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| System definition – REQUIREMENTS  Target Helium Cooling systems |
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|  | Name | Title |
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# Introduction

## Objective of this document

The main goal of this document is to define basic functions and all requirements for **Target Helium Cooling** consisting of 3 sub-systems;

* Target Primary Cooling, 1010
* Target Primary Cooling Pressure Control, 1011
* Helium Injection, 1013

## Scope of this document

To achieve the objective of this document the following topics are covered:

* Purpose and scope of the systems
* Stakeholders
* System interfaces to surroundings
* Safety functions with focus on radiation impact on people and environment
* Basic functions briefly described (details in SDD-sol)
* Requirements
* Functional simulations and analyses

## Purpose and Scope of the systems

### Purposes

1. Keep the target wheel at an acceptable temperature
2. Send excess heat to intermediate systems for usage

### Scope and basic functions

Main functions:

1. Continuous heat removal from the target including pressure control (1010, 1011)
2. Keeping the potentially activated / contaminated fluid enclosed in the system(all)

Sub functions:

1. Collecting potentially radiated particles in a few locations, i.e. filters (system 1010)
2. Maintain particle content in the circuit at an acceptable level (system 1010)
3. Inject and/or collect helium to the rotational sealing in system Target wheel, shaft, bearings & drive (System 1013)
4. Enable filling, emptying, storage and removal of O2, H2O, CO2 etc. (systems 1012, 1011, Pristine Helium)

### Functional Model Analysis of the system

Refer to document [1] SDD-Sol Target Helium Cooling Systems

# System context and functions

## Stakeholders

Note that ESS owners, instrument operators and instrument users, ESS engineering team outside target station, the local community, European partners within ESS collaboration, suppliers, long term disposal facility and Swedish authorities are not included here. They are instead defined as stakeholders to the top level project. In this context stakeholders are limited to:

Target Station operators

Target helium cooling systems maintenance personnel

Waste management personnel

Radioprotection team

Work unit leader for WBS12.2.4 (Target helium cooling system)

Work package leader for WBS12.2 (Target systems)

Work package leader for WBS12.4 (Monolith system)

Work package leader for WBS12.5 (Fluid systems)

Work package leaders for WBS12.7 (Process Controls)

Work package leaders for WBS12.8 (Physics)

## Interfaces

### Environment Interaction Diagram

|  |
| --- |
|  |

Figure 1: Interaction diagram

## Operational functions

Brief orientation of how the systems work is described below.

How the functions are realized is described in document SDD-sol [1], i.e. Mechanical design, Process control functionality, Modes of operation etc.

### Target primary cooling, system 1010

The helium flow enters and leaves the target wheel via the top of the shaft and the heat is removed from the system by heat exchangers connected to the target intermediate cooling circuit. The picture below shows the major components in the primary cooling circuit. On the bottom right is the connection to Target Primary Cooling Pressure control, **1011**. During operation, helium flow is driven by the blowers and the pressure in the circuit is controlled by the **System 1011**.

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|  |

Figure 2 Flow diagram primary cooling circuit

### Part systems 1011 and 1013

System **1011** is actively controlling the pressure in system 1010 using a compressor/blower, storage volume, buffer tank and a connection to pristine helium supply. This system stores excessive helium when 1010 is drained, and stores helium temporarily during normal operation.

System **1013** is a support system for the target wheel rotational sealing, i.e. to enable controlled helium seal flows.

Note that system **1140** is taking care of helium in case the pressure in any part of the system exceeds rupture disc release pressure, and that this system is a part of the common gas system of the target station.

## Radiation safety functions

Refer to document SDD-sol [1]

# requirements

Requirements are defined within one of the 3 main groups:

* Requirements from top level (section 3.1)
* Requirements from system with interface to this system (section 3.2)
* Requirements within this system (section 3.3)

Requirements are labelled according to following principles:

- String: **System-SNN**.

Example: 1010-001 where the system part is the system abbreviation.

- The **System abbreviation** reflects the origin of the requirement

Example: Wheel-001, where the requirement is imposed by system “wheel” and put on another system. This means it is always easy to understand where a requirement comes from.

- **S** is used to divide the number series into groups

Examples: 1010-001, 1010-101 where 0 and 1 is used for Top level requirements. 1010-301 where 3 is used for requirements regarding process control.

