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REVISION HISTORY

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00	First issue for INSA information	11-12-2007
01	Integration of technical and co-applicant review comments	25-04-2008
02	PCSR June 2009 update: - clarification of text - inclusion of references - design evolutions to account for December 2008 design freeze (partial cooldown gradient, connection temperature for the RIS/RRA [SIS/RHRS], removal of activity measurements, connection of flow measurements to ARE …)	24-06-2009
03	Consolidated Step 4 PCSR update: - Minor editorial changes - Clarification of text - References updated or added - Addition of a new sections (§0.3.1.7 and §7) regarding the High Integrity Component (HIC) classification of the main coolant lines - Clarification regarding closure of main steam isolation valves (§2.6) - Addition of information covering the design requirement for accessibility and controllability of the welds (§3.6.1)	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 - Clarification of the scope of HIC to include the MSIV (§0.3.1.7)	30-08-2012

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REVISION HISTORY (Cont'd)

Issue	Description	Date
04 cont'd	Consolidated PCSR update: - Addition of new paragraphs and reference in section 6.1 to present the analyses performed to ensure the accessibility and inspectability for ISI - Clarification of the scope of HIC in the introduction to section 7 - Update of section 7.2 for NDT to be applied to the MSL pipework - New sub-sections 7.1.2 and 7.2.2 added covering the application of the HIC methodology and NDT to be applied to the MSIV - Update of section 7.3 to include verification of the lower bound fracture toughness values for the MSIV	
05	Consolidated PCSR update: - General comments at start of sub-chapter deleted and text moved to section 0 "Safety requirements" - Minor updates to text throughout to refer to HIC rather than break preclusion	31-10-2012

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SUB-CHAPTER 10.3 – MAIN STEAM SUPPLY SYSTEM - (SAFETY CLASSIFIED PARTS) [REF-1] TO [REF-5]

0. SAFETY REQUIREMENTS

Sections of the main steam lines (MSL) inside and outside the containment, up to the terminal fixed point from the containment, are HIC[1] (see Sub-chapter 10.5). Consequently, double-ended breaks of this pipework are not within the design basis of the VVP [MSSS].

All pressures referred to in this document are in bar absolute.

0.1. SAFETY FUNCTIONS

0.1.1. Reactivity control

The VVP [MSSS] must ensure control of reactivity by isolating the steam pipework to limit the cooling of the primary system in the event of excessive increase in the steam flow rate (PCC-2). Furthermore, the increase in reactivity following a non-isolable break on the steam lines must prevent any fuel damage (PCC-3 and PCC-4).

0.1.2. Decay Heat removal

- In normal operation, the VVP [MSSS] must remove decay heat by transferring steam to the condenser, from power operation to the connection of RIS/RRA [SIS/RHRS].
- In any PCC-2 to PCC-4 events, the VVP [MSSS] must remove decay heat by dumping steam into the atmosphere to allow safe shutdown to be reached (connection of RIS/RRA [SIS/RHRS]).
- Following a small or intermediate break LOCA or SGTR, the VVP [MSSS] must cool the primary circuit through the VDA [MSRT] (partial cooling), until the MHSI injection pressure is reached.
- In the event of a secondary break, the VVP [MSSS] system must limit cooling so that the brittle fracture temperature limit of the pressure vessel is not reached.
- In the event of RRC events, the VVP [MSSS] must remove decay heat by discharging steam into the condenser (if available) or into the atmosphere to allow progression to safe shutdown.

[1] *Although the MSL are designated as HIC for the UK EPR and the associated requirements are described in Sub-chapter 3.4, additional conservative risk reduction measures inherent to the break preclusion concept are described in Sub chapter 10.5)*

0.1.3. Containment of radioactive substances

In PCC-2 to PCC-4 and RRC events, the VVP [MSSS] must fulfil the following functions:

- contain the activity of the primary system in the event of SGTR (PCC-3 and PCC-4, and specific SGTR and MSLB studies, see Sub-chapters 14.4 and 14.5) by isolating the affected SG on the steam side,
- limit the containment pressure in the event of MSLB inside the containment (specific study),
- in the event of a primary break in the containment, VVP [MSSS] sections inside the reactor building act as an extension to the third containment barrier,
- ensure overpressure protection of the steam generator by discharging steam,
- contain activity by isolating the main steam line in event of low pressure core meltdown with damaged SG tubes (RRC-B).

0.2. FUNCTIONAL CRITERIA

0.2.1. Reactivity control

The steam lines up to the support, downstream of the isolation valve (VIV [MSIV]), are HIC (see Sub-chapter 10.5). Rupture of the main line as well as the main branch pipes (except for two extruded branch pipes of the steam isolation valve bypass line) is therefore excluded from the Design Basis.

As a conservative measure, in the event of steam pipework leak or rupture, the rapid closure of the steam line isolation VIV [MSIVs] must ensure that the damaged line is isolated to limit the cooling of the primary system to a level which ensures that fuel limits are not breached.

The VIV [MSIV] must terminate the flow of steam (even if two-phase) in normal or reverse flow direction (in the event of rupture upstream of a steam valve).

0.2.2. Removal of decay heat

The atmospheric discharge system (VDA [MSRT]) must remove decay heat, to ensure that the fuel temperature remains at an acceptable level and the primary circuit pressure remains below the design limits.

Decay heat removal must be achievable during PCC-2 to PCC-4 events even if off-site power is lost coincident with a single failure (failure to open a VDA [MSRT] line).

In the event of steam pipe rupture, closure of the VIV [MSIVs] must be fast enough to limit the cooling of the primary circuit so that the vessel brittle fracture conditions are not reached.

0.2.3. Containment of radioactive substances

In the event of rupture of steam pipework inside the containment, VIV [MSIV] closure must isolate the damaged line. Closure must be fast enough to limit the release of energy so that containment design limits are not exceeded.

In the event of reactor coolant pipe rupture (PCC-2 to PCC-4, those dealt with in RRC-A and in specific studies) steam lines inside the reactor building must remain intact so as not to provide a route for leakage from the containment.

The VVP [MSSS] contributes to the overpressure protection of the CSP [MSS] (see section 1 of Sub-chapter 3.4).

0.3. DESIGN-RELATED REQUIREMENTS

0.3.1. Safety classification requirements

0.3.1.1. Safety classification

The VVP [MSSS] shall be classified [Ref-1] as defined in Sub-chapter 3.2.

0.3.1.2. Single failure criterion (active and passive)

For components ensuring F1 functions, the single failure criterion is considered as an assumption to guarantee an adequate level of redundancy.

The single failure criterion therefore applies to VVP [MSSS], except for the mechanical closure part of the VIV [MSIVs] in the event of SGTR (however, the criterion applies to the pilot valves of these main valves).

0.3.1.3. Emergency power supply

Components with an F1 function must be backed-up by emergency power supply to ensure their functionality in the event of loss of off-site power.

0.3.1.4. Qualification for operating situations

VVP [MSSS] system components providing an F1 or F2 function shall be qualified to remain operational in normal and post-accident operating conditions (see Sub-chapter 3.6).

0.3.1.5. The classification of mechanical, electrical and Instrumentation and Control equipment

<u>Mechanical classification</u>

The mechanical classification requirements for the steam system are:

- RCC-M1 for the steam lines (main line and bypass line) from the steam generator to the support downstream of the isolation valves including the relief and safety valves.
- As defined in Sub-chapter 3.2 for the relief lines downstream of the relief and safety valves.

The electrical equipment and the control and instrumentation equipment are classified according to the rules in Sub-chapter 3.2. Furthermore, as the isolation valve oil pump is not required to perform F1 function, it is then classified NC.

0.3.1.6. Seismic classification

Parts of the VVP [MSSS] providing F1 functions shall be classified as seismic class 1 and are located in category 1 buildings.

The system must maintain its integrity, functional capacity and operability following a seismic event.

0.3.1.7. High Integrity Component classification

As stated in Sub-chapter 3.1, the Main Steam Lines from the Steam Generators up to the first terminal fixed points downstream of the steam isolation valves, including the pressure boundary parts of the Main Steam Isolation Valves (VIV [MSIV]), are High Integrity Components for which the specific measures, described in section 0.3.6 of Sub-chapter 3.4, concerning prevention, surveillance and mitigation contribute to their high integrity demonstration.

0.3.2. Regulatory requirements

0.3.2.1. Technical directives

The sections of the technical directives specific to the VVP [MSSS] are described in Sub-chapter 3.1.

0.3.3. Internal/external hazards

0.3.3.1. Internal hazards

VVP [MSSS] lines must be protected against internal hazards.

The VVP [MSSS] line main pipework inside the containment (between the SG outlet points and the containment penetration support) and outside the containment (between the containment penetration and the first support downstream of the steam isolation valve) are HIC, including the branch pipes of the three largest connected lines, namely, the VDA [MSRT] line to the isolation valve and the two branch pipes of the VVP [MSSS] safety valves. No break or hazard resulting from a break is considered within the design basis.

Nevertheless, as part of the defence in depth approach, the rupture of branch pipes located on the steam lines is taken into account in the design of the main steam lines.

The remaining VVP [MSSS] pipework and components, i.e. the smaller connected lines (namely the instrumentation piping, warm-up line, drain and vent lines), lines downstream of the safety valves, and the VIV [MSIV] actuator components (non pressure boundary part), are not HIC. These components must be protected against internal hazards as described in Sub-chapter 13.2.

0.3.3.2. External hazards

VVP [MSSS] lines are required to be protected against external events as described in Sub-chapter 13.1.

0.4. TESTS

0.4.1. Commissioning tests

Commissioning tests must demonstrate that the design and performance of the VVP [MSSS] system are satisfactory.

0.4.2. Periodic tests and in-service inspection

This system must be designed to allow periodic visual inspection of the main components, in particular to meet the requirements associated with HIC (see Sub-chapter 10.5).

1. ROLE OF THE SYSTEM

In addition to the safety functions outlined in section 0.1, the VVP [MSSS] is designed to ensure, during operation at power, a supply of steam to the turbine and the various other systems which require steam.

During operation the system must fulfil the following functions:

- transfer steam from the steam generators to the turbine,
- in certain test configurations, hot shutdown and low power, remove steam from the steam generators to the condenser when it is available,
- protect the steam generators against overpressure.

