UK EPR	Title: PCSR – Sub-chapter 5.1 – Description of the Reactor Coolant System
	UKEPR-0002-051 Issue 04

Total number of pages: 27	Page No.: I / III
Chapter Pilot: F. GHESTEMME *Name/Initials* *Date* *05-07-2012*	
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REVISION HISTORY

Issue	Description	Date
00	First issue for INSA information.	11-12-2007
01	Integration of technical and co-applicant review comments	29-04-2008
02	PCSR June 2009 update: – Clarification of text – Inclusion of references – Improvements regarding limitation of source term debris functionality and operating parameters at rated power 4500 MWth	26-06-2009
03	Consolidated Step 4 PCSR update: - Minor editorial changes - Update and translation of references - Addition of reactor coolant pressure control by RCV [CVCS] during monophasic start-up mode (§5.1)	31-03-2011
04	Consolidated PCSR update: - References listed under each numbered section or sub-section heading numbered [Ref-1], [Ref-2], [Ref-3], etc - Minor editorial and typographical changes - Clarification of text and addition of acronyms (§1, §3.3, §3.4, §3.5, §3.6, §4.2, §5.3)	06-07-2012

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SUB-CHAPTER 5.1 – DESCRIPTION OF THE REACTOR COOLANT SYSTEM

Sub-chapter 5.1 describes the functional role of the reactor coolant system, together with the design assumptions, fluid characteristics and design description of the key components (reactor vessel, pressuriser, reactor coolant pumps and steam generators). System parameters are given for both normal operating conditions and standard shutdown states. The main control functions are outlined: reactor coolant system pressure control, pressuriser level control, reactor coolant system loop level control, steam generator level control, and reactor coolant pump standstill seal system actuation.

1. FUNCTIONAL ROLE

The Reactor Coolant System RCP [RCS] fulfils the following functions:

a) Control of radioactive release

The RCP [RCS] serves as a boundary against the release of activity into the containment in the event of fuel cladding failure.

b) Heat transfer from the reactor - core cooling

The main function of the RCP [RCS] is to transfer heat from the reactor core to the secondary system, where steam is produced for use in operation of the turbine.

Heat is transferred from the reactor core to the steam generators (SGs) by the reactor coolant.

Heat is exchanged with the feedwater in the steam generators, generating steam which is then routed to the turbine via the main steam lines.

The Reactor Coolant Pumps provide a reactor coolant flow rate that is sufficient to remove heat from the reactor core and limit the temperature of the fuel, thereby maintaining the integrity of the fuel cladding.

The systems involved in the core cooling function are the:

- Main Steam Supply System (VVP [MSSS]), Turbine Main Steam Bypass System (GCT [MSB]), Steam Generator Main Feedwater System (ARE [MFWS]), Start-up and Shutdown Feedwater Systems (AAD [SSS]) (these systems are used under normal operation)
- Residual Heat Removal System (RIS/RRA [SIS/RHRS]) (used during shutdown)
- Emergency Feedwater System (ASG [EFWS]), used in the event of loss of Main Feedwater or Start-up and Shutdown Feedwater systems (AAD [SSS])
- Chemical and Volume Control System (RCV [CVCS]), used to maintain the inventory of reactor coolant water and compensate for minor leakage from the RCP [RCS]

- Safety Injection System (RIS/RRA [SIS/RHRS]) which:
  - maintains the inventory of the reactor coolant in the event of a Loss Of Coolant Accident (LOCA)
  - removes heat before connection of the RRA [RHRS] to RCP [RCS] in the event of a LOCA
  - removes heat in the event of a total loss of the heat removal functions.

c) Neutron moderator

The RCP [RCS] and its associated systems provide the reactor coolant used as the core neutron moderator, limiting the velocity of neutrons to the thermal range.

d) Reactivity control

The reactor coolant demineralised water in the RCP [RCS] serves as a solvent for boron addition, used for reactivity control, compensating for the effects of xenon transients, fuel burn-up and to ensure the plant is maintained in a sub-critical condition during shutdown.

The systems involved in the reactivity control function are the:

- Rod Cluster Control Assemblies (RCCAs)
- Chemical and Volume Control System (RCV [CVCS]) (in conjunction with the Reactor Boron and Water Makeup System) to adjust the boric acid concentration under normal operation
- Safety Injection System(RIS/RRA [SIS/RHRS])
- Extra Boration System (RBS [EBS]).

e) Reactor coolant pressure control

The reactor coolant system pressure must be greater than the saturation pressure corresponding to the temperature of the hot leg. This pressure difference is required to prevent a departure from nucleate boiling producing adverse effects on heat transfer and reactivity control.

The sub-cooling corresponding to the cold leg temperature of the reactor coolant must be sufficiently small to minimise the loads on the Reactor Pressure Vessel (RPV) internals in the event of a LOCA.

Control of the reactor coolant pressure is achieved by the pressuriser, which is connected to one of the hot legs of the RCP [RCS] by means of the surge line.

2. DESIGN ASSUMPTIONS AND FLUID CHARACTERISTICS

2.1. GENERAL ASSUMPTIONS FOR SYSTEM DESIGN

a) Heat transfer from the reactor - core cooling function

During normal operation, the core cooling function is provided through the circulation of reactor coolant and heat transfer via the steam generators.

The system is designed with four loops to ensure reactor coolant flow, with each loop connected to the Reactor Pressure Vessel (RPV) which contains the core.

Within each loop, the reactor coolant circulates:

- from the reactor pressure vessel to the steam generator via the “hot leg” pipework
- from the SG to the reactor coolant pump via the “crossover leg” pipework
- from the reactor coolant pump to the vessel via the “cold leg” pipework.

Under normal operating conditions, forced circulation through the core is provided by the four reactor coolant pumps. In the event that the pumps are unavailable, residual heat is removed by natural circulation through the core.

During shutdown conditions, when the circuit is not intact the steam generators are unavailable for core cooling. During this period, core cooling is provided by the RIS/RRA [SIS/RHRS] with the reactor coolant pumped on each loop from the hot leg and re-injected into the cold leg after cooling.

In the event of a LOCA or long-term removal of residual heat in the event of an accident, the core cooling function is provided by the RIS/RRA [SIS/RHRS].

In the event of total loss of heat removal functions, core cooling may be provided by the safety injection system in conjunction with pressuriser bleed to the containment building (the pressuriser discharge system is described in Sub-chapter 5.4).

Under normal operation, the inventory of the reactor coolant fluid is controlled by the chemical and volume control system (RCV [CVCS]).

In the event of loss of external power, the inertia of the reactor coolant pumps provides a flow transient maintaining the integrity of the fuel cladding.

b) Core neutron moderation function

Neutron moderation is provided by the primary circuit coolant contained in the RCP [RCS].

The total reactor coolant mass is controlled by the RCV [CVCS] (letdown line and charging lines). The pressuriser accommodates changes in reactor coolant volume during transients.

c) Reactivity control function

Reactivity is controlled by:

- The Rod Cluster Control Assemblies (RCCAs)
- The coolant boric acid concentration, controlled by the RCV [CVCS] (in conjunction with the Reactor Boron and Water Makeup System (REA [RBWMS])
- The Safety Injection System RIS [SIS] in the event of a LOCA or secondary system rupture (by using MHSI pumps)
- The Extra Boration System RBS [EBS], which provides a safety-classified boration method in order to reach safe shutdown state.

d) Control of radioactive release function

The Reactor Coolant System and its connected pipework, acts as a barrier to the release of radioactive products.