- **NN** is pure serial number within the S-group

## Requirements from ESS top level and authorities

### Applicable regulations, codes and standards

The system shall follow a set of quality standards as discussed in [4]; Establishment of Technical and Quality Regulations for ESS, also refer to [14].

Requirements for the design, fabrication, assembly and testing

Detailed accident analyses for ESS systems remain to be performed, so final specification of measures required for safety are yet to be finalized. The current basis for design and fabrication of the Target Helium Cooling System is that the *cooling* is not a safety function, but the *mechanical integrity* of the system is assumed to be a safety function (SaF). To ensure that we provide the required mechanical integrity, the IKC partner must follow the RCC-MRx Class 3 requirements in designing, fabricating, assembling, and testing this system. RCC-MRx Class 3 can be fulfilled by compliance with the usual PED standards EN 13445 and 13480 plus some additions, which are given in the RCC-MRx code. See also the comparison in ESS-0037516. Any additional third party review and inspections beyond those required in RCC-MRx that may be imposed by the Swedish regulator (SSM) will be coordinated and paid by ESS AB, i.e. the IKC partner is only responsible for meeting the documentation, review, and inspection requirements specified in RCC-MRx (Class 3), working with ESS AB to facilitate the additional SSM-required reviews and inspections, and providing allowances in the schedule for such activities. Refer to requirement 1010-157.

Should these requirements change, the ESS change control process will be used to evaluate the cost and schedule implications. Adjustments to delivery dates and budget will be negotiated with the IKC partner and implemented into a revised baseline. The change control process, including the IKC partner’s role, is described in the Target Baseline Management Process document (ESS-0016499).

### General requirements related to the Target Station applicable for the system

| ID | **1010-001** | **Reliability** |
| --- | --- | --- |
| **Requirement** | The target helium cooling system components shall have a reliability according to normal industry standard | |
| **Rationale/Reference** | Since the plan is to install 2 helium circulators in parallel and the reliability for ESS is defined to be the probability of delivering without failure at least 50% of scheduled neutrons over a period of one hour. This means the operation of one circulator is enough to deliver neutrons without failure. Also refer to [5]  If a severe failure in any component, except the circulators, within the systems during operation, the basic cooling functionality is not affected until several hours or even days has passed without correction. | |

| ID | **ICS-001** | **Communication bus** |
| --- | --- | --- |
| **Requirement** | The communication bus system to use is Modbus to/from the system | |
| **Rationale/Reference** | To avoid multiple bus types | |

| ID | **ESSM-100** | **Target cooling system Operational mode behaviour relative ESS Operational mode** |
| --- | --- | --- |
| **Requirement** | The Target cooling system must at any situation be in it’s in *proper operational mode* relative to ESS/Target station operational mode.  The Target cooling system must report to superior systems if expected operational mode or functionality is *not fulfilled*.  The Target cooling system must report to superior systems when expected operational mode or functionality *is started and fulfilled*. | |
| **Rationale/Reference** | To secure cooling functionality when ESS/Target station requires it. To secure that the failure - and confirmation information to superior systems are available. | |

Note that requirements regarding monitoring and report the radiation activity outside the target helium cooling system is a part of ES&H / PSS.

### Design requirements related to SAR

Refer to [26]

### Design requirements related to the GSO

Refer to [25]

### Requirements related to fire protection

Refer to [17]

### Requirements related to global management of radioactive waste

Foreseen waste is irradiated particles from filters during maintenance stops refer to [18]. Foreseen waste is irradiated steel when decommissioning [22].

### Summary table of general parameters

Refer to [1]

## Requirements related to systems with interface to this system

### Target safety system, TSS

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| TSSP-101 | Pipe flanges for TSS safety classified instruments target inlet | [10] |
| TSSP-102 | Pipe flanges for TSS safety classified instruments target outlet | [10] |

Requirements imposed on system 1010 by TSS

### Target wheel, system 1000

The tables below summarises the requirements between the 2 systems.

