



## **ASN resolution n° 2018-DC-0643 authorising commissioning and operation of the Flamanville NPP EPR reactor pressure vessel (BNI 67)**

The French nuclear safety authority (ASN),

Having regard to the Environment Code, in particular its articles L. 557-4, L. 557-5 and L. 557-1-3;

Having regard to decree 2007-534 of 10 April 2007, amended, authorising the creation of the BNI referred to as Flamanville 3, comprising an EPR type nuclear reactor, on the Flamanville site (Manche *département*, France);

Having regard to the order of 10 November 1999, amended, relative to the monitoring of the operation of the main primary system and the main secondary systems of nuclear pressurized water reactors, notably its article 12;

Having regard to the order of 30 December 2015, amended, relative to nuclear pressure equipment and to some safety accessories intended to their protection, more specifically its article 9 and its appendix I;

Having regard to resolution CODEP-CLG-2016-047916 from the ASN Chairman of 7 December 2016 concerning the acceptance of the technical baseline requirements for assessing the conformity of level N1 nuclear pressure equipment intended for BNI 167, called Flamanville 3;

Having regard to resolution CODEP-CLG-2018-033892 from the ASN Chairman of 3 July 2018 concerning the acceptance of the technical baseline requirements for assessing the conformity of level N1 nuclear pressure equipment and assemblies comprising at least one such equipment item, intended for BNI 167, called Flamanville 3;

Having regard to ASN opinion 2017-AV-0298 of 10 October 2017 concerning the anomaly in the composition of the steel used for the Flamanville NPP (BNI 167) EPR reactor pressure vessel bottom head and closure head;

Having regard to the report from ASN and the Institute for Radiation Protection and Nuclear Safety, reference CODEP-DEP-2015-037971 – IRSN/2015-00010 of 30th September 2015 concerning the analysis of the approach proposed by Areva NP to demonstrate the adequate toughness of the Flamanville EPR reactor pressure vessel lower head and closure head domes;

Having regard to ASN letter reference CODEP-DEP-2015-043888 of 14 December 2015 concerning its position on the approach used to demonstrate the adequate toughness of the Flamanville 3 EPR vessel bottom head and vessel closure head domes;

Having regard to the report from ASN and the Institute for Radiation Protection and Nuclear Safety (IRSN), reference CODEP-DEP-2016-019209 – IRSN/2016-00005 of 17 June 2016 concerning an interim review of the approach proposed by Areva NP to demonstrate the adequate toughness of the Flamanville EPR reactor pressure vessel bottom head and closure head domes;

Having regard to the ASN letter to Areva NP reference CODEP-DEP-2016-031435 of 26 September 2016 concerning an interim review of the approach used to demonstrate the adequate toughness of the Flamanville EPR vessel bottom head and vessel closure head domes;

Having regard to the ASN and IRSN report reference CODEP-DEP-2017-019368 - IRSN/2017-00011 of 15 June 2017, on the analysis of the consequences of the anomaly in the Flamanville EPR reactor vessel head domes on their serviceability;

Having regard to the recommendations of the Advisory Committee for Nuclear Pressure Equipment of 30 September 2015, reference CODEP-MEA-2015-040055 of 1 October 2015;

Having regard to the observations of the Advisory Committee for Nuclear Pressure Equipment reference CODEP-MEA-2016-027702 of 7 July 2016;

Having regard to the opinion of the Advisory Committee for Nuclear Pressure Equipment of 27 June 2017 concerning the consequences of the carbon concentration anomaly in the Flamanville EPR reactor pressure vessel domes on their serviceability reference CODEP-MEA-2017-028273;

Having regard to the technical report from the manufacturer of the Flamanville EPR reactor pressure vessel, Areva NP, reference D02-PEEM-F-15-0368, revision B of 31 July 2015 concerning the demonstration approach used for the Flamanville EPR reactor pressure vessel closure head and bottom head;

Having regard to the Areva NP technical report, reference D02-PEEM-F-16-0260, revision A of 20 May 2016 concerning the general methodology used to demonstrate compliance with the mechanical criteria for the Flamanville EPR reactor pressure vessel domes;

Having regard to the technical file transmitted by Areva NP to ASN on 16 December 2016, and then subsequently updated, more specifically the technical report reference D02-ARV-01-104-503, revision B of 27 April 2017 concerning the demonstration of the adequate toughness of the Flamanville EPR reactor pressure vessel bottom head and closure head domes;

