TSS classification report

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1. SCOPE

The scope of this document is to derive the safety classification for the TSS, based on the stipulated safety category of the radiation safety functions that have been either explicitly assigned to this Structure/System/Component (SSC) or are expected to be fulfilled by it, by design. For completeness, this document also details the quality classification for the parts, if any, of this SSC that are not assigned any radiation safety function.

Applicable quality and design rules are specified, through references in chapter 8 for the different disciplines. Where needed the classification is differentiated and broken down to the appropriate level of detail.

2. ISSUING ORGANISATION

This document is issued by Target Division.

3. INTRODUCTION

An SSC can be identified as Important to Safety (I2S) either through assignment of an explicit Radiation Safety Function (RSF) related to prevention or mitigation of unacceptable consequences in postulated accident scenarios, or due to that it by design implicitly constitutes an operational condition or is part of a facility configuration that may affect the course of events during such postulated accidents. The selected radiation safety functions are described, together with all assumed normal operation conditions and realistically possible facility configurations, in a set of reports that compile the results of the accident analyses. Those reports also determine the safety category of the credited radiation safety functions. However, it is not in scope of the categorisation reports to define or describe the physical implementation or realisation of the radiation safety functions.

4. IDENTIFIED RADIATION SAFETY FUNCTION(S)

Categorisation report [1] concludes and defines several radiation safety functions, some of which are assigned to the TSS as listed in Table 1. This table also reiterates the categorisation for the radiation safety functions and the associated SSC, as concluded in [1]. These radiation safety functions correspond to specific functional requirements in ESS-0002776 [13]. [13] also defines requirements for other functions (than radiation safety functions); these functions are not defined in [1] but categorized and classified in this document only.

Radiation Safety Function	Group	Associated SSC	Loads to withstand	General design req.	Quality class	Category
Stop beam if low Target wheel rotational speed (RSF-68).	Safety group	Safety	H3-H4	RFPD	Q1	Cat 1
Stop beam if low helium pressure (RSF-69)	Safety group	Safety	H3-H4	RFPD	Q1	Cat 1
Stop beam if high monolith pressure (RSF-70)	Safety group	Safety	H3-H4	RFPD	Q1	Cat 1
Stop beam if high helium temperature (RSF-71)	Safety group	Safety	H3-H4	RFPD	Q1	Cat 1
Stop beam if low helium mass flow (RSF-72)	Safety group	Safety	H3-H4	RFPD	Q1	Cat 1

Table 1 Categorisation of the radiation safety functions assigned to TSS, according to [1]

5. IMPLEMENTATION OF RADIATION SAFETY FUNCTION(S)

The radiation safety functions in Table 1 are implemented by the Target Safety System (TSS).

The radiation safety functions in Table 1 (RSF-68, RSF-69, RSF-70, RSF-71 and RSF-72) monitor physical parameters in the target station, evaluate the parameters, and stop the beam both at the ion source and at the RFQ in the accelerator when needed.

The purpose of the TSS is to prevent and mitigate radiation doses to the public.

The TSS includes also service functions and manual control functions which are not explicitly identified as radiation safety functions in the accident analyses of the target station, and thus are not identified in [1] or Table 1. As implicit parts of the TSS design, these functions are assigned, at most, the same category as the radiation safety functions. They are summarized below and further described, categorized and classified in their dedicated sections below.

- Static beam permit (TSS-TSS-201 in [13])
- Manual safety stop (TSS-TSS-202 in [13])
- Operational monitoring of TSS (TSS-TSS-203 in [13])
- Manual operational start/stop of TSS (TSS-TSS-204 in [13])
- Safety monitoring of TSS (TSS-TSS-205 in [13])

Details of the functional requirements and the architectural design of the TSS are described in [12], [13], and [14].

The TSS is an electrical and I&C system but includes also some mechanical parts; RSF-69 “Helium pressure”, RSF-70 “Monolith pressure” and RSF-72 “Helium mass flow” include mechanical parts to support instrumentation of the TSS radiation safety functions.

6. SSC CLASSIFICATION

6.1. Mechanical discipline

6.1.1. RSF-69 “Helium pressure”

Functional description

This radiation safety function is mainly an electrical and I&C function but includes mechanical parts to support TSS instrumentation; sensing lines interconnected with the primary cooling system main pipe. The function of the main primary cooling pipe is to keep the confinement, i.e. to keep the helium inside. The functions of the sensing lines are to keep the confinement, and to contribute to TSS detection of pressure changes by propagating the confined helium gas pressure to the TSS sensors. The sensors are distanced from the primary cooling process due to environmental reasons.