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| 1010-200 | Order signal variable to set a fixed cooling helium flow | [3] |

Signal interface from system 1000 to 1010

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| 1010-201 | Pipe flange with flow to target | [3] |
| 1010-202 | Pipe flange with flow from target | [3] |
| 1010-203 | Pipe flange with seal flow to/from target | [3] |

Physical connection interfaces

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| 1010-204 | Maximum amount of particles formed in the target during 1 year of operation | [3] |
| 1010-205 | Maximum pressure drop between inlet- and outlet flanges at max. normal flow | [3] |

Requirements imposed on system 1000 by 1010

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| 1000-200 | Heat removal power from the target wheel | [3] |
| 1000-201 | Cooling media (Helium) | [3] |
| 1000-202 | Cooling media maximum normal flow | [3] |
| 1000-203 | Cooling media temperature values; max inlet, min inlet, max outlet | [3] |
| 1000-204 | Maximum operational pressure  - Maximum operational pressure  - Maximum operational pressure | [3] |
| 1000-205 | Minimum operational pressure  - Maximum operational pressure  - Maximum operational pressure | [3] |
| 1000-206 | Pipe connections adapted for plug removal | [3] |
| 1000-207 | Seal gas mass flow | [3] |
| 1000-208 | Seal gas maximum temperature | [3] |
| 1000-209 | Cooling media concentration of solid particulates | [3] |
| 1000-210 | Cooling media concentration of oil particulates | [3] |

General process requirements imposed on system 1010 by system 1000

### Target helium purification (within Fluid systems, FS)

The tables below summarises the requirements between the 2 systems

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| 1000-801 | Cooling media oxygen maximum concentration | [2] |
| 1000-802 | Cooling media carbon dioxide maximum concentration | [2] |
| 1000-803 | Cooling media water maximum concentration | [2] |
| 1000-804 | Cooling media particulates concentration | [2] |
| 1000-805 | Purification system Availability (requirement from system 1000) | [2] |
| 1000-806 | Purification system capacity at start-up | [2] |

Interface requirements imposed on system 1010 (and Target helium purification) by the wheel

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| 1010-701 | Hydrogen maximum concentration (H2 + HT + T2) | [2] |
| 1010-702 | Iodine maximum concentration (I2) | [2] |
| 1010-703 | Tritiated water maximum concentration (H2O + HTO + T2O) | [2] |
| 1010-704 | Particulates maximum concentration (adsorbed radioactive nuclides) | [2] |
| 1010-705 | Total impurity maximum concentration | [2] |
| 1010-706 | Purification system Availability (requirement from 1010) | [2] |
| 1010-707 | Purification system capacity after downtime | [2] |
| 1010-708 | Operational Temperature range | [2] |
| 1010-709 | Operational Pressure range | [2] |
| 1010-710 | Operational purification maximum flow | [2] |

Interface requirements imposed on Target helium purification by 1010

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| 1015-201 | Maximum amount of tritium released per time unit | [2] |
| 1015-202 | Maximum amount of iodine released per time unit | [2] |
| 1015-203 | Particulates max. concentration to avoid clogging of the HEPA filter | [2] |
| 1015-204 | Residual air max. concentration (e.g. at start-up or disturbance) | [2] |
| 1015-205 | Max. leakage to surroundings (dimensional req. from Helium purification) | [2] |
| 1015-206 | Physical connection | [2] |

Interface requirements imposed on 1000 (and 1010) by Target helium purification

### Target Intermediate cooling system (within Fluid systems, FS)

The tables below summarises the requirements between the 2 systems.

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| 1010-400 | Target intermediate cooling system status | [8] |
| 1010-401 | Temperature in the return water from heat exchanger #1 | [8] |
| 1010-402 | Water flow control set point, heat exchanger #1 | [8] |
| 1010-403 | Water flow control set point, heat exchanger #2 | [8] |
| 1010-404 | Water flow control set point, heat exchanger #3 | [8] |

Signal interfaces

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| 1010-451 | Pipe flange dimension, material, inlet temp, pressure and normal flow HX#1 | [8] |
| 1010-452 | Pipe flange dimension, material, outlet temp, pressure and normal flow HX#1 | [8] |
| 1010-453 | Pipe flange dimension, material, inlet temp, pressure and normal flow HX#2 | [8] |
| 1010-454 | Pipe flange dimension, material, outlet temp, pressure and normal flow HX#2 | [8] |
| 1010-455 | Pipe flange dimension, material, inlet temp, pressure and normal flow HX#3 | [8] |
| 1010-456 | Pipe flange dimension, material, outlet temp, pressure and normal flow HX#3 | [8] |
| 1010-457 | Transferred normal maximum heat power, heat exchanger #1 | [8] |
| 1010-458 | Transferred normal maximum heat power, heat exchanger #2 | [8] |
| 1010-459 | Transferred normal maximum heat power, heat exchanger #3 | [8] |

Water flanges

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| 1046-100 | Heat exchangers barrier resistance to tritium diffusion | [8] |

Process parameters

### Requirements related to Process control/MPS

The tables below summarises the interface requirements between the 2 systems.

