

Technical Specifications (In-Cash Procurement)

**Technical specification for IBED PHTS heater 26PHBD-
HT-1000**

This is a Technical specification for IBED PHTS heater 26PHBD-HT-1000

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1 Preamble

This Technical Specification is to be read in combination with the General Management Specification for Service and Supply (GM3S) – ref. [25] that constitutes a full part of the technical requirements.

In case of conflict, the content of the Technical Specification supersedes the content of ref.[25].

2 Purpose

The purpose of the Services described in this Specification is to provide the design, fabrication, inspection, examination, testing, preparation for delivery and shipment of an electrical heater, 26PHBD-HT-1000.

The Contractor shall take all the necessary provisions to comply with the requirements imposed by the PED [1] and ESPN [3]. In case of non-conformity or in case of divergence of interpretation between the provision of this technical specification and the Regulation, the Contractor is requested to ask the IO for decision.

3 Acronyms & Definitions

3.1 Acronyms

The following acronyms are the main one relevant to this document.

For a complete list of ITER abbreviations, see ref. [26].

Table 1 – list of abbreviations

Abbreviation	Description
ACP	Activated Corrosion Products
ASME	American Society of Mechanical Engineers
B&PV	Boiler & Pressure Vessel
BLK	BLanKet
CAD	Computer Aided Design
CCPR	Components contributing to the pressure resistance
CCWS	Component Cooling Water System
CFD	Computational Fluid Dynamics
CVCS	Chemical & Volume Control Systems
DIV	DIVertor
DN	Nominal Diameter

DNRE	Dimensions Necessary for Compliance with regulatory requirements
ELM	Edge Localized Mode
EP	Embedded Plate
ESP	Equipement Sous Pression (Pressure Equipment)
ESPN	Equipement Sous Pression Nucléaire (Nuclear Pressure Equipment)
ESR	Essential Safety Requirement of the applicable regulation
FW	First Wall
GM3S	General Management Specification for Service and Supply [25]
HRA	Hazard and Risk Analysis
IDM	ITER Document Management (system)
IO	ITER Organization
ITER	International Thermonuclear Experimental Reactor
IBED	Integrated loop of Blanket, ELM-VS, and Divertor PHTS
KoM	Kick off Meeting
MPBP	Main Pressure Bearing Parts
MRR	Manufacturing Readiness Review
NPMA	Nuclear Particular Material Appraisal
OP	Other Parts
PED	Pressure Equipment Directive
PHBD	Primary Heat Transfer System for IBED
PHTS	Primary Heat Transfer System
PIA	Protection Important Activity
PIC	Protection Important Component
PP	Pressurized parts
PZR	Pressurizer
QA	Quality Assurance
QC	Quality Class
SIC	Safety Important Component
SMDD	System for the Management of Diagrams and Drawings
TCWS	Tokamak Cooling Water System
VS	Vertical Stabilization
VV	Vacuum Vessel

3.2 Definitions

ANB: Notified Body approved by ASN to perform the conformity assessment of NPE.

As Low as Reasonably Achievable (ALARA): means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Contract: An all-inclusive term used to cover all legal obligations between the IO and the Contractor for the performance of part or whole work defined in the present document. These obligations are enforceable immediately at its date of entry into force, including any amendment(s). Refer to contract conditions for more details.

Contractor: Economic operator who have signed the Contract in which this document is referenced. The Contractor is responsible for the performance of a portion of the work or the whole work defined in the present document.

Contractor's Premises: Any location, apart from the Site, where the Contractor or Subcontractors carry out any work defined in the present document.

Delivery Location: Location specified by the IO where the supplies will have to be delivered by the Contractor.

Documentation: The procedures, test reports, certifications, manuals, instructions, and other data specified to be delivered by the Contractor.

Nuclear Particular Material Appraisal (EPMN French Acronym): Specific Assessment of Nuclear Material. - French Environmental Code article L557 and R557 ref.[2], concerning equipment at risk which is a transposition of PED (2014/68/UE) ref. [1].

French ESPN Order related to NPE: French Order dated 30 December 2015 concerning nuclear pressure equipment ref. [3]. The ESPN follows a pressure classification and conformity assessment procedure that is in many cases based on PED assessment modules. It is the responsibility of the Manufacturer to comply with all requirements of this Order.

Heat: a generic term denoting a specific lot of steel, based up on steelmaking and casting considerations.

Heat number: the alpha, numeric, or alphanumeric designator used to identify a specific heat of steel.

INCOTERM Named Place: A location specified for the collection/delivery location of the goods.

ITER Organization (IO): As used in this specification, IO is the owner and Operator of the ITER research facility.

ITER Site: ITER construction site located at the following address: ITER WORKSITE RD 952-Entrée Nord - CS 80 001 -13066 Saint Paul les Durance Cedex. –

Manufacturer: The Manufacturer is the Legal entity to which the Contract is awarded and to which the supply order is addressed. It is also called “Contractor”. The Manufacturer is the legal entity which assumes responsibility for the design and manufacture of a product to be marketed under its name or trademark following [1] and [3].

Notified Body (NB): Technical organization approved in an EU state, either for approval and monitoring of the Manufacturer’s quality assurance system or for direct product inspection.

Nuclear Regulatory Authorities/ Nuclear Regulator: referred to in this Specification are mainly MSNR (Office of the Ministries in charge of nuclear safety and radioprotection), ASN Autorité de Sûreté Nucléaire, French Nuclear regulator) and its technical support IRSN (Institute of nuclear safety and radioprotection).

Operator: the IO is the Operator of the IBED PHTS heaters. For nuclear pressure equipment, the Operator is the person holding the permission of creation of the nuclear basic installation in which the nuclear pressure equipment is installed or intended to be installed.

Plant Breakdown Structure (PBS): The PBS is the hierarchical breakdown of the ITER Plant into distinct ITER elements. The PBS identifies the links between parent/child elements, so that there is only one rooting between a parent element and one of its child elements (and vice versa).

Pressure Equipment Directive (PED): European Directive 2014/68/UE related to Pressure Equipment

Product: Any type of deliverable, goods and services resulting from the Technical Specification.

Protection Important Component (PIC): component important for protecting the interests of public security (including nuclear safety, radioprotection and prevention and fight against malevolent acts and civil security actions in the case of an accident), health and sanitation, the protection of nature and of the environment, i.e. any structure, equipment, system (programmed or not), material, component or software that is present in the basic nuclear installation or that is under the responsibility of the nuclear operator and that implements a function required for the demonstration mentioned under the second paragraph of Article L. 593-1 of the Environmental Code or that ensures that this function is implemented per articles 1.3 and 2.5.1 of Order 7th February 2012 ref. [4].

Quality Assurance Program: A controlled system of planned and systematic actions required to provide adequate confidence that an item designed and constructed is in accordance with Code requirements. - **Quality Assurance Manual:** A written document that describes a Quality Assurance Program.

