MYRRHA phase 1 implementation
MINERVA

SCK CEN Ref.: =NA.PS01_PDB501
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PS01 Cooling Systems Description

Contract name: Design Engineering Contract
Project phase: Basic Design
SBS level: MYRRHA - MINERVA ACC - Nuclear Facilities - Process systems, equipment and piping

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CLASSIFICATION

Contains information for the design of structures, systems or components: Yes ☒ No ☐

Design verification : Not applicable ☐ Head of OU/Supervisor ☒ Verifier Level 1 ☐ Level 2 ☐

CONTROL OF MODIFICATIONS

Issue	Modifications
0	First issue
1	This document has been updated according to SCK´s comments to previous version of the document (NA.PS01_PDB501_Rev.0 Comments Sheet).
2	Updated for Basic Design (IIB). General revision of the document.

PRELIMINARY OR PENDING INFORMATION

Issue	Paragraphs	Subject	Status
2	Section 4	Information set as preliminary / pending in section 4 "Assumptions".	Preliminary / Pending
	Section 8.4	Purification systems configuration in ACC cooling loops	Preliminary
	Section 9	Control philosophy of valves NA.PS01.PAB12.AA302 / AA303 (based on operational state of NA.CP cryogenic supply system)	Pending

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Table of Content

1 Introduction

The MINERVA project is embedded in the overall MYRRHA programme. Following the phased MYRRHA implementation strategy, the first facility that will be constructed at SCK CEN, Mol (Belgium) will be the first part of the 600 MeV MYRRHA LINAC that will deliver intense proton beams up to 100 MeV. The 100 MeV accelerator together with the proton target facility and FPF is named MINERVA (MYRRHA Isotopes productioN coupling the linEar acceleRator to the Versatile proton target fAcility).

Tractebel together with its Consortium Partner Empresarios Agrupados will act as Design Engineer of all the Structures, Systems and Components (SSC) necessary to operate the MINERVA Accelerator, and covered under the Nuclear Facilities (NF), except for the accelerator systems themselves, which are excluded from the Design.

The framework and more details about this project can be found in the Project Execution Plan Ref. [1]

2 Scope and Purpose

This document describes the functions and physical layout of the PS01 Cooling Systems. It also defines the system's instrumentation and control, its interfaces with other systems and the most important characteristics of its major components, including also Operation and Control and normal functionality (see Chapters 8 and 9).

Other aspects such as design conditions and data are included in Sizing, Design and Capacity Calculations of Cooling Systems, Ref.[8].

3 Acronyms

The complete list of acronyms used in the MINERVA project is included in the SCK CEN document "Abbreviations, Glossary and symbols", SCK CEN\8905079 Ref. [2].

4 Assumptions

The following assumptions have been taken into account in the design of the MINERVA Cooling System:

1. The number of adiabatic coolers required in the PS01 Cooling Systems and described in this document is preliminary, based on the information provided by a potential supplier (TOPAZ NEO modules from ESINDUS/JACIR). The final number of units and their dimensions should be defined based on the manufacturer finally selected.
2. It is assumed that there is no material incompatibilities between the internals of different equipment cooled by a single cooling loop, to be confirmed by ACC / SCK CEN based on the cooling loops distribution detailed in Section 8. Cu and Al components in a same cooling loop must be avoided.
3. It is assumed that the cooling load demanded by the consumers included in one cooling loop is simultaneous, unless otherwise is explicitly indicated in the detailed description of the cooling loop.
4. It is considered that HV06 can be directly connected to the WCS heat recovery oil cooler of the He compressors, included in the package supply of the Cryoplant.

Other assumptions related with the sizing of the system are included in Section 4 of Ref.[8].

5 Input Data List

LIST OF DOCUMENT INPUT DATA

No	Source Document			Requirement/Data	Status
	No.	Issue	Title		
1	=NA.PS01_MEC001	v0 (25-08-2022)	PS01 Cooling Systems Functional Specifications	System functional specifications and requirements	V
2	=NA.AA_BMA002	06-07-2022	High Level Interface List - ID2558	List of ACC cooling water consumers and requirements.	V
3	=NA.PS-ID1169 SCK·CEN/48331860	04-07-2022	Results of the radiolysis calculations for the system design	The highest expected activation of water in potentially activated cooling loops is B02	V
4	=NA.PS-ID2554 SCK·CEN/48288754	23-03-2022	Operating Domain Update	The following utilization factor is to be considered ACC PS = 10/12 months ACC NF = 11/12 months	V
5	Not used				
6	SCK·CEN/37754722	31-03-2020	NA.PS_PDB002 - Answer to RFI – ID1162	Complete set of environmental conditions of MINERVA site	V
7	=NA.PS-ID1164 (SCK·CEN/48336594)	17-11-2022	Cooling water requirements of PTF / FTS systems	Cooling water requirements for the MAC.	V
8	Not used				
9	SCK·CEN/37819244	01-12-2020	NA.PS_PDB011 - Answer to RFI – ID1244	Characteristics of DUMP-I	V
10	SCK·CEN/42265583	29-04-2021	NA.PS_PDB014 - Answer to RFI – ID2253	Inputs for the geothermal feasibility analysis: BR2 groundwater wells Assumption from SCK.CEN that the historic VITO installation does not affect the future MINERVA ATES installation.	V
11	Not used				

No	Source Document			Requirement/Data	Status
	No.	Issue	Title		
12	-	16/04/2021	MoM BA meeting Email from KSA to BGI 04/05 (Internal reference EA: 092-423-CE-SCK-EAI-21/0385	DUMP-I cooling loop will be placed the MCB Cooling system room.	V
13	SCK CEN/43231392	12/04/2021	MoM Integration Meeting 016	Requisites to locate the cooling towers on the top of AUB/RF Gallery: the height should not exceed 3,5 m	V
14	=NA.PS-ID2551 SCK·CEN/48289298	22-03-2022	Procurement approach	.17°C/27°C intermediate circuit does not supply any user directly and is always separated by an additional HX. . Combination of SC LINAC and BT transfer into a single circuit is the preferred design and to be serviced by the 17°C/27°C heat sink. . The injector room magnets require a dedicated circuit.	V
15	=NA.PS-ID2539 SCK·CEN/48337004	25-03-2022	Chilled water temperature levels	2 temperature levels of supply considered: . 17ºC: Intermediate geothermal cooling loop . 7ºC: Chilled water to HVAC users	V
16	=NA.AA-ID2565	13-05-2022	Cooling lines under RF cabinets	Configuration of the cooling lines below cabinets and trenches at RF Gallery.	V
17	=NA.PS-ID1165 SCK·CEN/48336051	12-07-2022	Requirements of activated cooling loop in case of power loss	No requirement for heat dissipation if the beam is off	V
18	=NA.PS-ID1167 SCK·CEN/48332265	15-07-2022	Cooling System operation modes	ACC commissioning and operation modes for partial loads	V
19	SCK·CEN/51855847	09-11-2022	NA.PS discipline meeting	ACC NF design to consider DUMP-I design as 10 kW. DL RF loads reduction from 275 to 130 kW with dedicated supply (not “daisy-chain”).	V
20	=NA.AA_BMA003	30-11-2022	Interface List Cryoplant	Cryoplant cooling water consumers and requirements.	V
21	=NA.PS-ID2582 SCK·CEN/52003731	13-12-2022	Cu/Al contact areas of ACC equipment in PS01 cooling loops	Copper wetted parts the corrosion rate: < 2.5 mg/(m^2d) No aluminium wetted parts expected Cu contact areas of ACC equipment in cooling loops	V

No	Source Document			Requirement/Data	Status
	No.	Issue	Title		
22	=NA.PS-ID1225 SCK·CEN/48337671	23-12-2022	Remote Handling requirements for resins exchange	Resin is expected to be of a LAVA category, so no remote handling is currently envisaged for the various resin / purification systems for the ACC NF based on the water activation. To be later confirmed by safety.	P
23	Internal reference EA: #Ref: 092-423-CE-SCK-EAI-23/0007	04-01-2023	E-mail: SCK CEN - WCS cooling terminal points	Compressors equipped with a heat recovery system that require two separated cooling water loops: . Oil and helium coolers are cooled by PS01. . The heat recovery oil cooler is cooled by a separated loop (HV06). Max. 80% of oil heat can be recovered: ~ 500 kW.	P
24	SCK CEN presentation	11-02-2022	“PS01 configuration/architecture.ppt”	Site Meteorological data / yearly temperature distribution (BEERSE)	V
25	NA.PS01_PDD501_rev2_Comment Sheet	15-08-2021	PS01 Cooling System Sizing, Design and Capacity Calculations_Comment Sheet	Buffer tanks sizing criteria: minimum volume ≥7 l per kW heat load.	V
26	=NA.PS-IDD001 SCK CEN/48732777	08-04-2022	ATES sub-system	SCK CEN allows for the installation of the ATES doublets on the entire 600 MeV site (MYRRHA phase 2), if needed	V
27	=NA.PS01_PDD501 R02_CS	26-04-2023	Comment Sheet (CS) resolution and agreement_PS01 Cooling Systems Sizing, design and Capacity calculations (R02)	The conductivity for the demin water for PGB31 must be maintained below 0.5 µS/cm: pH should be reduced from the previous value of 9. No degassing units required in Water Purification Units (preliminary).	V

6 System Functions and Configuration

6.1 System Functions

The main function of the PS01 Cooling System is to provide cooling to the different equipment of the Accelerator (ACC), cryogenic facility, HVAC systems and MAC NF of MINERVA.

Cooling systems are essential for the operation of the MINERVA main systems. The following main functionalities are identified:

- To transfer and reject to the environment all the heat loads that needs to be removed from the different main systems of the MINERVA facility, under all its modes of operation.
- To supply suitable cooling water at the specified quality, temperature, flowrate and pressure as required by the different consumers.
- To maintain the coolant temperatures and flowrates within the specified limits under all system operation modes and under all environmental conditions.
- To maintain the cooling water chemistry within the prescribed limits for each subsystem.
- To prevent the dissemination of radioactive materials in potentially contaminated cooling loops, guaranteeing the function of barrier of confinement.
- To provide thermal regeneration of the groundwater when it is used as heat sink of the ACC heat loads.
- To provide the means to drain and refill the system components for maintenance.

To accomplish these functions, and as shown in the PFD (Ref.[7]) and P&ID (Ref.[6]), the Cooling Systems consist mainly of:

- A set of closed primary cooling loops that provide cooling water to the different ACC and NF equipment at different temperature levels.
- A chilled water subsystem (NA.PS01.PGB20) that supplies chilled water to HVAC systems.
- An intermediate closed cooling loop (NA.PS01.PGB30) that transfer the heat rejected by the ACC primary cooling loops to the heat sinks of the facility.
- A geothermal cooling subsystem (NA.PS01.PCB30) that supplies groundwater as heat sink of the heat rejected by the ACC primary cooling loops during summer / warmer conditions.
- A low temperature adiabatic cooling subsystem (NA.PS01.PAB11) that supply cooling water to the chilled water subsystem as well as rejects to the environment the heat rejected by the ACC primary cooling loops during winter / colder conditions. This subsystem also provides aquifer regeneration by cooling the groundwater.
- A medium temperature adiabatic cooling subsystem (NA.PS01.PAB12) that supply cooling water to the Cryogenic Supply System (NA.CP) and medium temperature MAC consumers.
- A propylene glycol supply subsystem (NA.PS01.PUA10) that provides the glycol or water/glycol (40%wt.) mixture cooling media required at the adiabatic and chilled water cooling loops.

Cooling is not a nuclear safety function for the accelerator systems.

6.2 System List

To accomplish the required system functions, and taking into account the different cooling water requirements set by the final consumers as well as the potential activation of the cooling water, the following subsystems have been considered into the Cooling Systems:

Table 1 – PS01 Subsystems List

Subsystem Name	Subsystem ID
Low Temperature Adiabatic Cooling Subsystem	NA.PS01.PAB11
Medium Temperature Adiabatic Cooling Subsystem	NA.PS01.PAB12
Chilled Water Subsystem	NA.PS01.PGB20
Geothermal Cooling Subsystem	NA.PS01.PCB30
Intermediate Geothermal Cooling Loop	NA.PS01.PGB30
PCO & SSA Cooling Loop	NA.PS01.PGB31
Low Activated Injector Magnets Cooling Loop	NA.PS01.PJB31
Low Activated Injector NC-RF Cavities Cooling Loop	NA.PS01.PJB32
Low Activated DUMP-I Cooling Loop	NA.PS01.PJB33
Low Activated SC LINAC Tunnel / BTT Cooling Loop	NA.PS01.PJB34
Propylene Glycol Supply Subsystem	NA.PS01.PUA10

The complete list of subsystems and equipment that comprise the system will be included in the MINERVA ACC NF SCC List, Ref. [14].

6.3 Fluid Characterization

The different fluid process media that are considered in the PS01 Cooling Systems are included in the ACC NF Fluid List (=NA.AA_BPB503) Ref. [16]. They are mainly the following:

- Softened water, produced at MINERVA facility by the PS02 Water preparation and supply system, used as:
  - Cooling media of the intermediate geothermal cooling loop (NA.PS01.PGB30)
  - Make-up water of the water/propylene glycol cooling loops (NA.PS01.PAB11, NA.PS01.PAB12 & NA.PS01.PGB20)
  - Make-up water for the humidifying pads of the adiabatic coolers.
- Softened water/propylene glycol (40%wt), used as:
  - Cooling media of the adiabatic cooling loops (NA.PS01.PAB11 & NA.PS01.PAB12)
  - Cooling media of the chilled water subsystem (NA.PS01.PGB20)
- Recycled water/glycol (40%wt), coming from the PS03 Industrial glycol wastewater subsystem (NA.PS03.GMB10), recycled to the water/glycol cooling loops as make-up water in case the water quality meets the requirements.
- Groundwater, used as cooling media of the geothermal cooling system (NA.PS01.PCB30). This water is extracted from the aquifer available at MINERVA site (Diest formation) and re-injected in the soil previous water temperature regeneration when the environmental conditions allow it (see Section 8)
- Demineralized water, produced at MINERVA facility by the PS02 Water preparation and supply system and used as cooling media of all the ACC primary closed cooling loops.

- Recycled demineralized water, coming from the PS03 Industrial demineralized wastewater subsystem (NA.PS03.GMB60), recycled to the demineralized water cooling loops as make-up water in case the water quality meets the requirements.
- Propylene Glycol, stored in a tank, to be dosed to the water/glycol cooling loops in case it is required.

Stream information of the main process lines of the different subsystems, including the process fluid and their operating conditions, is included in the Line List (Ref. [18]).

7 System Boundaries and Interfaces

The interfaces of the system with other systems or related equipment are described below. The interfaces are classified into:

- Support systems: those that are necessary for the system operation
- Dependent systems: those that are supplied by the system and needed so that other systems can perform their function

The systems which interface with the PS01 Cooling Systems are set out below:

7.1 Support systems

- PS02 Water Preparation and Supply System:
    - Softened water subsystem (NA.PS02.GKC10), that supplies the make-up water for the adiabatic coolers as well as make-up water to specific cooling loops.
    - Demineralized water subsystem (NA.PS02.GHC10), that supplies demineralized water for the ACC primary cooling loops.
- PS03 Wastewater Treatment System:
    - Industrial Glycol Wastewater Subsystem (NA.PS03.GMB10), which collects the water/glycol mixture drains from the cooling loops for its posterior recycling or disposal.
    - Industrial Softened Wastewater Subsystem (NA.PS03.GMB40), which collects the drains from the softened water cooling loops and discharges them into the industrial sewer system.
    - Industrial Adiabatic Coolers Blowdown Wastewater Subsystem (NA.PS03.GMB50), which collects and discharges the blowdown from the adiabatic coolers.
    - Industrial Demineralized Wastewater Subsystem (NA.PS03.GMB60), which collects the drains from the demineralized water cooling loops for its posterior recycling or disposal.
    - Potentially Contaminated / Activated B02 Wastewater Subsystem (NA.PS03.GMD10), that collects and manages the water drains from the potentially contaminated / activated Cooling loops for its posterior recycling or disposal.
- PS04 Solid Waste Treatment System, for the safety management of the contaminated ion exchange resins cartridges that should be periodically replaced in the activated cooling loops (NA.PS04.KPB20)
- PS05 Industrial gases:
    - Instrument Air Storage and Distribution (NA.PS05.QFB10), for the compressed air supply to the pneumatic valves of the system.
    - Bulk Nitrogen Storage and Supply (NA.PS05.QJB20), for the supply of nitrogen to the surge tanks of the different closed cooling loops to maintain a specific pressure and to limit oxygen and CO_2 ingression.
- Low voltage system (NA.ES02), for the operation of the different electrical equipment of the system.
- Instrumentation and Control (I&C).

7.2 Dependent Systems

- Accelerator systems, requiring the cooling of the different ACC equipment.
- MAC systems, requiring PS01 as the final heat sink of MAC cooling loops. PS01 provides cooling media to MAC at different temperatures and water qualities by specific terminal points, defined as closed valves and blind flange connections.
- Cryogenic Supply System (NA.CP) facility, that requires cooling water for the Warm Compressors Station (WCS) and Refrigerator Cold-Box.
- Nuclear HVAC & Conventional HVAC systems for buildings, requiring chilled water at 7ºC.
- HV06 Heating System that recovers heat from the geothermal cooling loop.

7.3 Terminal Point List

The different interfaces of the PS01 Cooling System with the site external facilities, accelerator equipment and MAC are included in the MINERVA ACC NF Terminal Point List Ref. [13].

These terminal points are also identified and numbered in the System Process Flow Diagram (Ref. [7]) and in the PS01 Cooling Systems P&ID (Ref. [6]).

8 System Design Description

8.1 Cooling system main configuration

8.1.1 Cooling water consumer list

The different cooling water consumers at the MINERVA NF, taken from the system Functional Specification (I.D.1), ACC interface list (I.D.2), Cryogenic Supply System (NA.CP) interface list (I.D.20), MAC requirements (I.D.7) and HVAC systems requirements (Refs. [19] & [20]) are summarized in the following table:

Table 2 – Cooling water consumers of MINERVA NF

Final consumers description	Water activation	Nominal Inlet Temperature (°C)	Minimum Inlet Temperature (°C)	Maximum Inlet Temperature Fluctuations (°C)
Cryogenic Supply System (NA.CP) - Warm Compressor Station (WCS)	-	27	Above dew point	N/A
Cryogenic Supply System (NA.CP) - Refrigerator cold-box (QRB)	-	27	Above dew point	N/A
ACC - Injector magnets and others (pumps, ion source, others)	B02	25	Above dew point	+2/-2
ACC - NC-RF cavities	B02	20	Regulated	+0.3/-0.3
ACC - DUMP-I	B02	20	Above dew point	+2/-2
ACC - Low Beta LINAC (magnets, others)	B02	25	Above dew point	+2/-2
ACC - Low Beta LINAC (RF coupler)	B02	20	Above dew point	+2/-2
ACC - Target Section (magnets, others)	B02	25	Above dew point	+2/-2
ACC - Target Section (septum)	B02	20	Above dew point	+2/-2
ACC - Beam towards PTF (magnets, others)	B02	20	Above dew point	+2/-2
ACC - Beam towards FPF (magnets, others)	B02	20	Above dew point	+2/-2
ACC - PCO & SSA I1UB	-	20	Above dew point	+2/-2
ACC - PCO & SSA AUB	-	20	Above dew point	+2/-2
ACC - Circulators	-	20	Regulated	+0.5/-0.5
ACC - RF Loads	-	20	Above dew point	+2/-2
MAC – TP.PS01.4001	-	27	Above dew point	N/A
MAC – TP.PS01.4007	-	17	N/A	N/A
MAC – TP.PS01.4011	-	7	N/A	N/A
Conventional HVAC	-	7	N/A	N/A
Nuclear HVAC	-	7	N/A	N/A

At this stage of the project, no other equipment in ACC NF are expected to be cooled by the PS01 system.

8.1.2 Cooling loops distribution criteria

Along the beam transport line some of the protons are scattered and end up in the beam transport magnets, so the cooling water of these components is subjected to proton as well as secondary neutron irradiation. In addition, spallation neutrons activate the corrosion products present in the cooling water, which generates long-lived radionuclides and makes the cooling water as potentially contaminated and/or activated.

In consequence, the distribution of the different ACC and other NF equipment in the different cooling loops has been made, in a first approach, attending to the potential activation of the cooling water in the loop, avoiding to consider in a same single cooling loop ACC equipment with risk of potential activation and other equipment or conventional facilities with no risk of water activation.

In addition, the following requirements set by the different cooling water consumers have been also considered for the distribution of the different ACC and other NF equipment in the different loops:

- Cooling water inlet temperature and temperature stability;
- Cooling water quality, mainly in terms of required conductivity and pH;
- Cooling water pressure requirements;
- Consumers location;
- Material compatibility between the different consumers in a single cooling loop, avoiding including in a same loop materials made of aluminium and copper parts (due to potential galvanic corrosion and water conditioning requirements)

Coolant temperature and stability, flowrate profile and thermal load are the main factors involved in the operation of the Cooling Systems. Temperature ranges have been selected in order to harmonize consumer performance and system capacities.

8.1.3 Cooling loops distribution

Based on the cooling water consumers requirements listed in section 8.1.1., and considering the distribution criteria described in section 8.1.2, the final configuration of the different cooling loops in the MINERVA PS01 Cooling System is set as is summarized the following table:

Table 3 – PS01 Cooling loops distribution

Cooling Loop Description	Cooling Loop ID	Coolant	Activation level	Operating Temperature at cold side (°C)	Maximum Temperature Fluctuations (°C)	Consumers
Low Temperature Adiabatic Cooling Subsystem	NA.PS01.PAB11	Soft.water / PG (40%)	-	27 - 3	N/A	. Chillers condenser . Chillers free-cooling . Intermediate geothermal heat exchanger ("HX2") . Regeneration heat exchangers ("HX3", "HX4")
Medium Temperature Adiabatic Cooling Subsystem	NA.PS01.PAB12	Soft.water / PG (40%)	-	27	N/A	. Cryogenics WCS . Cryogenics Cold QRB . MAC (TP.PS01.4001/4002)

Cooling Loop Description	Cooling Loop ID	Coolant	Activation level	Operating Temperature at cold side (ºC)	Maximum Temperature Fluctuations (ºC)	Consumers
Chilled Water Subsystem	NA.PS01.PGB20	Soft.water / PG (40%)	-	7	N/A	. Conventional HVAC loads . Nuclear HVAC loads . MAC (TP.PS01.4011/4012)
Geothermal Cooling Subsystem	NA.PS01.PCB30	Groundwater	-	13	N/A	. Intermediate geothermal heat exchanger "HX1"
Intermediate Geothermal Cooling Loop	NA.PS01.PGB30	Softened Water	-	17	N/A	. ACC primary cooling loops heat exchangers (PGB31, PJB31, PJB32, PJB33, PJB34) . MAC (TP.PS01.4007/4008)
PCO & SSA Cooling Loop	NA.PS01.PGB31	Demineralized water	-	20 / 22	+0.5/-0.5	. PCO & SSA I1UB . PCO & SSA AUB . Circulators . RF Loads
Low Activated Injector Magnets Cooling Loop	NA.PS01.PJB31	Demineralized water	B02	25	+2/-2	. Injector magnets and components (pumps, BD, ion source)
Low Activated Injector NC-RF Cavities Cooling Loop	NA.PS01.PJB32	Demineralized water	B02	20 / 22	+0.3/-0.3	. Injector NC-RF cavity
Low Activated DUMP-I Cooling Loop	NA.PS01.PJB33	Demineralized water	B02	20	+2/-2	. DUMP-I
Low Activated SC LINAC Tunnel / BTT Cooling Loop	NA.PS01.PJB34	Demineralized water	B02	20	+2/-2	. Low Beta LINAC comp. . Target Section comp. . Beam towards PTF components . Beam towards FPF components

8.2 System Operation

The following system main operation modes and switch points are stablished for the different subsystems for the proper operation of the PS01 Cooling System. These operation modes are described more in detail in Sections 8.3 and 9 of this document.