Having regard to the undertakings made by Areva NP and sent to ASN in the letter reference ARV-DEP-00755 of 6 June 2017;

Having regard to the undertakings made by the licensee Électricité de France (EDF), sent to ASN in the letter reference D458517029486 of 6 June concerning in-service monitoring of the Flamanville EPR reactor pressure vessel bottom head and closure head, letter reference D458517029054 of 6 June 2017 concerning the thermal ageing monitoring programme, letter reference D458517029531 of 6 June 2017 concerning the exhaustive nature of the list of thermal shock situations for the Flamanville EPR reactor pressure vessel domes, letter reference D458517030291 of 9 June 2017 concerning in-service monitoring of the Flamanville EPR reactor pressure vessel closure head and letter reference D458518020869 of 13 April concerning the progress made in the actions described in the above-mentioned letters;

Having regard to the Framatome letter reference FRA-DEP-00031 of 22 March 2018, requesting an assessment of the conformity of the Flamanville NPP EPR reactor pressure vessel, in accordance with the provisions of module G of article 6-II of the above-mentioned Order of 30 December 2015;

Having regard to Framatome letter reference FRA-DEP-00114 of 13 July 2018, requesting authorisation for commissioning and operation of the reactor pressure vessel, by virtue of article 9 of the Order of 30 December 2015;

Having regard to the opinion of the Standing Sub-committee for Pressure Equipment of the High Council for the Prevention of Technological Risks of 18 September 2018 ;

Having regard to the Framatome letter of 14 September 2018 informing ASN that it had no comments regarding the draft resolution;

Having regard to the EDF letter of 14 September 2018 informing ASN that it had no comments regarding the draft resolution;

Having regard to the results of the public consultation held from 3 to 24 September 2018;

Whereas, as of 1 January 2018, in the conditions set out in the partial transfer of assets agreement, the Framatome company, 1 place Jean Millier, 92400 Courbevoie, RCS Nanterre 379 041 395, assumed the rights and obligations of the Areva NP company connected with the Flamanville EPR reactor pressure vessel manufacturing activities;

Whereas the Flamanville EPR reactor pressure vessel is subject to the essential safety requirements of appendix I of the above-mentioned order of 30 September 2015, notably that regarding technical qualification;

Whereas the tests performed on the Flamanville EPR reactor pressure vessel bottom head and closure head domes revealed the fact that the characteristics of these components are not as initially required by the manufacturer in the design;

Whereas this anomaly is due to the presence of a residual carbon positive macrosegregation zone which was not sufficiently eliminated by the manufacturing process adopted by the manufacturer;

Whereas the risk of heterogeneity due to residual positive carbon macrosegregations, a known metallurgical phenomenon, was inadequately assessed and its consequences inadequately quantified by the manufacturer, even though techniques are available for eliminating this risk;

Whereas the technical qualification requirement mentioned in point 3.2 of appendix I of the above-mentioned order of 30 December 2015 is therefore not met for the Flamanville EPR reactor pressure vessel; the manufacturer failed to take sufficient account of the state of progress of technology and practices at the time of design and manufacture; therefore this equipment does not meet all the essential safety requirements mentioned in article L.557-4 of the Environment Code;

Whereas the manufacturer's above-mentioned request of 13 July 2018 is accompanied by an analysis, carried out together with the licensee, of the consequences for the protection of the interests mentioned in article L. 593-1 of the Environment Code;

Whereas, if the impact bending energy value at 0°C defined in point 4.2 of appendix I of the above-mentioned Order of 30 December 2015 is not met, the manufacturer may by other means demonstrate that the material is sufficiently ductile and tough, in accordance with this same appendix; in this respect, the manufacturer has implemented a specific characterisation programme designed to demonstrate that the material is sufficiently ductile and tough and to demonstrate an equivalent overall level of safety;

Whereas the presence of a positive carbon macrosegregation zone can in certain conditions reduce the toughness of the steel, in other words its ability to withstand crack propagation and is liable to compromise its fast fracture strength;

Whereas, in its above-mentioned letter of 14 December 2015, ASN considered that, with certain reservations, the approach adopted by the manufacturer to demonstrate that the anomaly did not compromise the serviceability of the Flamanville EPR reactor pressure vessel bottom head and closure head, presented in the above-mentioned technical report of 31 July 2015, was acceptable in principle, notably in the light of the conclusions of the above-mentioned report of 16 September 2015 and the above-mentioned opinion of the Advisory Committee for Nuclear Pressure Equipment of 1 October 2015;

