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SUB-CHAPTER 17.2 - DEMONSTRATION OF RELEVANT GOOD PRACTICE IN EPR DESIGN

1. INTRODUCTION

Guidance from HSE in application of the As Low As Reasonably Practicable (ALARP) principle to new UK nuclear power stations requires a demonstration that the design process has followed Relevant Good Practice [Ref-1].

The present sub-chapter summarises the relevant good practices and standards applied in the EPR design process. In particular, information is presented on the following:

- Review of the experience of EPR designers and a summary of the review and assessment process applied to the design. Summary of R&D effort underpinning the EPR design.
- Review of the design codes used in EPR design (reference is made to Sub-chapter 3.8 of the PCSR).
- Use of operational feedback from French and German plants in optimising EPR design.
- Discussion of a comparison of the EPR design against the HSE Safety Assessment Principles (SAPs), to confirm that all the key nuclear safety requirements embodied in the SAPs are met by the EPR design.

2. EPR DESIGN PROCESS

The EPR is a Generation 3+ PWR design developed by NPI (now AREVA NP) a joint subsidiary of FRAMATOME and Siemens, using experience gained by EDF, the German Utilities, FRAMATOME and Siemens in the design, manufacturing, construction, and operation of PWRs (corresponding to over 1000 reactor-years of operation). The reactor has been designed to meet safety specifications developed by the French Nuclear Regulatory Authority (ASN) as set down in the Technical Guidelines (TGs) [Ref-1]. These guidelines were developed following an extensive optioneering process carried out in France and Germany between 1987 and 2000, on the design of a Generation 3 PWR suitable for construction in Europe in the 21st century. The outcome of the optioneering exercise was reviewed by independent safety experts from several European Countries and the USA, on behalf of the French and German regulatory authorities.

A description of the design development and design review process and the organisations involved is given below.

2.1. ORGANISATIONS INVOLVED IN EPR DESIGN AND LICENSING

The three main types of organisations involved in the design and licensing process of the EPR have been the design organisations, the safety authorities (in France and Germany) and the bodies appointed to provide technical support to the safety authorities. A description of these bodies and their roles is given below. The organisational arrangements are shown in Sub-chapter 17.2 - Tables 1 and 2.

2.1.1. Design organisations

The EPR design organisations consist of reactor vendor and utility companies from France and Germany.

The EPR project began in 1987 when the vendor companies FRAMATOME and Siemens began cooperation to develop and commercialise a common PWR design aimed at the international export market. The aim of the collaboration was to pool the experience of the two companies in order to share the huge effort involved in developing a new reactor design. The companies founded a joint subsidiary company Nuclear Power International (NPI) to lead the work. Within a short time French and German electrical utilities had joined the project, which rapidly replaced other reactor development programmes underway in France and Germany. The new reactor design was renamed EPR.

NPI (now AREVA NP) led the organisation for the EPR design from 1990 up to the end of the Basic Design Optimisation phase in 2000. In 2003, AREVA NP was awarded the supply contract for the Olkiluoto 3 (OL3) EPR in Finland, under a turnkey scheme, and developed the detailed design.

When the detailed design phase for FA3 began (after the Basic Design Optimisation Phase), EDF, in its role as Architect Engineer for EPR power stations constructed in France, led the detailed design effort, in cooperation with AREVA NP and SOFINEL (a joint subsidiary of EDF and AREVA NP).

2.1.2. Safety authorities

In 1989 the French and German Nuclear Safety Authorities (ASN and BMU) created a joint safety directorate (DFD) to oversee the EPR project. Cooperation agreements were signed at the same time between the French and German technical support organisations (IRSN and GRS), and between the independent safety advisory groups supporting both regulators (the GPR in France and the RSK in Germany).

At that time, the French and German safety authorities were as follows:

- French Nuclear Installations Safety Directorate. This body is attached to the Ministries for Industry, for Health and for Environment. Its main duty is to conduct or monitor the regulatory procedures as required under the Basic Nuclear Installation Decree (December 11, 1963).

- German Federal Ministry for Environment and Reactor Safety (BMU).

2.1.3. Bodies providing technical support to national safety authorities

During the evaluation and assessment of the EPR design, the French nuclear safety authority was supported by the following organisations:

- The Institute for Nuclear Safety and Radioprotection (IRSN, formerly IPSN). The role of the IRSN, which consists of 1500 professional scientists and engineers, is to provide technical support to the French safety authority in relation to reactor safety and licensing and to conduct analytical studies, research and other work relating to nuclear safety on behalf of ministerial departments and interested organisations. Results of IPSN/IRSN studies are submitted to GPR (see below) and/or to the French safety authority.

- The Central Committee for Pressure Vessels (CCAP, article 26 of decree 99-1046 of 13 December 1999 concerning pressure vessels) is a consultative organisation. It comprises members of the various administrations concerned, persons chosen for their particular competence and representatives of the manufacturers and users of pressure vessels and of the relevant technical and professional organisations.

- For particular supervision of the more important pressure vessels in nuclear installations, the CCAP set up a Standing Nuclear Section (SPN), the role of which is to issue recommendations on application of pressure vessel regulations to the main nuclear steam supply systems.

- The Standing Group for Nuclear Reactors (GPR). This is an advisory body established by the French Minister of Industry, to support the French regulatory authority. It consists of 30 professional scientists and engineers from France, other European countries, and members of French Safety Authorities and advisory bodies, who are specialists in the fields of safety, construction, commissioning and operation of nuclear reactors.

