IDM UID
8L9YN9
VERSION CREATED ON / VERSION / STATUS
28 Feb 2025 / 3.2 / Approved
EXTERNAL REFERENCE / VERSION

Sub-System or Equipment Design Description

Classification of DMS cryogenic system

The purpose of this document is to define and justify the classification (Quality, Safety, Seismic, Vacuum, Pressure Equipment, Tritium) of the DMS Cryogenic System.

Approval Process			
	Name	*Action*	*Job Title / Affiliation*
Author	**Giors S.**	**28 Feb 2025:signed**	**Nuclear Technologies Engineer**
Co-Authors			
Reviewers	**Avigni P.** **Dibon M.** **Jourdan T.**	**17 Mar 2025:recommended** **28 Feb 2025:recommended** **07 Mar 2025:recommended**	**Safety Analyst** **Fuelling Engineer** **Nuclear Pressure Equipment Coordina...**
Approver	**Kruezi U.**	**31 Mar 2025:approved**	**Project Leader**
Information Protection Level: Non-Public - Unclassified *RO: Kruezi Uron*			
Read Access	**LG: DMS Contractors, LG: US-DA FPIS, LG: TO#11 DMS Contractors, LG: TO#33 DMS Contractors, LG: DMS IO_Team, LG: FCED DH , LG: DMS Project Team, AD: ITER, AD: IO_Director-General, AD: External Management Advisory Board, AD: IDM_Controller, AD: OBS - Disruption Mitigation System Project (DMS), AD: OBS...**		

#drn#

Change Log			
Classification of DMS cryogenic system (8L9YN9)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	In Work	22 Aug 2023	
v2.0	Signed	22 Aug 2023	First version for review.
v2.1	Signed	23 Aug 2023	Mismatch in QC of ITL/DTL vs. Appendix calculation updated: QC3 --> QC2. Some typos corrected.
v2.2	Signed	22 Sep 2023	Incorporated comments from reviewers: - Tritium classification TC1 - PED classification (vessels Art 4.3, nomenclature) - Safety and seismic: IPC second barrier SIC-2, CDB non PIC/SIC, SC2, justification of non safety isolation.
v2.3	Approved	26 Oct 2023	5.4 changes in blue: SR/SC1(S) for helium circuit inside IPC. Safety class of supports according to so supported system.
v3.0	Revision Required	13 Mar 2024	Safety and Seismic Classification of cryogenic system updated (non-PIC/SIC) consistently with: ITER_D_ALX28Y - DMS Nuclear Safety Strategy ITER_D_9D3WL2 - Classification of DMS injector system
v3.1	Approved	08 Nov 2024	ESPN classification checked and excluded according to input from T. Jourdan The Safety classifications were changed to SIC-2 for all T2 containing components as agreed with P. Avigni. SC1(S) classification maintained for SIC-2 components and for SR cryogenic circuit, in order to ensure confinement of T2 and contain He leak into the room respectively.
v3.2	Approved	28 Feb 2025	Design pressure PS for Gas pre-cooler, gas pipes and acceleration tube reduced from 100 bar(g) to 70 bar(g) due to operation maximum pressure at 60 bar(g). The PED classification does not change, Gas group 1, Art 4.3.

1 Scope

The scope of this document is to define and justify the classification (Quality, Safety, Seismic, Vacuum, Pressure Equipment, Tritium) of the DMS Cryogenic System.

The DMS cryogenic system includes the Helium process pipes/vessels/heat exchangers part of cryogenic transfer lines and Cold Distribution Boxes, the cryogenic guard vacuum enclosures and the pellet formation and regeneration devices (acceleration tube, gas pipes, pre-cooler, thermal shield) inside the Injectors Prismatic Cryostat (IPC).

It extends from the PBS31 CVBs in lower port C07, 13, 16 and 11-L3 gallery, up to the injectors in EP 02, 08, 17 and UP 02, 08, 14.

The scope is part of the following P&IDs:

- DMS Cryogenic networks #1, #2, #3, #4: [RD1], [RD2], [RD3], [RD4]
- Cold Distribution Box (CDB), Intermediate Transfer Lines (DTL), Intermediate Transfer Lines (ITL): [RD5]. Only EP8 referenced, but classification valid for all EP/UP locations.
- Cold Cell Assembly (CCA) and Injector Prismatic Cryostat (IPC): [RD6]. Only EP8 referenced, but classification valid for all EP/UP locations.

2 Reference Documents

[RD1]. 18.DM.31 – DMS Cryogenic Network#1 (YPPNUD)
[RD2]. 18.DM.32 – DMS Cryogenic Network#2 – PID (YPPTFV)
[RD3]. 18.DM.33 – DMS Cryogenic Network#3 – PID (YPQ8NN)
[RD4]. 18.DM.34 – DMS Cryogenic Network#4 – PID (YPQHTA)
[RD5]. 18.DM.HX – Cryogenic distribution system of Drawer 1 of Equatorial Port 08 – PID (6R3CCX).
[RD6]. 18.DM.HA – Injector 01 of Drawer 1 of Equatorial Port 08 – PID (4GKRDP).
[RD7]. Quality Classification Determination (24VQES v5.2).
[RD8]. Safety Important Functions and Components Classification Criteria and Methodology (347SF3 v1.8).
[RD9]. ITER Seismic Nuclear Safety Approach (2DRVPE v1.6).
[RD10]. ITER Vacuum Handbook (2EZ9UM v2.5).
[RD11]. Pressure Equipment Directive (PED) 2014/68/UE, https://single-market-economy.ec.europa.eu/sectors/pressure-equipment-and-gas-appliances/pressure-equipment-sector/pressure-equipment-directive_en
[RD12]. In service monitoring of PENPE Vessels and piping (YSMDP3 v1.2)
[RD13]. CTP- 152-02/D Dispositions specifiques applicables aux récipients à double paroi utilisés à la production ou l'emmagasinage de gaz liquéfiés à basse température, aux réchauffeurs cryogéniques atmosphériques dits « HP » et de type « piscine » (5HEXV5 v1.0).
[RD14]. Tritium Release Memorandum (AV6YQS v1.1)
[RD15]. Tritium Handbook (2LAJTW v1.4).
[RD16]. Réponse engagement 19.3 : double enveloppe autour des équipements contenant des isotopes d'hydrogène (GNQA2Z v2.0)

[RD17]. 18.DM.30 - IOTS - 000200 : Specification for the Design and Manufacturing of DMS Cryolines [In-Cash Procurement] (YSMR7G v1.1)
[RD18]. ITER_D_A8DHRG - FDR Chits CRYO Cat2 close-out report: #3, #13, #33
[RD19]. ITER_D_9D3WL2 - Classification of DMS injector system
[RD20]. Safety requirement Roombook (KF63PB v2.11)
[RD21]. ITER_D_ALX28Y - DMS Nuclear Safety Strategy.
[RD22]. ITER_D_45P8YK - Defined requirements PBS 18 DMS

3 Acronyms and definitions

Acronym	**Definition**
CDB	Cold Distribution Box
CC	Cold Cell
CCA	Cold Cell Assembly
CVB	Cold Valve Box
DMS	Disruption Mitigation System
DTL	Disconnection Transfer Line
EP	Equatorial Port
IPC	Injectors Prismatic Cryostat
ITL	Intermediate Transfer Line
MLI	Multi-Layer insulation
NA	Nota Applicable
PED	Pressure Equipment Directive
SEP	Sound Engineering Practise
SSC	System Subsystem or Component
TIV	Torus Isolation Valve
UP	Upper Port