Safety Importance Class (SIC): a classification scheme for structures, systems, and components of ITER that perform a safety function and contribute towards meeting the General Safety Objectives at IO during incident/ accident situations.

Subcontractor: An entity furnishing services, materials, or components required to perform the work to the Contractor.

Supplier: See definition of “Contractor”.

Supply Order: Instrument produced by the IO to request supplies from the Contractor. Refer to contract conditions for more details.

Third Party: Is someone who may be indirectly involved but is not a principal party with a vested interest in carrying out the requirements of this Specification.

4 Applicable Documents & Codes and standards

4.1 Applicable Documents

The following documents are to be respected on the understanding that they prevail on each other in the following order:

- Decrees and Ministerial Orders,
- Standards and Rules whose application has been made mandatory by a Ministerial decision.
- Specific quality rules from the IO
- Standards and Rules whose application has not been made mandatory by a Ministerial decision.

In the case where the codes, standards and the relevant regulations would be modified after the base date of the economic conditions of this contract, the Manufacturer has the obligation to inform IO immediately to define by mutual agreement the following decision to take.

This is the responsibility of the Contractor to identify and request for any documents that would not have been transmitted by IO, including the below list of reference documents.

In case of conflicting information, this is the responsibility of the Contractor to seek clarification from IO.

Upon notification of any revision of the applicable document transmitted officially to the Contractor, the Contractor shall advise within 4 weeks of any impact on the execution of the contract. Without any response after this period, no impact will be considered.

4.1.1 Applicable Regulations Requirements

- [1]. Directive 2014/68/UE of the European Parliament and Council dated 15 May 2014 on the harmonization of the laws of the member states relating to the market availability of pressure equipment (PED)
- [2]. French Regulation for Pressure Equipment (ESP) (transposition of PED in French law), French Environmental Code, Articles L557 and R557,
- [3]. French Order dated 30 December 2015 on Nuclear Pressure Equipment (ESPN), modified by order dated 03 September 2018
- [4]. French Order dated 7 February 2012 setting the general rules relative to basic nuclear installations.

4.1.2 Applicable Reference Codes and Standards

For each European standard, the latest version issued by the European Committee for Standardization on the date of contract notification is applicable.

- [5]. ASN Guide No. 8, Conformity Assessment of Nuclear Pressure Equipment
- [6]. ASN Guide No. 19, Application of the order of the 12 December 2005 relative to the nuclear pressure equipment
- [7]. ASME Boiler and Pressure Vessel Code, Section VIII, Rules for the Construction of Pressure Vessels, Division 2 — Alternative Rules, ASME BPVC.VIII.2-2017
- [8]. EN 13445:2021 -part 1 to part 5 - Unfired pressure vessels
- [9]. EN 13555:2021 – Flanges and their joints – Gasket parameters and test procedures relevant to the design rules for gasketed circular flanges.
- [10]. EN1591-1:2014 flanges and their joints. Design rules for gasketed circular flange connection. Calculation Method
- [11]. RCC-M 2012, Annex F-III – water quality
- [12]. Quality Assurance Requirements for Nuclear Facility Applications, ASME NQA-1 2017
- [13]. Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard, ASME B16.5-2020

- [14]. Stainless Steel Pipe, ASME B36.19M-2018
- [15]. Metallic Products—Types of Inspection Documents, EN 10204:2005
- [16]. Standard Practice for Cleaning, Descaling, and Passivation of Stainless-Steel Parts, Equipment, and Systems, ASTM A380/A380M 17
- [17]. Test Uncertainty, ASME PTC 19.1-2018
- [18]. NF EN ISO 9712:2022 “Non-Destructive Testing – Qualification and Certification of NDT Personnel”
- [19]. EN 1991-1-2: 2004 “Eurocode 1: Actions on structures – Part 1-2: General actions – Actions on structures exposed to fire”
- [20]. EN 13501-2:2018 – Fire Classification of construction products and buildings elements – part 2: classification using data from fire resistance tests, excluding ventilation services
- [21]. EN 1779:1999 – Leak Testing Criteria for method and technique selection
- [22]. International Chamber of Commerce (ICC). Incoterms® 2020. ICC Publication No.723, 2020 Edition
- [23]. CLAP Files - <https://www.afiap.org/informations-clap>
- [24]. COLEN Files - <https://www.aquap.org/fr/colen/fiches-colen>

4.1.3 Applicable Documents

The documents addressing general requirements presented in the chapter 3 of General Management Specification for Service and supply ref. [25] are all applicable for this Technical Specification and are not recalled in this chapter.

- [25]. General Management Specification for Service and Supply, [ITER_D_82MXQK v1.4](#)
- [26]. ITER Abbreviations, [ITER_D_2MU6W5 v1.18](#)
- [27]. ITER Quality Assurance Program (QAP), [ITER_D_22K4QX v8.5](#)
- [28]. Project Requirements, [ITER_D_27ZRW8 v6.3](#)
- [29]. Safety Requirement Room book, [ITER_D_KF63PB v2.11](#)
- [30]. Defined Requirement for PBS26, [ITER_D_M369M3 v2.1](#), (Section 6.2.1 only)
- [31]. Overall Surveillance Plan of External Interveners Chain for Protection Important Components, Structures and Systems and Protection Important Activities, [ITER_D_4EUQFL v7.4](#)

- [32]. Surveillance Plan for PBS 26 - Cooling Water System , [ITER_D_CAJTAL v3.1](#)
- [33]. Safety Important Functions and Components Classification Criteria and Methodology, [ITER_D_347SF3 v1.8](#)
- [34]. Annex 2 - Detailed list of PIAs, [ITER_D_Q8B5C4 v1.2](#)
- [35]. Propagation of the Defined Requirements for Protection Important Components Through the Chain of External Interveners, [ITER_D_BG2GYB v3.3](#)
- [36]. System Requirement (SRD) Document SRD-26-PH,-CV,-DR,-DY (TCWS) from DOORS, [ITER_D_2823A2 v6.5](#)
- [37]. SRD-26-CC (CCWS) from DOORS, [ITER_D_2DVV9N v4.3](#)
- [38]. Requirements for Producing an Inspection Plan, [ITER_D_22MDZD v3.7](#)
- [39]. ITER Radiation Protection Professional Guidelines for the Nuclear Pressure Equipment in Application of Order dated 12 December 2005, [ITER_D_2LTQ96 v2.3](#)
- [40]. Allowable Values and Limits in Service Level C and D of ITER Mechanical Components, [ITER_D_3G3SYJ v3.1](#)
- [41]. Codes and Standards for ITER Mechanical Components, [ITER_D_25EW4K v4.0](#)
- [42]. Chemical composition and impurity requirements for materials, [ITER_D_REYV5V v3.1](#)
- [43]. Proposal of new impurity controls requirements for PBS26, [ITER_D_9LPHJE v3.0](#)
- [44]. Pressure equipment - ASME austenitic steel 1% yield strength for allowable stresses as per DESP 2014/68/UE and decree 30/12/2015, [ITER_D_26PNE4 v3.0](#)
- [45]. Quality Classification Determination, [ITER_D_24VQES v5.2](#)
- [46]. TCWS Load Specification, [ITER_D_SZE5MR v2.6](#)
- [47]. Fluid radioactivity concentration for the ITER Tokamak Cooling Water System, [ITER_D_26GLXV v2.4](#)
- [48]. Radmap Mode-0 (DT1/DT2): Maximum dose rate values per room, [ITER_D_E2RNZF v1.0](#)
- [49]. Anticipated use of 2020 radiation maps for TCWS major components, [ITER_D_4655X7 v1.0](#)
- [50]. Residual radioactivity source terms to be used for contamination analysis of TCWS cooling pump maintenance scenario, [ITER_D_WMDG88 v1.3](#)
- [51]. PBS26 Secondary and Tertiary Tritium Contamination, [ITER_D_ASU4V6 v1.0](#)

