The Inspector General's report

on Nuclear Safety and Radiation Protection

2019

EDF

FOREWORD

This report, written for the Chairman of EDF, gives my assessment of nuclear safety and radiation protection within the EDF Group.

The report is also intended for all those in the company who contribute in any way to nuclear safety and radiation protection through their day-to-day actions and decisions. It will have achieved its purpose if it provides food for thought on their contributions in these areas.

It also aims at identifying any early warning signs and recommending areas for improvement. It therefore focuses on difficulties and weaknesses rather than strengths and progress. This may seem unfair to those who spare no effort to ensure that complex, demanding nuclear power facilities are designed, built and operated safely.

Like each year, this report does not set out to cover all subjects. The number and length of the chapters are intentionally kept to a minimum to highlight the most important points.

This report focuses on all matters within the EDF Group that contribute in any way to the safety of nuclear activities. This is particularly the case for engineering and operations in both France and the United Kingdom. It is, however, important to avoid making any hasty comparisons between these two fleets as the reactor technologies, fleet sizes and regulatory contexts differ.

My assessment is based on information gathered and observations made during the year, whether from workers in the field, or during visits to plants and meetings with the main stakeholders: staff representatives, members of the medical profession, contractors, etc. It also makes use of comparisons with other international players on the nuclear scene, and draws on dialogue with WANO[1] and the nuclear safety regulators.

I would like to thank all those I met for their unstinting help and candour, not to mention the breadth of our discussions. Their openness, which determines the relevance of this report, is fully in keeping with the spirit of a nuclear safety culture.

I would also like to thank Jean-Michel Fourment, André Palu, Bertrand de L'Epinois and Stephen Preece who have been relentless in their efforts, particularly in drafting this report. I would like to give a special mention to John Morrison who left the team in 2019. Like last year, the chapter focusing on Framatome has been written by its Inspector General, Alain Payement.

Finally, although this document has not been written for public relations purposes, it is available to the public in both French and English on the EDF website (*www.edf.fr*).

EDF Group Inspector General
for Nuclear Safety and Radiation Protection

François de Lastic
Paris, 22 January 2020

[1] *World Association of Nuclear Operators*

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Chooz nuclear power plant

My view

THE GLOBAL NUCLEAR SCENE

Following the IPCC's[1] 2018 report, more and more institutions and communications, in particular in the European Union, are emphasising the significant benefit of nuclear energy in the fight against global warming.

The Russians and the Chinese are notably active in the civil nuclear industry. One third of the reactors[2] under construction worldwide use Russian technology. In China, with 47 reactors in service, the fleet has more than doubled in size between 2014 and 2019, and more than 40 further reactors are either under construction or planned. There is also a ship-based SMR[3] in Siberia.

In the US, the situation is contrasted:

- The American nuclear fleet generated more electricity than ever in 2018
- Two reactors were shut down in 2019 due to competition from shale gas
- There is considerable excitement about plans for innovative nuclear reactors.

In France, the Energy and Climate Act, passed in November 2019, sets a target for nuclear energy to provide 50% of electricity generation by 2035. The "French energy and climate strategy" draft (also called the long-term energy plan) was issued in January 2019 for discussion, and will soon be finalised. The draft includes:

- Closing 14 nuclear reactors, most of which will have been in operation for 50 years
- Completing, by mid-2021, a work programme for potentially starting the construction of new reactors
- Designing a French SMR
- Starting a research and development programme on multiple recycling of fuel (see Chapter 5).

I would like to link this last point with the French Alternative Energies & Atomic Energy Commission's (CEA) statement in August 2019, stating that *"the industrial development of fourth-generation reactors is no longer planned before the second half of this century"*. In reality, this puts an end to the Astrid project on fast reactors, a technology in which France has considerable skills.

To meet the requirements of the French energy and climate strategy, the nuclear industry is focusing on certain key areas in which I note determined efforts with regard to skills, which are central to quality and nuclear safety.

The CEA, TechnicAtome, Naval Group and EDF announced their SMR project in September 2019. This 180 MWe modular PWR, named Nuward, will incorporate several major innovations (see Chapter 8).

In the UK, Toshiba has abandoned its planned construction of a new reactor at Wylfa; conversely, the nuclear safety authority's assessment of the CGN-designed[4] Hualong reactor is progressing. EDF, as CGN's partner in this project, must assess whether the Hualong reactor complies with its own nuclear safety practices and standards.

THE EDF GROUP

The envisaged major reorganisation of the EDF Group is causing a great deal of apprehension within the company. This reorganisation is linked to a potential change in the French regulations governing the sale of electricity. From a nuclear safety perspective, it is essential that the new organisation, however it is structured, maintain consistency and synergies between all the nuclear functions across the French and UK fleets, the engineering divisions, R&D, etc.

In December 2019, EDF announced its '*Excell*' plan to boost its industrial capacity. To be deployed from 2020, this plan should "*allow the French nuclear industry to reach the highest possible level of rigour, quality and excellence.*" It addresses the issues raised in the

[1] *Intergovernmental Panel on Climate Change*
[2] *In late 2018, 15 of the 45 reactors under construction were using Russian technology*
[3] *SMR: Small Modular Reactor, generating between 10 and 300 MWe*
[4] *China General Nuclear Power Corporation*

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report by J-M Folz and will be equally beneficial for new nuclear build projects and the current fleet in service. I note the effort made to improve quality - and thus nuclear safety - by consolidating:

- Customer-supplier relations
- Qualification of the most sensitive manufacturing processes
- Skills, e.g. welding
- Management of major nuclear projects.

THE FRENCH FLEET

In 2019, Tricastin was the first of the 900 MWe reactors to complete a fourth ten-yearly inspection outage (VD4). These outages generate a considerable workload, around twice that of the VD3 outages. Extensive forward planning of work, modifications performed with units in service, and increased engineering support made it possible to complete the first of these VD4 outages successfully. However, I am concerned that the next VD4 outages will be less straightforward due to the specific features of these sites and the fact that outages will be undertaken simultaneously.

Modifications made to the plant during these VD4 outages will greatly enhance nuclear safety, particularly with regard to resistance to internal and external hazards (see Chapter 6). However, the large number of modifications could result in increasingly complex systems (see Chapter 2) and I have some concerns on staff ownership of all these changes.

During the earthquake on 11 November 2019, the plants in the Rhône valley responded as designed. In line with its internal rules, EDF manually shut down the Cruas reactors, located approximately 12 kilometres from the epicentre. Inspections and verifications of the site, under the supervision of the French nuclear safety authority (ASN), revealed no nuclear safety anomalies associated with the earthquake. This confirms the robustness of the design and the inherent margins.

Machine operator - Paluel nuclear power plant

The severity of this earthquake was comparable to that of the maximum historically probable earthquake (MHPE). It is therefore necessary to fully characterise this event and confirm or re-examine the seismic assumptions within the current design.

Earthquakes and design of nuclear power plants

Earthquakes are measured by their intensity, which assesses the damage observed on the earth's surface (scale from 1 - 12), and by their magnitude, which assesses the energy generated by an earthquake source (logarithmic scale). Three different scales can be used to measure magnitude: local magnitude (Richter scale), which is the most well-known; moment magnitude, used by scientists to represent the energy released at the epicentre of the earthquake; and surface-wave magnitude, used in nuclear power plant design.

In France, the seismic hazard is based on a deterministic approach established by the ASN (RFS 2001-01). Seismic zones and faults are identified in the region of each site; they are then used to calculate the highest intensity historical earthquakes and the maximum historically probable earthquake (MHPE). The magnitude of the MHPE is then increased by 0.5 to obtain the safe shutdown earthquake value (SSE). The plant design-basis acceleration values are then calculated based on the SSE. The SSE values are reassessed at every ten-yearly periodic safety reassessment.

The current MHPE (from VD3) for Cruas and Tricastin was determined based on an earthquake in 1873, which had a surface-wave magnitude of 4.7 and a depth of 4 km. This resulted in an SSE with a surface-wave magnitude of 5.2 and accelerations of 0.26 g for Cruas and 0.285 g for Tricastin.

A local magnitude of 5.1 - 5.4 was measured during the earthquake on 11 November 2019, corresponding to a moment magnitude of 4.8 - 4.9 and a surface-wave magnitude of about 4.5. The maximum acceleration measured at Cruas (about 12 km from the epicentre) was 0.045 g and less than 0.01 g at Tricastin (about 25 km from the epicentre).

	Surface magnitude	Depth and distance from the epicentre	Acceleration (Cruas)
MHPE	4.7	Depth = 4 km Distance = 0 km	0.18 g
SSE	5.2	Depth = 4 km Distance = 0 km	0.26 g
Earthquake on 11 November 2019	4.5	Depth = 1-5 km Distance = 10-15 km	0.045 g

DECOMMISSIONING: AN EMERGING INDUSTRIAL SECTOR

In September 2019, EDF submitted the application to permanently withdraw Fessenheim from service in 2020. Despite this, the staff have remained committed to operating the plant in a very professional way. The Group is devoting a great deal of attention to the future of the plant staff. I have also seen significant effort in the preparation of the plant's final shutdown and the aim to carry out the dismantling quickly and safely.

The decommissioning sites are making progress including: cutting up the Chooz A pressurised water reactor (PWR) vessel prior to complete dismantling, and the opening of the fast reactor vessel at Creys-Malville.

With respect to the UNGG[5] reactors, I believe that building a demonstrator to develop graphite-cutting techniques prior to their widespread use is a sensible approach. The fire risk assessments will need to be taken a step further for this difficult cutting phase. In the meantime, the ageing structures of these plants should be maintained in a good condition.

FABRICATION: SURVEILLANCE TO BE INCREASED

In 2019, Framatome identified a non-conformity on some steam generator welds (see Chapter 9) regarding compliance with the temperature ranges during the weld stress-relieving heat treatment process. This affected a number of reactors and I note that this problem is being handled well by Framatome and EDF. They quickly proved these components were fit for service and held constructive discussions with the ASN. An inspection plan and additional actions to prove long-term fitness for service have been implemented. This event has been examined in the Group's Council for Nuclear Safety.

The in-factory surveillance of component fabrication is becoming increasingly important due to recent quality problems and suspicions of malpractice (see my 2017 Report).

The DIPNN's[6] Industrial Division is strengthening its surveillance arrangements with more risk assessments, industrial process qualifications, random inspections, cross-checking of measurements, and laboratory tests, together with a deeper assessment of the whole supply chain.

MAINTAINING MOTIVATION

The nuclear divisions have successfully recruited new staff and I have met many high-quality, motivated young people whose experience is growing. Their first-line managers are making a significant contribution to their development (see Chapter 4). This bodes well for successfully dealing with the fleet challenges and new-build projects over the coming years. The divisions must continue to work on training and professional development as many skills take time to acquire. These new recruits must be managed proactively and given good prospects for the future to maintain their motivation.

I note a slight increase in the number of resignations and a few recruitment issues. These weak signals may indicate a lack of appeal and a decline in the image of the Group or the nuclear industry in general. Staff often tell me how disappointed they are with the lack of more positive communication in the external media in favour of the nuclear industry.

A chemist - Flamanville 3 nuclear power plant

THE UK FLEET

Hunterston B R3 remained shut down for the whole year due to cracking in some of its graphite core bricks. This cracking mechanism (called keyway root cracking) was expected as the core aged, but it has occurred at a faster rate than previously predicted. Currently the UK regulator, the Office for Nuclear Regulation (ONR), is awaiting the results of additional analysis before authorising the restart of R3. As agreed with the ONR, Hunterston B R4 operated for a limited time in 2019 before being shut down for inspection in December as planned. The condition of the graphite bricks will probably determine the service lives of the AGRs (see my 2018 report).

[5] *Gas-cooled graphite-moderated reactor*
[6] *Engineering & new-build projects directorate*

Both reactors at another AGR site have been shut down since autumn 2018 due to high levels of corrosion and cracking in several systems, including the essential cooling water systems. Considerable work has been done to address these problems. Most importantly, the late realisation of this situation indicates a weakness in the site's nuclear safety culture, for which an improvement plan has been started (see Chapter 2). This event has been examined in the Group's Council for Nuclear Safety.

The investments needed in the AGRs, right up to their eventual closure, must be given careful consideration in light of the issues encountered.

Graphite in AGRs

In advanced gas-cooled reactors (AGR), moderation (slowing down the fast neutrons) is achieved using graphite bricks around the core rather than water as used in PWRs. Subjected to neutron bombardment and oxidation, these non-replaceable graphite bricks lose weight and as a result will start to crack. In the event of an earthquake, these cracked bricks could move and restrict the control rods from entering the reactor core post-trip.
Keyway root cracking is a known phenomenon and these graphite bricks have been regularly monitored for many years. Cracking remained limited and in line with predictions until spring 2018, when the inspections revealed an unexpected acceleration. The existing cracks did not put operations at risk, but the reactors were kept shut down to allow time to understand this acceleration.
In response, an action plan has been implemented, which includes more graphite inspections in all AGRs, experiments to gain a better understanding of brick cracking mechanisms, tests and modelling under seismic conditions, and modifications to the control rods.

EPRs

In China, the two Taishan reactors are operating satisfactorily. I applaud TNPJVC[7] in how they used the operating experience (OPEX) gained during the commissioning of Reactor 1 to improve its operation and the subsequent commissioning of Reactor 2.

Taishan has obtained a great deal of OPEX. Elements of this, especially from the construction and the mechanical, electrical and HVAC (MEH) activities, are being incorporated into the Hinkley Point C (HPC) project. Teams from the DIPNN's Technical division and Framatome have been involved in the core physics tests during the commissioning of the Taishan EPRs. They have analysed the data from these tests so it can be used for Flamanville 3 and HPC. Flamanville 3 and HPC should ensure they receive and make full use of all OPEX from the Taishan commissioning phases.

At Flamanville 3, I note significant improvement in the state of the plant and that the hot functional tests are progressing smoothly. Repair of the main secondary system containment penetration welds, which will be difficult and demanding, has resulted in the fuel loading date being delayed by three years. This delay must be used to resolve all the remaining design and construction gaps including: component thermal fatigue, electrical connector installations, bolt tightening settings, primary system hydrogen control, etc.

In the UK, I was very impressed by my visit to the HPC construction site. The main milestones have been met, including the completion of the raft for the first reactor in June 2019. I note the proactive management of the project, but the organisation and interfaces are still complex.

I am surprised by the number of problems encountered by the nuclear island engineering team when producing the civil engineering construction drawings, both in terms of quality and timeliness. Equipment fabrication, MEH work, and the related surveillance activities are the next major challenges. I note that the project organisation will be adapted accordingly at the beginning of 2020.

The main secondary system at Flamanville 3

Two types of non-conformity have been detected in this system.
First, it became apparent that the break preclusion specifications of this pipework had not been fully implemented. Break preclusion means that a guillotine failure is deemed sufficiently improbable that it does not require a safety case covering all the consequences of such an event. To support this position, it is expected that more stringent manufacturing and quality assurance requirements be applied.
Second, EDF has identified defects in about 30% of other welds in the system, which had not been detected during any of the fabrication and construction inspections.
EDF has developed a global weld repair programme. The ASN has specifically required that the 8 containment penetrations welds be remade. EDF has developed several potential repair options and in October 2019 chose a solution that will use remote-controlled welding robots. The technique still has to be qualified, so an alternative option based on removing the sections concerned has been kept as a standby.

[7] *CGN-EDF joint venture*

In France, the ASN has given a globally positive view on the safety options for the EPR 2. In my opinion, the methods used in this project, particularly in system engineering, represent a significant step forward. I note greater involvement of the Operator and encourage this to be increased further. At this stage in the design, the project must continue to work on operability in areas such as: maintenance, operational flexibility and autonomy in the event of loss of support systems (for example ventilation).

MAIN RESULTS FOR 2019

IN FRANCE, RESULTS DOWN ON LAST YEAR

The 2019 nuclear safety indicators have deteriorated slightly compared with 2018, with 3 INES Level 2 significant nuclear safety events. Several plants are required to implement a recovery action plan to improve their safety results.

I am concerned by the number of non-compliances with technical specifications, which has increased for the second consecutive year. An effort must be made to correct this, especially through improved training. Plant alignment errors have also increased.

Reactor outage overruns are still an issue and imply several weaknesses in areas such as preparation, multi-year planning, and skills.

Improvements in 2019 include a decrease in the number of operations and maintenance quality issues; the action plan initiated at the end of 2017 must be continued and completed (see Chapters 1 and 2).

I regret the death that occurred during a load-handling incident. Overall, the industrial safety indicators in the DPN have deteriorated, with an LTIR[8] of 2.4. The radiation protection results have remained steady. I note, however, some weak signals regarding compliance with red zone access and an increased number of internal contamination events. I repeat my 2018 warning about radiography work (see Chapter 3).

IN THE UK, SLIGHT IMPROVEMENT IN NUCLEAR SAFETY

The nuclear safety results improved slightly in 2019. The number of manual and automatic reactor trips has fallen. The main areas for concern appear to be plant alignment errors and a high defect backlog.

The accident rate within EDF Energy Nuclear Generation has decreased and the industrial safety environment remains good (LTIR 0.3). The results for the HPC construction site are particularly good.

The radiation protection results are excellent.

INDEPENDENT OVERSIGHT

The independent nuclear safety oversight teams in both nuclear fleets remain professional and have strong voices.

In EDF Energy Nuclear Generation, I have noticed that the Independent Nuclear Assurance department (INA) is suffering from an insufficient number of suitably skilled staff. In France, the DPN's Nuclear Inspectorate is robust and well-managed. Its auditing scope has been increased to include site security, the DIPDE, and some activities of the engineering divisions outside the DPNT.

Discussions on strengthening the role and visibility of the independent nuclear safety oversight team in the engineering and new-build projects directorate (DIPNN) look promising in principle. The DIPNN can make use of good-quality analyses provided by the DFISQ[9]. In addition, the DACI, the internal oversight body of Edvance (nuclear island engineering subsidiary of EDF and Framatome), continues to establish itself. The surveillance of Edvance by the EDF Group is still necessary and needs attention.

From 1 July 2019, the DPN has had greater autonomy to self-approve modifications to equipment, documents and procedures, rather than obtaining ASN approval before commencing the work. Thanks to sound preparation, the first modification proposals have been processed without any major problems. However, the number of proposals has been small to date and is expected to increase as experience grows.

Recording parameters - Hartlepool nuclear power plant

8 *Lost-time injury rate*

9 *Independent nuclear safety and quality oversight department (DIPNN)*

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This year again, I have checked the skills and independence of the "*Organe d'Inspection de l'Utilisateur*" (OIU[10]) and found no significant concerns. With the completion of fabrication and assembly activities at Flamanville 3, the workload and scope of the OIU's activities are changing and moving towards supporting the fleet and the HPC project.

Concerning Framatome, following my 2018 report I note the emergence of an independent oversight team in its Engineering and Technical Directorate (DTI). This looks to be based on sound principles and must now be implemented. With the expected increased resources, the General Inspectorate will be able to develop an overall assessment of nuclear safety across the whole of Framatome's remit.

RELATIONS WITH THE NUCLEAR SAFETY REGULATORS

A good relationship between nuclear operators and the nuclear safety regulators is vital. On both sides of the English Channel, these relationships are frequent and productive.

IN THE UK

The relationship between EDF Energy and the ONR, which has historically been good, continues to be marked by mutual respect and understanding.

However, recent issues eroded ONR's confidence in EDF Energy. Notably, EDF Energy may have been over-optimistic on graphite brick cracking, and particular issues were identified at one site (corrosion and a weakness in nuclear safety culture). I encourage the continued efforts to correct this situation.

Conversely, the previously strained relationship between the HPC project and the ONR has been rebuilt and confidence seems to be restored.

IN FRANCE

This year again, I have noted extensive dialogue between the plants and the regional offices of the ASN.

Confidence seems to be returning at the corporate level of both organisations, especially at high-level. This improvement can be seen in particular in the frequently pragmatic and appropriate management of events and concerns. However, there is still room for improvement, especially through technical discussions at the earliest possible stage.

Although relationships are improving, I would nevertheless like to draw attention to the major difficulty EDF has in fully illustrating and expressing its industrial and human factor constraints in such a way that the ASN takes these into account.

Civaux nuclear power plant

[10] *Attached to the DIPNN's Industrial Division (DI), responsible for assessing the conformity of nuclear related pressure equipment*

ISSUES REQUIRING ATTENTION

I believe that increasing complexity is one of the greatest threats to nuclear safety. The conviction that every human error and every unforeseen event can be prevented by exhaustively documenting everything that may contribute to nuclear safety has led to the development of ever-increasing requirements. And this has been intensified by a hostile media environment and a growing trend in litigation. Specifiers and designers too often take the easy option and add more measures, without sufficiently considering the ability to implement them, and the related human and organisational factors (HOF).

IN A CONTEXT OF INCREASINGLY COMPLEX REQUIREMENTS…

Although EDF and the ASN deal with unforeseen events in a balanced way, I am concerned about the increasing complexity resulting from the expansion of regulations and requirements that are not being adequately prioritised. If we are not careful, this could lead to a situation where Operators will no longer be able to take ownership of all the requirements or deal with the resulting conflicts.

For example, the increasing complexity resulting from the nuclear related pressure equipment regulations (ESPN) has been overcome through a tremendous effort on both sides, which would be difficult to do again. More serious is the fact that many workers implement parts of the regulations without always understanding its link to nuclear and industrial safety: only a handful of people within EDF and its contract partners fully understand these regulations.

I am also very concerned about the complexity resulting from the application of the regulations on licensed nuclear facilities (INB). This has resulted in sites having to deal with several tens of thousands of "*equipment and activities classified for the protection of interests*", each with a number of "*defined requirements*". This extensive multiplication of requirements seems hardly compatible with the ability to understand their meaning, the nuclear safety issues and priorities.

Another example is the planned changes to the operating rules regarding system or equipment availability. This will compel sites to devote more and more resources to deal with the increasingly complex rules (due to more "group 1"[11], "group 2" and accumulation rules). Avoiding a prohibited combination of unavailabilities may result in a reluctance to isolate additional equipment to undertake preventive maintenance or reduce the defect backlog.

Adding systems and functionalities to plant equipment, including those to enhance nuclear safety, increases the operational complexity. A balance must therefore be found in existing reactors as an excessive number of technical changes may adversely affect nuclear safety. The rate of modifications must also take account of the time needed for plant staff to take full ownership of them.

I strongly suggest a halt to this increasingly complex environment (see Chapter 2), apart from important safety matters, where operators can take on board the requirements of new equipment and regulations, and the nuclear safety authorities can prioritise the important modifications. In my view, the senior management of the ASN, IRSN and EDF should work together to find ways of 'streamlining' complexity.

… KEEP IT SIMPLE AND PRIORITISE…

The increased numbers of external regulations must not be used as an excuse to hide the fact that this increasing complexity is, to a great extent, generated internally. This affects a number of aspects:

- Organisations, where unwieldy processes and unclear decision-making procedures dilute responsibility and require a great deal of effort
- Requirements, which are too numerous and lengthy
- Plant processes, which become too complex.

I believe it is essential to halt this escalation, which is already adversely affecting efficiency and will eventually lead to nuclear safety problems. I am aware that it will not be easy to reverse this trend, and I repeat my previous recommendations:

- Do not lose sight of the original intention of any action, and do not let the means take priority over the objective
- Look for global overall simplifications or optimisations, rather than in individual teams or groups
- Bring specifiers and designers closer to the plant. They must put themselves in the place of the end-user and consider whether what they are proposing is realistic
- Design plants and systems that are easier to build, use and maintain
- Limit the number of priorities and restrict the list of tasks. For each new requirement, at least one other should be eliminated.

Above all, this requires a change in behaviour; keep it simple, prioritise and know how to say no or postpone.

… AND REITERATE OPERATORS' PRIMARY RESPONSIBILITY FOR NUCLEAR SAFETY

During my visits, I observed that reactor design and operation is increasingly seen as a set of rules to be followed and documentary

[11] *Classification of equipment according to its nuclear safety duty. The action to be taken depends on this classification.*

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processes to be managed. I have too often seen a propensity, in both operations and engineering, to deal with technical subjects and nuclear safety issues as a function of questions posed by the nuclear safety authority or of the authorisations to be obtained. Connection with the plant and perception of risk are fading.

It seems to me that the plethora of requirements and processes is having a negative effect on nuclear safety culture. It is distancing the Operator from the plants. They tend to concentrate on the ASN's questions, enquiries and approvals, rather than looking ahead and assessing issues using their own judgement.

Faced with the issue of compliance with too many rules, the purpose of which is sometimes poorly understood, the Operator may lose their questioning attitude once regulatory compliance has been achieved.

The Operator must hold on to their primary responsibility for nuclear safety. I call on EDF management to:

- Stabilise the standards in collaboration with the ASN
- Focus on the plants and those who operate them
- Work on technical skills
- Give a new impetus to risk perception (e.g. study of accidents)
- Maintain a questioning attitude, in particular among management and the independent nuclear safety oversight teams.

AGRs: INVESTING BASED ON A FIRM CLOSURE DATE

In the UK, as the AGRs approach their end of life, their life extensions are being managed incrementally because of technical issues with graphite and lack of OPEX on this technology. This could result in short-term investments. This approach is not sustainable as the possible extensions might not be suitably anticipated or prepared for in advance.

