ASN opinion 2017-AV-XXX of XXX concerning the anomaly in the composition of the steel used for the Flamanville NPP EPR reactor pressure vessel lower head and closure head (BNI 167)

ASN (Autorité de Sûreté Nucléaire – French Nuclear Safety Authority),

Having regard to the Environment Code, in particular its articles L. 557-4 to L. 557-6 and R. 557-1-3;

Having regard to the order of 10th 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;

Having regard to the order of 30th December 2015 relative to nuclear pressure equipment, more specifically its article 9 and its appendix I;

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 14th December 2015 concerning its position on the approach used to demonstrate the adequate toughness of the Flamanville 3 EPR vessel lower head and vessel closure head domes;

Having regard to the report from ASN and the Institute for Radiation Protection and Nuclear Safety, reference CODEP-DEP-2016-019209 – IRSN/2016-00005 of 17th 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 lower head and closure head domes;

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

Having regard to the ASN and IRSN report reference CODEP-DEP-2017-019368 - IRSN/2017-00011 of 15th 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 technical report from the manufacturer of the Flamanville EPR reactor pressure vessel, Areva NP, reference D02-PEEM-F-15-0368, revision B of 31st July 2015 concerning the demonstration approach used for the Flamanville EPR reactor pressure vessel closure head and lower head;

Having regard to the Areva NP technical report, reference D02-PEEM-F-16-0260, revision A of 20th 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 16th December 2016, and then subsequently updated, more specifically the technical report reference D02-ARV-01-104-503, revision B of 27th April 2017 concerning the demonstration of the adequate toughness of the Flamanville EPR reactor pressure vessel lower 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 6th June 2017;

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

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

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

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

Having regard to the opinion of the French High Council for Technological Risk Prevention, dated XXX;

Having regard to the Areva NP observations transmitted by letter reference XXX of XXX;

Having regard to the EDF observations transmitted by letter reference XXX of XXX;

Having regard to the results of the public consultation organised from XXX to XXX;

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

Whereas the tests performed for technical qualification of the Flamanville EPR reactor pressure vessel lower 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 Areva NP;

Whereas the risk of heterogeneity due to residual positive carbon macrosegregations, a known metallurgical phenomenon, was inadequately assessed and its consequences inadequately quantified by Areva NP, 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 30th December 2015 is therefore not met; whereas Areva NP failed to take sufficient account of the state of progress of technology and practices at the time of design and manufacture;

Whereas Areva NP envisages sending ASN an application for authorisation to commission and utilise the Flamanville EPR reactor pressure vessel pursuant to article 9 of the above-mentioned order of 30th December 2015 and requested the opinion of ASN on its demonstration approach;

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

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

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

Whereas the above-mentioned Areva NP technical file of 16th December 2016 concludes that the anomaly does not compromise the serviceability of the Flamanville EPR reactor pressure vessel lower head and closure head; whereas Areva NP 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, Areva NP demonstrated that the manufacturing process used was not such as to create flaws prejudicial to the quality of the parts; whereas it also carried out non-destructive surface and volume inspections to detect the flaws present in the reactor pressure vessel lower head and closure head and these inspections did not reveal any flaw larger than the detection limit; whereas ASN asked an independent body to monitor the performance of these non-destructive inspections;

Whereas, with regard to the mechanical properties of the material, Areva NP 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; whereas this programme enabled the mechanical properties of the steel to be evaluated in the residual carbon positive macrosegregation zone; whereas ASN mandated independent organisations to monitor the performance of the programme and ensured that this was carried out primarily by laboratories independent from the Areva group;

Whereas, with respect to the thermal-mechanical loadings, all the situations which could stress the lower head and closure head of the reactor pressure vessel were identified and characterised; whereas Areva NP must however confirm the mechanical loads on the closure head in the rod ejection situation;

Whereas, despite the mechanical characteristics of the material being lower than those of the design, they are sufficient to preclude the risk of fast fracture of the reactor pressure vessel lower head and closure head, with the required safety margins, taking account of the potential worst case flaw;

Whereas the Flamanville EPR reactor pressure vessel lower head and closure head were partly manufactured by Creusot Forge; whereas irregularities were detected in this plant; whereas – at the request of ASN - Areva NP repeated certain non-destructive mechanical tests and volume inspections carried out at the time of manufacturing; whereas ASN asked independent organisations to monitor their performance; whereas these new tests and inspections, the results of which are satisfactory and consistent with those of the original test, provide complementary guarantees regarding the quality of the parts concerned;

Whereas this technical file was the subject of a review by ASN and the Institute for Radiation Protection and Nuclear Safety, the conclusions of which are presented in the above-mentioned report of 15th June 2017 and the above-mentioned opinion of the Advisory Committee for nuclear pressure equipment of 27th June 2017;

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 lower head and closure head is based on a demonstration of the preclusion of the risk of fast fracture, based on the three parameters mentioned above; whereas it is essential throughout the operating life of the reactor to ensure that these parameters remain consistent with the demonstration and more specifically to guarantee that no flaws appear;

Whereas the licensee is required to immediately implement complementary periodic inspections to ensure that no flaws appear;

Whereas it is possible to carry out such inspections on the vessel lower 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 the closure head must therefore only be used be for a limited period of time;

Whereas the manufacture of a new closure head would take about seven years and a new closure head could therefore 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 reactors, whereas 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,

Issues the following opinion:

The anomaly in the carbon composition of the steel used for the lower head and closure head of the Flamanville EPR reactor pressure vessel is not liable to compromise its serviceability, subject to the following conditions.

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 shall be carried out on the Flamanville EPR reactor pressure vessel lower head at each complete requalification of the main primary system.

Use of the Flamanville EPR reactor pressure vessel closure head may not be authorised beyond 31st December 2024.

The undertakings by Areva NP and EDF, expressed in the above-mentioned letters of 6th and 9th June, more specifically with regard to the programme of thermal ageing monitoring tests and the inspections carried out during operation of the reactor, shall be incorporated into the authorisation application stipulated in article 9 of the order of 30th December 2015.

In this authorisation application, Areva NP shall confirm the mechanical loadings on the closure head in the rod ejection situation.

Signed in Montrouge on XXX,

The ASN Commission,