In Germany, BMU was supported by the Gesellschaft für Anlagen und Reaktorsicherheit (GRS) which plays the same role as the IPSN (IRSN) in France, and the Reaktor Sicherheitskommission (RSK) which plays the same role as the French GPR.

After the completion of the Basic Design Phase of the EPR in 1998, BMU withdrew from the EPR design evaluation project. However, GRS and IRSN carried on with their joint review work, and experts from Germany continued to participate as invited members of the GPR, particularly in the definition of the Technical Guidelines.

2.2. MAIN PHASES OF THE EPR PROJECT

The phases of the EPR design process are summarised in Sub-chapter 17.2 - Table 3 and described below.

In 1985, the REP 2000 research programme was launched in France to develop an evolutionary design for the next generation of PWRs, taking the N4 plant series (Chooz 1&2, Civaux 1&2) as a starting point, which was launched by EDF, CEA and FRAMATOME. Studies were carried out under REP 2000 on the design of key equipment and phenomena such as the fuel, core, safeguards systems, I&C and HMI, severe accidents, etc.

In 1987, FRAMATOME and Siemens began co-operation on a project to develop a next generation PWR aimed at the international market: the “Common Product”. In 1989 after NPI was created, the different existing development programmes (“REP 2000”, “Common Product” and Siemens and German utilities “Plannung Auftrag”) were merged into a wider project (EPR Project) to design and license the next generation of Nuclear Power Plants (NPPs) for construction in France and Germany. The development of this model was based on design, construction and operating experience of the French N4 and German KONVOI plants. Contacts were established with the French and German safety authorities. Both authorities responded positively and the French safety authority specified its initial views on possible improvements that could be introduced in the design of future NPPs [Ref-1].

In 1993 NPI submitted a conceptual design specification (Conceptual Safety Features Review File or CSFRF) for EPR to the French and German safety authorities.

In the period 1993-1995 the safety authorities, supported by IPSN/GPR and GRS/RSK, carried out a detailed assessment of the EPR design specification, and requested certain enhancements and changes. The outcome was an updated design specification (Main Feature File (MFF)) which presented the detailed design requirements for the EPR plant and the rationale for the options chosen.

The Basic Design studies were started in early 1995. In 1997 a Basic Design Report was issued and formed the first version of the EPR preliminary safety report.

Further work was carried out in the period 1997-1999 to improve and optimise the design and the investment costs within the fundamental design specification, resulting in an updated Basic Design Report (Basic Design Optimisation Phase). BMU withdrew from the joint project during this period.

Subsequently, in the period 1999-2001, there was a further Post Basic Design Optimisation Phase, in which further design consolidation took place, particularly with regard to radiation protection of workers and environmental emissions.

In 2000 the GPR adopted the Technical Guidelines [Ref-2], which set down design principles for future PWRs that would be acceptable for construction in France. These TGs define the initiating events that would have to be addressed within the design basis for new PWRs, and defined certain multiple failure sequences and core melt sequences that had to be considered in the design. The TGs also included requirements for design against external hazards. The functional requirements of safety systems and principles for their safety classification were stated, including assumptions that needed be made with regard to single failures, and the equipment unavailability due to maintenance.

Following issue of the TGs, further enhancements were made to the EPR design, and three further updates were produced to the EPR safety report.

In Finland, following a call for tenders by TVO for the Finland 5 Project, the EPR was selected for construction, and a contract signed in December 2003, with AREVA NP as the turn-key supplier of a plant to be constructed on the Olkiluoto site. Following the preparation by the Consortium (AREVA NP/Siemens) of the relevant technical data, the application (PSAR and related documentation) for a Construction Licence for the Olkiluoto 3 EPR, was submitted by the utility TVO in early January 2004. The Finnish Safety Authority, STUK, issued its statement and its safety evaluation on January 21, 2005, and a Construction Licence was granted in February 2005.

During the detailed design phase, detailed design modifications on both projects (in France and Finland) were the subject of discussions between AREVA NP and EDF.

In 2005, EDF applied for a license to construct the first French EPR at the Flamanville site in Normandy. A Preliminary Safety Analysis report for the FA3 EPR unit was approved by the ASN in 2006 and agreement to begin construction was given in 2007. The FA3 EPR design is the design submitted Generic Design Assessment in the UK.

Since 1993, some 6 EPR Safety Reports and approximately 180 supporting technical references have been produced and assessed in detail by independent experts in IRSN/GPR (and by GRS/RSK up to 1998). During this period approximately 90 evaluation reports were issued by IRSN/GRS, some 200 meetings were held between the EPR project (EDF, German Utilities and the industrial partners) and the regulatory agencies, and close to one million hours of work were carried out within the EDF-SA engineering functions alone.

It is thus seen that the EPR design proposed for construction in the UK has undergone a 20 year process of design optimisation to maximise the safety of the plant within the constraints of practical constructability. The design optimisation process is very similar to the process of design optimisation to achieve an ALARP position, applied in the UK. The EPR design process has been carried out in consultation with regulatory authorities in France (and Germany initially), and all design documentation has been independently reviewed and scrutinised by a large panel of experts in organisations which were independent from the vendor and utility companies.

