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01	Integration of technical and co-applicant comments	26-04-2008
02	PCSR June 2009 Update: – Clarification of text – Inclusion of references – Design evolutions to account for December 2008 design freeze (Soda Injection, pressure conditioning, LHSI mini flow line safety valves set, simplified flow diagram, operational parameters, protection signals list …)	26-06-2009
03	Consolidated Step 4 PCSR update - Minor editorial changes - Addition of IRWST filtration description (section 2.3, CCI added) - Clarification regarding cavitation/gas ingestion - Protect Commercial markings added	26-03-2011
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 text and figures (§1.2.3.3, §1.3.1, §2.1, Figures 5 & 6)	05-10-2012

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REVISION HISTORY (Cont'd)

Issue	Description	Date
04 Cont'd	Consolidated PCSR update (cont'd): - Sentence added regarding hydrazine injection during thermal conditioning (§1.4.4.2) - Figure 1 corrected ("RIS tank" deleted)	

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SUB-CHAPTER 6.3 – SAFETY INJECTION SYSTEM (RIS [SIS])

0. SAFETY REQUIREMENTS

0.1. SAFETY FUNCTIONS

0.1.1. Controlling reactivity

In safety injection mode, the safety injection system (RIS [SIS]) injects borated water from the IRWST into the primary cooling system to control core reactivity in PCC-3 to PCC-4 and RRC-A and RRC-B incidents and accidents (the IRWST is the only source of borated water claimed in the analysis of RRC-B conditions).

The IRWST boron concentration must be sufficiently high and homogeneous to ensure core subcriticality.

0.1.2. Decay heat removal

The RIS/RRA [SIS/RHRS] system is required for decay heat removal in the following situations:

- in normal shutdown states with the core loaded when the steam generators can no longer perform this function;
- in most PCC-2 to PCC-4 events not involving primary breaks, connection to the RRA [RHRS] signifies that the safe shutdown state has been achieved. The RIS/RRA [SIS/RHRS] must be capable of maintaining this safe state by removing the core decay heat and the heat generated by the primary coolant pumps;
- in all primary breaks (LOCA and SGTR in PCC-3 and PCC-4, LOCA in RRC-A, up to 2A-LOCA), the RIS/RRA [SIS/RHRS] system must maintain the primary cooling system water inventory and the temperature of the cooling water such that the reactor core can be cooled;
- in the event of loss of primary inventory with non-isolatable containment bypass, the RIS/RRA [SIS/RHRS] must ensure that the system is cooled to a temperature that enables the leak to be terminated;
- in the event of MSLB, the RIS/RRA [SIS/RHRS] system must be capable of supplying sufficient boron to prevent power excursions.
- in RRC-A conditions, the RIS/RRA [SIS/RHRS] must be capable of removing decay heat when the normal means of ensuring cooling using the secondary cooling system is unavailable.

In addition, during a severe accident (RRC-B), the IRWST must be capable of ensuring flooding of the corium spreading compartment using passive devices (to transfer the corium decay heat into the containment atmosphere).

0.1.3. Containment of radioactive substances

The parts of the RIS/RRA [SIS/RHRS] system located outside the containment provide the containment function for the primary coolant in the following events:

- for all LOCA events (PCC-3, PCC-4, RRC-A to 2A-LOCA) because the system constitutes an extension of the third barrier,
- in RRA [RHRS] operating mode when the system forms an extension to the primary cooling system.

In all LOCA events, the RIS/RRA [SIS/RHRS] must ensure that the production of steam is sufficiently low to remain within the containment design pressure limit.

In the event of RRC-B accidents, the RIS/RRA [SIS/RHRS] must prevent damage to the foundation raft by flooding the corium spreading compartment with water from the IRWST.

0.2. FUNCTIONAL CRITERIA

0.2.1. Controlling reactivity

When the RIS [SIS] function is initiated in PCC-3, PCC-4, RRC-A or RCC–B incidents and accidents, the injected water must not result in boron dilution: use of injection water with a boron concentration lower than that of the primary cooling system is therefore prohibited.

In the event of a LOCA (PCC-4), the RIS/RRA [SIS/RHRS] must compensate for the reactivity insertion resulting from cooling.

The negative reactivity provided by the RIS/RRA [SIS/RHRS], combined with the action of reactivity control systems, must ensure that the fuel integrity criteria are met during conditions of excessive reactivity addition caused by rapid heat extraction by the secondary cooling system (PCC-3 and PCC-4). In the particular case of MSLB, the safety injection system must supply water with enough boron concentration sufficiently quickly to ensure core subcriticality.

0.2.2. Decay heat removal

The RIS/RRA [SIS/RHRS] must ensure removal of the decay heat when:

- the reactor vessel is open for refuelling,
- maintenance operations are being carried out with a ¾ loop level in the primary coolant pipework.

Also, for any PCC or RRC-A event or accident requiring the RIS/RRA [SIS/RHRS], the cooling capacity must be sufficient to ensure that the authorised and specified limits for the fuel and the primary coolant pressure boundary are met. The RIS/RRA [SIS/RHRS] is designed so that in the event of a PCC-3 to RRC-A category accident, only a small fraction of the fuel assemblies will be damaged (< 10% for PCC-4 and RRC-A accidents).

In all cases of LOCA (from PCC-3 to 2A-LOCA and to the primary breaks considered in RRC-A), the flow of borated water injected via the RIS/RRA [SIS/RHRS] must be sufficient to transfer the energy produced by the core and meet the specific criteria defined in Chapter 14. In particular, following shutdown of the nuclear reaction, the cooling provided by the RIS/RRA [SIS/RHRS] must be sufficient to prevent deformation of the fuel assemblies and/or internal equipment, which could inhibit core cooling.

In all situations where water is injected from the IRWST, the RIS [SIS] and EVU [CHRS] system filtering systems (e.g. IRWST filters) must ensure that the RIS [SIS] and EVU [CHRS] pump suction conditions remain acceptable and thus ensure their operation over the long term.

During total loss of operation of the secondary cooling system, the decay heat can only be removed if the primary cooling system is rapidly placed into the "bleed and feed" configuration. The safety injection system injects water into the primary cooling system and the decay heat is transferred into the containment by opening the pressuriser lines used for severe accident mitigation.

When the system is operating in residual heat removal mode, the LHSI pumps must be protected from degraded hot leg suction conditions to remove the risk of damage which could arise from cavitation or vortex operation.

0.2.3. Containment of radioactive substances

In all operating conditions (PCC-1 to PCC-4, RRC-A and RRC-B) that bring the RIS/RRA [SIS/RHRS] into operation, those parts of the system outside the containment must remain intact. Nevertheless, in the event of rupture or loss of leaktightness of a segment of the RIS/RRA [SIS/RHRS] located outside containment, it must be possible to isolate the segment from the primary cooling system.

The MHSI pump injection pressure must be designed to prevent a primary leak to the environment in the event of a steam generator tube rupture.

0.3. REQUIREMENTS RELATING TO THE DESIGN

0.3.1. Requirements from safety classifications

0.3.1.1. Safety classification

The RIS/RRA [SIS/RHRS] must be safety classified in accordance with the classification indicated in Sub-chapter 3.2.

0.3.1.2. Single failure criterion (active and passive)

For components that perform F1 functions, the single failure criterion is applied to ensure adequate redundancy (Sub-chapter 3.2).

The single failure to open a RIS/RRA [SIS/RHRS] accumulator check valve doesn’t need to be considered in the case of LOCA.

0.3.1.3. Emergency power supplies

The power supply for components that have an F1 function are backed-up so that their functions are ensured in the event of loss of external power supplies.

0.3.1.4. Qualification for operating conditions

Those parts of the RIS/RRA [SIS/RHRS] that provide F1 or F2 functions must be qualified to remain operational in normal and post-accident conditions. The RIS/RRA [SIS/RHRS] system must be designed and qualified so that none of the accidents studied in Chapters 14 and 16 prevent the system from satisfactorily performing its safety functions. The forces caused by pressure waves, and the reaction forces resulting from rupture of an RIS/RRA [SIS/RHRS] injection line connection to the RCP [RCS] must be taken into account.

0.3.1.5. Mechanical, electrical instrumentation and control classifications

Mechanical, electrical and instrumentation and control classifications follow the rules described in Sub-chapter 3.2.

0.3.1.6. Seismic classification

To meet the safety requirements in terms of resistance to earthquakes, the RIS/RRA [SIS/RHRS] must be seismically classified, according to the classification presented in Sub-chapter 3.2.

0.3.1.7. Design and manufacturing provisions

With respect to system safety functions, all of the damage modes must be considered at the design stage, in particular, those relating to erosion, cavitation, vibration, and fatigue with local thermal-hydraulic type phenomena. For this purpose, operational feedback must be taken into account, particularly where this is related to the thermal fatigue phenomenon. In relation to cavitation, the RIS/RRA [SIS/RHRS] system is always filled with liquid (during normal and accident operations) to avoid air ingress. For this reason, there is no risk of gas ingress due to a connection with another gaseous system.

Furthermore, the RIS/RRA [SIS/RHRS] design must allow for the system to be fully inspected whilst in service.

0.3.2. Other statutory requirements

0.3.2.1. Basic Safety Rules

See Sub-chapter 1.4

0.3.2.2. Technical guidelines

RIS/RRA [SIS/RHRS] specific requirements are presented in the Technical Guidelines (Sub-chapter 3.1).

Furthermore, as the RIS/RRA [SIS/RHRS] is connected to the primary cooling system and penetrates the containment, it is designed and operated in accordance with Sub-chapter 3.1 of the Technical Guidelines so that its risk of failure leading to an accident sequence with containment bypass is "practically eliminated".

0.3.3. Internal and external hazards

0.3.3.1. Internal hazards

The RIS/RRA [SIS/RHRS], including the IRWST and the filtering system, must be protected against internal hazards, in accordance with the requirements presented in Sub-chapter 13.2.

0.3.3.2. External hazards

The RIS/RRA [SIS/RHRS], including the IRWST and the filtering system, must be protected against external hazards, in accordance with the requirements presented in Sub-chapter 13.1.

0.4. TESTS

0.4.1. Pre-operational tests

Pre-operational tests ensure the acceptability of the design and performance of the system.

0.4.2. Periodic tests and in-service inspection

This system must be designed to allow a visual periodic inspection of the main components.

The RIS/RRA [SIS/RHRS] must be designed to allow periodic tests to be carried out.

1. SAFETY INJECTION/RESIDUAL HEAT REMOVAL SYSTEM (EXCLUDING THE IRWST) [REF-1] TO [REF-4]

1.1. SYSTEM FUNCTIONS

In normal operating conditions, and in PCC-2 to PCC-4 conditions, the RIS/RRA [SIS/RHRS] provides the following operational functions:

1.1.1. During normal power plant operation

- Normal cooling.
  When decay heat removal by the secondary cooling system via the steam generators is no longer possible due to the primary cooling system temperature being too low for the steam generators to operate efficiently, the RIS/RRA [SIS/RHRS] trains continue to cool the RCP [RCS]. For cooling between 120°C (135°C if GCT [MSB] is not available) and 100°C, only two RRA [RHRS] trains are used (trains 1 and 4), the other trains (trains 2 and 3) are only used below 100°C .

- Controlling the primary coolant temperature during shutdown.
  During shutdown, the RIS/RRA [SIS/RHRS] trains in residual heat removal mode maintain the RCP [RCS] temperature within the authorised limits for refuelling and maintenance. This applies both to a completely full RCP [RCS] and for a reduced level of water in the primary coolant loops.

- Mixing of the RCP [RCS] coolant for a plant startup or shutdown.
  After shutdown of the reactor coolant pumps the RIS/RRA [SIS/RHRS] trains in residual heat removal mode ensure mixing of the RCP [RCS] coolant.

- Discharging coolant into the RCV [CVCS] (trains 3 and 4).
  The coolant is discharged using the RIS/RRA [SIS/RHRS] pumps for pressures lower than the RCV [CVCS] high pressure relief valve operating pressure.

- Filling the reactor cavity.
  Water is transferred from the in-containment refuelling water storage tank (IRWST) to the reactor cavity in preparation for refuelling operations.

- Heat removal during a ¾ loop operation.
  Heat is removed during a ¾ loop operation with three of the four RIS/RRA [SIS/RHRS] trains in residual heat removal mode to maintain a maximum RCP [RCS] temperature of 55°C.

- Cooling the IRWST.
  Cooling and mixing of the IRWST (if necessary) during normal plant operation.

- Filling the accumulators.
  Normal filling, or filling following a periodic test, of the four accumulators with borated water is carried out using the corresponding MHSI pump which draws water from the IRWST via a dedicated filling line for each train.

1.1.2. In PCC-2 to PCC-4 conditions and in RRC accidents

- Injecting boric acid into the core to control reactivity in the event of PCC-2 to PCC-4 events and in RRC accidents. This function is performed by:

  - the MHSI and LHSI systems which draw borated water from the IRWST, since the IRWST forms an integral part of the RIS/RRA [SIS/RHRS];

  - the RIS/RRA [SIS/RHRS] accumulators.

- Injecting water into the core to terminate draining and limit the maximum cladding temperature during LOCA (PCC-3, PCC-4 and RRC-A). The requirement is to ensure integrity of the first barrier, maintain the core geometry without deformation and maintain the core in a state in which it may be cooled. This function is carried out by the RIS/RRA [SIS/RHRS] pumps and accumulators.

- Providing a level in the loop that is compatible with the LHSI operation in decay heat removal mode in the case of a small break in the primary cooling system (PCC-3) or during a ¾ loop operation. This function is carried out by injecting water from the IRWST using the MHSI pumps at a reduced discharge head achieved by opening the pumps' high output minimum flow lines.

- Providing the LHSI makeup during total loss of the RRI [CCWS] (RRC-A accident) in cold shutdown mode with the vessel open.

- Removing the decay heat in bleed and feed mode using the MHSI and the pressuriser lines used for severe accident mitigation (in RRC-A accidents).

- Containing radioactive substances: the RIS/RRA [SIS/RHRS] in safety injection mode ensures recirculation of the primary coolant following an LOCA: the RIS/RRA [SIS/RHRS] therefore constitutes an extension of the third barrier. It allows the long-term production of steam to be limited, thus reducing the pressure increase in the containment. Operator action is required to isolate the RIS/RRA [SIS/RHRS] penetrations (in the event of passive failure). If a break occurs outside containment, in the LHSI pump hot leg suction line (LHSI in decay heat removal mode) in the safeguard building, the primary cooling system first and second isolation valves on the hot leg suction line will be automatically closed. This is initiated by the detection of water or high pressure in the safeguard building.

- Flooding the corium spreading compartment during an RRC-B severe accident (following passive opening of the flooding systems).

- Filtering all of the debris in the IRWST to ensure correct operation of the RIS/RRA [SIS/RHRS] and EVU [CHRS] components and to prevent blocking of the fuel assembly cooling channels.

- To limit the production and release of radioactive iodine in the event of a LOCA (PCC-4), a sodium hydroxide solution that allow to alkalinise the water of the IRWST, is manually injected by the RIS [SIS] by mean of a connection with the EVU [CHRS]. No automatism is implemented in order to prevent uncontrolled injections.