The PS01 cooling systems are designed for a continuous operation, providing cooling water at the required conditions to the different equipment of the MINERVA NF.

As is defined in (I.D.4), ACC primary systems consider an annual operating factor of 10/12 months. During the normal operation of the ACC, the different PS01 primary cooling loops (NA.PS01.PGB31, NA.PS01.PJB31, NA.PS01.PJB32, NA.PS01.PJB33, & NA.PS01.PJB34) will provide cooling water at the temperature defined in Table 3. For these consumers, a constant annual load profile is assumed, considering a constant flowrate in the loops. Any potential load variation in the final consumers (that will cause variations in the outlet water temperature) will be managed by the control system of the loop, in order to keep the supply temperature in the values required in Table 3 (see section 8.3.2 and section 9), while a constant flowrate through the different ACC consumers is maintained.

All these primary cooling loops are cooled by an intermediate loop (NA.PS01.PGB30), that operates in a temperature regimen of 17ºC (supply) / 27ºC (return). In this case, the cooling loop will operate at variable flowrate by the use of VFD in the pumps, that will adapt the operation to the flowrate required at the different heat exchangers of the primary cooling loops to fulfil with the temperature requirements of the ACC consumers. The heat sink of this intermediate cooling loop changes attending to the environmental conditions at the facility:

- For summer/warmer conditions, the heat load rejected by the intermediate cooling loop (NA.PS01.PGB30) is cooled by the Geothermal Cooling System (NA.PS01.PAC30). This geothermal system is comprised by a set of wells that provides groundwater at a constant temperature of 13ºC to the process cooling heat exchangers NA.PS01.PGB30AC011/012 (referred as "HX1" in Ref.[4 & 7]) and reinjects the water into the soil. See Figure 1.

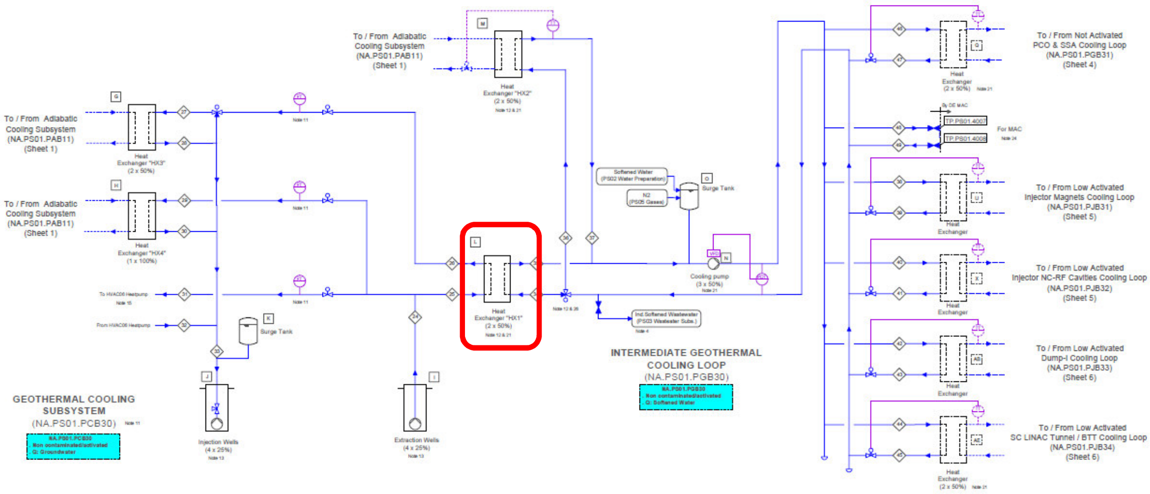


Figure 1 – Process cooling through NA.PS01.PGB30AC011/012 (Ref.[7])

  In the hottest periods, and after increasing its temperature in the process cooling heat exchanger HX1, groundwater is re-injected into the soil at a maximum temperature of 25ºC. As ambient temperature decreases, groundwater thermal pollution can be partially reduced through the heat exchangers NA.PS01.PCB30AC011/012 (referred as "HX3" in Ref.[4 & 7]), placed in series with "HX1". The heat sink of these regeneration heat exchangers is the low temperature adiabatic cooling subsystem (NA.PS01.PAB11) that provides cooling water at low temperature (from 27ºC in summer design conditions to 3ºC in the coldest period).

  Under these conditions, NA.PS01.PAB11 also provides cooling to the condenser side of the chillers of the chilled water subsystem (NA.PS01.PGB20), that supply chilled water at 7ºC to the HVAC loads of the MINERVA facility.

- For winter/colder conditions, the heat load rejected by the intermediate cooling loop (NA.PS01.PGB30) is cooled by the low temperature adiabatic cooler subsystem (NA.PS01.PAB11) through the process cooling heat exchangers NA.PS01.PGB30AC021/022 (referred as "HX2" in Ref.[4 & 7]), see Figure 2.

  Under these conditions, groundwater flowrate is maintained through the regeneration heat exchanger "HX3", with an inlet temperature of 13ºC, so aquifer regeneration is achieved as far as the water temperature at the low temperature adiabatic cooler subsystem (NA.PS01.PAB11) is below 13ºC. At colder conditions, groundwater extraction can be maximized to achieve supplemental regeneration heat exchanger NA.PS01.PCB30AC020 (referred as "HX4" in Ref.[4 & 7]) as well as allowing heat recovery at the HV06 heat pump. Under this circumstances, aquifer regeneration can be yearly balanced and completed.

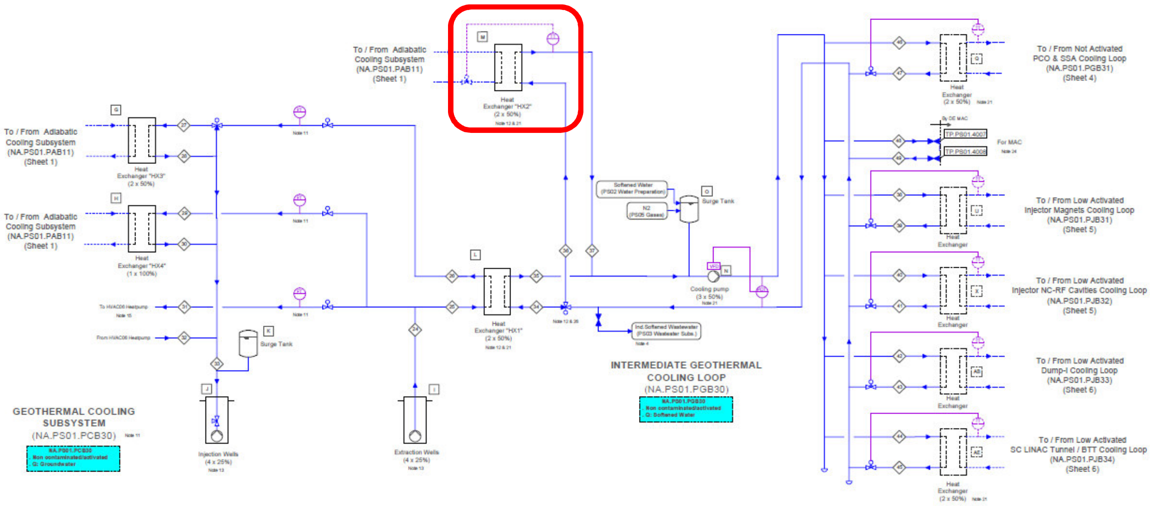


Figure 2 – Process cooling through NA.PS01.PGB30AC021/022 (Ref.[7])

Based on above, adiabatic cooling subsystem NA.PS01.PAB11 has a seasonal operation. The performance of the adiabatic coolers at the different environmental conditions are preliminary designed to maintain constant water flow through the cooling modules in operation with their fans at nominal speed. The fans of the adiabatic coolers will operate constantly at their nominal cooling power at full fan speed, to reduce the temperature of the water at the outlet of the adiabatic coolers as much as possible, with a minimum water temperature of 3ºC. These modules start and stop depending on cooling requirements while the excess flow is bypassed by means of a control valve, maintaining always a constant flow through each module.

The main switch point of this low adiabatic cooling subsystem NA.PS01.PAB11 subsystem are the following ones:

- Water temperature at the outlet of the modules (T_{adiab}): variable (27ºC – 3ºC)
- Dry/wet adiabatic cooler switch point: DBT = 10ºC (Preliminary, based on Topaz Neo TH11-E09-D3-12830-B-6, see assumption 1)
- The change of heat exchangers operation has been determined to fulfill with the annual aquifer thermal regeneration according to the temperature at the outlet of adiabatic coolers (Tadiab):
    - ACC cooling through PGB30AC021/022 ("HX2"): Tadiab ≤ 14ºC (DBT ~ 10ºC, 46.5% time)
    - Regeneration through PCB30AC011/012 ("HX3"): Tadiab ≤ 21ºC (WBT ~ 18ºC, 95% time)
    - Regeneration through PCB30AC020 ("HX4"): Tadiab ≤ 10ºC (DBT ~ 5ºC, 21% time)
    - Free-cooling through PGB20AC010: Tadiab ≤ 6ºC (DBT ~ 0ºC, 6.6% time)

The following table summarizes the different system main operation modes and switch points preliminary considered during the normal operation of this subsystem:

Table 4 – Seasonal operation of NA.PS01.PAB11

Ambient Cond.		ACC Process Cooling (HX1/HX2)	NA.PS01.PAB11					
DBT (ºC)	WBT (ºC)		Oper. Mode	Water Tout (1) (ºC)	Regen. HX3	Regen. HX4	Chiller condenser cooling	Chillers free-cooling
<-3	< -3.6	HX2	Dry	≥3	Yes	Yes	No	Yes
≤ 0	≤ 0.5	HX2	Dry	≤6	Yes	Yes	No	Yes
5	4.3	HX2	Dry	9.7	Yes	Yes	Yes	No
~ 9	7.5	HX2	Dry	≤14	Yes (2)	No	Yes	No
~ 10	8.7	HX1	Wet	>14	Yes	No	Yes	No
≤ 23	≤ 18	HX1	Wet	≤21	Yes	No	Yes	No
>23	>18	HX1	Wet	>21	No	No	Yes	No

(1) *Preliminary performance of the adiabatic coolers, to be confirmed by the manufacturer selected.*

(2) *In those conditions where the water temperature at the outlet of the adiabatic cooler is higher than groundwater temperature, HX3 hot side is bypassed.*

On the other hand, the medium temperature adiabatic cooling subsystem (NA.PS01.PAB12) cools the Cryogenic Supply System (NA.CP) and MAC medium temperature consumers (TP.PS01.4001/4002), maintaining constant temperature of the water at the outlet of the adiabatic coolers. Consequently, this subsystem has only one mode of operation, regulating the temperature required by the consumers at a constant value. In this case, adiabatic coolers work with variable speed drives to adjust said temperature.

The main switch point of this NA.PS01.PAB12 subsystem are the following ones:

- Water temperature at the outlet of the modules (T_{adiab}): constant, 27ºC
- Dry/wet switch point: DBT = 23.6ºC (Preliminary, based on Topaz Neo TH7-E09-D3-8430-B-6, see assumption 1)

For the global and seasonal design parameters of each cooling loop, see the document “PS01 Cooling Systems Sizing, Design and Capacity Calculations” (Ref.[8]).

8.3 Design description

Each ACC primary closed cooling loop is defined as a single closed cooling system mainly composed by a heat exchanger, a pumping group, a surge tank, a buffer tank, distribution pipes to the different water consumers, regulating and isolating vales and the I&C elements required for the proper operation of the system. The main characteristics of each of the PS01 Cooling Subsystems are detailed below.

8.3.1 Non activated ACC primary cooling loop (NA.PS01.PGB31)

8.3.1.1 Component description

This cooling water loop supplies cooling water to the different power supplies / power converters (PCO) of magnets, solid-state amplifiers (SSA), RF loads and circulators of the accelerator systems, PTF and FPF.

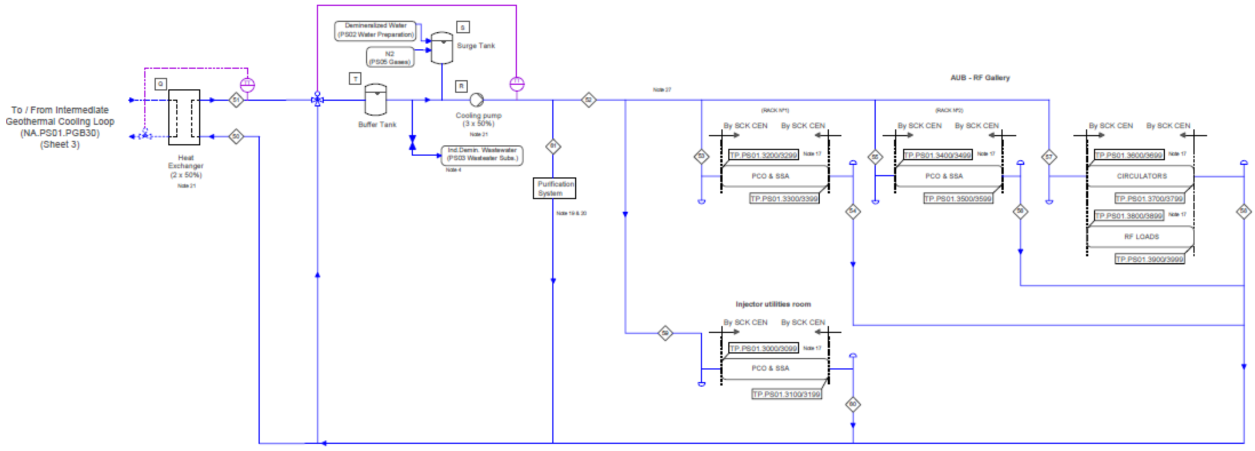


Figure 3 – NA.PS01.PGB31 primary cooling loop (Ref.[7])

The coolant media is demineralized water with low conductivity (< 0.5 µS/cm), O_2 free and CO_2 reduced, supplied by the PS02 demineralized water subsystem (NA.PS02.GHC10) or by the PS03 Industrial Demineralized Wastewater Subsystem (NA.PS03.GMB60), in case the wastewater meets the quality requirements. This cooling media has no risk of activation.

This cooling loop is mainly integrated by:

- 2 x 50% plate type heat exchangers, made of stainless steel. This configuration takes into account the cooling systems operation modes and partial loads required for the sequential MINERVA primary systems during commissioning (I.D.18). The cooling water temperature at the outlet of each heat exchanger is adjusted by the regulation of a 2-way control valve placed in the cold side of the heat exchanger.
- 3 x 50% cooling pumps that recirculate water through the heat exchangers to cool the different equipment in the cooling loop. These pumps will operate at constant flowrate in order to maintain the cooling stability, so load variations will cause variations in the outlet water temperature of the equipment. Also this configuration takes into account the cooling systems operation modes and partial loads required for the sequential MINERVA primary systems during commissioning.
- A 3-way mixing valve that will adjust the cooling water inlet temperature to the different equipment, commanded by a temperature transmitter located at the inlet of the buffer tank. This configuration could be replaced by two (2) control valves, if necessary, attending to reliability and stability requirements (TBC).
- A buffer vessel , located downstream the 3-way valve, in order to avoid affectation in consumers with temperature stability requirements. Internal deflectors for buffer vessel shall be required to guarantee a correct temperature homogenization.
- An expansion vessel (surge tank), that will compensate the variation of water volume in the loop due to temperature changes and pressure transients. This tank will be diaphragm type, pressurized with nitrogen to limit oxygen and CO_2 ingression and will be equipped with self-regulating N_2 pressure valve and safety valve discharging to the atmosphere.
- A water purification system that will maintain the required cooling water chemistry in the loop, see section 8.4.
- The piping material considered for all demineralized water cooling loops is Stainless Steel A-312 Gr.TP304L. Most of the accelerator components are made of copper. In consequence, the use of

stainless steel 304(L) has been considered for the main equipment and pipes of the cooling loops in order to have similar galvanic or compatible properties.

As previously indicated, this cooling loop will maintain the supply temperature in the values referred in Table 3 by:

- The regulation of a 2-way control valve, located in the cold side of the heat exchanger, commanded by a temperature transmitter located at outlet pipe in the hot side.
- The regulation of the 3-way mixing valve, located upstream the buffer tank, commanded by a temperature transmitter located at the inlet of the tank. The temperature set-point for this 3-way valve will be slightly higher than the previous control valve in order to ensure a stable temperature entering into the buffer.

All components in this circuit related to temperature control shall be specified with enough accuracy and quality to achieve the restrictive temperature fluctuation that has been required.

For a more detailed description of the Instrumentation and Control of these ACC primary cooling loops, see section 9.

This cooling loop NA.PS01.PGB31 provides cooling water to the ACC final consumers with the following configuration:

- Cooling water distribution in the RF Gallery: a cooling water main distribution header of 4" is distributed through the east trench (before the first cabinet) and is divided into 3 headers:
    - 2 inlet/outlet headers of 2 ½" of under the RF cabinets supporting structure, for the cooling of PCO and SSA.
    - 1 inlet/outlet header of 2" for the cooling of circulators and RF Loads, next to the RF Gallery south wall.

  Return piping crosses the RF Gallery through the west trench, located after the last cabinet, considering a reverse return configuration.
- Cooling water distribution in the Injector Utilities room: a main distribution header of 4" is considered for the cooling of PCO and SSA in this room. The cooling water distribution under cabinets is pending to be confirmed, based on the cabinets distribution inside the room.

Each distribution header is equipped point-of-use cartridge filter of 100 micron with differential pressure measurement as well as pressure gauge and isolation valve. At each return header, a relief valve, drainage point, temperature transmitter, flowmeter, pressure gauge and isolation valve are provided. In addition, a closed connection is located at the inlet / outlet of the ACC equipment for the installation of a pipe / hose for bypassing the SCC during the cleaning of the loop after maintenance or repair operations.

System drains are collected by the Industrial Demineralized Wastewater Subsystem (NA.PS03.GMB60).

8.3.1.2 Components arrangement

As this is a non activated cooling loop, main equipment are placed in the Cooling System in the AUB, as is shown in the following figure:

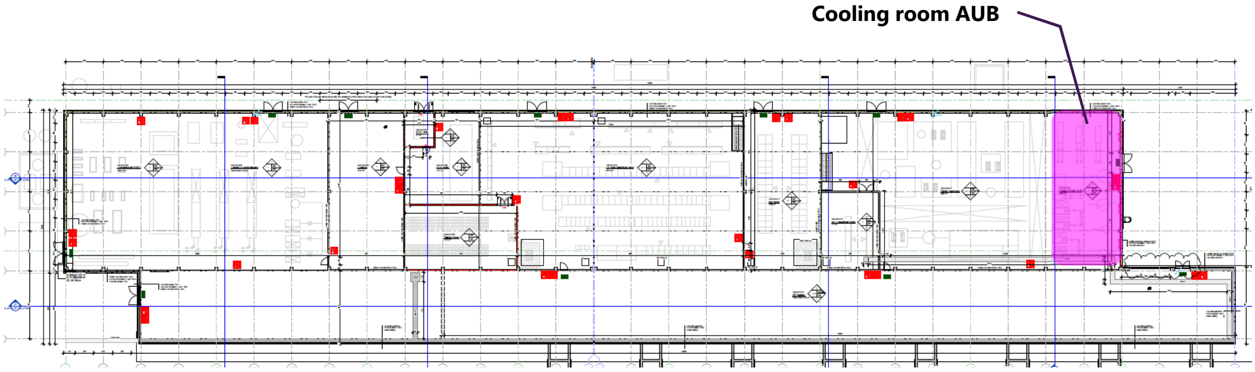


Figure 4 –Location of the Cooling System Room, in AUB (Ref.[21])

8.3.2 Low activated ACC primary cooling loops (NA.PS01.PJB31/PJB32/PJB33/PJB34)

8.3.2.1 Component description

These cooling loops supply cooling water to the different ACC equipment located in the Injector Room, SC LINAC Tunnel and BTT, with the configuration and distribution detailed in Table 3.

The coolant media is demineralized water with low conductivity (< 0.5 µS/cm), O2 free and CO2 reduced, supplied by the PS02 demineralized water subsystem NA.PS02.GHC10 (or by the Potentially Contaminated / Activated B02 Wastewater Subsystem NA.PS03.GMD10, in case the wastewater meets the quality requirements), that could be potentially activated during the cooling of the accelerator (B02 radiation level).

The main configuration of these ACC primary cooling loops is similar to the one described in previous section for NA.PS01.PGB31 cooling loop, with the main difference that these loops contain low activated water (B02), so the following provisions are considered in the design:

- Welded plate heat exchangers are considered ,in pressure cascade configuration (higher pressure in the non-contaminated side than in the contaminated side). The configuration 1 x 100% or 2 x 50% attends to the expected operation at partial loads during commissioning (I.D.18).
- Pipes and fittings are joined preferably by welding.
- Buffer tanks are placed in a leak tight containment pit.
- System drains are collected by the Potentially Contaminated / Activated B02 Wastewater Subsystem (NA.PS03.GMD10). In addition, safety valves discharge are routed to the PS03 holding tank, connected to the nuclear HVAC extraction.
- Activated pipes are jacketed in wall penetrations
- Radiation monitors are foreseen.

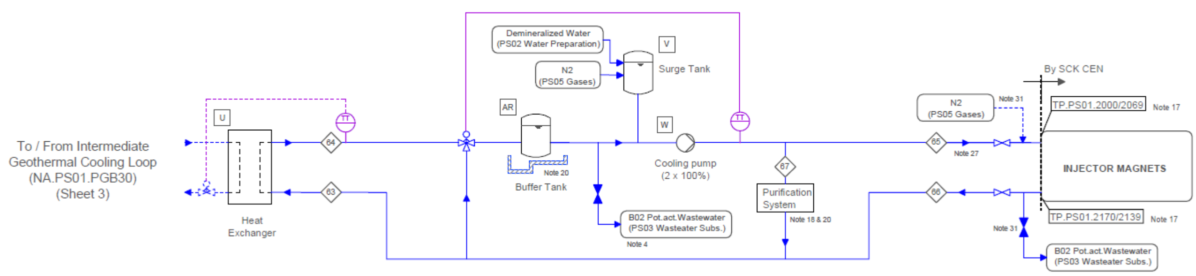


Figure 5 – Example of a low activated ACC primary cooling loop (Ref.[7])

In the specific case of DUMP-I cooling loop (NA.PS01.PJB33), 3 x 100% cooling pumps are considered, following the requirement [SSF 3.17] defined in (I.D.1).