In particular, leaks along the reactor coolant pump shafts are controlled by a shaft sealing system incorporating:

- Seal injection from the RCV [CVCS] maintains the leak resistance of the seals and includes recovery of the controlled seal leakage via the leak-off line
- Thermal barrier cooling supplied by the RRI [CCWS]. This cools down the reactor coolant fluid flowing towards the seals
- A StandStill Seal System DEA [SSSS], which can be activated when the pumps are stopped.

e) Reactor coolant pressure control function

Reactor coolant pressure is controlled by the pressuriser connected to one of hot legs via the surge line.

In the pressuriser, reactor coolant water and steam are held in equilibrium under saturated conditions.

Pressure control in the pressuriser is achieved by:

- Electric heaters to produce steam and increase the reactor coolant pressure
- Two cold water spray lines in the pressuriser steam phase condense the steam and reduce reactor coolant pressure.

The spray lines are connected to two of the cold legs (the spray flow rate is provided by the reactor coolant pumps and controlled by the spray valves).

Each spray line comprises two valves in parallel: one main control valve to control the reactor coolant pressure and one manual control valve to ensure enough flow rate for thermal conditioning of spray lines and surge line.

If the two normal spray lines are insufficient to control the reactor coolant pressure, or in the event of loss or shutdown of the reactor coolant pumps, auxiliary spray is provided by a line connected from the RCV [CVCS] pumps, to the pressuriser.

A pressuriser relief system is mounted on the pressuriser and is described in Sub-chapter 5.4.

f) Limitation of source term debris function

In addition to the physical separation of the reactor building into two compartments and the absence of spraying in LOCA (not required), the RCP [RCS] contributes to the source term debris limitation function due to the improvement in its thermal insulation design.

This function aims at preventing the sumps strainers plugging.

The main principles retained to perform this function are:

- The use of thermal insulation cassettes, in particular on Steam Generators and Pressuriser
- The reinforcement of these cassettes and the improvement of the mounting system for cassettes on Steam Generators and Pressuriser
- The limitation of the use of Microtherm as thermal insulator.

2.2. RCP [RCS] FLUID CHARACTERISTICS

The pressures and temperatures for the Reactor Coolant System [Ref-1] are as follows:

- RCP [RCS] operating pressure = 155 bar abs in the pressuriser
- RCP [RCS] design pressure = 176 bar abs
- Pressuriser temperature in operation = saturation temperature for 155 bar abs = 345°C
- RCP [RCS] loop design temperature = 351°C
- Pressuriser design temperature = 362°C.

The operating parameters at rated power 4500 MWth, are as follows:

- RCP [RCS] pump flow rates: three values are used for the various studies (without plugging and with clean steam generator tubes):
  - Best Estimate flow (BE): is the nominal flow corresponding to the intersection between the reactor coolant pumps (head-flow) performance curve and the RCP [RCS] flow resistance characteristic curve, with no uncertainties (margin) assigned to either curve
  - Thermal-Hydraulic flow (TH): is the minimum flow used in the design of the reactor core thermal performance, taking into account the uncertainties of the reactor coolant pumps head-flow curve and the accuracy of the measurement of the reactor coolant flow

- Mechanical design flow (ME): is the maximum flow used for the mechanical design basis of the components exposed to the primary coolant, including the vessel internals and fuel assemblies.

BE vessel flow rate (by loop) = 28,320 m^3/h.

TH vessel flow rate (by loop) = 27,185 m^3/h.

ME vessel flow rate (by loop) = 30,585 m^3/h.

RCP [RCS] loop temperature at hot standby (0% power) = 303.3°C.

RCP [RCS] loop temperature at nominal power:

- Cold leg:
  - BE = 295.9°C
  - TH = 295.6°C
  - ME = 296.6°C.
- Hot leg:
  - BE = 328.9°C
  - TH = 329.8°C
  - ME = 327.2°C.
- Core outlet:
  - BE = 330.0°C
  - TH = 331.6°C
  - ME = 327.6°C.

  } (warm dome configuration)

3. FLOW DIAGRAMS AND MAIN EQUIPMENT CHARACTERISTICS

3.1. FLOW DIAGRAMS

Simplified flow diagrams [Ref-1] of the RCP [RCS] are shown in Sub-chapter 5.1 - Figure 2.

3.2. SAFETY CLASSIFICATION

The detailed safety classification is given in the construction, components and systems classification chapter (see Sub-chapter 3.2).

3.3. REACTOR PRESSURE VESSEL

The reactor vessel is cylindrical with a welded lower hemispherical domed head and a removable flanged upper hemispherical domed head. The reactor vessel is designed to hold the reactor core (sufficient volume), the Rod Cluster Control Assemblies (RCCAs), the heavy reflector and internal equipment. The reactor vessel has four inlet and four outlet nozzles located horizontally below the reactor vessel flange, but above the top of the core. The reactor coolant from the cold legs enters the reactor vessel through the inlet nozzle and flows down through the annular space between the core barrel and the reactor vessel wall. The coolant turns at the bottom of the reactor vessel and flows upwards inside the core towards the hot leg outlet nozzles.

The reactor vessel head supports the Control Rod Drive Mechanisms (RGL [CRDM]) and the in-core instrumentation.

The reactor vessel flange and head are sealed by means of two metal seals. Any leaks from the seals are detected by instrumentation connected to a leak-off located between the internal and external seals.

The vent line in the reactor vessel head can be connected to the RPE [NVDS] vacuum pump for filling of the reactor vessel.

It is also possible to inject nitrogen and air via the reactor vessel vent line to drain the RCP [RCS] before opening.

3.4. REACTOR COOLANT PIPEWORK

The reactor coolant pipework [Ref-1] comprises:

- Four heat transfer loops, each comprising a hot leg connecting the reactor vessel to the SG, a crossover leg connecting the SG to the reactor coolant pump and a cold leg connecting the reactor coolant pump to the reactor vessel
- One pressuriser surge line connecting the pressuriser to one hot leg pipe
- Two pressuriser spray lines connecting the pressuriser normal spray nozzles to two cold legs.

Pressuriser relief is discussed in Sub-chapter 5.4.

<u>Connections to auxiliary systems</u>

- RIS/RRA [SIS/RHRS]:
    - Four nozzles on the hot legs used for RRA [RHRS] suction and RIS [SIS] injection
    - Four nozzles on the cold legs used for accumulator discharge, RBS [EBS] injection, RIS [SIS] (MHSI and LHSI) and RRA [RHRS] injection to these four loops

- RCV [CVCS]:
  - Two nozzles on the cold legs (RCV [CVCS] make-up on two loops)
  - One nozzle on the crossover leg (RCV [CVCS] letdown on one loop)
  - One nozzle on the pressuriser for the auxiliary spray line
- Other connections:
  - Nitrogen and air supply to the reactor coolant pumps
  - Connections to the sampling system
  - Instrument nozzles

3.5. PRESSURISER

a) General description

The pressuriser is a vertical cylindrical shell, closed at both ends by upper and lower hemispherical heads.