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| [9], APPENDIX 1 | Object signal interfaces including mode of operation signals | [9] |
| MPS-201, APPENDIX 1 | Object signal interfaces; Machine protection process values. A set of machine protection process values defined shall be available for the MPS system. | [9] |

Signal interfaces

Note that if the control system as a unit is later considered as an integrated part of the target helium cooling systems, only signal interfaces to the EPICS application is needed, thus APPENDIX 1 will be simplified, and requirements describing control loops will be a system internal requirement, e.g. 1010-303, --307.

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| 1010-301 | GUI main process picture content for Target helium cooling | [9] |
| 1010-302 | GUI detailed process pictures content for all sub systems | [9] |
| 1010-303 | Pressure control of the primary cooling loop | [9] |
| 1010-304 | Temperature control of the helium leaving heat exchanger W03 | [9] |
| 1010-305 | Temperature control of the helium leaving heat exchanger W02 | [9] |
| 1010-306 | Temperature control of the return water from heat exchanger W01 | [9] |
| 1010-307 | Perform calculations according to blocks in P&ID’s | [9] |
| 1010-308 | Show process values on process screens according to Appendix in [9] | [9] |
| 1010-309 | Enter and send set points from process screens according to Appendix in [9] | [9] |
| 1010-310 | Send order signals from process screens according to Appendix in [9] | [9] |
| 1013-301 | Pressure control of the buffer tank in the Helium Injection system | [9] |

Functional requirements imposed on Process control system by Target helium cooling

### Requirements to/from Building and CF

The tables below summarises the requirements between the 2 systems.

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference document** |
| 1010-551 | Electric power; Switchgear total power | [6] |
| 1010-552 | Electric power; Sockets total power for tools | [6] |
| 1010-553 | Lighting; total luminosity and allocation | [6] |
| 1010-554 | Protective earth connections, total number and capacity | [6] |
| 1010-555 | Back-up power supply capacity for control system parts | [6] |

Electric power, signal and control system interfaces between Target helium cooling and CF

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference document** |
| 1010-501 | Space requirements room 2, level 110 | [6] |
| 1010-502 | Space requirements room 4, level 110 | [6] |
| 1010-503 | Roof hatch size between rooms 2 and 5 | [6] |
| 1010-504 | Door size, location and orientation rooms 2 & 4, level 110 | [6] |
| 1010-505 | Door size, location and orientation rooms 2 & 6, level 110 | [6] |
| 1010-506 | Space requirements room2, level 100 | [6] |
| 1010-509 | Floor openings for pipes between level 100 and 110 | [6] |
| 1010-510 | Wall and floor openings for process pipes and electric installations | [6] |

Building Interfaces between Target helium cooling and CF

### Ventilation system for activated gases (HVAC)

The table below summarises the requirements between the 2 systems. The reference document handles all requirements for the target station utility rooms as a unit.

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference document** |
| 1010-601 | Ventilation capacity during normal operation | [20] |
| 1010-602 | Ventilation capacity and ventilation hoods during maintenance | [20] |
| 1010-603 | Ventilation capacity to handle ODH | [20] |

Interface requirements imposed on HVAC system by Target helium cooling systems

### Fluids supply & process (within Fluid systems, FS)

The table below summarises the requirements between the 2 systems.