Whereas the manufacturer supplemented its demonstration approach by the above-mentioned technical report of 20 May 2016; ASN submitted additional requests in the above-mentioned letter of 26 September 2016, notably in the light of the above-mentioned report of 17 June 2016 and the above-mentioned observations of the Advisory Committee for Nuclear Pressure Equipment of 7 July 2016;

Whereas the above-mentioned manufacturer's technical file of 16 December 2016 concludes that the anomaly does not compromise the serviceability of the Flamanville EPR reactor pressure vessel bottom head and closure head; the manufacturer conducted an assessment demonstrating that the properties of the material preclude the risk of fast fracture of these components;

Whereas this assessment is based on the evaluation of three parameters: the dimensions, orientation and position of any flaws, such as cracks, the mechanical properties of the steel comprising excess carbon and the thermomechanical loads resulting from temperature and pressure changes during normal and accident operation of the reactor;

Whereas, with regard to any flaws, the manufacturer demonstrated that the manufacturing process used was not such as to create flaws prejudicial to the quality of the parts; it also carried out non-destructive surface and volume inspections to detect the flaws present in the reactor pressure vessel bottom head and closure head and these inspections did not reveal any flaw larger than the detection limit; ASN asked an independent body to monitor the performance of these non-destructive inspections;

Whereas, with regard to the mechanical properties of the material, the manufacturer carried out a programme of chemical analyses and mechanical tests on components manufactured in the same conditions as those of the Flamanville EPR reactor pressure vessel and demonstrated that these components are representative of those of Flamanville; this programme enabled the mechanical properties of the steel to be evaluated in the residual carbon positive macrosegregation zone; ASN asked independent organisations to monitor the performance of the programme and ensured that this was carried out primarily by laboratories independent from the Areva group; ASN carried out inspections in two laboratories of the Areva group which took part in implementing this programme;

Whereas, with respect to the thermal-mechanical loadings, all the situations which could stress the bottom head and closure head of the reactor pressure vessel were identified and characterised; the manufacturer met its commitments as stated in the above-mentioned letter of 6 June 2017, more particularly with regard to the mechanical loads on the closure head in the rod ejection situation;

Whereas, despite the impact strength characteristics of the material being locally lower than those of the design, the toughness properties are sufficient to preclude the risk of fast fracture of the reactor pressure vessel bottom head and closure head, with the required safety margins, taking account of the worst-case flaw;

Whereas the Flamanville EPR reactor pressure vessel bottom head and closure head were partly manufactured by Creusot Forge; irregularities were detected in this plant; at the request of ASN the manufacturer repeated certain non-destructive mechanical tests and volume inspections carried

out at the time of manufacturing; ASN asked independent organisations to monitor their performance; these new tests and inspections, the results of which are satisfactory and consistent with those of the original test, provide additional guarantees regarding the quality of the parts concerned;

Whereas the technical file concerning the anomaly in the chemical composition of the steel in the Flamanville EPR reactor pressure vessel bottom head and closure head was examined by ASN and the Institute for Radiation Protection and Nuclear Safety, whose conclusions are presented in the above-mentioned report of 15 June 2017 and is the subject of the above-mentioned opinion of the Advisory committee for nuclear pressure equipment of 27 June 2017; in particular, as part of the analysis of the mechanical strength of the material, the IRSN carried out its own calculations, which do not call into question the results presented by the manufacturer;

Whereas Framatome demonstrated that all the heterogeneity risks identified for the Flamanville EPR reactor pressure vessel domes, other than the risk related to carbon residual positive macrosegregations, were managed;

Whereas all of these elements indicate that the risks are sufficiently prevented and mitigated;

Whereas, moreover, the APAVE company, mandated by ASN, assessed the conformity of the Flamanville EPR reactor pressure vessel as an approved organisation mentioned in article L. 557-31 of the Environment Code;

Whereas the above-mentioned Framatome request is accompanied by the APAVE report reference 31222257/1 N°152 of 12 July 2018 which concludes that, for the scope of assessment entrusted to it by ASN, the Flamanville EPR reactor pressure vessel is in conformity with the essential safety requirements of the above-mentioned Order of 30 December 2015, according to the technical baseline requirements accepted by ASN in the above-mentioned resolutions of 7 December 2016 and 3 July 2018;