This could lead to:

- Premature closure of a reactor which still has potential but requires a substantial amount of investment not implemented in due time
- More importantly, continually adding on incremental extensions (resulting in a much longer operational period) without first making the necessary investments, which would not be acceptable for nuclear safety.

A realistic end-of-life planning date must be set for each reactor, which can be optimistic, and an investment strategy must be planned based on this time limit. It should of course be possible to close a reactor before this final date.

ADAPTING THE ENGINEERING DIVISIONS TO A HEAVY WORKLOAD

The EDF Group has significant engineering capabilities. During my visits, I constantly met motivated people who are aware of the issues within their work area. I have seen positive changes in methods, for example: in system engineering, and in increased support to operations from the engineering divisions.

I note that the Group is experiencing some problems responding to the large number of requests, in terms of quality and time-scales.

EDF SA's nuclear engineering capabilities are distributed across a number of divisions, attached to the DIPNN, DPNT, EDF Hydro and EDF R&D. These divisions often rely on other engineering functions, Framatome or design offices, whose services require surveillance. This distribution of resources is historic, arising from successive organisational changes. A great deal of time and effort is spent ensuring these functions have consistent work practices, and managing the interfaces between them (see Chapters 2 and 6).

The engineering workload is also very heavy and the regulatory requirements and internal constraints continue to increase. The current VD4s for the 900 MW fleet, with the nuclear safety reassessments and the corresponding volume of modifications, require a great deal more engineering work than the previous ten-yearly inspection outages. Eventually this workload should decrease once these VD4s have all been completed, but in reality, the heavy workload will continue with the expected increase in decommissioning activities. In new-build engineering, Edvance is working at full capacity on a number of projects including the EPRs in the UK, Flamanville 3 and EPR 2. In addition, the SMR and possible export projects are also developing areas requiring significant engineering input from Edvance.

It takes some time for individuals to become suitably qualified and experienced in the engineering functions, either technically or in project management.

The current heavy workload has led to the significant use of contractors, which is not risk-free in terms of fulfilling EDF's architect-engineering role and surveillance capabilities.

I believe we need to draw conclusions on:

- Simplifying the organisations
- The type and volume of work to be carried out internally or externally in order to adapt to variations in workload
- The quality and quantity of engineering resources needed.

Human and organisational factors (HOF)

View of André Claude Lacoste, Chairman of the ICSI and FONCSI[12]

Ultimately, the performance and safety of production systems always rely on the men and women that design, build, operate and maintain them.

A ‘human and organisational factors’ approach involves questioning what makes an effective, safe activity easy or complicated. In the past, human factors has focused on analysing the characteristics of humans, which can be taken into account but cannot be changed. A series of military plane crashes during the Second World War were thus explained to have been caused by the confusing display systems in the cockpit, deemed incompatible with how pilots’ minds operated.

Rather than focus just on the ‘behaviour’ of people (the only observable aspect of the activity), we are now taking into account four different types of influencing factors:

- Individual’s physical and psychological traits, as well as their experience and training
- Work conditions (in particular the design of technical means and the environment)
- Working group(s) to which the individual belongs
- Management practices.

Most accident analyses will highlight that one or two errors from these four categories have significantly contributed to the event. For instance, some events have revealed that latent errors can significantly increase the probability of a person making a mistake. Therefore, contrary to what the operators believed in the Three Mile Island reactor in 1979, the discharge valve indicator did not show it was closed, but simply that the command to close the valve had been given. The valve, however, was stuck in open position.

Management practices also influence the extent to which people will commit to nuclear safety. Indiscriminate disciplinary action in the workplace will affect how information is reported back to management, whereas methods that value listening and encourage awareness of individual and group responsibilities with a questioning attitude will be more conducive to a nuclear safety culture.

To avoid serious, fatal or major technical accidents, it is necessary to identify, from design and throughout the entire service life of the system, how the use of human performance tools can strengthen the lines of defence to prevent, recover and mitigate situations.

This is why the fundamentals of an HOF approach should be assimilated in all levels of a company, from managers and leaders to operatives; specialised high-level skills must also be available to support the different functions.

I am convinced that the nuclear industry - having long invested in human performance tools - must continue in this direction to maximise the humans’ contribution to nuclear safety.

[12] *Institute and Foundation for an Industrial Safety Culture*

In France, there has been some progress made in maintenance and operations quality, but the number of non-compliances with technical specifications has risen.

In the UK, some indicators are showing signs of improvement, although the defect backlog is still too high.

Statutory outage overruns have been excessive in both fleets, exposing some industrial and quality issues.

Turbine hall - Civaux nuclear power plant

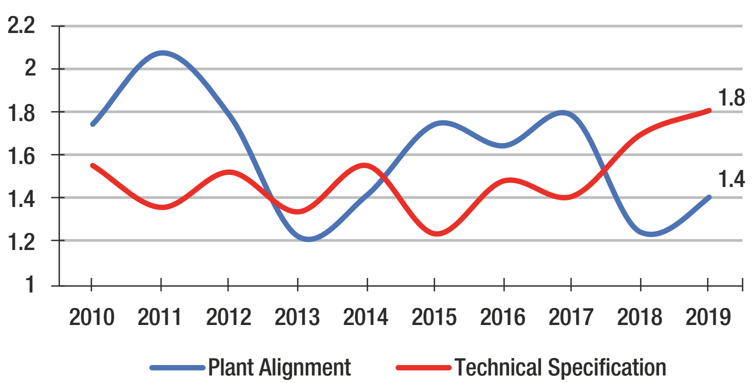
Operational nuclear safety 01

FRENCH RESULTS DOWN

There were 3 significant nuclear safety events graded Level 2 on the INES scale in 2019: one was related to a plant alignment error, another was caused by defective electrical contactors that were recently installed, and the last concerned the earthquake resistance of diesel generator auxiliaries.

The number of Level 1 INES events rose again, to 1.4 per reactor (average), from 1.3 in 2018 and 1.1 in 2017. The total number of significant nuclear safety events (Level 0 and 1 events) was 12 per reactor and continues to reflect a good level of detection and transparency.

With the exception of fire safety, there has been an overall deterioration in the safety indicators, especially in the number of non-compliances with technical specifications and plant alignment errors. The number of non-compliances with technical specifications continued to rise, reaching 1.8 per reactor in 2019 (1.7 in 2018, 1.4 in 2017). The number of plant alignment errors also increased to 1.4 per reactor, reversing progress made in 2018 (1.2 in 2018, 1.8 in 2017).



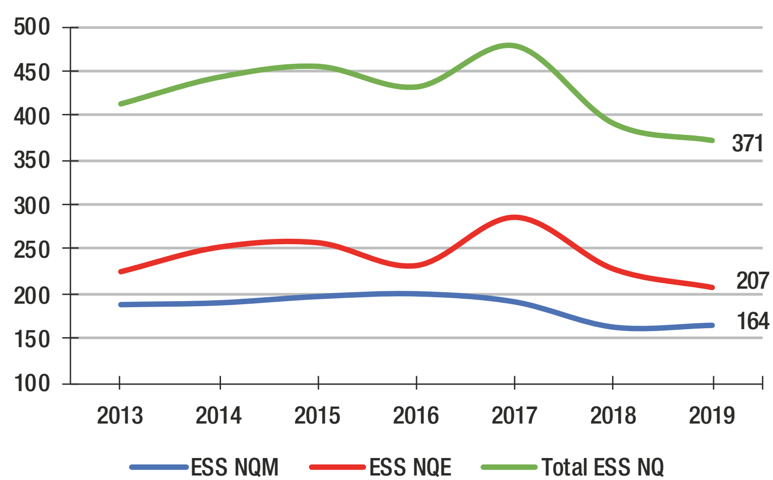
Plant alignment errors and non-compliance with technical specifications

I commend the good results achieved at Fessenheim given its impending withdrawal from service. I urge everyone to continue to work rigorously and openly up to the end of operations and then through the shutdown and decommissioning phases.

GROUNDS FOR SATISFACTION

The number of fire outbreaks has fallen for another successive year with 4 major or significant events in 2019 (5 in 2018, 9 in 2017). I will be following this risk closely.

The fire safety action plan launched at the end of 2017 as part of the campaign to raise standards in maintenance and operations continues to bear fruit. With 371 cases of sub-standard maintenance or operations work, the results for 2019 remain similar to those of 2018 (390).



Number of significant nuclear safety events (ESS) related to non-quality in maintenance (NQM)and operations (NQE)

Safety system availability remains high; unplanned unavailability rates in 2019 were: 0.06% for the safety injection systems, 0.01% for the auxiliary feedwater systems and 0.02% for the standby diesel generators.

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AREAS OF CONCERN

The number of automatic reactor trips rose again in 2019 to 31, compared with the record low of 18 reported in 2018 (22 in 2017, 28 in 2016 and 38 in 2015). The initial impetus of the campaign to reduce the number of automatic reactor trips has evidently tailed off: it is important to remain vigilant.

Grinding operation - Flamanville nuclear power plant

The deterioration in non-compliance with technical specifications shows a wide disparity between sites; it should therefore be possible to improve performance considerably. The following causes of non-compliance caught my attention:

- Inadequate knowledge and application of the technical specifications appear at times to be hampering efforts; additional training and greater ownership are essential to address this issue.
- High-risk activities associated with technical specifications are not always identified and prioritised, putting them at risk of being diluted in the overall maintenance and operations work plan. Sites achieving success in this respect are able to identify the specific activities that could potentially breach a technical specification.
- Sub-standard maintenance work that renders safety-related equipment unavailable is only being discovered later when the equipment is required for use by the technical specifications. A significant amount of work is necessary to improve maintenance standards before any progress can be made in this area.

The number of plant alignment errors has increased slightly. Consistently and comprehensively deploying and applying the rule of not interrupting the alignment process is fundamental to improving and maintaining nuclear safety functions. One of the Level 2 events in 2019, which could have led to the loss of coolant during reactor shutdown, is a prime example of why this is necessary. This is a timely reminder to all field operators to ensure they do not carry out any other tasks or allow themselves to become distracted by anyone - supervisors or co-workers - once they have started the alignment process.

I note that some diesel generators were unavailable at one site in October 2019. This was due to a significant amount of corrosion on the auxiliary systems, which had not been identified by the plant and was only detected during an ASN inspection. This is simply unacceptable; the Operator made the wise decision of shutting down the reactor to refurbish the equipment in question. I call for heightened vigilance in the field of corrosion inspection and treatment, in particular at coastal plants.

Alignment error during drainage of a primary cooling system

On 8 October 2019, the operator started to drain the reactor primary cooling system, which is a preliminary step before refuelling and maintenance. The primary cooling system is maintained at atmospheric pressure and decay heat is removed via the shutdown cooling system. A vent at the top of the pressuriser has to be opened to allow air into the system and balance the pressure as the water level drops.

However, when the field operator came to open the vent, he was distracted from his alignment operations by a co-worker who asked a question. When he resumed his task, he mistakenly thought he had already opened the vent.

With the vent remaining closed, draining created a vacuum above the water level, causing the coolant to boil and interfere with the level measurements. It was only at the end of the transient that the operations team realised the error when the calculated water level did not correspond to the measured water level. Having established that the pressuriser vent was still closed, the operations team then requested it to be opened.

This caused significant water movements between the pressuriser, the steam generators and the reactor vessel, resulting in considerable variations in water levels. More water was added to the system to redress the balance, but this should have been done before the vent was opened.

Ultimately, this Level 2 incident did not compromise safety since core cooling was still achieved. A significant amount of operating experience is needed by operations teams to improve understanding of the physical phenomena involved.

The uptake of recommendations issued by the DPN's Nuclear Inspectorate (49%) must be improved.

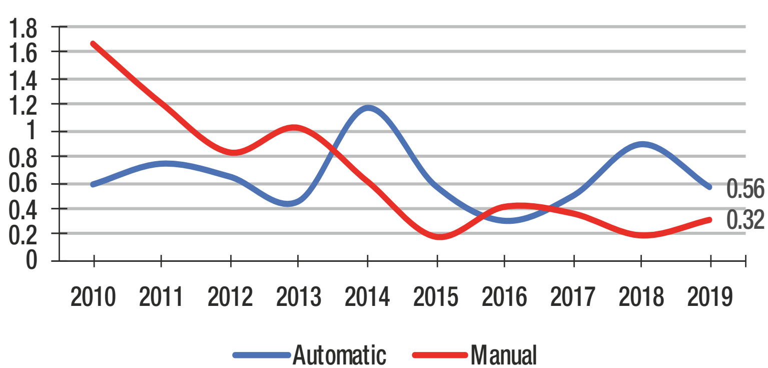
The same can be said for the uptake of WANO observations and recommendations: the action plans must be strengthened, whether at the sites most concerned by these plans or at fleet level. In particular, this needs to be done for areas for improvement (AFI) affecting all or part of the fleet. The number of recurring AFIs (observations issued by two successive peer reviews) is too high at 4 (average) per peer review. The resolution of AFIs is low (70% classified as level A or B during the follow-up review) and the completion of SOER[13] recommendations (79%) have both fallen short of their objectives (90% and 85% respectively).

After a few good performance levels at several sites early in the year, maintenance outage overruns crept up again, with some sites experiencing long delays.

RELATIVELY STABLE RESULTS IN THE UK

Overall, 2019 saw a slight improvement in the safety indicators after the downward trend experienced in 2018. However, the full picture remains somewhat mixed.

No INES Level 2 event was declared in 2019. The number of Level 1 events hit an all-time low, falling to 0.27 per reactor (4 events), compared with 0.53 per reactor (8 events) in 2018.



EDF Energy Nuclear Generation automatic and manual reactor trip rates

I must point out, however, that the British and French safety authorities apply different declaration criteria, and hence we cannot make direct comparisons between the numbers of Level 1 events in each country. The number of Level 0 events remains stable at around 6 per reactor (91 events) and reflects a good level of transparency.

In my 2018 report, I commented upon the downturn in performance following a lengthy period of continuous improvement. Some indicators, such as the number of automatic and manual reactor trips did see an improvement in 2019, yet the number of technical specification non-compliances and alignment errors shows little change compared with the previous year. Efforts will have to be redoubled, or new strategies will need to be developed to improve this situation.

GROUNDS FOR SATISFACTION

With regard to fire safety, no major or significant events were reported in 2019 and the number of minor fires (where flames are detected but can be put out with a single extinguisher) has fallen again. However, the number of smouldering fires (smoke without flames) has risen; 70% of these kinds of incidents detected were caused by an electrical problem, such as a fuse fault.

With 11 automatic or manual reactor trips (16 in 2018), 2019 shows a significant improvement compared with 2018. This performance is also good in terms of the number of trips per operating hour (0.88 trips per 7000 hours in 2019, 1.09 in 2018). The efforts made through the trip hardening programme must therefore be continued, notably with respect to control room standards (human performance tools and operator fundamentals), equipment reliability and experience sharing.

These remain the focus areas, especially given that the most frequent causes of reactor trips are human error and a failure to learn from previous similar events.

The number of non-compliances with technical specifications has remained the same at 0.6 per reactor for the past 3 years.

Safety system availability is good overall, showing a slight improvement on 2018. The unavailability rates for the AGR fleet in 2019 were: 0.045% for the emergency cooling systems (0.06% in 2018), 0.035% for the auxiliary feedwater supply (0.094% in 2018), and 0.221% for the emergency power supplies (0.22% in 2018). The Sizewell B PWR achieved 100% availability for the twelfth consecutive year.

There have been some issues with the auxiliary power supplies (diesel generators or gas turbines) that need to be addressed. Availability of back-up power supplies is worse on two of the three sites where gas turbines perform this function instead of diesel generators, as used in the rest of the fleet. The gas turbines are old, sensitive machines; they differ from one site to another, and are extremely difficult to maintain, often requiring specialist maintenance engineers, who are few and

13 Significant Operating Experience Report far between. A recent incident highlights the need for much tighter technical surveillance, including at contractor work sites where the main maintenance and refurbishment operations are performed.

This year again, the indicators for the uptake of WANO peer review and SOER recommendations are excellent, at 83% and 92% respectively.

Gas turbines

Gas turbines are used on some AGR sites to provide an independent power supply for the safety functions in the event of a power outage. Each site has four 17.5 MWe turbines; one turbine alone can supply enough power to guarantee the safety functions of two reactors.
During routine tests at one site, engineers discovered that the tips of the turbine blades were scraping the turbine casing. Analysis showed deficiencies in either its initial installation or during a subsequent maintenance overhaul. The necessary repair work meant that the turbine was out of service for 18 months.

AREAS OF CONCERN

The number of alignment errors of 1.67 per reactor is the same as in 2018 and remains too high.

The level of defect backlog is also high, and delays in preventive maintenance (more than 50% into the tolerance period) have risen again, continuing this upward trend. This applies to all equipment, including some that are essential to nuclear safety.

Statutory outage durations are still proving difficult to meet. Planned changes to work schedules can have a negative effect on team morale and this could affect the quality of work. The average outage overrun was significantly higher in 2019 than last year.

PROGRESS IN FIRE AND ATEX HAZARDS NEEDS CONSOLIDATING

The overall trend here is positive, demonstrating wider adoption of a fire prevention culture.

I am pleased to see the following results in France and the UK:
- A reduction in the number of fire outbreaks
- Better control of fire loading
- Constant monitoring of hot work operations such as grinding and welding in the UK fleet and at some French plants.

In June 2018, DPN management decided to launch a programme to test the alarm buzzers on all fire doors located in the most safety-critical areas (the buzzer sounds if the door stays open). I have seen similar systems work very well in EDF Energy and at other locations worldwide. The delay to this programme is regrettable, and I urge the DPN to invest more time in this initiative.

Control room operators - Flamanville nuclear power plant

Work to control explosion risks in potentially explosive atmospheres is under way in France and set to continue. The EDF standard was effectively lagging behind practices in other more directly impacted industries, i.e. oil, chemical. Specific challenges relate to protecting personnel (which is the main purpose of controlling ATEX hazards) and nuclear safety (to eliminate the consequences of a potential explosion on equipment that contributes to safety). There is still room for improvement in terms of how gas cylinders are managed by contractors; more rigorous practices and stricter monitoring are necessary in this area. This will require the cooperation of several teams at plant level and strong coordination at corporate level.

STRONGER INDUSTRIAL STANDARDS AND PRACTICES NEEDED

PLANT CONDITION - GREATER FOCUS NEEDED ON THE DEFECT BACKLOG

Housekeeping in France is generally satisfactory, which I have seen for myself during my visits. I also appreciate the vast improvements achieved in the UK fleet over the past few years.

When comparing both fleets with others worldwide, I think it would be worth making a greater effort to maintain peripheral buildings and outside areas, such as roadways and grassed or landscaped sections on site.

The MEEI initiative for maintaining exemplary housekeeping standards has made real progress in France. The DPN's Nuclear Inspectorate has made this initiative an area for assessment in its own right. I have been examining its classifications carefully and recommend improving the way in which certain aspects are taken into account, e.g.:

- Defect backlog and average repair time for leaks, protection-important equipment, fire-fighting equipment, etc.
- Observations about fire loading, packaging, foreign material exclusion (FME), equipment corrosion, housekeeping in control rooms, etc.

In the UK, measures have been taken to reduce the defect backlog, which is improving but remains high. I often hear in my meetings with staff that a reason for delay is that the majority of resources and manpower is focused on tackling urgent unplanned outages, generic problems, obsolescence and difficulties associated with statutory outages. I recommend that efforts be stepped up to further reduce the defect backlog.

In France, the high workload required to implement the numerous modifications has caused some plants to postpone maintenance activities on non-safety-related equipment. This approach has a detrimental effect on the quality of work; for instance, operating teams and fuel loading teams (see Chapter 5) are forced to find workarounds. This is not conducive to achieving a productive work environment and can ultimately divert teams away from more essential operations.

Participants in an AGR craft training centre

QUALITY MANAGEMENT - A CALL FOR GREATER COOPERATION WITH CONTRACTORS

The French campaign launched in 2018 to raise standards in maintenance and operations, which I mentioned in my 2018 report, is ongoing. The efficient way in which this plan is being managed leads me to believe that progress will be achieved in the mid-term. Several of the campaign's initiatives - peer reviews, focus on preparing properly for operations ("*je suis prêt*"), use of human performance tools, and implementation of the 'uninterrupted alignment' rule - look likely to deliver long-term results.

In my opinion, deep and long-lasting improvement of the maintenance and operations standards will involve a considerable amount of work in the fields of industrial process management and skills within EDF and its contract partners. The DPN's move towards a higher degree of specialisation for people working on the most sensitive equipment should help.

I also think it is important to improve cooperation with contract partners and to organise more training sessions as soon as possible, before work is due to commence.

I will be monitoring the DPN's actions in this area closely over the coming months.

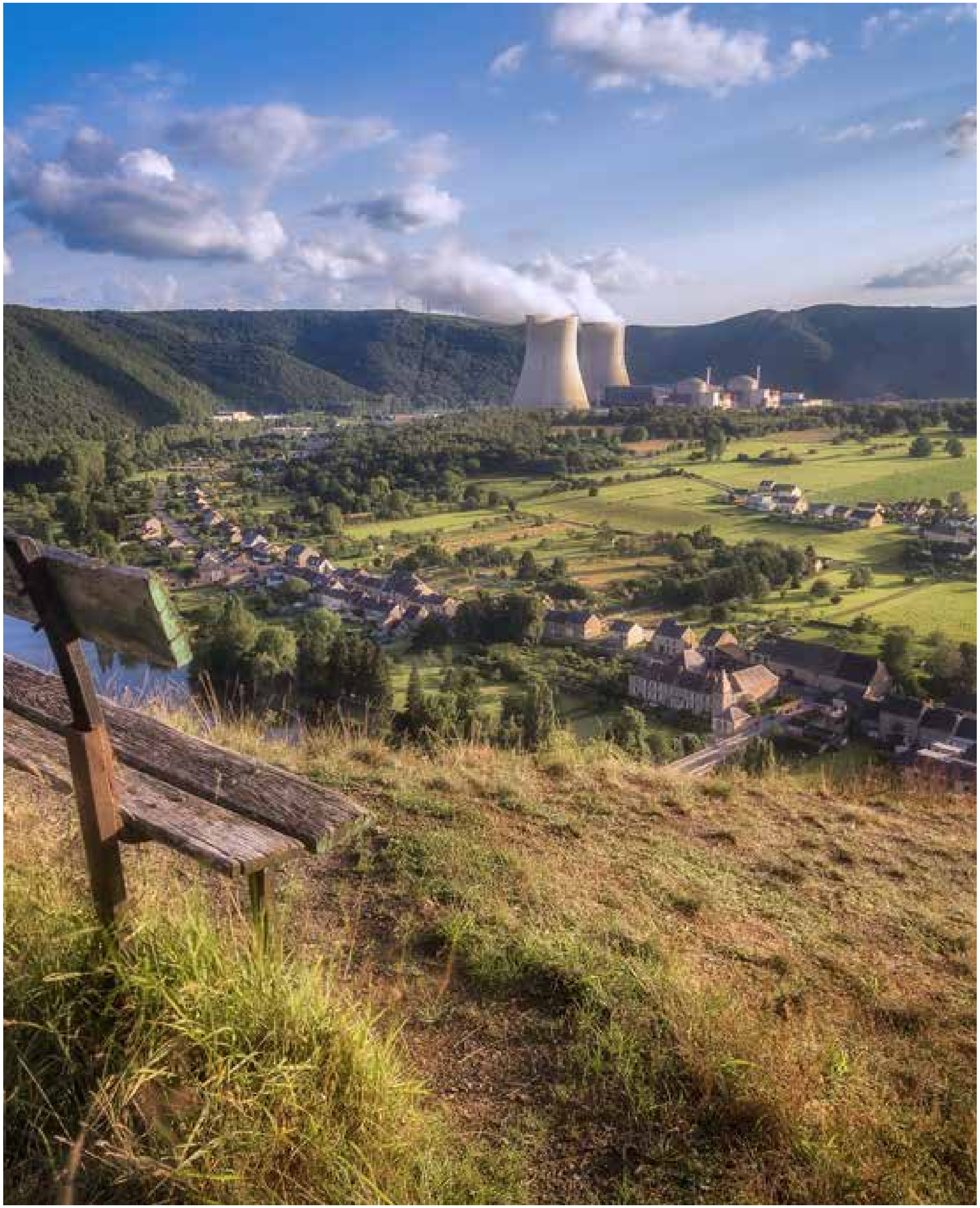
THE INDUSTRIAL AND SAFETY-RELATED CHALLENGES OF OUTAGE MANAGEMENT

Good outage management is necessary for a safe working environment, for better work quality and for improved nuclear safety (see my 2018 report). Further, good outage management is not just about economics, it indicates the robustness of the industrial processes involved, which is synonymous with better maintenance and operations quality and therefore with improved nuclear safety.

Changes to outage schedules disrupt maintenance and operations activities. Consequently, these changes can affect the morale, concentration and proficiency of EDF Group and contractor staff scheduled to undertake the work.

I noticed in 2019 that the UK fleet analysed the recent outage overruns; from this, they identified the root causes and put in place actions to improve. However, the actions taken to date have not yet resulted in any noticeable improvement. The DPN also launched an initiative to reduce the defect backlog. I will continue to focus on these issues in 2020.