2. DESIGN BASIS

2.1. GENERAL ASSUMPTIONS FOR THE DESIGN OF THE SYSTEM

The VVP [MSSS] system has the following functions [Ref-1]:

- supply steam to the turbine and all the other systems demanding steam in the turbine hall during normal operation,
- manage primary/secondary imbalances which are not fully controlled by the control system via the GCT [MSB] bypass system, if available,
- remove decay heat to the GCT [MSB] during hot shutdown,
- remove decay heat to the GCT [MSB] during cooling for refuelling,
- allow periodic testing as far as possible without disrupting the operation of the plant,
- isolate the pre-heating line (isolation valve in closed fail-safe position) when operating at power, cooling and after the warm-up process during start-up,

- prevent an excessive rise in the steam flow rate due to spurious lift of the GCT [MSB],
- bring the primary circuit to RRA [RHRS] conditions after an incident, reduce steam flow rate following spurious opening of a VDA [MSRT] dump valve or a safety relief valve,
- cool the primary side and bring it to a pressure below 60 bar at a rate of 250ºC/h:
  - o following a small break LOCA by using the GCT [MSB] (if available),
  - o following an SGTR (one tube) during loss of off-site power through VDA [MSRT] valves.
- isolate the steam side of the SG in the event of a small MSLB, small non-isolatable ARE [MFWS] or ASG [EFWS] pipework rupture,
- contain activity by isolating the steam side in the event of an SGTR (one tube),
- cool the primary system at a rate of 250ºC/h until a SG pressure of 60 bar is reached[2] therefore allowing MHSI injection:
  - o following an intermediate break LOCA by using the GCT [MSB] (if available),
  - o following an SGTR (two tubes in one SG) under loss of off-site power supply conditions through VDA [MSRT] valves.
- maintain the primary and secondary side pressure level at a value which is below the RCC-M level C threshold in the event of an ATWS,
- isolate the steam side of the SG in event of coincident MSLB and SGTR,
- cool the primary system and bring it below 15 bar in the event of a small break LOCA with MHSI loss via the GCT [MSB] (if available).

2.2. FUNCTIONAL DESIGN ASPECTS

The VVP [MSSS] is composed of four identical, safety classified trains. Each train comprises:

- a steam isolation valve with a hydro-pneumatic actuator,
- two spring-loaded steam pressure safety relief valves,
- pipework between the steam generator flow limiter and the outlet point of the VVP [MSSS] compartments through the above mentioned valves,
- the safety classified valves (motorised) and the pipework of the pre-heating line,
- the safety classified valves on the condensate blowdown circuit,
- a connection with the associated VDA [MSRT] line.

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[2] The 60 bar value after partial cooling applies for the VDA [MSRT], 55 bar applies if partial cooling occurs through the GCT [MSB].

The safety classified parts of the lines are strictly segregated into four trains. In particular, the lines situated between the containment penetrations and the steam isolation valves are located in compartments which ensure segregation.

2.3. OTHER DESIGN FEATURES

The other design features are:

- the capacity of each safety relief valve is equal to 25% of steam production at full load at the design pressure;
- the pre-heating line must be used as an auxiliary device to depressurise the steam generators when a steam generator is isolated, particularly in events involving an inactive loop and unavailable VDA [MSRT] line, and is designed accordingly;
- there must be sufficient diversity between the VDA [MSRT] line and the safety relief valves;
- if all relief paths are opened, there is a total of 100% flow relief capacity (taking into account 1x discharge VDA [MSRT] line 50% of full capacity and 2x discharge VVP [MSSS] lines each 25% capacity) at SG design pressure of 100 bar, and the sizing of components are in accordance with overpressure protection studies (see section 1 of Sub-chapter 3.4);
- the design and fitting of VVP [MSSS] valves, including their regulation devices and support systems, must be such that requirements regarding periodic testing, preventive maintenance (only possible on the pilot valves during at power operations), repair and inspection are met;
- with regard to at power operation, the main steam system must be designed in accordance with the load curve of the plant, which determines the behaviour of the plant under load conditions;
- main steam pipework, including valves, must be designed to withstand the hydrostatic water pressures required for pressure testing;
- main steam pipework, including valves, must be designed to withstand dynamic loads resulting from overfeeding the SG with sub-cooled feedwater.

2.4. STEAM CONDITIONS

- PCC-1:
  - the fluid transported by the main steam line is saturated steam,
  - the mass flow of the VVP [MSSS] per train at full power is 638.1 kg/s,
  - the pressure of the main steam complies with the load diagram,
  - the flow velocity of the steam in the main steam line is 40 - 50 m/s.

- PCC-2:
    - the fluid transported by the main steam line is saturated steam,
- PCC-3:
    - the fluid transported by the main steam line is saturated steam or a steam/water mixture.
- PCC-4:
    - the fluid transported by the main steam line is saturated steam or a steam/water mixture.
- RRC-A:
    - the fluid transported by the main steam line is saturated steam or a steam/water mixture or water.
- External events:
    - the fluid transported by the main steam line is saturated steam or a steam/water mixture.
- 2A-MSLB:
    - the fluid transported by the main steam line is saturated steam.

Notes on steam conditions

- saturated steam during normal operation;
- a water/steam mixture results from vaporisation of the steam generator inventory when the steam pipework ruptures;
- overfeeding of the steam generator leads to water flow rather than steam.

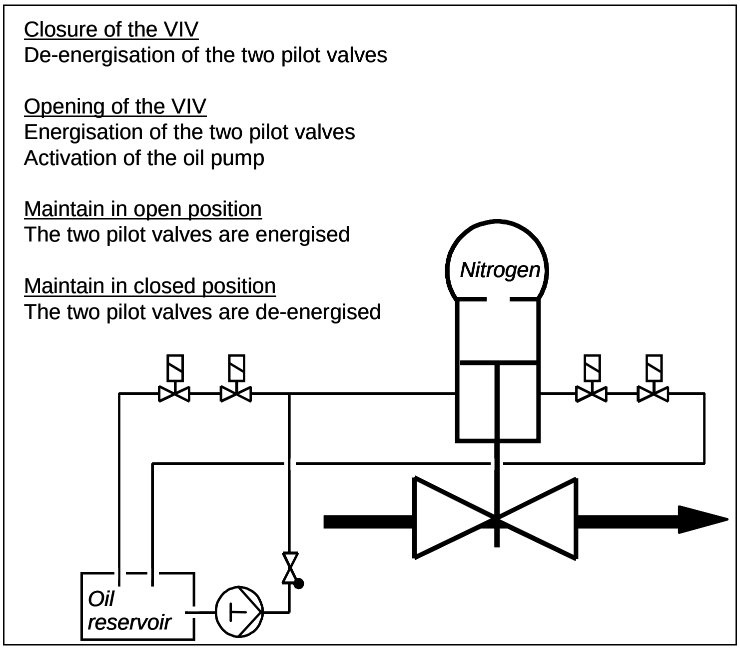
2.5. FLOW DIAGRAMS

The VVP [MSSS] (safety classified part) is composed of four identical trains. The simplified flow diagram [Ref-1] of train 1 is given as an example in Sub-chapter 10.3 - Figure 1.

2.6. DESCRIPTION OF THE MAIN COMPONENTS

Main steam isolation valve (VIV [MSIV]) [Ref-1]

The VIV [MSIV] is welded on a straight part of the main steam pipe between the containment penetration and its downstream support. It is a hydro-pneumatic valve controlled by four fail-open pilot solenoid valves. They are placed in pairs, in series, on each of the two redundant control lines. This layout prevents the failure of a pilot solenoid valve from spuriously closing the VIV [MSIV] (two pilot valves in series) or creating a failure to close fault (two redundant control lines) on the VIV [MSIV]. Closure of the VIV [MSIV] is triggered by opening the solenoid pilot valves, which is achieved by de-energisation.



Safety Relief valve [Ref-1]

The two safety relief valves are globe valves. Each safety relief valve is welded on the length of the main steam line, between the containment penetration and the main steam isolation valves (VIV [MSIV]).

Pre-heating line

The pre-heating line has a motorised isolation valve and a motorised control valve.

Blowdown line

The blowdown lines are fitted upstream of the main steam isolation valve and are equipped with a drain pot and two valves each driven by an electric motor.

3. OPERATING CONDITIONS

3.1. GENERAL DESCRIPTION OF THE SYSTEM

Outside the outer containment, the safety classified part of the VVP [MSSS] is composed of four identical trains which are strictly segregated. Each train comprises (the position of the valves in normal operation is indicated in italics):

- one VIV [MSIV] with a hydro-pneumatic actuator (*open*),
- two relief valves (*closed*),
- a pre-heating line with a motorised control valve (*closed*) and a motorised isolation valve (*closed*) upstream of the control valve,
- the associated pipework comprising the blowdown and venting lines within the system boundaries.

The VDA [MSRT] connection and two relief valves are arranged along the piping outside containment between the penetration and the VIV [MSIV].

The VVP [MSSS], segregated by train, are situated in the top part of two safeguard equipment buildings.

3.2. NORMAL OPERATING STATE OF THE SYSTEM

The normal operating state of the system corresponds to the ‘at power’ operation of the plant. The four trains of the VVP [MSSS] transport the steam produced in the steam generators to the turbine. The drainage collected in the lowest point of VVP [MSSS] is transported to the bleed system.

3.3. IDENTIFIED OPERATING STATES OF THE SYSTEM

3.3.1. PCC-1

Other than normal operation, the identified operating states of the VVP [MSSS] in PCC-1 conditions are hot and cold standby:

<u>Hot standby through the GCT [MSB]</u>

The reactor is shutdown and the four trains of the VVP [MSSS] are functioning and discharge the steam produced in the steam generators to the GCT [MSB] bypass system. Drains at the lowest point of the VVP [MSSS] connect to the non-active blowdown circuit.

This state is maintained by means of the GCT [MSB] controls.

Hot standby through the VDA [MSRT] (if the condenser is unavailable)

The reactor is shutdown and the four trains of the VVP [MSSS] discharge the steam produced in the steam generators to atmosphere. Drains at the lowest point of the VVP [MSSS] connect to the non-active blowdown circuit.

This state is maintained by means of the VDA [MSRT] controls.

Cold standby

The reactor is shutdown and the primary side is cooled, decay heat being removed through the RIS/RRA [SIS/RHRS]. It is necessary, at least when the primary system is still closed or can be rapidly closed, for two steam generators to remain available (namely, filled and ready to operate) to deal with the possible loss of the RRA [RHRS].

3.3.2. PCC-2 to PCC-4

Following PCC-2 to PCC-4 events, the operating state of the VVP [MSSS] is hot standby (following the automatic trip of the reactor and the turbine, the loss of the condenser or the loss of off-site power, for example). In the event of a small break LOCA (PCC-3), the operating state of the VVP [MSSS] corresponds to the pressure of the main steam after partial cooling. It is assumed that only the safety classified systems are available and therefore that the steam is removed through the VDA [MSRT] (although it can also be removed via the GCT [MSB], if the condenser is available). The state described in section 3.3.1 for 'Hot standby through the VDA [MSRT]' applies.