The cooling performance of these cooling loops are:

- The supply water temperature and flow rate to the final equipment is constant to all the consumers of the cooling loop, so load variations will cause variations in the outlet water temperature of the equipment.
- Cooling loops will maintain the supply temperature in the values referred in Table 3 by:
    - The regulation of a 2-way control valve, located in the cold side of the heat exchanger, commanded by a temperature transmitter located at outlet pipe in the hot side.
    - The regulation of the 3-way mixing valve, located upstream the buffer tank, commanded by a temperature transmitter located at the inlet of the tank. For PJB32, the temperature set-point for this 3-way valve will be slightly higher than the previous control valve set-point in order to ensure a stable temperature entering into the buffer.
- The water purification system will maintain the required cooling water chemistry in the loop. See details in section 8.4.

Similarly as described in 8.3.1 for NA.PS01.PGB31, a reverse return configuration is considered for these cooling loops PJB31, PJB32, PJB33 & PJB34. Each distribution header is equipped point-of-use cartridge filter of 100 micron with differential pressure measurement as well as pressure gauge and isolation valve. At each return header, a relief valve, drainage point, temperature transmitter, flowmeter, pressure gauge and isolation valve is provided. In addition, a closed connection is provided at the inlet / outlet of the ACC equipment for the installation of a pipe / hose for bypassing the SCC during the cleaning of the loop after maintenance or repair operations.

As is indicated in (I.D.17), there is no requirement for back-up power if the beam is stopped for any of the ACC primary cooling loops, as there is no heat dissipation (heat removal) required if there is no active beam.

The main requirement for LOOP (loss of offsite power) that causes LOCA (loss of cooling accident) is to interlock the beam and remove the heat source, being a requirement for the I&C interlock system.

8.3.2.2 Components arrangement

As these are low activated cooling loops, main equipment are placed in the Cooling System room in the MCB, as is shown in the following figure:

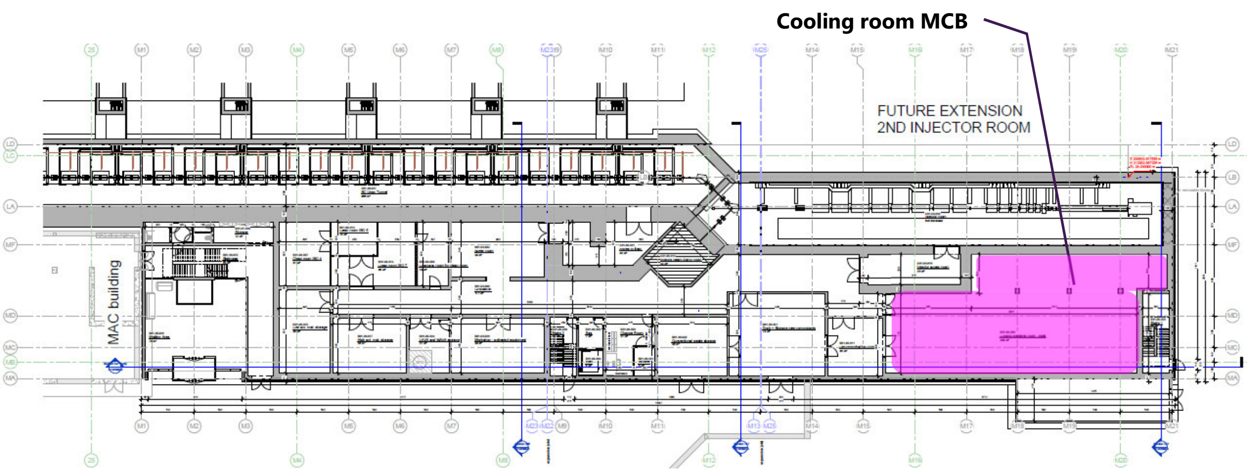


Figure 6 –Location of the Cooling System Room, in MCB (Ref.[23])

8.3.3 Intermediate Geothermal Cooling Loop (NA.PS01.PGB30)

8.3.3.1 Component description

This cooling water loop supplies cooling water at 17ºC to the different heat exchangers of the ACC primary cooling loops as well as to the MAC (TP.PS01.4007/4008).

The coolant media is softened water supplied by the PS02 Softened water subsystem (NA.PS02.GKC10). This cooling media has no risk of activation.

This cooling loop is mainly integrated by:

- Two (2) sets of plate heat exchangers to adapt to the different heat sinks of the system (as described in Section 8.2):
    - 2 x 50% process cooling heat exchangers ("HX1") cooled by the geothermal cooling system (NA.PS01.PCB30)
    - 2 x 50% process cooling heat exchangers ("HX2") cooled by the low temperature adiabatic cooling subsystem (NA.PS01.PAB11)

  The operation with "HX1" or "HX2" depends on the environmental conditions, based on the cooling water temperature at the outlet of the adiabatic coolers at PAB11 subsystem, and is commanded by the opening/closing of the valves NA.PS01.PGB30AA351/352.

  The 2 x 50% configuration takes into account the cooling systems operation modes and partial loads required for the sequential MINERVA primary systems during commissioning (I.D.18).
- 3 x 50% cooling pumps with variable speed drive to adapt to ACC cooling requirements and providing flexibility to the different ACC operation modes. Flow regulation will be considered in this cooling loop, regulating the flowrate to keep the pump discharge pressure, reducing pumping requirements and, consequently, the electrical consumption of the global system.
- An expansion vessel (surge tank), that will compensate the variation of water volume in the loop due to temperature changes and pressure transients. This tank will be diaphragm type, pressurized with nitrogen to limit oxygen and CO_2 ingression and will be equipped with self-regulating N_2 pressure valve and safety valve discharging to the atmosphere.
- The piping material considered for this loop is Stainless Steel A-312 Gr.TP304L. Anti-sweat insulation is considered in those areas where the dew point of the room exceeds the cooling water temperature.

This cooling loop will maintain the supply temperature in the values referred in Table 3 by means of the regulation with a 2-way control valve, located in the cold side of the heat exchangers (heat sink), commanded by a temperature transmitter located at outlet pipe in the hot side.

This cooling loop NA.PS01.PGB30 provides cooling water to the cold side of the different heat exchangers of the ACC primary cooling with the following configuration:

- At the inlet pipe, a temperature indicator and pressure gauge are foreseen.
- At the outlet pipe, a 2-way control valve regulates the flowrate commanded by a temperature transmitter located at outlet pipe in the hot side. In addition, a temperature transmitter, pressure gauge and relief valve are considered. For those heat exchangers of activated loops, a radiation monitor is foreseen that isolates the defective heat exchanger in case of high radiation level.

Isolation valves, vents and drains to the industrial softened wastewater subsystem (NA.PS03.GMB40) are also considered.

For a more detailed description of the Instrumentation and Control of these ACC primary cooling loops, see section 9.

8.3.3.2 Components arrangement

As this is a non-activated cooling loop, main equipment is placed in the Cooling System in the AUB, as is shown in the previous Figure 4.

8.3.4 Chilled Water Subsystem (NA.PS01.PGB20)

8.3.4.1 Component description

The chilled water cooling loop supplies direct cooling water to nuclear and conventional HVAC loads of the MINERVA facility, including MAC HVAC loads (TP.PS01.4011/4012).

The coolant media is a softened water/propylene glycol (40%wt), supplied by the make-up from PS02 Softened water subsystem (NA.PS02.GKC10) and the dosing from the PS01 Propylene Glycol Supply Subsystem (NA.PS01.PUA10). A filling connection from a tank trailer is also available for the first filling of the loop. This cooling media has no risk of activation.

System drains are collected in portable collection bins (NA.PS03.GMB10).

This cooling loop is mainly integrated by:

- 3 x 50% water-cooled chillers, equipped with a variable frequency drive to optimize flexibility, turn ratio and improve partial load efficiency.
- 3 x 50% cooling pumps with variable speed drive to adapt to HVAC cooling requirements. Flow regulation will be considered in this cooling loop, regulating the flowrate in function of the cooling demand, reducing pumping requirements and, consequently, the electrical consumption of the global system.
- An expansion vessel (surge tank), that will compensate the variation of water volume in the loop due to temperature changes. This tank will be diaphragm type, pressurized with nitrogen to limit oxygen and CO_2 ingression and will be equipped with self-regulating N_2 pressure valve and safety valve discharging to the atmosphere.
- 1 x 100% heat exchanger for free-cooling when the environmental conditions allow it.
- The piping material considered for this loop is Carbon Steel A-106 Gr.B. As the operation temperature of this subsystem falls below the dew point of the different technical rooms in AUB & MCB, anti-sweat insulation is considered in the pipes.
- A bypass for ensuring a minimum flowrate through the chillers is also provided

This cooling loop will maintain the supply temperature in the values referred in Table 3 by:

- The operation of the chillers during the normal operation of the plant at hot / warm environmental conditions. A 2-way regulating valve is considered in the condenser water side of the chillers in order to allow the start-up and normal operation of the chillers at low condenser temperatures. As the condenser water temperature entering the chiller decreases, the chiller control system send a signal to close this regulating valve, reducing the flow of water through the condenser and stabilizing the saturated condensing temperature.
- The operation through the free-cooling heat exchanger at colder environmental temperatures. When water from the adiabatic coolers PAB11 is cold enough (below 6ºC), a complete free-cooling is performed and chillers can be bypassed. For those conditions where the cooling water falls below

6ºC, the regulation of a 2-way control valve located in the cold side of the heat exchanger (and commanded by a TT located at outlet pipe in the hot side of the heat exchanger) allows to maintain a constant chilled water supply at 7ºC.

For a more detailed description of the Instrumentation and Control of these ACC primary cooling loops, see section 9.

8.3.4.2 Components arrangement

8.3.4.3 Main equipment of this chilled water subsystem are located in the Chillers & Compressors Room, in the AUB, as is shown in the following figure:

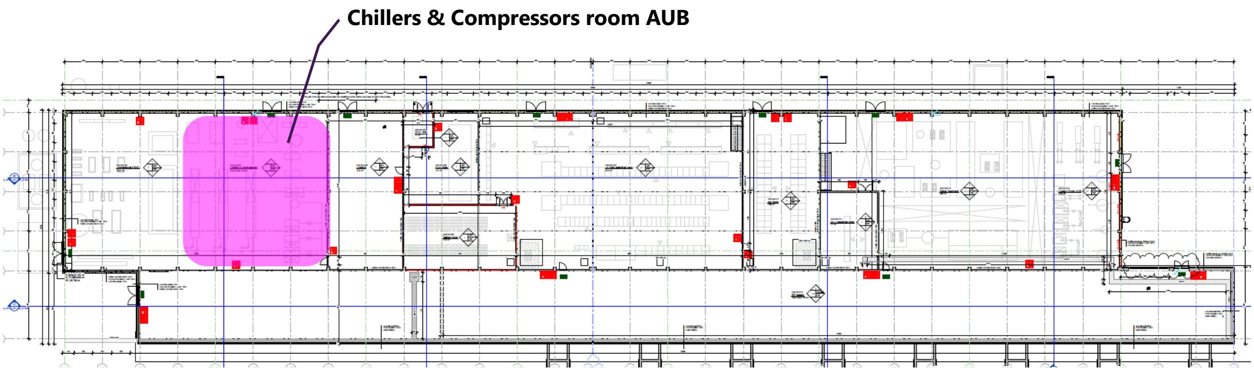


Figure 7 –Location of the Chillers & Compressors room, in AUB (Ref.[21])

8.3.5 Low Temperature Adiabatic Cooling Subsystem (NA.PS01.PAB11)

8.3.5.1 Component description

As is described in Section 8.2, the low temperature adiabatic cooling subsystem has seasonal performance, providing cooling water to the following subsystems and consumers:

- Chilled water subsystem (NA.PS01.PGB20), providing cooling water to the water-condenser chillers and/or to the free-cooling heat exchanger when environmental conditions allow it.
- Intermediate geothermal cooling subsystem (NA.PS01.PGB30), providing cooling water to the heat exchanger “HX2” during winter/colder conditions, rejecting to the environment the heat load rejected from ACC primary cooling loops.
- Geothermal Cooling Subsystem (NA.PS01.PCB30), providing groundwater regeneration through the regeneration heat exchangers “HX3” and “HX4” when environmental conditions allow it, reducing the temperature of the groundwater re-injected into the soil after the process cooling and avoiding the thermal pollution of the aquifer.

The coolant media of this closed cooling loop is a softened water/propylene glycol (40%wt), supplied by the make-up from PS02 Softened water subsystem (NA.PS02.GKC10) and the dosing from the PS01 Propylene Glycol Supply Subsystem (NA.PS01.PUA10). A filling connection from a tank trailer is also available for the first filling of the loop. This cooling media has no risk of activation.

System drains are collected in portable collection bins (NA.PS03.GMB10).

This cooling loop is mainly integrated by:

- A set of modular adiabatic coolers, with a design cooling capacity of 2.48 MW in summer (design WBT of 23ºC) and maximized to 7.92 MW in winter conditions (design DBT of -3ºC), providing cooling water at low temperature. Based on information provided by a potential supplier (see assumption 1), a configuration comprising 6 TOPAZ Neo modules (TH11-E09-D3-12830-B-4, 22 fan per cooler) has been preliminary defined for this adiabatic cooling subsystem. Under winter conditions (maximized design conditions), no redundancy is required.

- 3 x 50% cooling pumps with variable speed drive to adapt to seasonal cooling requirements. Flow regulation will be considered in this cooling loop, regulating the flowrate to keep constant flow through modules on service, reducing pumping requirements and, consequently, the electrical consumption of the global system.
- An expansion vessel (surge tank), that will compensate the variation of water volume in the loop due to temperature changes and reduce pressure transients. This tank will be diaphragm type, pressurized with nitrogen to limit oxygen and CO_2 ingression and will be equipped with self-regulating N_2 pressure valve and safety valve discharging to the atmosphere.
- The piping material considered for this loop is Carbon Steel A-106 Gr.B. As the operation temperature of this subsystem falls below the dew point of the different technical rooms in AUB & MCB, anti-sweat insulation will be applied in the pipes.
- A bypass control valve for ensuring nominal flowrate through the adiabatic coolers is also provided

This cooling loop will provide cooling water at lower temperature as possible, from 27ºC at summer design conditions (WBT=23ºC) to 3ºC during winter period. For this purpose, the adiabatic coolers in operation will maintain the fans running constantly at nominal speed (close to 100% fan speed) to reduce the temperature of the water at the outlet as much as possible, with a minimum water temperature of 3ºC. Below this temperature, the fans could reduce the speed in order maintain this minimum cooling water supply temperature.

The motor fan sets are equipped with variable speed drive and are located on the top of the unit. The axial fans are low speed, low noise and high performance design.

This type of cooler can operate as a regular dry cooler but, as soon as the ambient temperature increases, also offers the option to switch on an adiabatic pre-cooling section that lowers ambient air temperature by evaporating water on adiabatic pads, specially designed for this purpose. These humidifying pads are made of special cellulose, chemically treated to avoid moisture and to improve water absorption characteristics.

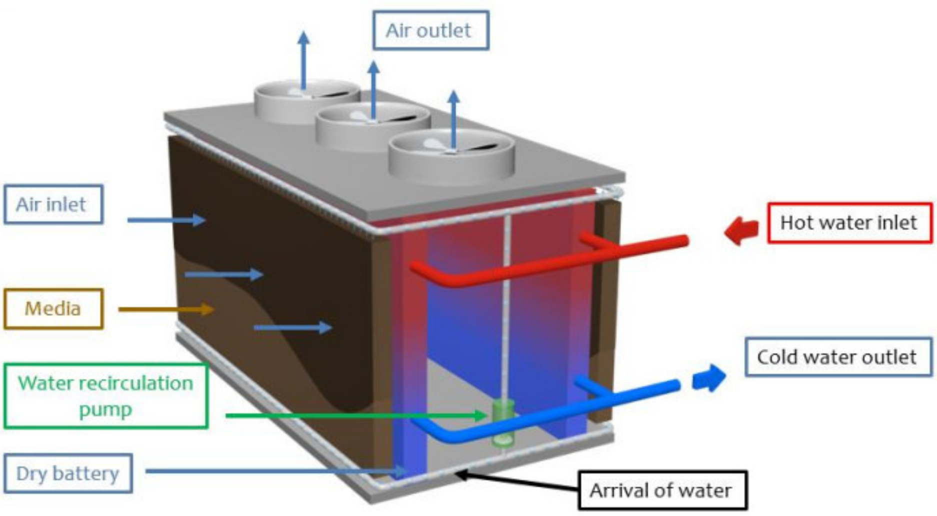


Figure 8 – General overview of an adiabatic cooler

The following operation modes are suitable with this type of adiabatic coolers, attending to the process requirements and ambient temperature:

- Dry mode operation:
  - The fluid is cooled in the dry tube coil, thanks to the ambient air flow. The air is pulled by fans. The humidifying pads located at the air inlets are dry in this mode.
  - The fans are working at nominal speed to reduce outlet temperature as possible. The air is then evacuated upwards.
- Adiabatic mode operation:
  - When cooling in dry mode is not efficient enough, the pads are humidified with softened water supplied by the PS02 Softened water subsystem (NA.PS02.GKC10).
  - The ambient air is cooled by evaporation when crossing the pads.
  - This pre cooled air enters then in contact with the tube coils, and cools the fluid.
  - The water which has not been evaporated on the pads is collected in a stainless steel collector, and then flows to sewer. As an option, it can be re-circulated and used with the water make up to feed the pads.

For the requested performance of this set of adiabatic coolers (NA.PS01.PAB11), the dry/wet switch DB temperature will be reduced to 10ºC approximately (to be confirmed with the selected manufacturer), in order to maximize the cooling capacity of the modules.

8.3.5.2 Components arrangement

Adiabatic coolers will be placed in the available area on the roof on the RF Gallery, at level N1, with a maximum height not exceeding 3.5 m (I.D.13). The installation of this modular equipment will be made according to the manufacturers rules and criteria in order to guarantee the optimal thermal performance of the equipment, maintaining the minimum required free space between modules and adjacent walls.

The cooling towers technical room will be placed at the west side of this area for the location of the associated equipment of this cooling loop, as pumping stations and surge tank.

The modules of the two (2) different adiabatic cooling subsystems of the PS01 Cooling System (PAB11 for low temperature cooling water and PAB12 for medium temperature) are grouped all along the roof. For a preliminary layout, total number of unit coolers has been estimated based on the information provided by one of the potential manufacturers of these type of coolers (see assumption 1). The final number of units and their dimensions will be defined by the manufacturer selected as a result of the tendering process.

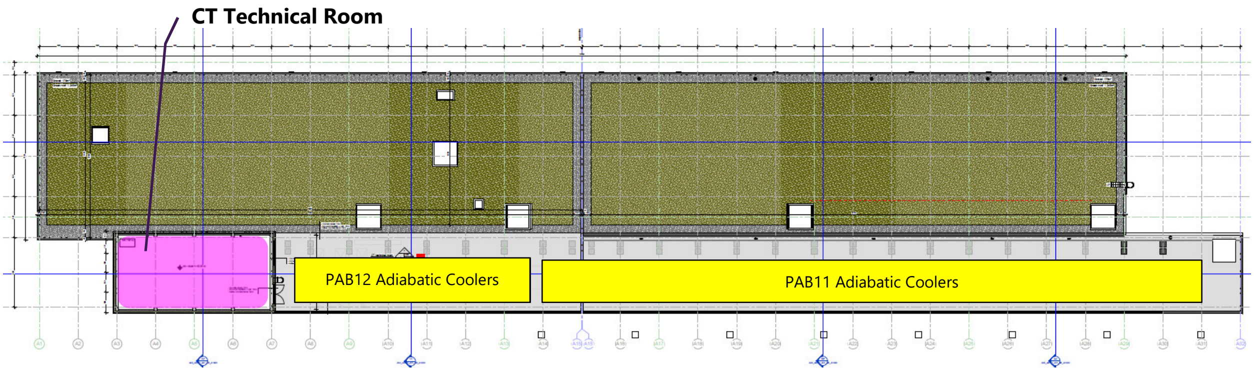


Figure 9 – Location of adiabatic coolers and CT Technical room in RF Gallery roof (level N1) (Ref.[21])

8.3.6 Medium Temperature Adiabatic Cooling Subsystem (NA.PS01.PAB12)

8.3.6.1 Component description

This adiabatic cooling subsystem provides cooling water to Cryogenic Supply System (NA.CP) facility (Warm Compressor Station and Cold Box) as well as to the MAC, through the terminal point TP.PS01.4001/4002.

The main configuration of this adiabatic cooling loop NA.PS01.PAB12 is similar to the one already described for the NA.PS01.PAB11, with the main difference that this subsystem provides cooling water at a constant medium temperature (27ºC), instead of low water temperature. This operation involves differences mainly in the control philosophy of the adiabatic coolers.

The coolant media of this closed cooling loop is a softened water/propylene glycol (40%wt) mixture, supplied by the make-up from PS02 Softened water subsystem (NA.PS02.GKC10) and the dosing from the PS01 Propylene Glycol Supply Subsystem (NA.PS01.PUA10). A filling connection from a tank trailer is also available for the first filling of the loop. This cooling media has no risk of activation.

System drains are collected in portable collection bins (NA.PS03.GMB10).

Similarly to PAB11, this cooling loop is mainly integrated by:

- A set of modular adiabatic coolers, with a design cooling capacity of 1.95 MW, providing cooling water at 27ºC. Under certain environmental conditions, this cooling demand could be reduced to 1.45 kW by the heat recovery of the WCS oil heat in a separated loop by the HV06 (max. 500 kW, I.D.23).

  Based on information provided by a potential supplier (see assumption 1), a 2 x 50% configuration has been preliminary defined for this adiabatic cooling subsystem, considering 2 TOPAZ Neo modules (TH8-E09-D3-9530-B-6, 16 fan per cooler), with a nominal heat load dissipated per module of 976 kW at the design conditions, with 2 standby fans per module.

- 3 x 50% cooling pumps with variable speed drive to adapt to cooling requirements. Flow regulation will be considered in this cooling loop, regulating the flowrate in function of the cooling demand, reducing pumping requirements and, consequently, the electrical consumption of the global system.

  Based on information provided by SCK.CEN, the Cryogenic Supply System (NA.CP) is expected to operate for periods even when the rest of the LINAC might not. In this turn-down state (thus very reduced heat load), cryomodules are kept cold to avoid defrosting the entire system, leading to the reduction of the pumping energy of the system at a very reduced flowrate from the main pumps design point.

- Two-way control valves are placed at the outlet of the cryogenic facilities to regulate the flowrate at the different operating scenarios. The flow setting of these valves will be based on the operational regime, controlled by UBMS based on global operation (operational state of NA.CP cryogenic supply system).

- An expansion vessel (surge tank), that will compensate the variation of water volume in the loop due to temperature changes. This tank will be diaphragm type, pressurized with nitrogen to limit oxygen and CO_2 ingression and will be equipped with self-regulating N_2 pressure valve and safety valve discharging to the atmosphere.