1.2. DESIGN BASIS

1.2.1. Applicable criteria

The criteria to be met are as follows:

- the system design meets the single failure criterion in accordance with the principles of Sub-chapter 3.2;

- the system is designed against the effects of internal and external hazards in accordance with the principles of Sub-chapters 13.1 and 13.2;

- the system is safety and seismically classified in accordance with the principles of Sub-chapter 3.2.

1.2.2. General assumptions for system design (see Chapter 14)

Safety injection following a small break, intermediate break or large break LOCA on the primary side

In a loss of coolant accident (PCC-3 and PCC-4), the role of the RIS/RRA [SIS/RHRS] is to limit the consequences of the accident by flooding and cooling the core. In conjunction with the RRI [CCWS] and the SEC [ESWS], the RIS/RRA [SIS/RHRS] heat exchangers (whilst meeting the single failure criterion), enable decay heat to be removed from the core, and therefore, from the containment.

Main data

- Temperature,
    - temperature of the RIS/RRA [SIS/RHRS] water in the IRWST (in safety injection mode) < 120°C,
    - the temperature of the RRI [CCWS] cooling the LHSI pumps and the heat exchangers of the trains in residual heat removal mode depends on the RRI [CCWS] design and heat sink temperature,
- Flow rate,
    - during an LOCA, the flow through the LHSI and MHSI injection lines into the RCS and through the LHSI and MHSI minimum flow lines to IRWST depends on the RCP [RCS] back pressure,
    - the RRI [CCWS] cools the RRA [RHRS] pumps and heat exchangers,
- Pressure,
    - the LHSI discharge pressure depends on the break size (for small break LOCA, it corresponds to the minimum flow pressure), and the MHSI discharge pressure depends on the primary coolant pressure.

The safety injection function is provided by the low and medium pressure injection systems and the accumulators.

Safety injection using the MHSI and the LHSI pumps starts simultaneously. The MHSI and LHSI pumps draw water from the IRWST. The MHSI and LHSI pumps and the accumulators inject water into the RCP [RCS] cold legs.

Following an intermediate break or large break LOCA, and when the latter is located in the cold leg, it is necessary to prevent boron precipitation in the core, and to terminate steam flow at the break within 1.5 hours. Consequently, additional injection into the hot legs is provided (operator action). For this injection, an alignment between the LHSI discharge lines and the RCP [RCS] hot legs is used.

The main requirements for the various break sizes are as follows (Chapter 14):

- Small break LOCA, Ø size ≤ 25 mm/5 cm^2 (PCC-3).
  The RIS/RRA [SIS/RHRS] operating in safety injection mode, in conjunction with automatic partial cooling on the secondary side, is capable of injecting sufficient borated water into the RCP [RCS] to limit drainage from the primary coolant loops (whilst allowing for a single failure, n+1).

- Small break LOCA, Ø size ≤50 mm/20 cm^2 (PCC-3).
  The RIS/RRA [SIS/RHRS] in safety injection mode, in conjunction with automatic partial cooling on the secondary side, is capable of injecting sufficient borated water into the RCP [RCS] to prevent core uncovery (whilst assuming the most onerous single failure together with the most onerous preventive maintenance state, n+2). A break size of 20 cm^2 (Ø = 50 mm) defines the limit between PCC-3 and PCC-4 events.

- Intermediate break and large break LOCA, Ø size > 50 mm/20 cm^2 and up to the largest RCP [RCS] connection line (PCC-4).
  The RIS/RRA [SIS/RHRS] in safety injection mode, in conjunction with automatic partial cooling on the secondary side, is able to inject sufficient borated water into the RCP [RCS] to limit the period which the core is uncovered such that the maximum cladding temperatures (peak rod) ≤ 900°C (whilst assuming the most adverse single failure together with the most onerous preventive maintenance state, n+2).

- 2A-LOCA (note that the 2A-LOCA is neither a PCC nor an RRC-A accident). In the event of 2A-LOCA, the RIS/RRA [SIS/RHRS] in safety injection mode (MHSI, LHSI and accumulators) is able to inject sufficient water to ensure core reflooding based on a best estimate calculation. The system is designed to inject sufficient cooled water to terminate the steam flow through the break in less than 1.5 hours.

Specific requirements for RIS/RRA [SIS/RHRS] ruptures during RRA [RHRS] operation (Chapter 14):

- A break results in a loss of primary coolant which, if not compensated for by normal makeup, results in safety injection starting (low ΔP_{sat} signal or low loop level) via the MHSI to prevent the core from becoming uncovered.
  Depending on the break size, degradation of the primary cooling system inventory may result in the automatic shutdown of the RRA [RHRS] pumps (LHSI).
  For breaks smaller than or equal to 50 mm diameter, the MHSI pumps may compensate for the loss of primary coolant. The LHSI pumps, initially functioning in residual heat removal mode, remain in service.

- For breaks between 50 and 250 mm diameter, the LHSI pumps, operating in residual heat removal mode, may be automatically shut down by a very low loop level signal to prevent vortex phenomena, or by a very low ΔP_{sat} signal to prevent pump cavitation.

- For breaks outside containment, it is essential to limit the discharge of radioactive primary coolant into the safeguard building. The RRA [RHRS] train in the division where the rupture is detected (by the presence of water or high pressure in certain safeguard building rooms) is automatically isolated in approximately 15 minutes for a break diameter ≥ 50 mm. For small breaks or when the RCP [RCS] temperature is less than 100°C, the high pressure signal is not generated; only the high water level signal in the sumps of safeguard building rooms initiates the isolation.

- For breaks inside containment, it is not possible to automatically identify the affected train, because the water from the break is collected in the IRWST, which is shared by the four RIS/RRA [SIS/RHRS] trains. The operator must therefore identify the affected train and isolate it, or isolate the four trains if the RRA [RHRS] pumps have been shut down automatically. The primary cooling system water inventory is then replenished using make-up from the MHSI pumps (high output minimum flow line opens).

- Then, depending on the break, the decay heat is removed:

  - by RRA [RHRS] trains remaining in operation,

  - by RRA [RHRS] trains that are available in a shutdown state but can be started by the operator,

  - possibly by RRA [RHRS] trains that shut down automatically and are then restarted by the operator.

Redundancy

Taking into account the results of safety injection system calculations, preventive maintenance of the LHSI and MHSI systems (with the exception of the accumulators, certain valves, certain pipes, the IRWST, etc.) may be performed during power operation whilst meeting the requirements for limiting the consequences of a small, intermediate or large break LOCA.

Safety injection following rupture of the main steam lines

During main steam line breaks (PCC-3 and PCC-4), the function of the MHSI trains is to borate the primary cooling system and prevent core uncovery as the primary coolant water volume contracts.

Safety injection following steam generator tube rupture

In the event of SGTR, the MHSI role is the same as for a small break LOCA, i.e. to inject borated water from the IRWST into the primary cooling system to maintain sufficient water inventory.

In order to minimise the risk of containment bypass during a SGTR (PCC-3), the maximum shut-off head of the MHSI pumps in minimum flow operation is lower than the set point for the main steam safety relief valves (MSSV), including uncertainties.

Makeup to the RCP [RCS] to ensure operation in residual heat removal mode following a small break LOCA

To allow the RIS/RRA [SIS/RHRS] to operate in residual heat removal mode following a small or intermediate break LOCA, the water level in the RCP [RCS] must be sufficiently high. The MHSI trains compensate for the break discharge and also monitor the RCP [RCS] level.

Change to a "safe shutdown" with decay heat removal via the RIS/RRA [SIS/RHRS] for a break size less than 20 cm^2 (Ø ≤ 50 mm)

The RIS/RRA [SIS/RHRS] is capable of maintaining RCP [RCS] conditions compatible with operation in a "safe shutdown" state. This state corresponds to the moment when the ASG [EFWS] tanks and SGs are empty (including the effect of the most onerous single failure together with the most onerous preventive maintenance of equipment, n+2). When connecting the RIS/RRA [SIS/RHRS], all of the MHSI pumps are assumed to be shutdown, with only the RIS/RRA [SIS/RHRS] providing injection into the RCP [RCS] during operation in residual heat removal mode. In that case, the compensation for the break flow may then be provided by the MHSI pumps with a reduced shut-off head by opening the high output minimum flow lines.

Cooling and mixing of the IRWST using the RRA [RHRS] trains

During a small or intermediate break LOCA, the LHSI minimum flow operation (when the primary coolant pressure is greater than the LHSI shut-off head) enables the temperature in the IRWST to be maintained below 120°C. The minimum flow from the LHSI pumps mixes the contents of the IRWST to prevent hot regions developing. This LHSI operating mode is also required during primary cooling bleed and feed operation.

Makeup following an RCP [RCS] break during shutdown or in ¾ loop operation

During unplanned drainage of the RCP [RCS] or small break LOCA during residual heat removal operations, makeup to the RCP [RCS] is provided by the MHSI pumps.

Under these circumstances, the MHSI pumps’ shut-off head is reduced by opening the high output minimum flow line before resuming the residual heat removal mode via the RIS/RRA [SIS/RHRS] (note that the low output minimum flow lines are permanently open).

The RCP [RCS] makeup provided by the MHSI depends on the number of primary coolant pumps that are in service and the size of the break.

For a small break LOCA, since the closing of the RCV [CVCS] relief line and the MHSI start-up are initiated sufficiently early, the RRA [RHRS] pumps continue to operate, such that the risk of loss of RIS/RRA [SIS/RHRS] is practically eliminated. The primary coolant pressure remains lower than approximately 40 bar.

1.2.3. Other design assumptions (Chapter 14)

1.2.3.1. Allowance for common mode failure

Loss of SG heat removal

In the event of total loss of SG heat removal capability, the RIS/RRA [SIS/RHRS] operating in safety injection mode, together with manual opening of the pressuriser discharge line, ensures injection of borated water from the IRWST which in turn ensures RCP [RCS] decay heat removal via bleed and feed operation.

Loss of the MHSI function in a small break LOCA

In the event of a small break LOCA with total loss of the MHSI function (multiple failures), the four accumulators and four LHSI trains, in conjunction with manual start-up of rapid cooling of the secondary side, are capable of ensuring injection of sufficient borated water to prevent core uncovery.

1.2.3.2. Taking a total loss of the cooling system into account

<u>Using LHSI pumps for RCP [RCS] make-up in state D</u>

For makeup in state D, e.g. in the event of total loss of the cooling system, the LHSI pumps of trains 1 and 4 are used. Consequently, the motors of these two LHSI pumps are provided with two cooling sources (diversification).

1.2.3.3. Operational functions

<u>RRA [RHRS] requirements</u>

The following conditions must be met by the RRA [RHRS] in order to perform the cooling function (three of the four RIS/RRA [SIS/RHRS] trains are used to remove the decay heat):

- Requirements for RRA [RHRS] connection

In normal cooling mode

- RCP [RCS] temperature ≤ 120°C for trains 1 and 4 (135°C if GCT [MSB] is not available), ≤ 100°C for trains 2 and 3

- RCP [RCS] pressure ≤ 32 bar

In cooling mode following an accident

- RCP [RCS] temperature ≤ 180°C

- RCP [RCS] pressure ≤ 32 bar

<u>*Cooling mode time*</u>

- During normal cooling, the RCP [RCS] is cooled from 303°C to 55°C within 16 hours. Cooling from 303°C to 120°C is provided by the secondary side (SG) for the first 10 hours and the RIS/RRA [SIS/RHRS], in residual heat removal mode, ensures that the RCP [RCS] can be cooled from 120 to 55°C within a further 6 hours.

- In transient or accident conditions, there is no time limit.

<u>*Cooling temperature gradient*</u>

- During normal cooling with the RRA [RHRS], the maximum permitted cooling rate is 50°C/hr.

<u>*Reactor Coolant Pumps operation during normal cooling*</u>

- When the RIS/RRA [SIS/RHRS] is operating in residual heat removal mode, two of the four reactor coolant pumps operate to mix the primary coolant. The RCP [RCS] temperature, when the reactor coolant pumps may be shut down during cooling, depends on the requirement to achieve a maximum vessel head metal temperature of 70°C, 16 hours after shutdown with an RCP [RCS] temperature lower than 55°C.

- When the RCP [RCS] temperature reaches 70°C the penultimate reactor coolant pump may be shutdown

- When the RCP [RCS] temperature reaches 55°C the last reactor coolant pump may be shutdown
- Decay heat to be removed:
  - o The decay heat depends on the time after reactor shutdown
  - o Specific heat is approximately 5900 MJ/K
  - o Power of each reactor coolant pump is approximately 10 MW (cold condition)
  - o Power of each LHSI pump is approximately 0.28 MW

RCP [RCS] temperature to be maintained during shutdown

- During shutdown, the RCP [RCS] temperature is maintained below 55°C by the RIS/RRA [SIS/RHRS] trains in residual heat removal mode.

Reduced water level inside the primary coolant loops

- The water level inside the primary coolant loops is reduced to approximately ¾ of the loop diameter.
- The water level and the pressure in the RCP [RCS] are reduced in order to carry out degassing of the primary coolant noble gases (caused by fuel leaks).

Note: if the activity limit requirements are not met, scavenging of the gaseous phase is required before the RCP [RCS] is opened for refuelling. This operation is only performed with a reduced water level.

Filling the accumulators

Normal filling (or filling following a periodic test) of the four accumulators with borated water is carried out using the corresponding MHSI pump, which draws water from the IRWST through a dedicated filling line for each train.

Filling the reactor cavities

Filling the pools in preparation for refuelling operations is carried out using the LHSI pumps, which draw water from the IRWST and inject it through the cold leg injection lines. It is also possible to fill the cavities via the hot leg injection lines. The filling process simultaneously performs a full flow rate test of the pumps.

In this operating mode, it is also possible to start the MHSI pumps to perform a full flow rate test and also to test the operability of the primary isolation check valves.

1.2.4. Controlling chemical characteristics

In normal plant shutdown mode, the RIS/RRA [SIS/RHRS] in residual heat removal mode ensures primary coolant circulation. The RCP [RCS] chemistry monitoring function is provided by the RCV [CVCS] purification/degassing system.

1.2.5. Design requirements for the RIS/RRA [SIS/RHRS] system

The tee downstream of the RIS/RRA [SIS/RHRS] heat exchanger is recognised as a region that could suffer damage from fatigue due to thermal striping, where flows of water at different temperatures mix. Design provisions address this concern (see section 1.6.1).

Note concerning gas ingestion in the system:

In residual heat removal mode and in safety injection mode, the RIS/RRA [SIS/RHRS] system is always filled with liquid (in normal and in accidental operations) and there is, therefore, no risk of gas ingestion due to a connection with another gaseous system.

- In Safety injection mode, the water level in the RIS [SIS] suction area (IRWST) is sufficient to avoid any vortex formation or any air ingestion, even assuming onerous conditions (pumps at maximum flow rate during recirculation phase following a LOCA).