3.3.3. RRC-A and RRC-B

In RRC-A conditions, the operating state of the VVP [MSSS] is hot standby following reactor/ turbine trip. There may or may not have been a loss of power. All of the usable systems are assumed to be available and therefore the steam is removed through the GCT [MSB] (if available) or the VDA [MSRT]. The state described in section 3.3.1 for ‘Hot standby through the GCT' or 'Hot standby through the VDA [MSRT]’ applies.

3.4. TRANSIENT CONDITIONS OF THE SYSTEM

3.4.1. PCC-1

In PCC-1 conditions, the transients experienced by the VVP [MSSS] are start-up and shutdown operations and extended cycle operation. For the latter, the main function of the VVP [MSSS] is to modify the overpressure protection correspond to the plant state via a reduction the set point of the VDA [MSRT].

3.4.2. PCC-2 to PCC-4

The transient response of the VVP [MSSS] in PCC-2 to PCC-4 events which challenge the system is summarised below:

Excessive rise in the steam flow rate due to spurious lifting of the GCT [MSB]

In this case, the GCT [MSB] control valves and the series isolation valves are closed by the redundant protective devices. If this measure fails, the Reactor Protection System (RPR [PS]) (abnormal steam pressure reduction or low steam pressure) closes the steam isolation valves.

MSLB / FWLB

Following rupture of a steam pipe or rupture of a feedwater pipe, the reactor is tripped and the steam isolation valves are closed by the RPR [PS] (abnormal pressure reduction or low steam pressure).

If steam pipework rupture occurs downstream of the steam isolation valves, the rupture is isolated by automatic closure of the steam isolation valves.

Feedwater pipe rupture can only occur within the containment.

As a conservative measure, a steam pipework rupture within the containment upstream of the steam isolation valves is also postulated. The three unaffected steam generators are isolated from the rupture by automatic closure of all of the steam isolation valves. The feedwater side of the affected steam generator is then isolated to terminate steam production within the containment. Making the assumption of a break in the train 1, the fluid state is as follows:

- The fluid state for affected SG 1: containment ambient conditions.
- The fluid state for unaffected SG (2, 3, 4): P = 95.5 bar and T = 307°C

Small break LOCA and some Intermediate break LOCAs

The event is detected by the RPR [PS] through a Safety Injection (SI) signal which automatically controls the secondary side cooling to a rate of 250°C/h until a steam pressure of 60 bar is reached. Cooling is ensured by the GCT [MSB] or the VDA [MSRT] if the GCT [MSB] is unavailable (e.g. following a loss of off-site power). After reaching a steam line pressure of 60 bar, cooling is terminated automatically and pressure is maintained at this value. Cooling is subsequently manually controlled until the RRA [RHRS] can take over decay heat removal (see below).

Note: the pressure of 60 bar after a partial cooldown given in this section is valid for the VDA [MSRT] valves. If the partial cooldown is performed by mean of the GCT [MSB], the cooldown will stop when the pressure is 55 bar.

LOCA with larger break sizes does not require the secondary circuit to mitigate the event. Cooling is initiated but does not have any effect on the development of the event.

SGTR

Following an SGTR, the VVP [MSSS] ensures:

- isolation of the affected SG to contain activity (including closure of the pilot valves of the VDA [MSRT] isolation valve of the affected SG, closure of the condensate lines, and verification of the closure of the pre-heating lines;

- cooling of the primary coolant until a pressure below the opening pressure of the non-isolatable safety relief valves is reached in the event of subsequent loss of off-site power. This measure also allows the loss of primary coolant to be made up by the MHSI.

NB: If return to cold shutdown is necessary before the return of off-site power with a single failure in the VDA [MSRT] of the affected SG, boron dilution due to back leakage can be prevented by controlled depressurisation of the secondary side through the VIV [MSIV] bypass line of the affected SG.

NB: If a VDA [MSRT] control valve remains stuck open following an SGTR, the VDA [MSRT] can be isolated by closing the VDA [MSRT] isolation valve.

Cooling until RIS/RRA [SIS/RHRS] connection conditions are achieved

After reaching the controlled state of a PCC-2 to PCC-4 event, the VVP [MSSS] lowers the temperature of the primary side to below 180ºC / 32 bar to enable long-term removal of decay heat via the RIS/RRA [SIS/RHRS]. Cooling is ensured by the GCT [MSB] or the VDA [MSRT] if the GCT [MSB] is unavailable (e.g. following a loss of off-site power).

After a small break LOCA or an SGTR, the initial vapour pressure is 60 bar.

3.4.3. RRC-A and RRC-B

The RRC-A transients relevant to the VVP [MSSS] are:

- ATWS, MSLB and SGTR (one tube), multiple SGTR, small break LOCA and loss of MHSI, total loss of power supplies, loss of heat sink.

ATWS

The development of these sequences strongly depends on the transient which initiates the trip demand.

With regard to overpressure of the secondary side, the design transient is the 'spurious closure of all steam isolation valves'. With respect to overpressure of the primary side, the design transient is the 'loss of normal feedwater'.

The single failure criterion is not applied for ATWS. All VDA [MSRT] and relief valves operate together to limit the conditions on the primary and secondary sides within values corresponding to those required by RCC-M level C. Furthermore, if available during the transient, the GCT [MSB] will contribute to overpressure protection.

Steam conditions vary considerably depending on the various ATWS sequences considered, but remain within design limits.

MSLB and SGTR (one tube)

This event is mitigated by closure of the steam isolation valves to stop radioactive discharges to the environment through the break. The pipework between the containment and the support downstream of the steam isolation valves is HIC so that any pipework rupture between the two is precluded. Consequently if rupture occurs inside the containment, closure of all the steam isolation valves contains the activity released. If rupture occurs outside the containment, closure of all the steam isolation valves terminates the release of steam (and activity) as in the event of an MSLB PCC-3 or PCC-4. The steam isolation valves are automatically closed by the RPR [PS] on detection of significant steam pressure drop or low steam pressure.

If the MSLB occurs downstream of the steam isolation valves, it is isolated by closure of the main steam isolation valves. Subsequently normal SGTR mitigation (see section 3.4.2) will cope with the subsequent development of the event, i.e. activity release through the discharge devices of the affected steam generator will be terminated or prevented.

If the MSLB occurs upstream of the steam isolation valves, i.e. inside the containment, the three unaffected steam generators are isolated from the rupture by automatic closure of the steam isolation valves. Steam release within the containment due to the SGTR is terminated following isolation of the feedwater side of the affected steam generator by cooling the primary system down to ambient conditions.

Multiple SGTR

Mitigation of an SGTR is described in section 3.4.2

Small break LOCA + loss of MHSI

Mitigation of the impact of the transient commences as indicated in section 3.4.2 'Small break LOCA'. When the unavailability of the MHSI is detected a sufficiently rapid cooling to reach the injection pressure of the accumulator, LHSI, is manually initiated.

Total loss of power supplies

Each of the two ultimate emergency diesel generators supplies the VDA [MSRT] in its train (as well as the dedicated ASG [EFWS] pump). The two corresponding VDA [MSRT] trains maintain the plant on hot standby (see section 3.3) over the long term. As the four VDA [MSRT] trains are battery-backed, it is also possible to account for the water inventory of the steam generators in the two trains which are not supplied by the emergency diesel generators.

Loss of heat sink

When heat sink is lost, the four VDA [MSRT] trains maintain the plant on hot standby (see section 3.3.1).

RRC-B

During a low pressure core melt accident, the function of the VVP [MSSS] system is to contain activity through manual closure of the steam isolation valves.

3.5. NORMAL START-UP AND SHUTDOWN OF THE SYSTEM

Start-up

Start-up of the VVP [MSSS] consists of pre-heating the steam pipework and the components. This procedure can commence when the feedwater tank is ready to function, the VVP [MSSS] has been drained. At this stage the steam isolation valves are closed. For pre-heating, the pre-heating line isolation valve is fully open. The heating rate is controlled manually via the pre-heating line control valve so as not to exceed 4ºC/min. When all of the secondary side is at 120ºC / 2 bar, the steam isolation valves are opened and the pre-heating line is closed. Subsequent heating is achieved using the steam line.

The steam isolation valves are opened prior to pre-heating to allow the primary and secondary sides to heat in parallel. In this way, the heating rate generated by the reactor coolant pumps cannot exceed the maximum allowable for the steam lines.

During start-up the largest amount of condensate has to be removed by the blowdown line, compared with other operating states.

Shutdown

To shut the plant down, the VVP [MSSS] automatically ensures cooling through the GCT [MSB]. RRA [RHRS] cuts in over when the primary side is at 120ºC / 32 bar while the GCT [MSB] continues to function.

4. INSTRUMENTATION AND CONTROL

4.1. GENERAL DESIGN

The safety classified part of the VVP [MSSS] comprises four independent trains. In each train, the following components are powered, controlled and monitored by I&C equipment:

- the pilot solenoid valves of the VIV [MSIV] (four units per main steam valve , each one being DC powered from a different electrical train),

- the main steam valve oil pump (AC powered from the same electrical train as the mechanical train of the VIV [MSIV]),

- the motors of the isolation valve and the control valve of the pre-heating line. (The isolation valve is supplied by the emergency supply of the same electrical train as its mechanical train; the control valve is supplied by the emergency supply from a neighbouring electrical train),

- the motors of the blowdown line isolation valves. (One valve is supplied by the emergency supply of the same electrical train as its mechanical train, the other is supplied by the emergency supply from a neighbouring electrical train),

The safety classified part of the VVP [MSSS] is controlled by the I&C safety classified equipment of the four trains and also by the conventional control and instrumentation system. For each above mentioned actuator, the safety classified I&C train (which delivers the control signal) and the electrical train (which delivers the power supply) are dedicated to the same train.

4.1.1. Operating

During at power operation, the I&C equipment maintains the system in the following state:

- the main steam isolation valve is kept open by the oil pressure in the lower piston chamber. The pilot valves are therefore kept closed and de-energised. If the oil pressure drops, the oil pump is automatically activated.
- the pre-heating line is closed and its two motorised valves are kept closed,
- the blowdown line is open and its two motorised isolation valves are kept open.

During PCC and RRC-A situations, the operator may modify the system states by manually altering the position of each valve in line with plant operating conditions.

4.1.2. Automatic control

Given the various functions of each of the VVP [MSSS] valves, automatic controls are supplied separately for each valve/train. The term 'automatic control' means actions which are triggered and controlled automatically.

