AUTORITÉ DE SÛRETÉ NUCLÉAIRE
Direction des équipements sous pression nucléaires

Référence courrier :
CODEP-DEP-2022-037594

Monsieur le Directeur
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Dijon, July, 26, 2022

Subject: Discovery of stress corrosion cracks on several reactors in the NPP fleet, plus associated strategy.

References: [**1**] EDF letter D455022004385 of 13 July 2022
[**2**] ASN letter CODEP-DEP-2022-026625 of 14 June 2022.

For the attention of the Director,

At the end of 2021, you informed me that cracks had been discovered as a result of a stress corrosion cracking (SCC) phenomenon on the piping of the safety injection system (SIS) of the main primary system of Civaux NPP reactor 1, and then on Penly NPP reactor 1. This type of crack was not expected on these stainless steel lines. This situation led you to shut down the four N4 type reactors and carry out investigations on all of your reactors.

Since then, and in regular contact with my departments, you have started a programme of in-depth inspections and appraisal in order to clarify your understanding of this phenomenon and its implications for the fleet as a whole. Thanks to this programme, you defined and implemented an inspection strategy covering all types of reactors in the fleet and cut sections of piping from a representative sample of these reactors, as metallurgical analysis following cutting is at present the only means of determining the presence of SC flaws with any certainty. This led you (on 13 July 2022) to carry out nearly 70 laboratory assessments of welds sampled from eight reactors. These assessments are essential to acquiring full knowledge of the characteristics of these flaws and data concerning the various parameters liable to influence the initiation of SCC.

At the same time you initiated significant development work on a new means of ultrasonic inspection, called “improved UT”, the aim of which is to create a non-destructive inspection system capable of detecting small SC cracks and measuring their depth. Your first results, made possible by comparing acquisitions performed on actual flaws with metallurgical analysis data, are encouraging. In the forthcoming months inspections will performed on high-priority reactors to consolidate existing knowledge of the scale of the SCC phenomenon, including its extent.

Your analyses also led you to issue a hypothesis regarding the influence of mechanical loading in the lines. You thus consider the geometry and thermohydraulic phenomena in the lines to be decisive factors in their susceptibility to SCC. Thus, in your letter in reference [1], you propose an initial classification of the susceptibility to the SCC phenomenon of the auxiliary piping in the fleet's reactors based on this hypothesis and on all the analysis and assessment results currently available. This classification in particular identifies the "cold leg” SIS (Safety Injection System) lines and “hot leg” RHRS (Residual Heat Removal System) lines of the N4 type reactors and the “cold leg” SIS lines of the P’4 type reactors as being most susceptible to the SCC phenomenon.

On this basis, you first propose a programme of additional inspections by the end of 2022, with non-destructive examination of the lines you have identified as the most affected, as well as of those undergoing requalification during their ten-yearly outage. You then propose an overall strategy for inspection and continued acquisition of knowledge for the coming three years. This overall strategy will be clarified in autumn with regard to the exact scope of the inspection to be carried out with improved UT, or other inspection processes.

ASN considers that the initial results from the analyses and assessments were essential for the development of your strategy and are such as to underpin the prioritisation of the forthcoming inspections. On the basis of all of this information, of the demonstrations of mechanical strength in the presence of cracks and of the safety studies performed, ASN considers your strategy to be appropriate.

However, ASN considers that the proposed inspection during the Belleville NPP reactor 2 outage in 2024 is too late given the susceptibility of this type of reactor (P’4).

The results of the additional inspections and analyses scheduled for 2022 and the subsequent years are liable to change the available knowledge about the SCC phenomenon and the factors leading to its onset. You may need therefore to consider your strategy as evolving, in the light of phenomenon understanding, which means that this strategy cannot be considered definitive at this time.

Your strategy and the data supporting it call for the comments and observations contained in the appendix. ASN is continuing to examine the information provided in your letter [1].

Yours sincerely,

ASN Director General

Appendix to letter CODEP-DEP-2022-037594

1. Safety study and operating provisions

You have initiated a programme of mechanical studies on the SIS and RHRS lines for all types of reactors. I duly note your undertaking to complete these studies by September 2022. I also note that a flaw 6.48 mm in depth discovered on an SIS line of the Civaux NPP reactor 1, currently shut down for analysis, is also being included, as this flaw depth is not currently covered by the mechanical studies conducted for the N4 type reactors.

Using realistic hypotheses, you also studied the potential safety consequences of the rupture of two SIS lines on the cold leg in your 900 and 1300 MWe reactors. These studies conclude that the safety criteria defined for loss of coolant accidents would be met. You intend to carry out these same studies for the N4 type reactors (currently shut down) and for ruptures on the RHRS system.

I note your undertaking to carry out these additional studies. The ongoing examination of the studies already transmitted or yet to be received, with the support of IRSN, could lead to additional requests.

At the same time as these safety studies, you deployed compensatory operating measures for your operating reactors. These compensatory measures aim to limit the transients, which could significantly load the stress corrosion cracks, but also to detect any leaks that could come from these cracks as early as possible. These measures will shortly be supplemented in order to take account of the lessons learned from their application and the analysis carried out by IRSN. The application of these measures was checked by your departments and inspected by ASN. I would ask you to analyse any deviations that were found by ASN during these inspections on the various sites and, as necessary, to take steps to ensure that similar deviations are not found on other sites.

2. Implementation of the improved UT

In your letter [1] you detail the initial results obtained during development of the improved UT process and the current estimate of its performance regarding detection of an SCC flaw and the evaluation of its depth.

You also give your forecasts in terms of the implementation capacity of this process, with ten measuring instruments being in service as of the end of August 2022, and twenty as of the end of September 2022.