I am pleased to see that the DPN and EDF Energy Nuclear Generation have made outage management a core component of their strategy, with all that this entails in terms of improvement to the: outage organisation and management, outage work content, risk management, relationship with contract partners, and personnel skills and knowledge.



Chooz nuclear power plant

In France, the ten-yearly inspections have significantly improved nuclear safety, ensuring that reactors can continue operating.

However, an excessive number of modifications made over a short period - regardless of whether they are technical, organisational or regulatory, or imposed from within or outside the organisation - can lead to increasing levels of complexity to the detriment of safety.

In the UK, the AGR fleet service life extension programme requires special attention to ensure the integrity and availability of equipment.

Increased complexity: detrimental to nuclear safety 02

IN FRANCE, HIGH-LEVEL REQUIREMENTS… TO BE RATIONALISED

The policy in France of periodic safety reviews, combined with the ASN's demanding requirements, has been driving progress in the French fleet and has led to substantial improvements in nuclear safety. The design of the EPR, with new features that will enhance the safety of next-generation reactors, has also provided the opportunity to re-examine the choices made for the existing fleet.

Yet it seems - somewhat paradoxically - that implementing this policy to the extreme could actually have an adverse impact on safety.

DETERMINING THE RESOURCES REQUIRED TO MEET OBLIGATIONS

For the existing fleet and new-build projects, the current and planned workload for plant and engineering teams is substantial.

Numerous modifications are planned for the ten-yearly inspection outages (VD2, VD3, VD4 and VD5) for each reactor series (CP0, 900, 1300 and N4) and for each reactor. Engineering functions need to improve their productivity, making sure they have sufficient resources and expertise to handle this increasing workload. In reality, this means a significant rise in outsourcing, potentially resulting in the loss of in-house expertise and subsequent difficulties in undertaking contractor surveillance.

The modifications prepared by engineering divisions for the plants are sometimes not at the expected standard and frequently arrive late despite the efforts made. This presents difficulties for the Operator, not only in terms of implementing the changes such as updating the documentation and training staff, but also in taking overall ownership of these modifications. Some modifications intended to improve safety performance can take some time to be fully implemented and operational (see Chapters 5 and 6).

As far as new-build projects are concerned - regardless of whether they are current (Flamanville 3, HPC) or future (EPR 2, Sizewell C, Jaitapur) - it seems to me that successive changes, particularly to the standards, mean that every project ends up as a "first-in-series". This generally comes at a hefty price in terms of the associated engineering work and man hours required.

ESTABLISHING NEW RELATIONSHIPS WITH THE ASN

Over the past few years, my discussions with engineers, their managers and leadership teams have highlighted the intense pressure they are all under to meet the ASN's requirements and to respond to the questions raised by IRSN[14], within the desired time frames.

This results in a situation where individuals have convinced themselves that their primary role is to "*rigorously respond to the requirements of the ASN*", which can progressively be reduced to *"strictly answering the questions raised by the ASN"*, or simply even *"what would the ASN think?"*

This is a somewhat risky attitude; if the Operator is not careful, they could find that their responsibility for safety has shifted to the nuclear safety authority. I have seen several examples of where issues addressed from an essentially regulatory perspective have led to a loss of ownership of the nuclear safety issues.

The tendency to focus solely on responding to the nuclear safety authority, combined with this feeling of drowning under the workload, will undoubtedly drive the Operator to:

- Step back from their responsibility, almost to the point where their relationship with the nuclear safety authority is one of "obedience"
- Not proactively anticipate nuclear safety issues.

Both of these potential outcomes are contradictory to the level of accountability that should be demonstrated by the Operator (see My view).

Without challenging the relevance of IRSN's questions, or the Operator's willingness to do the right thing, this apparent shift in behaviour is sufficient for me to urge the management teams at

[14] *French Institute for Radiation Protection and Nuclear Safety*

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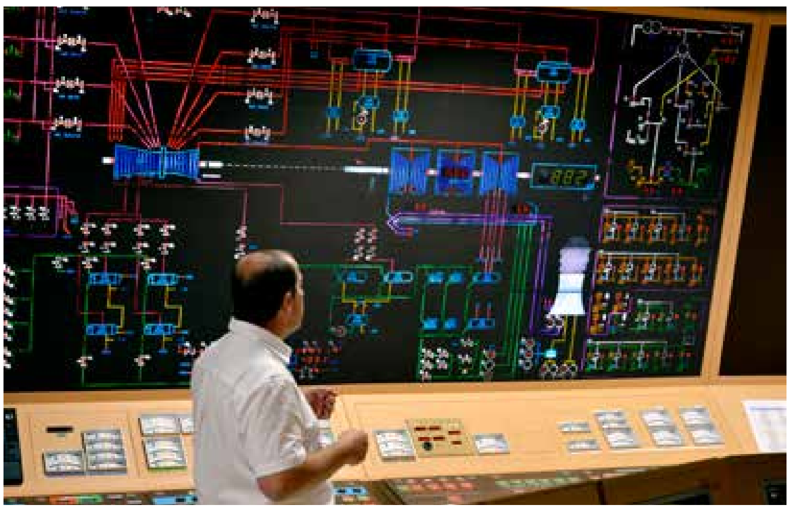
EDF SA, IRSN and the ASN to work together to define new working practices.

The Operator is free to choose how to meet the specified objectives and must be capable of addressing them.

To this end, it seems to me that EDF SA and the ASN must reach agreement on the following:

- Stabilising the standards
- Capping the number of plant upgrades over time
- Defining the methods and assumptions, sufficiently ahead of time
- Prioritising and curbing the number of questions
- Setting schedules that are compatible with regulatory assessment duration and the industrial programmes.



Control room - Civaux nuclear power plant

COMPLEXITY IS NOT SYNONYMOUS WITH SAFETY…

This situation has not arisen through deliberate intent, but rather as a consequence of a collective conviction or belief that risks can always be controlled by adding new systems, new rules and especially more procedures. However, is this risk management or merely a form of reassurance?

Clearly, it is safer and more effective to plan how an activity will unfold and identify the associated risks of failure to ensure appropriate protection measures can be taken. However, when the number of requirements and procedures is multiplied by the number of different activities, this volume becomes difficult to manage. Hence, a sense of being straitjacketed starts to develop, which is not conducive to efficiency, quality or a questioning attitude.

My point here is not to question the principle of a demanding set of standards - which is imperative in high-risk facilities - nor is it to state that the specified requirements are not necessary. I am simply drawing attention to the changing practices that are creating organisations weighed down by complexity, with excessive tasks and an increasing number of interfaces.

… THE GROUP NEEDS TO MAKE A REAL EFFORT

This increasing complexity comes largely from within the organisation. In my meetings with the Group's leadership teams, everyone agrees about the overriding need to simplify, to make sure that demands are reasonable and to ease the workload for all staff. Yet from my many discussions with engineering, maintenance and operations staff as well as with contractors, it is clear that the situation has not changed. I appeal to senior managers to make sure that they and their management teams make a real effort to avoid introducing yet more complexity.

I am convinced that nuclear safety needs continuous improvement, the next step of which should be "simplification" (see My view).

TEN-YEARLY INSPECTION OUTAGES AND HAZARD ASSESSMENTS

SIGNIFICANT IMPROVEMENTS TO BE COMPLETED PROMPTLY

The level of safety in the French fleet improves at every ten-yearly inspection, due mainly to new equipment and safety system upgrades. However, I have noted a certain slowness in carrying out requalification tests after modifications have been implemented, and in rectifying minor non-compliances. This leads to delays in the availability of systems necessary to enhance safety (see Chapters 5 and 6). I urge all Project Managers in charge of modifications and Plant Managers to make sure these are finalised as soon as possible.

The project to install ultimate emergency diesel generators (DUS) is progressing well with a strong level of commitment from all involved. However, I note that the operating teams were late in being integrated into the commissioning tests, and I advise that lessons be learnt from this experience.

The improvements made in hazard mitigation represent a major step forward. The EDF Group, often at the instigation of the safety authority, has sought to gain a deeper understanding of the phenomena involved and has taken appropriate measures as and when required. Greater design margins are needed for situations that are difficult to simulate. This is required to avoid the need for further analysis and rework, which will only add to the workload. I have seen that independent nuclear safety oversight teams are often too far removed from the hazard mitigation assessment (see Chapter 6).

THE DECISION-MAKING PROCESS NEEDS ENHANCING

CULTIVATING INDIVIDUAL ACCOUNTABILITY

A number of events in the industry have demonstrated an all too prevalent dilution of accountability and decision-making. Everyone should learn from the analyses conducted by EDF R&D on the causes and effects of past accidents.

The lengthy delay in ensuring compliance of a dam in 2017 is just one example of this issue. Responsibility for this project was shared between several entities, yet although all parties worked on the structural resistance studies, no one party assumed overall responsibility. The time factor - which can sometimes span several years - and a high level of staff mobility were not conducive to fostering individual accountability. I am sorry to say that the HOF[15] analysis that I requested some time ago has not yet been started.

However, I note that to improve handling of non-compliance with regulatory requirements, the DPN promptly set up a reactive non-compliance analysis initiative called AREC[16] as part of their process.

After non-conformities were found on welds on the main secondary system at Flamanville 3, the DIPNN Director requested a full technical analysis from the Independent nuclear safety and quality oversight department. It would also be useful to complete an HOF analysis to determine the impact of organising and sharing responsibilities on decision-making mechanisms.

In a complex organisation, defining roles and responsibilities precisely is one of the key elements of good governance. It is also essential that everyone involved have a clear understanding of the safety implications of their specific tasks and of their own accountability.

MORE INVOLVEMENT OF EXPERTS IN DECISION-MAKING

Every year, I meet many highly experienced experts working in a multitude of disciplines, whether in EDF R&D, Engineering or Framatome (see Chapter 8).

It surprises me that experts - all of whom are convinced that some higher performance modelling methods are essential to gain more accurate analysis of phenomena - are not engaged in a process to develop such methods. No request has been forthcoming from management lines, nor is there a corresponding budget for them to do so. The financial mechanisms must afford the Group's experts a certain degree of autonomy to research beyond the scope of current projects. We must monitor this aspect.

The role of experts is not only to provide evidence to substantiate cases, but also to alert the business to any shortfalls. Sometimes, their work is restricted to responding to specific questions and they are not asked to express any further opinion, nor do they take it upon themselves to do so (see Chapter 6). Yet one of the key elements of operational decision-making is the ability to do just that.

The independent nuclear safety oversight body must also be in a position to challenge choices, practices and behaviours as and when necessary.

In my opinion, the Group's Chief Technical Officer (CTO) should build on the recent initiative to raise the profile of experts by involving them more actively in decision-making processes and ensuring that budgets are allocated to allow experts to assume their cross-functional role.

Paluel nuclear power plant

CONFORMITY - A STEP IN THE RIGHT DIRECTION

The AREC process at the DPN and engineering departments seems to me to be well established with prompt reporting of non-conformities. Given the importance of this issue and the associated workload, I urge DPN management to further develop the on-site safety analysis capabilities (identification of a 'safe path').

[15] *Human and organisational factors*
[16] *French acronym for* analyse réactive des écarts de conformité *(reactive analysis of non-conformities)*

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The Engineering divisions have been audited by the DPN's Nuclear Inspectorate and several areas for improvement have been identified. Major progress should be made in the following areas in 2020:

- Standardising the non-conformity handling processes between engineering functions
- Ensuring that the duration of investigation following detection of a potential anomaly is kept in check
- Making staff and contractors aware of their obligation to report any potential anomalies as quickly as possible.

The Design Authority (DESA)[17] has set up an identity card for each reactor in the French fleet. This document specifies the reactor's design status and the key modifications to be carried out during the next maintenance outages (VD and VP)[18]. This seems like an effective system to me, yet I have been surprised to meet some Technical Directors and Safety & Quality Managers who are not familiar with these ID cards. I urge the DPN to promote their use more widely.

Working in a controlled area - Bugey nuclear power plant

INB MINISTERIAL ORDER: "PROTECTION-IMPORTANT ACTIVITIES AND COMPONENTS[19]"

A joint initiative led by the DPN with all the engineering functions resulted in the publication of guidelines to help identify protection-important activities (PIA) and components (PIC) together with the relevant defined requirements in compliance with the French ministerial order on licensed nuclear facilities (INB).

The risk analysis methodology for assigning requirements proportionate to each protection-important activity or component is positive, although I regret that the overly complicated wording makes it difficult to follow in places. The way the regulatory text has been interpreted by the ASN and the excessive number of engineering and operations documents issued by the utility, serve only to underline the legal obligations rather than creating a process that manages the technical risks effectively. Nevertheless, the process of implementing this regulation has resulted in stronger equipment inspection and monitoring procedures, which can only be a good thing.

The standards are now set and it is up to each station director to ensure that they are fully implemented. I suggest that the DPN's Nuclear Inspectorate continue to monitor progress in this respect.

IN THE UK - TECHNICAL DIFFICULTIES AND SAFETY CULTURE

In 2018, I mentioned the widespread corrosion found in one of the AGRs, which has since required a lengthy outage for repairs. The time taken to detect and deal with this phenomenon reveals several causes, including the acceptance of an increasing level of corrosion, which in my opinion indicates a weakness in the site's nuclear safety culture.

Various actions were undertaken in 2019 to improve the situation, including:

- Appointment of new leaders (senior management, departments and teams)
- Staff transfers and support from the INA to bring in outside expertise
- Reconditioning of equipment and new investments
- Additional training (on human performance and individual accountability).

I strongly urge the management on site and within EDF Energy Nuclear Generation to continue their efforts to improve and sustain the nuclear safety culture. I will be monitoring progress closely.

A recent problem in one of the AGRs illustrates how the condition of equipment is assessed mainly on the basis of numerical models and operating conditions. Hence, I would urge EDF Energy Nuclear Generation to continue their work on improving modelling tools, as well as developing in-service inspections in parallel. This will not only allow the actual condition of equipment to be determined, but will also enable the models to be qualified.

17 *A DIPDE group responsible for ensuring that plant design integrity is maintained throughout the operating life*
18 *Ten-yearly inspection outage and partial inspection outage*
19 *Activity/equipment important to protecting interests*

In light of the problems encountered in the AGR fleet, there must now be a period of reflection to determine the investment required proportional to their life span (see My view).

Oxidation of steam generator materials in AGRs

Under normal AGR operating conditions, oxidation of the 9% chromium steel alloy boiler tubes is slow due to the formation of a protective surface oxide layer within the CO_2 atmosphere. Under these conditions, tube failure is therefore considered highly unlikely.
However, above a certain temperature '9%Cr breakaway oxidation' can occur where this protective layer is no longer stable and oxidation increases at such a rate that a tube leak could occur.
During a routine validation of the code used to assess the tube metal temperatures, it was found that two tubes (in each boiler) could be as much as 20°C hotter than initially modelled. At these predicted temperatures, the risk of breakaway oxidation and hence boiler tube failure is significantly higher and challenges the existing safety case.

THE PLACE OF INDEPENDENT NUCLEAR SAFETY OVERSIGHT

IN ENGINEERING: THE EMERGENCE OF INDEPENDENT NUCLEAR SAFETY OVERSIGHT IN FRANCE

In 2018, I suggested that the DIPNN consider setting up an independent nuclear safety oversight (FIS) function. I am pleased to see that some key principles regarding this function have now been approved, namely:

- The scope of the FIS divided into three parts: advice, assessment and alerting
- A direct reporting line from FIS managers to the relevant director (DIPNN, engineering functions and projects)
- Authority and credibility of the independent nuclear safety oversight functions.

There is still a substantial amount of work to do. I think it would be appropriate to examine the following points in more depth:

- The choice of entity tasked with assessing compliance on behalf of the DIPNN Director and the respective reporting lines
- Definition of a single oversight standard for all engineering functions
- Coordination of the DIPNN FIS function with other FIS teams (DPN, Flamanville 3, HPC and DIPDE), and their respective roles in committees.

In addition, EDF SA's surveillance of Edvance remains a sensitive issue. I will be keeping an eye on the implementation of these planned measures, in particular with regards to the scopes, resources, expertise, independence and tasks completed.

The Nuclear Inspectorate has also carried out checks, on behalf of the DPN, in the engineering centres to evaluate how non-conformities are handled and how the INB regulations are being applied. This is a sensible approach in ensuring compliance with the regulatory requirements.

Torness nuclear power plant

IN OPERATIONS: ROBUST INDEPENDENT NUCLEAR SAFETY OVERSIGHT IN FRANCE

The Fleet Director for nuclear safety and the DPN's Nuclear Inspectorate make sure that the voice of the sites' independent nuclear safety oversight team is heard and questions both the relevance of event reports and the quality of their analysis. Now would be a good time for DPN management to reflect upon the following:

- Management of hazards by the site's safety & quality manager (who also manages the site FIS) restricts the ability to have complete independent oversight of this area (see Chapter 6)
- Increasing share of security-related issues in a safety & quality manager's responsibilities.

The site's independent nuclear safety oversight team strengthens the safety requirements at plant level; it will not hesitate to alert

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management in the event of any disputes with operations teams. However, plants need to:

- Ensure that safety engineers assess criticality and low-load operations more systematically (see Chapter 5)
- Enhance safety engineers' (and shift managers') knowledge of the risks associated with the potential hazards and strengthen assessment processes in this regard (see Chapter 6)
- Ensure that emergency preparedness is covered comprehensively by the site's FIS (see Chapter 7) and safety & quality managers
- Promote awareness of the INB ministerial order.

KEEPING A WATCHFUL EYE ON THE INA'S RESOURCES IN THE UK

The UK fleet has a robust set-up for handling nuclear safety issues. A TSSM[20], assisted by expert engineers, supports the operations teams at each site. At corporate level, this role is assumed by the Design Authority.

Maintenance work in an AGR

The independent nuclear safety assessments conducted by experienced INA teams and often overseen by the ONR certainly inspire confidence. They are wholly independent from site management and thus are impartial. However, they must make sure they continue to alert site management of potential concerns in all sites. Furthermore, the INA is finding it increasingly difficult to replace experienced retiring inspectors primarily due to the lesser appeal of this kind of position. I recommend that the UK fleet seek to redress this problem by promoting INA within career paths.

I am pleased to see that the role of the independent nuclear safety oversight team has been strengthened by a formal mandate issued by the Project Director for Hinkley Point C (HPC). This team has benefited from the presence of external peers, which has enhanced their performance.

The challenge of complexity

EDF R&D has expressed concerns[21] about the impact of an increasing degree of complexity and proposed a number of suggestions, such as:

- Adopt a less prescriptive approach; place greater emphasis on analysing informal aspects (through listening, consideration and debate)
- Tackle the issue of excessive fragmentation within organisations; keep the number of interfaces to a minimum to simplify relationships as much as possible; beware of overly subdividing tasks, which makes it more difficult to manage the numerous interfaces
- Reinvest in skills management; maintain the balance between generalists and specialists; make greater use of the skills base; develop strategies to reduce staff turnover
- Introduce a more progressive approach to organisational changes; conduct a risk assessment focused primarily on technical and organisational changes; increase the pace of change aimed at enhancing safety
- Address contentious issues promptly; provide opportunities for debate and reflection; promote free, open discussion and encourage feedback; develop different evalutions and cross-analyses; set up training and conditions that nurture a reflective and self-critical style of management
- Reduce the potential dangers and vulnerabilities associated with systems, taking a more balanced approach; seek better ways to manage production-related pressures such as time and stress and their impact on the organisation; build support teams to help resolve critical situations.

[20] *Technical Safety and Support Manager*

[21] *See paper : "La complexité des systèmes sociotechniques à risques rend-t-elle les accidents inévitables?" (Does the complexity of high-risk socio-technical systems make accidents inevitable?) Y. Dien, N. Dechy, M. Llory, October 2012*

MY RECOMMENDATIONS

At the DPN, the standards for applying the INB ministerial order are established, the "*protection-important activities and components*" have been identified, and audits are progressing. Given the complex nature of these standards, it is advisable to simplify the internal documents to ensure greater ownership by the sites. I also recommend that the DPN Director improve the existing training provision or develop new training programmes for the respective disciplines.

The DIPNN defined the profile for its independent nuclear safety oversight function at the end of 2019. I recommend that the Director of the DIPNN follow through with its deployment. I recommend that the Directors of the DIPNN and the DPNT make sure there is close coordination between the various independent nuclear safety oversight teams, especially in decision-making committees.

In France, EDF needs to ensure they have the necessary capacity to handle the substantial workload planned for both the existing fleet (ten-yearly inspection outages) and for new-build projects (HPC, EPR2, Sizewell, etc.). I recommend that the Directors of the DPNT and the DIPNN:

- Build a multi-year programme, in conjunction with the ASN, covering all projects and modifications envisaged
- Ensure that the Operator maintains full ownership of its nuclear safety responsibilities.

In the UK, incremental extensions to the operating life of the AGR fleet could mean that investments necessary for the final end-of-life date may not have been implemented. I recommend that the Director of EDF Energy assess their past and future investments and ensure they are based on the maximum planned operating life that will not be exceeded.

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A fatality that occurred during an equipment unloading operation, as well as several potentially serious accidents, highlight just how important situational awareness is at all times.

The industrial safety results have degraded in France.

The radiation protection results have remained satisfactory, but I noticed some hazardous situations.

Actions to prevent and to test drug and alcohol abuse need to be introduced widely in France, as is already the case for the UK fleet and Framatome.

Industrial safety and radiation protection 03

PREVENTING CRITICAL RISKS: A TOP PRIORITY

I deeply regret the fatality that occurred at one of our plants while a truck was being unloaded. The Group's priority is, and will always be, to eliminate the possibility of any fatal accident: nothing can justify the loss of life at the workplace. This tragedy is a sad reminder of the need to continue the efforts engaged on all levels, with in-house staff and contractors, to prevent such events.

The life-saving rules and procedures specific to each profession are widely known. It is encouraged to share good practices, with regular training and communication campaigns. It is regrettable that these rules - designed to prevent people from getting hurt - are often considered as simply 'more requirements' and are not given the higher level of priority they deserve.

As requested by the EDF Chairman, a 'STOP' safety break was organised on 3 October 2019 across the Group to "*allow reflection in a team, encouraging open conversations, with respect to our life-saving rules, health and safety fundamentals and the obstacles encountered in their application*". All staff and contractors were invited to take part in this initiative. Progress commitments and action plans were drawn up by each team, and I will be tracking the efficiency of these documents.

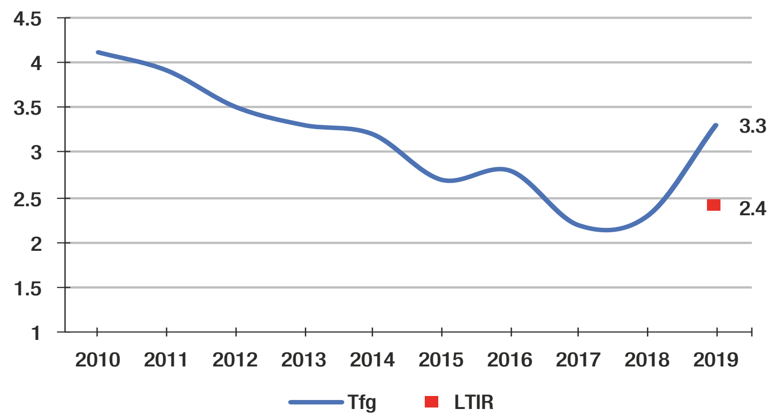
Since 2015, EDF SA and EDF Energy have been working together to roll out joint safety campaigns. In 2019, the subject of electrical hazards was chosen to raise awareness among the Group's staff and contractors.

IN FRANCE: A DETERIORATION IN RESULTS…

At the Nuclear generation division (DPN), the lost-time injury rate (LTIR) was 2.4 and the overall accident rate (Tfg) was 3.3, marking a deterioration in results compared with 2018 (2.3).

Following a steady reduction since 2016, the number of accidents due to critical risks has begun to rise again: 5 accidents with lost time in 2019 (4 in 2018) and 11 accidents without lost time (6 in 2018).

Activities responsible for the highest number of potentially serious safety incidents are electrical work, working at height, load handling, and radiography work. The DPN's Nuclear Inspectorate identified that the critical rules for electrical hazards and working at height are still implemented inconsistently across worksites. I have noticed that this risk increases during the summer period. This is a reminder that the battle to improve safety is never won. I urge all staff, whether EDF or contractors, to respond swiftly to improve the situation.



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

In the engineering functions, the DIPNN results (excluding Flamanville 3) remain disappointing with an LTIR of 2.0 (1.4 in 2018), and an overall accident rate of 3.0 (2.0 in 2018). At the DIPDE, the results are on a positive upward trend with an LTIR of 1.8 (2.8 in 2018). In the site joint project teams, the risk of working at height and electrical hazards contribute to the greatest number of 'high-potential' events.

At Flamanville 3, the LTIR has remained very high at 5.9 (4.6 in 2018), while the overall accident rate reached 6.5 (5.5 in 2018). Despite the actions to counter this trend, which have been initiated by the site management team in collaboration with contractors, I note there are still many near-misses and hazardous situations, most related to electrical work. To support these actions, I believe more focus should be placed on keeping worksites clean and tidy to improve risk prevention.

On decommissioning sites, the LTIR was 0.5 (4.7 in 2018).

