

The EPR – the future of nuclear expansion or rather a failed technology?

Old and new design problems: Oda Becker

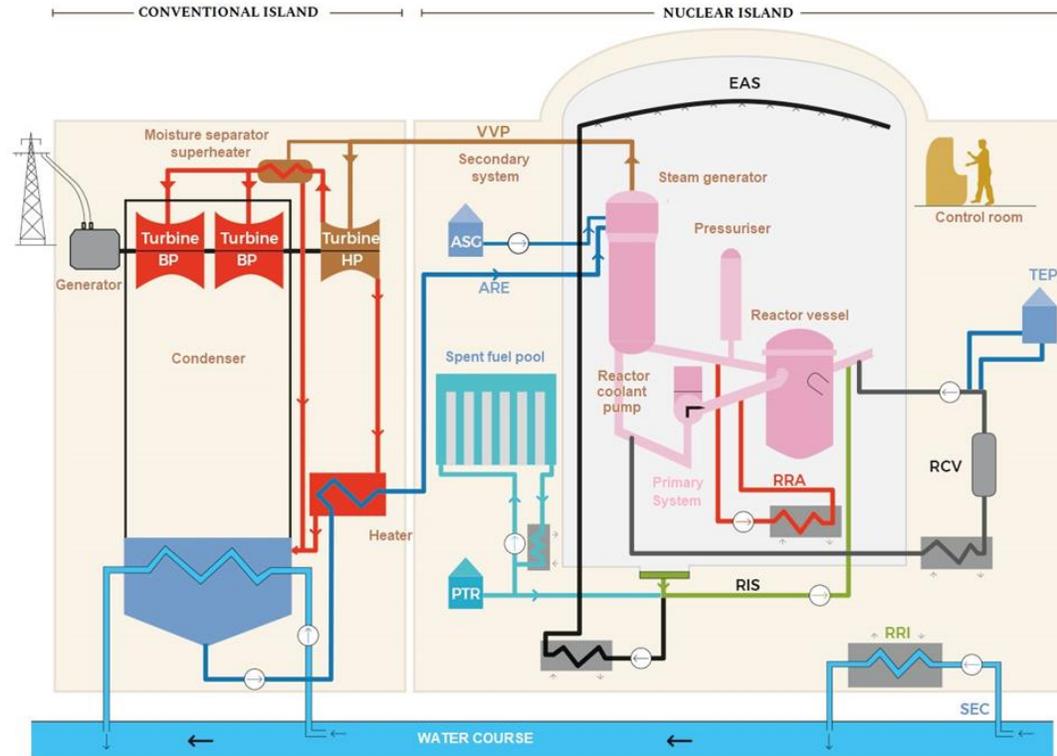
Joint Project

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Corrosion Problems

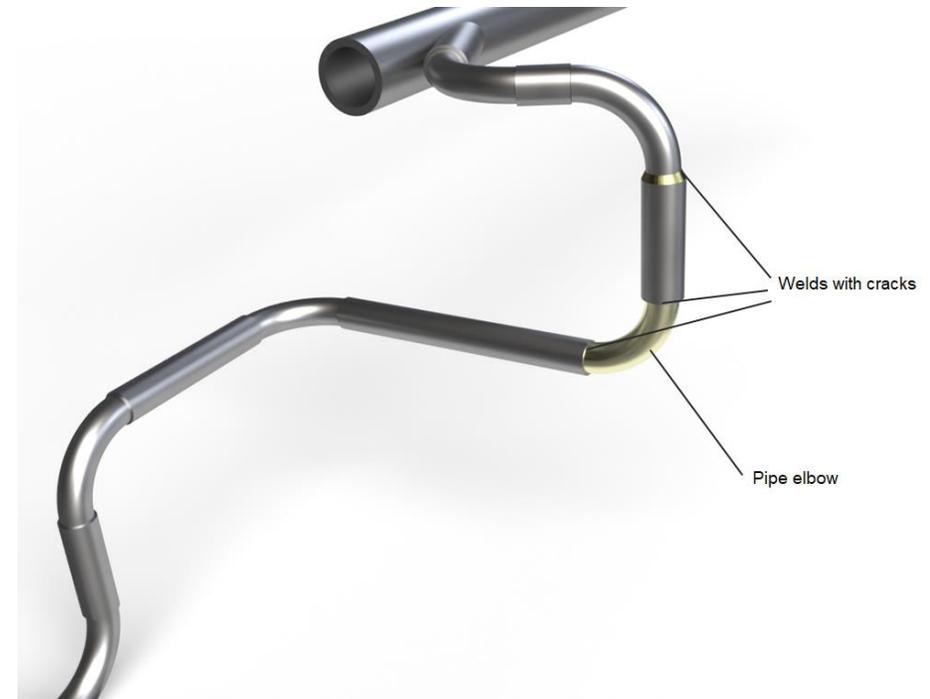
- On 21 October 2021, following ultrasonic inspections performed during the ten-yearly outage inspection of the Civaux NPP, EDF had detected “indications” on welds on the elbows of the pipes connecting the safety injection system to the reactor’s main primary system. (emergency core cooling system)
- In order to identify the origin of these indications, the parts of the pipes concerned were cut for metallurgical analysis in the laboratory.
- **This type of crack was not expected on these stainless-steel lines.**