- In residual heat removal mode, the system is supplied by RCP [RCS] and by IRWST (when the reactor cavity is being filled).

Thus, the RIS/RRA [SIS/RHRS] system has been designed to avoid a risk of gas locks in any operating mode.

1.3. DESCRIPTION

1.3.1. Functional Diagram

The RIS/RRA [SIS/RHRS] consists of four separate trains (one train for each loop) located in the four safety divisions. The RIS/RRA [SIS/RHRS] trains are designated as trains 1, 2, 3 and 4.

Simplified flow diagrams [Ref-3] of the RIS/RRA [SIS/RHRS] trains are shown in Sub-chapter 6.3 - Figure 1.

Location of an RIS/RRA [SIS/RHRS] train

An RIS/RRA [SIS/RHRS] train consists of the MHSI system, the accumulator injection system, the LHSI system, the MHSI/LHSI shared suction line from the IRWST and the suction line from the RCP [RCS] hot leg.

Medium head safety injection (MHSI)

The MHSI system consists of the following equipment: the MHSI pump, the suction line from the IRWST and the discharge line with a power-operated containment isolation valve located in the engineered safeguard building. Inside the containment, the discharge line is connected to the LHSI cold leg injection line between the LHSI train 1st and 2nd isolation check valves.

The high and low output minimum flow lines of the MHSI pump are connected upstream of the RCP [RCS] 2nd isolation check valve and return to the IRWST.

An accumulator filling line is connected upstream of the low output minimum flow line.

Accumulator safety injection

The accumulator safety injection system is located inside the containment and consists of an accumulator connected to the LHSI cold leg injection line. The accumulator is separated from the primary coolant loop by the 1st isolation check valve of the cold leg safety injection and by an isolation valve and a check valve specific to the accumulator.

Low head safety injection (LHSI)

The LHSI system consists of:

- the low head safety injection pump
- the low pressure heat exchanger
- the bypass for this exchanger with its control valve
- the suction line from the IRWST with a power-operated isolation valve
- the discharge line with the control valve and a power-operated electrical isolation valve downstream of the low pressure heat exchanger outside of the containment
- the valve located downstream the low pressure heat exchanger and the control valve is equipped with a travel stop and is partially closed in RIS [SIS] mode and opened in RRA [RHRS] mode. The function of this valve is to introduce head losses in RIS [SIS] mode
- the suction line in the RCP [RCS] hot leg with the first and second isolation valves inside the containment and a third isolation valve located in the engineered safeguard building.

The connection line between the LHSI discharge line and the suction line in the RCP [RCS] hot leg is used as a hot leg injection line for intermediate or large break LOCA. It also enables LHSI pump conditioning to be carried out before connection in residual heat removal mode.

Inside the containment, the LHSI consists of the cold leg injection line with three isolation valves (check valves). The intermediate check valves are diverse and the lines are instrumented to continuously monitor the leaktightness of the primary coolant system first isolation check valves. The MHSI injection lines are designed in a similar way.

The MHSI discharge line and the accumulator are connected between the LHSI cold leg injection line first and second isolation check valves. Upstream of the second isolation check valve, two minimum flow lines are connected to the IRWST. They are arranged tangentially and radially to the IRWST walls. In normal operation, the radial minimum flow line is used to enable the IRWST contents to be uniformly mixed. In an accident, only the tangential minimum flow lines are used to prevent turbulence close to the filtering systems during pump suction.

Because of uncertainties regarding the primary coolant pressure during the changeover from cold leg to hot leg injection using the LHSI pump, a minimum flow is required. The tangential minimum flow line is used for this operation. A low pressure containment isolation valve bypass is installed to maintain water flow in the minimum flow line from the pump even if injection into the hot leg is interrupted.

Trains 3 and 4 of the RRA [RHRS] are connected to the RCV [CVCS] low pressure relief line so that the primary coolant can be purified when the primary coolant pressure is not high enough to open up the relief line. The lines to the RCV [CVCS], upstream of the exchanger control valves and their bypass, are connected to a header, which is in turn connected to the RCV [CVCS].

The design of the RIS/RRA [SIS/RHRS] trains 1 and 2 is similar to the design of trains 3 and 4 except for the connection of the purification line to the RCV [CVCS].

Location of the spring-loaded pressure relief valves on the suction line

The spring-loaded pressure relief valves between the 2nd and 3rd isolation valves protect the hot leg suction line in the event of boiling and also protect the RRA [RHRS] against overpressure once the RRA [RHRS] is connected to the RCP [RCS] during cooldown. If primary coolant overpressure occurs whilst in these states, the spring-loaded pressure relief valves are required to open before the pressuriser relief valves. Their relief capacity is sufficient to maintain the pressure below the RRA [RHRS] design pressure [Ref-2].

1.3.2. Main equipment data [Ref-1] [Ref-2]

Each RIS/RRA [SIS/RHRS] train consists of the following equipment:

- a medium head safety injection pump (MHSI),
- a low head safety injection pump (LHSI),
- a low head safety injection heat exchanger,
- an accumulator.

Main data for MHSI pumps:

- Type: centrifugal horizontal
- Design basis Pressure/Temperature: 111 bar abs / 120°C
- Required flow rate: approximately 37.3 kg/s
- Head at the required flow rate: approximately 685 m
- Minimum flow rate: approximately 10 kg/s
- Head at the minimum flow rate: approximately 928 m
- NPSH required at the maximum flow rate: approximately 3.2 m
- Motor power: approximately 455 kW
- Voltage: 10 kV
- Rotational speed: approximately 2980 rpm

Main data for LHSI pumps:

- Type: centrifugal horizontal
- Design basis Pressure/Temperature: 81 bar abs/ 180°C
- Required flow rate: approximately 136.7 kg/s
- Head at the required flow rate: approximately 143 m
- Minimum flow rate: approximately 33 kg/s
- Head at the minimum flow rate: approximately 223 m
- NPSH required at the maximum flow rate: approximately 2.1 m
- Motor power: approximately 340 kW
- Voltage: 690 V
- Rotational speed: approximately 1480 rpm

Main data for RIS/RRA [LHSI/RHRS] heat exchangers:

- Type: heat exchanger with U-tubes
- Design basis Pressure/Temperature on tube side: 81 bar abs/180°C
- Design basis Pressure/Temperature on shell side (RRI [CCWS]): 14 bar abs/120°C
- LHSI flow rate (tube side):
    - During LB-LOCA (with minimum flow lines opened) approximately 180 kg/s
    - During RRA [RHRS] in operation (with minimum flow lines closed): approximately 150 kg/s
- During LHSI on minimum flow lines operation (for cooling the IRWST): approximately 40 kg/s
- RRI [CCWS] flow rate for trains 1 and 4 (shell side): approximately 376 kg/s
- RRI [CCWS] flow rate for trains 2 and 3 (shell side): approximately 276 kg/s
- Heat transfer coefficient: approximately 1.2 MW/K^{-1}

Accumulators:

- Design basis Pressure/Temperature: 56 bar abs /120°C
- Operating pressure: approximately 47 bar
- Operating temperature: approximately 50°C

- Volume of water (per accumulator): approximately 30 to 35 m^3
- Volume of gas (per accumulator): approximately 12 to 17 m^3
- Total Volume (per accumulator): approximately 47 m^3
- Head loss of injection line: between 1500 and 2700 m^{-4}

1.4. OPERATING CONDITIONS

1.4.1. System normal state

1.4.1.1. Definition of the normal state

During plant operation the RIS/RRA [SIS/RHRS] is normally on standby and filled with borated water.

1.4.1.2. Description of the normal state

Status of the system

The normal state is defined by the following conditions:

- no RIS/RRA [SIS/RHRS] trains are in operation. The RRI [CCWS] valves located on the cooling lines of the LHSI and MHSI pump motors are open, and those on the cooling lines of the RIS/RRA [SIS/RHRS] heat exchangers and the LHSI pump seals are closed. The RIS/RRA [SIS/RHRS] is isolated from the RCP [RCS]. The isolation valves at the base of the accumulators are open;
- all valves are in a position that allows safety injection, in particular, the isolation valves outside the containment on the LHSI and MHSI pump injection lines are open. The minimum flow lines (tangential for the LHSI and low output for the MHSI) are open. The three suction line isolation valves from the RCP [RCS] hot leg are closed. The isolation valve for the connection between the discharge side of the LHSI pump and the suction line to the RCP [RCS] hot leg is closed;
- The 1^{st} and 2^{nd} check valves of each LHSI injection line to the RCP [RCS] cold legs, the check valve of each MHSI connection to the LHSI injection line and the check valve of each accumulator connection to the LHSI injection line ensure their isolation.

Main data

- Temperature
    - o the water inside RIS/RRA [SIS/RHRS] is at ambient temperature
    - o between the 1st and 2nd isolation valves the coolant may be warmer due to heat input from the RCP [RCS]

- Flow rate
  - o no flow through the RIS/RRA [SIS/RHRS] lines.
  - o RRI [CCWS] is isolated from the LHSI heat exchangers but it supplies the RIS/RRA [SIS/RHRS] pumps.
- Pressure
  - o The accumulators are not isolated during the normal operation of the Unit, hence the pressure between the 1st and 2nd isolation valves is maintained at accumulator pressure. This provides an intermediate pressure area between the RCP [RCS] itself and the RIS/RRA [SIS/RHRS] at the shutdown state.

1.4.2. System established operating conditions

1.4.2.1. Definition of established operating conditions

The RIS/RRA [SIS/RHRS] established operating conditions are as follows:

- maintaining 55°C during refuelling (with fuel in the reactor vessel);
- assuring continuous water makeup in the safety injection mode;
- long-term heat removal and water makeup during LOCA.

1.4.2.2. Description of established operating conditions

<u>Maintaining 55°C during refuelling</u>

Status of the system

This state occurs during shutdown and before startup, and is defined by the following conditions:

- The RCP [RCS] is cooled down to the required temperature, with no reactor coolant pumps operating;
- Three of the four RIS/RRA [SIS/RHRS] trains are operating in residual heat removal mode and are connected to the RCP [RCS];
- All of the isolation valves taking suction from the RCP [RCS] hot leg are open for the active RIS/RRA [SIS/RHRS] trains The valves on the discharge lines (for all of the trains) are open and the IRWST isolation valves are closed for the RIS/RRA [SIS/RHRS] trains operating residual heat removal mode. The isolation valve on the line between the LHSI discharge and the RRA [RHRS] suction is closed;
- The isolation valve on the line taking suction from the IRWST is closed;
- The valves located on the purification line to the RCV [CVCS], connected to the heat exchanger bypass line of train 3 or 4, are open;
- The isolation valve in the line between each accumulator and its corresponding LHSI injection line, and the check valves of the LHSI pump minimum flow lines to

the IRWST for the trains in residual heat removal mode, are closed to prevent discharge of the accumulators and primary coolant into the IRWST;

- The control valves are adjusted to ensure an RCP [RCS] temperature < 55°C;
- The MHSI trains are on standby to compensate for a possible leak from the RCP [RCS];
- The isolation valves of the MHSI pump high output minimum flow lines are open to reduce the pressure downstream of the MHSI pumps to approximately 40 bar if the pumps are started.

Main data [Ref-1]

- Temperature
  - o for the RIS/RRA [SIS/RHRS] train in RHR operation, the water inside the RIS/RRA [SIS/RHRS] is approx. 55°C for the suction line, and lower than 55°C downstream of the heat exchanger
  - o for the RIS/RRA [SIS/RHRS] and MHSI trains on standby the water inside is at ambient temperature or IRWST temperature
  - o the RRI [CCWS] temperature for the cooling of the operating RIS/RRA [SIS/RHRS] pump and heat exchanger depends on the RRI [CCWS] design
- Flow rate
  - o only through the RIS/RRA [SIS/RHRS] train in operation, at a flow rate of approx. 150 kg/s, (minimum flow lines closed)
  - o RIS/RRA [SIS/RHRS] flow rate of approx. 120 kg/s during RCP [RCS] draining mode.
  - o RRI [CCWS] supplies the RIS/RRA [SIS/RHRS] pump and heat exchanger of the RIS/RRA [SIS/RHRS] train in RRA [RHRS] operation
- Pressure (absolute pressure)
  - o minimum RCP [RCS] pressure: approx. 0.8 bar_{abs} during shutdown, and approx. 0.2 bar_{abs} before startup
  - o the pressure at the LHSI discharge of the train in RRA [RHRS] operation corresponds to the full flow pressure
- RCP [RCS] Loop Level
  - o the level can be lowered to the ¾ loop level
- NPSH (net pressure suction head)
  - o during reduced water level operation during shutdown, the $NPSH_{available}$ on the LHSI/RRA [RHRS] pump suction side is approx. 8 m

Safety injection mode and long-term makeup

Status of the system

This state corresponds to a continuous makeup in the event of a small break LOCA, and a long-term continuous makeup irrespective of the size of the LOCA, and is defined by the following conditions:

- During a small break LOCA, the MHSI pumps inject into the RCP [RCS] and the LHSI pumps inject via their tangential minimum flow line into the IRWST, both pumps drawing water from the IRWST. The RRI [CCWS] cools the LHSI and MHSI pumps and the RIS/RRA [SIS/RHRS] heat exchangers. The accumulators are also able to discharge into the RCP [RCS] depending on the RCP [RCS] pressure;

- During long-term makeup, irrespective of the LOCA considered, the LHSI and MHSI pumps inject into the RCP [RCS], drawing water from the IRWST. The RRI [CCWS] cools the LHSI and MHSI pumps and the RIS/RRA [SIS/RHRS] heat exchangers;

- All valves are in a position which enables safety injection and the three isolation valves on the RCP [RCS] hot leg suction line for the RIS/RRA [SIS/RHRS] trains are closed;

- During long-term makeup following a LOCA, and in order to prevent boron precipitation and long-term steam flow from the break, the isolation valves on the hot leg injection lines (connection between the LHSI discharge line and the suction line in the RCP [RCS] hot leg outside of the containment) will be opened. In addition, the 1st and 2nd isolation valves on the suction line in the RCP [RCS] hot leg inside the containment will also be opened. This arrangement allows injection into the hot legs from the LHSI pumps. Injection into the cold legs is maintained by the MHSI pumps. The main isolation valve downstream of the control valves on the LHSI cold leg injection line is closed, since its bypass valve is opened to protect the pump.

- During long-term makeup following a LOCA, and in order to limit the production and the release of radioactive iodine, the IRWST is alkalinised by means of sodium hydroxide injection via a device belonging EVU [CHRS]. This device is connected at the level of each of the RIS/ISBP [SIS/LHSI] pumps via a driving line with motor-operated valves.

Main data [Ref-1]

- Temperature

    - o the water temperature inside the RIS/RRA [SIS/RHRS] corresponds to the IRWST temperature

    - o the RRI [CCWS] temperature for the cooling of the RIS [SIS] pumps and heat exchangers depends on the RRI [CCWS] design and heat sink temperature.