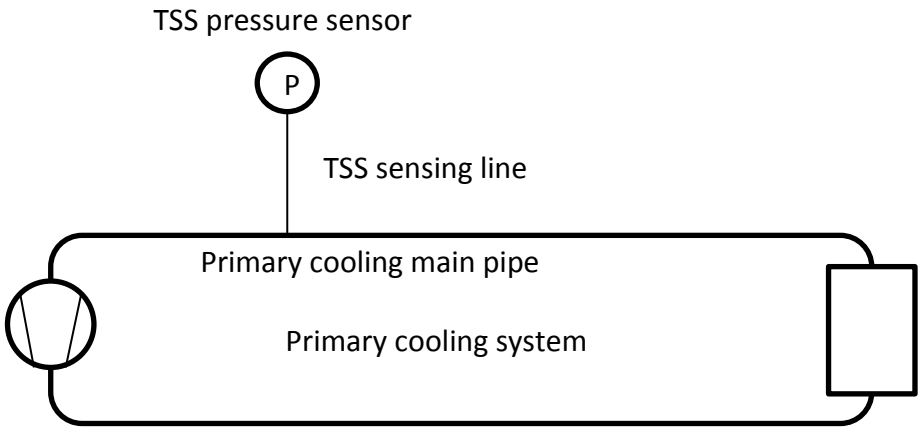

Figure 1 TSS instrument pipes on the primary cooling system

Categorization and classification

As a part of this radiation safety function, the sensing line is categorized as **Cat. 1** according to Table 1.

As the sensing line is an extension of the pipe boundary of the primary cooling system, it has the same mechanical quality class as the primary cooling system (see [4]): **MQC4** (derived from [16]).

6.1.2. RSF-70 “Monolith pressure”

This radiation safety function is mainly an electrical and I&C function but includes mechanical parts to support TSS instrumentation; sensing lines interconnected with the monolith vessel. The function of the monolith vessel is to keep the monolith vacuum intact. The vacuum is there to maintain the low concentration of impurities. The function of the sensing lines is to keep the vacuum intact, and to contribute to TSS detection of pressure changes by propagating monolith vessel pressure to the TSS pressure sensors. The sensors are distanced from the monolith due to environmental reasons.

The setup of impulse pipes is the same as for RSF-69 in Figure 1, except that they are connected to the monolith vessel.

Categorization and classification

As a part of this radiation safety function, the sensing line is categorized as **Cat. 1** according to Table 1.

As the sensing line is an extension of the pipe boundary of the monolith vessel, it has the same mechanical quality class as the monolith vessel (see [4]): **MQC4** (derived from [17]).

6.1.3. RSF-72 “Helium mass flow”

This radiation safety function is mainly an electrical and I&C function but includes mechanical parts to support TSS instrumentation; a venturi tube as part of the primary cooling system main pipe, and sensing lines interconnected with the venture tube. The function of the main primary cooling pipe is to keep the confinement, i.e. to keep the helium inside. The functions of the venturi tube are to keep the confinement, and to contribute to TSS detection of mass flow changes by generating different static pressures at two different points in the main pipe. The functions of the sensing lines are to keep the confinement, and to contribute to TSS detection of mass flow changes by propagating the different static pressures to the TSS sensors. The sensors are distanced from the primary cooling process due to environmental reasons.

