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01	Integration of technical and co-applicant comments	30.04.2008
02	PCSR June 2009 update including: - Text clarifications - Inclusion of references - Technical update with cross referencing to Sub-chapter 5.2 for Break Preclusion elements.	29-06-2009
03	Consolidated Step 4 PCSR update: - Minor editorial changes - Clarification of text - Addition of text defining the main steam lines as High Integrity Components (HIC) - Addition of references	30-03-2011
04	Consolidated PCSR update: - References listed under each numbered section or sub-section heading numbered [Ref-1], [Ref-2], [Ref-3], etc - Minor editorial changes (§1.2, References) - Clarification of text (§1.1, §1.2.2)	27-07-2012
05	Consolidated PCSR update: - Title of sub-chapter changed - Removal of cross-references to Sub-chapter 13.2 and text updated to clarify application of “break preclusion” and HIC (§0, §1, §2.1.2)	31-10-2012

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SUB-CHAPTER 10.5 – INTEGRITY OF THE MAIN STEAM LINES INSIDE AND OUTSIDE THE CONTAINMENT

0. SAFETY REQUIREMENTS

The main steam lines are High Integrity Components and belong to the break preclusion category. For this HIC piping, the specific measures described in Sub-chapter 3.4 section 0.3 that demonstrate the integrity of HIC are detailed in section 1.

Many of requirements relating to the demonstration of break preclusion are common to those described for the reactor coolant system (RCP [RCS]) in Sub-chapter 5.2. The common aspects of the break preclusion principle have been cross-referenced to Sub-chapter 5.2 where appropriate.

1. REQUIREMENTS RELATING TO THE DEMONSTRATION OF BREAK PRECLUSION

The requirements relating to the demonstration of break preclusion of the main steam lines (VVP [MSSS]) inside and outside the containment are equivalent to the requirements described in Sub-chapter 5.2 for break preclusion of the reactor coolant system (RCP [RCS]) pipework.

Implementation of the break preclusion concept allows a guillotine break of a VVP [MSSS] line to be excluded from the design basis.

An overview of the break preclusion assumption is illustrated in Sub-chapter 10.5 - Table 1 for the aspects specific to the VVP [MSSS] inside and outside the containment.

1.1. AREA OF APPLICATION OF BREAK PRECLUSION [REF-1] [REF-2]

The break preclusion concept applies to the 30" sections of the safety-classified steam lines. The limits of application of the break preclusion concept are the SG nozzles and the fixed points located downstream of the steam isolation valves (VIV [MSIV]).

The break preclusion concept is not implemented on the pipework connected to the 30" steam lines. Inside the reactor building, no pipework is connected to the 30" lines, except small bore instrumentation and venting lines. Outside the reactor building, the break preclusion concept is not applied to the steam isolation bypass lines.

Outside the reactor building, the valves (isolation valve of the VDA [MSRT] and the safety relief valves) of the three largest lines connected to the 30" VVP [MSSS] pipe are directly welded to the 30" extruded ends of the VVP [MSSS]. The break preclusion concept is also applied to these connection welds.

1.2. PREVENTIVE MEASURES

The preventive measures taken under the first level of defence-in-depth are equivalent to those taken for the RCP [RCS] as described in Sub-chapter 5.2.

1.2.1. Prevention of general damage

The measures to prevent general damage taken under the first level of defence-in-depth are equivalent to those taken for the RCP [RCS] as described in Sub-chapter 5.2.

Materials properties

The VVP [MSSS] lines are made of carbon steel grade P355NH. The steam generator nozzles are made of a low alloy steel (18MND5 or 20MND5 type) and the valves are made of a low alloy steel (C-Mn type) [Ref-1] [Ref-2].

There is a high quality of material properties, particularly toughness, and conservative stress thresholds.

Materials used are optimal, such as C-Mn steel, with moderate strength and high ductility, and with tight tolerances on material composition.

Concerning manufacturing processes, high quality of components is achieved by using forged connections and extruded branch nozzles.

The values of the mechanical properties used in the analyses will have to be validated for 60 years of plant operation (thermal ageing).

Design basis

The design basis aspects aimed at preventing general damage under the first level of defence-in-depth are equivalent to those taken for the RCP [RCS] as described in Sub-chapter 5.2, with the addition of the following.

Corrosion-erosion is avoided through adequate design, the maintenance of stable system conditions and suitable materials: choice of adequate materials; achievement of very low steam moisture contents; ensuring steam velocities are in the same range as those on existing units; functional design of pipework and valves. Concerning the material, a further precaution is taken by specifying a minimum chromium content of 0.15% [Ref-1] [Ref-2].