- [52]. Allowable leakage rate of the CCWS-1 and CCWS-1A clients, [ITER_D_RWGKT9 v2.3](#)
- [53]. Assessment of TCWS effluents, influents, and chronic leaks, [ITER_D_U7YB3K v4.0](#)
- [54]. Collection of Input Data to support Qualification Plan in charge of TCWS electro-mechanical equipment supplier, [ITER_D_YST3YH v2.3](#)
- [55]. TOKAMAK_COMPLEX_MAGNETIC_FIELD_L4, [ITER_D_2MS9EV v4.1](#)
- [56]. Guideline of Common Mode Failure (CMF) protections in TKM, [ITER_D_X2ZCJS v3.1](#)
- [57]. Design Seismic Floor Response Spectra in the Tokamak Complex, [ITER_D_SVBRJZ v1.1](#)
- [58]. IBED PHTS System Sizing Calculation, [ITER_D_PAVZLW v4.0](#)
- [59]. TCWS IBED PHTS System Process Loading Conditions, [ITER_D_YQCUY5 v2.1](#)
- [60]. Piping and Instrumentation Diagram (P&ID) IBED Primary Heat Transfer System (PHTS), [ITER_D_SNJ3LL v5.0](#)
- [61]. TCWS pressure vessels ESPN classification & ESP categorization, [ITER_D_XP4AFC v1.14](#)
- [62]. PBS26 IBED PHTS Pressure Vessels ESPN Classification, [ITER_D_UXKBZL v1.4](#)
- [63]. TCWS IBED PHTS Design Condition Calculation, [ITER_D_S2KSZ9 v3.3](#)
- [64]. Template for PE/NPE Nameplate, [ITER_D_Y3AZ83 v3.0](#)
- [65]. Software Qualification Policy, [ITER_D_KTU8HH v2.0](#)
- [66]. Gap analysis ASME VIII div.2 / DESP-ESPN requirements, [ITER_D_3E5HKQ v2.0](#)
- [67]. TCWS Piping & Equipment: Proof + Requalification Tests, [ITER_D_YC3UR5 v4.0](#)
- [68]. Report on the effect of cold work on the corrosion behaviour of 316L(N)-IG steel, [ITER_D_G5MDGV v2.0](#)
- [69]. Construction Design - PBS 62.11 - Tokamak Building – Calculation Report – Welding on Embedded Plates - ENG_50_CR_110225_CW, [ITER_D_YU29TG v1.0](#)
- [70]. Construction Design - PBS 62.11 - Tokamak Building – Technical Report - Recommendations for Welding on Embedded Plates - ENG_50_TR_110034_CW, [ITER_D_YUDA68 v2.0](#)
- [71]. Construction Design - PBS 62.11, 62.14 and 62.74 - Tokamak complex - Design Catalogue of Cast-in-Place Fastening Systems - Structural Calculation Note - ENG_50_CR_110002_CW, [ITER_D_AJSMNW v5.0](#)

- [72]. Tokamak Complex-L3 Level Construction Design Tolerances IO-PBS, [ITER_D_S939RJ v1.0](#)
- [73]. Platform L4 Vault Platform14 16 17 – FRS, [ITER_D_5UAZ7Z v1.0](#)
- [74]. Technical Specification for LV Electrical Cubicle and Systems for IBED PHTS, NBI PHTS & CVCS, [ITER_D_Y4YGUZ v2.0](#)
- [75]. Quality Requirements for IO Performers, [ITER_D_22MFG4 v6.4](#)
- [76]. Radiation Maps During Plasma Operations (Mode-0), [ITER_D_RJLLFY v2.1](#)
- [77]. Instructions for Structural Analyses, [ITER_D_35BVV3 v4.1](#)
- [78]. Instructions for the Storage of Analysis Models, [ITER_D_U34WF3 v2.0](#)
- [79]. Instructions for Seismic Analyses, [ITER_D_VT29D6 v2.1](#)

5 Scope of work

This document states the technical requirements for the material supply, design, fabrication, inspection, examination, testing, preparation for delivery and shipment of one baking heater (tag number 26PHBD-HT-1000) and control cubicles.

The Contractor as Manufacturer is the legal entity which assumes responsibility for the design and manufacture of the IBED PHTS baking heater to be marketed under its name or trademark following [1] and [3]. The Contractor shall hire an ANB to ensure the conformity assessment of the nuclear pressure equipment under module G.

The Contractor is responsible for the design, the supply, and the manufacturing of:

- 1 baking heater with all their constitutive elements (shell, heads, nozzles, flanges, counter flanges, bolts, gaskets)
- The supports
- The manifolds and primary tees to be welded to the heater, if any
- The handling devices for the inspection openings
- The liftings lugs and trunnions
- The transport supports.
- The counter plates, bolts, and shims
- The nameplate and its supports
- The insulation and insulation support.
- The grounding
- The tapes, gaskets, and all temporary devices for the hydrostatic test.

The services to be provided under the contract are the following:

- The design studies including ANSYS FEM models with output results and associated documentation,
- The required documentation including all the documentation following PED and ESPN requirements from the design to the commissioning to be approved first by the IO (including HRA, ESR, DNRE drawings, in-service inspection drawings and instruction manuals) as well as the final Declaration of Conformity.
- The delivery of materials following the requirements defined in the NPMA and material purchase specification,
- The manufacture and associated controls,
- The insulation qualification and supply
- The regulatory hydrostatic tests in workshop,
- The packaging for the transport from the Contractor's premises to IO site,
- A storage procedure,
- An installation manual (including the recommended equipment), assembly, adjustment, connection, and commissioning.