The pressuriser heaters are mounted vertically in the lower hemispherical head.

The surge line nozzle is positioned axially in the centre of the lower hemispherical head.

The surge line is connected to the hot leg of loop 3.

The relief valves and the twin discharge lines used for severe accident mitigation and bleed function (described in Sub-chapter 5.4) are connected to the upper hemispherical head. The spray lines are connected laterally to the upper section of the pressuriser cylindrical shell.

Cold water spray discharges to the steam phase, via two spray nozzles located at the end of the two spray lines.

b) Pressuriser heaters

The total heater power is shared between:

- Continuously controlled heaters
- Emergency power supplied on/off heaters
- Non-emergency power supplied on/off heaters.

c) Pressuriser spray system

The pressuriser is fitted with three separate spray nozzles:

- Two for normal spray
- One for auxiliary spray.

The spray nozzles used in normal operation, are connected via spray lines to the cold legs of loops 2 and 3.

Each normal spray line is controlled by a dedicated spray control valve, operated in either automatic or on/off mode. These valves enable a continuous spray rate to be maintained in each of the normal spray lines (when the reactor coolant pumps are operating).

An auxiliary spray line is connected to the RCV [CVCS].

d) Pressuriser venting and degassing system

A vent line connects the pressuriser to the RPE [NVDS].

A vacuum line to the RPE [NVDS] and a degassing line (to the RPE [NVDS]) are connected to this vent line. A nitrogen supply line is also connected to this line.

To reduce the volume of air trapped during initial RCP [RCS] filling, the vacuum line is also used to reduce RCP [RCS] pressure below atmospheric via a dedicated vacuum pump (part of the RPE [NVDS] system).

The vacuum line and vacuum pump are also used for sweeping nitrogen and air from the RCP [RCS] during mid-loop operation (in order to reduce the quantity of noble gases present before opening the RCP [RCS]).

The pressuriser degassing line can be used:

- To avoid a significant build-up of hydrogen in the pressuriser plenum during power operation by running at a low capacity flow of 6 kg/h [Ref-1]
- To eliminate gases trapped in the pressuriser during shutdown operations by running at a high capacity flow of 200 kg/h [Ref-1].

Gases are sent to the gaseous waste treatment system TEG [GWPS] via the RPE [NVDS] system.

As part of the shutdown procedure draining to mid-loop operation, the nitrogen supply line is used to maintain the reactor coolant pressure around 1 bar abs.

3.6. REACTOR COOLANT PUMPS

a) General description

The reactor coolant pump is a vertical, single-stage pump designed to circulate large volumes of reactor coolant at high pressure and temperature.

The shaft sealing system is designed to avoid any reactor coolant system leaks into the containment. The motor is an air-cooled three-phase motor.

Each reactor coolant pump consists of a vertical assembly comprising (from top to bottom) a flywheel, a motor, a seal assembly and a hydraulic unit.

The reactor coolant is pumped by an impeller attached to the base of the rotor shaft. The reactor coolant is drawn up into the suction nozzle of the casing, directed towards the impeller by the suction adapter, passes through the impeller and exists through the diffuser to the discharge nozzle.

The reactor coolant pumps are designed to supply sufficient flow rate, so as to ensure adequate cooling of the core.

The head of the reactor coolant pumps is designed so as to overcome the pressure drop in the reactor coolant system loops (vessel, steam generators and pipe).

The reactor coolant pumps are described in Sub-chapter 5.4.

b) Shaft sealing system

The water injected at the reactor coolant pump No.1 seal is supplied by the RCV [CVCS].

No. 1 seal leakage is also recovered by the RCV [CVCS].

Pressure upstream and downstream of the No.1 seal can be equalised using the seal bypass line. The bypass line is only open during RCP [RCS] vacuum filling to protect the No.1 seal against negative differential pressures.

No. 2 seal leakage is drained into the reactor coolant drains (part of the RPE [NVDS]).

No. 3 seal leakage is drained to the process drains (part of the RPE [NVDS]). The No.3 seal is also permanently flushed with demineralised water from the demineralised water system, SED.

The standstill seal system DEA [SSSS] is the final leak tightness mechanism of the shaft sealing system and creates a sealed surface with metal on metal contact ensuring the shaft is leak tight once the pump is shut down and all the leak-off lines are closed. The standstill seal system is pneumatically controlled (via nitrogen), and is open during normal pump operation.

Isolating valves are installed on the three seal leak-off connection lines.

c) Interface with the component cooling water system RRI [CCWS]

The reactor coolant pumps are fitted with coolers supplied by the RRI [CCWS] for:

- Cooling the motor (two air-coolers per pump)
- Cooling the motors' upper and lower bearings (one oil cooler per bearing).

The reactor coolant pump thermal barrier, cooled by the RRI [CCWS], provides cooling for the reactor coolant arriving at the seals in the event of failure of No. 1 seal injection.

3.7. STEAM GENERATORS

The steam generators are vertical shell and inverted-U tube evaporators fitted with integral moisture separating equipment [Ref-1]. They are also fitted with an axial pre-heater (or economiser) to obtain higher steam pressure.

The reactor coolant is circulated through the inverted-U tubes, entering and leaving by nozzles located in the steam generator channel head (lower hemispherical end). The lower end is divided (inlet chamber and outlet chamber) by a vertical separation (divider) plate extending from the tube sheet. Manholes provide access to both sides of the channel head.

The heat carried by the reactor coolant is transferred to the secondary fluid through the walls of the tube bundle.

On the secondary side, feedwater is directed towards the cold side of the tube sheet by a double wrapper in which the feedwater is injected through a feedwater distribution ring.

The economiser wrapper and the feedwater distribution ring cover only the half of the tube sheet that corresponds to the cold side. A separation (divider) plate separates the hot leg and the cold leg in the tube bundle (from the tube sheet until the sixth tube support plate). Once the feedwater reaches the bottom of the cold side, the water rises along the cold leg tube bundle and is heated to boiling point. The steam-water mixture rises, crosses the separators and driers and exits the steam generator by the outlet nozzle located on the SG elliptical upper end.

Water from the separators and driers is recirculated [Ref-1]:

- 90% on the hot side of the tube bundle where it is evaporated
- 10% mixed with the feedwater on the cold leg side of the tube bundle.

4. DESCRIPTION OF STATES

4.1. NORMAL OPERATION OF THE REACTOR COOLANT SYSTEM

Normal operation of the RCP [RCS] corresponds to power operation of the plant [Ref-1].

This covers all power levels ranging from 0% to 100% of nominal power.

The temperature of the hot leg, the cold leg and consequently the average temperature, depend on the load in accordance with the chart shown in Sub-chapter 5.1 - Figure 1.

The pressuriser pressure is constant and equals 155 bar abs irrespective of the load.

The pressuriser water level depends on the load.

The pressure on the secondary side of the steam generator depends on the load as shown in Sub-chapter 5.1 - Figure 1.

The values given in Sub-chapter 5.1 - Figure 1 are based on the best estimate (BE) value of the reactor coolant flow with four reactor coolant pumps operating.

In the event that one reactor coolant pump is lost, operation with three loops at reduced power output is possible.