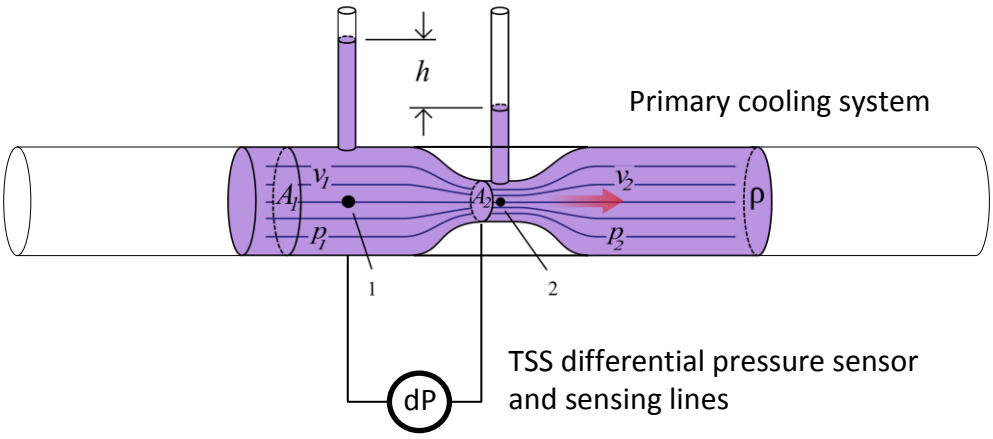

Figure 2 Venturi tube and TSS measurement of differential pressure on the primary cooling system

Categorization and classification

As parts of this radiation safety function, the sensing lines and the venturi tube are categorized as **Cat. 1** according to Table 1.

As the venturi tube and the sensing lines are integrated in or extension of the pipe boundary of the primary cooling system, they have the same mechanical quality class as the primary cooling system (see [4]): **MQC4** (derived from [16]).

6.2. Electrical and I&C discipline

Electrical and I&C SSCs shall be designed, manufactured and installed in accordance with [7]. The electrical and I&C class for each function shall be according to the subsections below.

6.2.1. RSF-68 “Target wheel rotation”

This radiation safety function is categorized as **Cat. 1** according to Table 1 and the discipline specific class is identified as **EICPA**, see Figure 3.

ESS-0016468 function	**Public radiation safety function**		
ESS-0016468 class	**Safety-related SSC**	**Safety SSC**	
ESS-0016468 category	**Cat. 4 – Cat. 5**	**Cat. 1**	**Cat. 2 – Cat. 3**
Electrical and I&C class	EIC0	EICPA	EICPB

Figure 3 Electrical and I&C class of TSS RSF-68 (based on ESS-0054158 [7]).

6.2.2. RSF-69 “Helium pressure”

This radiation safety function is categorized as **Cat. 1** according to Table 1 and the discipline specific class is identified as **EICPA**.

6.2.3. RSF-70 “Monolith pressure”

This radiation safety function is categorized as **Cat. 1** according to Table 1 and the discipline specific class is identified as **EICPA**.

6.2.4. RSF-71 “Helium temperature”

This radiation safety function is categorized as **Cat. 1** according to Table 1 and the discipline specific class is identified as **EICPA**.

6.2.5. RSF-72 “Helium mass flow”

This radiation safety function is categorized as **Cat. 1** according to Table 1 and the discipline specific class is identified as **EICPA**.

6.2.6. TSS-TSS-201 in [13] "Static beam permit"

This TSS function is not identified in [1], but it is defined in [13] for availability reasons (maintenance, testing, etc. for the accelerator).

Functional description

When the TSS secures the direction of the beam towards the beam dump, then this TSS function allows beam production independent of the Target status. It will be designed as a bypass of the TSS radiation safety functions (RSF-68 – RSF-72).

The consequences if this function fails could be the same as if the TSS radiation safety functions fail:

- IF this TSS function intends to direct the beam towards the dump
- AND this TSS function bypasses the TSS radiation safety functions
- AND there is a failure on this TSS function so that the beam is incorrectly sent to the Target
- AND the Target is in maintenance (for example not rotating or not cooled)
- THEN the TSS radiation safety functions are denied to stop the beam production

Categorization

No other function exists to prevent the consequences in case of failure. Therefor the category of this function must be upgraded to highest category among the TSS radiation safety functions (see [3], section 2.3.4, Case [2], Option 1 which is illustrated in Figure 4). Thus the function is therefore considered to belong to the safety group and is categorized as **Cat. 1**.

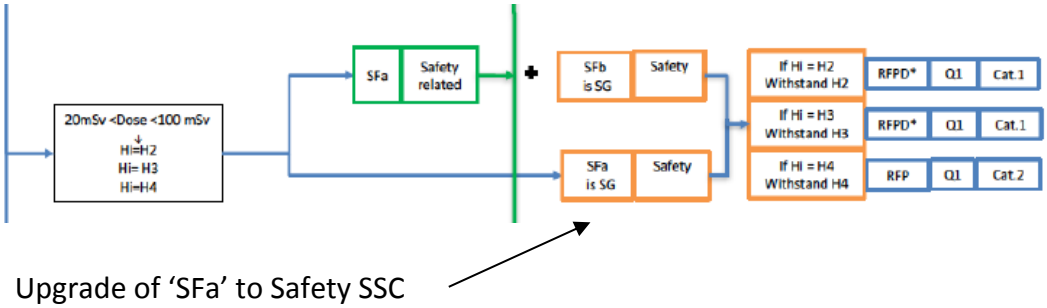

Figure 4 Extraction from Appendix 5 in ESS-0016468 [3] to illustrate option to upgrade the category