Corrosion is not significant with the materials used and the chemical composition of the water used.

Loads

The loading aspects aimed at preventing general damage under the first level of defence-in-depth are equivalent to those taken for the RCP [RCS] as described in Sub-chapter 5.2. In addition the following specific measures are applied to the Main Steam Lines:

The thermal transients specified during the design are confirmed during plant operation. The actual transients seen by the plant are considered to be relatively mild in comparison, based on actual operating experience.

Loads due to external events are examined in detail when calculating the stresses.

1.2.2. Prevention of local damage

Potential manufacturing defects

The measures taken to prevent manufacturing defects are equivalent to those taken for the RCP [RCS], as described in section 3 of Sub-chapter 5.2. The following additional measures are taken for welding operations of the VVP [MSSS] lines:

The significant reduction of the number of welds: the pipes are preferably fabricated from spools made of optimised materials and bent with induction heating. Seamless elbows, with extended straight ends, are used when necessary. There is no longitudinal weld in the pipework.

For pipework components, the use of seamless pipes, bends and special components fulfils the requirements of NDT. Machining of the external and internal surfaces of the pipework, as far as practicable, ensures optimal weld inspection. All the welds may potentially be inspected, which enables early detection of potential defect.

The welds are stress relieved by heat treatment in all break preclusion areas.

- The use of fine grain structural steel for the pipework components meets code requirements and is easily handled for the welds. The bodies of the steam isolation valves (VIV [MSIV]) are made of high purity C-Mn steel. There is extensive successful experience in the forging and welding of all of the materials chosen.

Extended straight ends also separate the body of penetrations from the pipe welds. Extruded branch nozzles separate the connected lines welds from the nozzle region. The use of these components leads to circumferential welds being located outside areas of high stress.

Initiation of potential defects in operation

Defects can be initiated during operation either through fatigue or corrosion induced cracking.

Damage from cumulative fatigue and from progressive deformation is examined in the component’s stress analysis records. Stress analysis records enable areas that are sensitive to such damage to be identified. In pressurised areas, for example, fatigue analysis must be carried out in three stages, namely analysis of the cracks initiation, crack propagation up to critical size and analysis of unstable cracks.

An area is considered to be affected by the risk of cracking through fatigue or progressive deformation when:

- The usage factor is greater than 1
- The initiating factor is greater than 1
- The progressive deformation criterion is exceeded.

Protection from fatigue damage is provided by a set of precautions taken:

- The thermal transients specified during the design are confirmed during plant operation. The actual transients seen by the plant are considered to be relatively mild in comparison, based on actual operating experience.
- The avoidance of stratification effects in the VVP [MSSS] lines.

- The effects of vibrations are negligible for the VVP [MSSS] lines.

Corrosion is not significant with the materials used and the chemical composition of the water used.

Loads

The loading aspects aimed at preventing local damage under the first level of defence-in-depth are equivalent to those taken for the RCP [RCS] as described in Sub-chapter 5.2.

Properties of materials

The materials selected have high toughness properties, giving excellent resistance to fast fracture risks throughout plant life. To ensure a satisfactory toughness level, a value of impact strength at the plateau of the resistance curve $J(\Delta a)$ of greater than or equal to 100 Joules is retained as a target.

It is confirmed that no significant transient occurs at a temperature that can lead to a cleavage fracture; this is straightforward as there is no transient load in the VVP [MSSS] lines at low temperature. The risk of brittle fracture is thus excluded for the VVP [MSSS] lines.

The materials selected and the welds are highly ductile at operating temperatures and have a ductile failure mode.

Risks of indirect damage

This involves, for example, the risk due to objects falling on the VVP [MSSS] piping, risks due to pipe break in earthquake conditions, risks due to guillotine pipe break in case of components to which break preclusion is not applied. Measures are taken to prevent a VVP [MSSS] line from being damaged by the postulated failure of other pipework.

1.3. SURVEILLANCE MEASURES

The surveillance measures undertaken as part of the second line of defence-in-depth are equivalent to those described in Sub-chapter 5.2 for the RCP [RCS].

1.3.1. Operational surveillance

A system for monitoring transients will be implemented with a recommended practice identical to the current practice on operating plants in France and Germany for the primary system loops.

This is a three-stage process:

- The temperature, pressure and flow values are monitored in order to evaluate the various types of stress for all of the normal, upset and emergency transients.

- Each relevant measured transient is compared with a design transient on the basis of mechanical consequences (fatigue damage) to the components.

- The number of events must remain below the number specified in the design. A deviation from the design transients list would have to be assessed in terms of consequent stresses and fatigue.