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Lost-time injury rate (LTIR)

This indicator measures the number of work-related lost-time injuries per million of hours worked.
Contrary to the overall accident rate (Tfg, used in EDF SA) that includes all lost-time injuries (including travel to/from work and non-work related injuries during working hours), the LTIR only takes into account injuries that are directly related to the professional activity in question.
The LTIR is designed to gauge the efficiency of the risk management policy and the actions deployed by the Group's business units. This indicator is recognised and widely accepted worldwide.

… THAT CALLS FOR GREATER COMMITMENT IN THE LONG RUN

The industrial safety teams that I met were motivated and proactive. They were driving improvement actions, many focusing on raising awareness. This was the case at the DPN with the MISEZ campaign set on reducing the risks of equipment loading and unloading operations. I also note that the road safety campaigns, initiated by the DPN after a spate of accidents in 2018, are producing positive results. This is reflected in the drop in the number and severity of road accidents involving staff.

Industrial safety inspection - Flamanville 3 nuclear power plant

Most sites are fully aware of the critical risks present. For example, the corporate services are generally informed of any events qualified as 'high potential' within 24 hours, although the lessons learnt from these events are not always identified and used sufficiently.

The use of safety messages is a widespread practice across the organisation; however, these tend to be confined to corporate communication media (such as posters and videos). Contrary to UK practices that actively seek out collaborative ways of making progress, in France they are rarely used as an opportunity for team sharing.

In industrial safety, as in other areas, the proliferation of rules can mask the most important ones. For this reason, the DPN decided to focus on 10 critical rules for the Group as part of its strategy to harmonise approaches. It must, however, be made sure that other rules, specific to nuclear sites, are also followed, e.g. not entering a demarcated area for radiography without authorisation.

The DPN's determination to simplify and harmonise approaches is also reflected through the single go-to standard it is drafting on personal protective equipment (PPE), which is expected to be published in 2020.

MISEZ: banking on industrial safety in France

This DPN communication campaign aims at making it easier to analyse the risks involved in any equipment loading/ unloading operation and at identifying 5 key points for securing such activities:

- **M**ass and centre of gravity are known
- Staff **I**ntervening are trained and authorised
- Load **S**tability and equipment has been checked
- Condition of the **E**quipment has been inspected
- Exclusion **Z**one is respected.

MISEZ SUR LA SÉCURITÉ

The role of a manager has always been recognised as essential by both by EDF and its contractors. I believe great benefit is gained by sites that organise joint manager-in-the-field visits with members from both EDF and contractors. I have noticed, however, that the duration and quality of these visits in the field are still inadequate and need improvment.

The zero-harm initiative launched in late 2015 within the DPN is still not properly integrated into the daily routine. Such an initiative and related behavioural changes can only move forward if there is strong managerial support to lead the way (see my 2018 report).

Many first-line managers have voiced their difficulty (see Chapter 4) in making sense of the excessive number of increasingly complex rules (detecting asbestos, lifting regulations, etc.) and in ensuring they are respected. The recommendation I made in 2018 to consolidate their training in industrial safety and to support them in the field is still relevant today.

IN THE UNITED KINGDOM: THE RESULTS ARE GOOD…

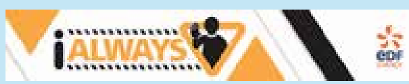
The results for the EDF Energy fleet are still at a good level: the LTIR dropped to 0.3 in 2019, compared with 0.5 in 2018. Working at height is still a concern.

The results for Hinkley Point C remain excellent, with an LTIR of 0.92 compared with 1.18 in 2018, which makes this construction site one of the best of its kind. I was able to appreciate the overall organisation of the site, its access routes and pedestrian paths, as well as the role of plant area owners. The areas for improvement remain: working under or near suspended loads during lifting operations (60,000 per month), dropped items and the risk of falling from height. I would like to draw attention to the consistent drive of the construction director in consolidating industrial safety. Much effort has been made to improve the mental health of the construction site staff, more than half of whom find themselves far from home.

‘I always’ initiative in the UK

This 6-week campaign targeted all EDF Energy staff and contractors and covered six different topics. Using an already familiar practice, a different safety message was published every day in support of the weekly topic. These topics were:

- Perception of risks and how to eliminate them
- Working at height
- Dropped loads
- Driving vehicles
- Hand injuries
- Use of tools.



Managers had access to factsheets available on EDF Energy’s Intranet that summarised the main daily messages. Additional information (videos, topics for discussion, questions, recommendations, and review of the rules) were provided to help them support the messages.
The safety messages were the same across EDF Energy, however the supporting information and images specifically targeted every profession, technique or service in the different business units.

… AND WILL REMAIN SO WITH CONTINUED SUPPORT FROM MANAGEMENT

In the UK, industrial safety is a fundamental value shared by all staff and contractors: risk prevention is a natural part of their professional conduct.

Prevention actions are deployed, often through targeted communication campaigns with powerful catchphrases. This is the case for the ‘I always’ communication campaign that was launched after a deterioration in the industrial safety results was observed in late 2018 and early 2019.

I encourage EDF Energy and contractor managers to pursue actions in the field that ingrain sustainable safety attitudes by continually supporting their teams and ensuring compliance with the safety rules.

A practice contamination check - Fessenheim nuclear power plant

PREVENTING DRUG AND ALCOHOL ABUSE

Alcohol consumption and drug-taking are forbidden on the plants as the related risks are highly incompatible with the nuclear industry.

In France, Directive DI 120 on alcohol consumption has been in force at the plants for several years. Alcohol testing is carried out regularly and this has helped drive the correct overall behaviours.

However, progress in detecting drug use is still quite weak. The internal rules of some units have been amended and whilst certain tests are now carried out, the overall implementation is still unsatisfactory. The Council for Nuclear Safety (CNS) that met on 26 June 2019 voiced the need to increase awareness and to undertake more frequent drug and alcohol testing. I once again call for the application of the Group’s policy in this field without any further delay.

In the UK, random drug and alcohol testing is a routine affair. This is a good practice.

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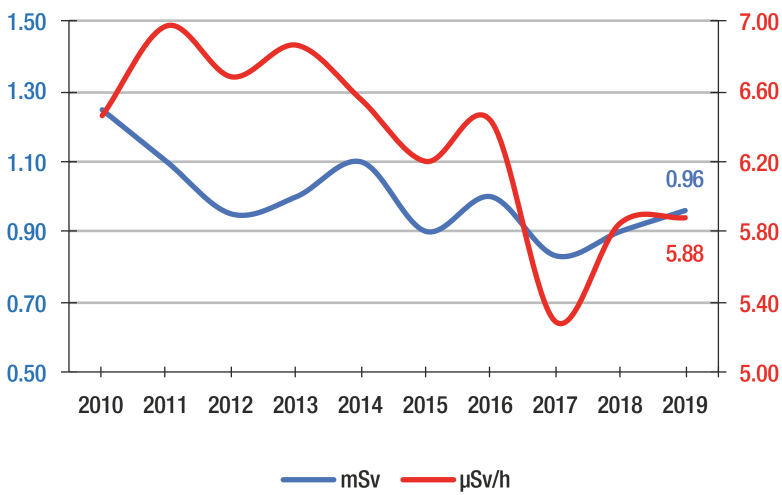
SATISFACTORY RADIATION PROTECTION RESULTS

IN FRANCE, STABLE RESULTS...

In 2019, with a rather turbulent industrial context due to 7 ten-yearly inspection outages, the collective dose was 0.74 man.Sievert/reactor, which is slightly higher than the DPN objective (0.70 manSv/reactor). This slight difference between the planned and actual dose was only seen during a small number of reactor outages.

The average individual dose for workers (EDF and contractors) reached 0.96 milliSievert (mSv), which is higher than the results of past years (0.90 mSv in 2018 and 0.83 mSv in 2017). A total of 151 operatives received an annual dose exceeding 10 mSv compared with 160 in 2018. None exceeded 14 mSv. The regulatory limit is 20 mSv.



Mean individual dose and hourly dose (EDF and contractors)

The 7 occurrences of external contamination wherein 25% of the annual regulatory limit was exceeded each time indicate that the rules for checking individual doses and for dressing and undressing are not always being followed correctly.

The occurrence of several significant events in 2019 highlights the fact that greater rigour and situational awareness is needed:

- 42 for operations in orange controlled areas (36 in 2018, 29 in 2017 and 45 in 2016)
- 4 for operations in red controlled areas (2 in 2018, 1 in 2017 and 4 in 2016)
- 9 for radiography work (6 in 2018, 6 in 2017 and 9 in 2016).

... WITH WARNING SIGNS THAT SHOULD NOT BE IGNORED

There were situations where staff found themselves inside areas that had been demarcated for radiography work, or where they had not respected the access rules for red controlled areas; such behaviours are unacceptable. The rule defined by the DPN after the 1999 radiation protection event states that one person alone cannot carry the two keys needed to open the access doors to a red controlled area. In 2019, there were 2 occasions where the second key was 'lent' to a colleague who already had the first key, therefore giving them free access into the room in question.

Red controlled areas: the origin of the two-key rule

In 1999, a staff member from a plant's risk management section (SPR) received a dose exceeding the regulatory threshold of 50 mSv/year in force at the time. This threshold has since been reduced to 20 mSv/year. This radiation protection worker went unauthorised into a red controlled area under the reactor vessel, access to which is usually strictly regulated, to remove some tools. The ensuing inquiry concluded that the worker and two of his SPR colleagues had not complied with the access rules.
In the wake of this event, which was classified INES Level 2, the DPN consolidated its measures to restrict access into red controlled areas by implementing a double-locking system with one key kept by the risk prevention section, and the other by control room staff.

Programmes to decontaminate the primary cooling systems help reduce doses significantly. Such programmes are running smoothly and should be continued. New methods for defining priorities have been devised by the DPN's Operations engineering unit (UNIE). I suggest they check the results of this clean-up work to see if it is sufficient to improve the average worker's dose levels within the fleet. The high volume of work during outages for maintenance must never become an excuse for postponing a clean-up campaign.

During its assessments, the DPN's Nuclear Inspectorate identified the following improvement areas:

- Use of feedback from radiation protection events
- Elimination of hot spots
- Radiological cleanliness of worksites.

I encourage the plants to make further progress in these areas.

The radiation protection (RP) teams that I met were committed and skilled. In my 2018 report, I stressed that RP was sometimes perceived as a matter for specialists. The above shows that we need to increase awareness and that the rules need to be followed more rigorously by all.

IN THE UK, SATISFACTORY RESULTS...

Owing to the specific design of the AGR, collective doses are inherently very low: 0.03 man.Sv/reactor in 2019 (0.05 man.Sv/reactor in 2018). The main contributor to the collective dose within the AGR fleet was statutory outage inspections performed within one reactor vessel.

The collective dose for the Sizewell B PWR was 0.26 man.Sv (0.1 in 2018 and 0.3 in 2017), which compares well internationally. The collective dose during this year's refuelling outage was the lowest ever and was managed well. The maximum individual dose in the UK fleet was 4.37 mSv (7.19 mSv in 2018 and 5.54 mSv in 2017).

In spite of the many statutory outages in 2019, the radiography work was managed well with no reportable events.

... THOUGH SOME POINTS NEED TO BE WATCHED

Though the radiation protection results for the UK fleet were good overall, some instances of unsuitable behaviour were pointed out to me: for example, going through barriers set up to temporarily prevent access to certain areas, or not using small-article monitors to check for contamination.

The advantage of the AGR design for radiation protection cannot be used to bypass any rules or to excuse lax behaviour.

For this reason, I believe the role of the ALARP[22] committees in charge of radiation protection should be strengthened in way that encourages the various professions to become sufficiently involved in this topic.

MY RECOMMENDATIONS

In 2019, I see that, globally, the Group has only progressed a little in industrial safety and radiation protection. I therefore feel compelled to reiterate my recommendations from the 2018 report.

"I recommend to the directors of the DPNT, the DIPNN and the CEO of EDF Energy that they join forces with their contract partners to consolidate the prevention of critical risks, such as:

- **Electrical hazards and radiography work in France**
- **Working at height across the board in the UK and working under or near suspended loads at HPC.**

Leader presence in the field is one of the key factors driving progress in industrial safety and radiation protection. I recommend to the directors of the DPNT, the DIPNN and the CEO of EDF Energy that managers and leaders be trained in a more comprehensive, operationally focused manner and that they benefit from personal support in the field from their supervisors.

Nuclear professionals require situational awareness and self-control. I recommend the directors of the DPNT and the DIPNN ensure that the Group's policy on drug abuse prevention and testing is rapidly deployed on the ground."

[22] *As Low As Reasonably Practicable*

Team meeting - Civaux nuclear power plant

Managers are responsible for conveying the nuclear safety message and exemplifying its priority, especially during periods of uncertainty, organisational change and changes to working practices.

They play an essential role in their teams' technical management, as well as in motivating and developing the skills of their staff, in support of Group performance.

They also have to deal with numerous, often conflicting, demands and adapt to a rapidly changing environment.

Key role of first-line managers 04

First-line managers are nuclear industry professionals who form the first level of management within the EDF Group.

In France and the UK, their role varies according to the specific features of the organisation, and the composition and size of their teams: a manager of a maintenance team, an operations manager in a nuclear power plant, and a group manager in an engineering function or R&D clearly have very different day-to-day responsibilities. I have chosen to look beyond these differences at some generic aspects illustrating the breadth and the difficulty of the role of first-line managers.

The first-line managers I have met are individuals with varying profiles and experience, who are motivated and highly committed to their work. During our conversations, they all expressed themselves in an open, constructive and transparent way. In 2019, I was pleased to note that, despite the challenges they face in their day-to-day work, their role has become more attractive in several business units.

FIRST-LINE MANAGERS ON ALL FRONTS

First-line managers are often torn between the demands of their line managers, technical realities and the day-to-day issues of their teams. Despite the increasing demands being placed on them, which are sometimes conflicting, and the time pressures involved, they must always make nuclear safety their overriding priority.

During my visits, first-line managers have increasingly told me of the considerable pressure put on them by the site, engineering or project management to keep to schedules and to improve productivity. If these demands are pushed too far they could, in some cases, lead to technical problems not being reported or result in quality issues. Conversely, a realistic, carefully monitored schedule will give both teams and first-line managers peace of mind and ensure quality work is produced. Providing more resources is often cited as a solution to accommodate for much heavier workloads. I believe that we must first look at improving the management of our industrial activities and at making our organisations more efficient.

In 2019 as in previous years, first-line managers have complained about increased bureaucracy, which keeps them away from essential matters. They have to spend too much time in numerous, inadequately prepared meetings. At a number of sites, too much of their time is taken up with management systems[23], administrative tasks and numerous reports. HR, administration and planning tools are increasing their workload even further rather than making things easier (see my 2018 Report).

They are aware that they should devote more time to their teams, despite their growing workload. I have been shown initiatives to free up two hours a day in the schedule of each manager at the DPN or improve meetings (number, duration and effectiveness): I will be monitoring their progress.

COMMITTED FIRST-LINE MANAGERS WORKING CLOSELY WITH THEIR TEAMS

SOME ENCOURAGING POSITIVE POINTS

In the latest My-EDF annual surveys, staff generally value the support they receive from their managers and trust them. First-line managers are generally getting the nuclear safety message across, especially its priority.

Contrary to popular belief, the organisation, traceability and application of the numerous requirements of the nuclear industry are compatible with empowerment, which means teams being accountable, proactive and engaged. At several sites in France and the UK, I have been shown innovative management initiatives, at various stages of development, including visual management, lean management and Teal.

These approaches encourage staff to express their opinions and be accountable within their remit. They cover a wide range of areas, including daily meetings, drawing up a team contract, dealing with minor problems, work organisation, types of activities to be subcontracted, etc.

I believe these approaches meet the high expectations of staff, both young and not so young. They have numerous benefits, which include boosting confidence, involvement, and team spirit. They also help improve performance, especially in the fields of nuclear safety

[23] *Integrated management system (SMI) in the DPN*

and quality. I urge managers to embark on such initiatives. Greater support from site management would make it easier to implement them.

A BALANCE MUST BE FOUND

When first-line managers have many years' experience of working in their team's profession, they have solid technical authority, but may find it difficult to become the manager of a team of which they were a former member. This has happened at many UK sites where many of the managers began their careers as apprentices. Conversely, when young engineers are made first-line managers they may experience difficulty or be reluctant to become involved in technical matters.

An engineering team using visual management

More generally, I am well aware of the difficulty first-line managers have in finding a satisfactory balance between the technical and managerial parts of their work. I do not believe there is just one answer, as this balance will differ according to the team, its activities and the profile of the manager. However, I advise against implementing a dogmatic approach which could result in first-line managers losing interest in the technical part of activities or, conversely, doing their staff's jobs for them.

This year again, I have seen that there is insufficient managerial presence in the field, either in terms of time or quality. In 2019, the DPN's Nuclear Inspectorate noted that, although managers are spending more time in the field, they are not focusing enough on the real issues (for example, support and monitoring). This is a prerequisite for improving performance, in particular nuclear safety, quality and industrial safety, and I reiterate my recommendations for improvement on this point.

It is not easy for first-line managers to find the right balance between supporting their staff and monitoring their activities. They must delegate wisely, give advice and carry out effective monitoring. They must also reconcile real-time demands with taking sufficient account of the bigger picture so they can anticipate and prepare for the future.

I urge first-line managers and their heads of department to make further progress finding this balance.

ACCOUNTABILITY IS ESSENTIAL

Site and corporate management teams, often concentrating on operational management in real time (operational focus), must also take account of longer-term issues likely to make the role of managers easier, in particular the adequacy of resources and skills for the workload in the medium and long term or improving surveillance of contract partners.

First-line managers must play a key role in the training and professional development of their teams and are generally aware of this. However, I still meet first-line managers who do not get sufficiently involved in staff training and support, relying totally on the training departments. I will be paying particular attention to this in 2020.

Many first-line managers are concerned about their lack of control over HR matters: they are often not included in discussions about recognition, recruitment and mobility. Site and corporate managers must ensure that first-line managers actually have the leverage to take on this important part of their role.

More generally, I believe it is essential that first-line managers, with the assistance of their management, take every opportunity to be proactive, and take responsibility for performing their role to the full and flourishing in their profession.

FIRST-LINE MANAGERS, A DRIVING FORCE FOR CHANGE

Amid numerous organisational changes and new working practices, it is essential that first-line managers are present in their teams, to listen, help and motivate their staff. At the same time, they must ensure compliance with the fundamentals of nuclear safety and quality, while making sure that operational performance is maintained. I have already mentioned the essential role of managers in the success of the changes within the EDF Group. Some progress has been made in a few areas in 2019, but it is still limited.

An example of this is the implementation of human performance tools in the DPN. For many years, their introduction has been led by managers, some of whom have not always been convinced of the need for their systematic implementation. They have not always applied the tools themselves and admitted that their staff have occasionally avoided using them when under pressure from deadlines. I have, however, seen some improvements in 2019 in plants where staff have understood the value of these tools. For example, if it becomes clear during a pre-job briefing that the conditions for successful completion of an activity have not been met, then some of those involved have been prepared to say that they are “not ready”. They feel supported and encouraged by their managers to do this, even though it will affect the work schedule. More generally, I am pleased to note that the DPN has initiated discussions on clarifying how to apply the human performance tools, in particular the meaning behind the term “*PFI en mode réflexe*”[24], the significance of which is not understood by everyone (see my 2018 Report).

The Teal initiative

In his 2014 book, Frédéric Laloux identifies four main stages in reinventing organisations, which then lead to a fifth organisational stage. Each stage is identified by a colour and a paradigm: red, characterised by the authority of a leader; amber; orange, which corresponds to most companies in France, focuses exclusively on the tangible objective aspects of the organisation (structure, procedures, practices and employee behaviour); green; and right through to teal which corresponds to a profound change in relation to the four preceding stages.
Moving from one paradigm (colour) to the next has speeded up and all the paradigms currently exist side by side, each of them addressing different situations and issues and an additional level of complexity.
A Teal organisation aims to give real power to teams so they can be proactive and make decisions, which will enhance both engagement and performance. This approach, based on willing commitment, involves the operations teams supported by their management hierarchy and backed up by a process champion. The teams adapt their actions to the context and progress at their own rate.
The first trials in the EDF Group, which began in 2017, have led to several managerial innovations, e.g. recognition, recruitment and skills development, workspaces and locations, organisation of activities, and decision-making.

The implementation of collective responsibility for industrial safety in France (see Chapter 3) seems to be encountering the same issues as the deployment of the human performance tools. This process launched in 2015 is struggling to make any progress, through lack of understanding of the meaning, inadequate managerial support and the lack of any examples being set at each level.

In the engineering divisions, the development of multidisciplinary project teams is continuing. They work well when those involved have shared the message and contributed to defining the organisations and the way they work.

People are sometimes seconded to other teams. They therefore have one manager in their original function and another in their seconded function. This is the case with DPN staff who are seconded part-time to the Nuclear rapid reaction force, FARN (see Chapter 7), as well as in the engineering divisions, where Edvance, DIPDE and CNEPE first-line managers are not always the line managers of their team members. The attitude of both managers is important for a successful secondment. They must work together and harmonise their practices, in particular in terms of recognition and career paths.

Using human performance tools - Civaux nuclear power plant

More generally, there have been many initiatives to improve the culture of engagement and performance throughout the Group. For these to be successful, it is essential that first-line managers understand their purpose, convey this to their teams, and deal with them as culture changes rather than more modifications to processes or tools, or a new set of requirements to be applied.

I have already mentioned the many benefits of the innovative management initiatives, which are starting to be implemented. Despite the strong impetus from the Group’s senior management, I have seen reluctance to commit to such initiatives in some divisions or sites. Yet these initiatives will give more meaning to the teams’ work and ultimately improve its quality.

[24] *Instinctive use of human performance tools*

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Like all staff, managers work in a changing environment in which new generations have different expectations. In-house and external requirements are increasing and becoming more complex, there are organisational changes and new working practices, and the digital transformation is growing. First-line managers must constantly adapt to this changing environment. It is therefore important that they are included in the strategic discussions within their units and receive appropriate training and professional development as I recommended in my 2018 report.

Pre-job briefing - Dungeness B nuclear power plant

PROFESSIONAL DEVELOPMENT OF FIRST-LINE MANAGERS

Most first-line managers value the training they receive. Nevertheless, some feel inadequately prepared for taking up their jobs. I urge senior management to be more proactive in identifying future managers, so that they receive basic managerial or leadership training prior to taking up the role.

I have also seen too many first-line managers left to their own devices who, if they were given some support, would be able to overcome problems and improve their ability to motivate their teams. As well as initial training, I believe it is essential that first-line managers be supported by their own managers for the whole time they are in the job. Targeted support from a professional coach may also be helpful.

Training first-line managers for leadership

In France, Pass MPL is a training course provided by the EDF Group Management University. Comprising 7 days spread over 6 months, it is open to all first-line managers with 6 to 18 months' experience in the role.
In the UK, the objective of the EDF Energy Leadership Programme, developed by the Nuclear Leadership Academy, is to improve leadership skills at all levels of management. The first level of this programme, designed for First-Line Leaders, runs over 6 days spread over 3 months. Those on the course are assisted by a mentor.
The purpose of both of these programmes is to provide first-line managers with the information and tools they need to:

- Understand their role and get to know one another better
- Familiarise themselves with the EDF Group's strategic environment and financial issues
- Manage each member of staff.

These programmes cover the responsibilities and behaviour expected from a first-line manager, mainly through case studies and the sharing of good practices.
At the end of these programmes, first-line managers are encouraged to draw up their own development plans to continue furthering their leadership skills.
Additional targeted training courses are also organised by the technical divisions or sites, such as the DPN's "*Académies métiers MPL*" (first-line manager vocational academies) in France.

Where first-line manager discussion periods have been introduced, I have seen greater managerial cohesion, less functioning in silos and greater solidarity between teams. These periods provide an opportunity to come up with suggestions for improving operations using a bottom-up approach. They also allow managers to open up to others and share their problems and good practices, and get away from their immediate concerns. In addition, meeting managers from other hazardous industries may provide interesting new ideas and a general broadening of their knowledge.

I strongly urge the general introduction of such approaches, which help to improve performance in all areas.