Support from IEC 61226 [18]

Functions to facilitate maintenance, testing or bypass are addressed in IEC 61226 [18] for Cat A (corresponding to Electrical and I&C class EICPA):

- Section 7.3.2.1: "*Testing may require suppression of output signals, or the provision of bypass facilities. If bypass facilities are incorporated, their integrity*

shall be justified to show that they cannot be applied in a way that would prevent the system from achieving its specified safety functions"

- Section 5.4.2: "*functions, the failure or spurious actuation of which would lead to unacceptable consequences, and for which no other category A function exists that prevents the unacceptable consequences*"

Classification

Based on the assigned category, and with support from IEC 61226 listed above, this function is classified **EICPA**.

6.2.7. TSS-TSS-202 in [13] “Manual safety stop”

This TSS function is not identified in [1], but it is defined in [13] for potential radiation safety reasons. It is also deemed by SSM in ESS-0121507 [15] section 11.2 that there shall be such a function:

- “*In the event of intentional neutron production, SSM deems that the operators shall be able to manually shut down the accelerator with safety systems and safety components in defence in depth level 3.”*

Functional description

This TSS function allows the operator to manually stop the production of the beam and to bring the spallation process to a safe state in case of any critical situation.

The failure of this TSS function has no impact on the TSS radiation safety functions since they are galvanically isolated.

Categorization

As a function in defence in depth level 3 the category shall be any of Cat. 1 – Cat. 3, see [3]. Since the function is actually not identified in [1] it is assigned the lowest category **Cat. 3**.

Classification

Based on the assigned category this function is assigned class **EICPB**.

6.2.8. TSS-TSS-203 in [13] "Operational monitoring"

This TSS function is not identified in [1], but it is defined in [13] for operational reasons.

Functional description

This function provides general status (e.g. operational mode, alarms, sensor status, voting status, actuator position, etc.) of the TSS radiation safety functions to the operator.

The failure of this function will withhold information from the operator, or modify the information to the operator, so that he/she may make faulty conclusions and decisions.

The failure of this function has no impact on the TSS radiation safety functions since they are functionally separated (galvanically isolated). Furthermore this function only reads information from the SSCs implementing the radiation safety functions.

Categorization

Monitoring of radiation safety functions is defined as a 'service function' in Table 2 of [3]. Thus it is important to radiation safety. In the absence of further categorization of service functions in [3], and since this function is intended for normal operation, and the fact that there is no impact on the radiation safety functions in case of failure, it is assigned category **Cat. 5** i.e. a safety-related SSC.

Support from IEC 61226 [18]

Functions to facilitate monitoring are addressed in IEC 61226 [18] for Cat B and Cat C as

- Cat B, section 5.4.3 g): "*functions that provide continuous or intermittent tests or monitoring of functions in category A to indicate their continued availability for operation and alert control room staff to their failures, <u>if no alternative means (e.g. periodic tests) are provided to verify their availability</u>.*"

- Cat C, section 5.4.4 c): "*functions that provide continuous or intermittent tests or monitoring of functions in category A and B to indicate their continued availability for operation and alert control room staff to their failures, <u>and are not classified category B according to 5.4.3 g)</u>;*"

The design of TSS includes means to perform regularly tests (periodic tests) of the radiation safety functions. Thus the monitoring function would be classified Cat C. For Cat C the following is stated:

- Section 5.3.4: "*Category C denotes functions that play an auxiliary or indirect role in the achievement or maintenance of NPP safety*" and "*They can be part of the total response to DBA but not be directly involved in mitigating the physical consequences of the accident*"
- Section 7.3.2.3: "*A system in this category does not generally need redundancy or separation*"

- Section 7.5.2.3: "*Systems and equipment performing category C functions may be accepted at a commercial QA level*"
- Table 1: "*Normal industrial practice*"

The above statements indicate that Cat C in IEC 61226 correlates to safety-related SSC in ESS-0016468 [3].