Corrosion Problems



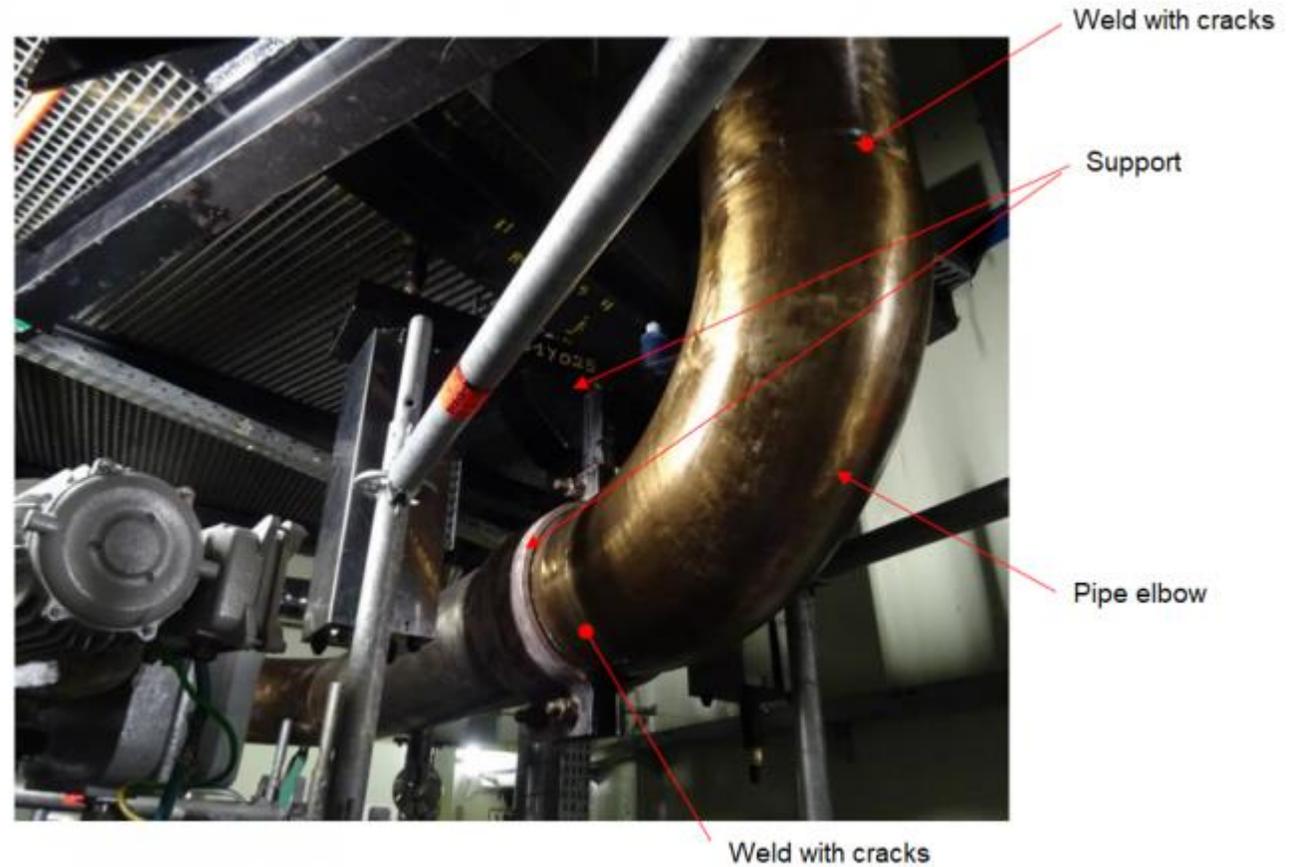
ARE: Feedwater flow control system
 ASG: Auxiliary feedwater system for Steam Generator
 EAS: Containment spray system
 PTR: Reactor cavity and spent fuel pit cooling and treatment system
 RCV: Chemical and volume control system
 RIS: Safety injection system
 ◻: Exchanger