2.3. PRODUCTION OF “TECHNICAL GUIDELINES”

French and German safety authorities decided in 1995 that “technical guidelines for future PWRs” should be developed with oversight provided by the GPR and RSK standing commissions. IPSN and GRS submitted a proposal for the structure and contents for the development of these guidelines which was adopted. The outcome of this work was the publication of the “Technical Guidelines” (TGs) which brought together all recommendations of GPR and RSK (German experts) during the period 1993 - 2000.

The Technical Guidelines implement and refine the EPR conceptual safety design features identified in 1993. Several steps were involved in their production, as follows:

- The first step was to propose a structure allowing the GPR/RSK recommendations to be implemented in such a way that the technical guidelines can be used in both French and German regulatory processes. This was the objective of the work performed in 1997,

- The second step was to organise the GPR/RSK recommendations in the adopted structure. This work was performed in the first part semester of 1998,

- In 1998, IPSN/GRS began to turn the text of the GPR/RSK recommendations into guideline text, rearranging and making some changes in the material (without changing the substances of the original GPR/RSK recommendations). An intermediate version of the Technical Guidelines was issued by IPSN/GRS at the end of 1998. This document was reviewed by GPR/RSK members and by the EPR design organisation, leading to the issue of an updated version in 1999.

The final text of the Technical Guidelines was adopted by GPR and German experts during the plenary meetings held on October 19 and 26, 2000. Chapter 3 of the PCSR presents the Technical Guidelines.

2.4. REVIEW AND VALIDATION OF EPR DESIGN OPTIONS

Each of the EPR project partners carried out design reviews in the early preparatory phase of the EPR project, and later on during the detailed design phases after the issue of the Technical Guidelines (see Sub-chapter 17.2 – Table 3). In the period in between, NPI had primary responsibility for the EPR technical design review.

During the consolidation phase and the Basic Design phase (see Sub-chapter 17.2 - Table 3), design work was performed under a Basic Design Contract between EDF, German Utilities, FRAMATOME, Siemens and NPI. The organisational arrangements are shown in Sub-chapter 17.2 - Table 2.

The following definitions are of assistance in understanding the work organisation for the definition and validation of the main options considered during the Basic Design Phase:

- Contractor refers to the group of companies formed by NPI, FRAMATOME and Siemens, these companies being jointly and severally liable to the Utilities, under the leadership of NPI.

- Utilities refer to the group of companies comprising EDF and the German Utilities.

- Designer is any of the three companies forming the Contractor (or EDF-CNEN, to the extent it is entrusted by the Contractor to perform services).

- EPR Project Directorate (EPD): refers to a joint group formed between the Utilities and the Contractor as project organisation. It makes decisions on all technical questions, apart from those reserved for the EPR Steering Committee (ESC) or submitted by the EPD to the ESC for a decision.

- EPR Project Leader Committee (PLC): refers to a joint group formed between the Utilities and the Contractor as project organisation. It is responsible for the realisation of the decisions taken by the ESC and the EPD with regard to technical questions. Furthermore, the PLC is responsible for the execution of the work in due time and appropriate manner according to the instructions of the EPD.

The Basic Design work was performed on the basis of objectives and guidelines defined during the Conceptual Design Phase and the Consolidation Phase. These objectives and guidelines were described in the so-called Main Feature Files (MFF). The Basic Design activities involved validating and complementing the requirements stated in the MFF which were by definition general and preliminary. In some cases departures from MFF objectives were required.

The EPR Project Directorate was responsible for deciding on such changes, based on proposals made by the Project Leader Committee. If the changes were highly significant, approval was required from the EPR Steering Committee.

2.4.1. Work of the Committees and Technical Working Groups

The following committees and working groups met on a regular basis during the EPR design phase to make decisions and carry out actions within their respective field of responsibility.

2.4.1.1. EPR Steering Committee (ESC)

The EPR Steering Committee was empowered to take any decision concerning the Basic Design Contract or where appropriate to delegate such decisions to another project body.

2.4.1.2. EPR Project Directorate (EPD)

The EPR Project Directorate was responsible for making decisions on all technical questions, apart from those reserved for the ESC or submitted by the EPR Project Directorate to the ESC for decision.

68 EPD Meetings were held: 27 during Conceptual Design Phase and Consolidation Phase, and 41 during Basic Design Phase and Basic Design Optimisation Phase.

2.4.1.3. EPR Project Leader Committee (PLC)

The EPR Project Leader Committee was responsible for the realisation of decisions taken by the ESC and the EPD concerning technical questions. Furthermore, the PLC was responsible for the execution of the work in due time and appropriate manner according to the instructions of the EPD.

The meetings of the PLC were organised in order to review the progress of the project (Progress Review Meeting), in order to control the activities of the working groups and to prepare the results for discussion in the EPD.

92 PLC Meetings were held: 36 during Conceptual Design Phase and Consolidation Phase and 56 during Basic Design Phase and Basic Design Optimisation Phase.

2.4.1.4. Working Group Meetings

Subject to approval of the EPD, the PLC established working groups for special problems. The working groups generally consisted of representatives of EDF and the German Utilities, as well as of members of the Contractor organisations and EDF-CNEN when acting on behalf of the Contractor.