4.2. STANDARD STATES OF THE REACTOR COOLANT SYSTEM AT SHUTDOWN

a) Hot shutdown (State A)

This is the normal state of the system when the reactor is not critical [Ref-1].

- The four reactor coolant pumps are operating (operation with a reduced number of pumps is possible)
- The pressuriser pressure is 155 bar abs
- The average temperature of the RCP [RCS] loops is 303.3°C
- The pressuriser is saturated, maintaining the RCP [RCS] pressure within acceptable limits, and the pressuriser level is adjusted to the no-load value of 25 m^3.

b) Intermediate shutdown (State B and part of State C)

This is an intermediate state reached during either unit start-up or shutdown, corresponding to the heating up or cooling down of the RCP [RCS] [Ref-1].

- The average temperature of the reactor coolant loops vary between 55°C and 303.3°C (pressure/temperature pairings remain within the acceptable limits as specified by the RCP [RCS] equipment designers)
- Below 120°C, RCP [RCS] temperature control is carried out by the Residual Heat Removal System
- Above 120°C, RCP [RCS] temperature control is carried out by the steam generators
- Below approximately 25 bar abs, all four reactor coolant pumps are stopped
- The pressuriser pressure is between 1 and 155 bar abs
- While the RRA [RHRS] is connected to RCP [RCS], the maximum pressure is limited to 32 bar
- The pressuriser is either:
    - Saturated and controls the RCP [RCS] pressure
    - Water solid, with RCP [RCS] pressure control by the RCV [CVCS].

c) Normal cold shutdown (end of State C)

This is the normal state of the system when cold [Ref-1].

- The RCP [RCS] circuit is closed (intact)
- No reactor coolant pumps are operating
- The pressuriser pressure is between 1 and 5 bar abs

- The average temperature of the reactor coolant loop is between 15°C and 55°C (pressure/temperature pairings remain within the acceptable limits as specified by the RCP [RCS] equipment designers)

- Nitrogen is injected at the top of the pressuriser during the drain down phase to mid-loop operation.

d) Cold shutdown for maintenance (State D)

This is the maintenance state where the RCP [RCS] is depressurised and partially drained [Ref-1].

- The RCP [RCS] is depressurised and whilst the reactor pressure vessel head may be closed (secured) the integrity of the reactor coolant pressure boundary is not guaranteed, hence, the system cannot be pressurised as it is assumed that the SGs are not available for heat removal

- No reactor coolant pumps are operating

- The average reactor coolant temperature is between 15°C and approximately 55°C

- The reactor coolant level is equal to or greater than the minimum level required for RRA [RHRS] operation at a reduced RCP [RCS] water level (mid-loop operation).

The mid-loop operation occurs:

- Prior to filling the RCP [RCS] (upon plant start-up), the RPE [NVDS] vacuum pump is connected to the pressuriser vent line enabling the RCP [RCS] pressure to be adjusted to approximately 0.2 bar abs for RCP [RCS] vacuum refilling

- During shutdown draining, the RCP [RCS] is firstly drained under nitrogen pressure to minimise off-gassing in the SG tubes. The RPE [NVDS] vacuum pump (connected via the pressuriser vent line) is then used to evacuate the nitrogen (or air) injected into the RCP [RCS] via the reactor coolant pump No. 1 seal injection lines and the reactor vessel head vent.

e) Shutdown for refuelling (State E)

The re-fuelling shutdown state corresponds to the RCP [RCS] conditions required to prepare for and carry out all fuel handling operations [Ref-1].

- The RCP [RCS] is at the containment pressure and the vessel is open (no reactor coolant pumps are operating)

- The average reactor coolant temperature is between 15°C and approximately 50°C

- The refuelling cavity has been filled with water from the IRWST (or filling or draining of the refuelling cavity is being carried out).

5. RCP [RCS] CONTROL FUNCTIONS [REF-1]

5.1. RCP [RCS] PRESSURE CONTROL

Control of RCP [RCS] pressure contributes to:

- The RCP [RCS] overpressure protection safety function by preventing the activation of the pressuriser relief valves
- The reactor heat transfer safety functions, core cooling and reactivity control by maintaining the RCP [RCS] pressure above saturation pressure.

Control of RCP [RCS] pressure is achieved by operation of the pressurise heaters and water spray. A control signal derived from the comparison between the measured pressuriser pressure and the reference pressure setpoint, leads the control actuators to:

- Activate the pressuriser heaters to increase pressure by heating the liquid phase of the pressuriser
- Introduce spray water in the steam phase of the pressuriser to reduce pressure.

When set in automatic mode, the pressuriser (continuously controlled) heaters and spray control valves, control the RCP [RCS] pressure during minor variations relative to the reference pressure setpoint.

On/off heaters and spray control valves in on/off mode are activated only in the event of a significant variation compared with this pressure setpoint.

RCP [RCS] pressure measurements contribute to the establishment of alarm set-points and automatic actions. Upper and lower RCP [RCS] set-points generate automatic alarms or limitation measures such as:

- Actuation or switch-off of the pressuriser heaters
- Opening or isolation of the normal and/or auxiliary spray
- Isolation of the RCV [CVCS] charging flow or switch-off of the RCV [CVCS] charging pump (high pressure).

RCP [RCS] pressure measurements are also used to activate the protection instrumentation and control functions (the Reactor Protection System is described in section 1 of Sub-chapter 7.3).

During monophasic intermediate start-up or shutdown states, the pressure is controlled by the RCV [CVCS].

Protection against overpressure in the RCP [RCS] is provided via the pressuriser relief valves and in the event of a severe accident via the RCP [RCS] depressurisation line, as described in Sub-chapter 5.4.

5.2. PRESSURISER LEVEL CONTROL

Control of the pressuriser level contributes to the safety function of maintaining the RCP [RCS] water inventory.

Pressuriser level control is based on the comparison between the measured pressuriser level and the pressuriser reference level. The level control provides a demand signal to the RCV [CVCS] high pressure letdown flow control valve.

The pressuriser reference level is a function of the RCP [RCS] temperature and is calculated to keep a constant reactor coolant mass for pressure levels between 0 and 100%.

Pressuriser level measurements contribute to the establishment of alarm set-points and automatic actions, thereby preventing the actuation of automated instrumentation and control protection functions. The upper and lower pressuriser level set-points generate automatic alarms or limitation measures such as:

- Opening or closing of the RCV [CVCS] high pressure letdown flow rate control valve
- Start up of the second RCV [CVCS] charging pump (low level)
- Isolation of the RCV [CVCS] charging flow (high level)
- Isolation of the pressuriser normal and/or auxiliary spray (high level)
- Switching off the pressuriser heaters (low level).

Pressuriser level measurements are also used to activate the protection instrumentation and control functions (the Reactor Protection System is described in Sub-chapter 7.3).

5.3. RCP [RCS] LOOP LEVEL CONTROL

The RCP [RCS] loop level control contributes to the safety function of controlling the RCP [RCS] water inventory during mid-loop operation (at shutdown) [Ref-1].

Loop level control is based on the comparison between the measured level in the loop and the loop reference level. The level control provides a demand signal to the RCV [CVCS] low pressure letdown flow control valve.