The automatic control of main steam isolation valves by safety classified I&C equipment only occurs during PCC-2 to PCC-4 events. The corresponding signals for the closure of steam isolation valves are:

- abnormal drop in steam pressure (MSLB or FWLB),
- low steam pressure (MSLB or FWLB),
- SG high level SGTR.

4.2. CONTROLS AVAILABLE TO THE OPERATOR

- Control of main steam isolation valves: all of the pilot valves can be activated individually (to control the steam isolation valves or to carry out tests) from the Main Control Room MCR. From the Remote Shutdown Station (RSS), the main valves can be closed by common actuation pilots.
- Control of pre-heating line valves: The isolation valve and the control valve of each line can be individually controlled from the MCR and the RSS.
- Control of blowdown line valves: The two isolation valves on each line can be individually controlled from the MCR and the RSS.

4.3. INFORMATION AVAILABLE TO THE OPERATOR

- VIV [MSIV] Control Room indications:
    - pilot valve positions,
    - main valves positions,

  - hydraulic oil pressure,
  - oil pump status,
  - nitrogen pressure.
- Relief valves Control Room Indications:
  - safety relief valve position (opened/closed).
- Pre-heating line valves Control Room Indications:
  - isolation valve and the control valve positions on each train.
- Blowdown line valves Control Room Indications:
  - position of the two isolation valves.
- Steam Properties Control Room Indications (for each loop):
  - steam pressure,
  - steam temperature,
- Other Control Room Indications:
  - pressure in the safety relief valve discharge lines,
  - level of the blowdown standpipes.

The information that the operator needs to attain and maintain shutdown conditions is also provided in the RSS.

5. SAFETY ANALYSIS

5.1. SINGLE FAILURE CRITERION

The safety classified part of the VVP [MSSS] is F1A classified (see section 5.3). It is designed to deal with PCC-2 to PCC-4 events. The single failure criterion must therefore be complied with.

Outside the containment, the safety classified part of the VVP [MSSS] comprises four trains which are identical but strictly distinct as each train is assigned to a steam generator (no planned preventive maintenance on the main valves is permitted when operating at power). This allows the system to deal with the loss of a train due to a single failure that affects a specific function, even if a train is lost because of an initiating event.

No active component is used inside the containment.

5.1.1. Consequences of single failures within the system

A detailed explanation of the consequences of single failure of a component is given in Sub-chapter 10.3 - Table 1.

5.1.2. Consequences of single failures outside the system

a) Failure of power supplies

The electrical systems needed to actuate the components that provide an F1 safety function are classified EE1. They function even if there is a total power failure (main and auxiliary circuits) and are backed-up with diesel generators and emergency batteries with a two-hour capacity.

The following functions are ensured during incident or accident situations (PCC), in the event of loss of both systems and outage of both diesel generator sets (single failure + preventive maintenance).

- closure of main steam isolation valves,
- isolation of the pre-heating and blowdown lines.

This requires battery-based electricity back-up.

The following measures are taken to deal with electrical failures (one or more trains):

- the main steam isolation valve is controlled by four pilot valves supplied by different electrical trains, taking account of train outages for maintenance;
- the power supply train to the steam isolation valve oil pump corresponds to the mechanical train of the steam isolation valve (e.g. electrical train 1 for the steam isolation valve associated with SG 1);
- on the pre-heating line, the control and isolation valves are supplied by different trains (the isolation valve is supplied by the same electrical train as its mechanical train);
- likewise, on the blowdown line, the two isolation valves are supplied by different electrical trains.

The main steam isolation valves function as follows when the power supply fails:

- In the event of the oil pump failing:
    - if the VIV [MSIV] is open, it remains open for at least eight hours so as not to affect the availability of the plant (non return valves prevent the oil pressure falling),
    - if the VIV [MSIV] is closed it remains closed because the oil pump is unavailable to open it,
- When the control valves lose their power supply, the VIV [MSIV] closes because of the loss of the two control valves in series.

Finally, if the Main Control Room is unavailable, the operator can operate and monitor all of the valves from the RSS.

b) Control and Instrumentation failure

The control and instrumentation equipment needed to actuate the components which provide an F1 safety function are classified E1A.

In PCC-2 to PCC-4 conditions, the I&C is designed so that a single failure affecting the I&C has no more effect on the steam system than a single failure of a VVP [MSSS] component.

c) In the event of failure of the working fluid supplies for the functioning of the valves, a leak, (other than the control and instrumentation equipment) the nitrogen bottles and the oil are still available to re-supply the steam isolation valve control system.

d) GCT [MSB] failure

In the event of spurious opening of the bypass system to the condenser, the steam flow rate will increase significantly. Return to normal is achieved by automatic closure of the condenser bypass system. If such closure fails, the steam isolation valve closes automatically following a sudden drop in steam pressure or low steam pressure.

5.2. PROTECTION AGAINST HAZARDS

5.2.1. Protection against external hazards

Aircraft crash

Two VVP [MSSS] systems are installed in the top part of one safeguard building and two are installed in the top part of a second safeguard building. The VVP [MSSS] systems are designed to withstand the vibrations caused by an aircraft crash; the two VVP [MSSS] systems which are not directly affected by the crash can thereby ensure decay heat removal after the event.

However, an APC (crash of a large commercial airplane) could potentially damage the steam valve and feedwater valves of the two VVP [MSSS] associated with one safeguard building. Therefore, a specific study of complete SG steam discharge from both affected SGs, with coincident failure of main feedwater line isolation, has been carried out (using less onerous assumptions than applied in PCC analysis) to confirm that consequences are acceptable (see Sub-chapter 3.4).

Earthquake

As the system is classified F1A, the safety classified part of the VVP [MSSS] is designed to withstand the design basis earthquake. Furthermore, the main steam isolation valves are designed to operate during the event to isolate any possible breaks in the conventional part of the plant.

Explosion

As the VVP [MSSS] system compartments are designed to withstand the shockwave due to an explosion, all of the safety classified part of the VVP [MSSS] is protected against this event.

5.2.2. Protection against internal hazards

Fire, missiles

Outside the containment, in the VVP [MSSS] compartments, the safety classified part of the VVP [MSSS] is composed of four identical trains which are strictly segregated. Consequently fires and missiles, will only affect one station.

Inside the containment, there is no strict segregation. Nevertheless, the layout (compartmentalisation and the protective metal liner of the containment) ensure that the steam pipework is protected against these events.

Internal explosions, load drop

Explosion inside the safety classified buildings is precluded. Dropped loads are ruled out by the design of the handling equipment.

Breaks in other circuit pipework

Outside the containment, in the VVP [MSSS] compartments, the safety classified part of the VVP [MSSS] is composed of four identical trains which are segregated. The VVP [MSSS] train and pipework between the SG and the support downstream of the steam isolation valve are HIC. Only one break on the steam isolation valve bypass line therefore needs to be considered, which is a break at a nozzle on the main steam line. The design ensures that the VVP [MSSS] system remains available despite the effects of pipe whip, reaction forces and jet impact in the event of such a break.

Inside the containment, strict segregation is not applied because of the HIC claim. Nevertheless, in the event of an MSLB occurring inside the containment, the layout of the steam lines is such that pipe whip does not cause propagation of damage to other unaffected lines.

The safety classified part of the VVP [MSSS] is designed to deal with the compression waves created by the rupture of steam pipework (see Sub-chapter 3.4, section 1.4).

Ambient conditions

The VVP [MSSS] valves withstand the most severe ambient conditions created by the break of a blowdown line inside the VVP [MSSS] compartment.

External flooding

The VVP [MSSS] compartments are located in the top part of two safeguard buildings while the rest of the safety classified steam pipework is located inside the containment. The safety classified part of the VVP [MSSS] is therefore protected from external flooding.

Internal flooding

There is no pipework that transports liquids above or inside the VVP [MSSS] compartments. As the feedwater valve compartments are separated from the steam valve compartments, there is no risk of flooding inside the VVP [MSSS] compartments.

5.3. CLASSIFICATION

5.3.1. Safety classification [Ref-1]

Functional classification

The VVP [MSSS] is required to bring the reactor into a controlled state.

Cooling of the primary system by discharging steam to atmosphere in the event of a small break in the primary system or rupture of a steam generator tube is classified F1A.

Isolation of the steam generator on the steam side in the event of an accident with a significant increase in the steam flow rate is classified F1A.

Protection against steam generator overpressure by discharging steam to atmosphere is classified F1A.

Removal of decay heat by discharging steam to atmosphere is classified F1A.

In the event of rupture of a steam generator tube, activity retention by isolation of the steam side (including the isolation valves of the blowdown and treatment lines) is classified F1A.

Cooling needed to reach RRA [RHRS] conditions by discharging steam to atmosphere or to the condenser, and maintaining the system in these conditions if the RRA [RHRS] is unavailable, are classified F1B.

The last function is in fact performed by equipment and pipework which participate in F1A classified functions. The entire system is therefore F1A classified.

5.3.2. Classification of equipment

The various pieces of equipment in the VVP [MSSS] are classified according to the classification in Sub-chapter 3.2.

5.3.3. Seismic classification

The safety classified part of the VVP [MSSS] is designed to retain its integrity after a design basis earthquake. Furthermore, the main steam isolation valve is designed to retain its operability during a design basis earthquake. The components of the safety classified part of the VVP [MSSS] are SC1 classified (see Sub-chapter 3.2).

5.3.4. Electrical classification

The electrical equipment needed to actuate the components of the safety classified part of the VVP [MSSS] is classified EE1 (except the oil pump for the VIV [MSIV] which is classified NC) (see Sub-chapter 3.2).

5.3.5. C&I classification

The I&C equipment needed to ensure the safety functions of the safety classified part of the VVP [MSSS] is classified E1A (see Sub-chapter 3.2).

5.4. QUALIFICATION

The materials are qualified in compliance with the requirements outlined in Sub-chapter 3.6.

5.5. SPECIFIC SAFETY MEASURES

- The VVP [MSSS] and the pipework between the containment penetration support and the pipe support downstream of the main steam isolation valve are HIC. It is possible to accommodate coincident SGTR and MSLB in relation to activity discharges into the environment, i.e. when the steam pipe break occurs inside the containment or downstream of the support. Closing the main steam isolation valve of the affected steam generator ensures that any release is contained.

- The main steam isolation valves are designed to close even if water or a mixture of steam/water is flowing through them. In certain double-ended steam line break scenarios (2A-MSLB), the steam/water front that is created by vaporisation can reach the steam isolation valve before it is fully closed.

- The spring-loaded safety relief valves need neither power supplies or I&C.

6. PRINCIPLES RELATED TO PERIODIC TESTS AND MAINTENANCE

6.1. EQUIPMENT PERFORMANCE TESTS

The functionality of the safety classified components of the VVP [MSSS] is required to be tested.