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference document** |
| 1010-901 | Pristine Helium supply pressure, flow, purity etc. | [24] |
| 1010-902 | Nitrogen supply pressure, flow, purity etc. | [24] |
| 1010-903 | Pristine Helium consumption, i.e. total weight required / year | [24] |

Interface requirements imposed on HVAC system by Target helium cooling systems

## Requirements within this system

### Safety related requirements

This section is about both radiation, pressure and general personnel safety.

| ID | **1010-002** | **Circuit shut-off valves** |
| --- | --- | --- |
| **Requirement** | Possibility to shut off the circuit from the target wheel rotary sealing unit | |
| **Rationale/Reference** | Valves are closed during maintenance of either or both the wheel drive and shaft, and the system 1010 circuit to isolate the 2 systems from each other. | |

| ID | **1010-003** | **Radiation limit to people** |
| --- | --- | --- |
| **Requirement** | Adequately radiation shielding of components that are subject to maintenance and/or inspection | |
| **Rationale/Reference** | Radiological requirements are described in two documents [7] and [11]. These requirements set limits on the dose rates from components to people. | |

| ID | **1010-004** | **Heat exchangers barrier strength** |
| --- | --- | --- |
| **Requirement** | The heat exchangers must have strong enough barrier structure to handle thermal movements from temperatures between 20°C and 300°C, at pressure difference between primary and secondary side based on design pressure is 13 bar | |
| **Rationale/Reference** | Basic pressure vessel requirements. The system design pressure of system 1010 is 13 bar and the test pressure is 1.57MPa [15]. Do not confuse with requirement 1046-100 “Heat exchangers barrier resistance to tritium diffusion | |

| ID | **1010-101** | **Enclosure of helium** |
| --- | --- | --- |
| **Requirement** | The potentially activated / contaminated helium gas shall be kept enclosed at all timesexcept for accepted leakage rates | |
| **Rationale/Reference** | To satisfy environmental release limits and release limits to workers. Helium is not to be released during maintenance. | |

| ID | **1010-102** | **Maximum leakage of helium** |
| --- | --- | --- |
| **Requirement** | Maximum total leakage rate of helium from all Target helium cooling systems is 1 g/h at operational pressure, helium purification system excluded. | |
| **Rationale/Reference** | To satisfy environmental release limits and release limits to workers. Also refer to [1] | |

| ID | **1010-103** | **Report radiation levels in systems** |
| --- | --- | --- |
| **Requirement** | Monitor and report the radiation activity contained in the systems | |
| **Rationale/Reference** | To enable radiation information functions, i.e. data logging. Note that this monitoring function is not radiation safety classified. TSS will probably have classified measuring devices. | |

| ID | **1010-104** | **Purging with clean helium** |
| --- | --- | --- |
| **Requirement** | All sub systems must be possible to fill with clean helium from a stand-alone volume | |
| **Rationale/Reference** | To enable manual purging of each system to remove e.g. remaining cleaning fluids, also refer to [1], section “Maintenance and handling solutions” | |

| ID | **1010-105** | **Pipe support structure** |
| --- | --- | --- |
| **Requirement** | The pipe system must have stable enough support structure to handle thermal movements from temperatures at 0°C to 300°C | |
| **Rationale/Reference** | To fulfil pressure safety functions, basic functions and reliability | |

### Neutronics requirements

N/A

### Internal system requirements

Helium in a closed cooling loop is the chosen basic principle for system 1010 to remove heat from the target wheel. Based on this solution the following requirements are identified;

| ID | **1010-150** | **Design pressure of the primary cooling circuit** |
| --- | --- | --- |
| **Requirement** | Maximum design pressure of primary cooling circuit system 1.3MPa (13 bar) | |
| **Rationale/Reference** | Based on engineering judgment by the target division [15] | |

| ID | **1010-151** | **Helium maximum inlet temperature** |
| --- | --- | --- |
| **Requirement** | Helium maximum inlet temperature 60°C | |
| **Rationale/Reference** | To fulfil machine protection and basic functions. Based on engineering judgment by the target division, i.e. to avoid higher temperature than approximately 270°C on the outlet from the target shaft. | |

| ID | **1010-152** | **Additional continuous heat removal** |
| --- | --- | --- |
| **Requirement** | Additional continuous heat removal of minimum 0.4 MW | |
| **Rationale/Reference** | Based on the foreseen additional heat to the helium circuit from the circulator and the decay heat of approximately 40kW during 3h and then declining. The total value may be reduced based on selection of circulator. Based on adiabatic compression heat from 8.8 bar to 10 bar at 40C. | |