The reference level is calculated to ensure RCP [RCS] level is sufficient for safe operation of the RRA [RHRS]/LHSI pumps and is in accordance with maintenance requirements.

Loop level measurements contribute to the establishment of alarm set-points and automatic actions, thereby preventing the actuation of automated instrumentation and control protection functions. The upper and lower RCP [RCS] loop level set-points generate automatic alarms or limitation measures such as the closing of the RCV [CVCS] low pressure letdown flow path (on low RCP [RCS] level).

The loop level measurements are also used to actuate the automated protection function in the event of failure of the above control methods or a LOCA, i.e. actuation of the safety injection system when the reactor coolant system loop levels are low. In the event of failure of the protection system, an RRC-A function is designed to actuate the safety injection system.

5.4. STEAM GENERATOR LEVEL CONTROL

Controlling the steam generator level contributes to the safety function of controlling the RCP [RCS] temperature.

SG level control is based on the comparison between the measured SG level and a setpoint. The level control provides a demand signal to the feedwater control valves.

The steam generator level setpoint is a constant and independent from the power levels exchanged by the steam generators.

On high SG level, the RCV [CVCS] charging line is isolated, helping to avoiding overfilling of the SG in the event of SGTR.

Steam generator level measurements are also used to actuate the automated protection control functions (the Reactor Protection System is described in Sub-chapter 7.3).

5.5. REACTOR COOLANT PUMP STANDSTILL SEAL SYSTEM ACTUATION

The reactor coolant pump standstill seal system prevents excessive loss of coolant along the shaft in the event of failure of the normal seals and hence contributes to the RCP [RCS] isolation safety function.

The standstill seal system automatically closes when reactor coolant pump shutdown is detected by pump rotational speed measurement sensors, in combination with simultaneous loss of seal cooling from the RCV [CVCS] and the RRI [CCWS].

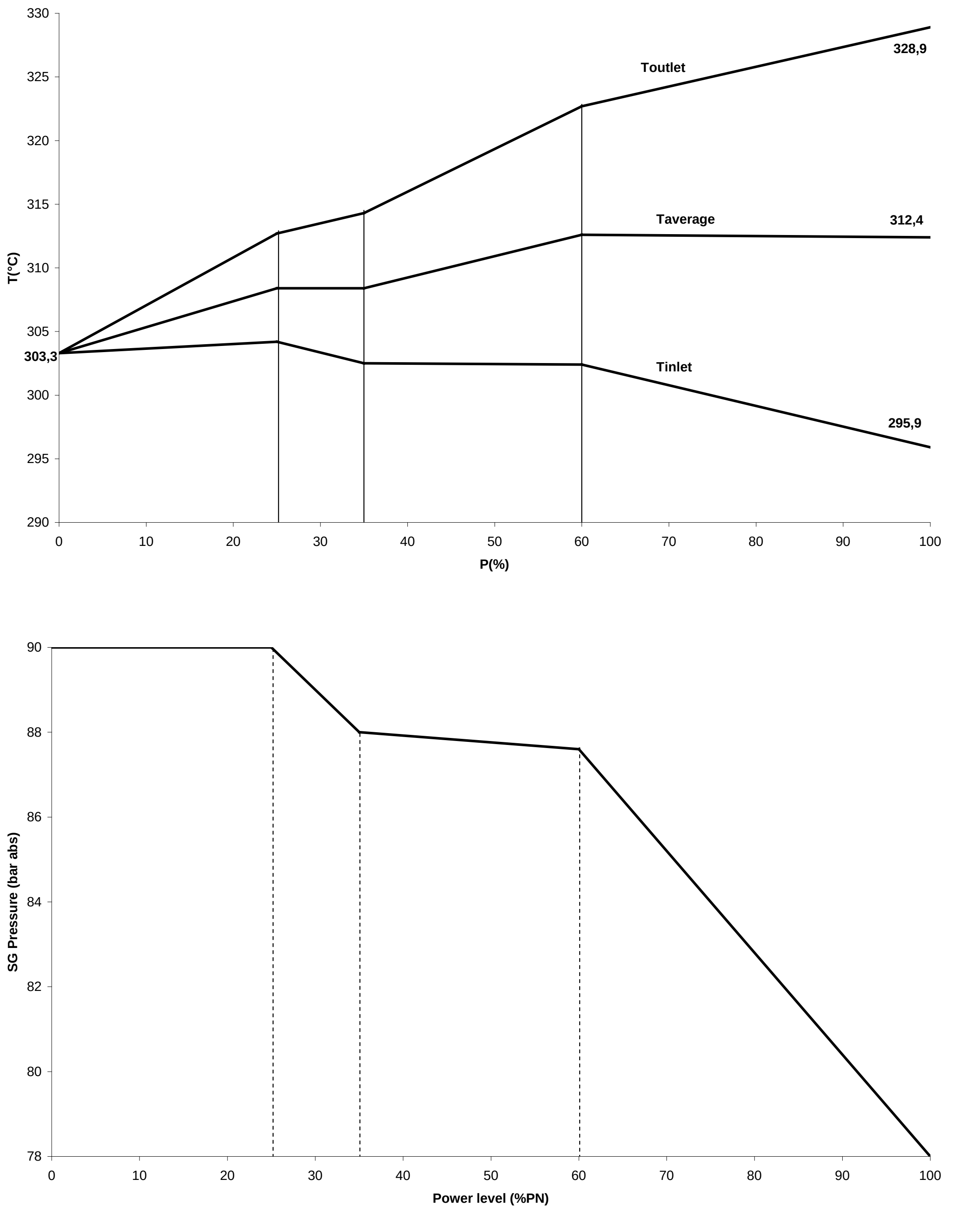
The standstill seal system is hydraulically actuated via a nitrogen seal gas supply and disabled via a seal gas relief to the containment building atmosphere.

All seal leak-off lines from the reactor coolant pumps are automatically isolated by closure of the motorised isolation valves on No. 1, 2 and 3 seal leakage recovery lines.