- The piping material considered for this loop is Carbon Steel A-106 Gr.B. Antisweat insulation is considered in those areas where the dew point of the room exceeds the cooling water temperature (as CCB).
- A bypass for ensuring a minimum flowrate through the adiabatic coolers is also provided

This cooling loop will provide cooling water at a constant medium temperature (27ºC). For this purpose, the adiabatic coolers in operation will operate at maximum load in summer conditions, in wet mode. As the environmental temperature decreases, the cooling tower will reduce the fan speed and will modify the operation mode to adiabatic / dry operation in order to maintain the required cooling tower water temperature, thus reducing the energy and water consumption of the global system.

For the requested performance of this set of adiabatic coolers (NA.PS01.PAB12), the dry/wet switch temperature will be adjusted at 23.6ºC approximately (to be confirmed with the selected manufacturer), in order to reduce the water consumption of the facility.

8.3.6.2 Components arrangement

Similarly to PAB11, adiabatic coolers will be placed in the available area on the roof on the RF Gallery, at level N1, with a maximum height not exceeding 3,5 m (I.D.13), see Figure 9. The installation of this modular equipment will be made according to the manufacturers rules and criteria in order to guarantee the optimal thermal performance of the equipment, maintaining the minimum required free space between modules and adjacent walls.

For a preliminary layout, total number of units coolers has been estimated based on the information provided by one of the potential manufacturers of these type of coolers. The final number of units and their dimensions will be defined by the manufacturer selected as a result of the tendering process.

8.3.7 Geothermal Cooling Subsystem (NA.PS01.PCB30)

8.3.7.1 Suitability of the implementation of a geothermal cooling system in MINERVA NF

As is described in Section 8.2, a geothermal cooling system is considered as an additional main heat sink of the cooling systems, providing cooling to the intermediate geothermal cooling loop (NA.PS01.PGB30) under certain environmental conditions.

Based on the input data provided by SCK.CEN (I.D.10), and based on the main assumption that the historic VITO installation does not impact the future MINERVA groundwater cooling system, a feasibility analysis has been performed (Ref.[4]) in order to confirm the feasibility of this alternative and to determine the best groundwater technology.

As a conclusion of this analysis, it is confirmed that the local geological conditions are very good to apply geothermal cooling systems, in particular an open source / one-way system, due to the availability of suitable underground aquifers.

This type of systems provides a simple and stable operation, as the groundwater temperature is constant all year round, so it has been found beneficial for consumers requiring cooling water at 12 – 20ºC (the soil is naturally 12 to 13ºC in Belgium) and a stable and constant load profile.

For the different geothermal technologies available, the implementation of a one-way Aquifer Thermal Energy Storage (or ATES) with Cold Storage/Recirculation (CS/R) is considered as the most efficient alternative for the MINERVA facility, comprised by two (2) set of wells (extraction wells and infiltration wells) where the groundwater flows unidirectional all year round.

In hottest conditions (summer), groundwater at a constant temperature (~13ºC) is pumped from the extraction wells to the process systems heat exchanger (HX1) and reinjected in the injection wells at high temperature (25ºC). As the environmental temperature drops, adiabatic cooling from PAB11 will be used through heat exchanger(s) HX3, placed in series with the HX1, to partially cool down the injected heated water in the injection wells, and thus limiting the thermal accumulation.

When environmental conditions drops below DBT ~ 10ºC, and the cooling of the loop NA.PS01.PBG30 is performed by the adiabatic cooling subsystem PAB11, the flowrate of groundwater at 13ºC is maintained through HX3 to regenerate the ATES CS/R system. In this scenario, the groundwater extraction rate is maximized in order to provide supplemental regeneration through HX4 as well as to recover heat through the heat pump of HV06 in parallel circuits. Flow transmitters and control valves regulate the flowrate in the different supply branches.

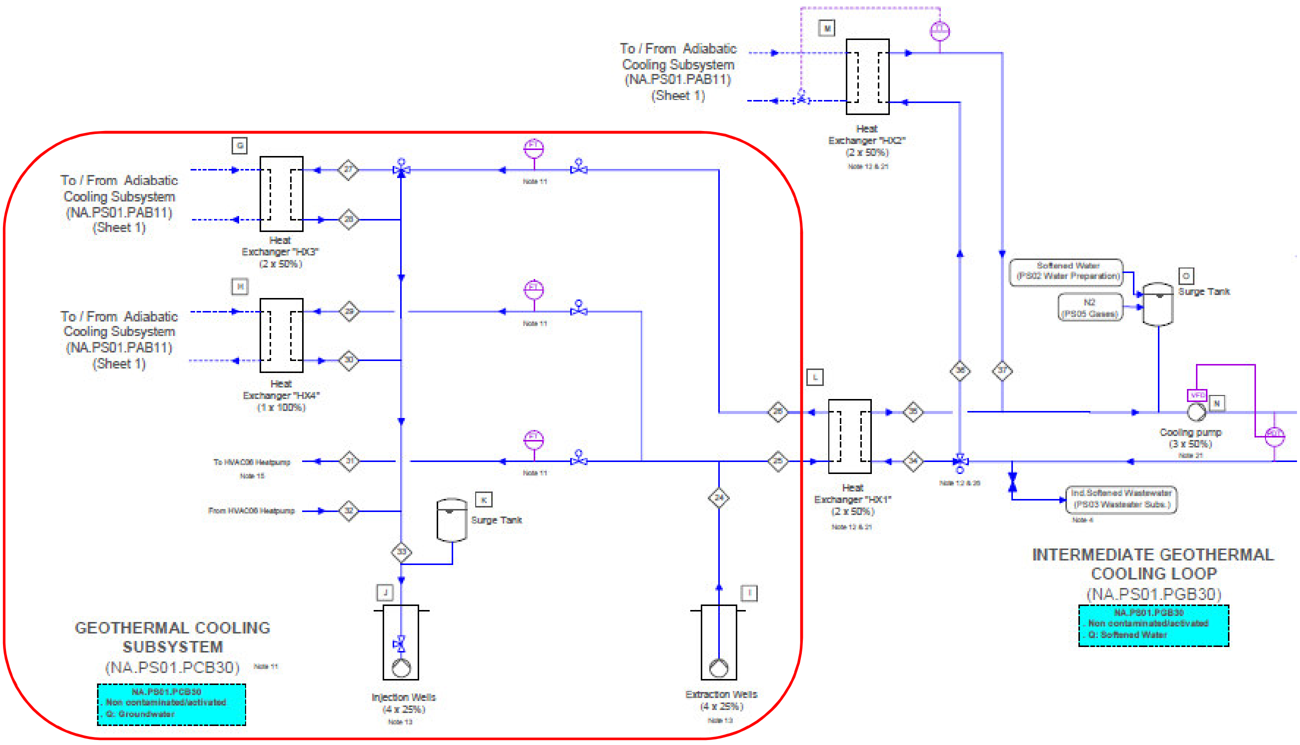


Figure 10 – Geothermal installation ATES with CS/R in MINERVA cooling systems ([Ref.7])

8.3.7.2 Component description

The ATES CS/R geothermal cooling subsystem is mainly integrated by ([Ref.4]):

- 4 well doublets, with a maximum production / injection capacity of 120 m^3/h per well doublet, with a filter element 80 m length and a total depth of 145 m approx. Extraction wells (4) are equipped with 4 x 25% submersible pumps (1 per extraction well) with frequency-controlled electric motors. Injection wells also consider the installation of submersible pumps (1 per injection well), to preventively drain or flush the wells during maintenance period. In addition, injection valves are considered for pressure regulation of the injected groundwater and flow limitation to protect the injection well.
- 2 x 50% regeneration heat exchangers ("HX3"), placed in series with the process system heat exchanger HX1(belonging to the intermediate geothermal cooling loop), cooled by the low temperature adiabatic cooling subsystem (NA.PS01.PAB11)

- 1 x 100% supplementary regeneration heat exchanger ("HX4"), cooled by the low temperature adiabatic cooling subsystem (NA.PS01.PAB11).
- An expansion vessel (surge tank), that will compensate the variation of water volume in the loop due to temperature changes and reduce pressure transients.
- The piping material considered for this loop is PE-100 for buried pipe and Stainless Steel A-312 Gr.TP304L for pipe in the technical rooms, where anti-sweat insulation will be installed.

The main parameters of the geothermal cooling subsystem are summarized in the following table:

Table 5 – Design parameters of the geothermal cooling subsystem (NA.PS01.PCB30)

Geothermal Cooling System (NA.PS01.PCB30)	
Required cooling capacity	3.21 MW
Geothermal technology	Open source, ATES CS/R (1)
Number of well doublets	4 x 25% (2)
Maximum flow rate per well doublet	120 m^3/h (3)
Groundwater temperature at extraction well	13ºC (4)
Groundwater maximum temperature at injection well	25ºC
Well depth	145 m [Ref.4]

Note 1: Aquifer Thermal Energy Storage (ATES), type Cold Storage / Recirculation (CS/R), [Ref.4]

Note 2: No redundancy required for aquifer thermal regeneration

Note 3: Sized for complete regeneration of the aquifer

Note 4: Groundwater temperature at extraction well is constant throughout the year (13ºC)

The detailed design of this geothermal subsystem is under the scope of the geothermal subsystem technologist, considering all these components as a package supply.

8.3.7.3 Components arrangement

The next figure shows the approximate location of the 4 well doublets of the ATES CS/R installation ([Ref.4]). Extraction wells will be placed at the northeast of the facility, while the injection wells will be placed at the northwest, following the natural groundwater flow in the aquifer (that is East to West oriented).

In this case, and taking into consideration the global thermal dissipation of the installation, the location of the wells is extended to the 600 MeV LINAC perimeter (MYRRHA Phase 2), maintaining a minimum distance between the extraction wells of 75 m and of 210 m between the extraction and the injection wells. The location of the wells at the north of the facility avoids crossing the LINAC tunnel in the geothermal pipe routing.

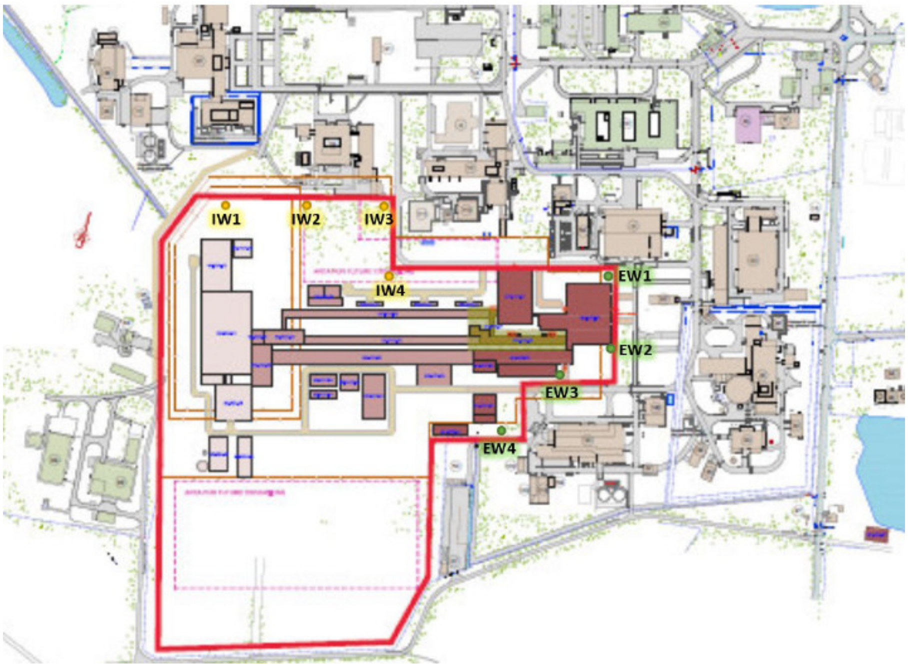


Figure 11 – Approximate location of geothermal Extraction and Injection Wells (EW/IW) ([Ref.4])

On each well, a concrete well chamber will be installed, preferred next to a road (max dimensions 1 x 2 m, with a minimum safe distance), and will be sealed on top with an easily accessible but lockable typical aluminum insulated checker plate cover (as is shown in the following figure), although different cover configurations can be applied, as long as accessibility is guaranteed.

Figure 12 – Typical well chamber (example)

Process heat exchangers “HX1”, belonging to the NA.PS01.PGB30 cooling loop, are placed in the cooling room of AUB. HX3 and HX4 will be placed in the Chillers and Compressors Room of the AUB, following the natural flow direction of the geothermal pipe routing.

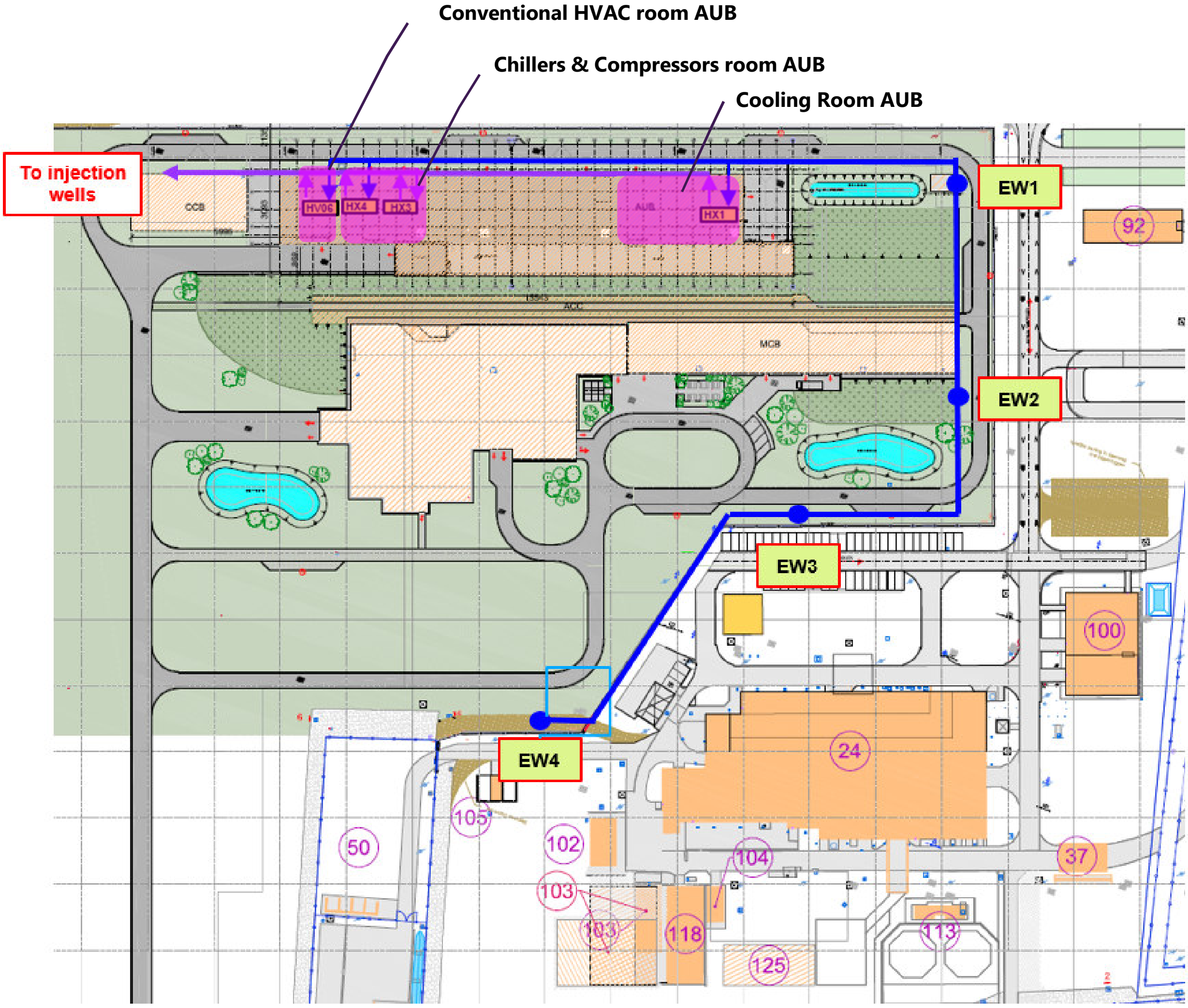


Figure 13 – Conceptual sketch of the geothermal cooling extraction wells (EW) and pipe routing ([Ref.5])

8.3.7.4 Heat recovery for Heating System (HV06)

In addition to the heat recovery implemented in the WCS of the He compressors of the cryogenic system, recovery from the geothermal cooling subsystem will be also used in the cooling systems. For this purpose, a fraction of the groundwater from the extraction wells at 13ºC is directly sent to a heat pump of the HV06 heating system when the ambient temperature is low enough (below a DBT of 5ºC, approx.). This heat pump is located in the Conventional HVAC room of the AUB, next to the Chillers and Compressors room, also following the natural flow direction of the geothermal pipe routing.

Colder groundwater at the outlet of the heat pump is sent-back to the groundwater return header to the injection wells, thus providing supplemental regeneration of the aquifer in winter conditions.

The heat recovery does not affect to the operation of the groundwater system. A control valve will isolate the heat pump in case heat recovery is not required and groundwater extraction will be reduced, accordingly.

8.3.8 Propylene Glycol supply subsystem (NA.PS01.PUA10)

8.3.8.1 Component description

For the adiabatic coolers and chilled water cooling loops, a softened water/propylene glycol mixture is used as cooling media, so a propylene glycol dosing system has been foreseen in the MINERVA.

The measurement of glycol concentration in these loops is performed by the implementation of a Coriolis mass flow meter in the loop, that provides accurate measurement of mass flowrate and density of the coolant, together with the temperature measurement and appropriate conversion table of density to weight % glycol.

Propylene glycol dosing in the loop is manually started in conjunction with the opening of the softened water make-up valve, in order to maintain the desired 40%wt. of propylene glycol in the mixture.

The propylene glycol supply subsystem is considered as a package supply, mainly comprised by:

- 1 x 100% propylene glycol tank, where pure glycol will be stored (1 m^3)
- 1 x 100% propylene glycol dosing pump (2 m^3/h)
- 1 x 100% water/glycol filling pump for connection to a tank trailer by the connection to a temporary hose, for the first filling of the loops (if finally required).

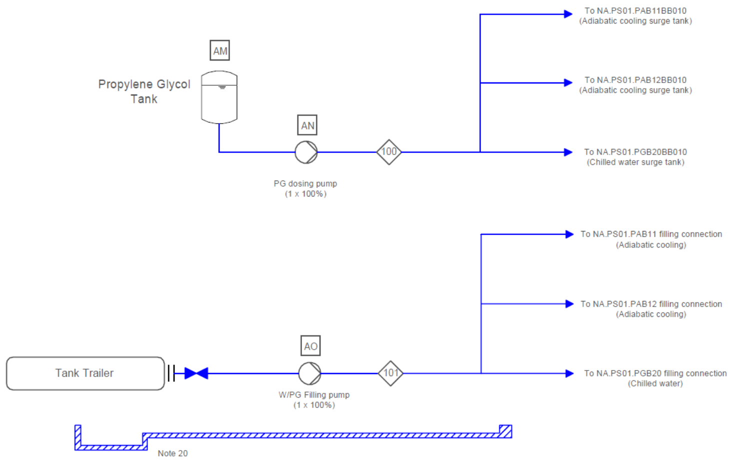


Figure 14 – NA.PS01.PUA10 Propylene Glycol supply subsystem (Ref.[7])

All these closed cooling loops are not expected to be drained and filled frequently, so the system is preliminarily designed just to supply the make-up mixture due to cooling loop losses, estimated as a 10% per year from the total volume of the loop (only expected due to maintenance activities, not during system operation), with a minimum autonomy to guarantee the make-up during the normal operation of the system (see PS01Sizing, Design and Capacity Calculations in Ref.[8]).

For a first filling of the circuits, or under maintenance operations where specific circuits could be completely drained and a large volume of water/glycol mixture should be provided, a trailer connection is foreseen to allow the direct filling from a commercial water/glycol cooling media, in case it is required.

Propylene glycol and water/glycol drains will be collected in portable collection bins.

8.3.8.2 Components arrangement

All these equipment will be located outside in the north area of the NF, next to the Chillers and Compressors Room of the AUB, in a leak tight containment pit. This area will be accessible from the road for inventory supply (final location to be confirmed in coordination by Masterplan discipline).

Preliminary location of the Propylene Glycol supply equipment

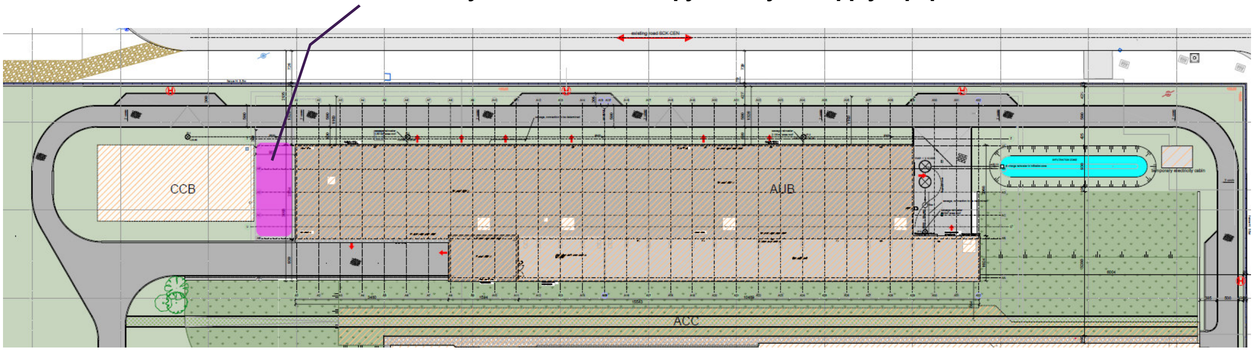


Figure 15 – Preliminary location of NA.PS01.PUA10 equipment (Ref.[5])

8.4 Cooling water chemistry in ACC cooling loops

In order to maintain the required fluid purity level and chemistry in the different ACC primary cooling loops during the operation of the facility, purification systems are included in each cooling loop. A flowrate of 5% of the total flowrate of the cooling loop will be derived through the polishing loops with the main goals of keeping the conductivity to specifications, avoiding the formation of deposits, scale build-up, corrosion and minimising radionuclide activation.

All closed cooling loops in all ACC circuits are initially filled and replenish, as necessary, with very low conductivity demineralized water (< 0,5 μS/cm), required to cool equipment with strong electrical and magnetic fields to minimize the activation of the water. In addition, this cooling water will be oxygen free (< 20 ppb) and CO_2 reduced to avoid corrosion.

Cooling loops purification systems, considered as package plants, will mainly comprised by:

- Pre-filter (< 5 microns), if required to protect the mixed bed from particle pollution
- Mixed bed ion exchange resin bottles, for the removal of salts and minerals, to be placed in a leak tight containment pit
- After-filters (< 10 microns), to protect downstream from broken resins

Demineralized water is directly supplied at the required water quality by the Demineralized water subsystem (NA.PS02.GHC10). In principle, it is not expected a constant gaseous products generation that could require the installation of other components as degassing units (I.D.27). No chemicals are expected to be added to the demineralized water in the cooling loops.