4 Classification approach and justification

4.1 Safety and seismic classification

Safety classification is defined based on [RD8], and is meant to allow the implementation of ITER safety functions, namely:

1. *Confinement of radioactivity: ensuring the personnel, public and the environment are protected against radioactive material releases. This function is achieved with confinement barriers and associated confinement systems.*
2. *Limitation of internal and external exposure to ionizing radiation.*

SIC-1 *SSCs are those required to bring to and to maintain ITER in a safe state.*

SIC-2 *SSCs are those used to prevent, detect or mitigate incidents or accidents, but not SIC-1 (not required for ITER to reach a safe state).*

*All other components are described as "**non-SIC**". However, some components, while not being SIC, may have some relevance to safety. These components are labelled "**Safety Relevant**", **SR**. They are not credited in the safety analysis and their failure would not impact any safety function. **Concerning the design phase**, no safety requirements are defined for these SR components. **In operation**, some requirements, such as periodical maintenance, could be defined.*

Seismic classification is defined in agreement with [RD9], as follows:

SC1 (S) - Seismic class one-S: Structural stability maintained in the event of an earthquake, i.e. no rupture of piping, no collapse of structures or equipment, limited plastic strain, limited concrete cracking, structural support functions maintained. With this level of requirement, it is possible that a small level of deformation could occur. Consequently, it could be necessary to inspect equipment before re-using it.

SC2 - Seismic class two: Non-damage to SC1 equipment; absence of damage to SC1equipment for buildings and structures housing and protecting safety important components, or to buildings that can potentially damage such structures in the event of collapse, no other requirements regarding structural or functional performance in the event of an earthquake.

4.1.1 *Tritium confinement and hydrogen explosion risk*

According to [RD21] *Nuclear Safety Strategy* all CCA components potentially coming in contract with Tritium, and upstream TIVs, shall be classified as PIC/SIC-2: this includes the acceleration tube, the de-sublimation gas pipes and pre-cooler heat exchanger gas pipes.

As a consequence, these components will be analysed for fire and seismic (SC1(S)), but they could have a faulted damage limit for category IV events.

The IPC will not need to be a PIC but just a cryogenic guard cryostat. As a consequence, IPC will be analysed for seismic (SC2), and could fail without damaging neighbour SC1(S) components.

4.1.2 *Helium confinement*

ITER safety functions do not imply helium confinement: from safety standpoint helium shall only be confined to prevent a radioactive release accident, e.g. because of a breach of the vacuum vessel or of the building caused by helium pressurization.

The project requirement **[PR2026-R;Defined Requirement]** *The system that supplies liquid helium to ITER systems shall limit the potential release of helium within the vacuum vessel to 50 kg (protection measure to guarantee the confinement function of the VVPSS)*, is not propagated to DMS defined requirements [RD22]. However we analysed the risk of Helium release in the VV.

DMS cryogenic circuit carries SCHe at 4.5 bar, 5K into a copper heat exchanger (Cold Cell) joined to the acceleration tube by electroforming or vacuum brazing. Both Cold Cell and acceleration tube are pressure equipment Art. 4.3, designed to EN13445 for PS=15 bar(g) and 70 bar(g) respectively. This double barrier (copper Cold Cell and stainless-steel acceleration tube wall) makes Helium leaks into the acceleration tube and hence release of helium into the vacuum vessel a very unlikely event. However we analysed the risk of Helium release in the VV in [RD18], in response to FDR Chit #3, and we concluded that the potential release from the double failure of one injector (cold cell plus acceleration tube) is ≈6.2 kg << 50 kg. For this reason the CDB cryogenic isolation valves for SHe supply and return to/from Cold cell, contrary to cryopumps isolation valves in PBS31 CVB, are classified as Non-PIC/SIC.

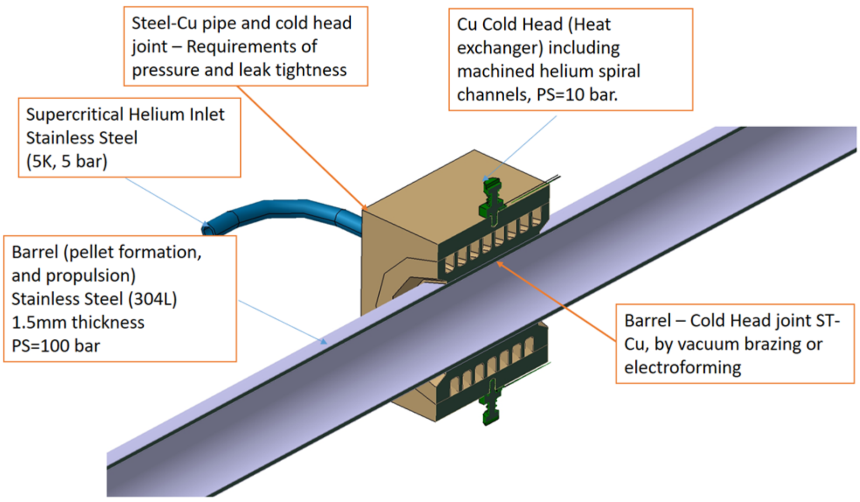

Figure 1: Cold Cell heat exchanger and joint to acceleration tube

Regarding the risk of Helium leak into the building, in case of failure of CDB LHe vessel or pipes, or in case of CDB loss of vacuum accident (LOVA), up to 120 L at 1.8 bar, 4.89 K, ≈13 kg of saturated Helium liquid, would release through CDB burst disk or vacuum relief device into the port cell (smallest V=219 m^3), producing a pressurization at 300K of Δp=m/V×R°/M×T=0.37 bar(g). As the port cells are designed for 0.6 bar(g) (LOCA III, see safety roombook [RD20])), no damage is expected. The cooling effect of 13 kg of LHe into 270 kg of port cell air is quantified in ≈ -60K, much less is expected in massive stainless-steel parts, which is not expected to create damages to stainless steel confinement barriers.

Moreover, in order to minimize the risk of a continuous cold He leak in case of cryogenic pipe failure upstream any CDB isolation valve, it is here recommended to classify the CDB, ITL and IPC/CCA cryogenic circuit as SC1(S), i.e. no pipe collapse in case of SL-2 seismic event, although small leaks could be expected.

In summary we propose to have the full SHe circuit classified as Non-PIC/SIC but keeping the structural integrity during and after a seismic event SC1(S).

4.2 Vacuum classification

The vacuum classification is defined according to the Iter Vacuum Handbook [RD10], with an exception for the Helium process pipes.

In fact the vacuum spaces of the DMS cryogenic system are mostly connected to Service Vacuum System (SVS) active (Injector Prismatic Cryostat IPC) and non-active (CDB, transfer lines), and as such they should be classified as VQC-3. However, due to their function, they can also be considered as cryogenic guard vacuum spaces, and classified as VQC-4.

It should be noted that VQC-3 was never conceived for cryogenic equipment, while VQC-4A is and includes some special requirements for the cryogenic process pipes (more stringent leak rates). **Hence we propose here to classify as VQC-4 the cryogenic process pipes boundary and cold equipment installed on them, and VQC-3 the atmospheric, room temperature vacuum boundary.**

Regarding the acceleration tube, its bellow and pellet gas pipes inside IPC, they shall be classified as VQC-1A because when the Torus Isolation Valves (TIVs) are open (DMS ready to fire) the acceleration tube boundary becomes an extension of the vacuum vessel.