5.1 Scope of Supply

5.1.1 Description

5.1.1.1 IBED PHTS System (global)

The IBED PHTS is a pressurized, closed-loop cooling water system with the primary function to provide cooling water to the plasma facing components (blanket modules and divertor cassettes) within the vacuum vessel. It also provides cooling water to the Edge Localized Modes (ELMs) and Vertical Stabilization (VS) coils and to the various clients in the upper, equatorial, and lower ports.

IBED PHTS baking heater is located at the L4 Building 11.

The IBED PHTS supplies cooling water to five cooling loops (3 FW/BLK, 1 Divertor (DIV), and 1 Equatorial Port) with a common set of eight parallel primary pump/heat exchanger trains.

These parallel cooling trains are connected to a common supply and return header that feeds the five cooling loops. Each primary train contains a heat exchanger (shell-and-tube type), and one main pump. Heat extracted from the IBED PHTS is rejected to the Heat Rejection System through the CCWS-1 loop. In addition to the eight primary cooling trains, there is a separate baking train which contains a baking heater, a baking cooler, a baking pump, and associated piping and valves.

The IBED PHTS piping, and components provide the primary confinement for radioactive material and must maintain leak-tight integrity during all operating modes. IBED PHTS is located inside the TCWS vault at B11 L4 and 11-L3-02E "TCWS East Area" providing the second confinement. The IBED PHTS is equipped with a pressurizer (PZR) in combination with a Chemical and Volume Control System (CVCS) to control system pressure and water volume during operations. The IBED PHTS PZR is located on the hot leg of the system, upstream of the main heat exchangers and pumps. Connections are provided to the CVCS to control water chemistry within the system. Connections to allow for draining, refilling, drying, and gas baking are also provided.

5.1.1.2 IBED PHTS baking heater (26PHBD-HT-1000)

The IBED PHTS Baking Heater (26PHBD-HT-1000) is used during baking mode of operation (cleanup of non-hydrogenic impurities from the vacuum chamber by maintaining the IBED PHTS baking temperature), during heat up the system to operating temperature and during standby mode, if needed (to maintain normal operating temperature at the inlet of IBED PHTS components). The scope of the HT supply also includes four control cubicles, as per [74]. The classifications parameters are summarized in the table below.

Table 2 – IBED PHTS baking heater Parameters.

No.	Classification/Parameter	Source
1	Pressure Category IV	Ref. [61]
2	ESPN level 3 – N3	Ref. [62]
3	Fluid Group 2	Ref. [62]
4	Safety Important Class 1 SIC-1 ^a	Ref. [33]; [46]
5	Fluid Type — Gas ^b	Ref. [62]
6	Seismic Classification of SC1(S) ^c	Ref. [33]; [46]
7	Quality Class 1 – QC-1	Ref. [63]
8	No code stamp ^d	Ref. [3]

^a For confinement only.

^b Fluid is demineralized water. But because the max allowable temperature is above the saturation temperature at 0.15 MPa, fluid type is “gas” for PED classification.

^c SC1 (S), Structural stability maintained in the event of an earthquake.

^d Nameplate shall have an ANB stamp.

5.1.2 Process Requirements

5.1.2.1 The process requirements for the 26PHBD-HT-1000 are the following:

Parameter	Value
Heater Power (kW)	3960
Design temperature (°C)	270
Design pressure (MPa)	5.0
Inlet temperature max (°C)	240
Inlet temperature min (°C)	20
Nominal inlet pressure (MPa)	3.6
Allowable pressure drops (MPa)	< 0.15
Heater voltage (V) Phase (-)/Cycle (Hz)	400/3/50
Mass flow rate (kg/s)	143.5

5.1.2.2 The chemical requirements are the following:

Table 3 – Chemical requirements

Parameters	IBED PHTS
Conductivity @25°C, $\mu\text{S}/\text{cm}$	≤ 0.2
pH @25°C	7.0 – 9.0
Sodium, ppb	≤ 5
Chloride, ppb	≤ 5
Hydrogen, ppb	≤ 350
Catalysed Hydrazine, ppb	≤ 30
Ammonia, ppb	≤ 1000
Oxygen, ppb	≤ 10
Iron, ppb	≤ 10
Copper, ppb	≤ 10

5.1.3 Design Requirements

- 5.1.3.1 The 26PHBD-HT-1000 shall be designed to be operated remotely. Safety devices shall be installed to monitor the parameters of the heater (overheating sensors, pressure relief valve, leak and short circuit sensor, high limit controls, water level controls). Other remote alarms and controls are detailed in 5.1.4
- 5.1.3.2 The 26PHBD-HT-1000 shall be designed for conditions specified and the required operational characteristics, filling, draining, testing, and applicable loading conditions defined within this Specification and Appendices.
- 5.1.3.3 The reference code of construction is American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC) Section VIII, Division 2 ref.[7]. 26PHBD-HT-1000 shall be designed, fabricated, examined, and tested in accordance with this code with supplemental requirements per this Specification and outputs from the HRA. EN 13445 ref. [8] as per Codes and Standards for ITER Mechanical Components ref.[41] may be selected by the Contractor to ensure the design, fabrication, examination but must be approved in writing by the IO prior to use. Calculation of the equipment and the supporting structure shall be done in elastic limit for category 1 and 2, and elasto-plastic analysis can be used for accidental cases, which are a part of category 3. Structural analysis shall be compliant with the use of the following instructions: Instructions for Structural Analyses [77], Instructions for Seismic Analyses [79] and Instructions for the Storage of Analysis Models [78].
- 5.1.3.4 The allowable stresses of the Code of Construction for the design of pressure parts have also to comply with the formulas provided in the chapter 7.1 of annex 1 of the Directive ref. [1].
- 5.1.3.5 The 26PHBD-HT-1000 will not be ASME BPVC U2 stamped. Conformité Européenne (CE) marking is not required for ESPN equipment.
- 5.1.3.6 The IBED HT is located in the Tokamak Building at the level L4 (11-L4-04). The environmental conditions for the 26PHBD-HT-1000 are given in Appendix A, A2.
- For the fire situation (category IV event), the detail temperature distribution per room elevation is not available and the fire to be modelled is following the “Nominal Temperature-Time curves” according Eurocode 1 for a duration of 2h, leading to a final temperature of 1049°C in the air ref. [19].