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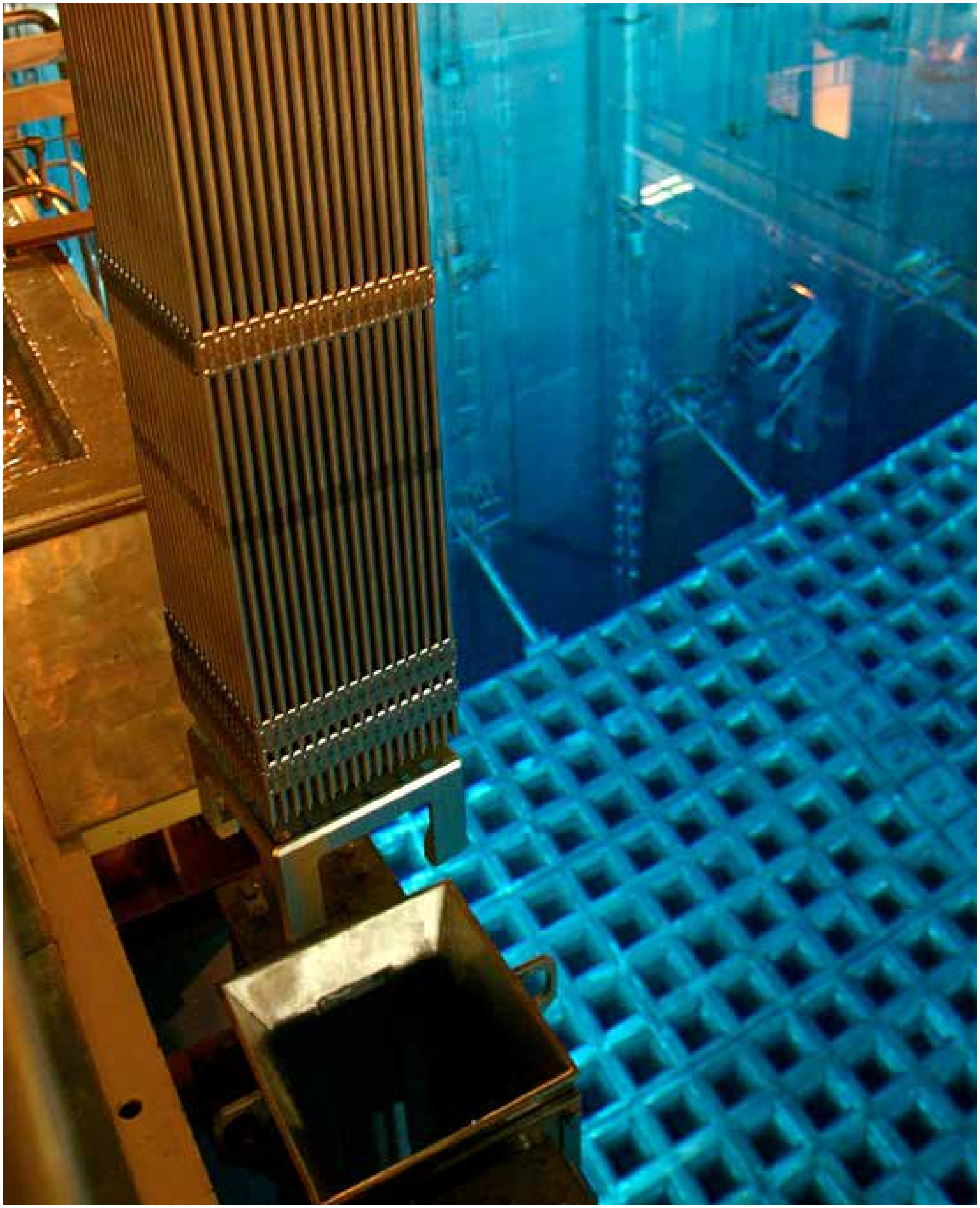
MY RECOMMENDATION

For first-line managers to support change, they must be aware of the issues involved. They must be an integral part of the whole management hierarchy and be sufficiently close to their team in the field. I recommend that the directors of the DIPNN, the DPNT, and EDF Energy:

- Protect first-line managers from any demands that would take them away from their teams and their own priorities
- Give them greater responsibility and freedom to work
- Continue initiatives to develop their leadership skills by providing them with personalised support, in particular from their own line managers.



Fresh fuel assembly on the edge of a PWR storage pool

The fuel in a reactor is central to nuclear safety as it affects reactivity control, decay heat removal and fission product containment.

This is where the nuclear reactions take place and decay heat is produced. The cladding around the fuel provides the first barrier between the fission products and the environment.

Nuclear fuel can release vast quantities of energy, which means that controlling its reactivity is the priority at all times, from fuel manufacturing to the end of the fuel cycle.

Nuclear fuel and reactivity control: the core of nuclear safety 05

REACTIVITY CONTROL: THE PRIORITY FOR NUCLEAR SAFETY

Controlling the fission reactions in the fuel is an inherent part of harnessing nuclear energy. Nuclear safety and energy production are thus closely related.

During my visits in France and the UK, I did not identify any major shortcomings in reactivity control. Yet we cannot settle for adequate performance in this area; we must strive for excellence at all times. Though few in number, some difficulties are definite weak signals, such as not recording the inverse counting rate[25] during criticality or problems with controlling reactivity at very low power. These incidents are a clear reminder that management - particularly at the plants - must embody the importance of reactivity control and confirm that it is managed correctly.

In France, the new standard for operators, which includes an additional position in control room supervision, is too good an opportunity to miss to consolidate operator support and oversight. The reactivity control guidelines available in France also provide a solid base from which operators can work.

From a training perspective, the risk of criticality and its control during fuel loading operations seem to be well covered. For example, OPEX from the incident that occurred at Dampierre in 2000 is included in the reactor operator training programme. Simulator training for control room operators is mainly focused on incident and accident scenarios; reaching criticality and operating at low power should be developed further.

SKILLS AND GOVERNANCE

In France, I met many skilled professionals in the fields of fuel technology, core physics, fuel procurement and fuel load management, all assuming their responsibilities diligently. The overall level of expertise is excellent, their communication network is working well, and the Core design and engineering group (GECC) within the Operations engineering unit (UNIE) is efficient. The sites' core and fuel engineers, who benefit from diversified training early in their careers, are able to provide valuable knowledge in core physics.

Fuel loading in a spiral configuration

Fuel assemblies are loaded into a reactor according to a very specific plan to ensure that sub-criticality conditions are maintained.

In 2000 at Dampierre, following a technical issue and a series of human and organisational errors, the loading sequence was offset by one fuel assembly each time. This error led to the accumulation of new fuel assemblies in one area, with the most reactive on one side of the core.

Analysis showed that the core could have reached criticality if the conditions had been different. Having analysed the OPEX, the loading sequence was then modified to use a spiral-like loading pattern to prevent such errors. The equipment and organisational measures in place were also strengthened, along with the training material.

There is, however, only a small pool of staff specialised in neutronics; this will need to be handled carefully both by EDF and Framatome in order to maintain this capability in the future.

All functions involved with nuclear fuel, including procurement, operations, engineering and R&D, are grouped under the Core-fuel directorate (DCC), which is therefore able to readily define fuel strategies and makes key decisions. Its governance in this field is effective.

Unfortunately, fuel handling does not benefit from having a similar structure or level of engagement.

[25] *Neutron flux measurements. The exact moment at which the reactor goes critical can be accurately predicted by tracing the inverse counting rate at reactor start-up*

PRESSURISED WATER REACTORS (PWR)

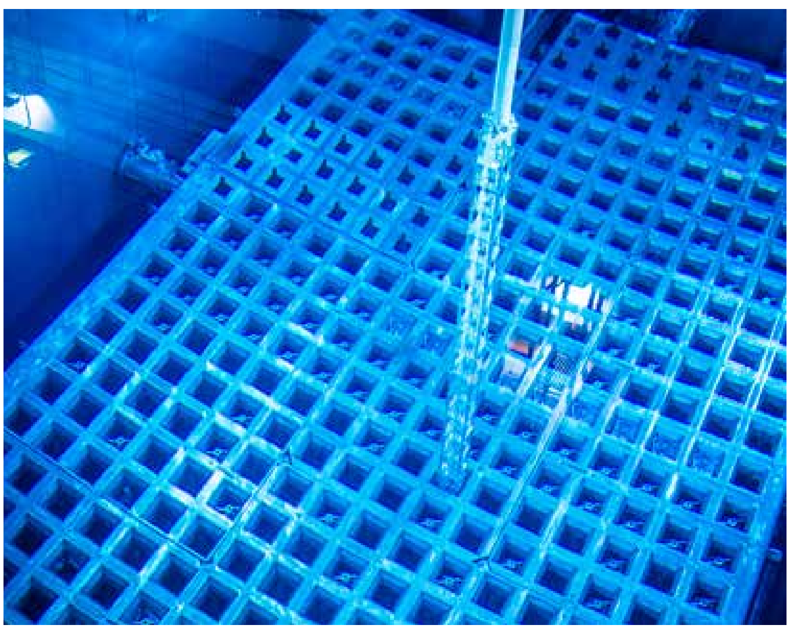
SATISFACTORY PERFORMANCE

In 2019, the fuel assembly failure rate in PWRs remained at a good low level.

In France, this failure rate was 0.11% (compared with 0.13% in 2018), representing a total of 8 fuel assembly leaks across 5 reactors. Foreign material and friction spring failure are the main causes of fuel rod failure. Because of stress corrosion, some spring components either break away to become foreign material or they remain partially attached and wear the cladding before perforating it. To remedy this problem, future springs will soon be heat-treated to improve their resistance to stress corrosion.

In 2019, 23 fuel assemblies could not be reloaded due to damage linked with handling (compared with 4 in 2018, 10 in 2017, and 8 in 2016); 22 were damaged at the top end (S holes), while the remaining fuel assembly had a damaged grid. The causes behind this significant increase must be investigated so lessons can be learned.

In the United Kingdom, Sizewell B has had no fuel cladding failure for over 10 years.



Fuel assembly handling in the storage pool - Blayais nuclear power plant

CONTINUOUS TECHNICAL IMPROVEMENTS

Improvements are regularly made to fuel assemblies. New zirconium alloys used in cladding[26] have made them more resistant to oxidation and/or to pellet-cladding interactions. The recent introduction of quaternary alloys has increased the stiffness of fuel assembly structures and hence their resistance to deformation.

Fuel assembly deformation in the 1300 MWe and N4 reactors has been an issue for a long time. Deformation can slow down or even prevent control rod insertion. To assess this, control rod insertion times are measured at each refuelling outage. The increased use of quaternary alloys is decreasing the extent of deformation.

NEUTRONIC SENSITIVITY

Fuel element deformation also has an impact on neutronics. In some areas, the volume of water (water gaps) between fuel rods can be greater because of deformation. Because this provides better neutron moderation[27], the local neutron flux can be higher. This complex phenomenon is now included in accident studies, which is satisfactory. Reaching this point however took time and was initiated by IRSN questions.

Over the past few years, a higher neutron flux at the top and bottom of fuel rods has been modelled: a larger quantity of water will further moderate and better reflect the neutrons, while a zircaloy spacer will reduce absorption. This phenomenon, which only affects fuel pellets at the ends of rods, had been underestimated. This problem is accentuated in mixed uranium and plutonium (MOX) fuel assemblies, where the presence of large plutonium particles in the pellets that can create hot spots. Compensatory measures have since been applied and there are plans to add a steel spacer with a hafnium plug to all new fuel rods to absorb neutrons.

MOX PROCUREMENT ISSUES

In 2019, it once again proved difficult to procure MOX because of manufacturing problems at the Melox production plant. As a result, some of the planned MOX fuel loads could not be delivered; uranium oxide fuel was loaded instead.

REMARKABLE WORK ON REVIEWING CRITERIA

In France, EDF devoted several years to an extensive scientific review of all fuel resistance criteria for incident and accident conditions. These criteria were written in the 1970s, the majority of which came from the United States. They define the different variables that must not be exceeded to comply with the safety objectives and are validated by accident studies.

[26] *M5, Zirlo and optimised Zirlo can replace zircaloy-4*

[27] *Slowing down neutrons by means of a moderating material - water in this case - which promotes the nuclear chain reaction*

The extensive review of these criteria was concluded with by ASN's standing group of experts[28] in 2017 and it is testimony to the quality of technical dialogue between EDF and IRSN. As a result of this process, some criteria were consolidated while others were amended. Additional work is still in progress.

An advantage of this kind of exercise is that the scientific rationale and meaning of the safety criteria are re-explained and shared between staff, especially among the younger generations. It also shows how important it is to push the boundaries of knowledge in physics and to maintain sufficient margins (see Chapter 8).

PREPARING FOR THE FUTURE WITH DETERMINATION AND INNOVATION

Validating new products, periodically reviewing safety cases, and improving physical margins all require proactive R&D in fuel physics (see Chapter 8).

I am pleased with the development of the *Odyssée* project that sets out to more accurately model reactor core physics. It is important this project continue to get the resources and management it needs to remain effective.

Odyssée

The purpose of this joint project between EDF and Framatome is to build a new reactor core physics computer code. It will cover the needs of nuclear reactor manufacturing, EDF engineering, and operations (reload calculations). It will include the capability to more accurately model phenomena like water gaps, control rod ejection, injection of non-borated water plugs into the core, etc. Seventy engineers contribute to this project. An important step will be the code's validation. The first operational version of this code is planned for 2023.

AGR FUEL ROUTE AND CARBON DEPOSITION

The fuel used in AGRs is unique and complex. The new generation of robust fuel for AGRs has been in use since 2011 and now makes up about 80% of all loaded AGR fuel assemblies. The lower cladding failure rate and increased reactor power due to improved fission gas pressures are two clear advantages of this fuel.

Carbon deposition is still the main cause of cladding failure and it has affected all reactors to varying degrees. These deposits limit thermal conduction across the cladding, causing it to heat up and become weaker. To limit this temperature rise, some reactors have had to reduce power. The source of carbon comes from the breakdown of methane under irradiation; the methane is deliberately injected into the gas coolant to limit oxidation of the graphite core (moderator). Several factors contribute to carbon deposition, which makes it difficult to manage completely.

AGR fuel assembly - Westinghouse Springfield nuclear fuel manufacturing site

In 2019, 5 fuel elements were found to be leaking (compared with 5 in 2018, 8 in 2017 and 20 in 2016), all in the same reactor. This reactor is being monitored closely and corrective measures are in place, such as modification of the CO_2 gas coolant chemistry, endoscopic inspections, and oxygen injections to remove carbon deposits.

MAKING HANDLING EQUIPMENT MORE RELIABLE

Only the cladding protects operatives against radioactive material during fuel handling. In 2019, a fuel assembly became stuck to the reactor internals during a fuel loading operation in France.

I often met many experienced and highly committed professionals in the fuel handling departments. However, involvement of the sites' core and fuel engineers (IECC) during fuel handling operations tended to be inconsistent across the plants; this needs to be strengthened.

The fuel handling equipment (e.g. loading machine, supervision system, heavy crane in the fuel building, etc.) experiences recurrent reliability and obsolescence issues. Too often, it has to be operated in a downgraded

[28] Groupe Permanent réacteurs*: group of experts advising the ASN on the main nuclear safety issues*

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mode. The maintenance and fuel departments at the plants are also isolated from each other. This topic sometimes seems lost within the corporate departments and the engineering division. Requests for equipment upgrades submitted by the plants and the Core design and engineering group (GECC) are not followed through. This area therefore requires some immediate action and more robust management.

Incident during a fuel unloading operation

In 2019, a fuel assembly remained stuck to the top core internals of a PWR during a routine activity prior to refuelling. The top of the fuel assembly was deformed, a problem that had been left untreated since the last outage. Two comparable incidents occurred at the same site in 2008 and 2009.
The stuck fuel assembly was detected, the reactor building was evacuated, and the incident was managed, in line with expectations using existing procedures.
The DPN's Nuclear Inspectorate identified that the teams had become accustomed to working with poor-quality video images, that OPEX was insufficiently taken into account, and that certain checks had not been performed.

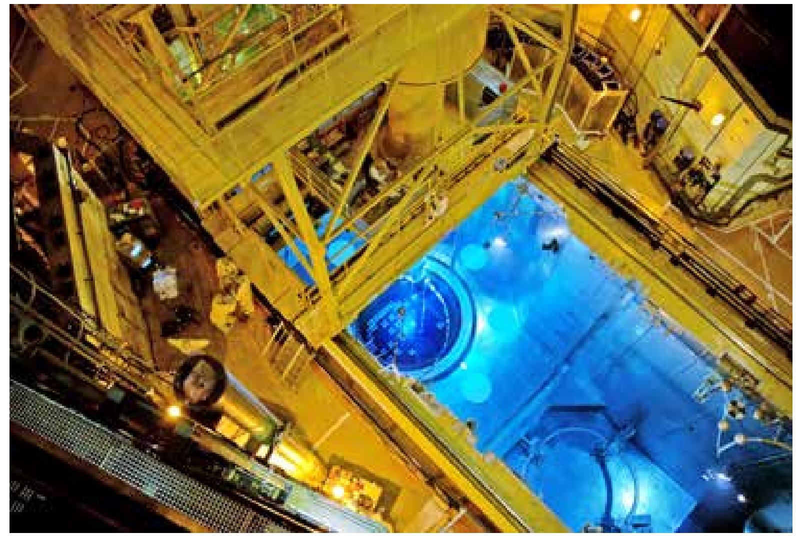
I was also surprised to learn that post-Fukushima changes, initiated in 2017 to ensure that a fuel assembly could be lowered manually in the event of a complete loss of power supplies during handling, have still not been fully deployed across the fleet (requalification of equipment under representative conditions, maintenance programme, and operator training).

The safety report excludes certain types of dropped loads, particularly over the fuel pool. This calls for specific design, manufacturing and operating requirements. Given the potential consequences and beyond the strict application of the regulations governing lifting equipment, I recommend regularly reviewing the load-drop exclusion conditions to ensure that all requirements are met.

In the UK, the fuel route includes all the fuel management resources allocated to AGRs, i.e. storage, assembly and dismantling of fuel elements, handling, loading and unloading. The fuel route is highly complex and particularly sensitive to equipment failures. At the plants, the fuel route services are often segregated, especially the maintenance and planning aspects of activities. Its reliability indicator (an aggregate indicator incorporating equipment behaviour, space availability in fuel ponds, etc.) is low at 72.7%. I therefore suggest that efforts be consolidated to improve the overall reliability of the fuel route.

MULTIPLE RECYCLING IN PWRs

Whilst confirming its strategy of a closed fuel cycle the French government recently decided to halt the new-generation sodium-cooled fast reactor (SFR) project called Astrid and to start an R&D programme on the multiple recycling of MOX fuel in PWRs (see My view).



Fuel loading machine - Cattenom nuclear power plant

This decision marks a turning point in the strategy for the fuel cycle and the use of natural resources and fissile material. A major R&D programme will be necessary to assess not only the feasibility, but also the pros and cons of this option.

Multiple recycling and the plutonium isotopes

Multiple recycling in PWRs is a complex affair due to the abundance of plutonium isotopes that changes with irradiation, and thus with each round of recycling. This abundance (sometimes referred to as a vector) indicates the proportion of each plutonium isotope[29]. With each irradiation cycle, the proportion of higher even-number isotopes increases[30], yet these isotopes are less able to undergo fission in a PWR; they are even considered as neutron poisons. Over time, the potential energy from plutonium in PWR fuel is therefore reduced.
The conditions are different in SFRs: all the isotopes undergo fission to the point where all the plutonium is spent. Waste - including the actinides - is therefore produced in smaller quantities.

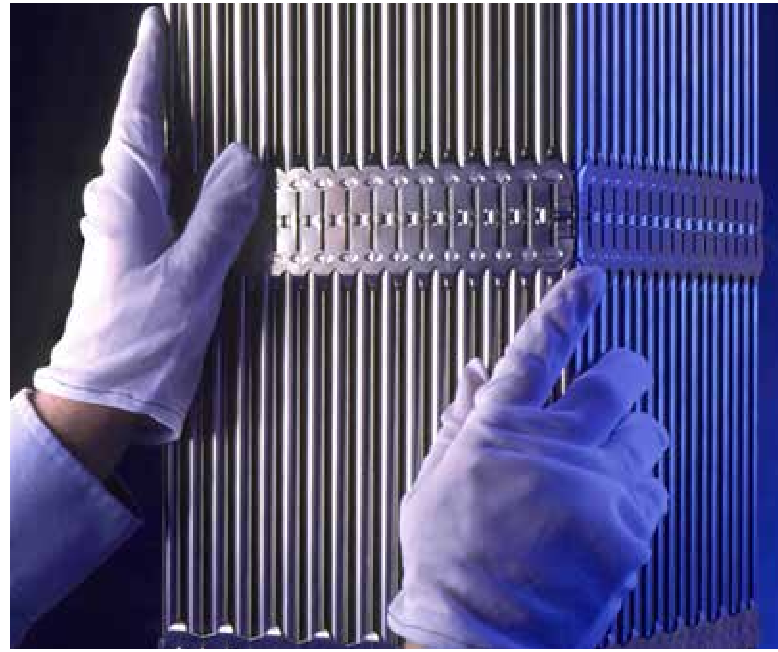
[29] *Isotopes are atoms of the same element that have the same number of protons, but a different number of neutrons in the nucleus*
[30] *Through the successive absorption of neutrons, U-238 produces Pu-239, before producing Pu-240, -241 (which produces americium) and -242 (which produces curium)*

Key subjects to be covered will include: the nuclear safety of PWRs loaded with irradiated MOX, the recycling of spent fuel, fuel manufacturing, radiation protection, final waste and its treatment.

As stressed in the long-term energy plan, the skills and knowledge in the field of SFRs must be maintained for the future. The resources and means to maintain these skills have not yet been defined, but practical projects will be required in addition to theoretical studies.

Fuel behaviour in accident conditions

Design-basis transients are classified into 4 categories: normal operation (cat 1), incidents (cat 2), unlikely accidents (cat 3), and hypothetical accidents (cat 4). Safety objectives are assigned to each category and each category has its own maximum acceptable radioactive release levels.
Each phenomenon is covered by technical criteria, such as: power released in the pellet, linear power density, cladding and pellet temperature, oxidation rate, cladding deformation rate, etc. Accident studies must show that these criteria remain in a predefined range within which we can be sure that the safety objectives will be met.



PWR fuel assembly - Framatome

MY RECOMMENDATIONS

The very nature of nuclear fission means that controlling reactivity must remain the priority at all times and from all levels. I recommend to the directors of the DPN and EDF Energy Nuclear Generation that the plants leadership consolidate their internal oversight of reactivity control in each relevant profession, as well as strengthen operator training in criticality and low-power operation.

I also recommend that the Director of the DPNT:
- **Reinforce the reliability, maintenance and management of obsolescence of the fuel handling equipment**
- **Reassess the conditions and means to guarantee the continued exclusion of certain dropped loads as assumed in the safety case.**

Loire River flooding in 2003 - Belleville nuclear power plant

Natural hazards may impact fundamentally the safety of a nuclear facility.

A number of events have occurred worldwide over the years, which have progressively led to improvements in risk assessment practices.

The sheer diversity and complexity of natural phenomena, combined with the fact that they are constantly evolving due to climate change, makes them difficult to fully understand and imposes a need for regular reassessment.

Continuing the effort in natural hazard risk management

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Natural hazards cover a wide variety of threats, including earthquakes, lightning, electromagnetic interference, extreme weather conditions and floods.

The flooding at Blayais in 1999 and the cooling system intake blockage at Cruas in 2009 illustrate the impact that natural phenomena can have on nuclear facilities.

The probabilistic safety assessments conducted as part of the fourth ten-yearly inspection outage of the 900 MWe fleet confirm the considerable influence these hazards have on the core damage frequency.

It was also flooding – due to a tsunami – that led to the nuclear accident at the Fukushima plant.

In this chapter, I have chosen to examine external flooding and hazards to the heat sink, which include the water intake systems of pumping stations. However, the majority of my observations and recommendations can be applied to any natural hazard.

INHERENT COMPLEXITY…

With each advance in scientific methods, the assessment, modelling and potential risk of each hazard phenomenon have evolved over time.

A number of hazards are attributable to the climate and so some risks are increasing due to global warming. Some phenomena can also occur very suddenly, like frazil ice[31] or dam failure.

The design and operational provisions intended to mitigate the consequences of these hazards therefore need to be reassessed at regular intervals. The height of flood defences, for instance, will be raised at some sites.

At the same time, regulations are also evolving. In France, ASN Guide No. 13, published in 2013, identifies the risks associated with external flooding. It defines methods for quantifying risk and recommendations on protection measures. It covers the impact of climate change based on existing knowledge at the time of writing and requires operators to incorporate these evolving considerations into every safety review.

In terms of heat sinks, there are numerous hazards to be considered, including low water levels, icing, sludging and silting, frazil ice, hydrocarbons (oil/petrol) and blockages caused by the mass intake of solid matter. The list of materials historically considered to cause blockages, such as fish, seaweed, jellyfish and mussels, has been expanded to include micro-organisms that could potentially clog cooling water intakes or heat exchangers.

Reference floods

According to ASN Guide No. 13, reference situations for external flooding are defined on the basis of an event or a combination of events, the characteristics of which are overestimated to compensate for the limited knowledge available.

Five reference floods are considered at every site: local rainfall, local catchment areas, deterioration or failure of structures, mechanically induced waves[32] and high groundwater levels.

Additional phenomena are taken into account at some sites depending on the specific geography:

- River sites: regional catchment areas, failure of water-retaining structures, local wind waves
- Coastal sites: sea level, waves and seiche[33].

[31] *Sudden formation of ice crystals which, in certain air and water temperature conditions, can form sheets of ice on the surface of the water or adhere to objects in the water*
[32] *A wave on the surface of water in a channel caused by a rapid change in flow rate*
[33] *A standing wave that can occur in enclosed or partially enclosed bodies of water like a harbour, reservoir, lake or bay*

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… INVOLVING MULTIPLE STAKEHOLDERS

COMPLEX ENGINEERING SET-UP IN FRANCE

Studies in every engineering function are organised by hazard: respective managers are appointed and their skills and expertise are improving; operational processes are implemented, with numerous interfaces between the parties involved.

I am pleased to see that the DIPNN's Technical division has resumed their role of steering the network of Hazard Managers and that a dedicated External Flooding Technical Committee was set up in 2018. This committee, led by the technical directorate for the Fleet upgrade programme *(Grand Carénage)*, aims to unify and coordinate the various projects and budgets.