4.3 PED classification

The DMS cryogenic system operating pressure does not exceed 4 bar(g).

The DMS cryogenic system interfaces with PBS31 CVB through:

- 5K supply network with maximum allowable pressure PS=20 bar(g).
- 6-100K return network with maximum allowable pressure PS=10 bar(g).

The DMS cryogenic system is designed with large margin, for consistency with interfacing return network and PBS34 XD 6-100K line, for a maximum allowable pressure PS=10 bar(g).

The supply networks from PBS31 CVBs and Disconnection Transfer Line (DTL), where designed for a maximum allowable pressure PS=20 bar(g), for consistency with PBS31 CVB design pressure.

The transition between 20 bar(g) and 10 bar(g) is at the interface between 5K supply DTL and CDB (see Figure 12, interface No. 1).

The ITL and the IPC cryogenic pipes and circuits are designed for a maximum allowable pressure PS=15 bar(g), due to the distance and corresponding pressure drop between the protected circuit (IPC, CCA) and the pressure relief valves located on the CDB (with set pressure of 10 bar(g)).

The DMS Helium piping system, including pipes of transfer lines, CDB and IPC, is an assembly of gas pipes, with DN ≤ 32, hence it shall be classified as **PED piping gas group 2, Art 4.3**, see Figure 2: Extract from PED directive [RD11]: Piping gas group 2.

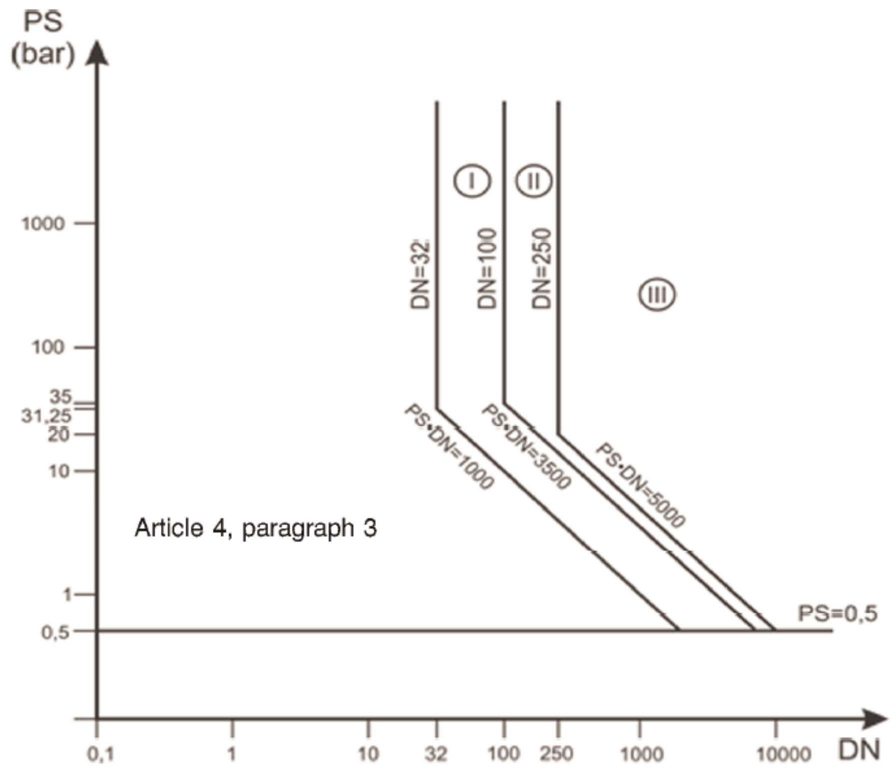

Table 7

Piping referred to in Article 4(1)(c)(i), second indent

Figure 2: Extract from PED directive [RD11]: Piping gas group 2.

The DMS Cold Distribution Box (CDB) contains a liquid helium vessel and a helium-helium Joule Thomson Heat exchanger (see Figure 3), which shall be classified as **PED vessels gas group 2**, according to Figure 4: Extract from PED directive [RD11]: Vessels gas group 2.

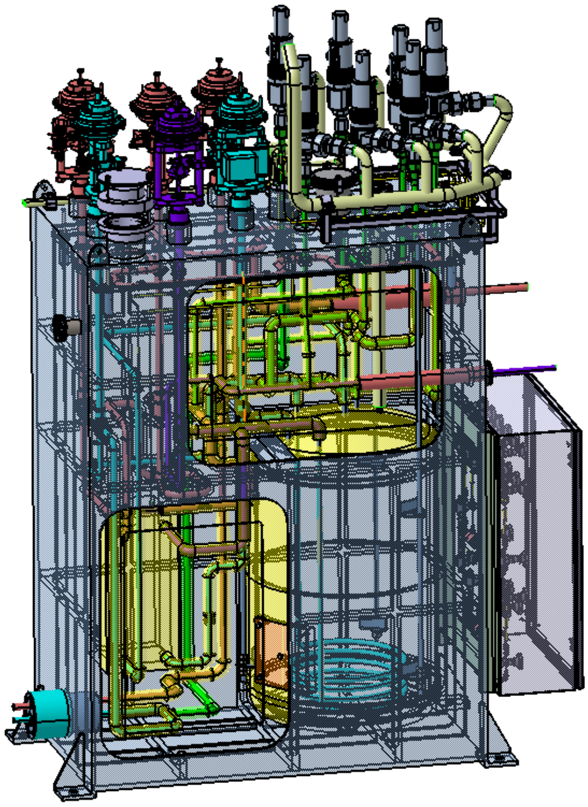

Figure 3: CDB design layout

The liquid helium vessel is designed for PS=10 bar(g) and has a volume V=120 L, PS×V≤1200 bar×L<3000 bar×L, hence it shall be classified as **PED vessel gas group 2, Cat. III**.

Periodic In-Service-Inspection (ISI) is normally required for vessels Cat. II, III, IV if PS>4 bar(g) (see [RD12]). Once insulated with MLI and integrated inside the vacuum cryostat of the CDB, the LHe vessel will not be accessible for visual inspection. However French law [RD13] CTP- 152-02/D allows to limit the ISI to the outer cold box cryostat, vacuum insulation and safety devices, which can be all verified from outside the cryostat.

The Joule-Thomson heat exchanger has is designed for PS=10 bar(g) and has a volume V=16L, PS×V=160 bar×L<200 bar×L, hence it shall be classified as **PED vessel gas group 2, Cat. I**.

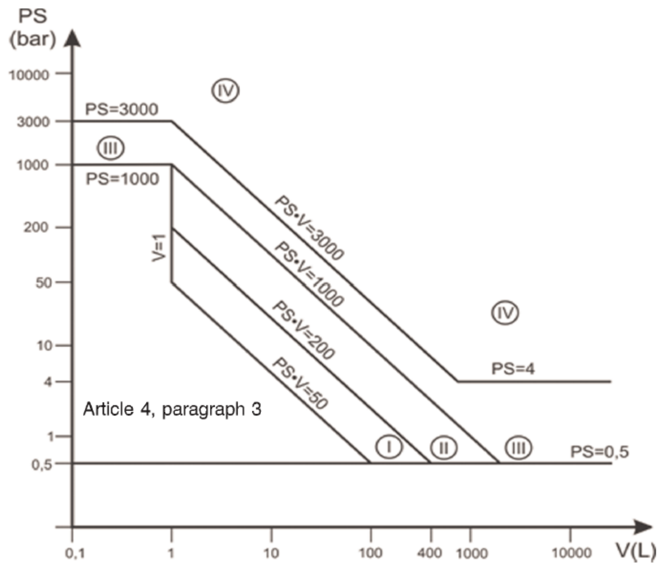

Table 2

Vessels referred to in Article 4(1)(a)(i), second indent

Figure 4: Extract from PED directive [RD11]: Vessels gas group 2.