I would urge you to continue to maximise these deployment efforts, notably with regard to the training of the necessary personnel. Insofar as you intend to trial this improved UT as of 2022 on several reactors, and systematically as of 2023, I duly note your commitment to continuing with the evaluation of the performance of this process. You will notably continue with the programme of metallurgical analyses you defined, with the aim of being able to present a substantiated performance justification file. Performing inspections with an NDT prior to its qualification is stipulated by the Order of 10 November 1999 and its circular, so that NDT development can be continued and the data needed for performance evaluation can be acquired. However, the NDT processes used will eventually need to be qualified.

Kindly inform me of the deadline you envisage for this qualification.

3. Susceptibility of lines and general principles adopted for the inspection strategy

In your letter [1], you classify the RHRS and SIS lines of the various types of reactor according to their susceptibility to the initiation of SC. Your classification is based both on the results of the analyses carried out after cutting and on your hypothesis with regard to the influence of the geometry of the lines on the thermomechanical loadings.

This classification, which is currently consistent with the results of the inspections carried out on the reactors, is liable to change with the results of the inspections yet to be conducted. I in particular note the inspections planned on the P’4 type reactors, which will supplement the existing sample.

You also provide initial susceptibility analysis data for lines other than the SIS and RHRS lines, as well as for the SIS and RHRS lines of diameter smaller than 10 inches. At the same time, you intend to supplement these data with a number of additional measures, such as the development of non-destructive inspection means suitable for these lines, the performance of inspections on parts already disassembled and analysis and assessment after disassembly at chosen locations. The assessments made regarding these other lines will have to be confirmed by inspections on the reactors.

In this respect, kindly inform me of the deadlines set for performance of these additional measures.

In all these respects, the scope of the inspections to be started as of 1 January 2023 on the reactors of the NPP fleet, using improved UT or other appropriate examination processes, shall take account of available knowledge regarding the susceptibility of all the lines and how they change over time. This scope will also be required to include inspections on lines considered to be less susceptible, but for which the risk of SC initiation cannot yet be ruled out.

4. Inspections performed on the NPP fleet in 2022 using improved UT

In the second part of 2022, you undertake to carry out improved UT inspections on an additional number of reactors, on lines you consider to be the most susceptible to the SCC risk. You notably took account of ASN's previous requests [2] aiming to carry out inspections on Penly NPP reactor 2, which has not yet undergone conventional UT inspection, including the welds which have been repaired.

You also undertook to use the outage of Cattenom NPP reactor 1 currently in progress to check the weld concerned by two indications detected with the conventional UT process during previous inspections.

I duly note the scope of the welds you intend to inspect on these 900 and 1300 MWe reactors. As you mention, even if the overall inspection programme you have undertaken to present in the autumn makes provision for expansion of this inspection scope to other lines, or other welds, the reactors inspected in 2022 will need to undergo additional inspections during the course of a subsequent outage.

For the CPY type reactors, and depending on the reactor, "cold leg" SIS lines n°1 or n°3 have different geometries from the other lines and are not required to undergo ultrasonic inspection by the traditional preventive maintenance programme. You state that active stratification is not possible on these lines owing to their geometry, whereas this is similar to that of the N4 type reactors in which SC has been detected.

The absence of stratification in these lines will need to be demonstrated. If not, you will adapt your inspection strategy for these lines.

More generally, in the light of the knowledge acquired - which can continue to evolve - you will need to consider your strategy as open to change, taking account of the available inspection capacity which, according to your undertakings, will expand rapidly and which ASN has asked you to mobilise to the extent possible.

5. Kinetics of SCC propagation and digital weld simulations.

In your letter [1], you mention the digital simulations of welds that you have produced and your estimates of the kinetics of SCC propagation.

The main result of the digital simulations of the welds that you highlight is, for the SIS welds studied, the existence of a compression zone close to the inner wall, owing to the effect of residual welding stresses. This compression zone was still in place when you studied the case of a repaired weld. The current results however are unable to determine the precise position and scope of this compression zone, on the basis of the welding parameters, the intensity of the in-service stresses (which are in addition to the residual stresses) and any repairs.

You intend to supplement these studies, notably by transmitting a study in December 2022 on SCC susceptibility according to the welding conditions and the presence of any manufacturing flaws.

With regard to the propagation kinetics of an SC crack, you present a conclusion whereby a propagation rate of 0.5 mm/year would be the worst-case flaw propagation scenario.

This conclusion raises questions, for a number of reasons, including the extreme sensitivity of the propagation models currently used to the input data (temperature, nature and intensity of residual stresses and operating stresses, welding conditions, material work hardening, etc.), and the fact that the development of a stress corrosion crack would appear – according to your analyses – to comprise several phases during which the propagation rates differ widely: initiation stage prior to propagation, rapid propagation stage under the effect of the increase in the stress intensity factor, potential slow-down phase under the effect of residual welding stresses.

ASN is continuing to examine these points and could therefore issue additional requests.

6. Inspection of the cold leg SIS connecting welds before repair

I duly note your undertaking to carry out improved UT inspection of the stainless steel piping side, on the primary nozzle connecting weld of the cold leg SIS lines of the N4 and P'4 type reactors undergoing repair. On this occasion you also intend to inspect the adjacent weld on these lines.

In support of this strategy, you provide arguments tending to show the lesser susceptibility of the weld on the main primary line side, owing to the presence of ferrite in the casting components. ASN is currently examining this point and could therefore issue additional requests.

Finally, more generally with respect to any repairs to be made after disassembly on lines which contained SCC flaws, I would draw your attention to the need to continue with your work to optimise the assembly processes, with the aim of better management of the parameters influencing SCC and minimising the risk of it reappearing.