The functions to be tested depend on the accident studies. For each safety function, the required performance is that assumed in the accident studies.

The test periodicity for all of the functions tested will be the subject of a specific study.

The UK EPR design takes into account the requirements to access the areas to be controlled during the pre-service inspection and the in-service inspections; for each inspection area, there is adequate design for accessibility and controllability of the welds to be inspected [Ref-1]. The systematic review of MSL welds confirms that all welds are physically accessible and are designed to facilitate the in-service inspections of the whole volume of the welds [Ref-2]:

- The examinations of the MSL welds are possible by scanning from outside of the pipe as is the case for in-service inspection.

- The full volume of the welds are accessible for scanning with angle beam 45° - 65° - 70° from both sides of the welds for the majority of welds or at least from one side with a complete examination in the other cases.

- The counterbores do not interfere with the NDT (Non Destructive Test) examinations because the counterbores are adequately long.

- The influence of the tapered surface has been taken into account by the use of a gentle and continuous slope in the design of certain MSL components.

  During manufacturing, all scanning surfaces will be verified after grinding by a UT probe or a template to ensure that there is no gap greater than 0.5 mm between the probe and the scanning surfaces. This requirement will be included in the equipment specification for the MSL.

The pre-service and in-service inspection programmes will be established in detail during the detailed design studies for the UK EPR. It will be confirmed that the performance expected from NDT will be compatible with design and manufacture (surface state, geometry, etc...). For any factory weld for which an inspection is planned, NDT will be carried out in the factory and will have the status of 'initial survey'.

Inspection of less sensitive components will be carried out to meet the defence in depth principle. The inspection programme for the less sensitive components will be reduced in comparison to the inspection programme for sensitive components as long as during the studies it has been confirmed that there is no risk of defects developing during operation, that the design loads meet the code limits and that NDT during manufacturing has confirmed that there are no unacceptable defects.

The periodic testing programme and the preventive maintenance programmes will be drawn up during the detailed design stage.

6.2. EQUIPMENT MAINTENANCE

There is no planned maintenance for the components of the safety classified part of the VVP [MSSS] when the reactor is at power.

The pilot valves of the main steam isolation valves are an exception to this rule. They can be removed when the reactor is on load for maintenance or repair after the dedicated isolation valves, which are adjacent to the pilot valves, have been closed. Preventive maintenance during shutdown takes place at the same time as the visual checks.

7. FAST FRACTURE ANALYSIS

As stated in Sub-chapter 3.1, the Main Steam Lines from the Steam Generators up to the first terminal fixed points downstream of the steam isolation valves are High Integrity Components (HIC) for which the specific measures described in section 0.3.6 of Sub-chapter 3.4 concerning prevention, surveillance and mitigation contribute to their high integrity demonstration.

With regards to the fast fracture risk, the three-legged approach presented in Sub-chapter 3.4 section 1.6 has been applied to the Main Steam Lines as follows:

- use of fracture mechanics to determine the end of life limiting defect size and demonstration that the Defect Size Margin between this critical defect size and the detectable defect increased by fatigue crack propagation over the lifetime is larger than 2 as far as is practicable;

- use of suitable redundant and diverse inspections during manufacturing, supplemented by the use of qualified inspection(s) at the end of manufacturing;

- verification of the lower bound fracture toughness values used to determine the critical defect size by measurements.

This methodology applies to the whole main steam lines, including welds and base metal. However, considering the higher probability of finding crack-like defects in welds than in forgings, and considering that the toughness is lower in the weld metal, the majority of the locations assessed are likely to be the welds. Consequently, the following sub-sections focus on welds, and the full demonstration including the base metal will be provided in the detailed design stage.

This methodology also applies to the pressure boundary parts of the Main Steam Isolation Valve, base metal and weld repair.

7.1. FRACTURE MECHANICS ANALYSIS

7.1.1. MSL pipework

For the Main Steam Lines, the HIC methodology applies to all welds inside the containment, and outside the containment up to the first terminal fixed point downstream of the main steam isolation valves as shown in Sub-chapter 10.3 - Figure 2 [Ref-1]. Seven bounding cases have been identified and fracture mechanics calculations have been performed on the most severe mechanical loadings:

- Connection to the SG weld (called W1 on Sub-chapter 10.3 – Figure 2),
- Connection to the penetration flange weld (called W4 on Sub-chapter 10.3 – Figure 2),
- Inside containment penetration weld (called SW2 on Sub-chapter 10.3 – Figure 3),
- Outside containment penetration weld - long train (called SW1 on Sub-chapter 10.3 – Figure 3),
- Terminal Fixed Point weld - short train (called W7 on Sub-chapter 10.3 – Figure 4),
- Main Steam Relief Train (MSRT) nozzle weld - short train (called A on Sub-chapter 10.3 – Figure 5),
- Main Steam Safety Valve (MSSV) nozzle weld - short train (called B on Sub-chapter 10.3 – Figure 5).

For the thick welds (37 – 60 mm) of the Main Steam Lines, the smallest End of Life Limiting Defect Size (ELLDS) is obtained for the penetration weld inside containment (SW2). The bounding case corresponds to an outer skin defect submitted to a mechanical loading set including main steam line break, after the terminal fixed point, and earthquake, which gives an ELLDS of **10 mm** in the ductile range.

For the thin welds (23 – 25 mm) of the Main Steam Lines, the smallest End of Life Limiting Defect Size is obtained for the MSSV nozzle weld. The bounding case corresponds to an outer skin defect submitted to a mechanical loading set including main steam line break, after the terminal fixed point, and earthquake, which gives an ELLDS of **8 mm** in the ductile range.

The limiting defect size calculated ensures that the size of a critical defect that would lead to failure is 10 mm for thick piping (> 30 mm) and 8 mm for thin piping (< 30 mm). These defect sizes will be used for the MSL welds to define the requirements for inspections which will be carried out at the end of manufacturing.

7.1.2. Main Steam Isolation Valve

For the Main Steam Isolation Valve, the HIC methodology applies to the pressure boundary parts of the valve: VIV [MSIV] body and VIV [MSIV] bonnet (see Sub-chapter 10.3 – Figure 6).

Due to the similarities in terms of casting, geometry and loadings between the main steam isolation valve body and the reactor coolant pump casing, estimates of critical defect sizes for the VIV [MSIV] body and bonnet have been made [Ref-1], based on the critical defect size calculated for the reactor coolant pump casing (see Sub-chapter 5.4, section 1.6), and it is concluded that end of life limiting defect sizes greater than 20 mm would seem achievable for the VIV [MSIV] body and bonnet, both for the base metal and the weld repairs.

7.2. NON DESTRUCTIVE TESTING

7.2.1. MSL pipework

The NDT selected to be qualified for the inspection of ferritic Main Steam Line welds is the Ultrasonic Testing (UT) technique used in addition to the non-qualified Radiological Testing (RT) technique [Ref-1]. This UT technique is made up of the pulse echo UT technique, using transverse waves 45° and 60° as required by RCC-M (half skip and full skip examination), supplemented by a 70° half skip examination. In addition, for the welds which are only accessible from one side, a full skip examination or at least a partial full skip (i.e. examination of at least the inner thickness when the full skip is not relevant due to a long ultrasound path) will also be deployed [Ref-2]. This technique is able to cover the whole volume of all the welds and detect all defects of structural concern.

The Main Steam Line welds are machined flush outside and inside, so that the whole volume of the weld can be covered and there is no problem with false ultrasonic indications due to the geometry variation. These welds are ferritic welds and the ultrasonic permeability is very good for this material.

According to the thickness of the material (between 23.7 mm and 60 mm, which is smaller than the main ferritic components), and considering the angle of the bevels, it is possible to perform a half skip or full skip examination and to obtain specular reflection on the fusion face of the weld bevel. A corner effect is also possible for defects near the inside and outside faces.

Moreover, the sensitivity calibration of this inspection is based on a 2 mm side drilled hole; a planar defect with a through wall extent of about 4 mm or 5 mm is more reflective with UT examination than the side drilled hole which confirms the capability of this UT technique to detect these defects.

This capability has been confirmed by simulation trials performed on software on two bounding cases: one thin thickness case and one thick thickness case with accessibility from one side of the weld only. The simulated defects can be adequately detected and, in particular, the 70° full skip or partial full skip examination for welds with limited accessibility enable the inspection objectives to be met.

Finally the capability of this control to detect and reject defects whose Qualified Examination Defect Size (QEDS) derived from the Fracture Mechanics Analyses is 4 to 5mm or greater can be achieved with a high level of reliability; smaller defects can also be detected with reasonable capability.

In conclusion for the MSL pipework, a Defect Size Margin of 2 has been attained with fracture mechanics calculations, while considering that the fatigue crack growth for these worst case defects with regards to fast fracture is negligible (a few tenths of a millimetre).

The UT techniques to be applied at the end of manufacturing will be qualified for any UK EPR project.

7.2.2. Main Steam Isolation Valve

The NDT selected for the volumetric inspection of the VIV [MSIV] body and VIV [MSIV] bonnet for the UK EPR have not been defined during the GDA phase, as the manufacturing and examination of the FA3 VIV [MSIV] have not been finalised. The NDT, which is likely to combine RT and UT techniques, will be defined in the nuclear site licensing phase once the definitive results from FA3 are known.

Although these final NDT techniques are not defined, the inspectability of the VIV [MSIV] body and bonnet is ensured for the following reasons [Ref-1]:

- The steel grade of the VIV [MSIV] body and bonnet is made up of carbon steel which has good ultrasonic permeability properties,

- Available tests performed on Olkiluoto 3 and Flamanville 3 VIV [MSIV]s show that inspectability using RT and UT can be achieved,

- For inspectability of repair welds the arguments and evidence developed for the reactor coolant pump casing (see Sub-chapter 5.4, section 1.6) are applicable: the inspectability of the repair welds in the VIV [MSIV] body and bonnet is also ensured.

Considering these arguments, there is a high level of confidence that any defects of structural concern with a through wall extent of 10 mm or more are likely to be detected using a combination of UT and RT which will be selected during the nuclear site licensing phase.

The need for qualification of the volumetric inspection(s) will be defined during the nuclear site licensing phase.

7.3. FRACTURE TOUGHNESS

The verification of the lower bound fracture toughness values used to determine the critical defect size of the MSL pipework will be performed by measurements of the fracture toughness on a mock-up using compact tensile specimens (CTJ) in the ductile range [Ref-1]. The mock-up will be representative of the UK EPR materials.