The Injector prismatic Cryostat (IPC) contains, in addition to already analysed helium pipes (see Figure 8):

- **Cold Cell and gradient control helium heat exchangers**: they have a volume V<1L each, hence, they will be classified as **PED vessel gas group 2, Art 4.3,** see Figure 4: Extract from PED directive [RD11]: Vessels gas group 2.
- **Gas pre-cooler heat exchangers (Helium to pellet gas, where gas can be H2)**: it shall be classified based on the most demanding gas side, which is the pellet gas, in gas group 1, with PS=70bar(g) < 200bar(g). It has a volume V<1L, hence it shall be classified as **PED vessel gas group 1 Art. 4.3**, see Figure 6: Extract from PED directive [RD11]: Vessels gas group 1.
- **Pellet gas pipes:** they carry H2 gas (flammable) and have DN <25, hence they shall be classified **PED piping gas group 1, Art 4.3,** see Figure 5: Extract from PED directive [RD11].

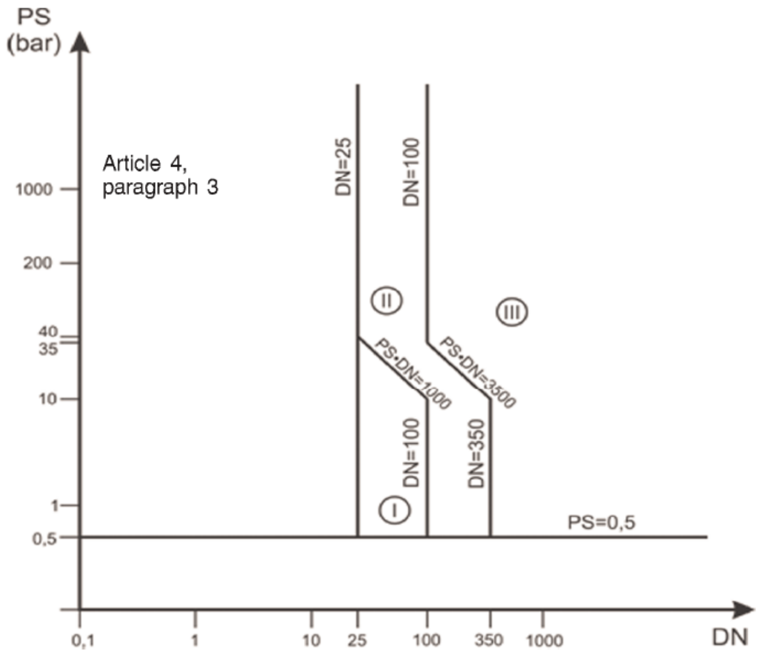

Table 6

Piping referred to in Article 4(1)(c)(i), first indent

Figure 5: Extract from PED directive [RD11]: piping gas group 1

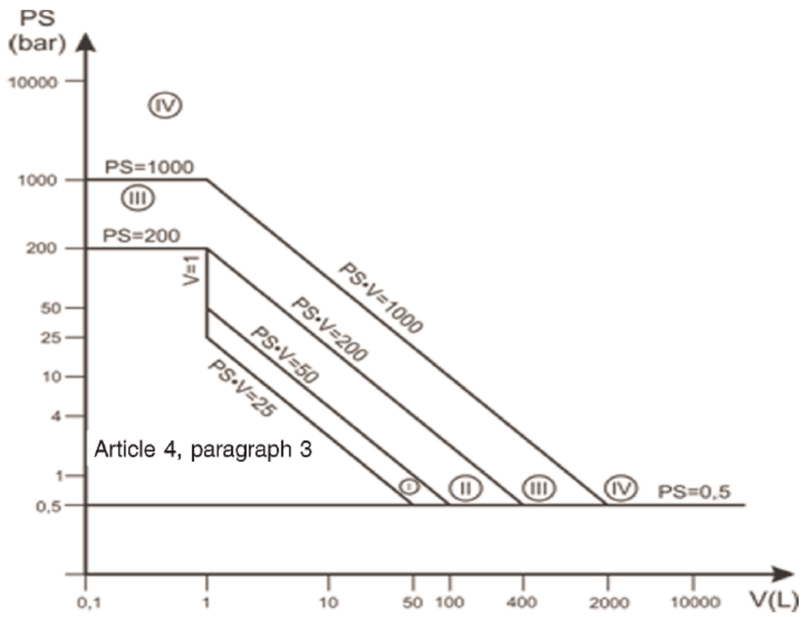

Table 1

Vessels referred to in Article 4(1)(a)(i), first indent

Figure 6: Extract from PED directive [RD11]: Vessels gas group 1.

- **The acceleration tube** is a special case deserving attention: its function is to allow the formation (de-sublimation) of H2 (or H2+Neon) pellets at a temperature in the range of 7 to 15 K and pressure below 200 mbar. Once the solid pellet is formed, the volume upstream of the pellet (breach) is pressurized by H2 at a pressure up to 70 bar(g), which dislodges and fires the pellet into the propellant suppressor volume, flight tube and finally into the vacuum vessel (see Figure 7 and Figure 8). The pressure in the breach of the acceleration tube can reach for short but repeated firing events 70 bar. The volume of the propellant suppressor (V=50L) is such that its pressure cannot exceed 0.5 bar(g) in the worst case of pellet sublimation plus propellant gas (65+6=71 bar L for Ne pellet). Hence the PED classification stops at acceleration tube exit into suppressor volume.

  According to PED, the acceleration tube is considered a cylindrical shape vessel, due to its function of pellet formation, of inner diameter ID=28.5 mm, length l=1050 mm, volume V=0.669L<1L, PS=70bar(g) < 200bar. According to Figure 6: Extract from PED directive [RD11]: Vessels gas group 1., we classify the acceleration tube as **PED vessel gas group 1, Art. 4.3**.

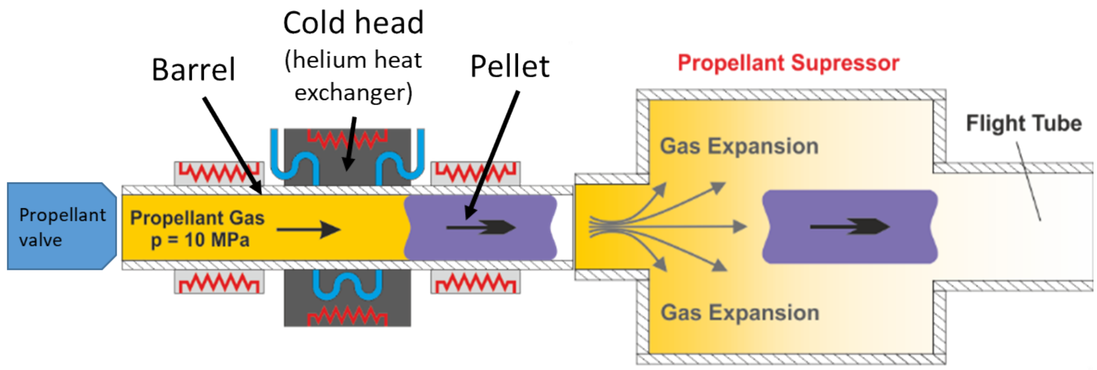

Figure 7: Schematics of acceleration tube layout and operation, pellet flights from left to right.