- 5.1.3.7 The 26PHBD-HT-1000 shall be qualified to function under the magnetic conditions for which its service required (during normal conditions or accident). The reference safety conditions are provided in the safety requirement Room Book ref. [29]. The document ref. [55] indicates the magnetic field. The magnetic loads can be mitigated by the usage of paramagnetic material such as austenitic stainless steel. They should be accounted and added to the dead weight for the supporting structures whenever they are made of ferromagnetic materials.
- 5.1.3.8 The 26PHBD-HT-1000 shall be filled with water and completely drained. Any water that appears to have pooled or collected shall be clearly indicated on the test report and reported to the IO. The inspection may be performed while draining the 26PHBD-HT-1000 after proof testing is completed.
- 5.1.3.9 The 26PHBD-HT-1000 shall be filled with water, heated under power to design temperature as per 5.1.2 and tested for insulation resistance.
- 5.1.3.10 To avoid the potential stress corrosion cracking of the tubes, bending shall be followed by heat treatment to release the stresses when the deformation ratio is higher than 20% (see 5.1.5.17).
- 5.1.3.11 The mechanical properties after bending shall be compliant with the values from the raw material presented in the NPMA (see 5.1.5.17).
- 5.1.3.12 Intergranular corrosion shall be avoided using low carbon content material. 304L is selected for the composition of the 26PHBD-HT-1000 (see 5.1.5.1)
- 5.1.3.13 The 26PHBD-HT-1000 shall be designed to avoid hot spots accumulation of radioactivity, such as avoiding cavities in which particles can deposit. shall be minimized. the roughness of internal surfaces shall be less than 1.6 μm (see 5.1.5.22).
- 5.1.3.14 Gaskets and hardware for all closed ports shall comply with EN 1591-1 [Ref.2.3.14] and shall be supplied with the HT. A leak rate class of L0.001 (specific leak rate $\leq 0.001 \text{ mg s}^{-1} \text{ m}^{-1}$) shall be achievable. Gasketing material shall be compatible with the intended service as stated in the HT DS (Appendix A).

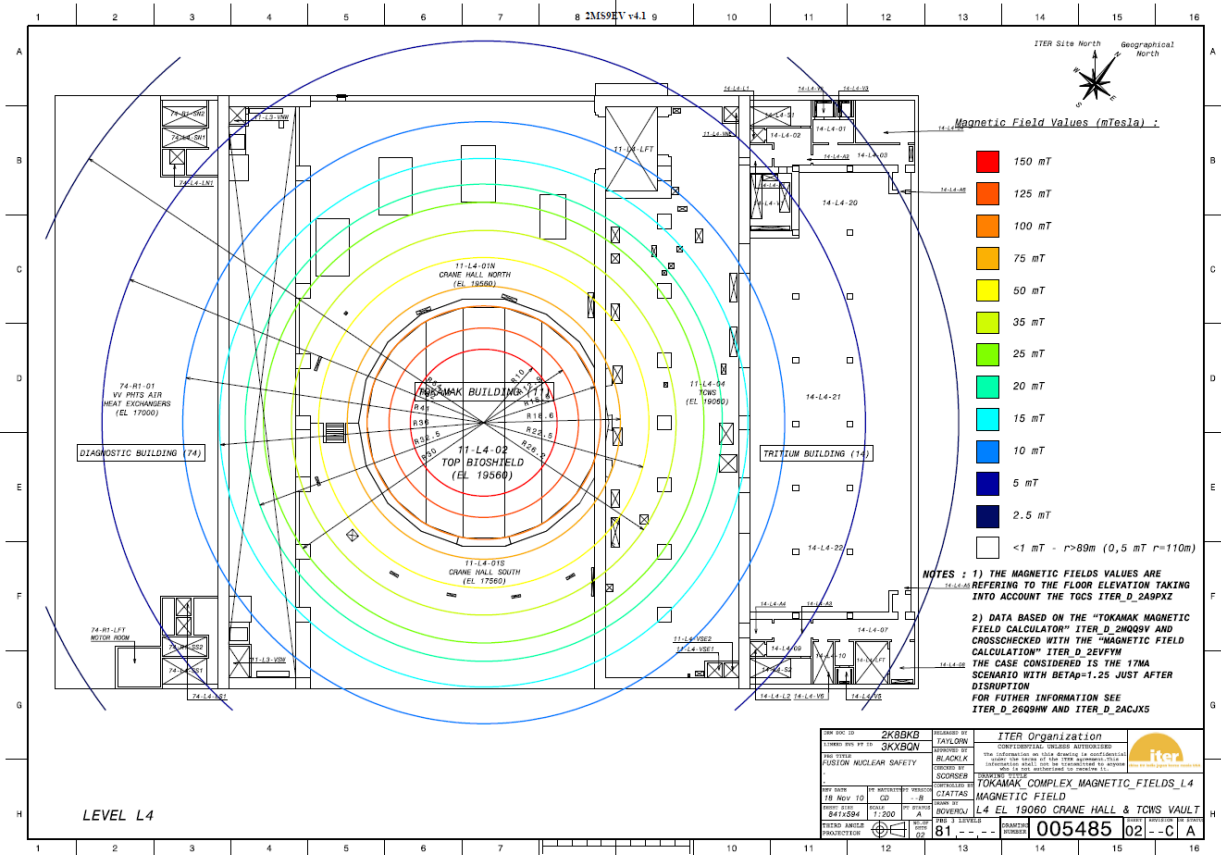


Figure 1 – magnetic map at L4

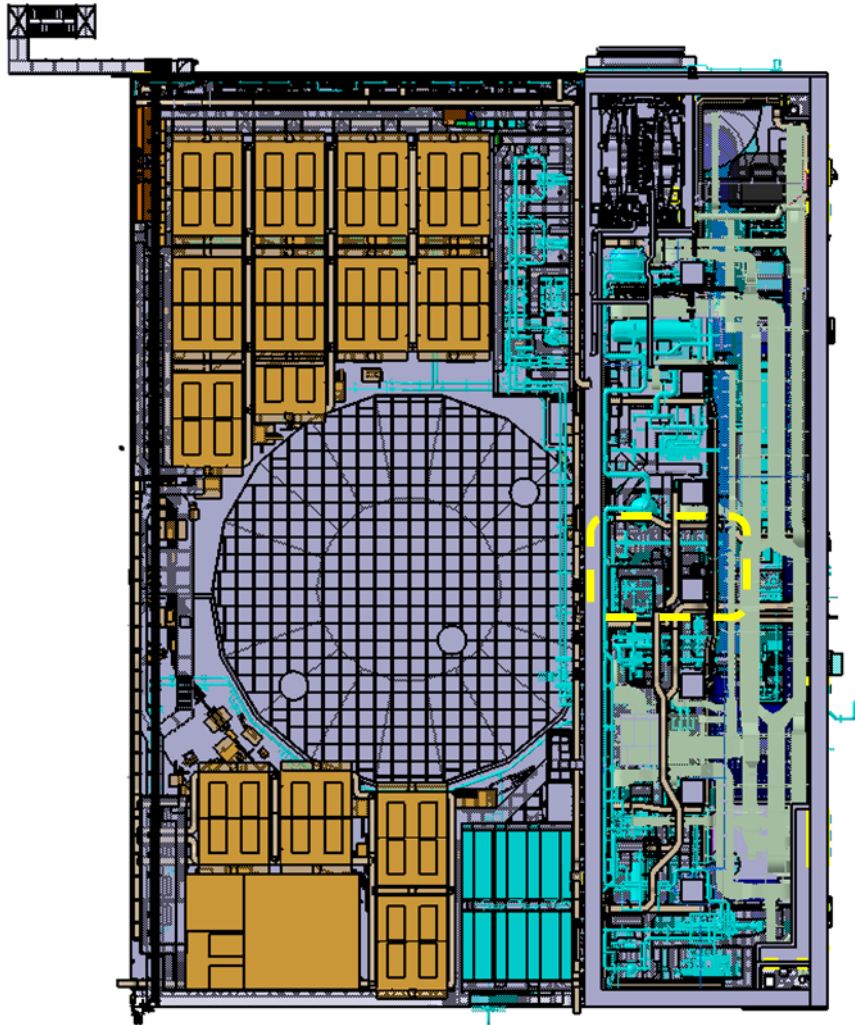


Figure 2 – 26PHBD-HT-1000 location at L4

5.1.3.15 During the design lifetime, the 26PHBD-HT-1000 and control cubicles will be subject to both neutron and gamma radiation. The accumulated dose rate is 10 kGy as per [49]. The operating life is 20 years, total irradiation time is only 4700 h.