Mock-up of the Flamanville water intake channel - LNHE[34]

There are at least a dozen different entities involved in mitigating external flooding and heat sink hazards. For heat sink hazards, the DIPNN's Technical division defines the standards, the CNEPE conducts or supervises the studies to apply these standards, and the conclusions of the studies are reviewed by the Design Authority from a safety perspective for the existing fleet and by the projects from a cost/lead-time perspective. EDF CIH, DTG[35] and R&D all provide support in their respective fields of expertise. They conduct specific studies, some of which are safety related. National weather services are also called upon. Decisions are made by project directorates and other bodies attached to the DIPNN and the DPNT, like the Technical Standards Committee and the Nuclear Safety Standards Directorate.

This multiplicity of parties involved, all reporting to several different directorates, can be justified due to the highly specific nature of the skills and expertise required. However, I would like to draw attention to the fact that this fragmentation of tasks increases complexity. It can also result in lower levels of individual accountability (see Chapter 2), as well as an increase in organisational inertia (refer to my 2018 Report) caused by slow information sharing and the fact that no one has an overall view of the bigger picture.

I am struck by the lack of overall responsibility for each hazard from either a technical or a nuclear safety perspective. It would be worthwhile establishing a means of cross-functional coordination for all projects and entities involved in hazard mitigation, from prospective studies right through to implementing actions on site.

IGUASOU initiative for improving heat sink performance

The IGUASOU project, set up to ensure heat sink safety and performance through innovation, is led by EDF R&D on behalf of the CNEPE, the DIPNN's Technical division and the DPN.
Its main aims are to improve knowledge of the physical phenomena involved and to develop numerical tools in a variety of fields, including:

- Environmental monitoring (characterising macrophytes, using acoustic cameras to view schools of breeding fish, detecting algae using hyperspectral imaging)
- Dynamics of water intake channels (sludging/silting and ensuring optimum dredging)
- Modelling filter clogging on pumping stations for the in-service fleet and EPR 2
- Physical mock-up of the EPR 2 pumping station, modelling the risk of vortex flows, blockages and sedimentation
- Frazil ice and associated modelling methods.

GREATER INVOLVEMENT OF EXPERTS

The complexity of these natural phenomena calls for highly specialised, varied and complementary expertise. Experts therefore have an essential role to play. The work carried out by EDF R&D

[34] *National Hydraulics & Environment Laboratory of EDF R&D*
[35] *Hydro Engineering Centre and General Technical Division (entities of EDF Hydro)*

in particular is a determining factor in the development of modelling methods and tools (see Chapter 8). I urge all engineering functions to take on board the new tools developed specifically for them as soon as possible.

Systems designed to prevent frazil ice formation

New modelling methods have been developed for external flooding studies. In some cases, they allow margins to be restored, but they can also produce more penalising results than earlier models. For instance, the SCHADEX[36] method, used for more than a decade to assess local catchment areas, can now be extended to assess regional catchment areas.

I encourage managers (project managers, engineering division directors, etc.) to use experts more widely to confirm that the reference flood levels are still valid and that they have not been superseded by new models and knowledge. In doing so, they can be better prepared to anticipate future changes.

On a more general note, it seems that centres of expertise are now focusing on providing hazard assessments in direct response to internal customer questions. These customers may be engineering functions or specific projects, looking largely to respond to the regulator's questions and substantiate safety cases within very tight time frames. They are not in a position to challenge the initial methodologies or assumptions used in the assessments. They do not always seek expert opinions to ascertain assessments of the risks and long-term implications before making their decisions (see Chapter 2).

ENGINEERING IN THE UK

Just like in France, the list of hazards was drawn up at the time the reactors were built.

Practically all safety studies are conducted by EDF Energy's central engineering function, which also supports each of the sites. The considerable workload on other sensitive safety cases regrettably means that hazard-related modifications or upgrades are sometimes delayed.

Engineers are trained and assessed on the basis of competency and indivudual performance based guidelines.

The Design Authority verifies all safety studies independently. Its teams also conduct station-specific hazard mitigation assessments and issue recommendations for each of the sites. I recommend that this approach be applied universally and the outputs shared across the station-specific teams and fleet.

The Design Authority also heads up the Hazard Governance Review Board (HGRB), which brings together experts from different disciplines within EDF Energy. This board sits regularly to examine how hazards are mitigated across the fleet and how staff are trained and qualified accordingly. The main threats identified are discussed during the regular contact meetings with the ONR.

In view of the plan to extend reactor service life, I urge Hazard Managers from EDF Energy and EDF SA to work together more closely on sharing information on risk management practices, evolving assumptions and modelling methods.

COMPLEX TECHNICAL STUDIES

The complexity and evolving characteristics of natural phenomena mean that margins need to be applied and re-examined periodically. I see that an embankment at one site needs to be raised again only a few years after it was first raised. I am surprised to see that walls, just

[36] *French acronym for* Simulation Climato-Hydrologique pour l'Appréciation des Débits EXtrêmes*, which is the climate and hydrology simulation model used to estimate extreme floods*

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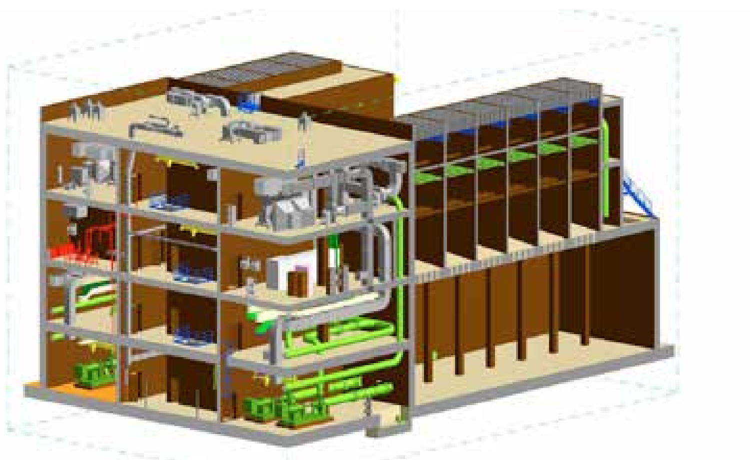
15 to 20 cm high, are being built at many sites to address a specific flooding scenario; building a higher wall in the first place would certainly avoid costly rework in terms of studies and construction that may be recommended in future reviews.

In terms of heat sink hazards, the CNEPE is taking advantage of its dual role in the existing fleet and new-build projects. Its cross-project vision affords an exceptional level of technical credibility. It maintains strong relations with the ASN, which makes for a smooth examination process.

Major safety enhancements are expected once the VD4 outages have been completed on the 900 MWe fleet. Facility robustness is improving. However, the high number of simultaneous modifications in progress, as well as questions raised by the ASN or IRSN, means that staff are overloaded. Some of these questions are in response to shortcomings in the engineering studies. Others highlight a lack of initial agreement by the main stakeholders on the scope of examination. This detracts from the ability to prioritise and tackle the most important issues (see Chapter 2).



EPR 2 building for the diverse heat sink system

Requirements for new build are naturally stricter compared with those for past projects. More severe hazards are taken into consideration in the design, which should avoid the need for subsequent modifications. I have been shown the design for the EPR 2 pumping stations and the changes incorporated since the previous generation of EPRs. Whilst this approach sets out to reduce costs and improve construction, it nonetheless encompasses all relevant nuclear safety aspects.

TAKING HAZARDS INTO ACCOUNT AT EACH SITE

IN FRANCE

With the same risk management objective, plants need to ensure compliance with all applicable requirements, incorporate all changes and take account of the new standards derived from safety reassessments. Hazard mitigation usually falls within the Safety & Quality Manager's remit. This affords them certain operational responsibilities, which could potentially conflict with their independent nuclear safety oversight role.

Hazard mitigation measures and equipment

This covers all active equipment required for safety purposes in the event of a hazard, as well as equipment that needs to be installed in the event of a known or imminent hazard. For instance, it includes heaters and temperature sensors for an extreme cold hazard, or automatic dam boards for a flooding hazard.

Chapter IX of the General Operating Rules stipulates regular testing of all this equipment, as well as the course of actions required and the associated time scales for any repairs in the event of damage (generally less than a month, unless specific actions are defined).

I am pleased to see that a 'hazards' stream has recently been set up by UNIE and is coordinating site representatives in a cross-functional approach. I urge the DPN to strengthen the role of this stream.

Hazard mitigation measures are subject to specific requirements laid down in a set of rules governing hazard specifications, known as RASA. These rules will form the basis of a future Chapter II in the General Operating Rules, as has already been done for EPRs. The Operator must take ownership of these rules. They define, for each type of hazard, the underlying assumptions for the safety studies, the list of hazard mitigation measures and equipment, and their operation and maintenance criteria. Formalising all this information in this way was no mean feat, but it will undoubtedly help to manage hazards far more effectively. The Operations & engineering training department (UFPI) has also developed training programmes and supporting guidance documents for each hazard.

I often note that engineers with responsibility for hazard mitigation only spend around 5 to 10% of their time on it, despite their own and the DPN's recommendation that it should be between 30 to 50%.

The hazard mitigation training of hazard engineers also needs to be consolidated. This should be addressed by the DPN as a matter of priority.

In terms of independent checks, I urge safety engineers to become more involved in hazard mitigation assessments as far as knowledge of the standards, facility compliance and skills are concerned.

I have noticed significant differences in maturity between plants in terms of requalification or maintenance of hazard mitigation equipment. For example, a floating boom designed to protect the heat sink from oil ingress has been waiting three years to be tested because of a contract dispute; maintenance of flood defences installed at a site several years ago only began in 2019, whereas similar maintenance programmes are already in place elsewhere.

In view of the critical role played by hazard mitigation measures and equipment, I advise the DPN to improve the management of spare parts in this field.

Fewer frequent hazards or those associated with more complex phenomena are particularly difficult to tackle. This is especially true of frazil ice, even though this is a known risk at several plants. Affected plants must complete the necessary modifications without delay to prevent damage to heat sinks.

IN THE UK

Although on-site staff in the UK are aware of the risks associated with external hazards, they do not adopt appropriate behaviours systematically. There is certainly room for improvement in the storage and maintenance of flood defence equipment and in equipment identification practices.

I am disappointed to learn that staff do not receive dedicated training on hazards and instead rely totally on teams from central engineering.

I recommend that a series of targeted, reciprocal visits involving central and site teams be organised to build a shared understanding of the potential hazards facing each facility. This should help to foster a hazard mitigation culture at each site.

Perimeter walls have been built around some sites to protect against external flooding. Improvements have been identified to strengthen several of these ageing structures. These actions must be seen through to completion.

EDF Energy Nuclear Generation has significant operating experience on heat sink hazards. Several reactors have had to be shut down after a mass influx of seaweed, fish, jellyfish or mussels. Procedures have now been adapted to predict this risk with more certainty and countermeasures are currently being investigated and deployed.

MY RECOMMENDATIONS

Making sure that sites are protected against external hazards involves understanding and managing complex physical phenomena and implementing the associated standards and requirements. I make the following recommendations to the Directors of the DIPNN, DPNT and EDF Energy:

- **Ensure that the ‘hazards’ stream has adequate resources in terms of staffing levels and breadth of expertise, both in the engineering functions and on site**
- **Tighten the checks carried out by the independent nuclear safety oversight function in each entity.**

Given the complexity of natural phenomena, their potential impact and the number of entities and interfaces involved in hazard mitigation, I recommend that the directors of the DIPNN and the DPNT:

- **Tighten hazard mitigation management for all projects and entities, primarily by designating one manager with overall responsibility for each hazard from both a technical and a safety perspective**
- **Ensure that expert opinions are sought, voiced and understood.**

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FARN practice training

The organisations, procedures and resources for dealing with a nuclear accident and limiting its consequences have changed considerably over the past ten years.

New equipment to strengthen the defence in depth is operational or in the process of being introduced. The capabilities of the FARN[1] for the French fleet and the DBUE[2] resources in the UK fleet are designed to address extreme situations.

The effectiveness and credibility of the system depend on the commitment of management and on training and regular drills for all those involved, in conjunction with the public authorities.

1 *Nuclear rapid reaction force*
2 *Deployable Back-Up Equipment*

Emergency preparedness: a decade of improvements

07

PREPARING FOR AN EMERGENCY

Emergency preparedness refers to all the organisations, techniques and resources needed to deal with an accident and to learn from it. An emergency is a rare situation, requiring special governance in response to requirements for rapid mobilisation, leadership and communication.

It requires sound preparation to ensure that trained, qualified staff and appropriate resources are available at all times, in line with regulatory requirements.

Following the Fukushima accident, the EDF Group strengthened its measures and resources for dealing with emergencies.

Symptom-based and event-based responses

The state or symptom-based approach consists in applying reactor operation strategies according to the actual state of the plant, irrespective of the causal events that led to this state.
Applied in incident or accident situations, the state-based approach procedures or guidelines are designed to limit the risks of an incident worsening due to subsequent human and/or equipment failures.
They include:

- Identifying the state of the plant at all times, based on plant conditions (criticality, power level, coolant inventory, decay heat removal, containment integrity, etc.)
- Defining the general objective of the actions to be taken and the plant condition priorities
- Specifying the actions required to manage the situation
- Carrying out general monitoring and availability assessments of the main systems, in order to mitigate against their potential unavailabilities.

An event-based approach consists in reacting to each type of incident or accident with a series of predetermined actions.

SPECIFIC PROCEDURES

The accident management strategy is designed to limit the risks and consequences of an incident worsening. Its main aim is to prevent the fuel being damaged.

In France, accident management is based on a state-based approach (APE), while in the UK, either an event-based or a state-based approach is applied within the symptom-based emergency response guidelines (SBERGs).

Measures are taken to address any safety system failure, using redundant equipment for mutual back-up or by installing mobile equipment.

Procedures for managing severe accidents take into account core meltdown. In the UK, the procedures have recently been revised to ensure beyond-design-basis accidents are integrated better.

A COMBINATION OF EQUIPMENT AND HUMAN RESOURCES

ORGANISATIONAL OBJECTIVES

Operators must have the necessary resources to deal with an emergency at all times.

Their responses are based on organisational measures and procedures and on the specific role of the operations team, who are constantly present, to apply these procedures.

The on-site emergency response plan (PUI) in France and the Emergency Handbook (EH) in the UK provide guidance on how to:

- Deal with the situation and limit its consequences
- Protect, rescue and inform staff
- Inform the public authorities and the media.

These plans are supported by dedicated documentation, designed to cover the most demanding situations, and by the use of a variety of diverse telecommunications solutions, including satellite-based systems, to deal with a total loss of networks.

Severe accidents

The transition from a design-basis accident to a severe accident is when core degradation starts, so this must lead to a change in priorities.
When a parameter (i.e. core outlet temperature or dose rate in the reactor containment) indicating severe damage to the fuel cladding is exceeded, the safeguarding of the containment (i.e. the third barrier) is prioritised over that of the fuel cladding and primary coolant system (i.e. the first two barriers).
In this instance, the potential source of radioactive releases into the environment is no longer limited to the fission products in the primary fluid, but to all the fission products and actinides stored in the fuel. Since the level of radioactivity in the fuel is around 50 times more than in the primary fluid, it is therefore vital to avoid, limit and delay radioactive releases into the environment via the atmosphere or groundwater.

PROACTIVE APPROACH IN FRANCE AND THE UK

In France, my observations and the assessments of the DPN's Nuclear Inspectorate confirm the overall robustness of the system.

The telecommunications systems, in which there were previously some weaknesses, were updated in mid-2019 with a new, more reliable system. I will be checking its effectiveness.

In early 2020 as planned, operations staff[37] will be organised into teams incorporating the appropriate skills and numbers of people to respond to events affecting several reactors at the same time. I would like to highlight the considerable amount of training that has been required to meet this ambitious objective and note that managerial support will still be needed.

The initial qualification procedure for the emergency teams is robust.

The assessment of the drills mainly focuses on the organisational aspects and interfaces, which can be considered a weakness. All the plants should also define, as some have already done, criteria for assessing the technical part of an event.

Emergency preparedness is not given a high enough priority in some plants. I therefore urge the independent nuclear safety oversight teams at sites to ensure that the response teams, equipment and plant are kept in an operational condition, based on the methods of the national emergency response organisation (ONC).

A FARN drill

Aside from the regulatory requirements, there are wide disparities in how the teams are prepared and trained in different plants. Some of the more effective training measures should be applied across the fleet.

It will take several years to complete the building of the new on-site emergency response centres (CCL) capable of withstanding extreme hazards. In the meantime, the current emergency centres must be kept in good working order, through maintenance programmes and routine testing. I note that the condition of these centres has been assessed and I will be checking that the planned improvements are implemented on time.

The connections for the FARN's equipment have been installed in the plants. Maintenance programmes must now be drawn up for these connections.

The storage, maintenance and monitoring of the on-site resources (mobile equipment, etc.) are satisfactory, but in the event of a defect or failure, repairs should be carried out as soon as possible instead of waiting for the maximum time specified in the regulations.

[37] *Operations staff are organised into extreme situation teams (ESE) in order to respond to emergencies*

In the UK, the training of the emergency response teams has been strengthend (i.e. how to install mobile equipment, relations with the external emergency services, etc.). Following additional analyses, EDF Energy has improved its emergency procedures and on-site emergency response plan and has purchased a large amount of additional back-up equipment.

During an exercise I observed, the resources were not being used as efficiently as expected. I appreciate the management's statement that part of the scenario needed to be re-enacted, as the objectives had not been fully met.

EXTERNAL ASSISTANCE FOR SITES: FARN AND DBUE

Following the Fukushima accident, the EDF Group enhanced its emergency preparedness with the addition of the Nuclear rapid reaction force (FARN) in France and the Deployable Back-Up Equipment (DBUE) in the UK. Both of these can provide assistance quickly using offsite back-up equipment and staff, even when site access conditions are difficult.

In France, the FARN has grown in strength, and I am impressed by the numerous drills that mirror real extreme scenarios as closely as possible. The FARN intervenes to re-establish or continue reactor cooling in order to prevent a situation worsening and to limit radioactive releases into the environment. It is assessed every four years by the DPN's Nuclear Inspectorate.

Divided into four regions and using standardised equipment, the FARN, like the DBUE, intervenes progressively and according to the circumstances, from a support base set up near the site.

The main objectives of the FARN are to:
- Respond within 24 hours, in conjunction with the operations teams
- Operate autonomously for several days on a site that has been partly destroyed, where the environment may be radioactive or even affected by chemical pollution
- Reconnect the water, air and electricity supplies at the request of the emergency response team using the on-site resources or its own equipment.

This FARN or DBUE regional response equipment can be supplemented by heavy plant machinery from a central base. In the UK, the DBUE equipment would be delivered to site by external support (Forward Deployment Service, FDS), but would be deployed and used by the on-site emergency response teams.

I was impressed following my meetings with the members of the FARN team and my observation of their training. I met professional people who share strong values and are committed to maintaining high performance levels. Their training includes developing methods for assessing situations and managing stress. The human and equipment resources, the availability of which is monitored on a weekly basis, are excellent.

However, I would like to draw attention to some points that may weaken operational capacity.

Wanting to be as autonomous as possible, FARN team members are driving the equipment to sites themselves. This requires lengthy HGV driver training, which is not consistent with the length of time they are in their jobs. Staff may have also travelled several hundred kilometres by the time they arrive on-site.

Heavy goods vehicles - part of the DBUE

The FARN is having difficulty finding enough staff with plant operations skills to provide constant cover for all potential accident situations. This problem has been identified and I urge the DPN to find a solution quickly.

Starting in 2019, the FARN's responsibilities were extended to include some mobile equipment that is now referenced in the safety cases. This means that the associated requirements (such as equipment maintenance programmes, functional requalification, spare parts, etc.) must be equivalent to those for stationary safety-related equipment.

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During drills:

- It takes too long for the FARN or the DBUE to access sites because of lengthy access procedures when compared with the limited duration of the drills. This adversely affects the speed and realistic nature of the drill regarding the deployment of the equipment
- To declare that the connection of FARN equipment is operational, the plant must simultaneously carry out certain operations in the facility. These latter operations should be systematically checked.

I urge those responsible for creating scenarios, as well as managers from both the FARN and the plants, to take account of this when planning and carrying out drills.

In the UK, I note a recurrent lack of training on how to use some of the DBUE equipment. Regular practice is needed to ensure that the teams can work with complete autonomy.

Barnwood central emergency support centre (CESC)

GIE INTRA IN SYNERGY WITH THE FARN

Following the Chernobyl accident, EDF, the CEA and COGEMA (now called ORANO) decided to join forces to share remote-controlled equipment for use in place of people in highly radioactive environments. They created the GIE INTRA consortium that has a fleet of highly specific equipment (vehicles, robots, drones, etc.) and can respond within 24 hours in the event of a large-scale accident.

With a dynamic team of around 20 people, GIE INTRA equipment can be deployed outside and inside the plants. Drones can be used to carry out surveys or deploy radioactivity measurement probes. GIE INTRA has also developed new skills to support the FARN in defining optimised access routes.

Drone equipped with a measurement probe - GIE INTRA

I urge the partners to get together and update the scope of GIE INTRA in the light of OPEX, and renew its fleet of equipment as appropriate. The partners should also ensure that GIE INTRA covers all the Group's nuclear subsidiaries (Framatome and EDF Energy).

COORDINATION WITH THE PUBLIC AUTHORITIES

ROBUST NATIONAL ORGANISATION…

In France, I met EDF's corporate teams who work closely with the public authorities and their technical support organisations, such as: the Group's emergency preparedness department, the DPN's national emergency response teams and Framatome experts. I received a positive impression from all these meetings. The emergency response centres are well-designed, and the teams are well-managed and receive appropriate training, which must be closely monitored.

Following the transitional phase in the creation and build-up of the FARN, it is now time for the DPN to re-examine the overall governance of the various aspects of emergency preparedness.

I also urge plants to train their emergency response teams in decision-making in uncertain situations. The training programme has been developed by the ONC with considerable support from the EDF R&D human factors team. EDF R&D, in partnership with the academic world and research laboratories, is working on the topic of emergencies (accident studies, management of stress during emergencies, observation of operations teams in extreme situations, etc.). In particular, it is studying factors that are favourable or unfavourable to resilience in socio-technical situations.

In the UK, the organisation seems capable of dealing with an emergency. The equipment available in EDF Energy's central emergency support centre (CESC[38]), which includes procedures, cameras, screens, etc., can predict the possible worsening of a situation so that the affected site can deploy the appropriate means in advance.

… WORKING CLOSELY WITH THE PUBLIC AUTHORITIES

In France, the Prefect can initiate an off-site emergency plan (PPI) to enable deployment of government resources. Designed in particular to limit public exposure to radiation, it specifies the health measures to be taken at each site, according to the severity of the situation, such as:

- Provision of shelter for the public
- Administration of iodine tablets (to presaturate the thyroid gland with non-radioactive iodine)
- Evacuation of the public to assembly centres.

An EDF Group representative may be invited to join the government's national emergency response team (CIC). I believe this is essential to have the necessary information available when making decisions.

The EDF Group regularly takes part in exercises with the public authorities. This is important to ensure that arrangements and coordination are working correctly, and to gather relevant operating experience.

During my meeting with IRSN's emergency preparedness specialists, and my visit to their emergency response centre, I saw their remarkable capabilities, including the ability to identify the origin, type and quantity of radioactive releases in France and well beyond its borders.

In France, I also note that the campaign to distribute iodine tablets within a 10 to 20 kilometre radius of nuclear plants is under way. This has uncovered a number of regulatory issues that need to be analysed so the 2022 campaign can be further consolidated.

MY RECOMMENDATIONS

In France, to ensure optimal emergency preparedness, I recommend that the director of the DPN strengthen the overall management of emergency preparedness and increase the presence of its national emergency response teams in the field.

In the UK, the support of the DBUE is essential to deal with extreme situations. I recommend that the Managing director of EDF Energy Nuclear Generation ensures that staff are capable of using this mobile equipment, mainly through more frequent training.

GIE INTRA has unique equipment and its new reconnaissance capabilities complement those of the FARN. I recommend that the director of the DPN consult with EDF Group partners to update the scope, tasks and resources of GIE INTRA.

[38] *Central Emergency Support Centre*

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Contributing to the Group's success - Civaux nuclear power plant

Nuclear energy is a young technology, inextricably linked to research, science and innovation.

Simply making do with existing knowledge could be considered as a decline, as maintaining a high level of nuclear safety requires continuous improvement of knowledge, technologies and reactor operation.

The EDF Group must be confident in being ever more innovative.

Preparing for the future through research and innovation

08

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INNOVATION IS VITAL

RESEARCH AND DEVELOPMENT DRIVES THE NUCLEAR INDUSTRY

Through R&D and innovation, physical phenomena and basic principles are constantly questioned and studied in greater depth to advance knowledge.

This is particularly true for nuclear safety, which is only sustainable with progress. Without striving for improvement, it is possible to lose sight of the technical basics and practices behind the current nuclear safety strategies. Events also remind us that we do not know everything: nuclear safety assessments, as robust as they are, can never claim to be exhaustive.

Like any industry, nuclear energy must innovate to improve nuclear safety and competitiveness: the best innovations improve both at the same time.

In France, the reactors currently in operation are the result of successive optimisations. A great deal of equipment has been added gradually to address the increasing number of events taken into consideration.