- Flow rate

    - o during SB(LOCA), flow is through the MHSI injection line into the RCP [RCS], and through the LHSI and MHSI minimum flow lines to the IRWST,

- o during long term makeup for all LOCA events, flow is through the MHSI and / or LHSI injection lines into the RCP [RCS], and through minimum flow lines to the IRWST,
- o RRI [CCWS] supplies cooling water to the RIS [SIS] pumps and heat exchangers.

- Pressure
  - o the pressure at the LHSI discharge corresponds to the minimum flow pressure during SB(LOCA), and the MHSI discharge pressure depends on the RCP [RCS] pressure,
  - o during long term makeup for all LOCA events, the MHSI and / or LHSI discharge pressure corresponds to the full flow pressure.

- NPSH
  - o assuming a conservative level of – 3.11 m for the IRWST during SB(LOCA) as the design basis for the RIS/RRA [SIS/RHRS] pumps, the $NPSH_{required}$ on the LHSI pump suction side is approx. 2.1 m, and the $NPSH_{required}$ on the MHSI pump suction side is approx. 3.2 m.

<u>Long-term heat removal and makeup in a small break LOCA</u>

Status of the system

This state corresponds to continuous heat removal and makeup in the long-term phase of a small LOCA, and is defined by the following conditions:

- In the short-term phase of a small break LOCA, the MHSI pumps inject into the RCP [RCS] and the LHSI pumps inject through their tangential minimum flow line into the IRWST whilst drawing water from the IRWST, the heat being removed by the secondary side;
- When the required RCP [RCS] makeup is satisfied by the MHSI pumps, the pressure is reduced by opening the MHSI pumps' high output minimum flow lines, the low output minimum flow lines remain permanently open;
- After approximately 5 hours, one or two RIS/RRA [SIS/RHRS] trains are switched to residual heat removal mode (one train is capable of removing the decay heat; the other available LHSI trains remain in RIS [SIS] injection mode to provide a sufficiently high water level in the RCP [RCS] for effective residual heat removal);
- The position of the RIS/RRA [SIS/RHRS] train valves aligned in injection mode remains the same as for the "safety injection mode and long-term makeup".

For the train(s) in residual heat removal mode

- All of the valves on the suction line from the RCP [RCS] hot leg and the valves on the discharge line are open, whilst the IRWST isolation valve and the power-operated check valves for the LHSI pump minimum flow lines to the IRWST are closed.

Main data [Ref-1]

- Temperature
  - The water temperature inside the LHSI trains which are in injection mode corresponds to the IRWST temperature.
  - The water temperature inside the RIS/RRA [SIS/RHRS] train in RHR mode corresponds to the RCP [RCS] temperature, i.e. a maximum of 180°C.
  - The RRI [CCWS] temperature for the cooling of the RIS [SIS] pumps and heat exchangers depends on the RRI [CCWS] design and heat sink temperature, i.e. a maximum of 45°C.
- Flow rate
  - During long-term makeup, the flow through the LHSI injection lines into the RCP [RCS] depends on the number of available LHSI trains and the characteristics of the break.
  - Flow through the RIS/RRA [SIS/RHRS] train in residual heat removal mode is approx. 150 kg/s.
  - The RRI [CCWS] supplies the RIS [SIS] pumps and heat exchangers.
- Pressure
  - During long-term makeup, the LHSI discharge pressure depends on the number of available LHSI trains and the characteristic of the break.
  - The pressure at the LHSI discharge in the operating RRA [RHRS] train corresponds to the full flow pressure plus RCP [RCS].
- NPSH
  - Assuming a minimum level of –3.11 m for the IRWST during SB (LOCA) as the design basis for the RIS [SIS] pumps, the $NPSH_{required}$ on the LHSI pump suction side shall not exceed 2.1 m at full flow rate.
  - There are no NPSH problems for the LHSI pump in RRA [RHRS] operation, due to the RCP [RCS] pressure and sufficient elevation head.

1.4.3. System transient states

1.4.3.1. Definition of transient states

The following transient states apply to the RIS/RRA [SIS/RHRS]:

- normal steam generator cooling from 120°C to 55°C;
- normal steam generator startup from < 55°C to 120°C;

- filling the accumulators or compensating for an accumulator leak using the MHSI pumps;
- filling the reactor cavities using the LHSI and MHSI pumps;
- cooling and mixing of the IRWST contents using the LHSI pumps;
- continuous makeup using the MHSI trains in the event of unscheduled drainage or small break LOCA during shutdown;
- bleed and feed operation with IRSWT cooling using the LHSI pumps.

1.4.3.2. Description of transient states

Normal steam generator cooling

Status of the system

This state consists of two phases to minimise the consequences of a high energy rupture outside containment. During the first phase (RCP [RCS] temperature ≥ 100°C), only the RIS/RRA [SIS/RHRS] trains in divisions 1 and 4 operate in residual heat removal mode, whereas during the second phase (RCP [RCS] temperature ≤ 100°C), all the trains are used in residual heat removal mode. The RRI [CCWS] cools the RIS/RRA [SIS/RHRS] pumps and heat exchangers for the trains in residual heat removal mode.

- a maximum of two reactor coolant pumps are operating;
- the valve state is identical to that specified in section 1.4.2 (maintaining 55°C when refuelling).

Main data [Ref-1]

- Temperature
  - o RIS [SIS] water temperature < 120°C for the operating RIS/RRA [SIS/RHRS] train,
  - o the RRI [CCWS] temperature for the cooling of the LHSI/RHR pumps and heat exchangers in the operating RRA [RHRS] trains depends on the RRI [CCWS] design.
- Flow rate
  - o only through the operating RIS/RRA [SIS/RHRS] train, with a flow rate of 150 kg/s, (minimum flow line closed),
  - o the RRI [CCWS] supplies the LHSI/RRA [RHRS] pumps and heat exchanger in the operating RRA [RHRS] trains.
- Pressure
  - o RCP [RCS] pressure ≤ 32 bar,

- o the pressure at the RIS/RRA [SIS/RHRS] discharge side of the operating RRA [RHRS] train corresponds to the full flow pressure plus RCP [RCS] pressure.

- NPSH
  - o During 3/4 loop level operation at the end of cooldown, the $NPSH_{available}$ on the LHSI/RRA [RHRS] pump suction side is approx. 8 m.

<u>Normal steam generator startup</u>

Status of the system

This state is defined by the following conditions:

- At least, two of the four RIS/RRA [SIS/RHRS] trains are operating and are connected to the RCP [RCS] to ensure mixing of the primary coolant boron and heat removal;
- For the operating RIS/RRA [SIS/RHRS] trains, the valve state is identical to that specified in section 1.4.2 (maintaining 55°C during refuelling).

Main data [Ref-1]

- Temperature
  - o RIS/RRA [SIS/RHRS] water temperature ≤ 120°C (valid for trains 1 and 4) and ≤ 100°C (valid for trains 2 and 3)
  - o the RRI [CCWS] temperature for the cooling of the LHSI/RHR pumps and heat exchangers in the operating RRA [RHRS] trains depends on the RRI [CCWS] design. However it will be much lower than the permissible temperature since there is little heat to remove.
- Flow rate
  - o RIS/RRA [SIS/RHRS] flow rate of approx. 150 kg/s.
- Pressure
  - o RCP [RCS] pressure ≤ 32 bar,
  - o RIS/RRA [SIS/RHRS] pressure less than 44 bar.

<u>Filling the accumulators or compensating for an accumulator leak</u>

Status of the system

This state corresponds to unit startup if the accumulators were undergoing maintenance or inspection (filling the accumulators), or during normal operation (compensating for a leak), and is defined by the following conditions:

- The RIS/RRA [SIS/RHRS] is isolated from the RCP [RCS], the RRI [CCWS] cools the RIS [SIS] pumps and only the dedicated MHSI train(s) is/are operating;

- All the valves are in a position which allows safety injection, and the three isolation valves on the RCP [RCS] hot leg suction line of the RIS/RRA [SIS/RHRS] trains are closed;
- As described for the state in section 1.4.1 (normal state), the primary isolation check valves on the cold leg injection line are closed. For an un-pressurised RCP [RCS], one of the primary isolation check valves where the accumulator is filled and the accumulator isolation valves, are locked in the closed position

Main data [Ref-1]

- Temperature
  - o the water in the RIS/RRA [SIS/RHRS] is at ambient temperature,
  - o the RRI [CCWS] temperature for the cooling of the MHSI pumps depends on the RRI [CCWS] design.
- Flow rate
  - o flow only through the accumulator filling line and MHSI minimum flow line,
  - o RRI [CCWS] can be isolated from the LHSI heat exchangers (depending on RRI [CCWS] operation mode), but supplies the RIS [SIS] pumps.
- Pressure
  - o the pressure on the MHSI discharge side depends on the accumulator pressure and on the throttle design.

<u>Filling the reactor cavities</u>

Status of the system

This state may correspond to two phases during a shutdown; before fuel unloading and before fuel reloading, with the following limiting conditions:

- Depending on the RIS/RRA [SIS/RHRS] train operating mode, before fuel unloading one or two LHSI trains may fill the cavities at the same time by drawing water from the IRWST and by injecting into the primary cooling system cold legs;
- Depending on maintenance of the electrical trains, the LHSI pumps are also used to fill the cavities before fuel reloading. These pumps carry out a full flow test at the same time, whilst the RRI [CCWS] cools the RIS/RRA [SIS/RHRS] pumps and heat exchangers;
- Full flow tests may be performed by injecting the MHSI pumps into the RCP [RCS], Operability tests of the primary isolation check valves may also be carried out during this phase;
- For RIS/RRA [SIS/RHRS] trains which are in operation in RHR mode, the three isolation valves in the RCP [RCS] hot leg suction line are opened. For RIS/RRA [SIS/RHRS] trains ensuring the reactor cavities filling, these isolation valves are closed and the isolation valves from the IRWST are opened.

Main data [Ref-1]

- Temperature
  - o the water in the RIS/RRA [SIS/RHRS] is at ambient or at IRWST temperature,
  - o the RRI [CCWS] temperature for the cooling of the RIS [SIS] pumps and heat exchangers depends on the RRI [CCWS] design.
- Flow rate
  - o full flow through the LHSI lines to RCP [RCS], the minimum flow lines are open,
  - o RRI [CCWS] supplies the LHSI pumps and LHSI heat exchangers.
  - o full flow through the MHSI lines to RCP [RCS].
- Pressure
  - o the pressure at the LHSI discharge corresponds to the full flow pressure,
- NPSH
  - o there is sufficient NPSH for the LHSI and MHSI pumps, due to the low temperature and to adequate elevation head.

<u>Cooling and mixing of the IRWST contents</u>

Status of the system

This state corresponds to normal plant operation, mainly during periodic tests of the RIS [SIS] pumps, during LOCA, in bleed and feed mode, or to ensure mixing of the IRWST boron concentration and to obtain a uniform water temperature, with the following conditions:

- During periodic tests, the LHSI and MHSI pumps inject through their specific minimum flow lines into the IRWST (radial and tangential minimum flow lines for the LHSI), drawing water from the IRWST, whilst the RRI [CCWS] cools the RIS/RRA [SIS/RHRS] pumps and heat exchangers; the RIS/RRA [SIS/RHRS] is isolated from the RCP [RCS] by the two primary isolation check valves and by the three isolation valves on the RCP [RCS] hot leg suction line;
- During small break LOCA, or in bleed and feed mode, the MHSI pumps inject into the RCP [RCS] and the LHSI pumps operate on their minimum flow line (tangential), whilst the RRI [CCWS] cools the RIS/RRA [SIS/RHRS] pumps and heat exchangers;
- All the valves are in a position which allows safety injection and the three isolation valves on the RCP [RCS] hot leg suction line are closed.

Main data [Ref-1]

- Temperature
  - o the water inside the RIS/RRA [SIS/RHRS] is at ambient temperature. During SB(LOCA) or feed and bleed operation, the RIS/RRA [SIS/RHRS] water temperature will rise as the IRWST temperature increase,
  - o the RRI [CCWS] temperature for the cooling of the RIS/RRA [SIS/RHRS] pumps and heat exchangers depends on the RRI [CCWS] design.
- Flow rate
  - o flow through the LHSI and / or MHSI minimum flow lines to IRWST, and during SB(LOCA) or feed and bleed operation, through the MHSI injection line into the RCP [RCS],
  - o RRI [CCWS] supplies the RIS [SIS] pumps and heat exchangers.
- Pressure
  - o the pressure at the LHSI and / or MHSI discharge corresponds to the minimum flow pressure when performing periodic tests. During SB(LOCA) or feed and bleed operation, the MHSI discharge pressure depends on the RCP [RCS] pressure.
- NPSH
  - o for periodic tests or IRWST boron concentration and temperature monitoring, the IRWST is full and so there are no NPSH problems for the RIS [SIS] pumps. During SB(LOCA), see section 1.4.2 ("Safety injection mode and long term makeup") for the NPSH values.

<u>Continuous makeup during unscheduled drainage or a small break LOCA during shutdown using the MHSI trains</u>

Status of the system

This state corresponds to low water level in the primary coolant loops during shutdown with the following conditions:

- This state is identical to that specified in section 1.4.2 (maintaining 55°C during refuelling), and section 1.4.3 (normal power plant cooling). During unscheduled drainage of the RCP [RCS] or a small break LOCA during residual heat removal mode operation, makeup of the RCP [RCS] level is provided by the MHSI pumps. For this reason, the MHSI pump discharge head is reduced by opening the high output minimum flow line when changing to residual heat removal mode. The MHSI pumps draw water from the IRWST and inject it into the RCP [RCS] over a pressure range lower than the pressure relief valve opening pressure for the primary cooling system and the RIS/RRA [SIS/RHRS] trains. Provided the LHSI pump suction conditions are satisfactory, these pumps continue to operate in residual heat removal mode. Otherwise, they are automatically shut down to prevent them from being damaged. The RRI [CCWS] cools the RIS/RRA [SIS/RHRS] pumps and heat exchangers;

- The valve state is identical to that specified in section 1.4.2 (maintaining 55°C when refuelling).

Main data [Ref-1]

- Temperature
    - Normally, the RIS/RRA [SIS/RHRS] water temperature is ≤ 120°C for the RIS/RRA [SIS/RHRS] operating RRA [RHRS] train, depending on RCP [RCS] temperature. For the RIS [SIS] trains on standby, the temperature depends on the IRWST temperature;
    - the RRI [CCWS] temperature for the cooling of the RIS [SIS] pumps and heat exchangers, depends on the RRI [CCWS] design and heat sink temperature.
- Flow rate
    - through the RIS/RRA [SIS/RHRS] trains in RRA [RHRS] operation, the flow depends on the number of MHSI trains that are started and on the characteristics of the break and/or the letdown line. Including the large minimum flow the entire MHSI flow will be less than 249 m^3/h.
    - RRI [CCWS] supplies the RIS [SIS] pumps and heat exchangers in each of the 4 trains.
- Pressure
    - RCP [RCS] pressure: between 32 bar and 1 bar abs,
    - the pressure at the discharge of the RIS/RRA [SIS/RHRS] trains in RRA [RHRS] operation, corresponds to the full flow pressure, i.e. suction pressure plus the delivery head of the LHSI pump.
    - the pressure at the discharge side of the MHSI trains which are in makeup operation, will be lower than 43 bar.
- NPSH
    - There are no NPSH problems for the MHSI pumps, due to the low temperature and the adequate elevation head.