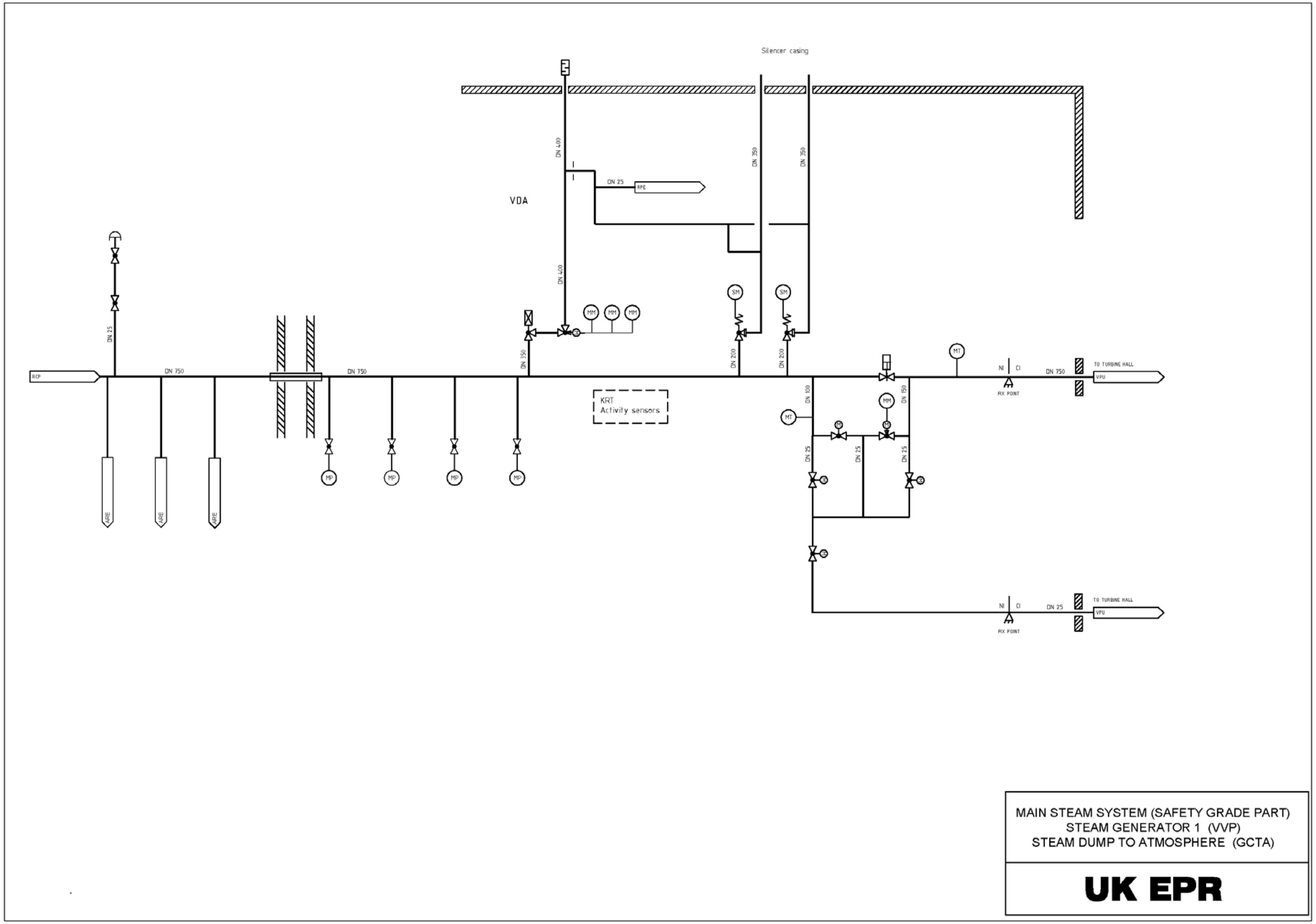
The verification of the lower bound fracture toughness values used to determine the critical defect size of the VIV [MSIV] body and bonnet will be performed by measurements of the fracture toughness on a cast carbon steel mock-up using compact tensile specimens (CTJ) in the ductile range [Ref-2]. The mock-up will be representative of the UK EPR materials for the VIV [MSIV] body and bonnet.

SUB-CHAPTER 10.3 - TABLE 1

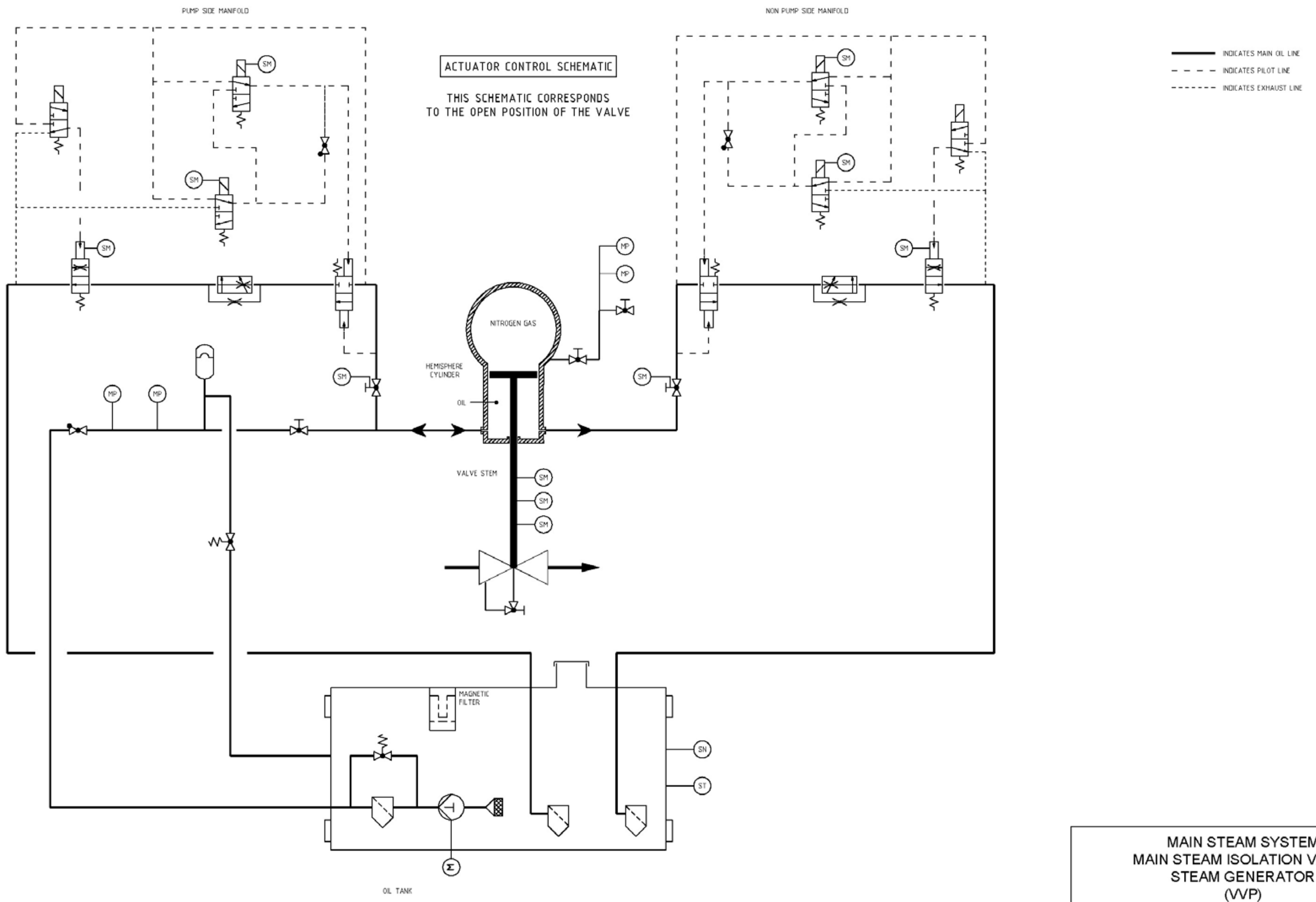
Consequences of a Single Failure

Component	Function	Single failure	Explanation
Main steam isolation valve	Prevents excessive steam flow rate following an MSLB	Failure to open of any pilot solenoid valve	No effect on the function because of the arrangement of the pilot solenoid valves.
		Failure to close of the main steam isolation valve	The three unaffected VIV [MSIV] isolate their SG from the rupture. The feed side of the affected SG will be isolated, thereby stopping the transient.
	Terminates the release of activity following an SGTR	Failure to open of any pilot solenoid valve	No effect on the function because of the arrangement of the pilot solenoid valves.
		Failure to close of the main steam isolation valve	This has not been considered due to the high reliability of closure of the VIV [MSIV].
Safety relief valve	Protection against overpressure	Failure to open	PCC-2 to 4: Following reactor trip the capacity of the other safety relief valves is sufficient for overpressure protection. RRC-A: Following an ATWS, the single failure criterion is not applicable.
	Terminates activity release following an SGTR	Failure to close after a demand to open	Not applicable as without a prior single failure of the VDA [MSRT], there is no demand on the safety relief valves.
Pre-heating line control valve	Terminates excessive steam flow rate following an MSLB or the activity release following an SGTR	Failure to close (if inadvertently opened)	Redundancy is provided by the pre-heating line isolation valve on the affected SG side.
Pre-heating line isolation valve	Terminates excessive steam flow rate following an MSLB or the release of activity following an SGTR	Failure to close (if inadvertently opened)	Redundancy is provided by the pre-heating line control valve on the affected SG side.
Blowdown line isolation valve	Terminates activity release following an SGTR	Failure to close	Redundancy is provided by the other isolation valves.