The meetings were organised by the project leaders who nominated qualified participants from their organisation. The following items were considered by permanent working groups with regular meetings:

1. Safety principles
2. Functional engineering and transient analysis
3. Systems and process
4. Reactor core
5. Containment
6. Layout, Civil (and. radiation protection)
7. I&C
8. Electrical systems
9. Components/Equipment units of the primary circuit
10. Severe accidents and radiological calculations

The working groups were involved from the very beginning in such a way that they were aware of ongoing engineering work and of the intermediate results, so they would have a common understanding of the design choices.

2.4.2. Technical Reviews

In addition to the periodic meetings, Technical Reviews were organised with the participation of the Contractor and the Utilities. Reviews were performed on specific subjects, such as:

- safety and systems, in particular severe accident reviews and systems reviews,
- layout, including building layout, accident prevention for personnel, radiation protection for personnel, fire protection, and other hazards.

A Technical Review Group was composed of experts from the Contractor and from Utilities and the Project Leader Committee. At the meetings, experts from the Contractor and Utilities presented their assessment reports, under the coordination of NPI, on the technical issues addressed by the Technical Review. The members of the Technical Review Group could request any further explanations and justifications. Their conclusions were presented in a report to the Project Leader Committee (PLC).

NPI were responsible for documenting the report of the Technical Review Group and distributing it to the PLC, the PED and the participants of the Technical Review. After approval by the PLC, the report became effective. NPI then issued a complete report of the meeting, including the comments of the various organisations represented at the meeting and rationales for the conclusions reached.

Technical reviews were held during the course of the Basic Design of the EPR, on different topics such as:

- ECC Mode – September 12, 1995
- Severe Accidents – December 1, 1995
- Severe Accidents – April 11, 1996
- I&C – September 17, 1996
- Layout – March 19, 1996
- Systems – February 20, 1996
- Systems – March 5, 1996
- Systems, December 16, 1997

Following the completion of the Basic Design there were further design phases, including the Design Optimisation and Detailed Design phases (see Sub-chapter 17.2 - Table 3). Technical Review Group meetings continued during these phases, addressing topics such as the design of the containment building and its liner, design of ventilation systems, selection of steam generator tube material, human factors, human-machine interface, radiological protection and environmental impact.

The phase of the project following the issuance of the Technical Guidelines is of particular interest for design process, as the French safety authority requested a number of improvements to the EPR design.

As a result of the requests, several letters were sent to the French safety authority in late 1999 and early 2000, making commitments to improve the design in areas such as:

- demonstration that some accident sequences (rapid reactivity insertion accidents, containment bypass sequences) would be “practically eliminated” from the design basis,

- reducing the consequences of accidents involving core melt (hydrogen mitigation, cooling of the corium, ...) and proposals regarding the design of systems to be used in these situations,

- role of the containment building and the peripheral buildings in the design of the “containment function”,

- definition of reference events considered in the design basis of the EPR, in particular with regard to cooling of the fuel inside the spent fuel pool,

- consideration of earthquakes in the design and the combination of loads to be assumed in design conditions with loads due to the design basis earthquake,

- the programme to be implemented for the equipment qualification, to ensure demonstration of qualification before start-up of the plant,

- the design objectives for radiation protection, radioactivity releases and radioactive waste production,

- consideration, at the design phase, of the specific needs and provisions to facilitate decommissioning of the EPR.

In addition, and on the basis of these commitments, design reviews on specific items were also conducted, including severe accident mitigation strategy, strategy for radiation protection etc.

2.5. SUMMARY OF R&D WORK UNDERPINNING THE EPR DESIGN

An extensive programme of Research and Development (R&D) work has been undertaken to validate EPR design aspects where changes have been made with respect to earlier plants. The R&D work is divided into 3 categories:

- Category 1: R&D work essential for the design and for the validation of key design choices (e.g. the behaviour of corium outside the reactor pressure vessel)

- Category 2: R&D work useful for improving and optimising the design (e.g. on the reactor vessel failure modes).

- Category 3: R&D confirmatory studies and work providing additional information to substantiate current design choices (e.g. steam explosion).

A summary of the main research areas is given below.

2.5.1. Subjects not related to severe accidents

Specific R&D not related to severe accidents is, in general, limited to qualification, adaptation or improvement of existing equipment. R&D topics studied cover the following areas:

- Elements within the vessel and in the bottom of the vessel,

- Control rods,
- Heavy reflector,
- Mitigation of accidents involving the loss of primary coolant,
- Mitigation of intermediate accidents involving the loss of primary coolant / steam generator pipe ruptures,
- Steam generator components

These topics have been the subject of an R&D programme for developing models and simulations for confirming the correct operation of EPR design features where differences exist with existing French and German plants. R&D programmes and tests are listed in Sub-chapter 17.2 – Table 4.

2.5.2. Severe accident topics

Specific EPR design features have been developed for mitigation of accidents involving core melt. In general terms no comparison with the existing French and German plants is possible. New R&D work was deemed necessary to justify the design solutions selected for the EPR, as R&D work in progress worldwide in the area of severe accidents was not specific to the EPR. Nevertheless, relevant worldwide R&D work on this subject was taken into account. The main areas of work were development and validation of calculation codes, including benchmark and validation tests at different scales with simulated and actual materials to identify key phenomena.