<u>Bleed and feed with IRWST cooling by the LHSI</u>

Status of the system

This state corresponds to bleed and feed operation, with RCP [RCS] makeup provided by the MHSI pumps and discharge from the pressuriser discharge line. At the same time the IRWST is cooled by the LHSI pumps. This state has the following conditions:

- The MHSI pumps inject into the RCP [RCS] and the LHSI pumps inject via their tangential minimum flow line into the IRWST, both drawing water from the IRWST. The RRI [CCWS] cools the RIS/RRA [SIS/RHRS] pumps and heat exchangers;

- All valves are in a position which allows safety injection and the three isolation valves on the RCP [RCS] hot leg suction line for the RIS/RRA [SIS/RHRS] are closed.

Main data [Ref-1]

- Temperature
  - o the water temperature inside the RIS/RRA [SIS/RHRS] corresponds to the IRWST temperature,
  - o the RRI [CCWS] temperature for the cooling of the RIS/RRA [SIS/RHRS] pumps and heat exchangers depends on the RRI [CCWS] design and heat sink temperature.
- Flow rate
  - o flow through the MHSI injection line into the RCP [RCS], and through the LHSI and MHSI minimum flow lines to IRWST,
  - o RRI [CCWS] supplies the RIS [SIS] pumps and RIS/RRA [SIS/RHRS] heat exchangers.
- Pressure
  - o the pressure at the LHSI discharge corresponds to the minimum flow pressure, and the MHSI discharge pressure depends on the RCP [RCS] pressure.
- NPSH
  - o The IRWST is full, so there are no NPSH problems for the RIS/RRA [SIS/RHRS] pumps.

1.4.4. System startup and shutdown

1.4.4.1. Startup of an RIS/RRA [SIS/RHRS] train

The RIS/RRA [SIS/RHRS] trains are started manually, to fill the accumulators, to compensate for leaks, to fill the reactor cavities for the periodic tests, and for monitoring of the IRWST boron concentration or temperature.

For decay heat removal operations the RIS/RRA [SIS/RHRS] trains are also started manually.

For safety injection duty, the RIS/RRA [SIS/RHRS] pumps are automatically started by a Safety Injection Signal. The MHSI pumps are also started automatically following loss of the RCP [RCS] loop level (makeup in residual heat removal mode).

1.4.4.2. Startup of an RIS/RRA [SIS/RHRS] train for operation in residual heat removal mode

The RIS/RRA [SIS/RHRS] trains are used if the specified conditions in the RCP [RCS] (temperature ≤ 120°C, pressure ≤ 32 bar for trains 1 and 4, and temperature ≤ 100°C for all trains) are met.

Boron concentration

The RIS/RRA [SIS/RHRS] boron concentration is adequate for all operating modes because the RIS/RRA [SIS/RHRS] is filled with borated water from the IRWST.

However, before starting up the RIS/RRA [SIS/RHRS] train, during secondary cooling when the primary coolant pressure is still greater than 50 bar, mixing of the boron is ensured by mixing the IRWST and RIS/RRA [SIS/RHRS] fluids using the LHSI pumps operating on the minimum flow line. The boron concentration is checked by REN [NSS] sampling.

Conditioning and heating of the RIS/RRA [SIS/RHRS] train

Pressure conditioning

- Pressure conditioning is performed in several successive stages: connecting to the RCV [CVCS] by opening the pressure balancing lines on the injection lines, opening the hot leg suction line valves (the connection to the RCV [CVCS] is then no more used), operating the LHSI pumps in closed circuit and then connecting to the primary cooling system.

Heating

- Temperature of the RIS/RRA [SIS/RHRS] water before heating must be at least 15°C. Most of the coolant inside the RIS/RRA [SIS/RHRS] trains is at room temperature. The coolant inside the heat exchanger may be at the RRI [CCWS] cold temperature.

Thermal conditioning

If thermal conditioning is required, then the RIS/RRA [SIS/RHRS] trains are conditioned in two stages:

- In the 1st stage, the containment isolation valve downstream of the heat exchanger is closed. The bypass valve and the isolation valve on the connection line between the LHSI discharge and RRA [RHRS] suction are open. The injection line in the hot leg and the third isolation valve on the RCP [RCS] hot leg suction line are opened. The IRWST isolation valve is opened to evacuate the expansion fluid. The LHSI pump is started and the contents of the part of the system which is outside containment are mixed and heated by the pump.

- In the 2nd stage, the RIS/RRA [SIS/RHRS] heated fluid is injected at a limited rate into the RCP [RCS] to prevent unacceptable thermal shocks at the connection. Prior to this, hydrazine is injected by the RCV [CVCS] to capture the dissolved oxygen to protect the RCP [RCS] (and particularly the pressuriser) from corrosion. In this 2nd stage, the isolation valve in the injection line into the hot leg is closed; the 1st and 2nd isolation valves in the RCP [RCS] hot leg suction line, the containment isolation valve downstream of the heat exchanger, its bypass valve and the control valve downstream of the exchanger are opened at the same time. Thus, the minimum temperature experienced by the injection connections is the ambient temperature, and the maximum is the mixed temperature of the primary coolant and the water in the leg of the injection line.

The temperature of the injected flow is monitored downstream of the heat exchanger and at the cold leg injection line.

Significant thermal stresses on the connections of the main cooling lines and on the RIS/RRA [SIS/RHRS] equipment are therefore avoided.

1.4.4.3. Shutdown of an RIS/RRA [SIS/RHRS] train

When the system is operating in RIS [SIS] mode, there is no automatic shutdown of the LHSI and MHSI pumps.

In residual heat removal mode, automatic shutdown of the LHSI pumps is provided in order to ensure availability of the cooling function over the long-term in the event of degradation of the hot leg suction conditions (low ΔP_{sat} signal or very low loop level).

The LHSI and MHSI pumps will also shut down automatically on equipment protection criteria such as bearing temperature, mechanical seal temperature, pressure at the level of the mechanical seal, and motor air temperature.

The following steps are taken to manually shutdown a RIS/RRA [SIS/RHRS] train following operation in residual heat removal mode:

- the LHSI pumps are shutdown,
- the three isolation valves in the RCP [RCS] hot leg suction line are closed,
- the IRWST valves are opened,
- the isolation valve of the LHSI tangential minimum flow line to the IRWST is opened,
- the isolation valves of the purification lines (trains 3 and 4 only) are closed,
- depending on the steam generator state and the RIS/RRA [SIS/RHRS] operating mode, the MHSI high output minimum flow line isolation valve may or may not be closed, since the low output minimum flow line is always open,
- the RRI [CCWS] is isolated at the RIS/RRA [SIS/RHRS] heat exchanger and at the LHSI pump mechanical seals.

1.4.5. Other system operating conditions

1.4.5.1. Definition of other operating conditions

Other RIS/RRA [SIS/RHRS] operating conditions are as follows:

- performing periodic tests via the MHSI and LHSI pump minimum flow lines (low or high output) to the IRWST;
- shutdown following loss of normal power supplies during operation in residual heat removal mode;

1.4.5.2. Description of the other operating conditions

Periodic functional tests

Status of the system

This state corresponds to normal plant operation, with the following conditions:

- the LHSI and MHSI pumps inject via dedicated minimum flow lines into the IRWST (low and high output for the MHSI), drawing water from the IRWST, whilst the RRI [CCWS] cools the LHSI and MHSI pumps and the RIS/RRA [SIS/RHRS] is isolated from the RCP [RCS];
- all of the valves are in a position which allows safety injection and the three isolation valves on the RCP [RCS] hot leg suction line are closed;
- as described for the normal state in section 1.4.3, the check valves ensure the isolation function, with the exception of those of the LHSI and MHSI minimum flow lines.

Main data [Ref-1]

- Temperature
  - o the water temperature inside the RIS/RRA [SIS/RHRS] corresponds to the IRWST temperature,
  - o the RRI [CCWS] temperature for the cooling of the RIS/RRA [SIS/RHRS] pumps and heat exchangers depends on the RRI [CCWS] design.
- Flow rate
  - o flow through LHSI and MHSI minimum flow lines to IRWST,
  - o RRI [CCWS] supplies the RIS/RRA [SIS/RHRS] pumps (and heat exchangers).
- Pressure
  - o the pressure at the LHSI discharge corresponds to the minimum flow pressure.

- NPSH
    - o The IRWST is full, so there are no NPSH problems for the RIS/RRA [SIS/RHRS] pumps.

Shutdown following loss of normal power supplies during residual heat removal mode operation

Each RIS/RRA [SIS/RHRS] train is supplied by a power busbar allocated to the corresponding emergency diesel generator set. Following loss of normal power supplies in residual heat removal mode, the RIS/RRA [SIS/RHRS] trains that operated before the power loss are offloaded automatically and restored using the emergency diesel generators.

An automatic action is required because the operator manual action time would be unacceptably long.

1.5. BRIEF DESCRIPTION OF SAFETY FUNCTIONS (INSTRUMENTATION AND CONTROL)

1.5.1. General design

The RIS/RRA [SIS/RHRS] consists of four trains which are allocated to divisions 1 to 4.

The components supplied by electrical power by each train:

- LHSI and MHSI pumps,
- power-operated valves,

are provided from a power supply dedicated to the allocated division.

Following a LOOP, these supplies are backed-up by the main diesel generator sets. The MHSI pumps are supplied at 10 kV, and the LHSI pumps at 690 V.

The RIS/RRA [SIS/RHRS] trains are monitored from the Main Control Room. The electrical equipment is allocated to engineered safeguard buildings 1 to 4.

Protection

The monitoring of protection for equipments belonging to the RIS/RRA [SIS/RHRS] trains is based on the following:

- A temperature or pressure increase between the CPP [RCPB] isolation valves caused by leaks from the RCP [RCS] (system on standby, RRA [RHRS] not connected);
- A pressure increase inside the RCP [RCS] during an operation in residual heat removal mode;
- The IRWST level measurement (under MIN3, LHSI and MHSI pumps are stopped if the SI signal is not present)
- Protection of the equipment: the seal water, bearing, motor oil, motor winding and air temperatures are monitored for as long as they remain available;

- Prevention of unacceptable pump operating conditions (e.g. pump suction saturation pressure too low or a hot leg water level too low in ¾ loop operation).

The detection of abnormal conditions automatically generates signals which are used to protect the equipment and alarms which warn the operator.

1.5.2. Actuator control logic

The RIS/RRA [SIS/RHRS] pumps are:

- automatically started by a safety injection signal when demanded in an accident;
- automatically shut down by an emergency power supply signal;
- manually started for a test, and in the case of the LHSI pumps, they are also required for filling the reactor cavities or cooling the IRWST, in RRA [RHRS] operating mode;
- the MHSI pumps are automatically started following loss of level in the RCP [RCS] in residual heat removal mode;
- the RIS/RRA [SIS/RHRS] pumps are restored following a LOOP if they were already in RIS [SIS] or residual heat removal mode before the shutdown;
- two of the LHSI pumps (belonging to trains 1 and 4) are manually started following total loss of cooling water in state D;
- the LHSI pumps in residual heat removal mode are shut down on a very low level signal in the loops or a very low ΔP_{sat} signal;
- the pumps are shut down for their protection (protection of the equipment) unless they are started up by the control system or the reactor protection system (RPR [PS]].

The following valves are operated:

- during a LOCA, the power-operated valves on the injection lines receive open signals, with the exception of the isolation valve on the hot leg injection line which is closed;
- in residual heat removal mode, there is a permissive signal which prohibits the 1st and 2nd isolation valves of the RCP [RCS] hot leg suction line from being opened if the primary coolant pressure or the RCP [RCS] temperature exceeds the permitted values;
- manual adjustment (by operator) of the control valve downstream of the RIS/RRA [SIS/RHRS] heat exchangers in residual heat removal mode (RCP [RCS] under vacuum);
- automatic "closing" (F1A) of the 1st and 2nd isolation valves on the RCP [RCS] hot leg suction line following pipe rupture outside the containment in residual heat removal mode.

1.5.3. Control operations

When the primary coolant temperature reaches 120°C, the RCP [RCS] is cooled by the RRA [RHRS] using the control valve downstream of the RIS/RRA [SIS/RHRS] heat exchanger and the control valve in the heat exchanger bypass. The flow rate for RIS/RRA [SIS/RHRS] trains 1 to 4 is maintained at a constant level during the cooling operation using the bypass regulating valves.

The RCP [RCS] cooling rate is controlled using dedicated temperature controls for the RRA [RHRS] trains. This involves a regulation loop defined on the minimal value between the temperature wide range (hot and cold legs) as the actual value and the injection temperature as the desired value.

The four temperature controls are activated via a main controller. This controller generates a reference cooldown gradient, which takes into account the initial gradient required by operator and the actual RCP [RCS] temperature.

1.5.4. Controls that are accessible to the operator

The control room screens display the electrical actuators that may be activated by the operator. The RIS/RRA [SIS/RHRS] control valves are equipped with a position indicator, so that the flow rate may be easily monitored.

1.5.5. Information that is accessible to the operator

During normal power operation, the manual and electrical valves are in the required position for safety injection. An incorrect electrical valve position is indicated in the Main Control Room as an "incorrect alignment" signal.

Required information on the state of the equipment, such as the level in the IRWST, the pressure and the level in the accumulators and the RCP [RCS] is available.

1.5.6. The system operating principles

The RIS/RRA [SIS/RHRS] operating modes are described in section 1.4. The system is automatically or manually started from the Main Control Room.

1.5.7. Analysis of a loss of power supply or loss of the Main Control Room

During a LOOP the system continues to function in the long term as in normal operation because the most important electrical equipment is provided with an emergency power supply. In safety injection mode the RIS [SIS] pumps are initially shut down by the emergency power supply signal, then restarted according to the diesel generator set restoration sequence.

In the event of loss of the Main Control Room, the operator may operate and monitor the RIS/RRA [SIS/RHRS] pumps as well as all the corresponding valves from the remote shutdown station in the same way as from the Main Control Room.

1.6. SAFETY EVALUATION

1.6.1. Meeting the criteria, classification and consequences of a failure

Meeting the applicable criteria is described in detail below.

1.6.1.1. Ambient conditions

For the RIS/RRA [SIS/RHRS] F1 equipment, ambient conditions such as irradiation, humidity, temperature and pressure resulting from the design conditions are taken into account. The design conditions are dependent on the location of the equipment e.g. in the reactor building or the safeguard building.

Irradiation

The total dose expected over the lifetime of the RIS/RRA [SIS/RHRS] equipment (components, actuators, cables, etc.) resulting from normal power plant operation and internal hazards is taken into account in the design.

Humidity

The humidity conditions are taken into account in the design of safety-related RIS/RRA [SIS/RHRS] equipment.

Temperature

The temperature conditions are taken into account in the design of safety-related RIS/RRA [SIS/RHRS] equipment.