| ID | **1010-153** | **Monitoring content of O2, C, H2O** |
| --- | --- | --- |
| **Requirement** | Monitor and report the content of O2, C (Σ carbon compounds) and H2O in the helium gas contained in the system | |
| **Rationale/Reference** | To fulfil radiation protection, basic functions and availability requirements | |

| ID | **1010-154** | **Monitoring machine protection data** |
| --- | --- | --- |
| **Requirement** | Enable monitor and report general machine protection information to MPS | |
| **Rationale/Reference** | To fulfil availability requirements. Refer to [9] | |

| ID | **1010-155** | **Filter operation period and efficiency** |
| --- | --- | --- |
| **Requirement** | Filters shall be designed for normal operation during 5400 h and will be designed to be exchanged during normal outages.  The filters are expected to:   * Capture up to 0.10 kg/5400h of solid particulates released from mainly the W blocks * Capture up to 2.5 kg/5400h of oil particulates released from other components within the target primary cooling loop * Keep the concentration of Particulates below values stated in requirements 1000-209 and 1000-210, see [3] | |
| **Rationale/Reference** | To fulfil basic functions and reliability, i.e. to avoid clogging of filters before a planned maintenance period.  The amount of oil particulates is based on the oil release from a standard industrial blower of 0.5 g/h.  The radiological impact from oil particulates in the loop or on the surface of W blocks is negligible but oil particulates is considered to have a similar effect as metallic particles, i.e. risk of mechanical clogging of filters and other narrow passages.  **I PROPOSE THAT WE KEEP ALL REQUIREMENTS HERE UNTIL THE FINAL CIRCULATOR IS DECIDED** | |

| ID | **1010-156** | **Filter pressure drop monitoring** |
| --- | --- | --- |
| **Requirement** | Pressure drop over filters shall be monitored | |
| **Rationale/Reference** | To fulfil availability requirements and basic functions | |

| ID | **1010-157** | **Radiation safety class** |
| --- | --- | --- |
| **Requirement** | The Target Helium Cooling Systems, shall be quality classified according to code RCC-MRx class 3, i.e. essentially following the Pressure Equipment Directive, PED, Norms EN-13445 and EN-13480, and additional requirements listed in RCC-MRx to fulfil radiation safety requirements. | |
| **Rationale/Reference** | Includes systems 1010, 1011 and 1013. Since the radiation dose to people in the utility rooms in case of helium release or particle accumulation/and/or release is high, only PED does not fulfil the quality class according to RCC-MRx where safety functions in Class 3 is stated: *“For the mechanical quality class with basic radiological safety functions, Applicable for components in safety class 3 (SC 3), the choice is Code Class N3Rx. In RCC-MRx, that level can be fulfilled by using PED codes, plus special extra conditions as listed in N3Rx”* | |

| ID | **1010-158** | **Pipe design** |
| --- | --- | --- |
| **Requirement** | Potential radiological hot-spots in pipes shall be minimized | |
| **Rationale/Reference** | To fulfil radiation protection and availability requirements | |

| ID | **1010-159** | **Valve seal type** |
| --- | --- | --- |
| **Requirement** | Valves shall be of seal-less types, i.e. bellows | |
| **Rationale/Reference** | To enable highest possible leak tightness | |

| ID | **1010-160** | **Maximum pressure drop in 1010** |
| --- | --- | --- |
| **Requirement** | Maximum pressure drop 60 kPa in the cooling circuit between inlet and outlet flanges to/from target at maximum normal flow | |
| **Rationale/Reference** | The total pressure drop must be kept as low as possible to minimize the cost for the system 1010 circulator and minimize heat generation.  Pressure drop calculations shows that the loop (pipes, valves, filters and heat exchangers) excluding the target 1000 may be possible to design for 0.56 bar according to [13] at normal helium flow 3.0 kg/s. 1010-205 states the maximum total pressure drop over *Target wheel, drive & shaft* system. | |

| ID | **1010-161** | **Helium flow control** |
| --- | --- | --- |
| **Requirement** | Continuous flow control of helium in the system 1010 circuit | |
| **Rationale/Reference** | To fulfil basic functions | |

| ID | **1011-101** | **Max pressure in the buffer tank** |
| --- | --- | --- |
| **Requirement** | Helium maximum design pressure in the buffer tank XX MPa | |
| **Rationale/Reference** | To fulfil pressure safety functions and limit cost. Ref to [1], section “Control loops in 1011”. | |