The following topics related to severe accidents were addressed in the programme. The work involved both general R&D carried out at research centres and specific R&D performed or initiated by the EPR designers:

- Performance of RCP [RCS] depressurisation valves,
- Vessel internals (lower section),
- Design of the reactor vessel support and the reactor vessel cavity, and behaviour of the RCP [RCS] in core melt situations
- Stabilisation of core melt,
- Mitigation of H_2 build-up,
- Removal of heat from the containment,
- Methods for limitation of radioactive releases,
- Internal structure of the containment

These topics have been the subject of experimental programmes to validate the design of EPR specific design features. R&D programmes and tests are listed in Sub-chapter 17.2 – Table 4.

3. CODES AND STANDARDS USED FOR EPR DESIGN

Sub-chapter 3.8 of the PCSR provides an overview of the codes and standards used for the EPR design.

4. INCORPORATION OF EXPERIENCE FEEDBACK INTO THE EPR DESIGN

In designing the EPR it was decided to follow an evolutionary approach: the advantage of basing an advanced design on operational experience from approximately 100 PWR nuclear power plants in the world (Belgium, Brazil, China, France, Germany, Korea, South Africa, Spain) constructed by FRAMATOME and Siemens was deemed by the designers to be very important.

In addition, experience feedback from other nuclear power plants has been reviewed and design features addressing any generic safety issues identified have been taken into account. The following examples illustrate this approach:

- Steam Generator (SG) tube integrity has been improved by the choice of Inconel 690 as the tube material to avoid corrosion cracking and intergranular attack. Denting and fretting are prevented by an optimised design of the internals and supports. In addition, the design provides accessibility to the tube bundle for inspection and maintenance.

- Overfilling of SG in case of SG tube rupture is avoided by reducing the head developed by the Medium Head Safety Injection (MHSI) pumps, by automatic initiation of fast RCP [RCS] cooldown and by an automatic shutdown of RCV [CVCS] charging pumps on detection of a high water level in the Steam Generators.

- RIS [SIS] sump blockage: in order to avoid blockage by insulation material and other debris, a staggered strategy for debris retention is adopted: this includes use of weirs and a trash rack for protection of openings in the heavy floor, large retention baskets with overflow space below the heavy floor opening and large screens with small meshes. The large screens with small mesh size above the sump pit have a robust construction to cope with increased head losses due to debris blockage and inclined subdivided sump screens are employed in order to facilitate filter cake detaching.

- In order to improve SG feedwater system availability, the EPR is equipped with a four independent train Emergency Feedwater System, each train being powered by a segregated diesel generator. In addition, the plant design includes a Startup and Shutdown Feedwater System.

- Improved reliability for the power supply system: The Emergency Power Supply System is equipped with four separate and independent diesel generator units that are safety grade and they are automatically started by low voltage or low frequency signals. In addition, the Station black-out power supply has two separate and independent diesel generators which are of a diverse design from the emergency diesel generators sets; they are also safety classified.

- Following a core melt accident, the containment integrity is ensured through design measures dealing with hydrogen detonation, direct containment heating, vessel lift, ex-vessel steam explosion, basemat (foundation raft) melt-through, containment pressurisation and containment leakage.

- Improved electrical design taking into account operating experience from the incident of 25 July 2006 at the Forsmark NPP in Sweden: the diversification in the power supply for I&C has been improved by adding four new distribution switchboards (220V DC) and by requiring diversification of suppliers for the 2 hour batteries between divisions 1/2 and 3/4. In addition, the protection of inverters in case of over-voltage has been modified (in particular, no inverter disconnection on high input voltage).

A systematic review has been carried out to confirm that the EPR design addresses generic issues identified in IAEA Technical Documents [Ref-1]. A similar review in regard of NRC generic safety issues (NUREG 09333) is in progress for a US EPR in the framework of USNRC Design Certification.

EDF and AREVA, who are co-applicants for Generic Design Acceptance for the UK PWR, remain actively aware of international developments in reactor design, operation and regulation through participation in a range of international organisations. In particular EDF is a member and active participant in the World Association of Nuclear Operators and AREVA chairs the FRAMATOME Reactor Owners Group.

5. COMPARISON OF EPR DESIGN WITH HSE SAPS

The UK HSE has developed Safety Assessment Principles (SAPs), against which it assesses safety submissions for civil nuclear facilities in the UK [Ref-1]. The SAPs are deemed to express HSE/ONR views on relevant good practice in reactor design and operation. Whilst the concept of compliance cannot be strictly applied between a design and an assessment principle, it has nonetheless been decided to perform a comparison between the EPR design and the expectations of the SAPs. This comparison is intended to be a contribution to the demonstration that the EPR design process has followed “relevant good practice”, as required by the guidance from HSE in application of the ALARP principle [Ref-2].

The EPR design was developed within a French and German framework involving both national Safety Authorities. The Safety Authorities produced a specific set of recommendations for the design of new PWRs, known as the “Technical Guidelines”, which were the fundamental requirements applied to the EPR design. Subsequently, the EPR design was compared against international standards such as IAEA safety guidelines, EURs and WENRA reference levels. These guidelines and principles do not correspond in all respects to the recommended practices suggested in the SAPs. Nonetheless, it is considered that all the key nuclear safety requirements embodied in the SAPs are met by the EPR design, and in particular that the EPR achieves the fundamental objective that the radiological risk to workers and the public is as low as reasonably practicable, which is the basic legal requirement underpinning UK nuclear safety regulations.

The detailed results of the assessment of the EPR design against the SAPs are presented in the document “Comparison of EPR design with HSE/NII SAPs“ [Ref-3].