Resins volumes and type / ratio will be finally defined for each type of cooling loop by the purification system manufacturers, attending to the incoming water quality and the required quantity of treated water.

On the other hand, a preliminary estimation of the resins considered in the cooling loops is performed in the PS01 Sizing Calculation Report (Ref. [8]) with the main purpose of providing and a preliminary input to SCK CEN / Safety to determine the potential radiological source term and shielding requirements for these resins. This is an iterative sizing that starts with the preliminary classification of these resins as LAVA, assuming that no remote handling is needed for its management based on the water activation (I.D.22).

At this design stage, different water treatment systems and water conditions have been preliminarily proposed for each type of cooling loop, mainly attending to the materials in contact with the cooling water in the different loops and the expected content of radionuclides in the cooling water, as it is described and detailed in the Design Justification and Substantiation Report, Ref. [4].

The following table summarizes the different water quality and treatment system preliminarily proposed for the different ACC primary cooling loops of the MINERVA Cooling System:

Table 6 – Cooling loops water quality and treatment (preliminary)

Cooling Loop Description	Cooling Loop ID	Water type	Activation level	Resins / pH	Resins min. volume (l) (Ref.[8])
PCO & SSA Cooling Loop (1)	NA.PS01.PGB31	Demi water Conduct. < 0,5 µS/cm O_2 < 20 ppb / CO_2 reduced	Non activated	Mixed bed (H^+ / Na^+) ion ex. resin pH ~ 7.5 – 8	179
Low Activated Injector Magnets Cooling Loop (1)	NA.PS01.PJB31	Demi water Conduct. < 0,5 µS/cm O_2 < 20 ppb / CO_2 reduced	B02	Mixed bed (H^+ / Na^+) ion ex. resin pH ~ 7.5 – 8	6
Low Activated Injector NC-RF Cavities Cooling Loop (1)	NA.PS01.PJB32	Demi water Conduct. < 0,5 µS/cm O_2 < 20 ppb / CO_2 reduced	B02	Mixed bed (H^+ / Na^+) ion ex. resin pH ~ 7.5 - 8	86
Low Activated DUMP-I Cooling Loop (1)	NA.PS01.PJB33	Demi water Conduct. < 0,5 µS/cm O_2 < 20 ppb / CO_2 reduced	B02	Mixed bed (H^+ / Na^+) ion ex. resin pH ~ 7.5 - 8	8
Low Activated SC LINAC Tunnel / BTT Cooling Loop (1)	NA.PS01.PJB34	Demi water Conduct. < 0,5 µS/cm O_2 < 20 ppb / CO_2 reduced	B02	Mixed bed (H^+ / Na^+) ion ex. resin pH ~ 7.5 - 8	36

(1) Assuming copper elements in the cooling loop

In any case, this preliminary proposal should be confirmed and detailed in cooperation with the ion exchange resins and package plant manufacturers, attending to the incoming water quality, cooling water loops final volumes and updated water activation analysis, taking into consideration the specific technologies available and the latest state-of-art of this type of resins.

9 Instrumentation and Control

The instruments and mechanical equipment will be identified in the PS01 P&ID (=NA.PS01_PFB503, Ref.[6]) and the signals associated to the devices are listed in the UBMS Control Interface Principle (=NA.CN_EDB502, Ref.[16]).

In the case of the package plant supplies such as the Chillers (NA.PS01.PGB20.AH011/012/013), the package plant devices shall be provided with the signals and alarms necessary for the satisfactory operation and supervision of the package plant. The control and monitoring will be specified by the package plant supplier.

The PS01 Cooling System Control Diagram (=NA.CN_EDB510, Ref.[17]) will provide with all detail about control, protections, alarms and graphical representation of the system.

9.1 Control General Criteria

9.1.1 Drivers Control Modes

All system drivers are monitored and controlled from the Conventional Control System HMI of the operator station located in the Control Room.

All drivers have two modes of operation: AUTOMATIC and MANUAL. The operator could press the AUTOMATIC/MANUAL buttons in the devices' faceplate. When the individual driver is in manual mode, it is operated and monitored by the operator from the Conventional Control System HMI, pressing the START/STOP or OPEN/CLOSE pushbuttons.

START/STOP or OPEN/CLOSE commands during operation in automatic mode come from immediately superior automatic control level. The automatic mode will be the normal mode for the normal operation.

The devices will be operated remotely or locally by the operator by the previous selection in the LOCAL/REMOTE faceplate selector:

- REMOTE mode means that all the orders come from the control system from the Control Room by means of the Conventional Control System HMI by acting on the devices' faceplate OPEN/CLOSE pushbuttons located in the corresponding valve´s faceplate.
- LOCAL means that all orders come acting on the OPEN/CLOSE or START/STOP pushbuttons located on field at the device control box.

9.1.2 Functional Group and Selector

The control system has a hierarchical control level structure based on functional groups (FG). The system can also be controlled from the lower hierarchical levels, either from functional subgroups (FSG) or from actuating directly on the different equipment as it is indicated in Section 9.1.1.

In order to control and supervise the groups, the system includes AUTOMATIC/MANUAL buttons in the groups' faceplates, used by the operator to select the control mode (automatic or manual), modify the set-points and actuate manually on the demand to the final control element. In order to actuate upon the different parameters.

When a functional group or equipment is in automatic mode, it is not possible to control it from their faceplate located on the graphic display of each system, and it will only follow the automatic orders from a higher hierarchical levels.

When a functional group or equipment is in manual mode, the operator has responsibility for control, since it will only be possible to control it from the control faceplate located on the graphic display of each system, and it ignores any automatic orders it receives from higher hierarchical levels.

Whenever there are redundant functional subgroups or equipment, a dedicated selector shall decide (following the operator previous selection) which equipment shall be started and which shall be in standby. If the system is started through the functional group and during operation the main equipment has a problem that prevents it from operating properly, the selector will automatically start up the standby equipment, stop the equipment in problems and change the selection, turning the standby equipment into main equipment, and vice versa. Once the problem is solved, and the equipment that suffered the problem is transferred to automatic mode, this equipment becomes the standby one, ready for any problem in the main equipment.

When a system is started from its functional group, all the actuators controlled by it shall be transferred to AUTO to ensure they all will follow the higher level commands.

Regardless of the control mode, the necessary start up permissives, protections and interlocks shall be programmed into the control system to prevent any type of actuation that could cause damage to the system equipment or dependent systems.

The functional group start permissive has to be defined in such a way that prevents the group to be started if due to their equipment status, it shall not be able to perform its main task properly.

9.1.3 HMI

All system drivers are monitored and controlled from the Conventional Control System HMI of the operator station located in the Control Room.

The user name will be included in the status bar of the Main Display Area – Mimic.

For more details about HMI see SCADA HMI Guideline (=NA.CN_EDB503, Ref.[23]).

9.1.4 On maintenance status

The Operator will set maintenance status in the faceplate of the devices in the Conventional Control System HMI. The representation of the maintenance status will be by the letter L in WHITE on a RED background on the graphic display of the equipment meaning that the equipment is not controllable by the Operator (equipment out of order).

The use of a password shall be required for operators to be able to configure out the system during the maintenance period.

Other maintenance activities will be described in the corresponding supplier maintenance procedures.

The maintainability has been taken into account in the design of the system.

9.1.5 PID Controller

A PID controller continuously calculates an error value as the difference between a desired set point (SP) and a measured process variable (PV) and applies a correction based on proportional, integral, and derivative terms (denoted P, I, and D respectively). A direct PID output tends to increase as the PV signal increases. A reverse PID output tends to decrease as the PV signal increases.

9.1.6 Anomaly

When an equipment has any problem that makes it unable to be controlled by the control system, its state switches to ANOMALY. An alarm is then generated to warn the operator to solve the problem.

An equipment in ANOMALY is rejected to manual and does not have permissives to be actuated until the cause is solved. Some causes to set an equipment in ANOMALY would be: electrical cabinet (or MOV actuator) not available, feedback anomaly, command failure, any kind of trip, etc.

An equipment in ANOMALY has to be acknowledge prior to be restored to AUTO control mode. The equipment cannot be acknowledged until the cause that generates the anomaly state has disappeared.

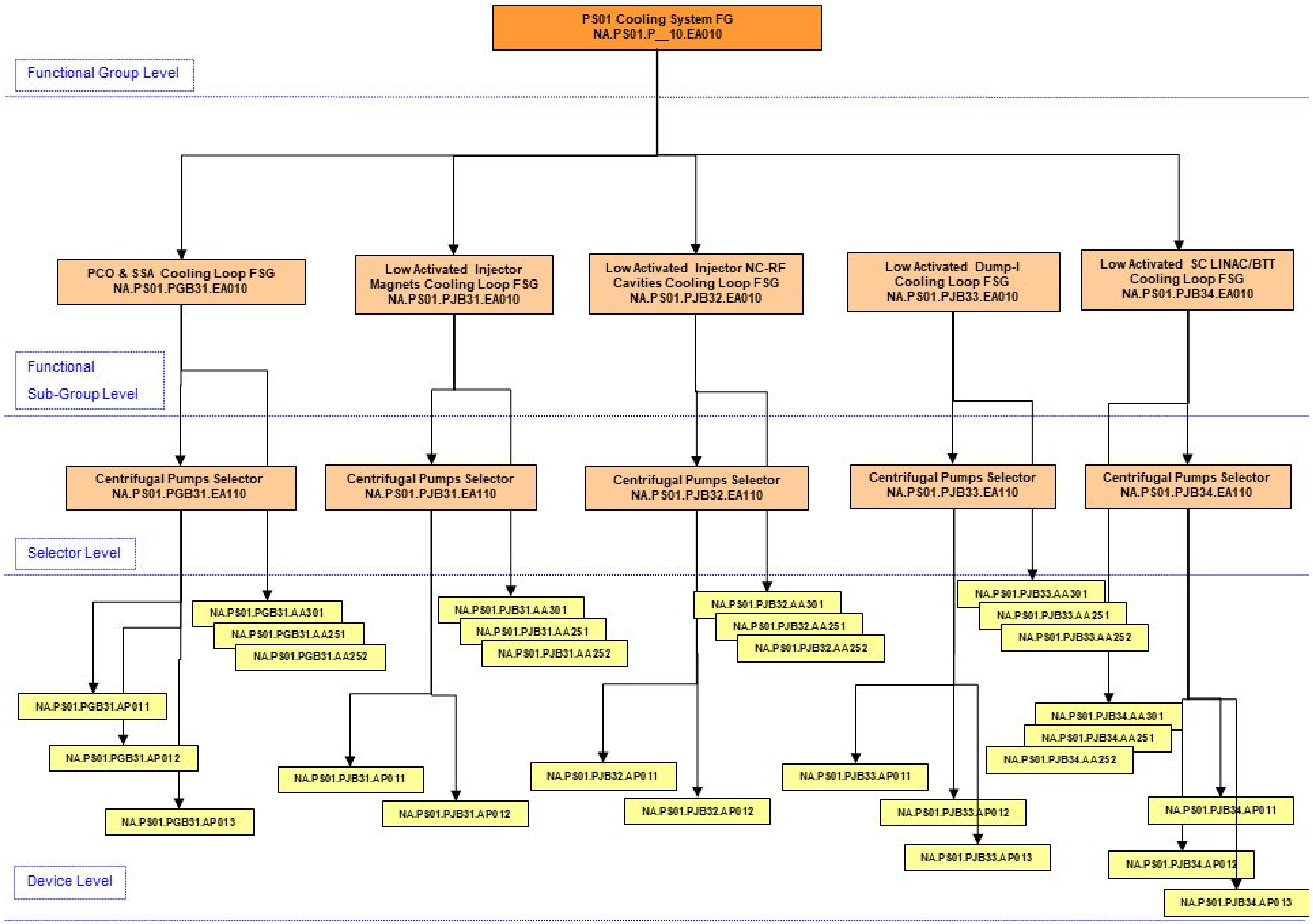
9.1.7 Forced Commands

When any equipment is set in manual control mode and the operator does not take care of its control, the necessary forced actuations shall be programmed in order to avoid any system equipment or dependent system equipment damage.

The forced commands shall actuate even if the corresponding actuation permissives are not met. When a forced command it shall be signalled through an alarm to warn operator about the anomaly situation. For any equipment forced to any state, the commands to override this state, either AUTO or MANUAL, are not permitted.

9.2 System Control

The hierarchical control structure is described in the following block diagram:


PS01 Cooling System FG
NA.PS01.P__10.EA010
Functional Group Level
PCO & SSA Cooling Loop FSG
NA.PS01.PGB31.EA010
Low Activated Injector Magnets Cooling Loop FSG
NA.PS01.PJB31.EA010
Low Activated Injector NC-RF Cavities Cooling Loop FSG
NA.PS01.PJB32.EA010
Low Activated Dump-I Cooling Loop FSG
NA.PS01.PJB33.EA010
Low Activated SC LINAC/BTT Cooling Loop FSG
NA.PS01.PJB34.EA010
Functional Sub-Group Level
Centrifugal Pumps Selector
NA.PS01.PGB31.EA110
Centrifugal Pumps Selector
NA.PS01.PJB31.EA110
Centrifugal Pumps Selector
NA.PS01.PJB32.EA110
Centrifugal Pumps Selector
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Centrifugal Pumps Selector
NA.PS01.PJB34.EA110
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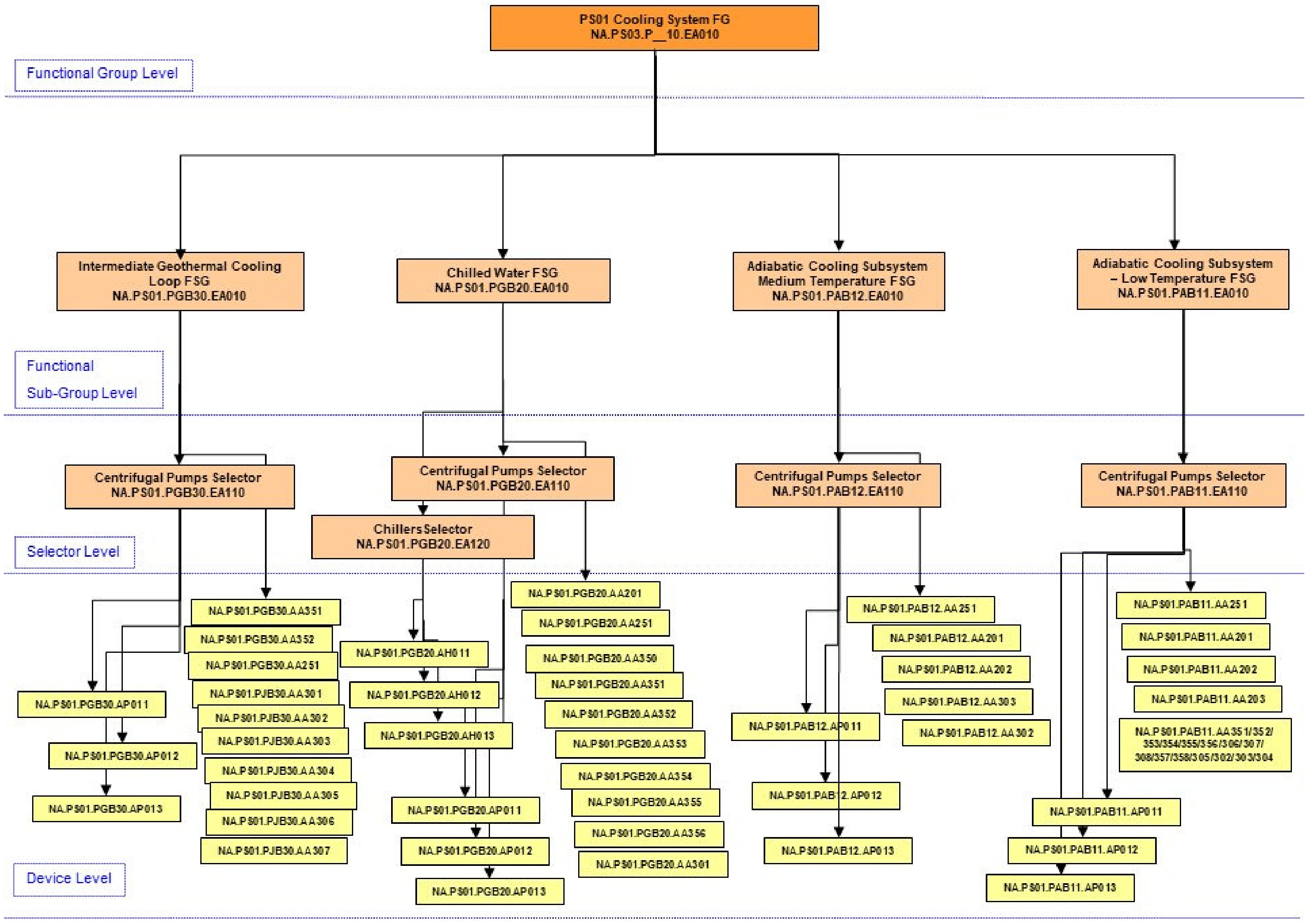
Device Level


PS01 Cooling System FG
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Functional Group Level
Intermediate Geothermal Cooling Loop FSG
NA.PS01.PGB30.EA010
Chilled Water FSG
NA.PS01.PGB20.EA010
Adiabatic Cooling Subsystem Medium Temperature FSG
NA.PS01.PAB12.EA010
Adiabatic Cooling Subsystem – Low Temperature FSG
NA.PS01.PAB11.EA010
Functional
Sub-Group Level
Centrifugal Pumps Selector
NA.PS01.PGB30.EA110
Centrifugal Pumps Selector
NA.PS01.PGB20.EA110
Chillers Selector
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Centrifugal Pumps Selector
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Centrifugal Pumps Selector
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Selector Level
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NA.PS01.PGB30.AA351
NA.PS01.PGB30.AA352
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NA.PS01.PAB11.AP012
NA.PS01.PAB11.AP013
Device Level

9.3 Operation Modes

9.3.1 Normal operation

9.3.1.1 PCO & SSA Cooling Loop NA.PS01.PGB31 (Non activated ACC Primary Cooling Loop)

As was previously described in section 8.3.1, the PCO & SSA Cooling loop is mainly comprised by two heat exchangers (NA.PS01.PGB31.AC011/AC012), a pumping group of three pumps (NA.PS01.PGB31.AP011/ AP012/ AP013), a surge tank (NA.PS01.PGB31.BB010), a buffer vessel (NA.PS01.PGB31.BB020) and a regulating 3-ways valve (NA.PS01.PGB31.AA301).

The Nitrogen make-up to the surge tank (NA.PS01.PGB31.BB010) will be done with a self-regulated valve NA.PS01.PGB31.AA601. The pressure in the tank will be measured by the pressure transmitter NA.PS01.PGB31.PT010.

The on-off valve NA.PS01.PGB31.AA251 will make-up demineralized water in the system from the demineralized water storage tank (NA.PS02.GHC10.BB010). In case demineralized wastewater is available at the required quality in the demineralized wastewater tanks (NA.PS03.GMB60.BB011/012), water make-up can also be performed by the opening of the on-off valve NA.PS01.PGB31.AA252. There is an interlock between them, so as not to open both at the same time. When the on-off valve NA.PS01.PGB31.AA252 is closed it will be send a signal to the PS03 system to close the on-off valve NA.PS03.GMB60.AA254 and to stop the pumps NA.PS03.GMB60.AP011/AP012.

The level in the Buffer tank (NA.PS01.PGB31.BB020) is measured by NA.PS01.PGB20.LT010.

The three pumps (NA.PS01.PGB31.AP011/ AP012/ AP013) are 3x50%. The pumps selected as main pumps will operate at constant flowrate, while the other shall remain on standby, awaiting actuation in the event any problem is detected in the main pumps. A pump operating hours counter will be programmed in the software in order that the operator can equally distribute the pumps operating hours.

The pressure and temperature at the suction of the pumps will be measured by the transmitters and NA.PS01.PGB31.PT040 and NA.PS01.PGB31.TT040.

In case that there is a pump started and the pressure at the discharge is low or high measured by NA.PS01.PGB31.PT110 there will be displayed an alarm in the HMI in the UBMS Conventional Control System HMI. The same for the flow measured by NA.PS01.PGB31.FT010.

The regulating 3-ways valve (NA.PS01.PGB31.AA301) will be controlled with the NA.PS01.PGB31.TT051/TT052. Depending on if the temperature is high or low the regulating 3-ways valve will open/close to get the appropriate temperature for the water.

The Purification System (NA.PS01.PGB31.AW010) will be controlled by a dedicated local control panel provided by the package plant supplier. The only remote monitoring in the UBMS Conventional Control System HMI will be at least two signals indicating 'No operational availability' and 'No fault of Purification System'. The package plant shall be provided with the signals and alarms necessary for the satisfactory operation and supervision of the package plant in the UBMS Conventional Control System HMI.

The temperature at the entrance of the Heat Exchangers NA.PS01.PGB31.AC011/AC012 will be measured by NA.PS01.PGB31.TT010/TT070.

The temperature at the exit of the Heat Exchangers NA.PS01.PGB31.AC011/AC012 will be measured by NA.PS01.PGB31.TT020/TT060. In order to control the temperature of the loop in the values requested by the ACC equipment, these temperature transmitters will command the 2-way control valves placed in the cold side of the heat exchangers (NA.PS01.PGB30.AA301/302). Consequently, in case the heat dissipated in the ACC consumers decreases, the flowrate through the cold side of the heat exchanger will be reduced in order to maintain the cooling water temperature at the requested value.

At the different distribution collectors to final consumers, there will be a cartridge filter (NA.PS01.PGB31.AT004/005/006/007) with differential pressure measurement (NA.PS01.PGB31.PT150/180/210/240).

In the return collectors it will be measured the temperature by NA.PS01.PGB31.TT080/090/100/110 and the flowrate by NA.PS01.PGB31.FT020/030/040/050.

9.3.1.2 Low Activated ACC Primary Cooling Loops (NA.PS01.PJB31/PJB32/PJB33/PJB34)

The normal operation of these cooling loops is equivalent as for the PCO & SSA Cooling Loop NA.PS01.PGB31. Consequently, the normal operation described in Section 9.3.1.1 is valid for these cooling loop (by changing PGB31 by PJB31/32/33/34).

The main difference between subsystems is the number of heat exchangers and pumping units (as previously described in section 8.3.2), as well as the main collectors distribution. In these cooling loops, one single main distribution collector is considered along the Injector Tunnel / SC LINAC Tunnel, equipped with a filter with differential pressure measurement (NA.PS01.PJB31/32/33/34.PT130). Equivalent as PGB31, the temperature and flow is measured in the return header by NA.PS01.PJB31/32/33/34.TT060 and NA.PS01.PJB31/32/33/34.FT020. In this case, as these are potentially activated loops, water activation level is also measured in the return header by NA.PS01.PJB31/32/33/34.RT010.

As previously described, these cooling loops will maintain the supply temperature in the values referred in Table 3 by:

- The regulation of the 3-way mixing valve (NA.PS01.PJB31/32/33/34.AA301), located upstream the buffer tank, commanded by a temperature transmitter located at the inlet of the tank (NA.PS01.PJB31/32/33/34.TT051/TT052).
- The regulation of a 2-way control valve (NA.PS01.PGB30.AA303/304/305/306/307), located in the cold side of the heat exchanger, commanded by a temperature transmitter located at outlet pipe in the hot side (NA.PS01.PJB31/32/33/34.TT020 and NA.PS01.PJB34.TT060).