Pressure

The pressure conditions are taken into account in the design of safety-related RIS/RRA [SIS/RHRS] equipment.

1.6.1.2. Single failure criterion

The RIS/RRA [SIS/RHRS] is designed to perform its function in all power plant states assuming loss of one of the four trains due to a short-term active single failure. This single failure may occur in the RIS/RRA [SIS/RHRS] itself or in one of the safety classified support systems (cooling system, emergency power supplies). A passive single failure is assumed over the long-term (more than 24 hrs).

Number of trains

The RIS/RRA [SIS/RHRS] consists of four 100% mechanical trains. These trains are redundant and each RIS/RRA [SIS/RHRS] train is supplied by a separate electrical system and cooled by a separate RRI [CCWS] train.

Segregation of the trains

The four RIS/RRA [SIS/RHRS] trains are structurally separated from one another. No connections are made between the four RIS/RRA [SIS/RHRS] trains.

Automatic shutdown of the LHSI in residual heat removal mode

Application of the single failure criterion to the automatic shutdown of the RRA [RHRS] pumps results in the shutdown of at least three of the four pumps (Chapter 14).

1.6.1.3. Containment isolation

The two main functions of the RIS/RRA [SIS/RHRS] are:

- to inject water into the RCP [RCS] (safety injection function),
- to remove the core decay heat when the steam generators are no longer available (RRA [RHRS] function),

Simultaneous automatic isolation of the containment penetrations is not provided for this system. However, in the event of a break in the RIS/RRA [SIS/RHRS] system outside containment, compliance with the containment isolation requirement (discussed in section 0.3.2.3) is ensured by the following isolation provisions:

- the part of the system connected to the RCP [RCS] hot leg is isolated from the break by automatically closing two valves in the affected train inside containment on receipt of a water level signal or possibly a high pressure signal in the safeguard building. This signal also shuts down the RRA [RHRS] pump in the affected division. The signal is based on 2 out of 4 logic to reduce the likelihood of spurious actuation and to allow for a single failure. The signals are derived from the following measurements in each division of the safeguard building:
  - four pressure measuring points (differential pressure measurements between the safeguard building rooms and the exterior) that are sufficiently accurate to rapidly detect a pressure increase;
  - four suitable level measurements (capacitive measurement) that can detect a water level increase in the safeguard building sumps. Each sensor is installed in a different room to ensure physical separation between 4 redundant sensors. This limits the risk of a spurious event and common mode failure of level sensors which could be caused by the local consequences of the break (pipe whip, steam jet). The level sensors are distributed so as to detect a leak with a minimum volume of $9m^3$;
- the part of the system connected to the RCP [RCS] cold leg is isolated from the break by closing check valves located inside containment in the low pressure injection line and medium pressure injection lines. The provision of three check valves in series in each RIS [SIS] low pressure and medium pressure injection line complies with the requirements discussed in section 0.2.3.

The external containment valves may be manually isolated to ensure containment integrity.

1.6.1.4. Isolation of the primary cooling system

For each RIS/RRA [SIS/RHRS] injection line, RCP [RCS] isolation is provided by two check valves.

RCP [RCS] isolation on the hot leg suction line is provided by two isolation valves. These valves are closed during normal operation.

1.6.1.5. System start-up and shutdown requirements in terms of safety

During normal plant operation and when the RIS/RRA [SIS/RHRS] is on standby, the valves in the injection lines and the IRWST suction lines of each of the four RIS/RRA [SIS/RHRS] trains are in the injection position, and the isolation valves in the suction line in the RCP [RCS] hot leg are closed.

All of the manual valves are equipped with a locking system to prevent any unscheduled opening or closing.

Unscheduled opening or closing of the electrical valves is prevented.

Also, an incorrect valve position (for a given plant state) activates an alarm in the Main Control Room.

1.6.1.6. Compatibility with defence in depth guidance

The RIS/RRA [SIS/RHRS] system design assumes the following:

- The 4 RIS/RRA [SIS/RHRS] trains are structurally separated from each other, and are supplied by a separate electrical system and cooled by a separate RRI [CCWS] train,

- Each train can operate either in residual heat removal mode or in LHSI mode, but not at the same time.

    - when the reactor is not in a shutdown state, the RIS/RRA [SIS/RHRS] is aligned in safety injection mode to ensure the safety injection function.

    - when the reactor is in a shutdown state with all RRA [RHRS] trains operating (RCP [RCS] temperature below 100°C), the MHSI pumps are used to ensure the safety injection function independently (with high output minimum flow lines open),

Thus, the RRA [RHRS] (used in normal operation mode) and RIS [SIS] (used in emergency operation mode) can be considered as functionally independent systems.

1.6.1.7. Protection against internal hazards

<u>Flooding</u>

The following scenarios are considered:

- flooding caused by leaks from the RIS/RRA [SIS/RHRS];

- flooding caused by leaks from other systems connected to the RIS/RRA [SIS/RHRS].

The segregation of the RIS/RRA [SIS/RHRS] trains ensures that flooding caused by a pipe rupture in part of the system downstream of the IRWST isolation valve inside the engineered safeguard building only has consequences (flooding) for the affected train. Similarly, in the event of pipe rupture in the other systems in a safeguard building division, then the segregation arrangements ensure that the other RIS/RRA [SIS/RHRS] trains maintain their operability.

In addition, IRWST drainage is prevented by closing the three-way isolation valve in the RIS/RRA [SIS/RHRS] suction line.

Protection of the system from failure of high energy pipes

The RIS/RRA [SIS/RHRS] pipes are protected so that they are not damaged by jet effects which could result from ruptures of, or leaks from, adjacent pipes.

Protection of the system from high and low energy pipes

The RIS/RRA [SIS/RHRS] pipes are protected so that they are not damaged by jet effects which could result from ruptures of, or leaks from, adjacent pipes.

Internal explosion

Materials that could form dangerous explosive atmospheres or mixtures are not permitted in the safeguard building. Hence, internal explosions cannot occur inside these buildings.

1.6.1.8. Protection against external hazards

Earthquake

The RIS/RRA [SIS/RHRS] provides F1 functions and is, therefore, Category 1 seismically classified.

Aircraft crash

To ensure that only one train of the RIS/RRA [SIS/RHRS] can be affected by an aircraft crash, it is designed with the following characteristics:

- Bunker construction (use of an aircraft shield) for two safeguard buildings and the reactor building, for electrical divisions 2 and 3,

- Geographical separation of the other two safeguard buildings, for electrical divisions 1 and 4.

Pressure wave

The system loads generated by the design basis earthquake bound the loads generated by the pressure wave defined in Sub-chapter 13.1. Hence as the RIS/RRA [SIS/RHRS] can withstand the design basis earthquake then it can also withstand loads generated by the defined pressure wave.

1.6.1.9. Fire

The RIS/RRA [SIS/RHRS] system is separated into four completely independent trains inside the fuel and safeguard buildings. The instrumentation and control and electrical sources are such that only one of the RIS/RRA [SIS/RHRS] trains can become unavailable in the event of a fire.

1.6.1.10. Missiles

The safeguard building structures are segregated, so that a postulated missile can only damage one RIS/RRA [SIS/RHRS] train.

Inside the reactor building, the segregation of trains is such that a postulated missile can only damage one RIS/RRA [SIS/RHRS] train.

1.6.1.11. In-service inspection

For parts of the RIS/RRA [SIS/RHRS] located outside the reactor building, some aspects of in-service inspection may be carried out during normal power operation. The remaining aspects of in-service inspection are carried out during shutdown.

The location and design of the RIS/RRA [SIS/RHRS] equipment facilitates access for periodic testing and in-service inspections.

The provision of inspection means for the RIS/RRA [SIS/RHRS] lines were considered at the preliminary design stage.

The IRWST equipment and leaktight liner are designed so that inspection is possible during a shutdown.

Measures are provided to enable detection of leaks between the liner and the concrete.

Monitoring the leaktightness of the double containment enclosing the RIS/RRA [SIS/RHRS] pump suction pipes is provided by continuous monitoring and periodic pressure tests. The welds outside the concrete are subject to inspection.

To facilitate continuous monitoring, the annulus between the suction pipe and the double containment is pressurised with dry compressed air. The double containment on each suction line incorporates two pressure monitors:

- a local pressure gauge (for periodic inspections);
- a pressure gauge for generating a low pressure alarm in the Main Control Room.

The IRWST suction lines form an implicit part of the containment tests. For the periodic test and inspection of the internals of the 3-way valves in the suction lines, a blanking plug may be installed after draining the IRWST.

1.6.1.12. Other requirements

This system is designed so that the risk of containment bypass is practically eliminated (see Sub-chapter 16.3).

The following provisions are made in the RIS/RRA [SIS/RHRS] design to reduce the risk of failure due to thermal fatigue:

- reduction in the number of mixing areas: for each train only one mixing area exists downstream of the RIS/RRA [SIS/RHRS] heat exchanger at the connection level with the heat exchanger bypass line;

- reduction of the primary coolant temperature at which the RRA [RHRS] is connected to the RCP [RCS]: during the steam generator cooling phase, RIS/RRA [SIS/RHRS] trains 1 and 4 are connected at 120°C and trains 2 and 3 at 100°C. Thus, the temperature difference between the two mixed fluids (upstream of the mixing area located at the bypass line downstream of the RIS/RRA [SIS/RHRS] heat exchanger) is limited;

- elimination of longitudinal welds in the RCC-M2 pipes and connections. The mixing tee was designed to move the circumferential weld away from this mixing area.

The mixing tee is completely polished and the three welds are levelled off.

1.6.2. Classification

Safety classification

Conformance of the design, materials and equipment to the requirements from the classification rules is described in detail in Sub-chapter 3.2.

Electrical classification

The electrical equipment for the F1A and F1B section of the RIS/RRA [SIS/RHRS] is EE1 classified.

Instrumentation and Control Classification

The instrumentation and control equipment for the F1A section of the RIS/RRA [SIS/RHRS] is E1A classified and equipment from the F1B section is E1B classified.

1.6.3. Specific safety measures

Monitoring concept and consequences of loss of system barriers

Leaks originating from the suction line in the IRWST, between the IRWST and the isolation valve can be excluded because this part of the system is equipped with a double containment.

Leaks originating from the part of the RIS/RRA [SIS/RHRS] downstream of the IRWST isolation valve inside the safeguard building can only cause flooding of a single train due to the segregation of divisions. However, the complete drainage of the IRWST must be avoided because IRWST is shared by the four RIS/RRA [SIS/RHRS] trains. Hence water level measuring devices are provided in the safeguard building for monitoring such leaks. If leaks are identified then isolation of the suction line in the IRWST can be carried out manually.

1.7. TESTS, INSPECTION AND MAINTENANCE

1.7.1. Equipment performance tests

The performance of the RIS/RRA [SIS/RHRS] pumps is validated by the manufacturers before installation.

During commissioning, the performance of the pumps and heat exchangers is tested by temporary measuring devices.

During refuelling shutdowns, the characteristics of the LHSI pumps are checked by gradually opening or closing the control valve located downstream of the RIS/RRA [SIS/RHRS] heat exchanger.

1.7.2. Periodic tests

Accident studies are performed to determine which safety functions must be periodically checked, and against which criteria.

The periodicity of the tests for all equipments will be defined as part of the site licensing.

1.7.3. Equipment maintenance

Preventive maintenance during normal power operation is permitted for most of the RIS/RRA [SIS/RHRS] components. The exceptions are the RCP [RCS] 1st and 2nd isolation valves, the IRWST isolation valves and pipes, and the accumulators.

1.8. SCHEMATIC DIAGRAMS

See Sub-chapter 6.3 - Figure 1.

2. IN-CONTAINMENT REFUELLING WATER STORAGE TANK (IRWST) [REF-1] TO [REF-4]

2.1. SYSTEM ROLES

The IRWST is a tank containing a large monitored quantity of borated water of uniform temperature and concentration.

Several systems draw water from, or inject water into, the IRWST.

The following lines form part of the IRWST:

- the suction lines (RIS [SIS], EVU [CHRS], RCV [CVCS], PTR [FPPS]) from the sump to the isolation valves (including the EVU [CHRS] isolation valves but excluding the RIS [SIS] three-way valves);
- the RIS/RRA [SIS/RHRS] minimum flow lines downstream of the isolation valve and the protection against overpressures lines (LHSI and reactor coolant drain tank) downstream of the safety relief valves;
- the reactor cavity drainage line and the pool treatment loop downstream of the PTR [FPPS] isolation valves;
- The RIS [SIS] filter unclogging via gravitational flow lines from the instrumentation lance pool.

The system role

The IRWST performs the following functions:

a) provision of water required to fill the reactor cavity during refuelling periods;

b) assurance of the water supply for the RCV [CVCS] charging pumps in the event of a low level in the volume control tank and after isolation of this tank on receipt of a boron dilution signal;

c) collection of the backflows from several systems;

d) provision of biological protection during refuelling periods;

e) filtration of the debris upstream of the RIS [SIS] and EVU [CHRS] pumps.

2.2. DESIGN BASES

2.2.1. General design criteria

In principle, the RIS/RRA [SIS/RHRS] is designed as an F1A system to deal with power plant PCC-2 to PCC-4 initiating events over the short-term, and meets the safety criteria according to PCC accident analysis rules.

The IRWST is located between the reactor pit and the containment internal wall, at the back of the reactor building, below the level of the heavy duty floor (supporting the primary components). The space between the IRWST and the containment wall is mainly filled with concrete to prevent any water from collecting there in the event of an accident, for example from condensation. The concrete filling is compatible with the installation and maintenance requirements of the equipment close to these areas.

If a pipe that draws water from the IRWST (for example, RIS/RRA [SIS/RHRS] or EVU [CHRS]) ruptures, the corresponding train is isolated by a sump valve to protect the IRWST water inventory. The sump isolation is F1B classified because it is only required for attaining the safe shutdown state. Nevertheless, on the RIS/RRA [SIS/RHRS] trains, this operation is carried out by the 3-way valve which is F1A classified because it plays a part in the safety injection.

The single failure criterion (active or passive) is applied to F1 systems to ensure sufficient redundancy and segregation of divisions. In particular, it is based on isolation of the sump and requires (passive single failure) protection pipes between the sump connections and the isolation valves.

The IRWST sump isolation devices located in the safeguard building are designed to remain available in degraded ambient conditions resulting from an internal containment pipe rupture.

In addition, measures are provided to prevent any pollution of the water inside the IRWST during normal operation.

Pump suction filters protect the RIS/RRA [SIS/RHRS] and EVU [CHRS] pumps from any debris transported by the IRWST fluid in accident conditions. The use of products or materials that are likely to degrade during accident conditions and/or generate a risk of filter clogging due to chemical effects are justified and the corresponding quantities are limited to those strictly necessary.

As the IRWST stores borated water, the tank is equipped with a leaktight stainless steel liner on the internal surface to prevent interactions between the boric acid and the containment wall. Nevertheless, the leaktight liner does not act as a containment barrier for the IRWST; this role is provided by the concrete.