Whereas the assessment of compliance with the technical qualification requirement, carried out in accordance with the technical baseline requirements accepted by ASN in the above-mentioned resolutions of 7 December 2016 and 3 July 2018, demonstrated that the components of the Flamanville EPR reactor pressure vessel, other than the bottom head and closure head domes, are in conformity with the above-mentioned Order of 30 December 2015;

Whereas the assessment of compliance with the requirements, other than those of the technical qualification and of consideration of the state of progress of technology and practices at the time of design and manufacture, carried out in accordance with the technical baseline requirements accepted by ASN in the above-mentioned resolutions of 7 December and 3 July, demonstrated that the Flamanville EPR reactor pressure vessel is in conformity with the above-mentioned provisions of articles L. 557-4, L. 557-5, chapter VII of title V of book V of the regulatory part of the Environment Code and the Order of 30 December 2015;

Whereas, in the above-mentioned request letter of 13 July 2018, the manufacturer presents elements demonstrating that operations to restore the conformity of the Flamanville EPR reactor pressure vessel, its bottom head in particular, by means of repairs or replacement of the components concerned cannot be reasonably envisaged; a particular difficulty, as defined in article 9 of the above-mentioned Order of 30 December 2015, is thus characterised;

Whereas all of these elements confirm that Framatome's above-mentioned request is duly justified;

Whereas the nuclear safety case for PWR reactors precludes vessel fracture on the basis of particularly demanding design, manufacturing and in-service monitoring provisions;

Whereas the serviceability of the Flamanville EPR reactor pressure vessel bottom head and closure head is based on demonstrating the preclusion of the risk of fast fracture based on the above-mentioned three parameters; it is essential throughout the operating life of the reactor to ensure that these parameters remain within the scope of the demonstration; pursuant to article 12 of the above-mentioned Order of 10 November 1999, it is necessary to check that the impact of thermal ageing on the mechanical properties of the steel in the carbon residual positive macrosegregation zone remains within the hypotheses adopted in the design and to guarantee that no flaws appear;

Whereas the licensee must then implement a programme to monitor the thermal ageing of test specimens taken from the carbon residual positive macrosegregation zone of components representative of the Flamanville EPR reactor pressure vessel domes;

Whereas the licensee should also implement additional periodic inspections to ensure that no flaws appear;

Whereas it is possible to carry out such inspections on the vessel bottom head and they must therefore be implemented;

Whereas, however, the technical feasibility of similar inspections on the pressure vessel closure head cannot be confirmed and, given the current state of knowledge, the closure head must therefore only be used for a limited period of time;

Whereas replacement of the closure head is technically feasible; the manufacture of a replacement closure head has begun and this closure head could thus be available by the end of 2024;

Whereas no mechanism has been identified that could lead to the rapid creation or propagation of a flaw during operation of the reactor, it is therefore acceptable that no inspection be performed before the end of 2024 and that consequently the use of the vessel closure head until this time is acceptable from the nuclear safety standpoint,

### **Hereby issues the following resolution:**

#### **Article 1**

Pursuant to article 9 of the above-mentioned Order of 30 December 2015, the reactor vessel intended for BNI 167 may be commissioned and operated. The use of the existing closure head for this pressure vessel is not however authorised beyond 31 December 2024.

#### **Article 2**

Pursuant to article 12 of the above-mentioned Order of 10 November 1999, EDF carries out a thermal ageing monitoring programme so that data representative of the end of the reactor's service life can be obtained in advance for the mechanical properties of the steel in the carbon residual positive macrosegregation zone subjected to thermal ageing. EDF transmits the first results of the ASN programme before the second complete requalification of the reactor's main primary system.

### Article 3

EDF carries out in-service inspections capable of detecting flaws perpendicular to the skins, regardless of their orientation, in the first 20 millimetres starting from the inner and outer surfaces of the base metal, on the Flamanville EPR reactor pressure vessel bottom head at each complete requalification of the main primary system.

### Article 4

The ASN Director General is tasked with implementation of this resolution, which will be published in the ASN Official Bulletin.

Signed in Montrouge on 9 October 2018,

The ASN Commission\*,

*Signed by*

Pierre-Franck CHEVET

Sylvie CADET-MERCIER

Philippe CHAUMET-RIFFAUD

Lydie EVRARD

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\* Commissioners attending the session