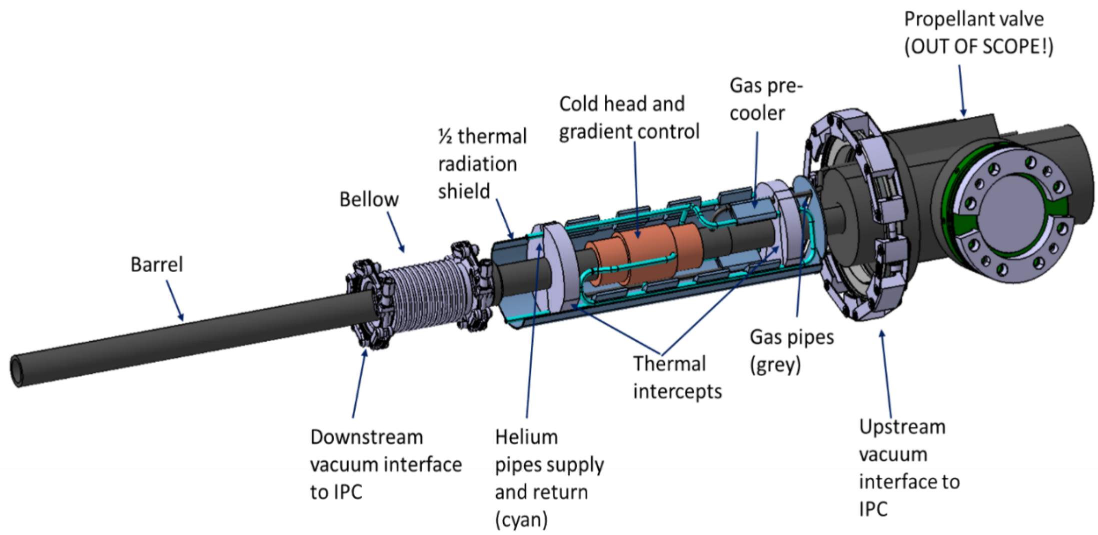

Figure 8: 3D model of acceleration tube layout: pellet flights from right to left.

4.3.1 *ESPN classification*

The acceleration tube, gas pipes and precooler are PED Category 0, and contain radioactivity (Tritium). If they released radioactivity over 370 MBq in case of failure, they would fall under ESPN.

The release of tritium radioactivity for a potential failure of the above mentioned components is calculated in [RD14] *Tritium release memorandum*, in normal operating conditions, for one injector volume upstream Torus Isolation Valves:

- Propellant gas with 20ppm Tritium from 6.1.4: 1.7 mg / 27 = **0.063 mg**.
- Tritium cryo-condensed on the pellet open to vacuum vessel from 6.3.4/appendix 2: **0.26 mg**.
- Realistic Tritium hold-up after a mitigated disruption from Appendix 3: **0.3 mg**.

TOTAL Tritium inventory per injector, upstream TIVs: **0.623 mg.**

TOTAL radioactivity release per injector, behind TIV 3.6×10^{14} Bq/g×0.63 mg/1000[1]=226 MBq < 370 MBq.

Hence the CCA components containing tritium do not fall under ESPN regulation, but just under PED Art 4.3.

4.4 Tritium classification

The Tritium classification is only applicable to the acceleration tube, its bellow, the pellet gas pipes, gas pre-cooler, and IPC, as they are the only parts susceptible to get in contact with Tritium. The acceleration tube, bellow, gas pipes and gas pre-cooler are connected to the vacuum vessel when DMS is ready to fire and TIV valves are open. The IPC cryostat might be contaminated by tritium in case of acceleration tube or gas pipe/pre-cooler failure.

According to Tritium Handbook [RD14], these parts shall be classified as follows:

- Acceleration tube, bellow, pellet gas pre-cooler and pipes: these are designed and manufactured under pressure code, and represent first confinement barrier of flammable gas: TC 1A.
- IPC: this represents additional barriers of the first confinement system: TC 1B.

4.5 Quality classification

The quality classification is defined in agreement with the methodology of [RD7], with the following main assumption:

- Failure has potential for a loss of plasma operations for long period or has impact on machine operation activities /performances: a failure of cryogenic instruments on CDB or CCA (T sensors, valves) requires days or weeks of warmup and venting. All cryogenic safety devices are on CDB. Leaks on ITL would probably not be compatible with operation and require long-term maintenance.

The detailed calculation of quality class can be found in APPENDIX 1.

[1] The radioactivity for Tritium needs to be divided by 1000 according to Art.2 of the ESPN.

5 Detailed DMS cryogenic system classification

5.1 Cryogenic transfer line networks (from PBS31 CVB to DMS Cold Distribution Boxes)

Please see scope in P&IDs, [RD1], [RD2], [RD3], [RD4].

Please note that classification of the cryogenic transfer lines was not updated since they are already manufactured and partially installed. In particular they include a SIC-2 classification for the building penetration (second confinement system for tritium).

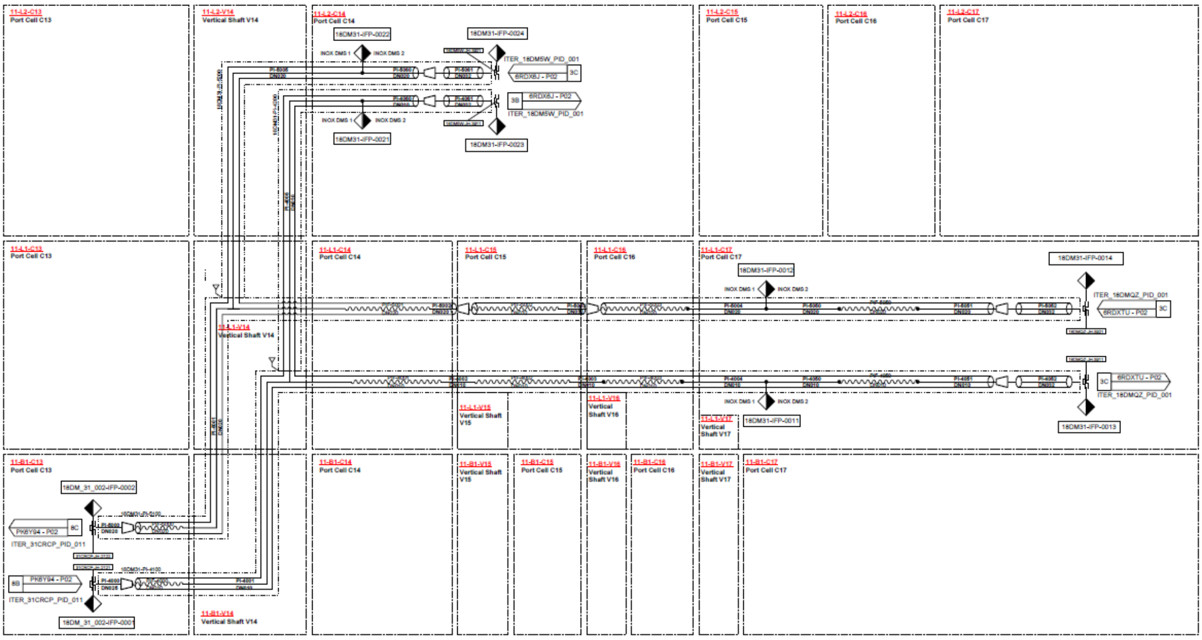

Figure 9 Example of Network 1 transfer line P&ID, from [RD1].