6. CONCLUSIONS ON DEMONSTRATION OF RELEVANT GOOD PRACTICE

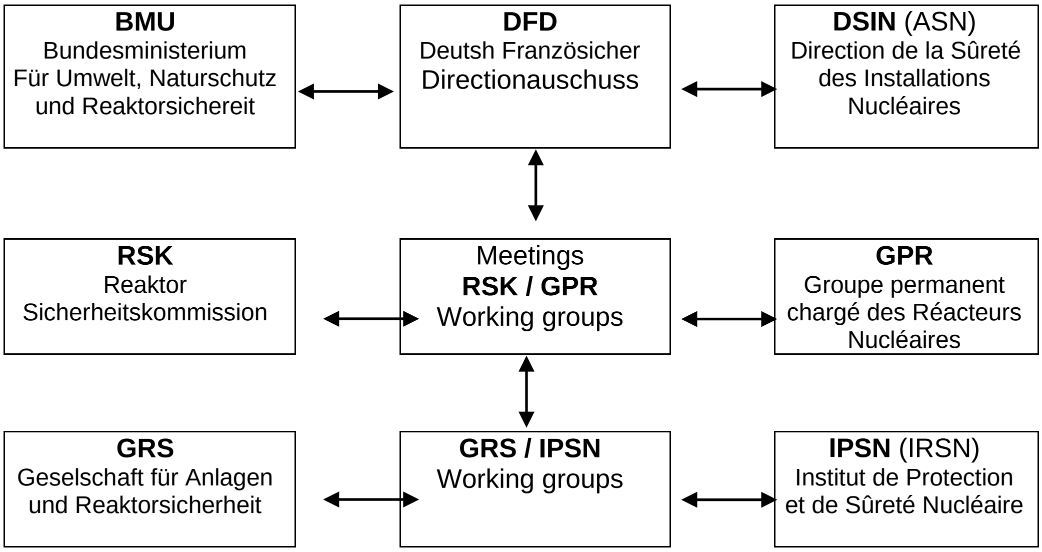
Guidance from HSE on application of the ALARP principle to new UK nuclear power stations requires a demonstration that the design process has followed Relevant Good Practice. Such a demonstration involves showing that the plant has been designed against internationally accepted codes and standards, and that feedback from relevant plant operating experiences and R&D is included in the design, and that compliance is achieved with HSE Safety Assessment Principles.

The present sub-chapter provides the demonstration of relevant good practice for the EPR design by summarising:

- the experience of EPR designers and the assessment process applied to the design,
- the R&D effort underpinning the design,
- the design codes and standards used in EPR design and their relationship to international codes,
- the use of operational feedback from French and German plants in optimising EPR design,
- the comparison of the EPR design against HSE SAPs to confirm that the SAPs requirements applicable at the plant design stage have been addressed.