SUB-CHAPTER 10.3 - FIGURE 1 (FOLIO 1/2): VVP [MSSS] SIMPLIFIED FLOW DIAGRAMS – OVERALL VIEW FOR TRAIN 1



SUB-CHAPTER 10.3 - FIGURE 1 (FOLIO 2/2): VVP [MSSS] SIMPLIFIED FLOW DIAGRAMS - VIV [MSIV]

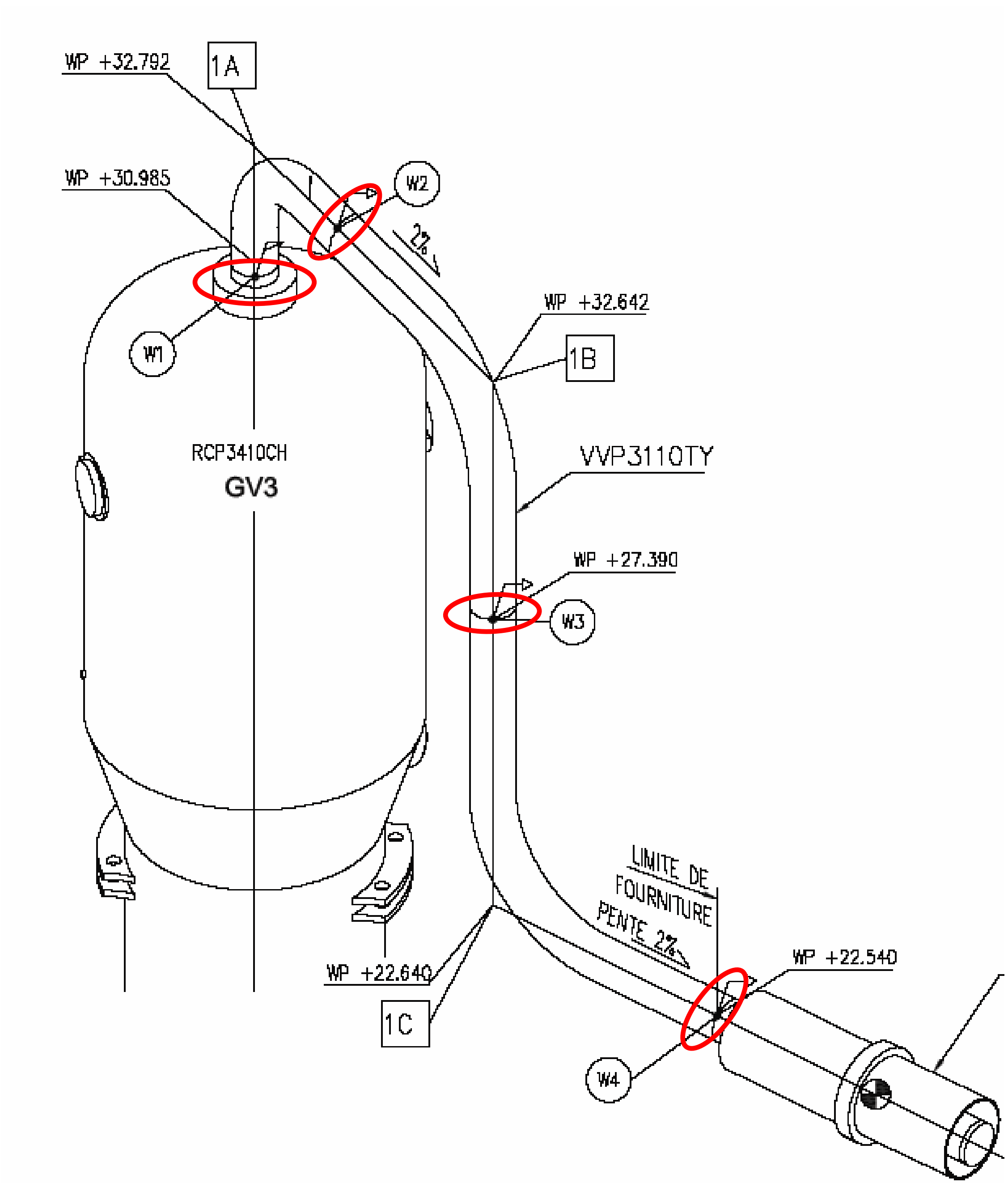


MAIN STEAM SYSTEM
MAIN STEAM ISOLATION VALVE
STEAM GENERATOR
(VVP)