Classification

Based on the assigned category, and with the support from IEC 61226 listed above, this function is assigned class **EIC0**.

6.2.9. TSS-TSS-204 in [13] "Manual operational start/stop"

This TSS function is not identified in [1], but it is defined in [13] for operational reasons.

Functional description

This function allows the operator to start and stop the TSS safety system during normal operation. Start of the system means that beam production is allowed by TSS, and that the TSS radiation safety functions are activate and ready to act on demand. Stop of the system means that the system is set in a safe state where TSS does not allow beam production, and that, for example, periodic tests of the system can be performed.

Failures of this function:

1. Spurious start of TSS safety system during beam off mode:
    - Then this function attempts to allow beam production, even if the parameters monitored by the TSS radiation safety functions (RSF-68 – RSF-72) indicate that the Target is not ready for beam. The TSS radiation safety functions will immediately actuate and prevent beam production.
2. Fail to start TSS safety system during beam off mode:
    - Then TSS will not allow beam production, independent of the TSS radiation safety function.
3. Spurious stop of TSS safety system during beam on mode:
    - Then this function will stop the beam production, independent of the TSS radiation safety functions.
4. Fail to stop TSS safety system during beam on mode:
    - Then TSS will keep on allowing beam production, but the TSS radiation safety functions (RSF-68 – RSF-72) remain active and ready to act on demand. Also the manual safety stop (TSS-TSS-202) is available to stop the beam production.

A faulty manual action (unintentional start or stop) by the operator will lead to any of the spurious start or spurious stop scenarios above.

This manual operational stop will be clearly differentiated from the manual safety stop, so that it is obvious to the operator which stop function to use in case of an emergency situation.

Note that neither manual safety stop (TSS-TSS-202) nor setting of static beam permit (TSS-TSS-201) is included in design of this function.

Categorization and classification

Since this function is intended for normal operation, and that failure of this function in some cases (see above) relies on the existence of other functions to mitigate the consequences, it is a safety related SSC and assigned category **Cat. 5** and class **EIC0**.

6.2.10. TSS-TSS-205 in [13] "Safety monitoring"

This TSS function is not identified in [1], but it is defined in [13] to provide TSS status to the operator beyond "operational monitoring" (TSS-TSS-203) during H3-H4 events.

Functional description

This function provides status of critical TSS parameters (e.g. actuator position, tripped or not tripped, etc.) to the operator. The parameters may be a subset of "operational monitoring" (TSS-TSS-203), but displayed using dedicated components.

The failure of this function will withhold information from the operator, or modify the information to the operator, so that he/she may make faulty conclusions and decisions.

The failure of this function has no impact on the TSS radiation safety functions since they are functionally separated (galvanically isolated). Furthermore this function only reads information from the SSCs implementing the radiation safety functions.

Categorization

Monitoring is defined as a 'service function' in Table 2 of [3]. Thus it is important to radiation safety. In the absence of further categorization of service functions in [3], and since there is no impact on the TSS radiation safety functions in case of failure, this function is assigned category **Cat.5** i.e. a safety-related SSC.

Support from IEC 61226 [18]

There is no equivalent function addressed in IEC 61226. The most similar function is the one to provide information that allows manual actions. That function can be either Cat A or Cat B based on the specific request for manual actions, and whether the manual action is the only possible action to reach a safe state. In general IEC 61226 indicates that the information that allows manual action is categorized the same as the corresponding manual action, see quotes below.

- Cat A, section 5.3.2: "*If specified manual actions are provided to reach the non-hazardous stable state, factors such as the availability of redundant, validated, information sources, sufficient duration of the grace time for operator evaluation of alternative sources of information, and whether the manual actions are the only possibility for mitigation of this sequence of events to preserve NPP safety, have to be considered*"
- Cat A, section 5.4.2: "*functions required to provide information and control capabilities that allow specified manual actions necessary to reach the non-hazardous stable state*"
- Cat A, section 7.3.2.1: "*In the case that category A functions have to be performed by operators, purpose designed monitoring and control of systems shall be provided which are separated from other monitoring and control of systems and which are designed to be suitable and adequate for the required reaction time."*

- Cat B, section 5.4.3: "*functions required to provide information or control capabilities that allow specified manual actions necessary after the non-hazardous stable state has been reached to prevent a DBE from leading to unacceptable consequences, or mitigate the consequences*"
- Cat B, section 7.3.3.2: "*The principal objectives for the functional design of systems required to provide information or control capabilities in the control room that allow specified manual actions necessary to mitigate the consequences of a DBE are to provide the operator with accurate, complete and timely information regarding the status of plant equipment and systems for all DBE*"

Classification

Based on the fact that the TSS function is not intended to provide information that allows manual actions, it would neither be assigned Cat A nor Cat B in IEC 61226. In combination with the assigned category, this leads to that this function is assigned class **EIC0**.