The on-off valves NA.PS01.PJB31/32/33/34.AA251 will make-up demineralized water in the systems from the demineralized water storage tank (NA.PS02.GHC10.BB010). In case demineralized wastewater is available at the required quality in the B02 demineralized wastewater holding tank (NA.PS03.GMD10.BB010), water make-up can also be performed by the opening of the on-off valves NA.PS01.PJB31/32/33/34.AA252. When one of these on-off valves close, they will be send a signal to the PS03 system to close the corresponding on-off valve that supplies water to the different subsystems (NA.PS03.GMD10.AA251/252/253/254) and to stop the pumps NA.PS03.GMD10.AP011/AP012.

9.3.1.3 Intermediate Geothermal Cooling Loop NA.PS01.PGB30

As was previously described in section 8.3.3, the Intermediate Geothermal Cooling Loop is mainly comprised by two (2) sets of heat exchangers (NA.PS01.PGB30.AC011/AC012 and NA.PS01.PGB30.AC021/AC022), a pumping group (NA.PS01.PGB30.AP011/ AP012/ AP013) and a surge tank (NA.PS01.PGB30.BB010).

The selection of the main heat sink of this subsystem and, consequently, the operation with the two (2) different set of heat exchangers, is determined by the environmental conditions, based on the cooling water temperature at the outlet of the adiabatic coolers at PAB11 subsystem:

- if the temperature measured by NA.PS01.PAB11.TT050 is low, valve NA.PS01.PGB30.AA351 will open and NA.PS01.PGB30.AA352 will close, cooling of the subsystem by the low temperature adiabatic cooling subsystem (NA.PS01.PAB11).
- if the temperature measured by NA.PS01.PAB11.TT050 is high, valve NA.PS01.PGB30.AA351 will close and NA.PS01.PGB30.AA352 will open, cooling of the subsystem by the geothermal cooling system (NA.PS01.PCB30).

The temperature at the entrance of the Heat Exchangers NA.PS01.PGB30.AC011/AC012/AC021/AC022 will be measured by NA.PS01.PGB30.TT090/TT110/TT010/TT070)

The temperature at the exit of the Heat Exchangers NA.PS01.PGB30.AC011/AC012/AC21/AC022 will be measured by NA.PS01.PGB31.TT080/TT100/TT020/TT060. In order to control the temperature of the loop in the values defined in Table 3, these temperature transmitters will command the 2-way control valves placed in the cold side of the heat exchangers.

The three centrifugal pumps NA.PS01.PGB30.AP011/AP012/AP013 are controlled by a VFD that keeps the pressure discharge NA.PS01.PGB30.PT110 constant. The pumps selected as main pumps will operate, while the other shall remain on standby, awaiting actuation in the event any problem is detected in the main pumps. A pump operating hours counter will be programmed in the software in order that the operator can equally distribute the pumps operating hours.

The pressure and temperature at the suction of the pumps will be measured by the transmitters and NA.PS01.PGB30.PT040 and NA.PS01.PGB30.TT040.

In case that there is a pump started and the pressure at the discharge is low or high measured by NA.PS01.PGB30.PT110 there will be displayed an alarm in the HMI in the UBMS Conventional Control System HMI. The same for the flow measured by NA.PS01.PGB30.FT010.

The NA.PS01.PGB30 supplies cold water to the cold side to the different heat exchangers of the ACC primary cooling loops as well as to the MAC (TP.PS01.4007/4008). Supply pipes are equipped with local temperature and pressure instrumentation while return pipes are equipped with temperature transmitters (NA.PS01.PGB30.TT120/140/160/180/200/220/240) and radiation transmitters (NA.PS01.PGB30.RT010/020/030/040/050) that will isolate the defective heat exchanger in case high radiation level is detected in the water.

As previously described, the control valves NA.PS01.PGB30.AA301/302/303/304/305/306/307 located in the return from each heat exchanger regulates the temperature of the different ACC primary cooling loops, commanded by a temperature transmitter located in the warm side (NA.PS01.PGB31.TT020/TT060, NA.PS01.PJB31.TT020, NA.PS01.PJB32.TT020, NA.PS01.PJB33.TT020 and NA.PS01.PJB34.TT020/TT060, respectively).

The Nitrogen make-up to the surge tank (NA.PS01.PGB30.BB010) will be done with a self-regulated valve NA.PS01.PGB30.AA601. The pressure in the tank will be measured by the pressure transmitter NA.PS01.PGB30.PT010.

The on-off valve NA.PS01.PGB30.AA251 will make-up softened water in the system from the softened water storage tank (NA.PS02.GKC10.BB010).

9.3.1.4 Chilled Water Subsystem NA.PS01.PGB20

As previously described in section 8.3.4, this cooling loop is mainly comprised by three chillers (NA.PS01.PGB20.AH011/AH012/AH013), a pumping group of three pumps (NA.PS01.PGB20.AP011/AP012/AP013) with VFD, a surge tank (NA.PS01.PGB20.BB010) and one Plate Heat Exchanger NA.PS01.PGB20.AC010 for free-cooling, as main equipment.

The Nitrogen make-up to the surge tank (NA.PS01.PGB20.BB010) will be done with a self-regulated valve NA.PS01.PGB20.AA601. The pressure in the tank will be measured by the pressure transmitter NA.PS01.PGB20.PT010.

The make-up of the mixture softened water/propylene glycol will be manually done by the opening of the on-off valve NA.PS01.PGB20.AA251 and the control valve NA.PS01.PGB20.AA201, with an interlock between them to open both at the same time. The flowrate of propylene glycol will be determined by the PUA10 dosing pump, while the appropriate flowrate of softened water is fixed by the control valve AA201, with intermediate positions to set the proper water/glycol percentage.

The three pumps (NA.PS01.PGB20.AP011/ AP012/ AP013) are 3x50%. The pumps selected as main pumps will operate at variable flowrate, regulated by the pressure at the discharge of the pumps measured by NA.PS01.PGB20.PT111/PT112, while the other shall remain on standby, awaiting actuation in the event any problem is detected in the main pumps. A pump operating hours counter will be programmed in the software in order that the operator can equally distribute the pumps operating hours.

The pressure and temperature at the suction of the pumps will be measured by the transmitters and NA.PS01.PGB20.PT040 and NA.PS01.PGB20.TT050.

During the most of the time of the year, chillers are in operation, with main header isolation valves NA.PS01.PGB20.AA350 and NA.PS01.PGB20.AA351 open and with the chillers bypass valve NA.PS01.PGB20.AA355 closed. Under these conditions, the free-cooling heat exchanger NA.PS01.PGB20.AC010 remains isolated with the valve NA.PS01.PGB20.AA356 in closed position.

As soon as the environmental conditions allows it, and the cooling water temperature at the outlet of the adiabatic coolers measured by NA.PS01.PAB11.TT050 is low, valve NA.PS01.PGB20.AA356 will open and NA.PS01.PGB20.AA350 will close, passing all the cooling loop flowrate through the free-cooling heat exchanger.

When the free-cooling is complete and temperature in the transmitter NA.PS01.PGB20.TT030 located in common discharge header is low (7ºC), valves NA.PS01.PGB20.AA351 and NA.PS01.PGB20.AA355 will be closed and opened respectively, completely bypassing the chillers.

The temperature at the entrance and return from the free-cooling Plate Heat Exchanger NA.PS01.PGB20.AC010 will be measured by NA.PS01.PGB20.TT010/TT020. In order to control the temperature of the loop in the values defined in Table 3, the return temperature transmitter will command the 2-way control valves placed in the cold side of the heat exchanger (PAB11).

Each chiller (NA.PS01.PGB20.AH011/AH012/AH013) will be controlled by a dedicated local control panel provided by the package plant supplier. The only remote monitoring in the UBMS Conventional Control System HMI will be at least two signals indicating ‘No operational availability’ and ‘No fault of Chiller System’. The package plant shall be provided with the signals and alarms necessary for the satisfactory operation and supervision of the package plant in the UBMS Conventional Control System HMI.

The three chillers (NA.PS01.PGB20.AH011/AH012/AH013) are 3x50%. The chillers selected as main chillers will operate at constant flowrate, while the other shall remain on standby, awaiting actuation in the event any problem is detected in the main chillers. A chiller operating hours counter will be programmed in the software in order that the operator can equally distribute the chillers operating hours. The chillers isolation valves NA.PS01.PGB20.AA352/AA353/AA354 will be opened automatically when its corresponding chiller is started.

The minimum flowrate bypass valve NA.PS01.PGB20.AA301 will regulate the recirculation when the flow meter NA.PS01.PGB20.FT010 measured low level.

The pressure at the different terminal points defined with the HVAC / MAC consumers is measured by NA.PS01.PGB20.PT120/PT130/PT140/PT150.

9.3.1.5 Low Temperature Adiabatic Cooling Subsystem NA.PS01.PAB11

As previously described in Section 8.3.5, the Low Temperature Adiabatic Cooling Subsystem is preliminary comprised by six adiabatic coolers (NA.PS01.PAB11.AH011/AH012/AH013/AH014/AH015/AH016), a pumping group of three pumps (NA.PS01.PAB11.AP011/AP012/AP013) with VFD and a surge tank (NA.PS01.PAB11.BB010) as main equipment.

The Nitrogen make-up to the surge tank (NA.PS01.PAB11.BB010) will be done with a self-regulated valve NA.PS01.PAB11.AA601. The pressure in the tank will be measured by the pressure transmitter NA.PS01.PAB11.PT010.

The make-up of the mixture softened water/propylene glycol will be manually done by the opening of the on-off valve NA.PS01.PAB11.AA251 and the control valve NA.PS01.PAB11.AA201, with an interlock between them to open both at the same time. The flowrate of propylene glycol will be determined by the PUA10 dosing pump, while the appropriate flowrate of softened water is fixed by the control valve AA201, with intermediate positions to set the proper water/glycol percentage.

The redundant control valves NA.PS01.PAB11.AA202/AA203 deviate the excess of flowrate required by the consumers, based on the flow measured at the discharge of the centrifugal pumps measured by NA.PS01.PAB11.FT010. Based on the opening position of these valves, the different adiabatic modules are put into operation or are stopped, acting the on-off motor operated isolation valves MOV NA.PS01.PAB11.AA351/352/353/354/355/356:

- If the opening for the control valves NA.PS01.PAB11.AA202/203 is near to 100% (meaning that the consumers require less cooling water), an adiabatic cooler will be stopped.
- On the contrary, if the demand for the control valves NA.PS01.PAB11.AA202/203 is near to 0% (meaning that the cooling water demand is increased), an additional adiabatic will be started one after other.

The three pumps (NA.PS01.PGB20.AP011/ AP012/ AP013) are 3x50%. The pumps selected as main pumps will operate at variable flowrate depending on the number of adiabatic coolers in operation, the VFD will allow to keep constant the pressure at the discharge of the pumps measured by (NA.PS01.PAB11.PT111/PT112). While the other shall remain on standby, awaiting actuation in the event any problem is detected in the main pumps. A pump operating hours counter will be programmed in the software in order that the operator can equally distribute the pumps operating hours.

The pressure and temperature at the suction of the pumps will be measured by the transmitters NA.PS01.PAB11.PT040 and NA.PS01.PAB11.TT040.

Each adiabatic cooler (NA.PS01.PAB11.AH011/AH012/AH013/AH014/AH015/AH016) will be controlled by a dedicated local control panel provided by the package plant supplier. The only remote monitoring in the UBMS Conventional Control System HMI will be at least two signals indicating ‘No operational availability’ and ‘No fault of Chillers System’. The package plant shall be provided with the signals and alarms necessary for the satisfactory operation and supervision of the package plant in the UBMS Conventional Control System HMI. The flow uses as process variable is NA.PS01.PAB11.FT010. The temperature is measured downstream the coolers measured by NA.PS01.PAB11.TT070/TT100/TT130/TT160/TT190/TT220. The temperature is measure in the return by NA.PS01.PAB11.TT060.

The low temperature adiabatic cooling subsystem supplies cooling water to the chillers condenser as well as to the cold side of the free-cooling heat exchanger, regeneration heat exchanger as well as process system heat exchanger of NA.PS01.PGB30 subsystem. Supply pipes are equipped with local temperature and pressure instrumentation, while return pipes are equipped with temperature transmitters and control valves to regulate the temperature in the warm side. In addition, these control valves have open permissives attending to the seasonal water temperature at the outlet of the adiabatic coolers, measured by NA.PS01.PAB11.TT050 at the main distribution header (at the discharge of the centrifugal pumps):

- The control motor operated valves MOV NA.PS01.PAB11.AA306/307 have a permissive in a high temperature to open. Their respective process variable are the NA.PS01.PGB30.TT020 (NA.PS01.PGB30.AC021) and NA.PS01.PGB30.TT060 (NA.PS01.PGB30.AC022), respectively.
- The control motor operated valve MOV NA.PS01.PAB11.AA308 has a permissive in a low temperature to open. Its respective process variable is the temperature measured at the NA.PS01.PCB30.AC020.
- The on-off motor operated valve MOV NA.PS01.PAB11.AA357/358 will open if the temperature at the discharge of the centrifugal pumps is high high. These valves will be forced to close if the temperature NA.PS01.PAB11.TT050 is higher or equal than the temperature measured in the NA.PS01.PCB30.TT110.
- The control motor operated valves MOV NA.PS01.PAB11.AA305 has a permissive in a low low temperature to start the regulation the temperature at the discharge of the centrifugal pumps measured by NA.PS01.PAB11.TT050 and its respective process variable is the NA.PS01.PGB20.TT020 (AC010).
- The control motor operated valves MOV NA.PS01.PAB11.AA302/AA303/AA304 regulates the flowrate through the chillers condenser and their respective process variables are the temperature transmitters NA.PS01.PGB20.TT070, NA.PS01.PGB20.TT080 and NA.PS01.PGB20.TT090, inside the chillers package plant supply (signals sent by the chiller control system).

9.3.1.6 Medium Temperature Adiabatic Cooling Subsystem NA.PS01.PAB12

As previously described in Section 8.3.6, the Medium Temperature Adiabatic Cooling Subsystem is mainly comprised by two adiabatic coolers (NA.PS01.PAB12.AH011/AH012), a pumping group of three pumps (NA.PS01.PAB12.AP011/AP012/AP013) with VFD and a surge tank (NA.PS01.PAB12.BB010) as main equipment.

The Nitrogen make-up to the surge tank (NA.PS01.PAB12.BB010) will be done with a self-regulated valve NA.PS01.PAB12.AA601. The pressure in the tank will be measured by the pressure transmitter NA.PS01.PAB12.PT010.

The make-up of the mixture softened water/propylene glycol will be manually done by the opening of the on-off valve NA.PS01.PAB12.AA251 and the control valve NA.PS01.PAB12.AA201, with an interlock between them to open both at the same time. The flowrate of propylene glycol will be determined by the PUA10 dosing pump, while the appropriate flowrate of softened water is fixed by the control valve AA201, with intermediate positions to set the proper water/glycol percentage.

The three pumps (NA.PS01.PAB12.AP011/ AP012/ AP013) are 3x50%. The pumps selected as main pumps will operate at variable flowrate, regulated by the pressure at the discharge of the pumps measured by (NA.PS01.PAB12.PT111/PT112). While the other shall remain on standby, awaiting actuation in the event any problem is detected in the main pumps. A pump operating hours counter will be programmed in the software in order that the operator can equally distribute the pumps operating hours.

The pressure and temperature at the suction of the pumps will be measured by the transmitters and NA.PS01.PAB12.PT040 and NA.PS01.PAB12.TT041/042.

The two modules (NA.PS01.PAB12.AH011/AH012) will be controlled by a dedicated local control panel provided by the package plant supplier. The only remote monitoring in the UBMS Conventional Control System HMI will be at least two signals indicating ‘No operational availability’ and ‘No fault of Chillers System’. The package plant shall be provided with the signals and alarms necessary for the satisfactory operation and supervision of the package plant in the UBMS Conventional Control System HMI. The temperature uses as process variable is NA.PS01.PAB12.PT041/042.

The valve NA.PS01.PAB12.AA202 will regulate the recirculation when the flow meter NA.PS01.PAB12.FT010 measured low level.

The temperature at the return header at the entrance of the adiabatic coolers is measured by NA.PS01.PAB12.TT080.

The valves NA.PS01.PAB12.AA302/303, at the return header of the WCS and Refrigerator Cold Box, respectively, will be regulated with a variable from NA.CP (by SCK CEN).

The temperature in the return to the valves NA.PS01.PAB12.AA302/303 is measured by NA.PS01.PAB12.PT090/PT110.

9.3.1.7 Geothermal Cooling Subsystem NA.PS01.PCB30

The Geothermal Cooling SubSystem (NA.PS01.PCB30) will be controlled by a dedicated local control panel provided by the package plant supplier. The only remote monitoring in the UBMS Conventional Control System HMI will be at least two signals indicating ‘No operational availability’ and ‘No fault of Purification System’. The package plant shall be provided with the signals and alarms necessary for the satisfactory operation and supervision of the package plant in the UBMS Conventional Control System HMI.

The detailed design of this subsystem, including the definition of the main control loops, will be later defined by the geothermal subsystem technologist.

9.3.1.8 Propylene Glycol Supply Subsystem NA.PS01.PUA10

The Propylene Glycol Supply Subsystem (NA.PS01.PUA10) will be controlled by a dedicated local control panel provided by the package plant supplier. The only remote monitoring in the UBMS Conventional Control System HMI will be at least two signals indicating ‘No operational availability’ and ‘No fault of Propylene Glycol Supply Subsystem’. The package plant shall be provided with the signals and alarms necessary for the satisfactory operation and supervision of the package plant in the UBMS Conventional Control System HMI.

9.3.2 Abnormal operation

- Low pressure in the discharge of the centrifugal pumps (NA.PS01.PGB31.PT110) (L).
- High pressure in the discharge of the centrifugal pumps (NA.PS01.PGB31.PT110) (H). TT040
- Low temperature in the discharge of the centrifugal pumps (NA.PS01.PGB31.TT050) (L).
- High temperature in the discharge of the centrifugal pumps (NA.PS01.PGB31.TT050) (H).
- Low pressure in the suction of the centrifugal pumps (NA.PS01.PGB31.PT040) (L). TT050
- High pressure in the suction of the centrifugal pumps (NA.PS01.PGB31.PT040) (H).
- Low temperature in the suction of the centrifugal pumps (NA.PS01.PGB31.TT040) (~~L~~).
- High temperature in the suction of the centrifugal pumps (NA.PS01.PGB31.TT040) (~~H~~).
- No operational availability of Purification System, NA.PS01.PGB31.AW010
- No fault of Purification System, NA.PS01.PGB31.AW010

(Note: The abnormal operation of the NA.PS01.PJB31, NA.PS01.PJB32, NA.PS01.PJB33, NA.PS01.PJB34 is valid changing PGB31 in the above abnormal operation by PJB31, PJB32, PJB33, PJB34 and PGB30.)

- No operational availability of Purification System, NA.PS01.PUA10.AW010
- No fault of Purification System, NA.PS01.PUA10.AW010
- No operational availability of Purification System, NA.PS01.PUA10.AW010
- No fault of Purification System, NA.PS01.PUA10.AW010
- No operational availability of Geothermal Cooling Subsystem, NA.PS01.PCB30
- No fault of Geothermal Cooling Subsystem, NA.PS01.PCB30
- Low pressure in the discharge of the centrifugal pumps (NA.PS01.PGB20.PT110) (L).
- High pressure in the discharge of the centrifugal pumps (NA.PS01.PGB20.PT110) (H).
- Low temperature in the discharge of the centrifugal pumps (NA.PS01.PGB20.TT050) (L).
- High temperature in the discharge of the centrifugal pumps (NA.PS01.PGB20.TT050) (H).
- Low pressure in the suction of the centrifugal pumps (NA.PS01.PGB20.PT040) (L).
- High pressure in the suction of the centrifugal pumps (NA.PS01.PGB20.PT040) (H).
- Low temperature in the suction of the centrifugal pumps (NA.PS01.PGB20.TT050) (L).
- High temperature in the suction of the centrifugal pumps (NA.PS01.PGB20.TT050) (H).
- Low pressure in the discharge of the centrifugal pumps (NA.PS01.PAB12.PT110) (L).
- High pressure in the discharge of the centrifugal pumps (NA.PS01.PAB12.PT110) (H).
- Low temperature in the discharge of the centrifugal pumps (NA.PS01.PAB12.TT050) (L).
- High temperature in the discharge of the centrifugal pumps (NA.PS01.PAB12.TT050) (H).
- Low pressure in the suction of the centrifugal pumps (NA.PS01.PAB12.PT040) (L).
- High pressure in the suction of the centrifugal pumps (NA.PS01.PAB12.PT040) (H).
- Low temperature in the suction of the centrifugal pumps (NA.PS01.PAB12.TT040) (L).
- High temperature in the suction of the centrifugal pumps (NA.PS01.PAB12.TT040) (H).
- Low pressure in the discharge of the centrifugal pumps (NA.PS01.PAB11.PT110) (L).
- High pressure in the discharge of the centrifugal pumps (NA.PS01.PAB11.PT110) (H).
- Low temperature in the discharge of the centrifugal pumps (NA.PS01.PAB11.TT050) (L).
- High temperature in the discharge of the centrifugal pumps (NA.PS01.PAB11.TT050) (H).
- Low pressure in the suction of the centrifugal pumps (NA.PS01.PAB11.PT040) (L).
- High pressure in the suction of the centrifugal pumps (NA.PS01.PAB11.PT040) (H).
- Low temperature in the suction of the centrifugal pumps (NA.PS01.PAB11.TT040) (L).
- High temperature in the suction of the centrifugal pumps (NA.PS01.PAB11.TT040) (H).
- No operational availability of chillers, NA.PS01.PGB20.AH011/AH012/AH013
- No fault of chillers, NA.PS01.PGB20.AH011/AH012/AH013
- No operational availability of cooling towers, NA.PS01.PAB11.AH011/AH012/AH013/AH014/AH015/AH016
- No fault of cooling towers, NA.PS01.PAB11.AH011/AH012/AH013/AH014/AH015/AH016
- No operational availability of chillers, NA.PS01.PAB12.AH011/AH012
- No fault of chillers, NA.PS01.PAB12.AH011/AH012

9.4 System Control

The different controls developed for the system are described in more detail below; however, all details about system control, protections, interlocks, alarms and automatic actions will be depicted in the corresponding system control diagram.

9.4.1 Analogue Control and Regulation

9.4.1.1 PCO & SSA Cooling Loop NA.PS01.PGB31

9.4.1.1.1 Temperature regulation with the Motor Operated Valve MOV NA.PS01.PGB31.AA301

- Control

The function of the valve shall be to ensure the required temperature by the ACC consumers measured by a redundant temperature transmitter (NA.PS01.PGB31.TT051/TT052). The required temperature will be the set point of the PID loop.

The process variable is the output from the block of two redundant measurements as, which shall be programmed in the control system and which is used to connect the two temperature transmitters installed at the inlet of the buffer tank.