Table 1: Cryogenic transfer line networks classification from [RD17].

Cryogenic networks						
	Safety class	Quality class	Seismic class	Vacuum quality class	PED class	Tritium class
Max Classification	PIC/ SIC-2	QC-1	SC1(S)	VQC-4	Piping gas group 2, Art 4.3	TC NA
Cryogenic pipes and joints/couplings (DN≤32), inside OVJ.	SR	QC-1	SC1(S)	VQC-4A	Piping gas group 2, Art 4.3	TC NA

Outer Vacuum jacket (OVJ) (pumped by CGVS or non-Active SVS) including bellows, vacuum barriers (except L3 HV Deck) and vacuum protection devices.	SR	QC-1	SC1(S)	VQC-4A	PED NA	TC NA
Building interfaces, external supports/hangers, penetration sealing (except L3 HV Deck)	SR	QC-1	SC1(S)	VQC-NA	PED NA	TC NA
L3 HV Deck penetration sealing, vacuum barrier, support and hangers	PIC/ SIC-2	QC-1	SC1(S)	VQC-NA	PED NA	TC NA
Vacuum accessories (flanges, hoses, valves and clamps)	NON PIC/SIC	QC-2	SC2	VQC-4A	PED NA	TC NA

5.2 Intermediate Transfer Lines (ITL) and Disconnection Transfer Lines (DTL)

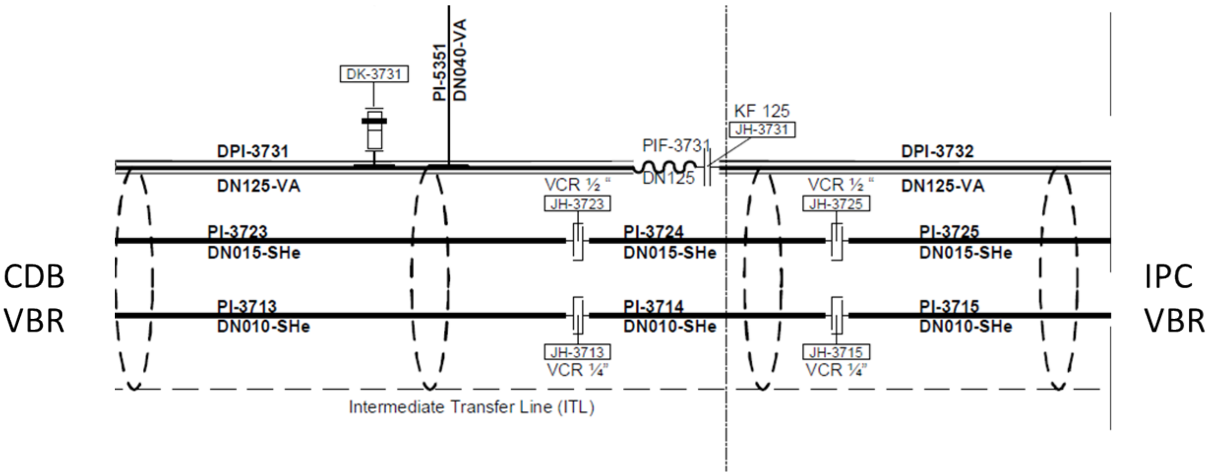

Figure 10: ITL P&ID, extract from [RD5].

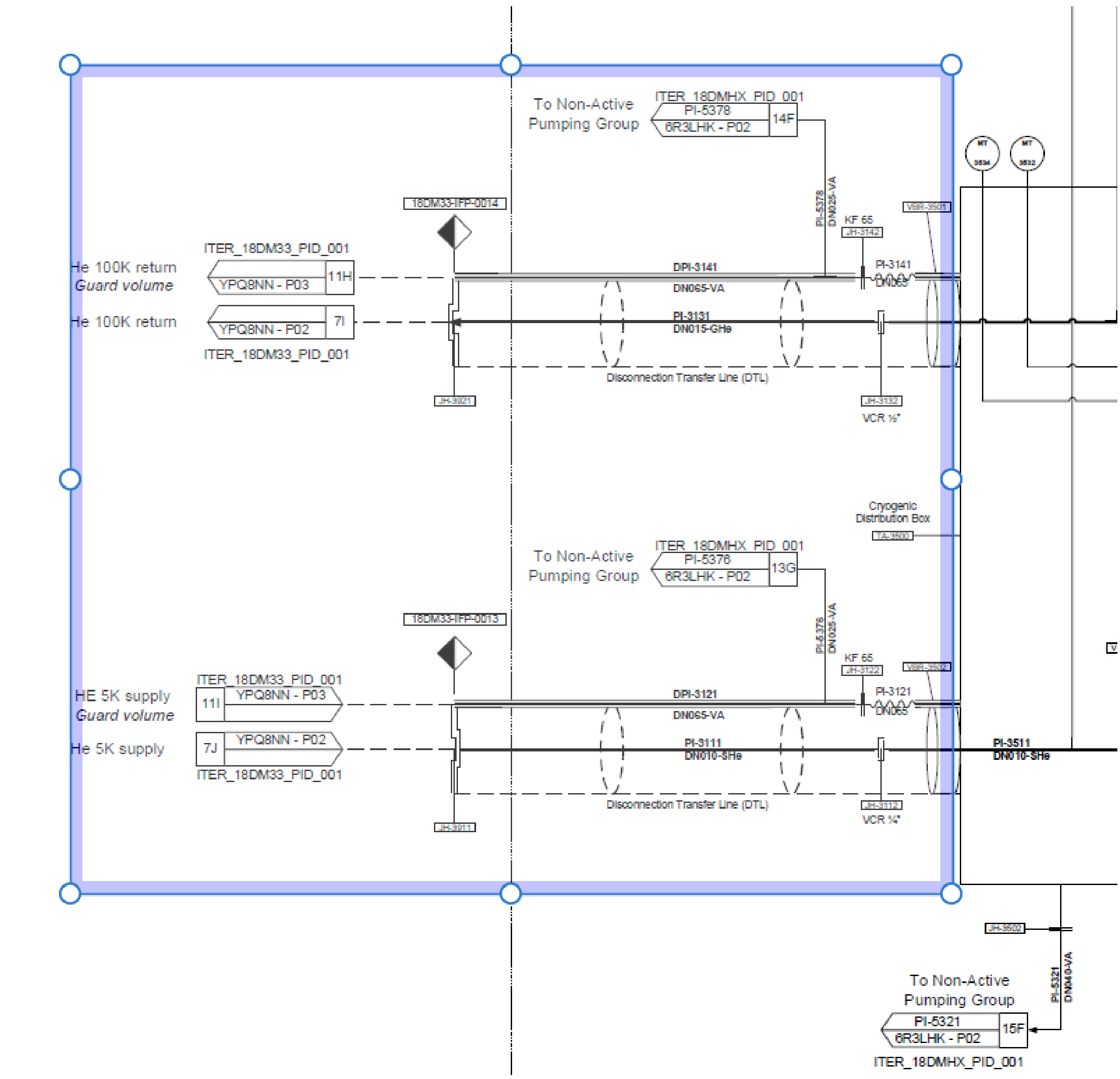

Figure 11: DTL P&ID, extract from [RD5].