RRA: Residual heat removal system
 RRI: Component cooling system
 SEC: Essential service water system
 TEP: Boron recycle system
 Turbine BP or HP: LP (low pressure) or HP (high pressure) turbine
 VVP: Main steam system
 ⊕: Pump



Corrosion issue

Ultrasonic examinations revealed the presence of faults near the welds of some pipe elbows.



Corrosion Problems

- The emergency core cooling system (ECCS) is a safety system that injects borated water into the reactor main coolant circuit (also called main primary circuit) to cool the core in the event of a breach.
- The ECCS is made up of two independent trains connected to the primary circuit via a hot leg and cold leg connecting pipe of each of the four loops of the primary circuit.
- Stress corrosion is a mode of damage that typically results from the combined action of mechanical stress and an aggressive environment with respect to the material.
- If these faults develop in the ECCS piping, it could lead to a leak or a break. The emergency core cooling system train unaffected by the breach would then ensure the injection of water into the primary circuit and the cooling of the core.
- If, on the other hand, this rupture or leak occurs simultaneously on several pipes, the cooling of the reactor core could potentially no longer be ensured.

Corrosion Problems

- EDF decided to preventively shutdown Civaux's No. 2 reactor on November 20, 2021. The first results of examinations on this reactor show the presence of defects at the same welds as on reactor No. 1.
- As a generic anomaly relating to the 1,450 MWe reactors cannot be ruled out at this stage, EDF has decided to shut down the two reactors at the Chooz B nuclear power plant are of the same type as those of Civaux, in order to carry out checks.
- In-depth investigations must be carried out in order to determine the phenomena at the origin of stress corrosion cracks and to define the scope of the examinations to be carried out.

Corrosion Problems

- EDF has carried out a considerable amount of work to more clearly understand the phenomenon and identify the zones concerned.
- These investigations of more than 70 assessments in the laboratory on welds sampled from only 8 reactors.
- EDF identifies the following as being the most susceptible:
 - the lines of the safety injection system (RIS) located on the cold leg and the intake lines of the residual heat removal system (RRA) for the four reactors of the N4 plant series (1450 MWe reactors of the Chooz B and Civaux NPPs)
 - the lines of the RIS injection system located on the cold leg of the 12 reactors of the P'4 plant series (1300 MWe reactors of the Belleville, Cattenom, Golfech, Nogent-sur-Seine and Penly NPPs.)

Corrosion Problems

- A total of 56 pressurized water reactors are operated at 18 NPP sites in France. They are subdivided into three classes (same construction type):
- 32 Reactors of the 900 MW class, subdivided into the following series
 - CP0 (Bugey),
 - CP1 (Le Blayais, Dampierre-en-Burly, Gravelines, Tricastin) and
 - CP2 (Chinon, Cruas-Meysses, Saint-Laurent-des-Eaux),
- 20 Reactors of the 1300 MW class, subdivided into the following series
 - P4 (Flamanville, Paluel, Saint-Alban) and
 - P4' (Belleville-sur-Loire, Cattenom, Golfech, Nogent-sur-Seine, Penly)
- 4 Reactors of the 1450 MW class or
 - N4 Series (Chooz, Civaux).

Corrosion Problems

- According to EDF, based on the available knowledge, it would appear that the susceptibility of the 8 reactors of the P4 (1300 MWe reactors of the Paluel, Saint-Alban and Flamanville NPPs] and the 32 reactors of the 900 MWe plant series to the stress corrosion phenomenon is low to very low.
- EDF intends to inspect all of its reactors by 2025, prioritising inspection of these most susceptible zones of the N4 and P'4 reactors.
- ASN considers that this strategy appropriate. However, with regard to Belleville NPP reactor 2, ASN considers that inspection of this reactor - scheduled for 2024 - needs to be brought forward.
- ASN considers that knowledge of the SC phenomenon will continue to develop, and that the inspection programme will have to be adapted if the inspections or analyses bring any new evidence to light.