Control shall be done through a direct PID loop that shall continuously compare the process variable with the established set point. If this variable is lower than the set point, the valve will tend to open the 3-way, connected to the warm return header of the loop, to increase the supply temperature. Otherwise, the valve will tend to have open only the 2-way, directly connecting the outlet header from the heat exchangers to the buffer tank inlet.

- Forcing conditions

A forced closing of the valve (2-way position) shall also be programmed whenever all the centrifugal pumps are stopped.

The final control element is a motorised 3-ways valve type, equipped with a positioner and a position transmitter, as well as position limit switches.

9.4.1.2 Low Activated Injector Magnets Cooling Loop NA.PS01.PJB31

9.4.1.2.1 Temperature regulation with the Motor Operated Valve MOV NA.PS01.PJB31.AA301

The control is the same described in section 9.4.1.1.1.

9.4.1.3 Low Activated Injector NC-RF Cavities Cooling Loop NA.PS01.PJB32

9.4.1.3.1 Temperature regulation with the Motor Operated Valve MOV NA.PS01.PJB32.AA301

The control is the same described in section 9.4.1.1.1.

9.4.1.4 Low Activated Dump-I Cooling Loop NA.PS01.PJB33

9.4.1.4.1 Temperature regulation with the Motor Operated Valve MOV NA.PS01.PJB33.AA301

The control is the same described in section 9.4.1.1.1.

9.4.1.5 Low Activated SC LINAC/BTT Cooling Loop NA.PS01.PJB34

9.4.1.5.1 Temperature regulation with the Motor Operated Valve MOV NA.PS01.PJB34.AA301

The control is the same described in section 9.4.1.1.1.

9.4.1.6 Intermediate Geothermal Cooling Loop NA.PS01.PGB30

9.4.1.6.1 Centrifugal Pumps with VFD (NA.PS01.PGB30.AP011/ AP012/ AP013)

The function of these pumps is to supply water to cool different consumers.

- Automatic Start
  - The pump starts automatically when the order to start is receive from the Selector NA.PS01.PGB30.EA110.
- Automatic Stop
  - The pump stops automatically when the order to stop is receive from the Selector NA.PS01.PGB30.EA110.
- Start Permissives
  - Discharge pressure transmitters available (NA.PS01.PGB31.PT111/PT112); and
  - Not low pressure at the pumps suction (NA.PS01.PGB31.PT040).
- Stop Permissive
  - The pumps are always permitted to stop.
- Trip conditions.
  - Not applicable.
- Forced stop
  - Not applicable.

The function of the pumps VFD shall be to ensure an appropriate centrifugal pumps pressure discharge by means of the pressure discharge (NA.PS01.PGB31.PT111/PT112)

Control shall be done through a reverse PID loop that shall continuously compare the process variable with the established set point. If this variable is greater than the set point, the VFD will tend to decrease the pumps velocity. Otherwise, the VFD will tend to increase the pump speed.

Only one controller (PID) shall be furnished for the centrifugal pumps, so that pumps started shall be always at same speed. It is not allowed to have pumps running at different speeds.

9.4.1.6.2 Motor Operated Valves NA.PS01.PGB30.AA301/302

- Control

The function of these valves shall be to ensure the regulation of the temperature at the outlet of the heat exchangers NA.PS01.PGB31.AC011/AC012 for the proper cooling of ACC equipment (PCO, SSA, RF Loads and circulators).

The process variable is the temperature measured at the outlet of the warm side of these heat exchangers, in the ACC primary cooling loop: NA.PS01.PGB31.TT020 (NA.PS01.PGB31.AC011) and NA.PS01.PGB31.TT060 (NA.PS01.PGB31.AC022), respectively.

Control shall be done through a direct PID loop that shall continuously compare the process variable with the established set point. If this variable is lower than the set point, the valve will tend to close the valve, to reduce the water flowrate in the cold side of the heat exchanger, keeping the required temperature in the ACC primary cooling loop. Otherwise, the PID will tend to open the valve.

- Forcing conditions

No forced conditions are programmed for these valves.

9.4.1.6.3 Motor Operated Valve NA.PS01.PGB30.AA303

- Control

The function of this valve shall be to ensure the regulation of the temperature at the outlet of the heat exchanger NA.PS01.PJB31.AC010 for the proper cooling of ACC equipment (injector magnets).

The process variable is the temperature measured at the outlet of the warm side of this heat exchanger, in the ACC primary cooling loop: NA.PS01.PJB31.TT020.

Control shall be done through a direct PID loop that shall continuously compare the process variable with the established set point. If this variable is lower than the set point, the valve will tend to close the valve, to reduce the water flowrate in the cold side of the heat exchanger, keeping the required temperature in the ACC primary cooling loop. Otherwise, the PID will tend to open the valve.

- Forcing conditions

This valve is forced to close in case high radiation level is detected in the cooling water by NA.PS01.PGB30.RT010, to isolate the defective heat exchanger.

9.4.1.6.4 Motor Operated Valve NA.PS01.PGB30.AA304

- Control

The function of this valve shall be to ensure the regulation of the temperature at the outlet of the heat exchanger NA.PS01.PJB32.AC010 for the proper cooling of ACC equipment (injector NC-RF cavities).

The process variable is the temperature measured at the outlet of the warm side of this heat exchanger, in the ACC primary cooling loop: NA.PS01.PJB32.TT020.

Control shall be done through a direct PID loop that shall continuously compare the process variable with the established set point. If this variable is lower than the set point, the valve will tend to close the valve, to reduce the water flowrate in the cold side of the heat exchanger, keeping the required temperature in the ACC primary cooling loop. Otherwise, the PID will tend to open the valve.

- Forcing conditions

This valve is forced to close in case high radiation level is detected in the cooling water by NA.PS01.PGB30.RT020, to isolate the defective heat exchanger.

9.4.1.6.5 Motor Operated Valve NA.PS01.PGB30.AA305

- Control

The function of this valve shall be to ensure the regulation of the temperature at the outlet of the heat exchanger NA.PS01.PJB33.AC010 for the proper cooling of ACC equipment (DUMP-I).

The process variable is the temperature measured at the outlet of the warm side of this heat exchanger, in the ACC primary cooling loop: NA.PS01.PJB33.TT020.

Control shall be done through a direct PID loop that shall continuously compare the process variable with the established set point. If this variable is lower than the set point, the valve will tend to close the valve, to reduce the water flowrate in the cold side of the heat exchanger, keeping the required temperature in the ACC primary cooling loop. Otherwise, the PID will tend to open the valve.

- Forcing conditions

This valve is forced to close in case high radiation level is detected in the cooling water by NA.PS01.PGB30.RT030, to isolate the defective heat exchanger.

9.4.1.6.6 Motor Operated Valves NA.PS01.PGB30.AA306/307

- Control

The function of these valves shall be to ensure the regulation of the temperature at the outlet of the heat exchangers NA.PS01.PJB34.AC011/AC012 for the proper cooling of ACC equipment (SC LINAC Tunnel / BTT equipment).

The process variable is the temperature measured at the outlet of the warm side of these heat exchangers, in the ACC primary cooling loop: NA.PS01.PJB34.TT020 (NA.PS01.PJB34.AC011) and NA. PJB34.PGB31.TT060 (NA.PS01.PJB34.AC022), respectively.

Control shall be done through a direct PID loop that shall continuously compare the process variable with the established set point. If this variable is lower than the set point, the valve will tend to close the valve, to reduce the water flowrate in the cold side of the heat exchanger, keeping the required temperature in the ACC primary cooling loop. Otherwise, the PID will tend to open the valve.

- Forcing conditions

These valves are forced to close in case high radiation level is detected in the cooling water by NA.PS01.PGB30.RT040/050, respectively, to isolate the defective heat exchanger.

9.4.1.7 Geothermal Cooling Subsystem NA.PS01.PCB30

The detailed design of this subsystem, including the definition of the main control loops, will be later defined by the geothermal subsystem technologist.

9.4.1.8 Chilled Water Subsystem NA.PS01.PGB20

9.4.1.8.1 Centrifugal Pumps with VFD (NA.PS01.PGB20.AP011/ AP012/ AP013)

The function of these pumps is to supply water to cool different consumers.

- Automatic Start
  - The pump starts automatically when the order to start is receive from the Selector NA.PS01.PGB20.EA110.
- Automatic Stop
  - The pump stops automatically when the order to stop is receive from the Selector NA.PS01.PGB20.EA110.
- Start Permissives
  - Discharge pressure transmitters available (NA.PS01.PGB20.PT111/PT112), and
  - Not low pressure at the pumps suction (NA.PS01.PGB20.PT040), and
  - Valves NA.PGB20.AA350 is open, and
  - Valves NA.PGB20.AA351 or NA.PGB20.AA355 are open
- Stop Permissive
  - The pumps are always permitted to stop.
- Trip conditions.
  - Not applicable.
- Forced stop
  - Not applicable.

The function of the pumps VFD shall be to ensure an appropriate centrifugal pumps pressure discharge by means of the pressure discharge (NA.PS01.PGB20.PT111/PT112)

Control shall be done through a reverse PID loop that shall continuously compare the process variable with the established set point. If this variable is greater than the set point, the VFD will tend to decrease the pumps velocity. Otherwise, the VFD will tend to increase the pump speed.

Only one controller (PID) shall be furnished for the centrifugal pumps, so that pumps started shall be always at same speed. It is not allowed to have pumps running at different speeds.

9.4.1.8.2 Softened Water make-up valve (NA.PS01.PGB20.AA201)

Despite the valve NA.PS01.PGB20.AA201 is a control valve, it is not going to regulate and this capacity will be used only to set the control valve to intermediate positions previously established depending on the percentage of propylene glycol make-up.

- Start Permissive
  - When the on-off valve NA.PS01.PGB20.AA251 is opened.
- Force to open
  - When the on-off valve NA.PS01.PGB20.AA251 is opened.
- Force to close
  - When the on-off valve NA.PS01.PGB20.AA251 is closed.

9.4.1.8.3 Minimun flow regulation with the Motor Operated Valve MOV NA.PS01.PGB20.AA301

- Control

The function of the valve shall be to ensure a minimum recirculation flow measured by the flow transmitter (NA.PS01.PGB20.FT010). The required minimum flow will be the set point of the PID loop.

The process variable is the flow measured by the flow transmitter (NA.PS01.PGB20.FT010).

Control shall be done through a direct PID loop that shall continuously compare the process variable with the established set point. If this variable is lower than the set point, the valve will tend to open to keep the minimum flow. Otherwise, the PID will tend to close the valve.

- Forcing conditions

A forced closing of the valve shall also be programmed whenever all the centrifugal pumps are stopped.

9.4.1.9 Adiabatic Cooling Subsystem – Low Temperature NA.PS01.PAB11

9.4.1.9.1 Centrifugal Pumps with VFD (NA.PS01.PAB11.AP011/ AP012/ AP013)

The function of these pumps is to supply water to cool different consumers.

- Automatic Start
  - The pump starts automatically when the order to start is receive from the Selector NA.PS01.PAB11.EA110.
- Automatic Stop
  - The pump stops automatically when the order to stop is receive from the Selector NA.PS01.PAB11.EA110.
- Start Permissives
  - Discharge pressure transmitters available (NA.PS01.PAB11.PT111/PT112), and
  - Not low pressure at the pumps suction (NA.PS01.PAB11.PT040).
- Stop Permissive
  - The pumps are always permitted to stop.
- Trip conditions.
  - Not applicable.

- Forced stop
    - Not applicable.

The function of the pumps VFD shall be to ensure an appropriate centrifugal pumps pressure discharge by means of the pressure discharge (NA.PS01.PAB11.PT111/PT112).

Control shall be done through a reverse PID loop that shall continuously compare the process variable with the established set point. If this variable is greater than the set point, the VFD will tend to decrease the pumps velocity. Otherwise, the VFD will tend to increase the pump speed. The set point will change depending on the flow transmitter NA.PS01.PAB11.FT010 that will dictate the number of adiabatic coolers that are needed.

Only one controller (PID) shall be furnished for the centrifugal pumps, so that pumps started shall be always at same speed. It is not allowed to have pumps running at different speeds.

9.4.1.9.2 Softened Water make-up valve (NA.PS01.PAB11.AA201)

Despite the valve NA.PS01.PAB11.AA201 is a control valve, it is not going to regulate and this capacity will be used only to set the control valve to intermediate positions previously established depending on the percentage of propylene glycol make-up.

- Start Permissive
    - When the on-off valve NA.PS01.PAB11.AA251 is opened.
- Force to open
    - When the on-off valve NA.PS01.PAB11.AA251 is opened.
- Force to close
    - When the on-off valve NA.PS01.PAB11.AA251 is closed.

9.4.1.9.3 Control Valves NA.PS01.PAB11.AA202/203

- Control

The function of the valve shall be to ensure the recirculation of flow not required by the consumers, maintaining a constant flowrate though the adiabatic coolers in operation. This flow is measured by the flow transmitter (NA.PS01.PAB11.FT010). The required minimum flow will be the set point of the PID loop.

The process variable is the flow measured by the flow transmitter (NA.PS01.PAB11.FT010).

Control shall be done through a direct PID loop that shall continuously compare the process variable with the established set point. If this variable is greater than the set point, the valve will tend to open to deviate the excess of flowrate. Otherwise, the PID will tend to close the valve.

- If the opening for the control valves NA.PS01.PAB11.AA202/203 is near to 100% (meaning that the consumers require less cooling water), an adiabatic cooler will be stopped by acting the on-off motor operated isolation valves MOV NA.PS01.PAB11.AA351/352/353/354/355/356:.
- On the contrary, if the demand for the control valves NA.PS01.PAB11.AA202/203 is near to 0% (meaning that the cooling water demand is increased), an additional adiabatic will be started one after other by acting the on-off motor operated isolation valves MOV NA.PS01.PAB11.AA351/352/353/354/355/356.

- Forcing conditions

A forced closing of the valve shall also be programmed whenever all the centrifugal pumps are stopped.

9.4.1.9.4 Motor Operated Valves NA.PS01.PAB11.AA306/307

- Control

The function of the valves shall be to ensure the regulation of the temperature at the outlet of the warm side of the heat exchangers NA.PS01.PGB30.AC021/AC022. These valves open and start to regulate when the temperature NA.PS01.PAB11.TT050 is high and will close when the temperature NA.PS01.PAB11.TT050 is no high.

The process variable is the temperature measured at the outlet of the warm side of the intermediate geothermal cooling loop heat exchangers: NA.PS01.PGB30.TT020 (NA.PS01.PGB30.AC021) and NA.PS01.PGB30.TT060 (NA.PS01.PGB30.AC022), respectively

Control shall be done through a direct PID loop that shall continuously compare the process variable with the established set point. If this variable is lower than the set point, the valve will tend to close the valve, to reduce the water flowrate in the cold side of the heat exchanger, keeping the required temperature in the warm side. Otherwise, the PID will tend to open the valve.

- Forcing conditions

A forced closing of the valve shall also be programmed whenever all the centrifugal pumps are stopped or when the temperature NA.PS01.PAB11.TT050 is no high.

9.4.1.9.5 Motor Operated Valves NA.PS01.PAB11.AA308

- Control

The function of the valve shall be to ensure a fixed flow through heat exchanger NA.PS01.PCB30AC020. This valve starts to regulate when the temperature NA.PS01.PAB11.TT050 is low and will close when the temperature NA.PS01.PAB11.TT050 is no low.

The process variable is the flow measured in the line.

Control shall be done through a direct PID loop that shall continuously compare the process variable with the established set point. If this variable is greater than the set point, the valve will tend to open to keep the required flow. Otherwise, the PID will tend to close the valve.

- Forcing conditions

A forced closing of the valve shall also be programmed whenever all the centrifugal pumps are stopped or when the temperature NA.PS01.PAB11.TT050 is no low.

9.4.1.9.6 Motor Operated Valves NA.PS01.PAB11.AA305

- Control

The function of the valve shall be to ensure the regulation of the temperature at the outlet of the warm side of the heat exchanger NA.PS01.PGB20.AC010. This valve start to regulate when the temperature NA.PS01.PAB11.TT050 is low low and will close when the temperature NA.PS01.PAB11.TT050 is no low low.

The process variable is the temperature measured at the outlet of the warm side of the free-cooling heat exchanger by NA.PS01.PGB20.TT020.

Control shall be done through a direct PID loop that shall continuously compare the process variable with the established set point. If this variable is lower than the set point, the valve will tend to close the valve, to reduce the water flowrate in the cold side of the heat exchanger, keeping the required temperature in the warm side. Otherwise, the PID will tend to open the valve.

- Forcing conditions

A forced closing of the valve shall also be programmed whenever all the centrifugal pumps are stopped or when the temperature NA.PS01.PAB11.TT050 is no low low.

9.4.1.9.7 Motor Operated Valves NA.PS01.PAB11.AA302/AA303/AA304

- Control

The function of these valves shall be to regulate the water flowrate through the chillers condenser to allow the start-up and normal operation of the chillers at low condenser temperatures. These valves will close when the temperature measured by NA.PS01.PGB20.TT030 is low.

The process variable is the temperature measured by the temperature transmitters NA.PS01.PGB20.TT070, NA.PS01.PGB20.TT080 and NA.PS01.PGB20.TT090 respectively, inside the chillers package plant supply.

The signal for controlling the water-regulating valve is an output from the chiller control system. The sensors in the chiller monitor the condenser pressure in each refrigeration circuit and the control algorithms vary the signal in response to the condensing pressure requirements.

As the condenser water temperature entering the chiller decreases, the chiller control sensors detect the reduction in the saturated condensing temperature. When the saturated condensing temperature reaches the minimum set point, the chiller control system varies the signal to the 2-way water regulating valve, causing the 2-way water regulating valve to close and reduce the flow of water through the condenser. The reduced water flow through the condenser results in higher delta T and the saturated condensing temperature stabilizes at the set point. As the entering condenser water temperature changes, the chiller controls will respond to the resulting change in the saturated condensing temperature and signal the 2-way water regulating valve to be repositioned to provide the correct water flow to allow the chiller to continue to operate properly.

- Forcing conditions

A forced closing of the valve shall also be programmed whenever all the centrifugal pumps are stopped or when the temperature measured by NA.PS01.PGB20.TT030 is low.

9.4.1.10 Adiabatic Cooling Subsystem – Medium Temperature NA.PS01.PAB12

9.4.1.10.1 Centrifugal Pumps with VFD (NA.PS01.PAB12.AP011/AP012/AP013)

The function of these pumps is to supply water to cool different consumers.

- Automatic Start
  - The pump starts automatically when the order to start is receive from the Selector NA.PS01.PAB12.EA110.
- Automatic Stop
  - The pump stops automatically when the order to stop is receive from the Selector NA.PS01.PAB12.EA110.
- Start Permissives
  - Discharge pressure transmitters available (NA.PS01.PAB12.PT111/PT112), and
  - Not low pressure at the pumps suction (NA.PS01.PAB12.PT040).
- Stop Permissive
  - The pumps are always permitted to stop.
- Trip conditions.
  - Not applicable.
- Forced stop
  - Not applicable.

The function of the pumps VFD shall be to ensure an appropriate centrifugal pumps pressure discharge by means of the pressure discharge (NA.PS01.PAB12.PT111/PT112).

Control shall be done through a reverse PID loop that shall continuously compare the process variable with the established set point. If this variable is greater than the set point, the VFD will tend to decrease the pumps velocity. Otherwise, the VFD will tend to increase the pump speed.

Only one controller (PID) shall be furnished for the centrifugal pumps, so that pumps started shall be always at same speed. It is not allowed to have pumps running at different speeds.

9.4.1.10.2 Softened Water make-up valve (NA.PS01.PAB12.AA201)

Despite the valve NA.PS01.PAB12.AA201 is a control valve, it is not going to regulate and this capacity will be used only to set the control valve to intermediate positions previously established depending on the percentage of propylene glycol make-up.

- Start Permissive
    - When the on-off valve NA.PS01.PAB12.AA251 is opened.
- Force to open
    - When the on-off valve NA.PS01.PAB12.AA251 is opened.
- Force to close
    - When the on-off valve NA.PS01.PAB12.AA251 is closed.

9.4.1.10.3 Minimun flow regulation with the Motor Operated Valve MOV NA.PS01.PAB12.AA202

- Control

The function of the valve shall be to ensure a minimum recirculation flow measured by the flow transmitter (NA.PS01.PAB12.FT010). The valve will start to regulate when the flow is low. The required minimum flow will be the set point of the PID loop.

The process variable is the flow measured by the flow transmitter (NA.PS01.PAB12.FT010).

Control shall be done through a direct PID loop that shall continuously compare the process variable with the established set point. If this variable is lower than the set point, the valve will tend to open to keep the minimum flow. Otherwise, the PID will tend to close the valve.

- Forcing conditions

A forced closing of the valve shall also be programmed whenever all the centrifugal pumps are stopped.

9.4.1.10.4 Motor Operated Valve MOV NA.PS01.PAB12.AA302/AA303

- Control

The function of these valves shall be to regulate the flowrate through the cryogenic facilities (NA.CP) at the different operating scenarios. The flow setting of these valves will be based on the operational regime, controlled by UBMS based on global operation (operational state of NA.CP cryogenic supply system).

The control of these valves is pending to be defined, based on information to be provided by NA.CP (by SCK CEN).

- Forcing conditions

Forcing conditions of these valves are pending to the defied, based on information to be provided by NA.CP (by SCK CEN).

The final control element is a motorised valve type, equipped with a positioner and a position transmitter, as well as, position limit switches.

9.4.1.11 Propylene Glycol Supply Subsystem NA.PS01.PUA10

Not applicable. There is no analogue control and regulation loop.

9.4.2 Logic Control and Protections

When the PS01 Cooling System is started up via its Functional Group (NA.PS01.P__.EA010) by the operator acting on the Conventional Control System HMI, the following actions will be carried out automatically:

- All drivers controlled by the functional group will be switched to automatic control mode.

In order to ensure that the functional group starts-up/stops only when it is able to fulfil their purpose, and to do it in a safe way for the equipment and for their dependent systems, the following start-up/stop permissives will be programmed:

- Start Permissives
  - PCO & SSA Cooling Loop Intake FSG NA.PS01.PGB31.EA010 is available.
  - Low Activated Injector Magnets Cooling Loop FSG NA.PS01.PJB31.EA010 is available.
  - Low Activated Injector NC-RF Cavities Cooling Loop FSG NA.PS01.PJB32.EA010 is available.
  - Low Activated Dump-I Cooling Loop FSG NA.PS01.PJB33.EA010 is available.
  - Low Activated SC LINAC/BTT Cooling Loop FSG NA.PS01.PJB34.EA010 is available.
  - Intermediate Geothermal Cooling Loop FSG NA.PS01.PGB30.EA010 is available.
  - Chilled Water Subsystem FSG NA.PS01.PGB20.EA010 is available.
  - Medium Temperature Adiabatic Cooling Subsystem FSG NA.PS01.PAB12.EA010 is available.
  - Low Temperature Adiabatic Cooling Subsystem FSG NA.PS01.PAB11 is available.
- Stop Permissive
  - Not applicable, the functional group shall always have the stop permissive.