It is now time to use innovation in search of more simplicity in the design, with increased nuclear safety, higher efficiency and reduced costs.

The global trend for innovation is positive, particularly in North America, China and Russia, and it is growing. There are increasing numbers of scientific theses, ideas for innovative reactors, and start-up companies, supported by high-tech entrepreneurs, public laboratories and governments.

Innovation is essential to revitalise the appeal of nuclear energy as a technology of the future, both with the younger generations and society as a whole.

KEY ROLE OF THE CEA AND THE GOVERNMENT

This chapter focuses on R&D and preparing for the future in the EDF Group, from a strictly nuclear viewpoint. A few representative examples are given to show this, but this chapter does not look at cross-cutting disciplines (digital technology, mathematics, etc.). Nor does it cover research conducted by the CEA and other organisations, which feeds into EDF's applied research.

Public facilities, such as test reactors and hot labs, are essential for understanding physical phenomena, qualifying computer codes and validating new technologies. I have seen a worrying decline in the test facilities that are accessible nationally and internationally. I believe it is essential to devise a strategy and establish an overview of the resources needed.

Public-sector research is a core asset of the French nuclear industry, and government support is crucial to ensure its sustainability.

GOOD-QUALITY R&D MANAGEMENT…

I note many positive points regarding R&D management within the Group. Jointly managed by EDF R&D, DIPNN and DPN via committees tasked with preparing for the future, R&D is closely linked to the needs of the projects and fleets.

I would like to underline the high technical quality of the teams and the R&D facilities that I have visited.

I consider the strategic guidelines (NOS) drawn up for each field (core-fuel, control systems, hazards, civil engineering, etc.) to be good practice. The challenges are set out clearly in these documents and the topics have been chosen wisely.

I appreciate the way R&D is organised into technological building blocks that are not tied to any design in particular, but can be used

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for the current fleet, for reactors on the drawing board, or for future projects. Each building block can thus be assigned its own R&D strategy, with its own pace of development and partnerships appropriate to the technical field in question.

The Group's experts are a great asset. They are at the top of their fields, and I am pleased to see that the process for recognising and promoting experts has been improved. It is, of course, important to ensure that the strategic disciplines are all represented. To grow expertise, career paths must also be further developed.

There are a number of valuable partnerships, including a three-party institute with Framatome and the CEA, a four-party institute with Framatome, the CEA and IRSN, as well as with universities, the CNRS (French National Centre for Scientific Research), the NEA's[39] international programmes, Nuclear Valley, and the French nuclear industry association (GIFEN).

Cabri test reactor

… WHICH SHOULD INCLUDE MORE LONG-TERM APPROACHES

R&D generally requires an unfettered area for study, with no immediate goal. It does not progress at the same rate as projects: it must in part precede the statement of requirements. This is the only way to work towards breakthrough innovations and to avoid ruling out options prematurely with statements such as: *"What a shame this solution is not ready"* or *"We really should have done more R&D beforehand"*.

It is also crucial to provide the right conditions that are conducive to innovation. We must communicate our expectations and aspirations for nuclear energy, especially to the younger generations.

The strategic guidelines drawn up for each field currently focus on a three to five year period. They should also include a longer-term component. It is important that R&D be guided both by the tangible needs of operations and projects, and by science with the leading question: *"In what direction do we want to go?"* With this in mind, it would be helpful to set out the technical strategy in a higher-level document showing the connections between the different fields. Akin to a nuclear safety roadmap, it would describe the main overall short-, medium- and long-term objectives.

BE AWARE OF OBSTACLES TO INNOVATION…

In-service reactors benefit from successive improvements, which is an essential component of nuclear safety fundamentals. New-generation reactors include additional nuclear safety improvements, e.g. the EPR. It is important to explain that a difference remains between the two, and accept a balanced approach when carrying out periodic nuclear safety reviews.

Wanting to fit existing reactors with all the new solutions designed for future reactors, even if it were possible and disregarding financial considerations, would lead to increased complexity that would be detrimental to nuclear safety (see Chapter 2). It could also impede innovation: developments could be slowed down for fear that, if they were completed, the Operator would have to backfit them in the fleet, whatever their own analysis.

When areas for innovation that could improve nuclear safety are identified, we must not stop ourselves from 'thinking outside the box', nor must we feel constrained by the standards. It is acceptable to suggest modifying the standards, whether regulatory or internal, as the technical context may have evolved.

… AND ENSURE THE OPERATOR EXERCISES ITS PRIME RESPONSIBILITY

In many fields, the reason often given for initiating some kind of R&D is to produce data in response to questions raised by the ASN. This is even the case when teams are convinced of the merit and need for these studies separate to any ASN involvement. I call for this practice to end, as it misleadingly gives the impression that R&D is controlled by the ASN.

[39] *OECD Nuclear Energy Agency*

It leads to a risk of only seeing the ASN's requests behind nuclear safety topics, forgetting the technical realities, or even weakening the Operator's prime responsibility for nuclear safety (see Chapter 2).

SETTING FUTURE PROSPECTS FOR REACTORS

A VISION FOR THE FUTURE…

I believe it is important to define trends and major objectives. A few examples are given below to stimulate debate.

The 'Holy Grail' would be to develop and design "intrinsically safe" reactors.

Until then, we could move towards reactors with greater autonomy regarding certain physical phenomena; they could be equipped with nuclear safety functions that rely less on active systems, but with equivalent nuclear safety performance levels. Although such developments are not a universal solution, I urge R&D on passive systems to be intensified in order to feed into projects.

PWRs have a remarkable feature: the primary cooling system is an extremely robust passive system when it is in a natural circulation mode[40]. Opening the steam valves and injecting around 20 tonnes of water an hour (the flow rate of a fire engine) into the steam generator secondary system is then sufficient for decay heat removal.

A further development would be the ability to cool the primary cooling system during natural circulation without having to worry about any possible return to criticality (without any active means of injecting boron[41]).

Likewise, solutions for leaktight primary coolant pump seals should be implemented, which would not require any high-pressure injection to prevent a leak.

Another R&D area is ensuring that certain key items of equipment (control system, certain pumps and electrical panels) remain operational, even when there is a total loss of air conditioning or the intermediate cooling system.

With regard to containment, one of the main objectives would be to avoid "recirculation" of radioactive fluid outside the containment in the event of an accident.

PWRs have been designed with large nuclear safety margins. Operation, operating experience and changes to standards have resulted in some of these margins being eroded. An objective must be to re-establish physical margins for the future, in particular for fuel.

FUEL: THE CENTRAL TECHNICAL BUILDING BLOCK

A nuclear reactor is often thought of as a containment building, various systems, a primary cooling system, and a vessel in which the fuel is inserted. From a nuclear safety perspective, the picture can be reversed: a reactor is first and foremost the fuel (i.e. the core) around which a vessel, a primary cooling system, other systems and a containment building are arranged.

This is why fuel is a vital R&D topic for nuclear reactors, which should be pursued with determination (see Chapter 5). Appropriate research facilities are required for this, including test reactors and hot labs such as the CEA's LECA[42] facility.

To illustrate this, the interpretation of EPR physics tests made use of the latest data and analysis of uncertainties on the uranium and steel cross-section reference data, an area that many believed to have been definitively established some time ago.

In the medium term, several technical developments are being examined, such as EATF[43]:

- Chromium-coated cladding further increases the PCI[44] margins in comparison with previous alloys (M5) and could improve the robustness of the fuel rods in the event of a loss-of-coolant accident (LOCA)
- Chromium-doped pellets could reduce the release of fission gases, decreasing the pressure in the fuel rod and the radioactive releases in the case of an accident.

Now is an appropriate time to carry out in-reactor testing of EATFs in France, as several countries have done already.

Another example: it could be useful to re-start work on adding mid-span mixing grids in fuel assemblies. These grids optimise the water around fuel rods, delaying its vaporisation upon contact with the cladding, thus increasing the nuclear safety margins.

In the longer term, the silicon carbide (SiC) cladding studied with the CEA could withstand higher temperatures.

[40] *Natural circulation is established between the core that is heated and the steam generators in which the primary water is cooled*
[41] *In order to control reactivity in a PWR, boron is injected into the primary system*
[42] *Active fuel examination laboratory*
[43] *Enhanced Accident Tolerant Fuel*
[44] *Pellet-cladding interactions*

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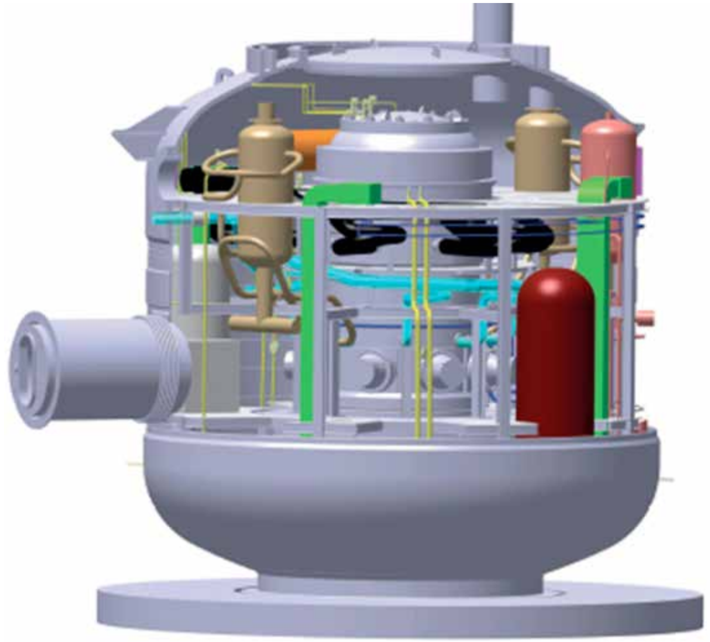

Nuward SMR project

The PWR core is tolerant in the event of uncontrolled reactivity insertion, as they have high neutron stability. It is however advisable to watch for the formation of clean or cold water plugs, which could lead to a significant increase in reactivity. I urge the various divisions involved (DIPNN, DPNT and EDF R&D) to identify further medium- and long-term areas for research and development to limit these risks.

More generally, when new reactor models are being considered, there is understandably a tendency to only consider using the same fuels. I believe that carrying out some prospective work could overcome this intellectual limitation, and lead to dynamic long-term studies.

CONTINUOUSLY INCREASING KNOWLEDGE

There has been excellent quality R&D on the physics of severe accidents since the 1980s, which has led to the defence in depth of EPRs and the PWR fleet being greatly enhanced. Some phenomena require further work: corium-water interactions, corium spread and its interaction with concrete, the behaviour and filtration of fission products.

Internal hazards (fire, flood, etc.) and external hazards (flood, earthquake, extreme cold and extreme heat, etc.) have become increasingly important in nuclear safety as a result of operating experience and their potential consequences, in particular the common-mode failures they can trigger. It is important to increase our knowledge of these phenomena further and to continue modelling them (see Chapter 6).

Recurring subjects include the efficiency of the recirculation sump filters in the event of a massive influx of debris caused by an accident (insulation fibres, paint, etc.). Testing and modelling must continue. A priority for future reactors would be to develop materials that produce less debris.

Alongside these examples of technical subjects, I am pleased to note that the other cornerstone of nuclear safety, human and organisational factors, is being studied by dedicated teams. The resources of these teams should be ensured in the long term, in particular for accident studies. I shall continue to take a close interest in this (see Chapter 2).

SMRs

The aim of small modular reactors (SMR), which have a power capacity of 10 to 300 MWe, is to:

- Allow faster construction, particularly by factory fabrication of the modules
- Benefit from a standardised design across a series of reactors
- Be located near to consumers in remote areas or where grids are less developed.

Many countries are interested in these reactors. An example of this is the *Akademic Lomonosov,* a floating platform with two on-board ice-breaker reactors, which started to supply power to a region of Siberia in late 2019.

One of the challenges for SMRs is offsetting the lack of economy-of-scale resulting from their lower power by simplification, modular construction and possible use of cogeneration.

From a nuclear safety viewpoint, SMRs are designed for greater simplicity and more intrinsic nuclear safety: their power-to-water-volume ratio and thermal conduction phenomena are favourable, improving reactor autonomy in case of an accident.

EDF, the CEA, TechnicAtome and the Naval Group have started the Nuward SMR project. France's wealth of experience in compact naval propulsion reactors gives it several advantages in this field. For example, Nuward's pressuriser and steam generator will be in the vessel, the reactor will be underwater in a pool and will be controlled without boron, there will be passive systems to remove the decay heat, and the reactor will have considerable autonomy if the power supplies or the heat sink are lost.

I believe this to be a very positive initiative, which complements the high-power reactor projects (EPR 2). It encourages innovation, broadens the range of possibilities and updates the image and appeal of nuclear energy, opening it up to new uses, locations, investors and stakeholders.

FUTURE CONCEPTS

Very different concepts are being studied both abroad and in France. These include molten salt reactors (MSR), nuclear fusion through ITER[45], sodium-cooled fast reactors (SFR), and SMRs in some countries such as the US and Canada.

MY RECOMMENDATIONS

Although the management of R&D is currently technically relevant and appropriate with its focus on the needs of the fleet and projects, I recommend that the Group's Chief Technical Officer (CTO) and the directors of the DIPNN and the DPNT make room for more long-term studies and formalise an overall technical strategy for nuclear safety.

Test facilities are essential to support research in the field of nuclear safety. I recommend that the CTO and the director of the DIPNN, together with the CEA, Framatome, IRSN and the French government, analyse the prospects and requirements for test facilities both in France and worldwide.

Reactors must have significant nuclear safety margins. Experience has shown that these can become partly eroded over time. I recommend that the CTO and the directors of both the DPNT and the DIPNN carry out research into innovations and developments to provide greater physical margins for plants and specifically for fuel.

[45] *The ITER project, bringing 35 countries together at Cadarache, aims to demonstrate that nuclear fusion can produce energy*

Grinding work at Saint Marcel, Framatome

In 2019, the nuclear safety culture continued to develop. A network of mentors has been created and training is being given to members of the TOP 120 and new staff.

The independent nuclear safety oversight organisation (FIS) is being structured, and inspection programmes must be deployed for all relevant activities (engineering, manufacturing, maintenance, etc.).

The Projects & components business unit was set up to strengthen Framatome's position and performance by boosting its capacity to take on more projects and plants.

Report by the General Inspectorate of Framatome 09

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

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

General Inspectorate of Framatome

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

The IG performs independent oversight of the organisation in the areas of nuclear safety, radiation protection, industrial safety[46], occupational safety, and the environment. Its activities are defined in a yearly programme, which is presented to the Framatome executive committee.

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

In 2019, the IG introduced the concept of site visits that solely assess how nuclear safety and industrial safety are perceived by staff regardless of their managerial level or profession. Staff are interviewed without their managers during these visits which provide another way of detecting any weak signals.

DEVELOPING A NUCLEAR SAFETY CULTURE

INSAG 4 clearly states that everyone, especially managers, must be committed to nuclear safety. This commitment has been part of Framatome's nuclear safety culture policy since 2018, which defines the nuclear safety responsibilities at each level in the organisation. The executive committee holds regular meetings on nuclear safety issues. The committee focused on training in 2019, with the objective of clearly setting out its safety culture principles. The strength of this approach lies in the safety culture 'mentors' appointed to each business unit and directorate who are tasked with training new employees within their first six months. In late 2019, 68% of all new employees and 55% of managers in the TOP 120 had received nuclear safety culture training.

The IG has assessed the nuclear safety culture at the Romans-sur-Isère and Jeumont sites. A team of around 12 people, including managers from other business units chosen by the executive committee, conducted more than 50 interviews and field visits at each site. The safety culture principles are understood at all managerial levels, but there is room for improvement, i.e.: greater managerial presence in the field, more rigorous enforcement of procedures, better preparation and implementation of actions, and training. The nuclear safety culture at two other sites will be assessed in 2020.

This initiative will be extended in 2021 to include self-assessments carried out by each business unit; this is a robust way of developing the company's nuclear safety culture

INDEPENDENT NUCLEAR SAFETY OVERSIGHT (FIS)

The nuclear safety policy at Framatome clearly states the responsibilities at all management levels. It also defines the responsibilities of the independent nuclear safety oversight organisation, i.e. to ensure that the policies implemented and the measures in place are appropriate. The FIS comprises two levels: the first level is based at each site, business unit, directorate and corporate body, while second is carried out by the IG.

In 2019, the Framatome CEO published the duties and organisation of the FIS. In this document, it affirms that:

- FIS level-1 members are to be appointed via a letter of engagement stating that their responsibilities and duties are to be independent

[46] *Particularly the management of industrial risks and chemical hazards*

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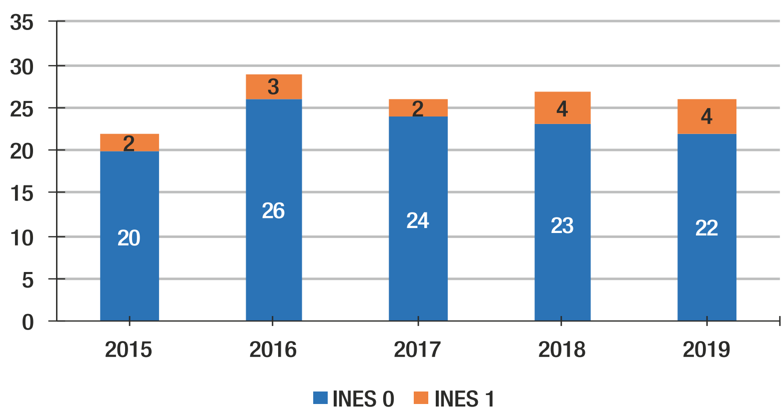
- Oversight programmes are to be drafted for each site or project
- Measures are to be implemented to detect, manage and track non-conformities, and to keep the FIS informed
- The FIS level-1 is to conduct a self-assessment every year.

The 2018 self-assessment results indicate that management is clearly listening to the FIS, particularly when it concerns the detection of non-conformities. The FIS resources and its independent oversight programmes are both judged to be appropriate. In several business units and directorates, however, there is still scope to improve the incorporation of safety issues into project management and training. I see that the FIS level-1 will be auditing one of the main projects in early 2020 as part of its programme to address this weak point. I will be looking closely at the results.

In light of the wide range of activities covered by the IG, Framatome's executive committee has agreed to create an additional inspector position in 2020.

CONSISTENT NUCLEAR SAFETY RESULTS ...

No Level 2 event or higher on the INES scale was declared in 2019. With 22 Level 0 events and 4 Level 1 events, the results are similar to those of 2018.



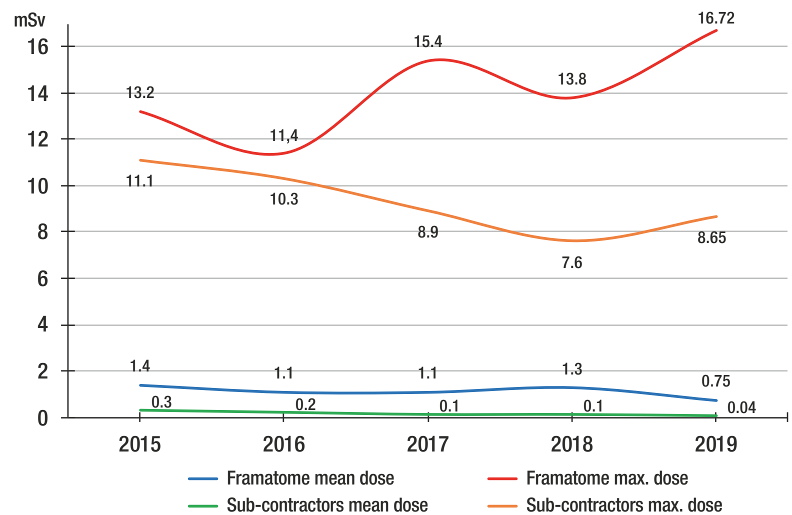
Variation in the number of INES events

All 4 INES Level 1 events occurred at the Romans-sur-Isère site, and all concerned criticality risk management. As in 2018, analysis of these events highlighted the importance of human factors. An action plan has been deployed to improve the use of human performance tools, non-conformity detection and management, and first-line manager responsibilities. These measures are a step in the right direction and I will be following the improvements closely.

... AND RADIATION PROTECTION RESULTS

In 2019, the mean occupational dose for Framatome employees was 0.75 mSv (1.3 mSv in 2018), and for contract partners it was 0.04 mSv (0.09 mSv in 2018). These doses have been steadily decreasing since 2014.

The number of workers who received a dose below the minimum recordable level (zero dose) rose: 38% for Framatome staff (30% in 2018) and 18% for contract partners (16% in 2018). Most doses received were below 2 mSv, which was true in the case of 82% of the Framatome staff (73% in 2018) and 99% of contract partner staff (98% in 2018).



Variation in doses for Framatome and its contract partners

The number of annual doses exceeding 10 mSv continued to drop: 26 in 2019 compared with 37 in 2018. The majority of the staff concerned were those providing reactor services (25 out of 26), and were mainly based in the US (18 out of 26, including 8 who received a dose exceeding 12 mSv). The highest dose received was 16.7 mSv, which is higher than 2018 (13.8 mSv), though below the limit of 20 mSv/year set by Framatome for employees in the US[47]. In such a context, the advance planning of these occupational doses must be robust and OPEX must be fully exploited during reactor operations.

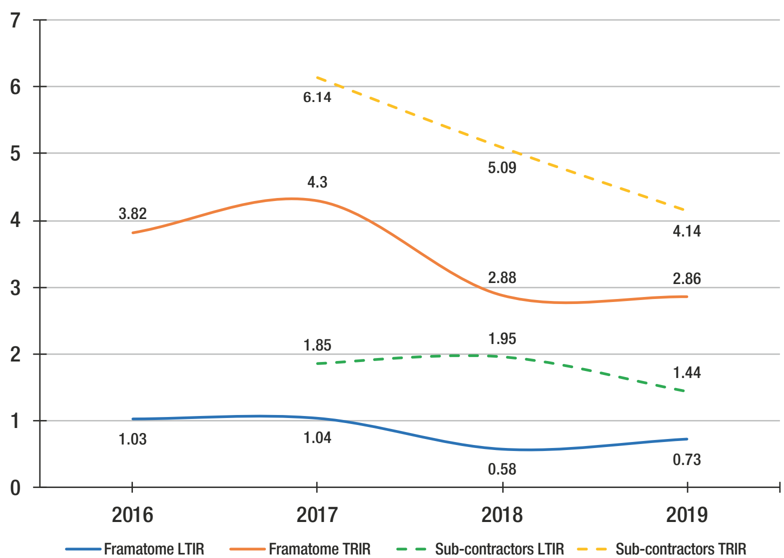
[47] *The regulatory limit in the US is 50 mSv/year*

INDUSTRIAL SAFETY

Sadly, the year 2019 was marked by the passing of an employee who, while on a business trip, died playing sport during their leisure time.

In 2019, Framatome met its objective to reduce the number of occupational accidents: the lost-time injury rate (LTIR) and the total recordable incident rate (TRIR) for Framatome staff were below their targets of 0.9 and 3.3 respectively. The LTIR objective for contract partners was to be below 1.5.

Overall, the LTIR (0.73) and the TRIR (2.86) for Framatome employees stabilised compared with 2018. The results for its contract partners continued to improve, with an LTIR of 1.44 and a TRIR of 4.14.



Variation in accident frequency indicator rates

Framatome has continued its 'TOP 5 killers' programme that sets out to eliminate fatal risks associated with working at height, lifting operations, managing energy sources, using mobile equipment, and confined spaces. This programme will bring each unit in line with best industry practices by mid-2020. The level of compliance was high overall, but this objective still calls for considerable effort.

The Installed Base (IB) and Projects & Components (PCM) business units were impacted by numerous near-misses during handling operations with potentially serious consequences. In addition to the measures already in place in the PCM business unit, I recommend carrying out a cross-functional analysis of these events to identify any generic causes.

VALUABLE FEEDBACK FROM INSPECTIONS

In 2019, the IG carried out 13 inspections on a specific subject and 7 follow-up inspections on its recommendations.

EMERGENCY RESPONSE AND FIRE SAFETY AT THE RICHLAND SITE

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

In 2019, the two inspections focused on emergency preparedness and fire safety. It was concluded that their emergency preparedness organisation was: robust; founded on clearly defined responsibilities; had experienced teams with good training; and redundant, well-maintained emergency response equipment. I encourage the Richland site management to question the adequacy of the means used to monitor remotely those industrial areas that represent a potential hazard.

Fire hazards are generally well managed using means such as: annual fire prevention objectives, an effective training system, regular practice sessions, and properly maintained fire detection and suppression systems. Following this inspection, the Richland site started to revise its fire safety documentation and initiated an action plan to improve its housekeeping in equipment rooms; the effectiveness of these measures was visible during my subsequent visit. This action plan on housekeeping standards is expected to continue throughout 2020.

CRITICALITY MANAGEMENT AT THE LINGEN AND ROMANS SITES

The organisation and documentation at both the Lingen (Germany) and Romans-sur-Isère (France) sites are in line with expectations. Regular internal and external oversight inspections are undertaken. Staff are trained, and their qualifications are checked on a regular basis.

Two areas for improvement were identified. The first concerns the analysis of operational events. Although the root causes are identified, there is room to improve the way in which follow-up actions are tracked and how repeat events are identified. The second concerns the need for better application and use of human performance tools. The Romans-sur-Isère site has initiated an action plan in this area; I encourage the Lingen site to follow suit.