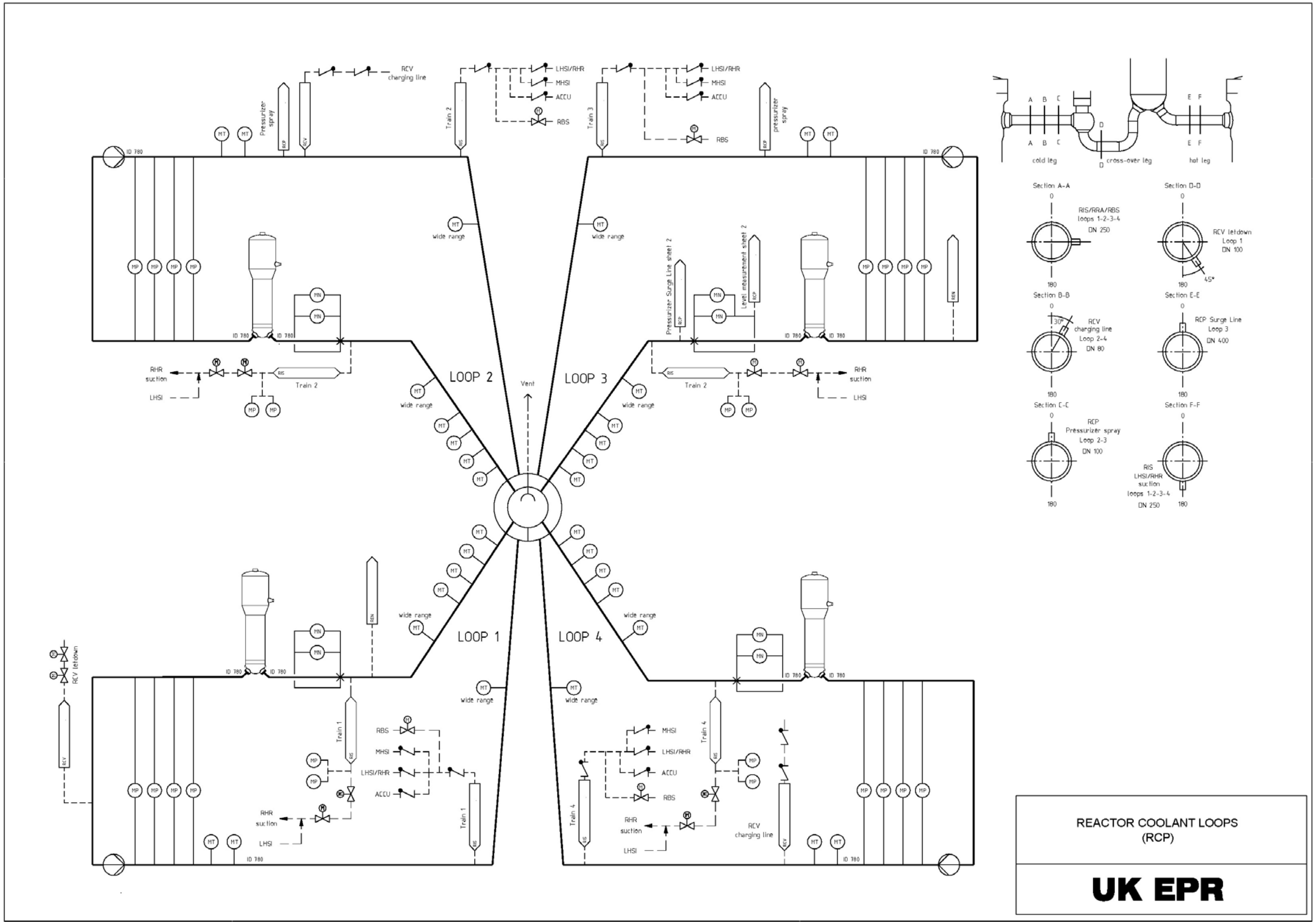
The standstill seal system is described in section 1 of Sub-chapter 5.4.

SUB-CHAPTER 5.1 - FIGURE 1

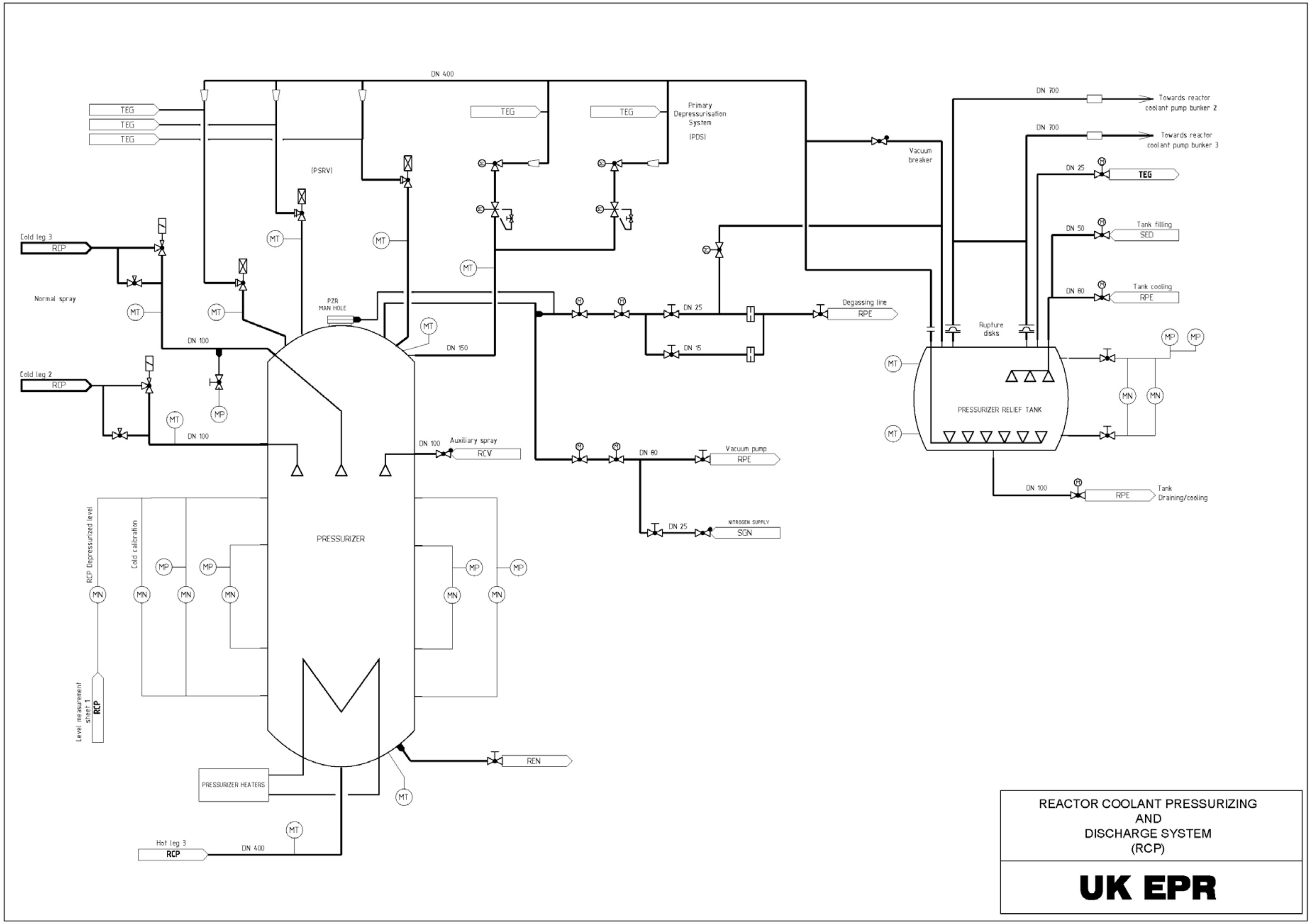
Part Load Diagram at BE Flow Rate for Primary Temperature and Secondary Pressure