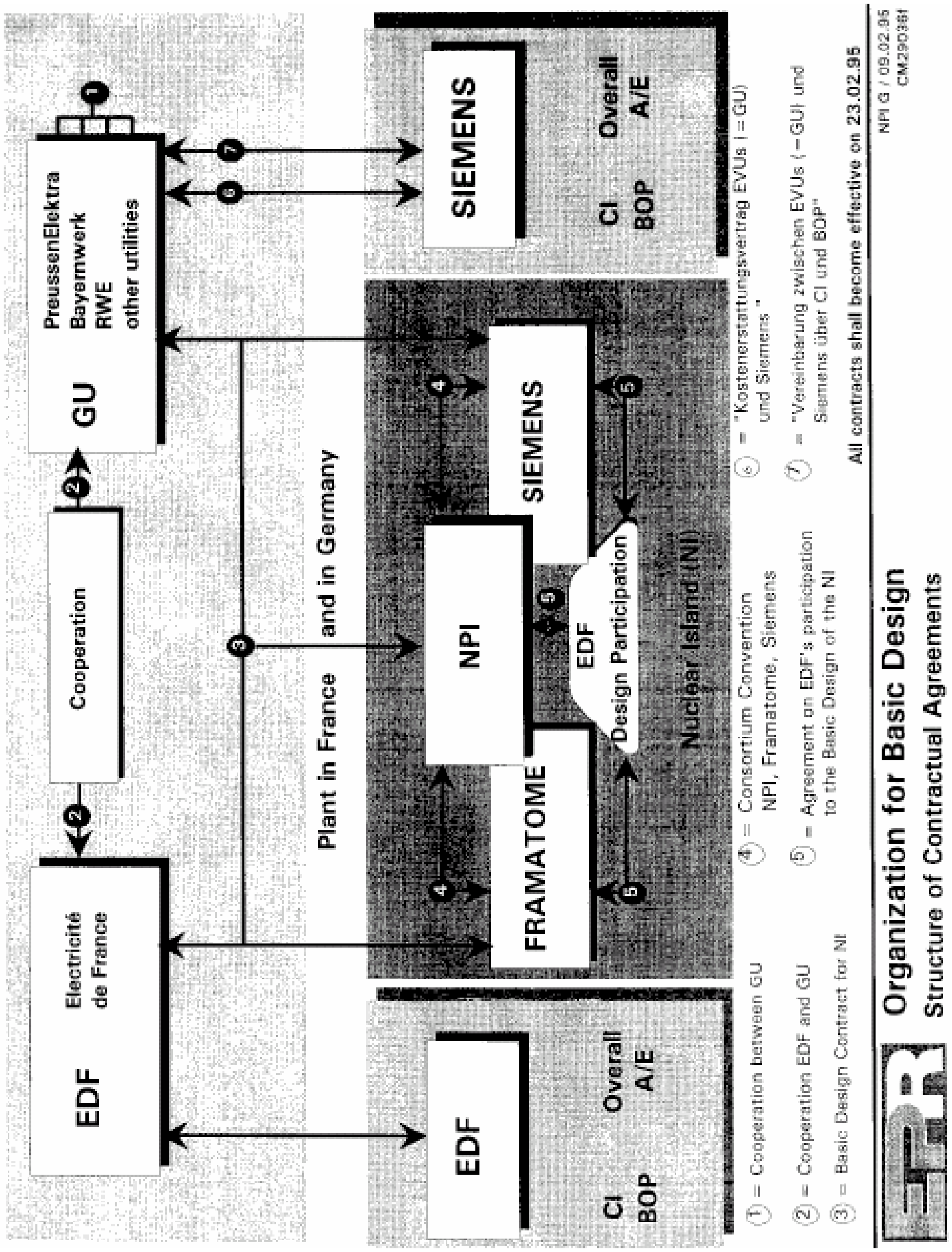
SUB-CHAPTER 17.2 - TABLE 1

Organisational relationships between French and German safety bodies



SUB-CHAPTER 17.2 - TABLE 2

Organisation of the relationship between French and German co-designers



SUB-CHAPTER 17.2 - TABLE 3

Different phases of the EPR design process

Dates	Design Phases	EPR Project deliverables	Safety bodies deliverables	Comments
1986 – 1991	Preparatory phase		Letter DSIN 984/91 Letter GPR 93/18	NPI founded in 1989
08/1993		Conceptual Safety Features Review File (CSFRF)	**Letter DSIN 1321/93**	
	Consolidation phase	Technical Reports	Letters GPR 94/20 ; GPR 94/28; GPR 94/42; GPR 94/50; GPR 94/62; GPR 95/04.	
01/1995		Main Features Files (MFF)	**Letter DSIN 51/95**	Signature of the BD contract
	Basic Design phase	Technical Reports	Letters GPR 95/54, GPR 95/59; GPR 96/24; GPR 96/25; GPR 96/47; GPR 97/01; GPR 97/25; GPR 97/41; GPR 97/60.	
10/1997		Basic Design Report (BDR 97)		Signature of the BDOP contract
	Basic Design Optimisation phase	Technical Reports	Letters GPR 98/07; GPR 98/15; GPR 98/31.	
11/1998		Basic Design Report (BDR 98)		Withdrawal of BMU/RSK

02/1999		Basic Design Report (BDR 99)		
	Post Basic Design Optimisation phase	Technical Reports	Letters GPR 99/06; GPR 99/32; GPR 99/43; GPR 99/55; GPR 00/16.	
10/2000		Letter EDF ref SN/99-1638	Technical Guidelines	EDF leader of the FA3 design
		Technical Reports	Letters GPR 02/24; GPR 03/25; GPR 04/12.	
12/2003	Detailed Design Studies phase	PSAR (project version) 2003	Letter DGSNR 729/2004 EPR Safety Options	Signature of OL3 contract
		PSAR (project version) 2005	Letters GPR 05/23; GPR 05/35.	Decision to launch FA3 project. Construction licence granted for OL3
05/2006	Request for construction license (DAC)	PSAR (project version) 2006	Letters GPR 06/06; GPR 06/21.	
04/2007	Construction licence granted for FA3		Decree 2007-534	

SUB-CHAPTER 17.2 - TABLE 4

R&D Programmes/Tests in support to the EPR Design

Components / Event	Physical Phenomena	Experimental Programmes/Tests
Vessel Internals (lower and upper plenums)	Hydraulic	Design relating to the flow distribution is based on STAR-CD calculations with a validation based on tests carried out in the HYDRA mock-up (small scale). The final validation has been achieved on the basis of the JULIETTE and ROMEO tests, for the lower and upper plenums respectively, at a 1/5 scale (Centre Technique du Creusot).
	Flow-induced vibration	Integral test: VIB, 1/8.5 scale mock-up.
Control rods – Rod Cluster Control Assembly (RCCA) guides	Hydraulic and vibration	MAGALY tests, 1/1 scale (design optimisation) CALVA tests
	Materials (wear)	AURORE and FANI tests
	Fatigue	CALVA tests
	Mechanical behaviour in case of LOCA and Earthquake	CALVA tests
Control rod drive mechanism (CRDM)	Many aspects of the CRDM performance, including the rod drop time	KOPRA tests
Heavy reflector	Hydraulic	HCL tests
Loss Of Coolant Accident (LOCA)	Thermal-Hydraulic	Complementary validation database for the CATHARE code (e.g. EPR specific features): UPTF tests [Ref-1] BETHSY tests (CEA) [Ref-2]
SGTR	Thermal-Hydraulic	BETHSY tests (CEA)
Steam Generator internals	Thermal-Hydraulic and flow-induced vibrations	Chooz B1 Steam Generator tests (confirmation of the results from CLOTAIRE Programme [Ref-3] and MEGEVE tests [Ref-4] to [Ref-6]