Maintenance work at Jeumont

NUCLEAR SAFETY MILESTONES FOR PROJECTS AT THE ROMANS SITE

Due to the number and magnitude of operations underway at the Romans-sur-Isère site, the IG conducted three inspections in 2019 to ensure projects were organised in a way that guaranteed the key nuclear safety milestones were met in line with expectations.

The different schedules were well managed thanks to the organisation in place that is founded on clearly defined project teams. For the projects requiring formal approval from the safety authority prior to operation, I recommend keeping all information proving that each project milestone has been reached successfully. The same applies to the technical solutions used to resolve non-compliances.

OPERATIONAL RIGOUR

In 2019, inspections at the Rugles and Paimboeuf sites focused on their compliance with the operational standards and the traceability of their activities.

The nuclear safety, industrial safety and quality policies at these two sites are clearly defined and enforced through annual objectives. Actions are properly tracked. The rate at which non-conformities are resolved is good and operating experience is used well. The training and qualification of operators is followed closely.

Focus should be placed on updating internal standards in line with the deadlines defined in the integrated management systems. It is also important to adhere to the schedules defined for regulatory periodic checks and tests of facilities.

Stress relief heat treatment

In 2019, it became known that there was an irregularity in how the stress relief heat treatments were being performed on steam generator and pressuriser welds. The non-conformity releates to not complying with the specified temperature range.

The pieces of equipment impacted by this non-conformity have been identified and the utilities have been informed. Framatome has set up a task force to support these utilities and subsequent projects. Together with EDF, Framatome has checked that the affected equipment is fit for service. After analysis, the ASN concluded that the affected reactors could continue operating subject to additional checks and an action plan to further substantiate the Operator's justifications.

OCCUPATIONAL RISK MANAGEMENT

The inspections conducted by the IG focused on:

- Three sites belonging to the Installed Base business unit: the CEDOS equipment maintenance and decontamination facility in Sully-sur-Loire, the CEMO equipment servicing and repair facility in Chalon-sur-Saône, and the Lynchburg site in the US
- The workshop of the Installed Base business unit at the Cruas plant in France
- The Karlstein and Erlangen sites under the Engineering & Technical Directorate (DTI) in Germany.

Generally, I note that visual management practices are now spreading throughout the company; this is a positive effect of the continuous improvement programme on 'operational excellence'. These tools are proving to be effective in the management of nuclear safety, industrial safety and quality.

The organisational systems in place at the French sites, including the IB team at the Cruas workshop, are clearly defined. The different responsibilities and delegation of activities are formalised. Overall, qualifications and authorisations are checked and updated when necessary. A team on the French side of the IB business unit is responsible for the independent oversight of industrial safety and radiation protection activities.

Framatome staff at the Cruas workshop are comfortable with and regularly use the human performance tools made available to them. The CEDOS and CEMO facilities need to improve in this area.

Operational excellence programme

This programme sets out to improve the quality of both preparation and delivery to "*make sure the job is done properly the first time round*" within the predefined deadlines. An objective is to promote the systematic use of quality tools frequently employed in other industries.
The 8D method, for instance, can be used to resolve problems and non-conformities through a structured analysis of the root causes and the identification of corrective and preventive actions. Other examples include: failure modes, effects and criticality analysis (FMECA) of processes; widespread use of human performance tools; and formalised methods of detecting and reporting weak signals.
Operational excellence also relies on stronger leader presence in the field to help resolve issues and promote a culture of continuous improvement.
This programme will be continued in 2020 with the intention of training all managerial staff.

Industrial safety and radiation protection at the two German sites (Karlstein and Erlangen) are well managed due to the support provided by Framatome GmbH. As a result, practical prevention measures have been deployed, there is a good level of industrial safety, and the nuclear safety culture has been assimilated by staff.

Framatome are tenants on these sites. This unique situation requires clearly defined safety equipment inspection procedures to avoid any misunderstandings between Framatome GmbH and the site owners.

Joint safety drills, with Framatome staff and the owners, should be carried out more often.

UPTAKE OF RECOMMENDATIONS

The number of recommendations in the process of being implemented has remained stable this year at 94, compared with 93 in 2018. Follow-up inspections led to the closure of 26 recommendations.

In 2019, the IG issued 37 recommendations that can be divided into three key areas:
- Operational rigour (78%)
- Regulatory compliance (16%)
- Management of non-conformities (6%).

The figures above draw attention to the significant number of non-conformities concerning the updating of internal standards.

The Framatome executive committee continues to monitor closely the recommendations that have still not been completed after three years. The business units each prepared their own schedule for completing these recommendations at the start of the year. I take note that most have been able to keep their commitments. Two recommendations older than three years still remain open.

This momentum will be continued in 2020, with the goal of reducing the number of legacy recommendations older than two years.

MY RECOMMENDATIONS

Developing and perpetuating a nuclear safety culture can only be assured if staff are properly trained and their knowledge is regularly updated. In addition to the measures already in place, I recommend that a relevant training programme, including refresher courses, be set up for all staff.

Human factors are the origin of too many events related to nuclear safety, industrial safety and quality. I recommend defining and implementing a policy on human performance tools based on an approach that is commensurate to the significance of the nuclear and industrial safety threats.

Flamanville nuclear power plant

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RESULTS FOR THE EDF SA FLEET

Nº	Indicators	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	Number of significant nuclear safety events graded 1 or greater on INES per reactor[1]	1.17	0.91	1.55	1.19	1.14	1.16	0.98	1.12	1.28	1.45
2	Number of significant nuclear safety events (0 or greater on INES) per reactor[1]	10.45	10.57	11.90	11.60	10.8	10.03	9.78	11.59	12.6	12.0
3	Number of cases of non-compliance with technical specifications per reactor	1.55	1.36	1.52	1.34	1.55	1.24	1.48	1.41	1.69	1.8
4	Number of alignment errors[2] per reactor	1.74	2.07	1.78	1.22	1.41	1.74	1.64	1.78	1.24	1.4
5	Number of trips per reactor (for 7,000 hours of criticality[3]) • Automatic • Manual	0.69 0.01	0.50 0.05	0.55 0.03	0.59 0.03	0.53 0.07	0.66 0	0.48 0	0.38 0.04	0.31 0	0.53 0
6	Average operational collective dose per nuclear unit in service (in man-Sv)	0.62	0.71	0.67	0.79	0.72	0.71	0.76	0.61	0.67	0.74
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 3 60	0 2 43	0 2 22	0 0 18	0 0 5	0 0 2	0 0 1	0 0 0	0 0 1	0 0 0
8	Number of significant radiation protection events	91	92	114	116	113	109	117	131	170	169
9	Availability (%)	78.5	80.7	79.7	78.0	80.9	80.8	79.6	77.1	76.5	74
10	Unplanned unavailability (%)	5.2	2.2	2.8	2.6	2.4	2.48	2.02	3.26	3.7	3.95
11	Occupational accident rate Tfg (per million hours worked)[4]	4.1	3.9	3.5	3.3	3.2	2.7	2.8	2.2	2.3	3.3
12	Occupational accident rate LTIR (per million hours worked)[4]	-	-	-	-	-	-	-	-	-	2.4

[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 (statistical data reviewed in 2018).*
[3] *Average value for all reactors. unlike the WANO parameter which is based on the median value.*
[4] *Accident rate for EDF SA and its contractors*

RESULTS FOR THE EDF ENERGY FLEET

Nº	Indicators		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	Number of significant nuclear safety events graded 1 or greater on INES per reactor[1]		0.93	1.33	0.80	0.80	0.33	0.47	0.27	0.47	0.53	0.27
2	Number of significant nuclear safety events (0 or greater on INES) per reactor[1]		5.60	4.70	4.60	5.13	4.47	7.40	10.00	6.13	5.93	6.33
3	Number of cases of non-compliance with technical specifications per reactor		0.60	0.33	1.67	0.67	1.53	1.00	0.80	0.60	0.60	0.60
4	Number of alignment errors[2] per reactor		0.60	0.33	3.07	3.33	2.80	2.87	3.13	0.93	1.67	1.67
5	Number of trips per reactor (per 7,000 hours of criticality[3])	• Automatic • Manual	0.58 1.68	0.74 1.22	0.64 0.84	0.45 1.03	1.17 0.62	0.57 0.19	0.3 0.42	0.49 0.37	0.89 0.20	0.56 0.32
6	Average operational collective dose per nuclear unit in service (in man-Sv)	• PWR • AGR	0.271 0.018	0.537 0.084	0.037 0.063	0.386 0.034	0.365 0.074	0.048 0.067	0.544 0.021	0.296 0.020	0.096 0.050	0.255 0.032
7	Number of individuals with doses above 15 mSv		0	0	0	0	0	0	0	0	0	0
8	Number of significant radiation protection events		43	43	50	27	27	18	20	10	23	28
9	Availability (%):	• EDF Energy fleet • PWR • AGR	65.7 45.6 67.1	72.0 82.5 71.3	78.0 89.2 76.3	78.9 83.0 78.2	72.1 84.1 70.2	77.3 100 73.7	83.0 82.0 83.1	81.6 83.8 81.2	76.1 89.4 74.0	65.8 80.6 63.5
10	Unplanned unavailability (%):	• EDF Energy fleet • PWR • AGR	19.6 54.3 17.1	13.0 3.4 13.7	8.9 9.9 8.7	6.9 0.2 7.9	10.7 0.7 12.3	2.3 0 2.7	5.1 0.1 5.8	5.0 0.0 5.7	3.1 2.2 3.3	4.0 0.2 4.7
11	Occupational accident rate LTIR (per million hours worked)[4]		0.4	0.6	0.5	0.2	0.2	0.4	0.3	0.2	0.5	0.3

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*

Factors to be taken into account in comparing the results of EDF SA with those of EDF Energy:

- **Line 2:** the procedure for declaring events to the UK nuclear safety authority was **changed in 2015,** which means more events are now declared than in the past
- **Lines 3, 4 and 8:** the event declaration procedures are not the same in the United Kingdom and France because of the respective nuclear safety authority requirements. **EDF Energy and EDF SA harmonised their event classification practices in 2012.**
- **Line 6:** the reactors of the two different fleets do not share the same technology (mostly AGRs in the UK and PWRs in France). The AGR design means that radiation exposure is some 10 times lower (source: WANO).

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	-
1977	Fessenheim 2	880	1990	2000	2011	-
1978	Bugey 2	910	1989	2000	2010	-
1978	Bugey 3	910	1991	2002	2013	-
1979	Bugey 4	880	1990	2001	2011	-
1979	Bugey 5	880	1991	2001	2011	-
1980	Dampierre 1	890	1990	2000	2011	-
1980	Dampierre 2	890	1991	2002	2012	-
1980	Gravelines 1	910	1990	2001	2011	-
1980	Gravelines 2	910	1991	2002	2013	-
1980	Gravelines 3	910	1992	2001	2012	-
1980	Tricastin 1	915	1990	1998	2009	2019
1980	Tricastin 2	915	1991	2000	2011	-
1980	Tricastin 3	915	1992	2001	2012	-
1981	Blayais 1	910	1992	2002	2012	-
1981	Dampierre 3	890	1992	2003	2013	-
1981	Dampierre 4	890	1993	2004	2014	-
1981	Gravelines 4	910	1992	2003	2014	-
1981	St-Laurent B1	915	1995	2005	2015	-
1981	St-Laurent B2	915	1993	2003	2013	-
1981	Tricastin 4	915	1992	2004	2014	-
1982	Blayais 2	910	1993	2003	2013	-
1982	Chinon B1	905	1994	2003	2013	-
1983	Blayais 3	910	1994	2004	2015	-
1983	Blayais 4	910	1995	2005	2015	-
1983	Chinon B2	905	1996	2006	2016	-
1983	Cruas 1	915	1995	2005	2015	-
1984	Cruas 2	915	1997	2007	2018	-
1984	Cruas 3	915	1994	2004	2014	-

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

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 RUP (1)	Planned date of withdrawal from service (2)
1976	Hinkley Point B	R3	480	2023
1976	Hinkley Point B	R4	475	2023
1976	Hunterston B	R3	480	2023
1976	Hunterston B	R4	485	2023
1983	Dungeness B	R21	525	2028
1983	Dungeness B	R22	525	2028
1983	Heysham 1	R1	580	2024
1983	Heysham 1	R2	575	2024
1983	Hartlepool	R1	595	2024
1983	Hartlepool	R2	585	2024
1988	Heysham 2	R7	615	2030
1988	Heysham 2	R8	615	2030
1988	Torness	R1	590	2030
1988	Torness	R2	595	2030
1995	Sizewell B		1198	2035

(1) Reference Unit Power (RUP):
the rated electrical power of the generating unit as declared by EDF Energy in its daily transactions at the end of 2014

(2) Dates of withdrawal from service, including all life extension decisions, updated in 2016 for the reactors at Heysham, Hartlepool and Torness.

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Abbreviations

EDF SA NUCLEAR SITES

Closed loop cooling

Open loop cooling

Pressurised Water Reactors
(operation and construction)

34	900 MWe	Operation
20	1 300 MWe	Operation
4	1 450 MWe	Operation
1	1 600 MWe (EPR)	Construction

Engineering

8 Engineering centre

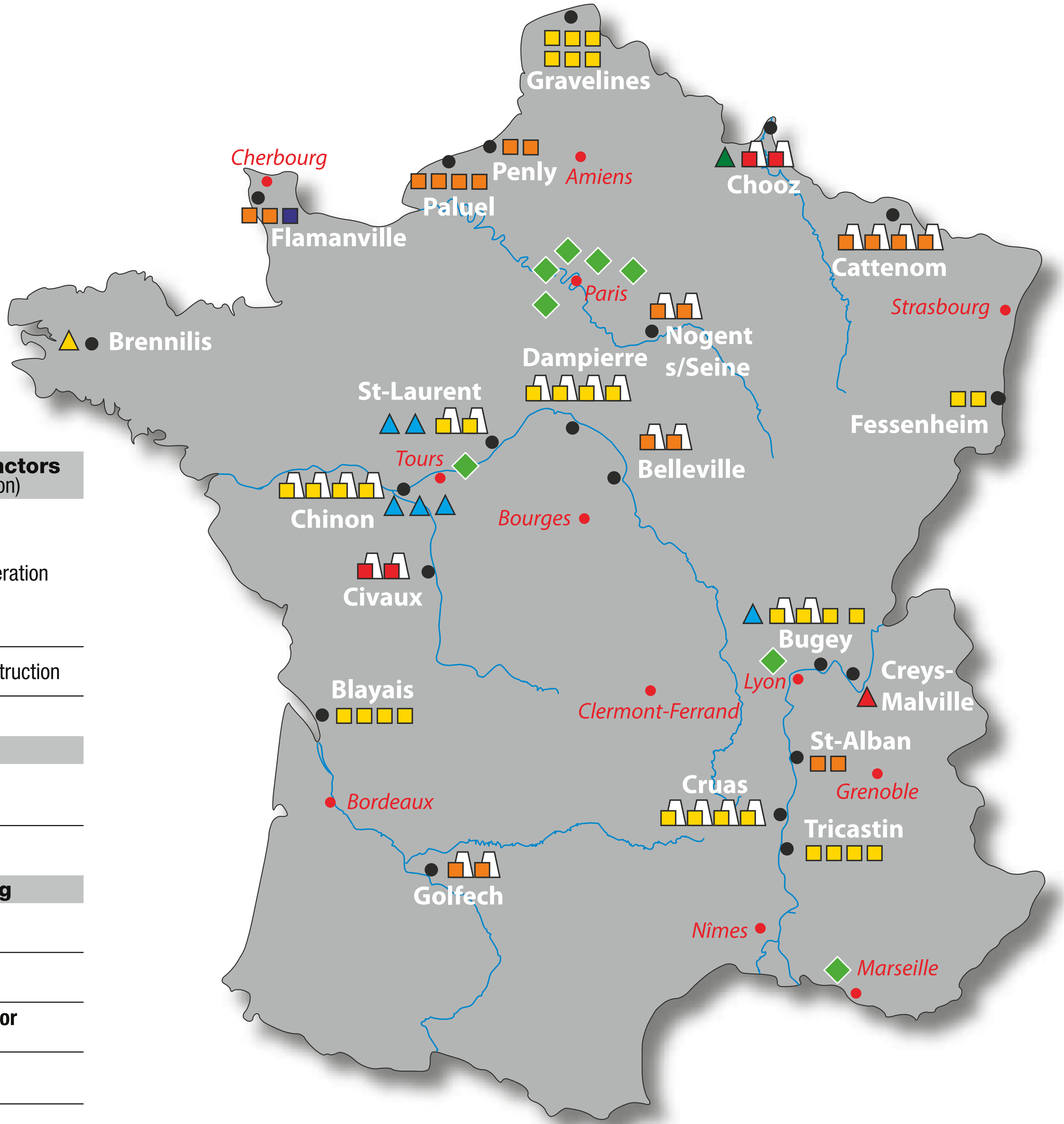
Decommissionning

6 Gas-Cooled Reactor

1 Heavy Water Reactor

1 Pressurised Water Reactor (300 MWe)

1 Fast Breeder Reactor



EDF ENERGY NUCLEAR SITES

FRAMATOME NUCLEAR SITES

TABLE OF ABBREVIATIONS

A

AFI	Areas for improvement
AGR	Advanced Gas-cooled Reactor
ALARP	As Low As Reasonably Practicable
AMT	EDF fleet maintenance agency
ANDRA	National Radioactive Waste Management Agency (F)
AREC	Reactive non-conformance analysis
ASN	Nuclear Safety Authority (F)
ATEX	Explosive atmosphere

C

CCL	Local emergency response centre
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
CETIC	PWR NSSS fieldwork technical validation experimental centre
CGN	China General Nuclear Power Company (China)
CLI	Local information commission (F)
CNC	Civil Nuclear Constabulary (UK)
CNEPE	Electromechanical & plant engineering support department (DIPNN)
CNRS	National centre for scientific research (F)
COLIMO	A DPN campaign to modernise isolation and alignment practices and methods
COMSAT	Unit outage nuclear safety commission
COPAT	Unit outage operational control committee
CRT	Technical standards committee
CSN	Council for Nuclear Safety
CSNE	DPN nuclear safety review meeting

D

DACI	Independent oversight directorate for EDVANCE
DBUE	Deployable Back-Up Equipment (UK)
DCC	Core-fuel directorate
DCN	Nuclear fuel division
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
DSPTN	Project support and digital transformation division (DIPNN)
DT	Technical division (DIPNN)
DTEAM	Conventional fleet multi-disciplinary expertise & industrial support division
DTEO	Transformation and operational efficiency directorate
DTG	General technical division (EDF Hydro)
DTI	Engineering and technical directorate (Framatome)

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
EH	Emergency Handbook (UK)
EIPS	Equipment protected for nuclear safety reasons
EMAT	Shared teams providing support during unit outages
ENISS	European Nuclear Installations Safety Standards
EPR	European Pressurised Reactor
EPRI	Electric Power Research Institute (US)
ESPN	Nuclear related 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

FARN	Nuclear rapid reaction force
FDS	Forward Deployment Service
FIS	Independent nuclear safety oversight (F)
FME	Foreign Material Exclusion
FMECA	Failure Modes, Effects and Criticality Analysis

G

GDA	Generic Design Assessment (UK)
GECC	Core design and engineering group (F)
GIE INTRA	Economic interest grouping providing post-accident robotic response solutions
GIFEN	Nuclear Energy Industry Group (F)
GK	Fleet upgrade programme (F)
GPEC	Advanced planning of jobs and skills
GPSN	Nuclear safety performance group (UNIE)
GT	Gas Turbine

H

HCTISN	High committee for transparency and information on nuclear matters (F)
HGRB	Hazard Governance Review Board (UK)
HOF	Human and organisational factors
HPC	Hinkley Point C (UK)
HPT	Human Performance Tools

I

IAEA	International Atomic Energy Agency
ICPE	Environmentally regulated facility
ICRP	International Commission on Radiological Protection
IECC	Core-fuel engineer
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)
IPCC	Intergovernmental panel on climate change (UN)
IRAS	Plant engineer assigned to relations with the ASN (NPPs)
IRSN	Institute for radiation protection and nuclear safety (F)

L

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
MARN	Nuclear hazard management support team
MEEI	Campaign for maintaining exemplary housekeeping (DPN initiative)
MHPE	Maximum historically probable earthquake
MLC	Onsite emergency response means
MME	Operations and maintenance methods
MQME	Campaign to raise the standards in maintenance and operation (DPN)

N

NCC	Operations core skills handbook
N3C	Tagging and circuit configuration errors
NCME	In-service maintenance professions common core
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)
NPP	Nuclear Power Plant
NQME	Non-quality in maintenance and operations
NRC	Nuclear Regulatory Commission (US)

O

ONC	National emergency response organisation (F)
ONR	Office for Nuclear Regulation (UK)
OPEX	Operating experience
OSART	Operational Safety Review Team (IAEA)

P

PBMP	Basic preventive maintenance programme
PCCF	Creusot forge compliance project
PCI	Pellet-cladding interactions
PDC	Nuclear engineering key skills development plan
PGAC	Worksite general assistance services
PIA	Protection-important activity
PIC	Protection-important component
PLM	Plant Lifecycle Management
PPAS	Multi-year nuclear safety improvement plan (Framatome)
PPI	Off-site emergency response plan (F)
PSPG	Police site protection unit (F)
PUI	Onsite emergency plan (F)
PWR	Pressurised Water Reactor

R

RASA	Rules governing hazard specifications (F)
R&D	Research & Development directorate
RGE	General operating rules (F)
RGV	Steam generator replacement
RIS	Emergency water injection system for reactor cooling
RTE	Power grid company (F)

S

SAT	Systematic Approach to Training
SBERG	Symptom-Based Emergency Response Guidelines
SCHADEX	Climate and hydrology simulation model
SDIN	Nuclear technical information system
SDIS	Local fire and rescue services (F)
SFR	Sodium-cooled fast reactor
SIR	Authorised internal inspection department
SMART	Digitalisation programme at the DIPDE
SMR	Small Modular Reactor
SODT	Safety Oversight Delivery Team (UK)
SOER	Significant Operating Experience Report issued by WANO
SOH	Socio-organizational and human approach
SPR	Risk management department
SSE	Safe Shutdown Earthquake
STE	Technical specifications
SWITCH	Digitalisation programme at the DIPNN
SYGMA	Computerised maintenance management system

T

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
TSM	Technical Support Mission by peers organised by WANO
TSN	Nuclear safety & transparency act (F)
TSSM	Technical Safety and Support Manager (UK)
TVO	Teollisuuden Voima Oyj (Finland)

U

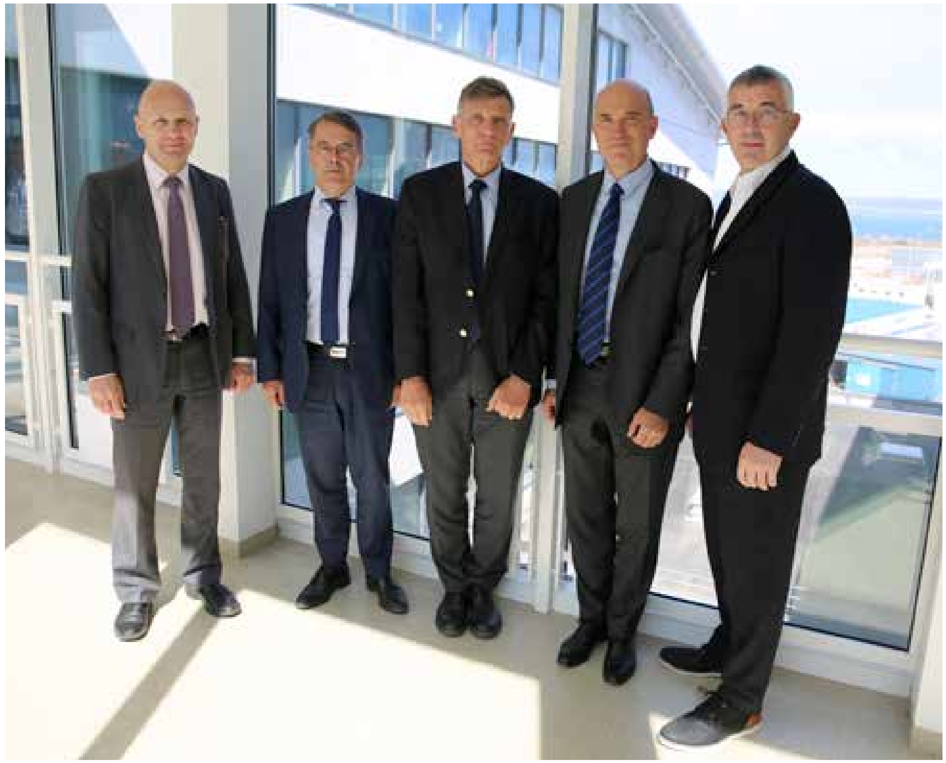
UFPI	Operations & engineering training department (DTEAM)
UGM	EDF Group Management University
UNGG	Gas-cooled graphite-moderated reactor (F)
UNIE	Operations engineering unit (DPN)
UTO	Central technical support department (DPN)

V

VD	Ten-yearly inspection outage
VP	Partial inspection outage

W

WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators Association



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