According to ref [76], Figure 3, the total neutron flux is between 10^6 and 10^7 n/cm²/s. The fusion power level for the neutron flux data corresponds to 700 MW.

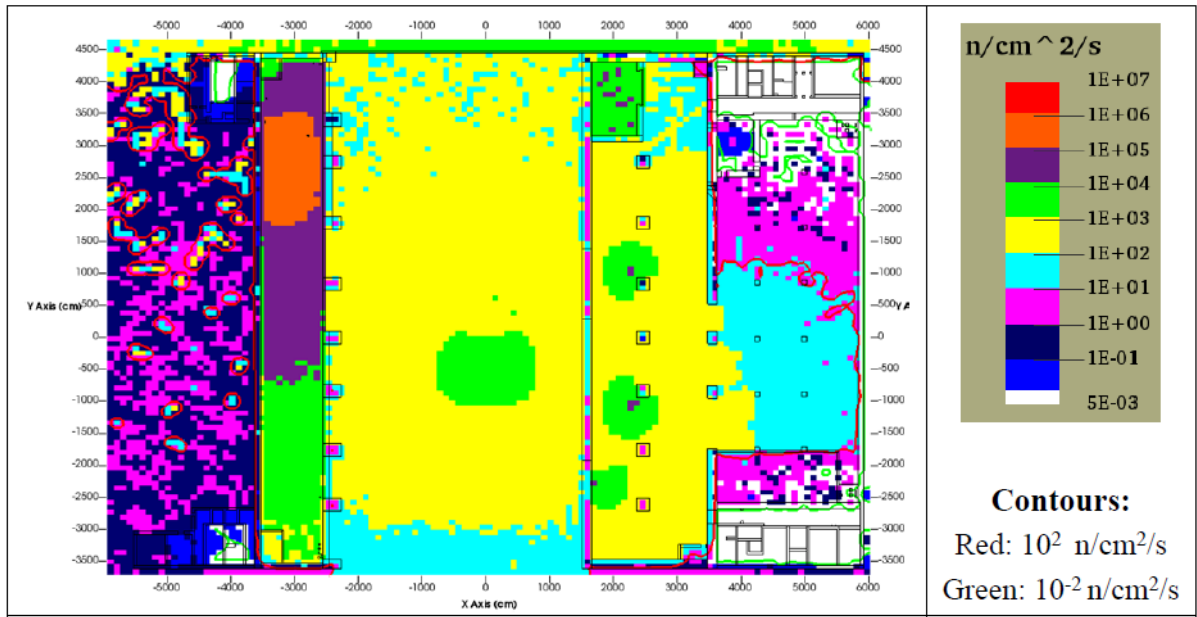


Figure 3 – total neutron flux map at L4

- 5.1.3.16 A Design Verification and Validation Plan shall be provided to IO as deliverable following the KOM including a logical sequence of works, the methods and codes used for the design and a list of all the design activities.
- 5.1.3.17 The 26PHBD-HT-1000 shall be designed to meet nozzle loads and seismic requirements specified in Appendices C and D and shall be designed to meet all load combinations as specified in the Appendix B.
- 5.1.3.18 The 26PHBD-HT-1000 shall be designed for an operating life of 20 years and 5 years of decommissioning.
- 5.1.3.19 Pressure boundary thickness shall be in accordance with the *Code of Construction*, as defined in Section 5.1.3.3. Sufficient allowance will be added to the wall thickness to compensate for corrosion, erosion, and abrasion over the lifetime of the baking heater for potential manufacture out-of-tolerance thicknesses.
- 5.1.3.20 The 26PHBD-HT-1000 design shall avoid unnecessary cavities where particles suspended in the process fluid can settle or collect (e.g., no socket welds or spare connections). The surface finish for wetted surfaces is detailed in Section 5.1.5.22.
- 5.1.3.21 Flanges

Flanges (DN 15 through DN 600) shall be in accordance with ASME B16.5 ref.[13].

Flanges shall be calculated according EN-1591 ref.[10] and their gasket shall comply with EN13555 ref. [9] in order to ensure a leak rate of L0.001 following ref.[53]. The use of the standard EN1591 ref.[10] is required for flanged joints in which the stress tightening is checked during initial tightening. In case of customized flanges that cannot be calculated with the standard EN1591 ref.[10], additional qualification and tests shall be carried out to ensure the leak rate L0.001.

Gasketing material shall be compatible with the fluid in the 26PHBD-HT-1000 and shall not include halogens.

The Contractor shall provide flanges, counter-flanges, bolts, nuts, washers and four gaskets (one installed and three spares).

The initial tightening torque and bolting sequence for the flange bolts considering the seating situation as well as the operating and exceptional situations shall be well indicated in the drawings and the instruction manual to ease the use on site during installation, commissioning, and maintenance.

5.1.3.22 Nozzles and openings

Nozzle No.	DN/SCH	Type
N1	400/80	Inlet
N2	400/80	Outlet
N3	25/40S	Vent
N4	25/40S	Drainage