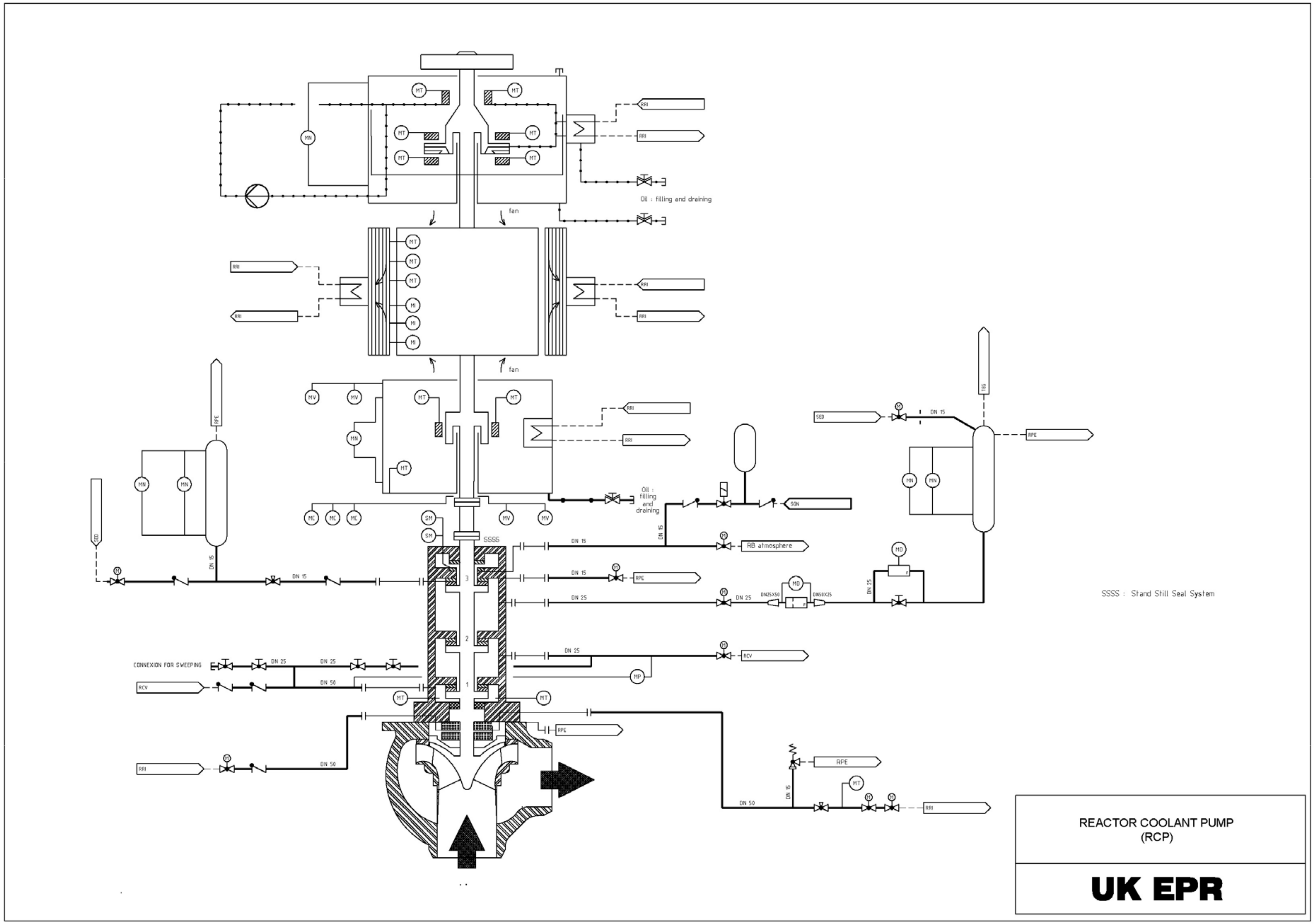
SUB-CHAPTER 5.1 - FIGURE 2 (FOLIO 1/5): SIMPLIFIED FLOW DIAGRAMS OF RCP [RCS]



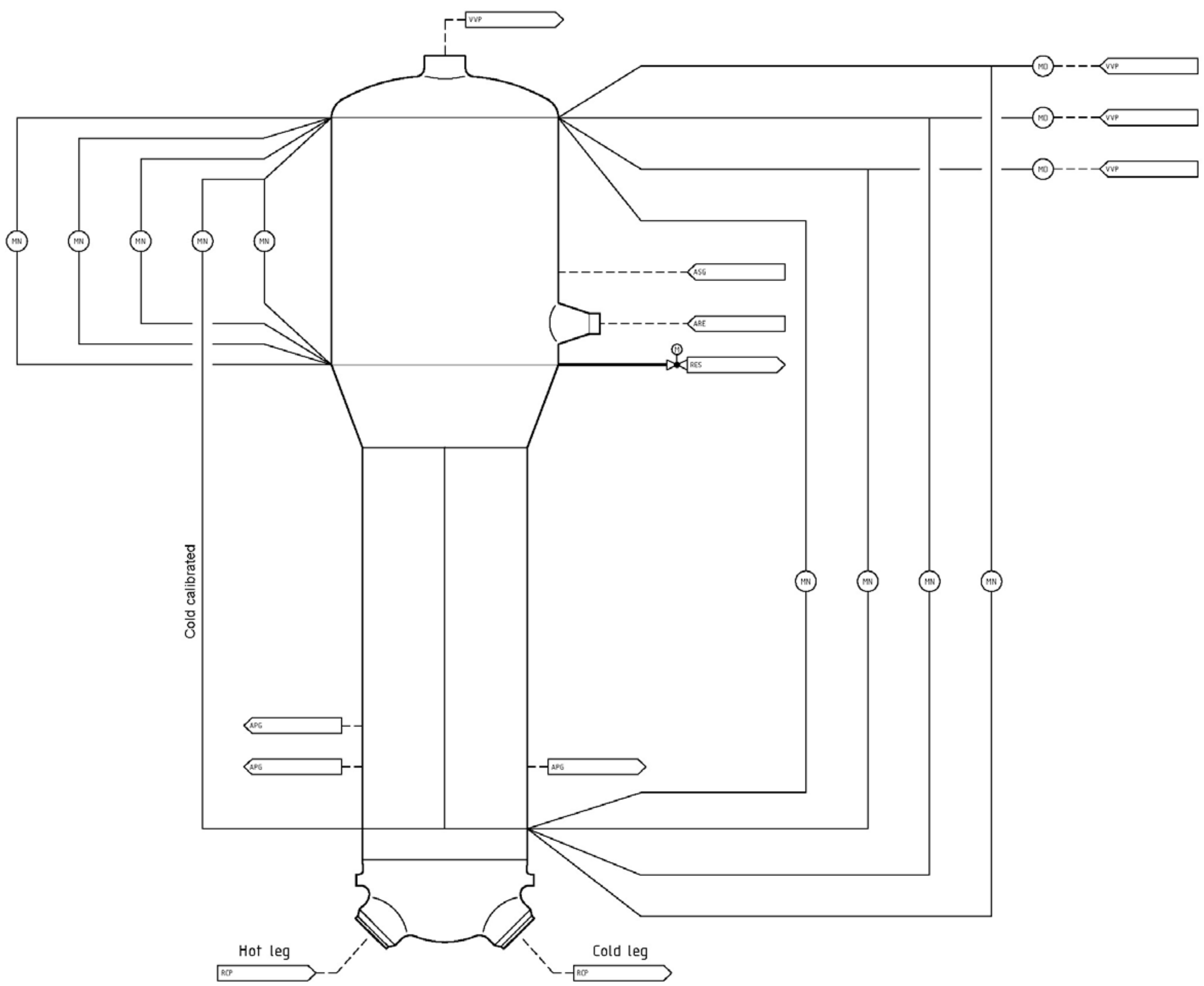
SUB-CHAPTER 5.1 - FIGURE 2 (FOLIO 2/5): SIMPLIFIED FLOW DIAGRAMS OF RCP [RCS]



