	1992	2004	2014	-
1982	Blayais 2	910	1993	2003	2013	-
1982	Chinon B1	905	1994	2003	2013	2023
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	2023	-
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

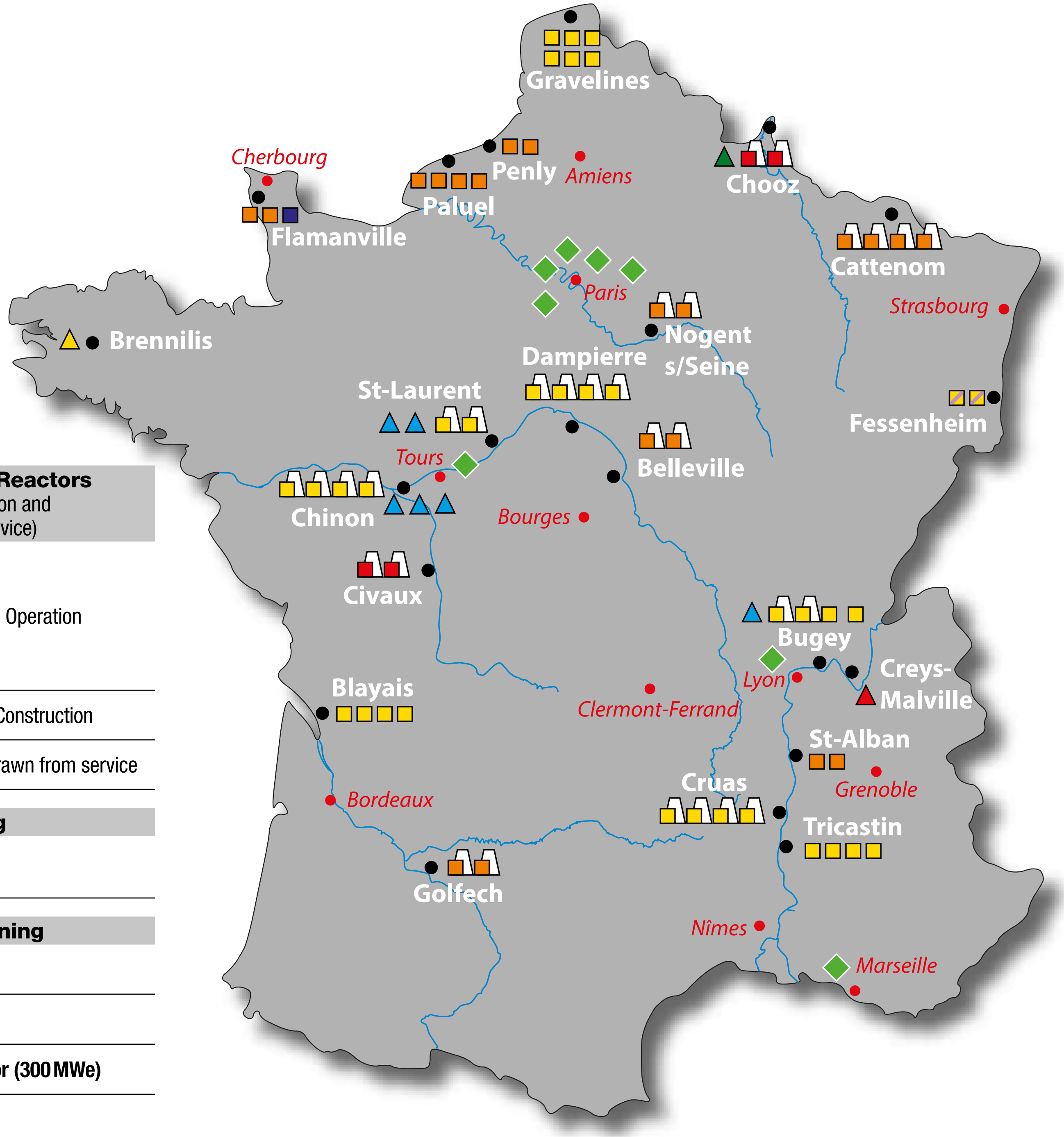
Year in service	Nuclear unit	Reactor number	Power MWe	Planned date of withdrawal from service
1976	Hinkley Point B	R3	480	2022
1976	Hinkley Point B	R4	475	2022
1976	Hunterston B	R3	480	2021
1976	Hunterston B	R4	485	2022
1983	Dungeness B	R21	525	2021
1983	Dungeness B	R22	525	2021
1983	Heysham 1	R1	580	2024
1983	Heysham 1	R2	575	2024
1983	Hartlepool	R1	595	2024
1983	Hartlepool	R2	585	2024
1988	Heysham 2	R7	615	2028
1988	Heysham 2	R8	615	2028
1988	Torness	R1	590	2028
1988	Torness	R2	595	2028
1995	Sizewell B		1198	2035

Contents
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

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	
4	1 450 MWe	
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
01
02
03
04
05
06
07
08
09
10
Appendices
Abbreviations

FRAMATOME NUCLEAR SITES

États-Unis

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

Reste du monde

8. Japon : Tokyo
9. Corée du Sud : Séoul
10. République tchèque : Prague
11. Russie : Moscou
12. Ukraine : Kiev
13. Bulgarie : Sofia
14. Slovaquie : Bratislava
15. Hongrie
16. Suède : Helsingborg
17. Espagne : Zaragoza, Tarragona, Madrid
18. Royaume-Uni : Londres
19. Afrique du Sud : Le Cap
20. Argentine
21. Brésil : Rio de Janeiro / Angra dos Reis
22. Canada : Pickering / Kincardine

Chine

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

Allemagne

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

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

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

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