Feedwater chemistry is monitored to avoid fouling of the heat transfer surfaces, fatigue and corrosion problems such as widespread corrosion or aggravated corrosion-erosion by feedwater flow, particularly in the SG and the steam lines (see section 2 of Sub-chapter 5.4).

1.3.2. In-service inspection

The in-service inspection programme undertaken as part of the second line of defence-in-depth is equivalent to those described in Sub-chapter 5.2 for the RCP [RCS], with the addition of the following for the VVP [MSSS] lines.

All of the areas specified in the in-service inspection programme will have been examined at the latest in the pre-service inspection, with the same NDT techniques as while operating, so as to define an end of manufacturing quality reference point.

The in-service inspection programme considers all design improvements so as to minimise the exposure of staff to radiation while carrying out NDT or preparatory or peripheral work.

The in-service inspection programme is likely to increase if events occur during the lifetime of the unit which were unforeseen at the design stage or if new forms of damage, considered as precursors for the EPR unit, were to be discovered on units currently being operated.

A selection of non-sensitive welds will be included in the in-service inspection programme as part of defence in depth.

<u>Implementation of in-service inspection and Break Preclusion</u>

A number of in-service inspection and visual inspection requirements are given below:

- Scope of In-service inspection: following assembly, an initial hydraulic test (see code RCC-M Section B 5000) of the system as well as an initial complete system check will be carried out so as to establish a reference. Inspection of selected representative welds will be carried out every ten years.
- The design and installation of the pipework system must ensure that the in-service NDT on the circumferential welds can be easily carried out.
- If examination techniques to be used for the in-service inspection differ from those used during the manufacturing inspection, an initial inspection will take place prior to first start-up using the techniques which will be subsequently applied during in-service inspection. The Authorised Inspection Agency must have received confirmation that these techniques can provide appropriate results.

2. REQUIREMENTS RELATING TO FURTHER LEVELS OF DEFENCE-IN-DEPTH

The two further lines of defence-in-depth are equivalent to those described in Sub-chapter 5.2 for the RCP [RCS], with the additional requirements for the VVP [MSSS] lines.

2.1. FIRST FURTHER LINE OF DEFENCE-IN-DEPTH

The requirements for the first further line of defence-in-depth are equivalent to those described in Sub-chapter 5.2.

2.1.1. Tolerance to large through-wall defects

The demonstration of tolerance to through-wall thickness defects is as described in Sub-chapter 5.2.

2.1.2. Leak detection

Leak detection function requirements

The leak detection function requirements' first further line of defence-in-depth are equivalent to those described in Sub-chapter 5.2.

2.2. SECOND FURTHER LINE OF DEFENCE

2.2.1. PCC-4 events

Integrity assessments are carried out on the basis of loads exerted by a postulated rupture on the VVP [MSSS] lines downstream of the main steam isolation valves or a rupture on the ARE [MFWS] lines.

The safety objective is to show that the controlled state and then the safe shutdown state can be reached. From a technical perspective this means that:

- The initial rupture does not cause the break preclusion areas or VIV [MSIV] to fail.
- The integrity of the SG and SG pipework is verified (level D criterion).

The break preclusion area of the VVP [MSSS], its components and their supports as well as the SG (including SG tubes) are capable of withstanding the loads due to the decompression wave created by a VVP [MSSS] rupture downstream of the main steam isolation valves (outside of the BP area), assuming a single failure (SF) of a VIV [MSIV]. The assessment also supplies data for the containment analysis. The SG tubes are also designed to withstand the total differential pressure between the primary system and an empty, depressurised SG. There is no damage propagation to the primary system or the break preclusion areas.

2.2.2. Additional technical provisions for the VVP [MSSS]

The stability of the SG is confirmed for a conventional static load of 2.p.A (p is the operating pressure and A is the pipe cross-section).

In addition, double-ended breaks (2A) are postulated on the VVP [MSSS] lines, to supply basic data for containment analysis (pressure and temperature rises) and the qualification of equipment for the pressure, temperature and humidity conditions following the accident, if these are not bounded by the conditions resulting from postulated double-ended breaks on the primary loops.

Concerning the over-cooling transient, no additional measures are required as the consideration of a VVP [MSSS] rupture downstream of the VIV [MSIV], with the SF on this valve and the pure steam discharge assumption, leads to the bounding over-cooling transient.

Nevertheless, despite implementation of the break preclusion concept, a double-ended break is postulated at the outlet point of the SG to provide a very pessimistic assessment of the core response. This combines the largest size steam break at the most unfavourable place with the application of the single failure criterion (SFC) as the worst stuck rod to produce the largest impact on reactivity.