SUB-CHAPTER 5.1 - FIGURE 2 (FOLIO 3/5): SIMPLIFIED FLOW DIAGRAMS OF RCP [RCS]



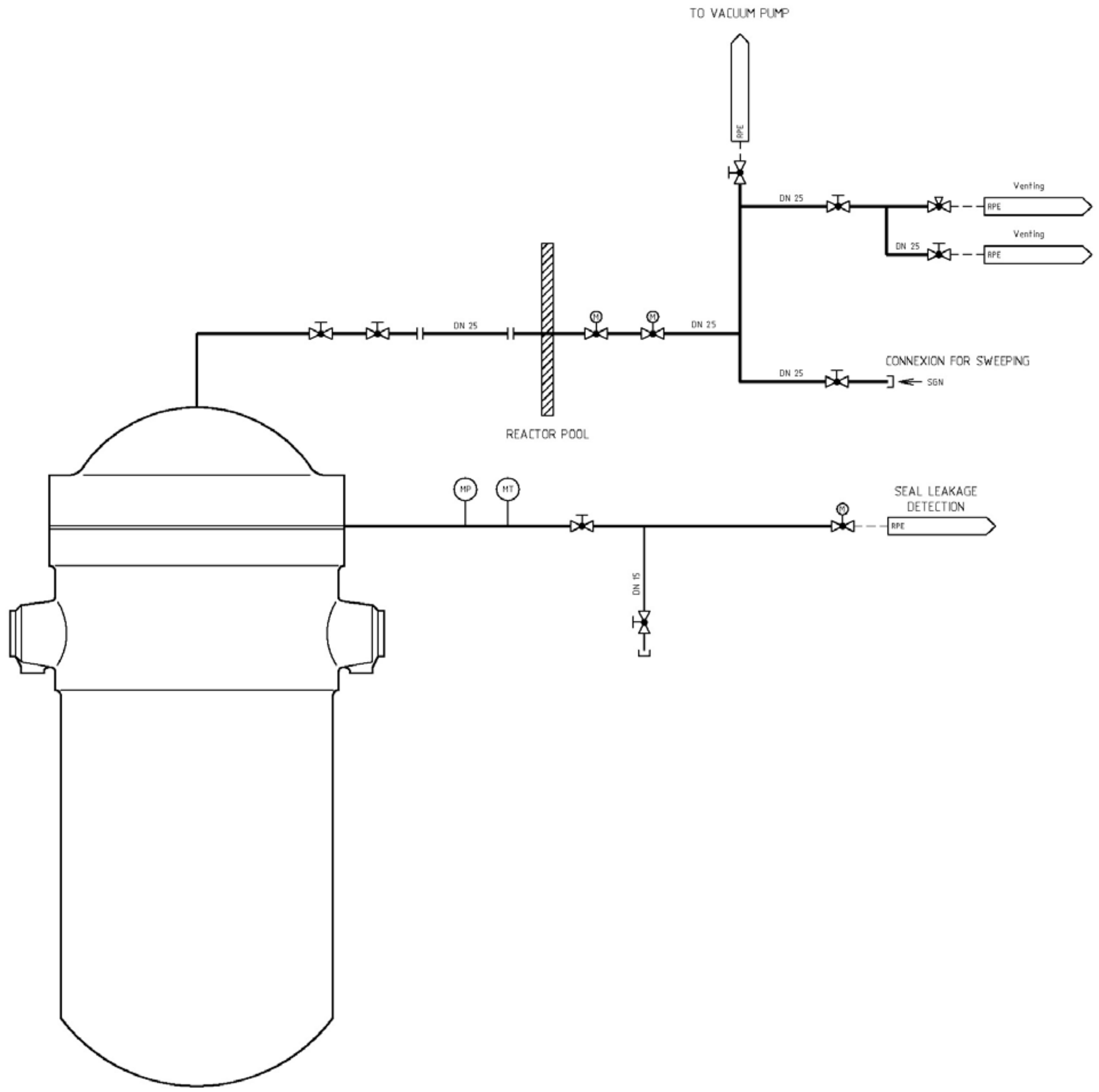
SUB-CHAPTER 5.1 - FIGURE 2 (FOLIO 4/5): SIMPLIFIED FLOW DIAGRAMS OF RCP [RCS]



REACTOR COOLANT SYSTEM
STEAM GENERATOR 1
(RCP)

UK EPR

SUB-CHAPTER 5.1 - FIGURE 2 (FOLIO 5/5): SIMPLIFIED FLOW DIAGRAMS OF RCP [RCS]



REACTOR PRESSURE VESSEL
(RCP)

UK EPR

SUB-CHAPTER 5.1 – 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.

2. DESIGN ASSUMPTIONS AND FLUID CHARACTERISTICS

2.2. RCP [RCS] FLUID CHARACTERISTICS

[Ref-1] System Design Manual - Reactor Coolant System (RCS) Part 3 - System and Component Sizing. NESS-F DC 534 Revision A. AREVA. April 2009. (E)

3. FLOW DIAGRAMS AND MAIN EQUIPMENT CHARACTERISTICS

3.1. FLOW DIAGRAMS

[Ref-1] System Design Manual - Reactor Coolant System (RCS) Part 4 – Flow Diagrams. NESS-F DC 545 Revision A. AREVA. June 2009. (E)

3.4. REACTOR COOLANT PIPEWORK

[Ref-1] System Design Manual - Reactor Coolant System (RCS) Part 2 - System Operation. NESS-F DC 538 Revision A. AREVA. May 2009. (E)

3.5. PRESSURISER

[Ref-1] System Design Manual - Reactor Coolant System (RCS) Part 2 - System Operation. NESS-F DC 538 Revision A. AREVA. May 2009. (E)

3.7. STEAM GENERATORS

[Ref-1] System Design Manual - Reactor Coolant System (RCS) Part 2 - System Operation. NESS-F DC 538 Revision A. AREVA. May 2009. (E)

4. DESCRIPTION OF STATES

4.1. NORMAL OPERATION OF THE REACTOR COOLANT SYSTEM

[Ref-1] System Design Manual - Reactor Coolant System (RCS) Part 2 - System Operation. NESS-F DC 538 Revision A. AREVA. May 2009. (E)

4.2. STANDARD STATES OF THE REACTOR COOLANT SYSTEM AT SHUTDOWN

[Ref-1] System Design Manual - Reactor Coolant System (RCS) Part 2 - System Operation. NESS-F DC 538 Revision A. AREVA. May 2009. (E)

5. RCP [RCS] CONTROL FUNCTIONS

[Ref-1] System Design Manual - Reactor Coolant System (RCS) Part 5 – Instrumentation and Control. NESS-F DC 613 Revision A. AREVA. November 2009. (E)

5.3. RCP [RCS] LOOP LEVEL CONTROL

[Ref-1] System Design Manual - Reactor Coolant System (RCS) Part 2 - System Operation. NESS-F DC 538 Revision A. AREVA. May 2009. (E)