Components / Event	Physical Phenomena	Experimental Programmes/Tests
Pressuriser Relief Valves	Hydraulic and Mechanic	Valve prototype tests
Core-melt Accident	Steam Explosion	BERDA tests (FZK) [Ref-7] [Ref-8] BILLEAU (CEA) [Ref-9] and QUEOS (FZK) [Ref-10] tests PREMIX (FZK) [Ref-11] and FARO (JRC Ispra) [Ref-12] tests ECO (FZK) and KROTOS (JRC Ispra) tests [Ref-12] [Ref-13] Analyses in the frame of the OECD SERENA Programme [Ref-14] [Ref-15]
Core-melt Accident	RCP [RCS] behaviour, including impact of RPV failure	Integral tests: PHEBUS FP Programme (IRSN) [Ref-16] to [Ref-19] RPV bottom mechanical behaviour: CORVIS (PSI) [Ref-20] and RUPTHER (CEA) [Ref-21] tests Corium behaviour in-vessel: KAJET (FZK) and BALI (CEA) tests [Ref-22], OECD Programmes RASPLAV and MASCA (Kurchatov Institute) [Ref-23] High Pressure Melt Ejection (corium dispersion) and DCH: SNL tests [Ref-24] and DISCO tests (FZK) [Ref-25] [Ref-26] Analysis of Thermo-Hydraulic and Thermochemistry coupled phenomena [Ref-27] Other analytical works using computer codes [Ref-28]
Core-melt Accident	Hydrogen production in-vessel	CORA tests (FZK) [Ref-29] QUENCH tests (FZK) [Ref-30] PHEBUS-FP tests (IRSN) Computer code analyses [Ref-31] to [Ref-38]
Core-melt Accident	Hydrogen Distribution in the Reactor Building	OECD State-of-the-art report of interest [Ref-39] HDR tests [Ref-40] [Ref-41] Battelle tests [Ref-42] [Ref-43] NUPEC tests [Ref-44] Computer code analyses [Ref-45] TOSQAN tests (IRSN) [Ref-46]

Components / Event	Physical Phenomena	Experimental Programmes/Tests
		MISTRA tests (CEA) [Ref-47] ThAI tests (Becker Technology) and OECD ISP-47 [Ref-48] [Ref-49]
Core-melt Accident	Hydrogen Combustion	OECD State-of-the-art report of interest [Ref-50] HDC experiments [Ref-51] [Ref-52] HYCOM Programme [Ref-53] [Ref-54], including tube experiments TORPEDO, DRIVER and RUT Detonation tests at FZK [Ref-55] and TUM [Ref-56] [Ref-57] ENACCEF tests (CNRS Orleans)
Passive Autocatalytic Recombiners	-	KALI H2 tests (CEA) [Ref-58] Battelle MC tests [Ref-59] [Ref-60] H2PAR tests (CEA-IRSN) [Ref-61] [Ref-62] Qualification Programme of the AREVA PARs [Ref-63] [Ref-64]
Core-melt Accident	Fission Product Transport in the core and primary system	PHEBUS-FP Programme (IRSN) [Ref-65] to [Ref-68], LOFT (INEL) [Ref-69] FALCON tests (AEA-Winfrith) [Ref-70] CHIP tests (CEA) [Ref-71]
	Fission Product Resuspension	STORM tests (JRC Ispra) [Ref-72] KAREX tests (FZK)
	Iodine behaviour	ThAI experiments [Ref-73] to [Ref-75] PARIS tests (AREVA) [Ref-76] SISYPHE tests (IRSN) [Ref-77] EPICUR tests (IRSN) [Ref-78]
	Aerosol Transport in the Reactor Building	KAEVER [Ref-79] (ISP-44)
Containment wall - Liner	Mechanical, Leakage	MAEVA (EDF)

Components / Event	Physical Phenomena	Experimental Programmes/Tests
Core-Catcher	Molten Core – Concrete Interaction (MCCI)	BETA tests (FZK) [Ref-80] ACE tests (ANL) [Ref-81] MACE tests (ANL) [Ref-82] to [Ref-84] BALI [Ref-85] and BALISE [Ref-86] tests (CEA) CORESA tests (Germany) [Ref-87] [Ref-88] OECD MCCI Programme (tests at ANL)
Core-Catcher	Corium – ZrO2 interaction	CIRMAT tests (LSK Saint-Petersburg) and CORESA programme (Germany) [Ref-89] [Ref-90]
Core-Catcher	Melt Plug behaviour	KAPOOL tests (FZK) [Ref-91]
Core-Catcher	Corium spreading	CORINE tests (CEA) [Ref-92] KATS tests (FZK) [Ref-93] to [Ref-95] COMAS tests (SNT) [Ref-96] VULCANO tests (CEA) [Ref-97] [Ref-98] FARO spreading tests (JRC Ispra) [Ref-99] S3E test (RIT) [Ref-100]
Core-Catcher	Corium Quenching	MACE tests (ANL) [Ref-101] to [Ref-103] KAPOOL tests (FZK) [Ref-104] PERCOLA tests (CEA) [Ref-105] SSWICS tests (ANL) [Ref-106] ECOKATS tests (FZK)
Core-Catcher	Long Term Corium Cooling	Corium behaviour: SULTAN tests (CEA) [Ref-107] Core Catcher Cooling Channel Thermal-Hydraulic tests (AREVA Erlangen) [Ref-108]

SUB-CHAPTER 17.2 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

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