Double-ended breaks on one of the three largest nozzles of the extruded branch pipes on the VVP [MSSS] lines (welds upstream of the VDA [MSRT] isolation valve and safety relief valves) are considered, so as to provide defence in depth. The maximum dynamic responses to these postulated ruptures are used to quantify the beyond design basis rupture load, which is considered as an additional accident load. The integrity of the break preclusion area of the VVP [MSSS] and of the penetration of the reactor building under this loading is confirmed.

Sub-chapter 10.5 - Table 2 summarises these additional provisions, included despite the break preclusion concept, and the PCC-4 events considered as part of the demonstration of conformance to the break preclusion concept of the VVP [MSSS] lines.

SUB-CHAPTER 10.5 - TABLE 1

Break Preclusion Concept

Break Preclusion demonstration	Prevention	Prescribed limits on system operating conditions
		Design of components, choice of materials and manufacturing
		Quality control and quality assurance
		Tolerance to large defects (based on a conventional demonstration of fast fracture)
	Monitoring and Inspection	Recording of transients and monitoring of water chemistry
		In-service inspection programme
Defence in depth	Mitigation	Tolerance to large through-wall defects
		Detection of leaks (for pipework inside the containment)
	Risk reduction	Integrity of the SG and SG pipework verified for a VVP [MSSS] rupture outside the BP area
		Stability of SG Containment design (pressure and temperature) Qualification of equipment for accident conditions
		Integrity of VVP [MSSS] lines and Reactor Building penetrations for postulated double-ended breaks on the nozzles of BP branch pipes

SUB-CHAPTER 10.5 - TABLE 2

Hypothetical Design Conditions assumed in the Context of Claiming Break Preclusion on the Steam Lines

	Effects on	Effects caused by	Postulated ruptures
Additional provisions despite Break Preclusion	SG supports	2pA static force at the nozzles level	Equivalent to a 2A break of a Main Steam Line
	Reactor Building containment	Rise in pressure Temperature	VVP [MSSS] 2A break if it is not covered by a 2A break of the primary coolant loops
	Qualification of equipment inside the Reactor Building in accident conditions	Pressure Temperature Humidity	VVP [MSSS] 2A break if it is not covered by a 2A break of the primary coolant loops
	Reactivity behaviour	Over-cooling transient	VVP [MSSS] guillotine break at the SG outlet point (SFC on stuck rod)
	Qualification of equipment (steam isolation valve) outside the Reactor Building in the environment	Pressure Temperature Humidity	2A break of the BP lines connected to the VVP [MSSS]
PCC-4 events	SG, including SG tubes and VVP [MSSS] BP areas	Dynamic effects of decompression	Guillotine break on non-BP areas
	SG tubes	Differential pressure between the primary system and the depressurised SG	VVP [MSSS] break downstream of the main steam isolation valve (SFC on main steam isolation valve)
	Reactor Building containment and internal structures	Differential pressure Temperature Flooding	Guillotine break of any other line connected to the SG (ARE [MFWS] or ASG [EFWS], for example)
	Reactivity behaviour	Over-cooling transient	VVP [MSSS] break downstream of the main steam isolation valve with pure steam blowdown (SFC on main steam isolation valve)
	Qualification of equipment outside the Reactor Building in the environment (steam isolation valve, etc.)	Pressure Temperature Humidity	2A opening of non-BP lines connected to the VVP [MSSS] (steam isolation valve bypass lines)

SUB-CHAPTER 10.5 – 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.

1. REQUIREMENTS RELATING TO THE DEMONSTRATION OF BREAK PRECLUSION

1.1. AREA OF APPLICATION OF BREAK PRECLUSION

[Ref-1] Application of the break preclusion assumption in the main reactor coolant and steam lines of the EPR FA3. ECEMA040920 Revision C1. EDF. (E)

[Ref-2] Break Preclusion in reactor main coolant lines and main steam lines. Positioning of the concept and associated safety requirements. ENSNDR080245 Revision A. EDF. (E)

1.2. PREVENTIVE MEASURES

1.2.1. Prevention of general damage

[Ref-1] Lepeytre. Specification for procurement of seamless P355NH steel pipes of Q1 level – Main VVP [MSSS] and ARE [MFWS] lines.
NESP-F DC 74 Revision D. AREVA. May 2008. (E)

[Ref-2] Lepeytre. Specification for procurement of P355NH steel elbows and fittings (forged or die formed) of Q1 level – Main VVP [MSSS] and ARE [MFWS] lines.
NESP-F DC 75 Revision D. AREVA. May 2008. (E)