The design and installation of filters and baskets complies with the protection against the internal and external hazard protection rules presented in Sub-chapters 13.1 and 13.2.

2.2.2. Flooding configuration for the spreading area

The IRWST is located at a higher elevation than the corium spreading area to enable passive flooding of this area by gravitational flow.

The pipe connecting the IRWST to the spreading compartment is closed in normal operation and in accidents (all of the PCC and RRC-A accidents) using valves equipped with a passive device which is melted by the corium causing the valves to open.

After the passive device has melted, the valves open and water flows into the spreading area. This flow ensures the required corium cooling conditions.

2.2.3. Ventilation of the IRWST

The IRWST atmosphere is ventilated to enable personnel access for weld monitoring, examination of the filters, etc.

The IRWST atmosphere is connected to the air treatment facilities (containment continuous ventilation).

2.2.4. Design criteria

a) IRWST capacity

The IRWST:

- contains enough water to fill the reactor cavity, the internal storage compartment, the fuel transfer compartment and the RCP [RCS] between ¾ loop and the highest level in the refuelling pool;

- establishes sufficient water height (static pressure) to ensure that the NPSH is sufficient for suction of all the pumps which can draw from the IRWST (in particular, the RIS [SIS], EVU [CHRS] and RCV [CVCS] pumps), even in accident conditions;

- provides sufficient cooling capacity to limit the production of steam and the associated pressure increase inside containment following a primary pipework break.

b) IRWST boron concentration

The boron concentration required depends upon:

- the type of fuel (UO_2 or MOX),

- the boron 10 enrichment.

The minimum required boron concentration (about 1700 ppm with 37% of ^{10}B) is sufficient to provide the required reactivity margins during refuelling and to provide the required negative reactivity margin in event of an accident.

Uniformity of the boron concentration is ensured during normal operation by the LHSI pumps using the radial minimum flow lines. The fuel pool water cooling and treatment system (PTR [FPPS]) also contributes to mixing.

c) IRWST water temperature

For all PCC-2 to PCC-4 events, the IRWST water temperature must not exceed 120°C.

Higher temperatures may be reached in RRC conditions. In the event of RRC-B, the IRWST temperature must not exceed 160°C.

Temperature measurements enable monitoring of the IRWST water temperature in normal operation and in post-accident conditions.

The temperature is kept uniform by the LHSI pump operation via the radial minimum flow lines.

Cooling of the IRWST water (for example, after refuelling) is carried out using the heat exchangers downstream of the LHSI pumps which provide the required subcooling margin with the aid of the radial minimum flow line.

In PCC and RRC conditions, the IRWST must be cooled in all events where hot water is collected in the IRWST, and in particular during a small break LOCA (primary coolant pressure greater than the shutoff head of the LHSI pumps).

The IRWST temperature increase must remain compatible with the MHSI and LHSI pump functional specifications (i.e. the IRWST temperature must always be lower than the MHSI and LHSI design temperature).

d) Design of the filtering system (Sub-chapter 6.3 - Figures 2 to 6)

The role of the filtering system is to filter any debris transported into the IRWST in accidents to ensure correct operation of the RIS/RRA [SIS/RHRS] and EVU [CHRS] components and to prevent the fuel assembly cooling channels from becoming blocked. Hence, the system must meet the following requirements [Ref-2]:

- compliance with the maximum allowed size (2 mm) of debris passing through the filters,
- compliance with the maximum allowed content of debris (500 ppm) downstream of the filters,
- the pressure drop in the filters is such that the margin between the required NPSH and available NPSH is positive over the 120°C (160°C for the EVU [CHRS]) to 40°C temperature range.

The filtering equipment functions are:

- retention of the debris upstream of the filters,
- filtering of the RIS [SIS] and EVU [CHRS] pump suction,

- unclogging of the filters to ensure their operation over the long-term.
  - For the RIS [SIS], this device provides a means for maintaining the filtering function over the long-term, to provide defence-in-depth,
  - For the EVU [CHRS], the operation of the filtering function depends on the operability of the unclogging system.

The filtering surface of the RIS [SIS] filters is compatible with the estimated debris source term for PCC and RRC-A accidents, enabling the RIS [SIS] pumps to operate without resorting to unclogging.

In addition, the filtering surface of the RIS [SIS] and EVU [CHRS] filters is maximised taking account of the following requirements and constraints:

- their shape facilitates unclogging (see section 2.3),
- their height is compatible with the minimum water level in the IRWST in post-accident situations to prevent filter uncovery,
- their overall dimensions are compatible with the installation constraints in the IRWST,
- their mechanical strength is compatible with the maximum design pressure drop.

2.3. DESCRIPTION

The EVU [CHRS] sumps are different from the RIS/RRA [SIS/RHRS] sumps.

Due to its borated water supply functions, the IRWST is connected to the RIS [SIS], PTR [FPPS] and the RCV [CVCS] suction. The PTR [FPPS] and the RCV [CVCS] do not draw water directly from the IRWST; they use the EVU [CHRS] suction line.

The connection between the EVU [CHRS] sump and the PTR [FPPS] enables the refuelling pools to be filled and the IRWST water to be purified and mixed. Each suction line is equipped with an isolation valve between the IRWST and the fluid system. This valve enables the containment and the IRWST to be isolated at the same time in the event of leakage at the fluid system level. Its normal position is open.

The suction lines are comprised of a "double containment" pipe, exiting the suction from the IRWST just downstream of the isolation valve. A "double containment" arrangement is provided in order to mitigate against a passive single failure. These double containment pipes form part of the containment barrier (thus, their design pressure is at least that of the containment).

The LHSI minimum flow lines are designed to enhance IRWST water mixing (uniformity of temperature and boron concentration).

In addition, the LHSI and RRA [RHRS] protection relief valves and the MHSI minimum flow lines discharge into the IRWST.

Characteristics [Ref-2]:

- Minimum useful volume: approximately 1,894 m^3

- Maximum level in normal operating conditions: approximately –2.35 m
- Temperature between 15 and 120°C
- Pressure in the gas phase = containment pressure

The IRWST consists of a leaktight stainless steel liner.

The filtering system consists of five successive levels (Sub-chapter 6.3 - Figures 2 to 6):

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b

2.4. OPERATING CONDITIONS

The following parameters are monitored in the IRWST:

- the water level, the change of which allows leaks to be detected;
- the water temperature; several monitors are provided to measure the temperature distribution inside the tank;
- the boron concentration. The connection towards the REN [NSS] sampling system downstream of the RIS/RRA [SIS/RHRS] heat exchanger is used to monitor the boron concentration inside the tank.

The following monitoring is carried out during normal operation (including shutdown).

a) Power operation

The IRWST is full (maximum level considered in normal operating conditions: –2.35 m). The level is permanently monitored. Any leak causing the IRWST level to drop is detected. Makeup or adjustment of the boron concentration may be carried out using the PTR [FPPS], or the boron REA [RBWMS] system.

b) Cold shutdown for refuelling

The reactor cavity is filled with water from the IRWST. A small quantity of water remains in the bottom of the IRWST to protect the RIS/RRA [SIS/RHRS] pumps (vortex type).

c) Operation during an accident

During an accident for which the RIS/RRA [SIS/RHRS] or EVU [CHRS] pumps are required, the IRWST plays an essential safety role. Steam and water are discharged into the containment. The water recirculates towards the IRWST, whereas the steam condenses on the structures. Part of the water in recirculation may be lost from the IRWST (the water lost into the containment reservoirs is taken into account in the IRWST design and in the calculation of the available NPSH).

2.5. MEETING THE CRITERIA AND CLASSIFICATION

The IRWST is mainly F1A classified because its functions contribute to safety injection.

The sump isolation function is F1B classified because it is required for maintaining a safe shutdown state in the event of a leak.

The RIS [SIS] filtering function (excepted the RIS [SIS] filter unclogging system which is F2 classified), for which the large debris meshes, baskets and RIS [SIS] filters form part, is F1A classified and the EVU [CHRS] filtering function is F2 classified.

Conformance of the design, materials and equipment to the requirements of the classification rules is described in detail in Sub-chapter 3.2.

The entire system is Category 1 seismic classified (integrity, functional capacity, functional capacity of the lines, actuator operability), with the exception of discharge from the overpressure protection line of the primary coolant drain tanks.

2.6. TESTS, INSPECTION AND MAINTENANCE

The IRWST leaktight liner and equipment are designed so that it is possible to carry out inspections during shutdown.

The IRWST consists of two symmetrical sections separated by a low wall. Each section may be drained during a shutdown to allow the leaktight liner to be inspected.

Measurements enable leaks to be detected between the leaktight liner and the concrete.

Monitoring of the leaktightness of the double containment pipes is ensured via periodic testing or continuous monitoring of system pressure.

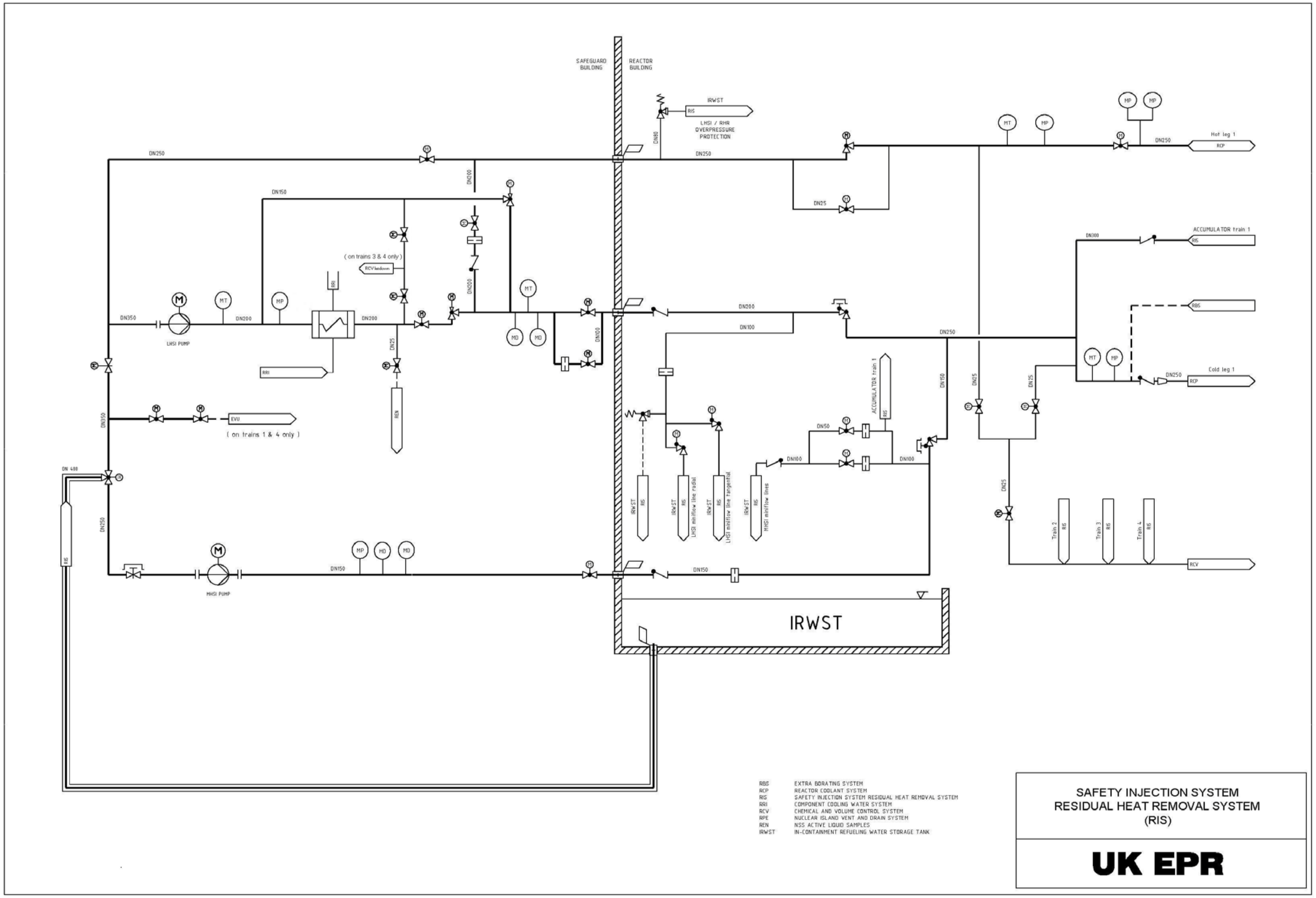
The RIS [SIS] baskets and filters are subject to periodic inspections to ensure their integrity.

2.7. SCHEMATIC DIAGRAM

A simplified schematic diagram is presented in Sub-chapter 6.3 - Figure 1.

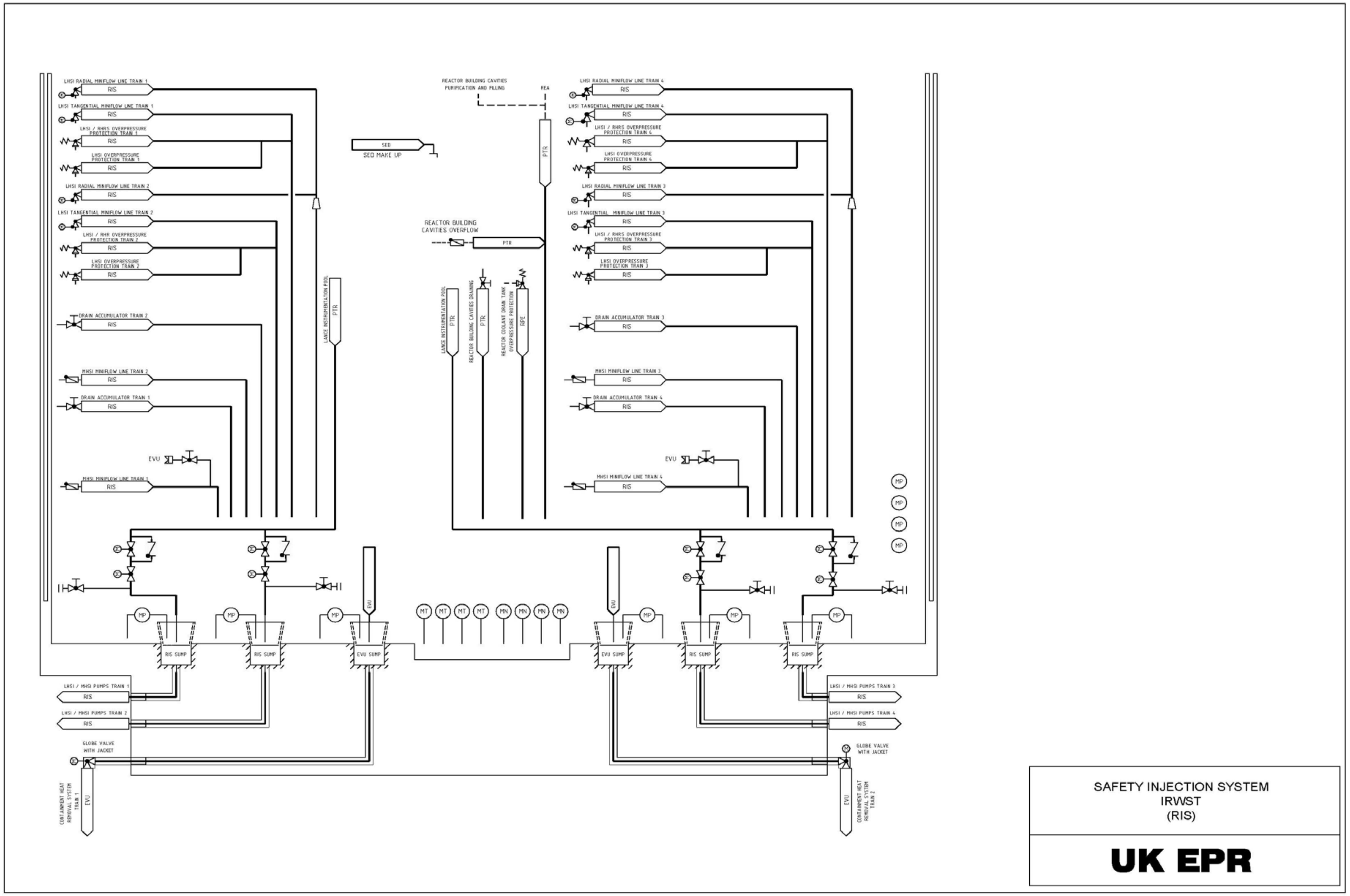
SUB-CHAPTER 6.3 - FIGURE 1 (FOLIO 1/3)