ITL + DTL + support						
	Safety class	Quality class	Seismic class	Vacuum quality class	PED class	Tritium class
Max Classification	SR	QC-2	SC1	VQC-3	Piping gas group 2, Art 4.3	TC NA
Cryogenic pipes and joints/couplings (DN≤32), inside OVJ.	SR	QC-2	SC1(S)	VQC-4A	Piping gas group 2, Art 4.3	TC NA

Outer Vacuum jacket (OVJ), connected to non-Active SVS, including bellows and vacuum protection devices.	Non-PIC/SIC	QC-2	SC2	VQC-3A	PED NA	TC NA
Structural supports, inside or outside vacuum (to PCSS or ISS) and bellow protection.	Non-PIC/SIC	QC-2	SC2	VQC-NA VQC4-B, if inside vacuum	PED NA	TC NA

5.3 Cold Distribution Boxes (CDB)

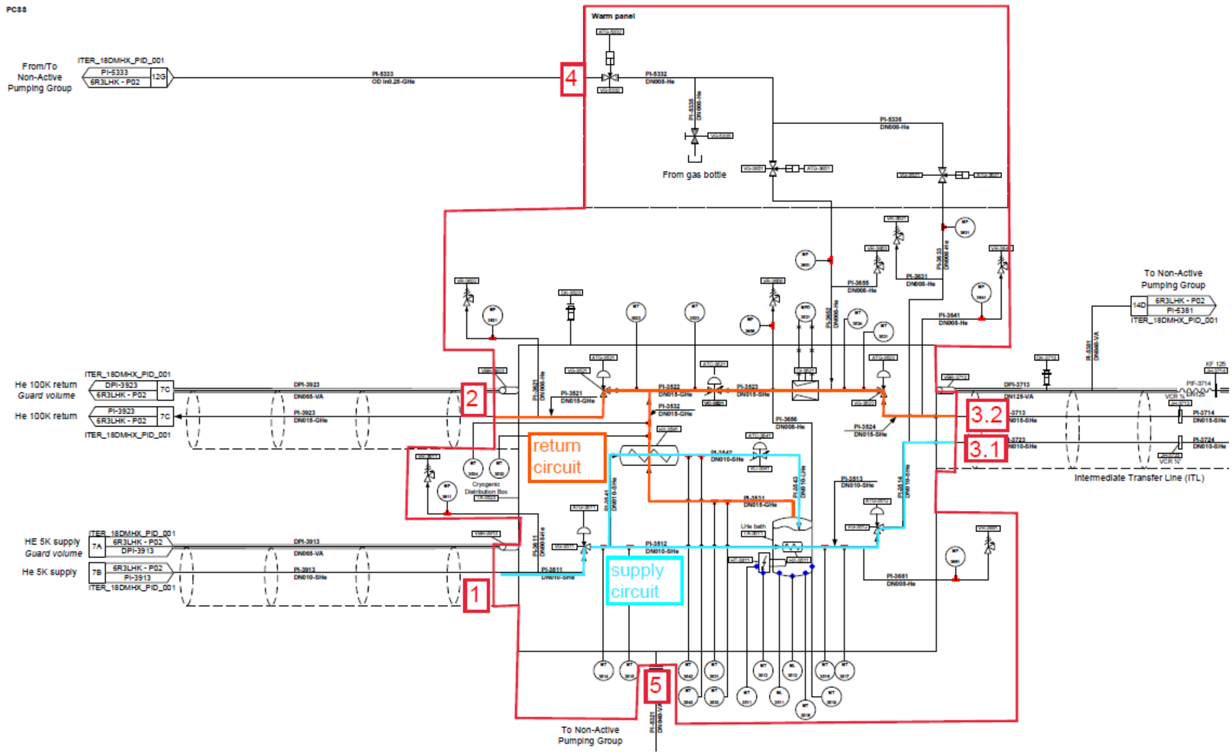

Figure 12: Marked-up P&ID of the CDB, with highlighted boundary and interfaces, extracted from [RD5].

CDB						
	Safety class	Quality class	Seismic class	Vacuum quality class	PED class	Tritium Class
Max Classification	SR	QC-1	SC1(S)	VQC-3	Gas group 2, Cat. III (Cat. IV for safety devices)	TC NA
Cryogenic pipes and valves (DN≤32), Venturi nozzle, relief and pressure sensor pipes inside vacuum guard vessel, submerged LHe heat exchanger.	SR	QC-1	SC1(S)	VQC-4A	Piping gas group 2, Art 4.3	TC NA
Joule Thompson heat exchanger	SR	QC-1	SC1(S)	VQC-4A	Vessel gas group 2, Cat I.	TC NA

Liquid helium vessel and its supports	SR	QC-1	SC1(S)	VQC-4A	Vessel gas group 2, Cat III.	TC NA
Cryogenic overpressure protection devices.	SR	QC-1	SC1(SF)	VQC-NA	Piping gas group 2, Cat IV.	TC NA
Vacuum guard vessel connected to non-Active SVS, including vacuum protection device.	Non-PIC/SIC	QC-1	SC2	VQC-3A	PED NA	TC NA
Instrumentation (T, p, level) valve actuators, pilots, switches.	Non-PIC/SIC	QC-2	SC2 (for valve actuators only)	VQC-NA VQC4-B, if inside vacuum.	PED NA	TC NA
Structural supports, inside or outside vacuum (to PCSS)	Non-PIC/SIC	QC-1	SC2	VQC-NA VQC4-B, if inside vacuum	PED NA	TC NA
Pipes and warm panel valves, outside vacuum guard vessel	Non-PIC/SIC	QC-2	NSC	VQC-NA	Piping gas group 2, Art 4.3	TC NA

5.4 Cold Cell Assembly (CCA) and Injectors Prismatic Cryostat (IPC)

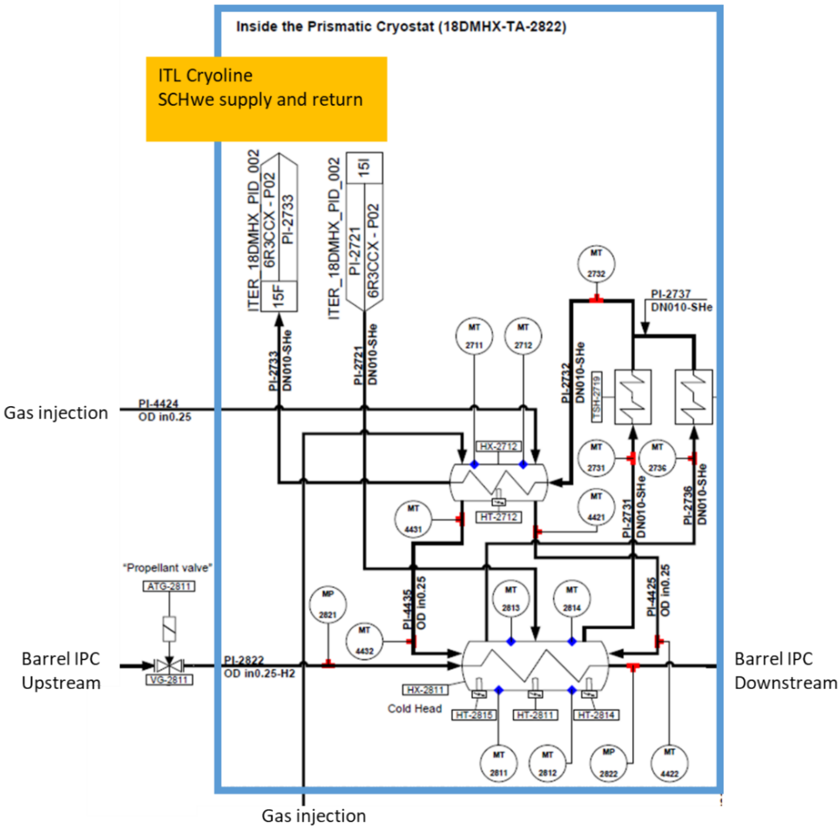

Figure 13: CCA and IPC marked-up P&ID, extracted from [RD6].