UK EPR

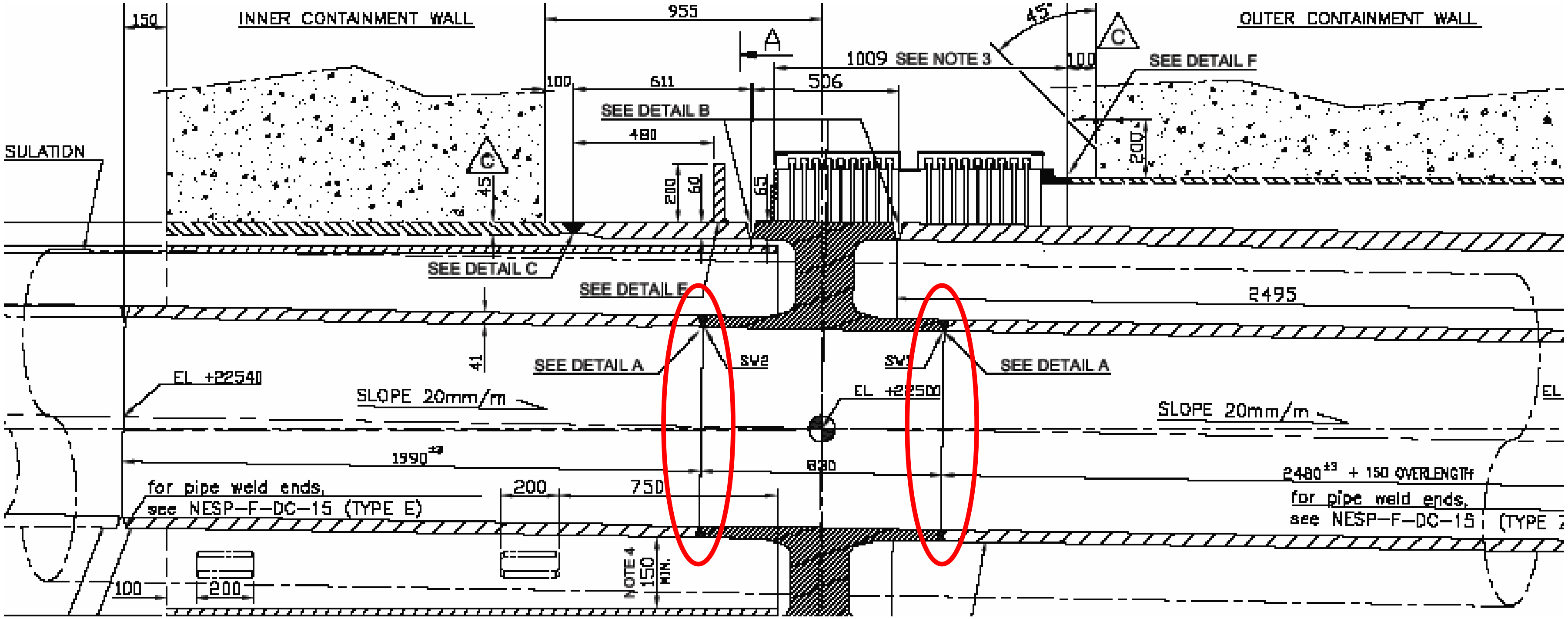
SUB-CHAPTER 10.3 - FIGURE 2

HIC Welds - Main steam line inside reactor building



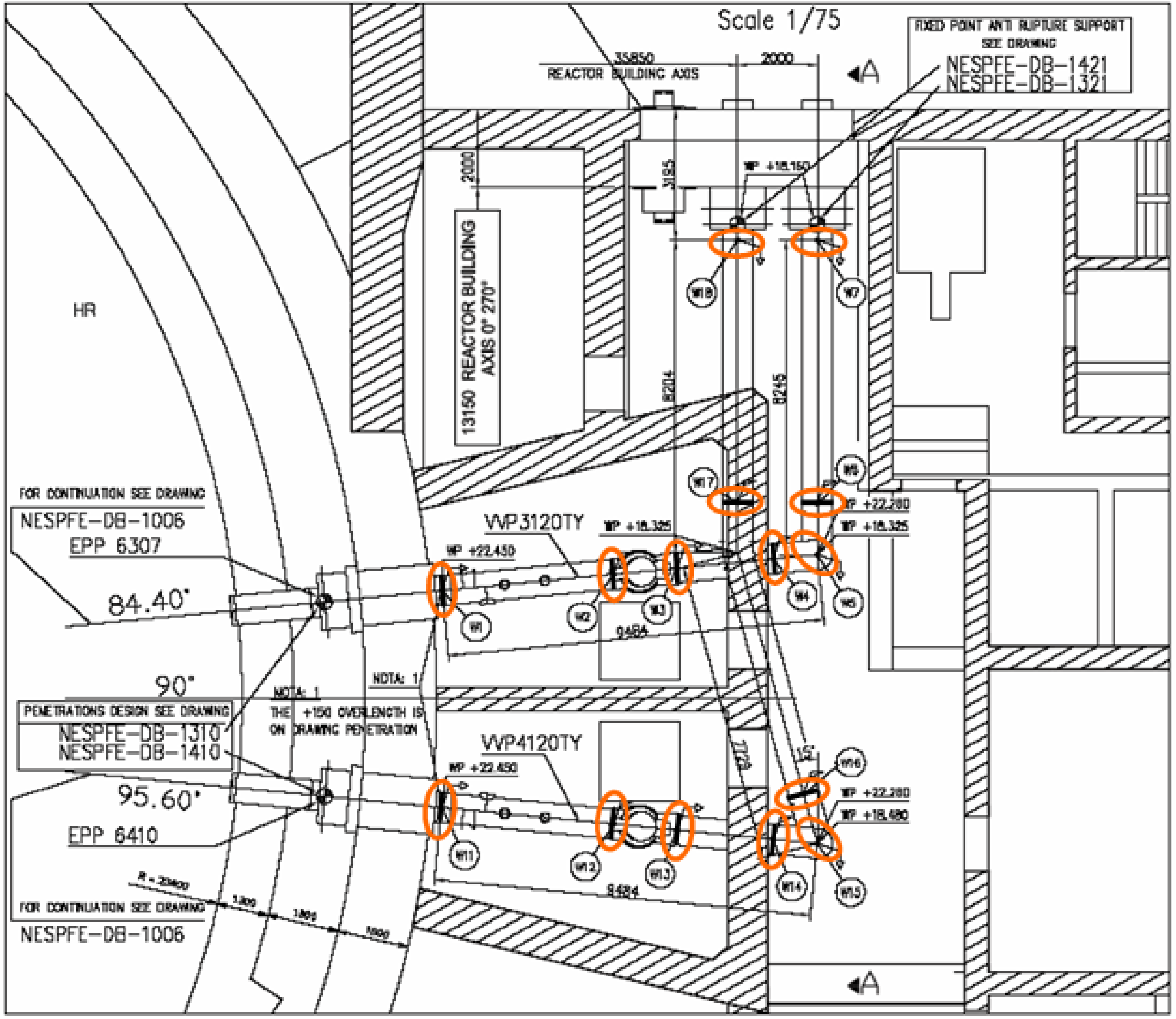
SUB-CHAPTER 10.3 – FIGURE 3

Main steam line penetrations



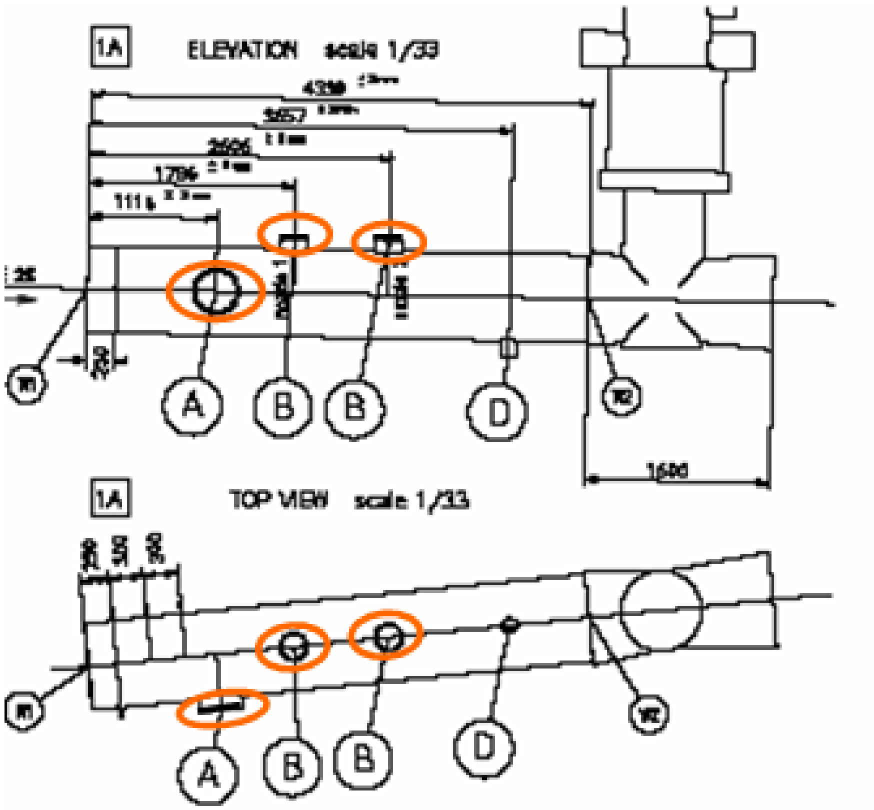
SUB-CHAPTER 10.3 – FIGURE 4

Main steam lines outside reactor building



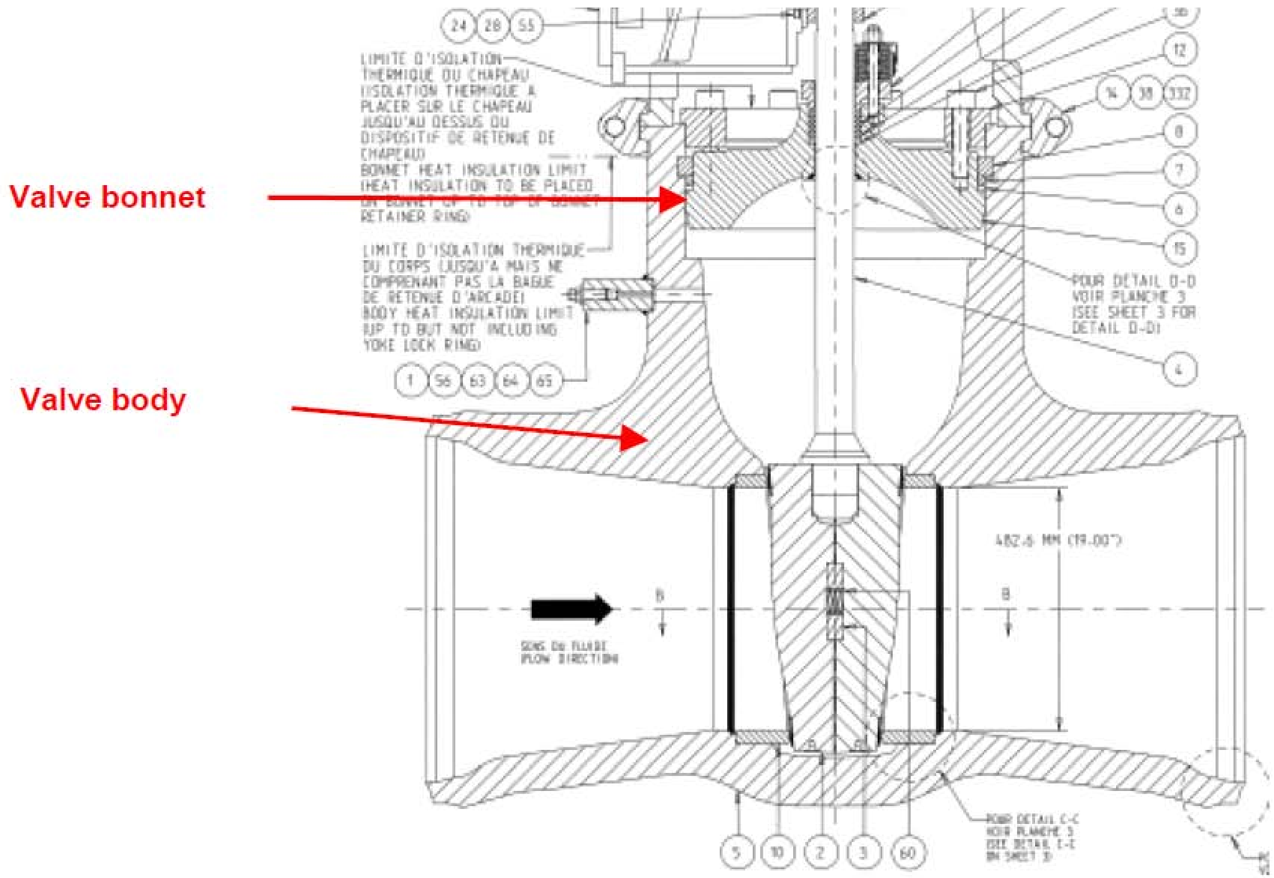
SUB-CHAPTER 10.3 – FIGURE 5

Main steam lines outside reactor building – MSRT and MSSV nozzles



SUB-CHAPTER 10.3 - FIGURE 6

Main Steam Isolation Valves – HIC parts



SUB-CHAPTER 10.3 – 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.

[Ref-1] System Design Manual – Main Steam Supply System (VVP [MSSS]) P1. NESS-F DC 623. Revision A. AREVA. December 2009. (E)

[Ref-2] System Design Manual - Main Steam Supply System (VVP [MSSS]) - Part 2: System Operation. NESS-F DC 578 Revision A. AREVA. November 2009. (E)

[Ref-3] System Design Manual - Main Steam Supply System (VVP [MSSS]) - Part 3: System Design. NESS-F DC 579 Revision A. AREVA. November 2009. (E)

[Ref-4] System Design Manual - Main Steam Supply System (VVP [MSSS]) - Part 4: Flow diagrams. NESS-F DC 594 Revision A. AREVA. September 2009. (E)

[Ref-5] System Design Manual – Main Steam Supply System (VVP [MSSS]) P5 - Instrumentation and Control. NESS-F DC 629. Revision A. AREVA. March 2010. (E)

0. SAFETY REQUIREMENTS

0.3. DESIGN-RELATED REQUIREMENTS

0.3.1. Safety classification requirements

0.3.1.1. Safety classification

[Ref-1] System Design Manual - Main Steam Supply System (VVP [MSSS]) - Part 2: System Operation. NESS-F DC 578 Revision A. AREVA. November 2009. (E)

2. DESIGN BASIS

2.1. GENERAL ASSUMPTIONS FOR THE DESIGN OF THE SYSTEM

[Ref-1] System Design Manual - Main Steam Supply System (VVP [MSSS]) - Part 2: System Operation. NESS-F DC 578 Revision A. AREVA. November 2009. (E)

2.5. FLOW DIAGRAMS

[Ref-1] System Design Manual - Main Steam Supply System (VVP [MSSS]) - Part 4: Flow diagrams NESS-F DC 594 Revision A. AREVA .September 2009. (E)

2.6. DESCRIPTION OF THE MAIN COMPONENTS

[Ref-1] System Design Manual - Main Steam Supply System (VVP [MSSS]) - Part 3: System Design NESS-F DC 579 Revision A. AREVA. November 2009. (E)

5. SAFETY ANALYSIS

5.3. CLASSIFICATION

5.3.1. Safety classification

[Ref-1] System Design Manual - Main Steam Supply System (VVP [MSSS]) - Part 2: System Operation. NESS-F DC 578 Revision A. AREVA. November 2009. (E)

6. PRINCIPLES RELATED TO PERIODIC TESTS AND MAINTENANCE

6.1. EQUIPMENT PERFORMANCE TESTS

[Ref-1] F Chavigny. Demonstration of the accessibility and controllability for in-service inspection of the structural integrity components.
ECEMA101028 Revision A. EDF. April 2010. (E)

[Ref-2] Ultrasonic examination of MSL girth welds
PEEM-F 11.0959 Revision B. AREVA. March 2012. (E)

7. FAST FRACTURE ANALYSIS

7.1. FRACTURE MECHANICS ANALYSIS

7.1.1. MSL pipework

[Ref-1] Demonstration of integrity of High Integrity Components against fast fracture. Fracture Mechanic Analyses – Non Destructive Testing – Fracture Toughness.
NEER-F 10.2070 Revision D. AREVA. August 2012. (E)

7.1.2. Main Steam Isolation Valve

[Ref-1] UK EPR - Avoidance of fracture demonstration of the Main Steam Isolation Valve.
PEEO-F 12.0359 Revision B. AREVA. July 2012. (E)

7.2. NON DESTRUCTIVE TESTING

7.2.1. MSL pipework

[Ref-1] UK Technical report on the manufacturing non destructive testing to be qualified.
PEEM-F 10.1134 Revision D. AREVA. December 2010. (E)

[Ref-2] Ultrasonic examination of MSL girth welds.
PEEM-F 11.0959 Revision B. AREVA. March 2012. (E)

7.2.2. Main Steam Isolation Valve

[Ref-1] UK EPR - Avoidance of fracture demonstration of the Main Steam Isolation Valve.
PEEO-F 12.0359 Revision B. AREVA. July 2012. (E)

7.3. FRACTURE TOUGHNESS

[Ref-1] UK EPRTM Avoidance of Fracture- Fracture mechanics and minimum fracture toughness aspects: Materials Data.
NEEM-F 10.0179 Revision E. AREVA. November 2010. (E)

[Ref-2] UK EPR - Avoidance of fracture demonstration of the Main Steam Isolation Valve.
PEEO-F 12.0359 Revision B. AREVA. July 2012. (E)