SIMPLIFIED FLOW DIAGRAMS OF THE RIS/RRA [SIS/RHRS]



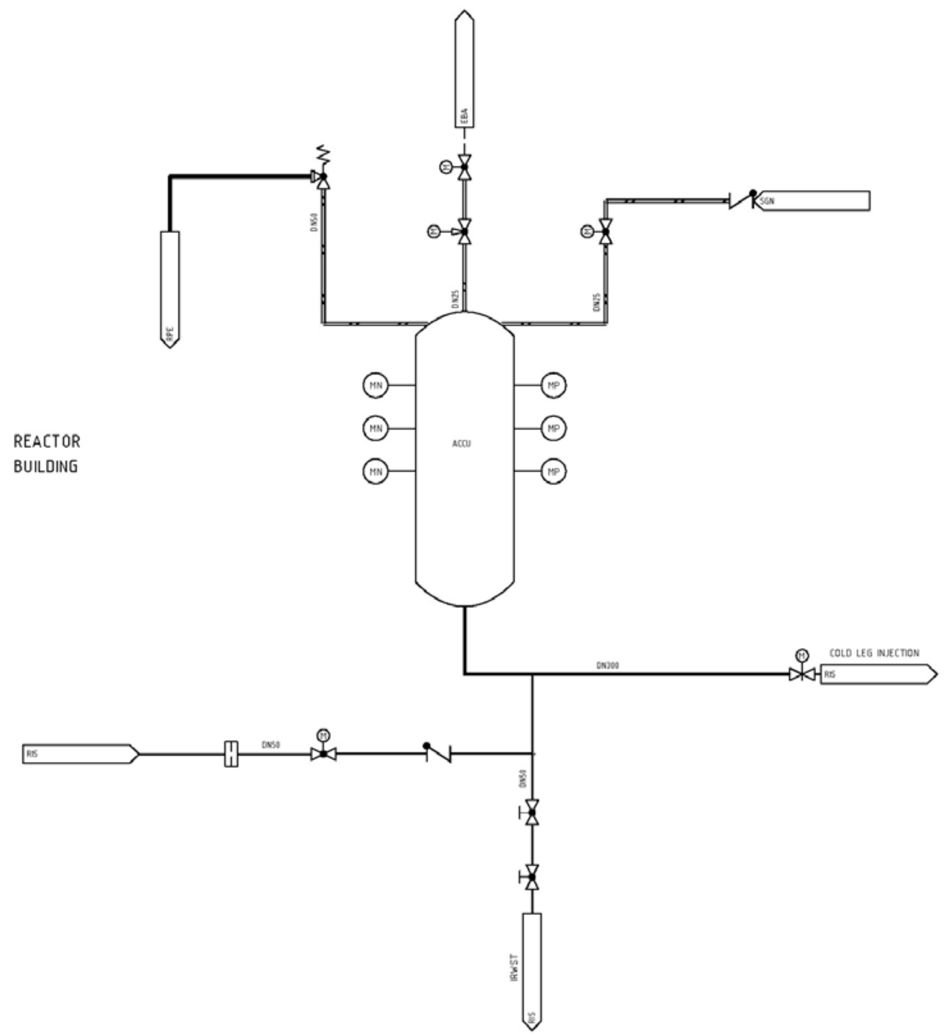
SUB-CHAPTER 6.3 - FIGURE 1 (FOLIO 2/3)

SIMPLIFIED FLOW DIAGRAMS OF THE RIS/RRA [SIS/RHRS]



SUB-CHAPTER 6.3 - FIGURE 1 (FOLIO 3/3)

SIMPLIFIED FLOW DIAGRAMS OF THE RIS/RRA [SIS/RHRS]



EBA REACTOR BUILDING SWEEPING VENTILATION SYSTEM
RIS SAFETY INJECTION SYSTEM , RESIDUAL HEAT REMOVAL SYSTEM
RPE COMPONENT VENT AND DRAIN SYSTEM
SGN NITROGEN DISTRIBUTION

SAFETY INJECTION SYSTEM
ACCUMULATOR TRAIN 1
(RIS)

UK EPR

SUB-CHAPTER 6.3 - FIGURE 2

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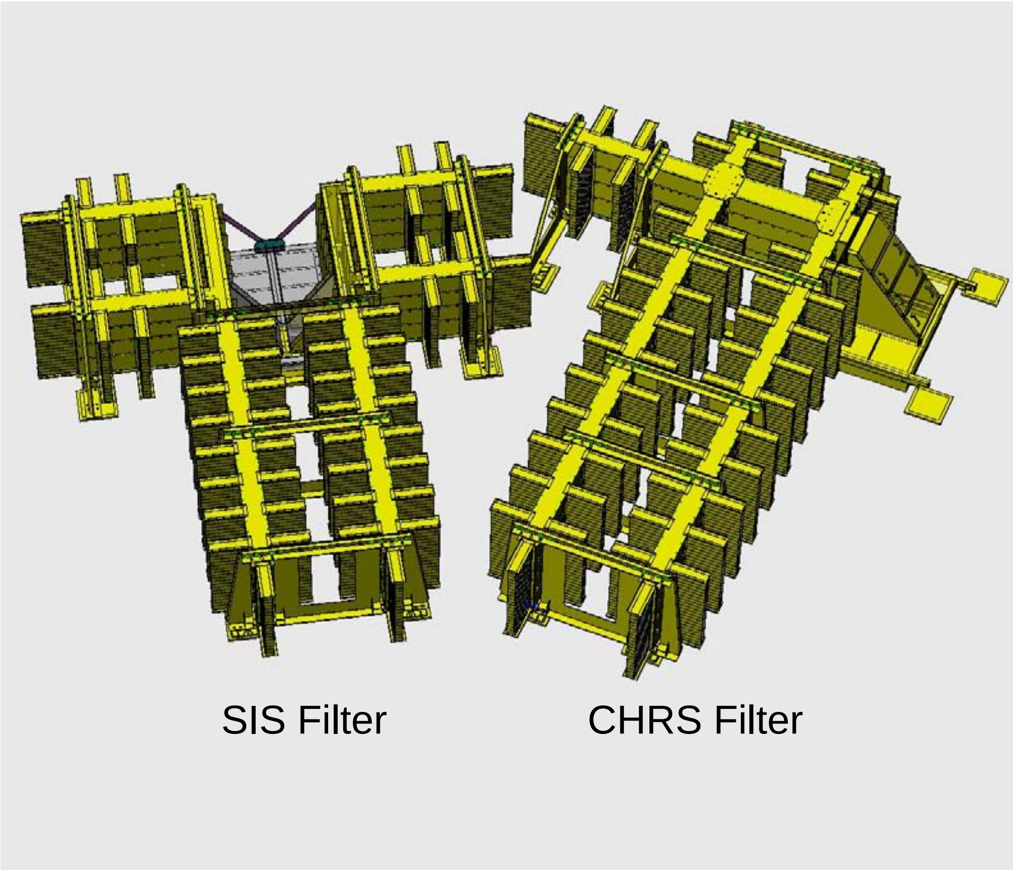
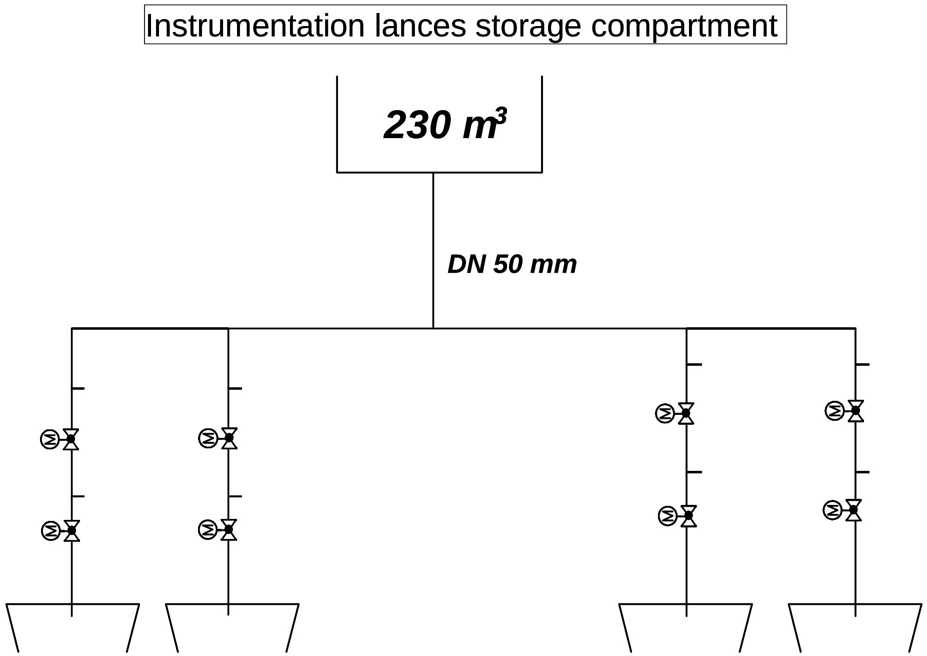
SUB-CHAPTER 6.3 - FIGURE 3

SUMP FILTERS (SCHEMATIC DIAGRAM)



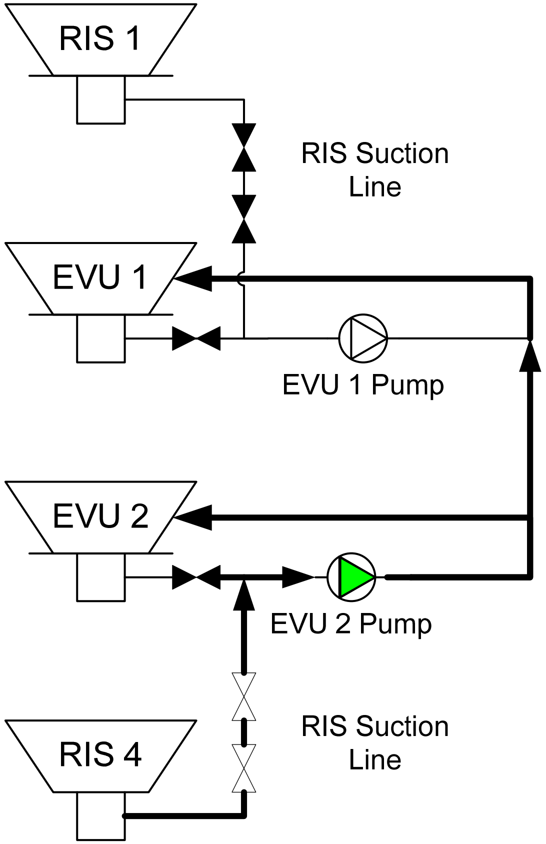
SUB-CHAPTER 6.3 - FIGURE 4

RIS [SIS] FILTER UNCLOGGING (BLOCK DIAGRAM)



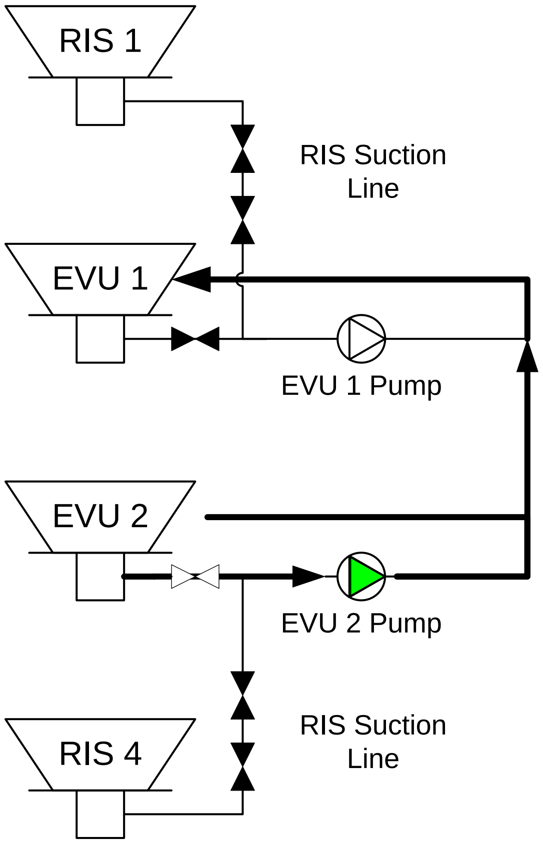
SUB-CHAPTER 6.3 - FIGURE 5

EVU [CHRS] FILTER UNCLOGGING WITH SUCTION TAKE FROM AN RIS [SIS] FILTER (BLOCK DIAGRAM)



SUB-CHAPTER 6.3 - FIGURE 6

CROSSED UNCLOGGING OF AN EVU [CHRS] FILTER (BLOCK DIAGRAM)



SUB-CHAPTER 6.3 – 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.

The following references are used throughout this sub-chapter:

[Ref-1] System Design Manual - Safety Injection System and Residual Heat Removal System - Part 2: System Operation. NESS-F DC 539 Revision A. AREVA. May 2009 (E)

[Ref-2] System Design Manual - Safety Injection System and Residual Heat Removal System - Part 3: System Sizing. NESS-F DC 540 Revision A. AREVA. May 2009. (E)

[Ref-3] System Design Manual - Safety Injection and Residual Heat Removal System - Part 4: Flow diagrams. NESS-F DC 546 Revision A. AREVA. June 2009. (E)

[Ref-4] System Design Manual - Safety Injection System - Residual Heat Removal (SIS-RHR) P5 – Instrumentation & Control. NESS-F DC 614 Revision A. AREVA. November 2009. (E)