CCA + IPC						
	Safety class	Quality class	Seismic class	Vacuum quality class	PED class	Tritium class
Max classification	PIC/ SIC-2	QC-1	SC1(S)	VQC-1	Gas group 1 or 2, Art 4.3	
Cryogenic pipes, joints (DN≤32), inside IPC	SR	QC-1	SC1(S)	VQC-4A	Piping gas group 2, Art 4.3	TC NA
Cold Cell, gradient control heat exchangers	SR	QC-1	SC1(S)	VQC-4A	Vessel gas group 2, Art 4.3	TC NA

Pellet gas (H2, Ne) pipes and joints (DN≤25), from IPC to pre-cooler and pre-cooler to acceleration tube.	PIC/ SIC-2	QC-1	SC1(S)	VQC-1A	Piping gas group 1, Art 4.3	TC-1A
Gas pre-cooler heat exchanger	PIC/ SIC-2	QC-1	SC1(S)	VQC-1A	Vessel gas group 1, Art 4.3	TC-1A
Acceleration tube (from propellant valve to acceleration tube exit), and its pressure gauges.	PIC/ SIC-2	QC-1	SC1(S)	VQC-1A	Vessel gas group 1, Art 4.3	TC-1A
Bellow (between acceleration tube and IPC)	PIC/ SIC-2	QC-1	SC1(S)	VQC-1A	PED NA	TC-1A
IPC vessel connected to Active SVS, including vacuum protection device, feedthroughs.	Non-PIC/SIC	QC-1	SC2	VQC-3A	PED NA	TC-1B
Instrumentation (T), electric heaters	Non-PIC/SIC	QC-2	NSC	VQC4-B	PED NA	TC NA
Structural supports, inside or outside vacuum (to ISS).	Same class as supported system.	QC-1	Same class as supported system	VQC4-B (if inside vacuum)	PED NA	TC NA

6 APPENDIX 1: QC determination spreadsheets

Please find below the classification calculation in agreement with the methodology of [RD7]. The classification methodology is presented for the highest classified SSCs for each subsystem, knowing that a lower classification can be justified for some SSCs.

6.1 Cryogenic transfer line networks (from PBS31 CVB to DMS Cold Distribution Boxes)

The Quality classification was inherited from [RD17].

6.2 Intermediate Transfer Lines (ITL) and Disconnection Transfer Lines (DTL)

	Factor type	Associated Risk	FQC	coefficient	Comment
F1QC	Functional and operational	Failure has potential for a loss of plasma operations for long period or has impact on machine operation activities /performances.	1	1.5	A failure of cryo system (leak) requires days or weeks of warmup and venting.
F2QC	Environment, industrial safety and health	Failure has potential for: (1) minimal impact on the health and safety of the public or a worker, such as injury or illness requiring minor supportive treatment but not requiring hospitalization, or (2) a negligible impact on the environment.	3	1.5	Small leaks of Helium considered
F3QC	cost and schedule impacts	Failure has potential for a financial loss less than 500K Euro and no impact on construction schedule.	3	1.5	
F4QC	compliance	Failure has potential for minor non-compliance with established management practices.	3	0.75	
F5QC	other classifications	The SSC has other classifications: PIC /SIC 2 or SR / seismic class 2 / vacuum class 2 / tritium class 2.	2	0.75	
F6QC	design complexity	The design efforts is normal, it involves different disciplines and independent validation of the design.	2	0.5	
F7QC	complexity of manufacturing	The product has critical characteristics and the fabrication requires normal processes, normal fabrication technologies and qualified personnel that are involved in manufacturing process.	2	0.5	
			Quality class	2	2.321428571

6.3 Cold Distribution Boxes (CDB)

	Factor type	Associated Risk	FQC	coefficient	Comment
F1QC	Functional and operational	Failure has potential for a loss of plasma operations for long period or has impact on machine operation activities /performances.	1	1.5	A failure of cryo system (T sendors, valve) requires days or weeks of warmup and venting. All safety devices are on CDB
F2QC	Environment, industrial safety and health	Failure has potential for: (1) injury or illness requiring hospitalization, temporary or partial disability, or (2) moderately adverse impact on the environment or health or safety of a worker or the public.	2	1.5	Pressure equipment failure can have dangerous consequences
F3QC	cost and schedule impacts	Failure has potential for a financial loss less than 500K Euro and no impact on construction schedule.	3	1.5	
F4QC	compliance	Failure has potential for non-compliance with established IO management practices and procedures.	2	0.75	
F5QC	other classifications	The SSC has other classifications: PIC /SIC 2 or SR / seismic class 2 / vacuum class 2 / tritium class 2.	2	0.75	
F6QC	design complexity	The design efforts is normal, it involves different disciplines and independent validation of the design.	2	0.5	
F7QC	complexity of manufacturing	The product has critical characteristics and the fabrication requires normal processes, normal fabrication technologies and qualified personnel that are involved in manufacturing process.	2	0.5	
			Quality class	1	2

6.4 Cold Cell Assembly (CCA) and Injectors Prismatic Cryostat (IPC)

	Factor type	Associated Risk	FQC	coefficient	Comment
F1QC	Functional and operational	Failure has potential for a loss of plasma operations for long period or has impact on machine operation activities /performances.	1	1.5	A failure of cryo system (T sentos, heater) requires days or weeks of warmup and venting and repair
F2QC	Environment, industrial safety and health	Failure has potential for: (1) minimal impact on the health and safety of the public or a worker, such as injury or illness requiring minor supportive treatment but not requiring hospitalization, or (2) a negligible impact on the environment.	3	1.5	Small leaks of Helium considered
F3QC	cost and schedule impacts	Failure has potential for a financial loss less than 500K Euro and no impact on construction schedule.	3	1.5	
F4QC	compliance	Failure has potential for non-compliance with established IO management practices and procedures.	2	0.75	
F5QC	other classifications	The SSC has other classifications: PIC/ SIC 1 or PIC/ SIC 2 or SR/ seismic class 1/ vacuum class 1/tritium class 1	1	0.75	
F6QC	design complexity	The design requires multiple discipline, interfaces, complex verifications, independent validation of the design and special software and models.	1	0.5	Special software, gas dynamics, cryo, thermal, phase change
F7QC	complexity of manufacturing	The product has multiple critical characteristics and fabrication requires multiple number of manufacturing processes, special process, complex technologies and high qualified personnel that is involved in manufacturing process	1	0.5	Brazing, welding, machining
			Quality class	1	1.964285714