The shutdown of the system through the functional group, by the operator acting on the Conventional Control System HMI, shall stop automatically all the pumps in operation.

All the drivers of the PS01 Cooling System will remain in automatic control mode unless express action by the operator.

9.4.2.1 PCO & SSA Cooling Loop NA.PS01.PGB31

9.4.2.1.1 PCO & SSA Cooling Loop FSG NA.PS01.PGB31.EA010

When the PCO & SSA Cooling Loop Subsystem is started up via its Functional Subgroup (NA.PS01.PGB31.EA010) by the operator acting on the Conventional Control System HMI or from a command coming from a higher hierarchical level (PS01 Cooling System FG (NA.PS01.P__.EA010)), the following actions will be carried out automatically:

- All drivers controlled by the Functional Subgroup (NA.PS01.PGB31.EA010) will be switched to automatic control mode.
- It will command the operation of the associated Centrifugal pumps (NA.PS01.PGB31.AP011/AP012/AP013) through a selector (NA.PS01.PGB31.EA110), so that it can manage the start-up and the stop of these pumps depending on the state of the system at any time.
- The Centrifugal Pumps Selector shall start-up the pump selected as main by operator on the Conventional Control System HMI. Once the Functional Subgroup (NA.PS01.PGB31.EA010) is started, the Selector shall start the pump previously selected as main.
- The Centrifugal Pumps Selector shall stop the pump running once the Functional Subgroup (NA.PS01.PGB31.EA010) is stopped.

In order to ensure that the Functional Subgroup starts-up only when it is able to fulfil their purpose, and to do it in a safe way for the equipment and for their dependent systems, the following start-up permissives will be programmed:

- Start Permissive
  - At least two Centrifugal Pump are available.
  - Not low level pressure in the system measured with by the pressure transmitter at the pumps suction NA.PS01.PGB31.PT040 (L).
- Stop Permissive
  - Not applicable. The Functional Subgroup shall always have the stop permissive.

The shutdown of the system through the Functional Subgroup, either by operator acting on the Conventional Control System HMI or from a command coming from a higher hierarchical level (PS01 Cooling System FG (NA.PS01.P__.EA010)), shall stop automatically the Centrifugal Pumps in operation.

All the drivers of the Functional Subgroup will remain in automatic control mode unless express action by the operator.

9.4.2.1.2 Centrifugal Pumps (NA.PS01.PGB31.AP011/ AP012/ AP013)

The function of these pumps is to supply water to cool different consumers.

- Automatic Start
  - The pump starts automatically when the order to start is receive from the Selector NA.PS01.PGB31.EA110.
- Automatic Stop
  - The pump stops automatically when the order to stop is receive from the Selector NA.PS01.PGB31.EA110.
- Start Permissive
  - Not low pressure in the system measured with NA.PS01.PGB31.PT040, (L).
- Stop Permissive
  - The pumps are always permitted to stop.
- Trip conditions.
  - Not applicable.
- Forced stop
  - Not applicable.

9.4.2.1.3 On-Off valve NA.PS01.PGB31.AA251

The function of this valve is to supply make-up demineralized water in the loop from the demineralized water storage tank (NA.PS02.GHC10.BB010).

- Automatic Open
  - The valve does not open automatically; its opening is only manual with the operator supervision.
- Automatic Close
  - The valve does not close automatically; its close is only manual with the operator supervision.
- Opening Permissive
  - When the on-off valve is NA.PS03.PGB31.AA252 is closed.
- Closing Permissive
  - The valve is always permitted to close.
- Forced Open
  - Not applicable.

9.4.2.1.4 On-Off valve NA.PS01.PGB31.AA252

The function of this valve is to supply make-up demineralized water in the loop from the demineralized wastewater storage tanks (NA.PS03.GMB60.BB011/012).

- Automatic Open
  - The valve does not open automatically; its opening is only manual with the operator supervision.
- Automatic Close
  - The valve does not close automatically; its close is only manual with the operator supervision.
- Opening Permissives
  - When the on-off valve is NA.PS03.PGB31.AA251 is closed.
- Closing Permissives
  - The valve is always permitted to close.
- Forced Open
  - Not applicable.

9.4.2.2 Low Activated Injector Magnets Cooling Loop NA.PS01.PJB31

The control of this subsystem is equivalent as the one described for the PCO & SSA Cooling Loop NA.PS01.PGB31. The control describe in Section 9.4.2.1 is valid changing PGB31 by PJB31.

9.4.2.3 Low Activated Injector NC-RF Cavities Cooling Loop NA.PS01.PJB32

The control of this subsystem is equivalent as the one described for the PCO & SSA Cooling Loop NA.PS01.PGB31. The control describe in Section 9.4.2.1 is valid changing PGB31 by PJB32.

9.4.2.4 Low Activated Dump-I Cooling Loop NA.PS01.PJB33

The control of this subsystem is equivalent as the one described for the PCO & SSA Cooling Loop NA.PS01.PGB31. The control describe in Section 9.4.2.1 is valid changing PGB31 by PJB33.

9.4.2.5 Low Activated SC LINAC/BTT Cooling Loop NA.PS01.PJB34

The control of this subsystem is equivalent as the one described for the PCO & SSA Cooling Loop NA.PS01.PGB31. The control describe in Section 9.4.2.1 is valid changing PGB31 by PJB34.

9.4.2.6 Intermediate Geothermal Cooling Loop NA.PS01.PGB30

The control of this subsystem is equivalent as the one described for the PCO & SSA Cooling Loop NA.PS01.PGB31. The control describe in Section 9.4.2.1 is valid changing PGB31 by PGB30, except for the following:

9.4.2.6.1 On-Off valve NA.PS01.PGB30.AA251

The function of this valve is to supply softened water to the loop from the Softened Water Storage Tank NA.PS02.GKC10.BB010.

- Automatic Open
  - The valve does not open automatically; its opening is only manual with the operator supervision.
- Automatic Close
  - The valve does not close automatically; its close is only manual with the operator supervision.

- Opening Permissives
    - The valve is always permitted to open.
- Closing Permissives
    - The valve is always permitted to close.
- Forced Open
    - Not applicable.

9.4.2.6.2 Motorised valve NA.PS01.PGB30.AA351

The control of this valve is the described hereafter:

- Automatic Open
    - The valve opens automatically when the temperature measured by NA.PS01.PAB11.TT050 is low, (L).
- Automatic Close
    - The valve closes automatically when the temperature measured by NA.PS01.PAB11.TT050 is high, (H).
- Opening Permissive
    - The valve is always permitted to open
- Closing Permissive
    - The valve is permitted to close when the valve NA.PS01.PGB30.AA352 is open.
- Forced Open
    - Not applicable.

9.4.2.6.3 Motorised valve NA.PS01.PGB30.AA352

The control of this valve is the described hereafter:

- Automatic Open
    - The valve opens automatically when the temperature measured by NA.PS01.PAB11.TT050 is high, (H).
- Automatic Close
    - The valve closes automatically when the temperature measured by NA.PS01.PAB11.TT050 is low, (L).
- Opening Permissive
    - The valve is always permitted to open.
- Closing Permissive
    - The valve is permitted to close when the valve NA.PS01.PGB30.AA351 is open.
- Forced Open
    - Not applicable.

9.4.2.7 Chilled Water Subsystem NA.PS01.PGB20

Chilled Water Subsystem FSG NA.PS01.PGB31.EA010

When the Chilled Water Subsystem is started up via its Functional Subgroup (NA.PS01.PGB20.EA010) by the operator acting on the Conventional Control System HMI or from a command coming from a higher hierarchical level (PS01 Cooling System FG (NA.PS01.P__.EA010)), the following actions will be carried out automatically:

- All drivers controlled by the Functional Subgroup (NA.PS01.PGB20.EA010) will be switched to automatic control mode.
- It will command the operation of the associated Centrifugal pumps (NA.PS01.PGB20.AP011/AP012/AP013) through a selector (NA.PS01.PGB20.EA110), so that it can manage the start-up and the stop of these pumps depending on the state of the system at any time.

- The Centrifugal Pumps Selector shall start-up the pump selected as main by operator on the Conventional Control System HMI. Once the Functional Subgroup (NA.PS01.PGB20.EA010) is started, the Selector shall start the pump previously selected as main.
- The Centrifugal Pumps Selector shall stop the pump running once the Functional Subgroup (NA.PS01.PGB20.EA010) is stopped.
- It will command the operation of the associated Chillers (NA.PS01.PGB20.AH011/AH012/AH013) through a selector (NA.PS01.PGB20.EA120), so that it can manage the start-up and the stop of these chillers depending on the state of the system at any time.
- The Chillers Selector shall start-up the pump selected as main by operator on the Conventional Control System HMI. Once the Functional Subgroup (NA.PS01.PGB20.EA010) is started, the Selector shall start the chillers previously selected as main.
- The Centrifugal Pumps Selector shall stop the chillers running once the Functional Subgroup (NA.PS01.PGB20.EA010) is stopped.

In order to ensure that the Functional Subgroup starts-up only when it is able to fulfil their purpose, and to do it in a safe way for the equipment and for their dependent systems, the following start-up permissives will be programmed:

- Start Permissive
    - At least two Centrifugal Pump are available.
    - Not low pressure in the system measured with by the pressure transmitter at the pumps suction NA.PS01.PGB31.PT040 (L).
    - Discharge pressure transmitters available (NA.PS01.PGB20.PT111/PT112), and
    - Valves NA.PGB20.AA350 is open, and
    - Valves NA.PGB20.AA351 or NA.PGB20.AA355 are open
    - At least two Chillers and their corresponding isolation valves are available.
    - The minimum flowrate bypass valve NA.PS01.PGB20.AA301 is available.
    - The flow meter NA.PS01.PGB20.FT010 is available.
- Stop Permissive
    - Not applicable. The Functional Subgroup shall always have the stop permissive.

The shutdown of the system through the Functional Subgroup, either by operator acting on the Conventional Control System HMI or from a command coming from a higher hierarchical level (PS01 Cooling System FG (NA.PS01.P__.EA010)), shall stop automatically the Centrifugal Pumps and Chillers in operation.

All the drivers of the Functional Subgroup will remain in automatic control mode unless express action by the operator.

9.4.2.7.1 On-Off valve NA.PS01.PGB20.AA251

The control of this valve is described hereafter:

- Automatic Open
    - The valve does not open automatically; its opening is only manual with the operator supervision.
- Automatic Close
    - The valve does not close automatically; its close is only manual with the operator supervision.
- Opening Permissive
    - The valve is permitted to open.
- Closing Permissive
    - The valve is always permitted to close.
- Forced Close
    - When the on-off valve NA.PS01.PGB20.AA201 is closed.

9.4.2.7.2 Motorised valve NA.PS01.PGB20.AA352/353/354

The control of these valves is the described hereafter:

- Automatic Open
  - The valve does open automatically when its corresponding chiller is running.
- Automatic Close
  - The valve does close automatically when its corresponding chiller is stopped.
- Opening Permissive
  - The valve is always permitted to open.
- Closing Permissive
  - The valve is always permitted to close.
- Forced Open
  - Not applicable.

9.4.2.7.3 On-Off Motorised valve NA.PS01.PGB20.AA351

The control of this valve is the described hereafter:

- Automatic Open
  - The valve opens automatically when the temperature measured by NA.PS01.PGB20.TT030 is no low.
- Automatic Close
  - The valve closed automatically when the temperature measured by NA.PS01.PGB20.TT030 is low, (L).
- Opening Permissive
  - The valve is always permitted to open.
- Closing Permissive
  - The valve is permitted to close when the valve NA.PS01.PGB30.AA355 is open.
- Forced Open
  - Not applicable.

9.4.2.7.4 On-Off Motorised valve NA.PS01.PGB20.AA355

The control of this valve is the described hereafter:

- Automatic Open
  - The valve opens automatically when the temperature measured by NA.PS01.PGB20.TT030 is low, (L).
- Automatic Close
  - The valve closed automatically when the temperature measured by NA.PS01.PGB20.TT030 is no low.
- Opening Permissive
  - The valve is always permitted to open.
- Closing Permissive
  - The valve is permitted to close when the valve NA.PS01.PGB30.AA351 is open.
- Forced Open
  - Not applicable.

9.4.2.7.5 Motorised valve NA.PS01.PGB20.AA356

The control of this valve is the described hereafter:

- Automatic Open
  - The valve opens automatically when the temperature measured by NA.PS01.PAB11.TT050 is low, (L).
- Automatic Close

- The valve closes automatically when the temperature measured by NA.PS01.PAB11.TT050 is no low.
- Opening Permissive
  - The valve is always permitted to open.
- Closing Permissive
  - The valve is permitted to close when the valve NA.PS01.PGB20.AA350 is open.
- Forced Open
  - Not applicable.

9.4.2.7.6 Motorised valve NA.PS01.PGB20.AA350

The control of this valve is the described hereafter:

- Automatic Open
  - The valve opens automatically when the temperature measured by NA.PS01.PAB11.TT050 is high, (H).
- Automatic Close
  - The valve closes automatically when the temperature measured by NA.PS01.PAB11.TT050 is low, (L).
- Opening Permissive
  - The valve is always permitted to open.
- Closing Permissive
  - The valve is permitted to close when the valve NA.PS01.PGB20.AA356 is open.
- Forced Open
  - Not applicable.

9.4.2.8 Adiabatic Cooling Subsystem – Low Temperature NA.PS01.PAB11

9.4.2.8.1 On-Off valve NA.PS01.PAB11.AA251

The control of this valve is the described hereafter:

- Automatic Open
  - The valve opens automatically when the control valve NA.PS01.PAB11.AA201 opens.
- Automatic Close
  - The valve closes automatically when the control valve NA.PS01.PAB11.AA201 closes.
- Opening Permissive
  - The valve is always permitted to open.
- Closing Permissive
  - The valve is always permitted to close.
- Forced Close
  - When the on-off valve NA.PS01.PAB11.AA201 is closed.

9.4.2.8.2 Motorised valves NA.PS01.PAB11.AA351/352/353/354/355/356

The control of these valves is the described hereafter:

- Automatic Open
  - The valves open automatically and sequentially when the opening percentage of the valves NA.PS01.PAB11.AA202/203 is lower than fixed set point. The valves will open one after other increasing the number of modules in operation depending on cooling water demand.
- Automatic Close
  - The valves close automatically and sequentially when the opening percentage of the valves NA.PS01.PAB11.AA202/203 is higher than a fixed set point. The valves will close one after other decreasing the number of modules in operation to adjust the cooling water demand.

- Opening Permissive
    - The valves are always permitted to close.
- Closing Permissive
    - The valves are always permitted to close.
- Forced Open
    - Not applicable.

9.4.2.8.3 Motorised valves NA.PS01.PAB11.AA357/358

The control of these valves is the described hereafter:

- Automatic Open
    - The valves open automatically when the temperature measured by NA.PS01.PAB11.TT050 is below or equal to high high, (HH).
- Automatic Close
    - The valves closes automatically when the temperature measured by NA.PS01.PAB11.TT050 is over high high, (HH).
- Opening Permissive
    - The valve is always permitted to open.
- Closing Permissive
    - The valve is always permitted to close.
- Forced Close
    - Not applicable.

9.4.2.9 Adiabatic Cooling Subsystem – Medium Temperature NA.PS01.PAB12

9.4.2.9.1 On-Off valve NA.PS01.PAB12.AA251

The control of this valve is the described hereafter:

- Automatic Open
    - The valve opens automatically when the control valve NA.PS01.PAB12.AA201 opens.
- Automatic Close
    - The valve closes automatically when the control valve NA.PS01.PAB12.AA201 closes.
- Opening Permissive
    - The valve is always permitted to open.
- Closing Permissive
    - The valve is always permitted to close.
- Forced Close
    - When the on-off valve NA.PS01.PAB12.AA201 is closed.

9.4.2.10 Propylene Glycol Supply Subsystem NA.PS01.PUA10

The Propylene Glycol Supply Subsystem (NA.PS01.PUA10) will be controlled by a dedicated local control panel provided by the package plant supplier as it is indicated in Section 9.3.1.8.

9.5 Sequence

The higher hierarchical level for the PS01 Cooling System FG is NA.PS01.P__10.EA010.

9.5.1 Start-up sequence

The operator will select the main pump to start on the Sector`s ((NA.PS01.PGB31.EA110, NA.PS01.PJB31.EA110, NA.PS01.PJB32.EA110, NA.PS01.PJB33.EA110, NA.PS01.PJB34.EA110, NA.PS01.PGB30.EA110, NA.PS01.PGB20.EA110, NA.PS01.PAB12.EA110, NA.PS01.PAB11.EA110) faceplate.

The Functional Group (NA.PS01.P__10.EA001) will be switched to automatic control mode by operator acting on the FG faceplate on the Conventional Control System HMI and all the FSG (NA.PS01.PGB31.EA010, NA.PS01.PJB31.EA010, NA.PS01.PJB32.EA010, NA.PS01.PJB33.EA010, NA.PS01.PJB34.EA010, NA.PS01.PGB30.EA010, NA.PS01.PGB20.EA010, NA.PS01.PAB12.EA010, NA.PS01.PAB11.EA010) along with their dependent equipment will be in auto mode too.

The PS01 Cooling System will be ready to regulate itself in automatic mode. The pumps start when their control loops required to them to start.

9.5.2 Shutdown sequence

The operator by acting on the Functional Group (NA.PS01.P__10.EA010) faceplate' stop button on the Conventional Control System HMI, will stop automatically all the pumps in operation.

All the drivers of the PS01 Cooling System will remain in automatic control mode unless express action by the operator.

9.6 Alarms

Hereafter are listed the PS01 Cooling System alarms due to the process, however, the whole alarm´s list with all details related to the alarms as tag-name, description, priority will be presented in the Alarm List document (=NA.CN_EPB502, Ref.[15]). A few of the below alarms will be pre-alarms of the abnormal operation indicated in section 9.3.2.

- Low pressure in the discharge of the centrifugal pumps (NA.PS01.PGB31.PT110) (L).
- High pressure in the discharge of the centrifugal pumps (NA.PS01.PGB31.PT110) (H).
- Bad quality pressure in the discharge of the centrifugal pumps (NA.PS01.PGB31.PT110).
- Low temperature in the discharge of the centrifugal pumps (NA.PS01.PGB31.TT050) (L).
- High temperature in the discharge of the centrifugal pumps (NA.PS01.PGB31.TT050) (H).
- Bad quality temperature in the discharge of the centrifugal pumps (NA.PS01.PGB31.TT050).
- Low pressure in the suction of the centrifugal pumps (NA.PS01.PGB31.PT040) (L).
- High pressure in the suction of the centrifugal pumps (NA.PS01.PGB31.PT040) (H).
- Bad quality pressure in the suction of the centrifugal pumps (NA.PS01.PGB31.PT040)
- Low temperature in the suction of the centrifugal pumps (NA.PS01.PGB31.TT040) (L).
- High temperature in the suction of the centrifugal pumps (NA.PS01.PGB31.TT040) (H).
- Bad quality temperature in the suction of the centrifugal pumps (NA.PS01.PGB31.TT040).
- Centrifugal pump (NA.PS01.PGB31.AP011) tripped.
- Centrifugal pump (NA.PS01.PGB31.AP011) not available.
- Centrifugal pump (NA.PS01.PGB31.AP012) tripped.
- Centrifugal pump (NA.PS01.PGB31.AP012) not available.
- Centrifugal pump (NA.PS01.PGB31.AP013) tripped.
- Centrifugal pump (NA.PS01.PGB31.AP013) not available.
- No operational availability of Purification System, NA.PS01.PGB31.AW010

- No fault of Purification System, NA.PS01.PGB31.AW010

(Note: The alarms above are applicable for the NA.PS01.PAB11, NA.PS01.PGB20, NA.PS01.PGB30, NA.PS01.PJB31, NA.PS01.PJB32, NA.PS01.PJB33, NA.PS01.PJB34 is valid changing PGB31 in the above systems by PAB11, PGB20, PGB30, PJB31, PJB32, PJB33, PJB34, PGB30, as well as, other alarms specific for each system that will be completed in the Alarm List document (=NA.CN_EPB502, Ref.[15]).

- No operational availability of Propylene Glycol Supply, NA.PS01.PUA10
- No fault of Propylene Glycol Supply, NA.PS01.PUA10
- No operational availability of Geothermal Cooling Subsystem, NA.PS01.PCB30
- No fault of Geothermal Cooling Subsystem, NA.PS01.PCB30
- No operational availability of chillers, NA.PS01.PGB20.AH011/AH012/AH013
- No fault of chillers, NA.PS01.PGB20.AH011/AH012/AH013
- No operational availability of adiabatic coolers, NA.PS01.PAB11.AH011/ AH012/ AH013/ AH014/ AH015/ AH016
- No fault of adiabatic coolers, NA.PS01.PAB11.AH011/AH012/AH013/AH014/AH015/AH016
- No operational availability of adiabatic coolers, NA.PS01.PAB12.AH011/AH012
- No fault of adiabatic coolers, NA.PS01.PAB12.AH011/AH012

References

[1] Project Execution Plan (MINERVA/4AV/0693237/000/00)

[2] Abbreviations, Glossary and Symbols (SCK·CEN\8905079)

[1] Applicable Codes and Standards (MINERVA/4NT/0691961/000/00)

[2] Process Systems, Equipment and Piping Design Criteria (=NA.PS_PDB501- 092-423-R-M-00400))

[3] Requirements Allocation Sheet (=NA.AC_BEB502 - MINERVA_4NT_701812_000_00)

[4] Feasibility study regarding geothermal cooling for MINERVA project at SCK CEN in Mol (IE16-FS01-201222), issue 8 (22/09/2022).

[5] Masterplan Layout (=NA.PM_CTA501)

[6] PS01 Cooling Systems P&ID (=NA.PS01_PFB503 - 092-423-DT-M-12300)

[7] PS01 Cooling Systems PFD (=NA.PS01_PFB502 - 092-423-DP-M-12300-B)

[8] PS01 Cooling Systems Sizing, Design and Capacity Calculations (=NA.PS01_PDD501 - 092-423-F-M-12300)

[9] MINERVA – General ALARA checklist and review (=MNRV_AQN002 - SCK CEN/38700667)

[10] Design Justification and Substantiation Report (=NA.AC_BDD502 - MINERVA/4NT/0694079/000/01)

[11] Not used.

[12] MINERVA ACC NF Fluid List (=NA.AA_BPB503)

[13] MINERVA ACC NF Terminal Point List (=NA.AA_BPB501)

[14] MINERVA ACC NF SCC List (=NA.AA_BPB502)

[15] Alarm list document (=NA.CN_EPB502)

[16] UBMS Control Interface Principle (=NA.CN_EDB502)

[17] Control basic diagram PS01 Cooling Systems (=NA.CN_EDB510 - 092-423-D-I-12200)

[18] Line List (=NA.PS_PPB501 - 092-423-LE-M-40400)

[19] Nuclear HVAC system requirements (=NA.HV_MEC502)

[20] Conventional and Industrial HVAC system requirements (=NA.HV_MEC501)

[21] Building Layout AUB (=NA.BA03_CTA501, march 2023)

[22] Building Layout MCB (=NA.BA01_CTA501, march 2023)

[23] SCADA HMI Guideline (=NA.CN_EDB503 – 092-423-R-I-00900)