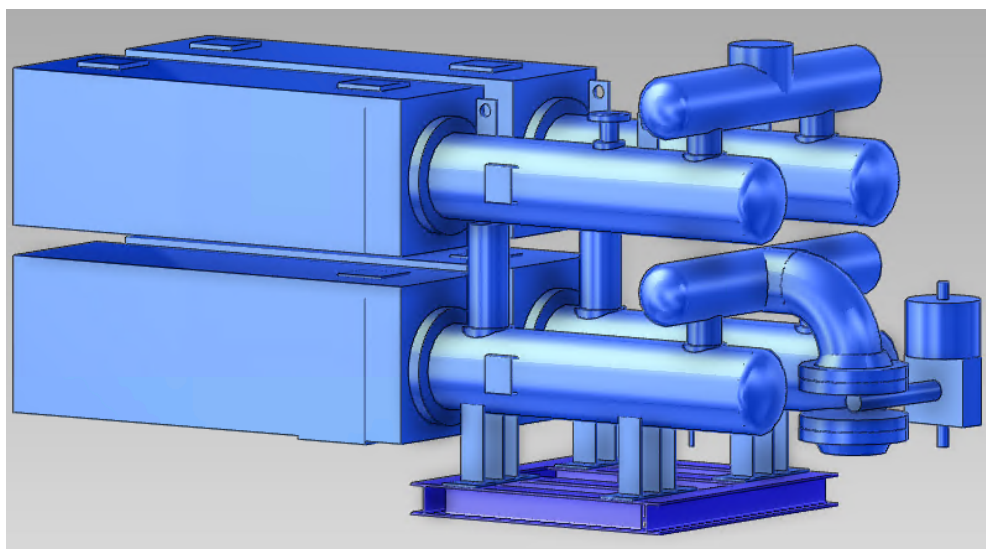


Figure 4 - Preliminary model of 26PHBD-HT-1000

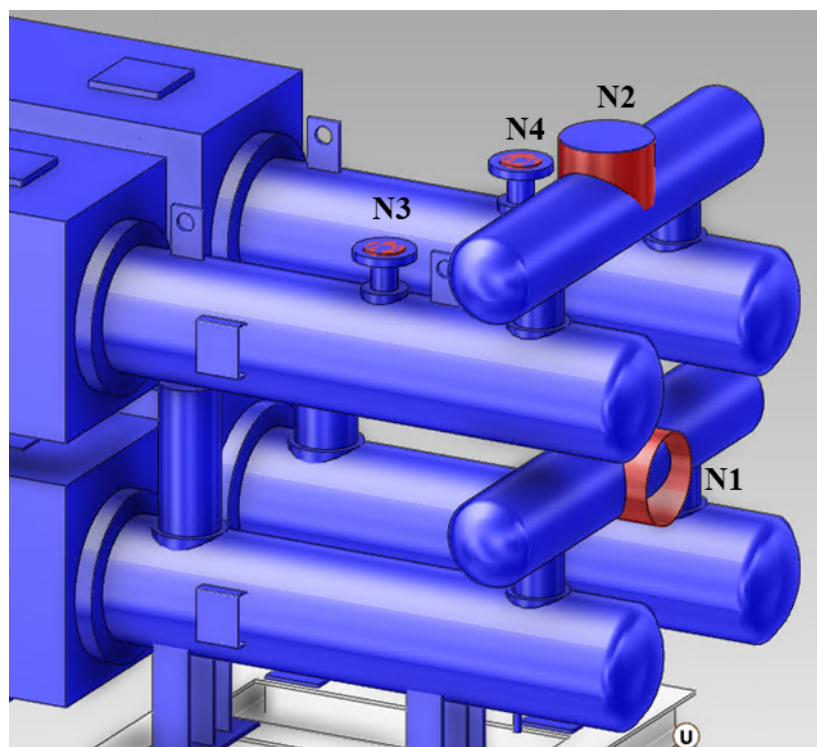


Figure 5 – Nozzle orientation for 26PHBD-HT-1000

26PHBD-HT-1000 is to be installed at L4, which is a congested area of the Tokamak building. To accommodate the design into the layout, specific attention must be given during the design of the support on the connections to the platform. Details of the space reservation and platform drawing will be provided as a separate package with the technical specification to the Contractor to have a clear understanding of the potential connection points and rigidity of the structure. A 3D model will be supplied as well for all other aspects.