6.3. Civil structures discipline

There is no part of the TSS that belongs to the civil structures discipline.

6.4. HVAC discipline

There is no part of the TSS that belongs to the HVAC discipline.

6.5. Other disciplines

There is no part of the TSS that belongs to other disciplines than those addressed above.

6.6. Summary of SSC classification and applicable design and construction rules

Table 2 summarises the quality classification of SSCs within the **TSS**.

SSC related to function	RSF Category	Mechanical	Electrical and I&C	Civil structures	HVAC	Other
RSF-68	Cat 1	N/A	EICPA	N/A	N/A	N/A
RSF-69 Sensing lines	Cat 1	MQC4	N/A	N/A	N/A	N/A
RSF-69 Electrical and I&C SSCs	Cat 1	N/A	EICPA	N/A	N/A	N/A
RSF-70 Venturi tube, sensing lines	Cat 1	MQC4	N/A	N/A	N/A	N/A
RSF-70 Electrical and I&C SSCs	Cat 1	N/A	EICPA	N/A	N/A	N/A
RSF-71	Cat 1	N/A	EICPA	N/A	N/A	N/A
RSF-72 Sensing lines	Cat 1	MQC4	N/A	N/A	N/A	N/A
RSF-72 Electrical and I&C SSCs	Cat 1	N/A	EICPA	N/A	N/A	N/A
TSS-TSS-201 in [13]	Cat 1	N/A	EICPA	N/A	N/A	N/A
TSS-TSS-202 in [13]	Cat 3	N/A	EICPB	N/A	N/A	N/A
TSS-TSS-203 in [13]	Cat 5	N/A	EIC0	N/A	N/A	N/A
TSS-TSS-204 in [13]	Cat 5	N/A	EIC0	N/A	N/A	N/A
TSS-TSS-205 in [13]	Cat 5	N/A	EIC0	N/A	N/A	N/A

Table 2 Classification of SSCs within the TSS

7. GLOSSARY

Term	Definition
RSF	Radiation Safety Function
SSC	Structure/System/Component
TSS	Target Safety System

8. REFERENCES

[1] Categorization of safety functions related to events internal to the monolith (ESS-0454232)
[2] Categorization of radiation safety functions related to events in the target utility systems (ESS-0454234)
[3] ESS rule for identification and classification of safety important components (ESS-0016468)
[4] ESS Rules for Radiation Safety Classification of Mechanical Equipment (ESS-0033258)
[5] ESS rules for technical requirements for mechanical equipment (ESS-0039311)
[6] ESS Rules for Quality Regulation for Mechanical Equipment RESSQ-Mech (ESS-0047989)
[7] ESS rules for radiation safety classification of Electrical and Instrumentation & control equipment including design and quality requirements (ESS-0054158)
[8] ESS Rules for Radiation Safety Classification of Civil Structure including Technical and Quality Requirements (ESS-0134987)
[9] ESS rules for radiation safety classification of HVAC systems and components (ESS-0036956)
[10] ESS rules for technical requirements applicable to HVAC systems and components (ESS-0037914)
[11] ESS rules for quality requirements applicable to HVAC systems and components (ESS-0083831)
[12] TSS concept specification (ESS-0037596)
[13] TSS system requirements specification (ESS-0002776)
[14] TSS system architecture specification (ESS-0045067)
[15] SSM Permit for Installation Appendix 1 Review Report (English) (ESS-0121507)
[16] SSC classification report for Target helium cooling systems (ESS-0052141)
[17] SSC classification report – Monolith Vessel (ESS-0099097)
[18] IEC 61226:2009, Nuclear power plants - Instrumentation and control important to safety - Classification of instrumentation and control functions

DOCUMENT REVISION HISTORY

Revision	Reason for and description of change	Author	Date
1	First issue	Mikael Olsson	2019-03-01