| ID | **1011-102** | **Pressure control of system 1010** |
| --- | --- | --- |
| **Requirement** | Continuous pressure control of the system 1010 circuit | |
| **Rationale/Reference** | To fulfil basic functions | |

| ID | **1011-151** | **Blower unit capacity** |
| --- | --- | --- |
| **Requirement** | Blower unit in 1011 capacity at maximum speed, 9 bar inlet pressure and 10 bar outlet pressure at least 5 g/s | |
| **Rationale/Reference** | Based on engineering judgment by the target division. Refer to [1], section “Hydro-thermo-mechanical” | |

| ID | **1011-153** | **Design pressure of 1011** |
| --- | --- | --- |
| **Requirement** | Maximum design pressure of sub system 1011 1.3MPa (13 bar) | |
| **Rationale/Reference** | Based on engineering judgment by the target division [15] | |

| ID | **1012-101** | **Design pressure Helium storage** |
| --- | --- | --- |
| **Requirement** | Maximum design pressure of sub system 1012 20MPa (200 bar), except outside of pressure limitation devices | |
| **Rationale/Reference** | Based on engineering judgment by the target division (cost) | |

| ID | **1012-152** | **Storage tank capacity** |
| --- | --- | --- |
| **Requirement** | The system must be able to accommodate the entire helium volume from systems 1010, 1011, 1013 and target wheel during controlled draining | |
| **Rationale/Reference** | Based on engineering judgment by the target division | |

| ID | **1012-153** | **Design pressure of gas storage** |
| --- | --- | --- |
| **Requirement** | Maximum operation pressure of gas storage parts in system 1011 20MPa (200 bar) including the compressor | |
| **Rationale/Reference** | Based on engineering judgment by the target division. Allows the usage of commercial gas bottles and reduce the storage volume and cost | |

#### Requirements on structural stability of system parts

This will be defined in the Equipment specification

#### Requirements related to hydro-thermo-mechanical qualification

This will be defined in the Equipment specification

#### Requirements related to redundancy, separation and functional diversification

Not applicable since the helium cooling system is not planned to be radiation safety classified class 2 or higher, nor planned to have complete redundancy.

### Constraints

#### Constraints related to building interfaces and location within the target station

Refer to [6]

#### Chemical constraints

Refer to [19]

#### Environmental constraints

Total maximum leakage of helium from Target helium cooling systems according to requirement 1010-102. Also refer to [19].

#### Material constraints

Refer to [19]

### Classification of equipment

This section is about information regarding categorization into *Mechanical quality class* and *Electric function class*.

All “mechanical” parts of the system must belong to a certain mechanical quality class and each piece of electrical equipment must belong to a specific functional class. The table below shows proposed mechanical classification for all major parts using classes according to [16].

|  |  |
| --- | --- |
| Part/parts | class |
| system 1010; Pipes in main helium loop | SC3\* |
| system 1010; Valves in main helium loop | SC3\* |
| system 1010; Heat exchangers | SC3\* |
| system 1010; Connection valves between main helium loop and other systems (1011, 1013, Helium purification) | SC3\* |
| system 1010; Circulator | SC3\* |
| system 1010; Particle filters | SC3\* |
| system 1010; Sensor connections in main helium loop | SC3\* |
| system 1010; Pressure relief valves in main helium loop | SC3\* |
| system 1011 | PED\*\* |
| system 1013 | PED\*\* |

Table 1 Mechanical quality classes

(\*) According to RCC-MRx Class 3:

For the mechanical quality class with basic radiological safety functions, applicable for components in safety class 3 (SC 3), the choice is Code Class N3Rx. In RCC-MRx, that level can be fulfilled by using PED codes, plus special extra conditions as listed in N3Rx.

(\*\*) Pressure Equipment Directive PED, 97/23/EC. Norms EN-13445 for pressurized vessels and EN-13480 for metal pipes. PED 97/23/ EG describes how system and components shall be categorized. Requirements are included in AFS 1999:4.

The *Zone classification* is handled by the target station as a unit.

# Life-cycle design requirements

## Sustainability requirements

The design shall follow guidelines stated in document “ESS Sustainability Policy”, [19].