Delays of the constructions of the EPRs

- In December 2003, Finland became the first country in Western Europe to order a new reactor since 1988. In 2005 the construction of the EPR in Olkiluoto started, the completion was expected in 2009. Commercial operation is now projected to begin December 2022.
- In 2005, the EPR in Flamanville (France) was approved with cost of €3bn. In 2007, construction started, completion was expected in 2012. In 2019, costs were increased to €10.9bn, commercial operation was expected in 2024. The project has been plagued with design issues and quality-control problems, including basic concrete and welding difficulties similar to those at the Olkiluoto (OL3) project in Finland
- In 2008, for the two EPRs in Hinkley Point C (UK), completion was expected in 2017. In 2022 the start for unit 1 of the Hinkley Point C plant is expected in June 2027.
- Taishan 1 and 2 in China were the first two reactors based on the EPR design to begin operating. The reactors entered commercial operation in December 2018 and September 2019, respectively. Construction started in 2009 and 2010 respectively.

Current problems of the EPR Flamanville 3

- The activities concerning weld repairs on the secondary systems (main steamlines and steam generator feedwater lines), involved considerable efforts of EDF, about a hundred secondary system welds needed to be repaired.
- Other work to correct deviations still has to be carried out ahead of commissioning, in particular concerning the primary system set-in nozzles.
- Considerable work is still to be done on numerous topics with major safety implications, already identified several years ago (e.g. reliability of the pressuriser valves and the performance of the filters for the water reinjected from the bottom of the reactor building in an accident situation).
- Finally, ASN is paying close attention to how EDF learns the lessons gained from the EPRs commissioned in Finland and China. In particular anomalies on fuel, in particular those affecting the Taishan reactor core.

Vibrations problems in the EPR OL3

- Vibrations were detected in surge line of the pressuriser of the Finnish EPR Olkiluoto-3.
- The Finnish Radiation Protection and Nuclear Safety Authority (STUK) classified the situation as safety-relevant and has decided that the work to suppress the vibrations in the pressure equalisation line must be verifiably completed before loading with fuel assemblies.
- The French IRSN also points to these vibration problems of EPR plants and recommends that the causes of the strong vibrations be clarified and eliminated in the EPR2 reactors currently under development.
- Laponche (2021) calls for a thorough analysis of the causes and appropriate retrofitting of the EPRs already under construction and in operation.
- Laponche points out another problem identified from the operation of the Taishan NPP:
 - the power in the centre of the core is slightly higher than expected and,
 - the (computerised and mathematical) tools used to calculate the power distribution have proven not to be entirely suitable.

Fuel problems in Taishan 1

- In June 2021 - midway through its second fuel cycle - an increase in the concentration of noble gases in the primary circuit of Taishan 1 was attributed to a few damaged fuel rods. China's National Nuclear Safety Administration (NNSA) estimated that of the more than 60,000 fuel rods in the core of Taishan 1, about five probably had damage to their cladding.
- China General Nuclear (CGN) took the unit offline on 30 July last year to investigate the cause of the fuel damage and to replace the defective fuel rods.
- Following an inspection of Taishan 1 between 26 and 29 July 2022, the NNSA gave its approval for the reactor to be restarted.
- Chinese EPR resumes power supply after extended outage 17 August 2022.
- Details about the cause and extent of the fuel damage were not disclosed.

EPR NM or EPR2

- EDF is developing a new reactor, called “EPR 2” (before EPR NM (New Model)). It aims to incorporate the lessons learned from the design, construction and commissioning of the EPR reactors and from operation of existing reactors.
- ASN’s technical support organization IRSN issued several critical assessments of EDF’s pre-design choices.
- On 16 July 2019, ASN then published its opinion on the proposed safety options. Additional justifications were in particular needed on the break preclusion approach for the main primary and secondary piping, the approach for dealing with hazards, fire and explosion in particular, and the design choices for certain safety systems.
- ASN had requested EDF to take into account the crash of a military plane in the design and safety studies. IRSN concluded in a note released in December 2020 that “EDF’s approach stays behind ASN’s request”, in particular that such a “crash does not entail an accident”.
- The double-walled containment building has been replaced by a containment building made of a very thick wall coated by a metallic liner.
- In another analysis published in March 2021, IRSN looks at a phenomenon identified in various EPRs in operation or under construction. Excessive vibrations have been identified.