## Considerations regarding component life-time

| ID | **1010-191** | **Components life-time** |
| --- | --- | --- |
| **Requirement** | All components life-time within Target helium cooling systems shall follow high quality industry standard | |
| **Rationale/Reference** | E.g. all parts of the main circulator shall be of such high quality that the life-time of the **circulator** exceeds 40 years of operation and high quality industrial valves and actuators has a life-time of at least 30 years, foreseen that the suppliers’ recommended *service*, *repair* and *maintenance* program is strictly followed and the *operational conditions* are within agreed limits. | |

## Requirements for prototyping

No prototypes are planned within the systems.

## Requirements for manufacturing and installation

This will be defined in the Equipment specification, also refer to SSM’s requirements [10]

## Requirements for commissioning

This will be defined together with the in-kind partner. Note that it is about requirements on the systems to enable planned testing.

## Requirements for system in service

### Requirements related to availability and reliability

Refer to section “Requirements from ESS top level and authorities”

### Operational waste management

Foreseen operational waste is filter cartridges with irradiated particles and lubricants from the blower in 1010, also refer to [18].

|  |  |  |
| --- | --- | --- |
| **Req. id** | **Brief description** | **Reference** |
| 1010-801 | Solid waste dimensions and amounts | [23] |
| 1010-802 | Liquid waste amounts | [23] |

Functional requirements imposed on Radioactive Waste Handling system by Target helium cooling

### Handling, transfer, storage

### Repair and replacement

### Maintainability Requirements

## Requirements for decommissioning

Refer to [19]

# Glossary and abbreviations

| Term | Definition |
| --- | --- |
| TSS | Target Safety System |
| PSS | Personal Safety System |
| MPS | Machine Protection System |
| SAR | Safety Analysis Report |
| ODH | Oxygen deficiency hazard |
| GSO | Global Safety Objectives |
| RWH | Radioactive Waste Handling |

Also refer to [21] for general ESS glossary and abbreviations.

# References

[1] ESS-0012527 SDD-Sol Target helium cooling

[2] ESS-0043689 ICD-R Target helium cooling – Helium purification

[3] ESS-0019346 ICD Target helium cooling – Target wheel, shaft & Drive

[4] ESS-0007136 Establishment of Technical and Quality Regulations for ESS

[5] ESS-0008886 [ESS Reliability and Availability requirements](javascript:link(%221%22,%2221308.51166.26112.31209%22,%22%22,%22%22,%22ESS%20Reliability%20and%20Availability%20requirements%22))

[6] ESS-0020682 ICD-R Target helium cooling – CF / Building

[7] ESS-0003520 “ESS Radiation Protection Strategy for Employees”.

[8] ESS-0018673 ICD-R System 1010 – Target intermediate cooling system

[9] ESS-0019347 ICD-R Target helium cooling – Process control/MPS

[10] ESS-0016380 ICD-R Target helium cooling – TSS

[11] ESS-0001786 “Definition of Supervised and Controlled Radiation Areas”

[12] A-0000193 Target Helium Cooling overview

[13] ESS-0035384 pressure drop calculation 1010 circuit

[14] SSM´s special requirements

[15] ESS-0012362 Decision basis for the pressure in the Target Helium Cooling System

[16] ESS-0033258 Radiological Safety Classification for Mechanical Equipment

[17] ESS-0003277 Standards and norms for fire Protection and Explosion safety

[18] ESS-0021306 Feasibility study of the radioactive waste management at ESS

[19] ESS-0030466 ESS Sustainability Policy

[20] ESS-0034725 ICD-R Utility Rooms - Target Station HVAC

[21] ESS-0000385 European spallation source glossary

[22] ESS-0020837 ICD Remote Handling Systems – Target Systems

[23] ESS-0037668 ICD-R System 1010 – Radioactive Waste Handling

[24] ESS-0038061 ICD-R System 1011 – Fluids supply & process

[25] ESS-0000004, General Safety Objectives for ESS

[26] ESS-0000002, Preliminary Safety Analysis Report

[27] ESS-0054291; One dimensional permeation of tritium through a thin stainless steel plate. Y. Lee, March 29, 2016

Document Revision history

| Version | Reason for revision | Date |
| --- | --- | --- |
| 1.0 | New document | 2015-06-02 |
|  |  |  |