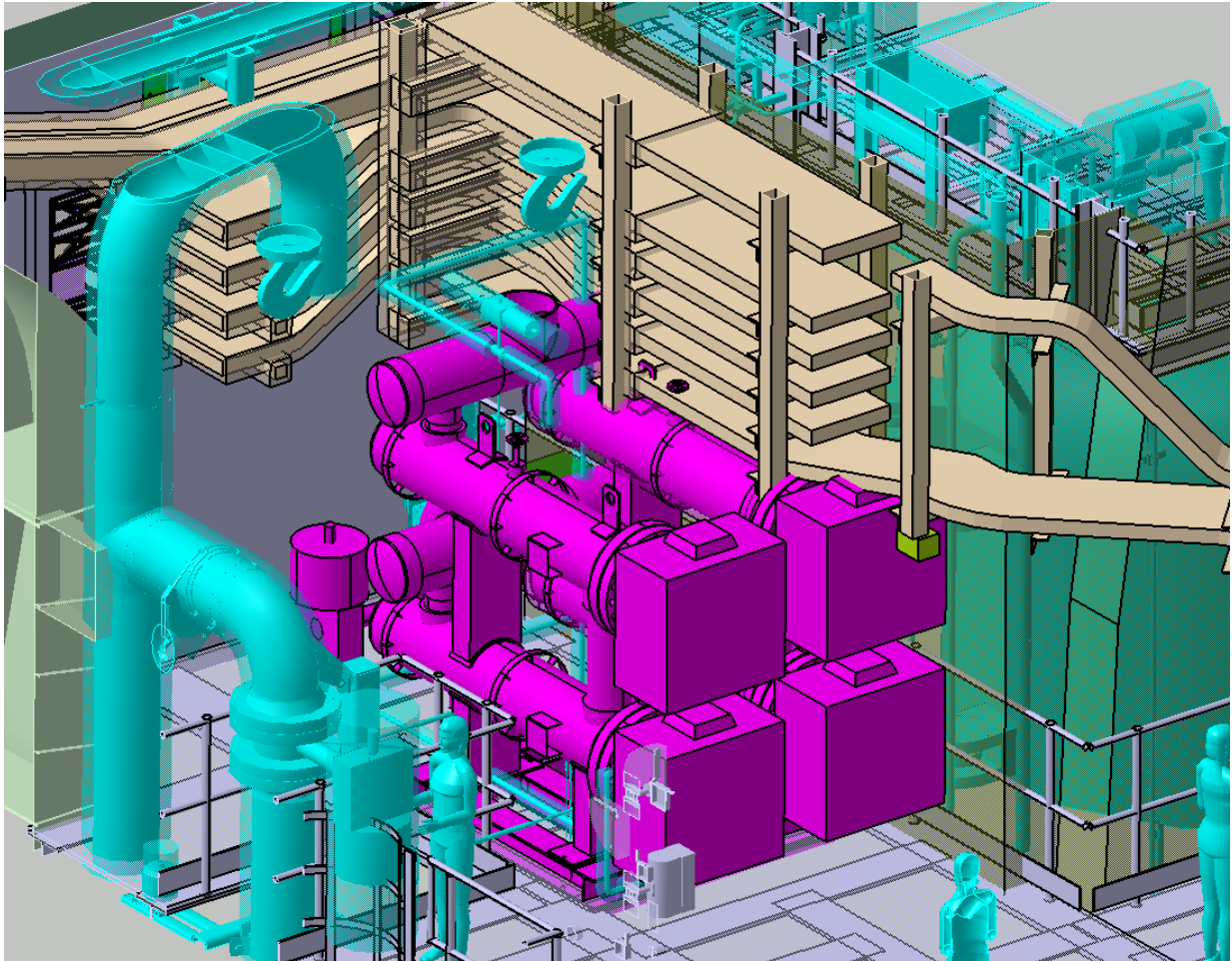


Figure 6 – 26PHBD-HT-1000 installation area

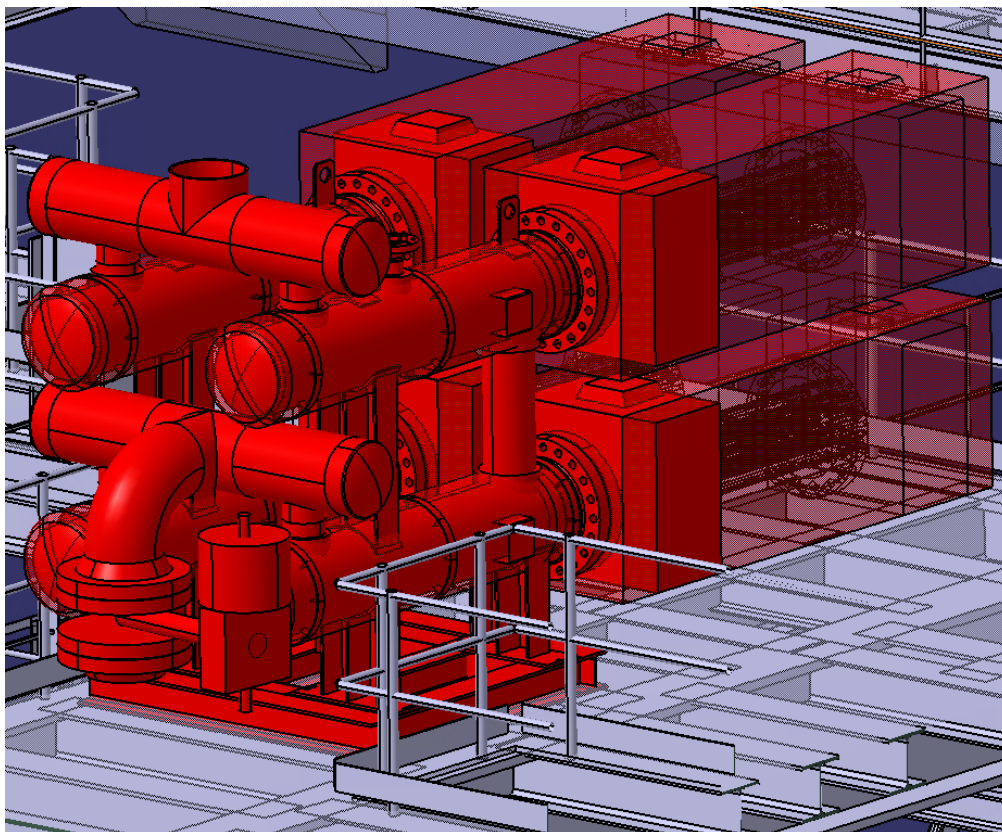


Figure 7 – Position on the platform

Orientation, location of all nozzles and the nozzle loads table shall be specified on the Contractor design drawings, which will require review and written approval by IO prior to start of manufacturing.

The nozzle loads are provided in the appendix C for the situation A/B (cat I and II normal situations), C (cat III exceptional situations) and D (IV highly improbable situations). They are not signed as they are the maximum values of several combinations from the pipe stress analyses. The Contractor shall provide the loads with the orientation that leads to the most penalizing results.

Each nozzle shall have its identification number, to be specified in the general arrangement drawing and permanently marked on the outside cylinder surface of the nozzle.

The dimensions of all nozzles and pipes shall conform to ASME B36.19M ref.[14] metric dimensions.

5.1.3.23 The 26PHBD-HT-1000 drawings shall, as a minimum, include the following information:

- A Bill of Materials (BOM) with a description of the individual component and the component identified on the drawing.
- Loads on nozzles.

- Drawing number.
- IO TAG number and IO PNI number.
- All information related to NPE.
- Maintenance space reservation,
- General arrangement drawing (weight and COG, lifting points, complete nozzle description, interface with the platform, overall dimensions).

5.1.3.24 Calculation studies

GM3S ref. [25] provides the procedures for Analyses and Calculations to be followed. The Contractor shall transmit the analysis models to IO.

5.1.3.24.1 Thermal hydraulic design

Thermal-hydraulic analysis of the 26PHBD-HT-1000 and electrical design shall be performed in a steady state case as per loading conditions provided in Appendix A – C. The HT design shall include required fouling factors and electrical power margins needed for the fluid and operating conditions specified in Appendix A – C.

5.1.3.24.2 Structural Analysis & Verification

The following mechanical analyses shall be performed:

- Perform the thickness calculation of the pressure equipment in a design calculation sheet following ASME VIII div.2 part 4 or EN 13445-3.
- Perform the stress analysis of the 26PHBD-HT-1000 assembly. The full design code shall be followed, and the stress report shall include the assessment of protection against plastic collapse, the assessment of protection against local failure, the ratcheting evaluation and the welds and bolts assessment.
- Perform a thermal analysis of 26PHBD-HT-1000 supports to evaluate its temperature at the interface points.
- Perform the fatigue analysis for all parts of the heater and nozzle connections based on process loading conditions provided in Appendix A. Screening criterion as ASME VIII Div.2 § 5.5.2 (Method B) can be used as first assessment and completed by a detailed fatigue analysis if the criteria are not satisfied.
- Provide the interface loads between the equipment support system and the platform. Reaction loads shall be given at both support base plates (fixed and sliding) for all individual load cases and all load combinations provided in Appendix B.

5.1.3.25 Supports

The 26PHBD-HT-1000 shall be designed to safely withstand all loading requirements, including the full weight, nozzles loads, seismic loads and restrained thermal expansion loads, in accordance with this Specification. Seismic and nozzle loading requirements are specified in Appendices D and C with the combinations provided in Appendix B. The design shall include the equipment support and the platform attachment locations and its type (i.e., fixed, sliding, etc.).

The 26PHBD-HT-1000 support shall be fixed on:

- the platform 14, Figure 8. Proposed means of fixation between the 26PHBD-HT-1000 support and the platform – welding.
- Fixation of the 26PHBD-HT-1000 equipment to the support shall be considered with thermal expansion of the equipment, (example of fixation: one side fixed in all degrees of freedom, the other is released in axial direction, along the thermal expansion).

The contractor will check and report the reaction forces and moments from the 26PHBD-HT-1000 support to the platform 14. This is a requirement to make sure that all loads are considered and verified for the allowable platform 14 displacements and stresses in all categories of events.

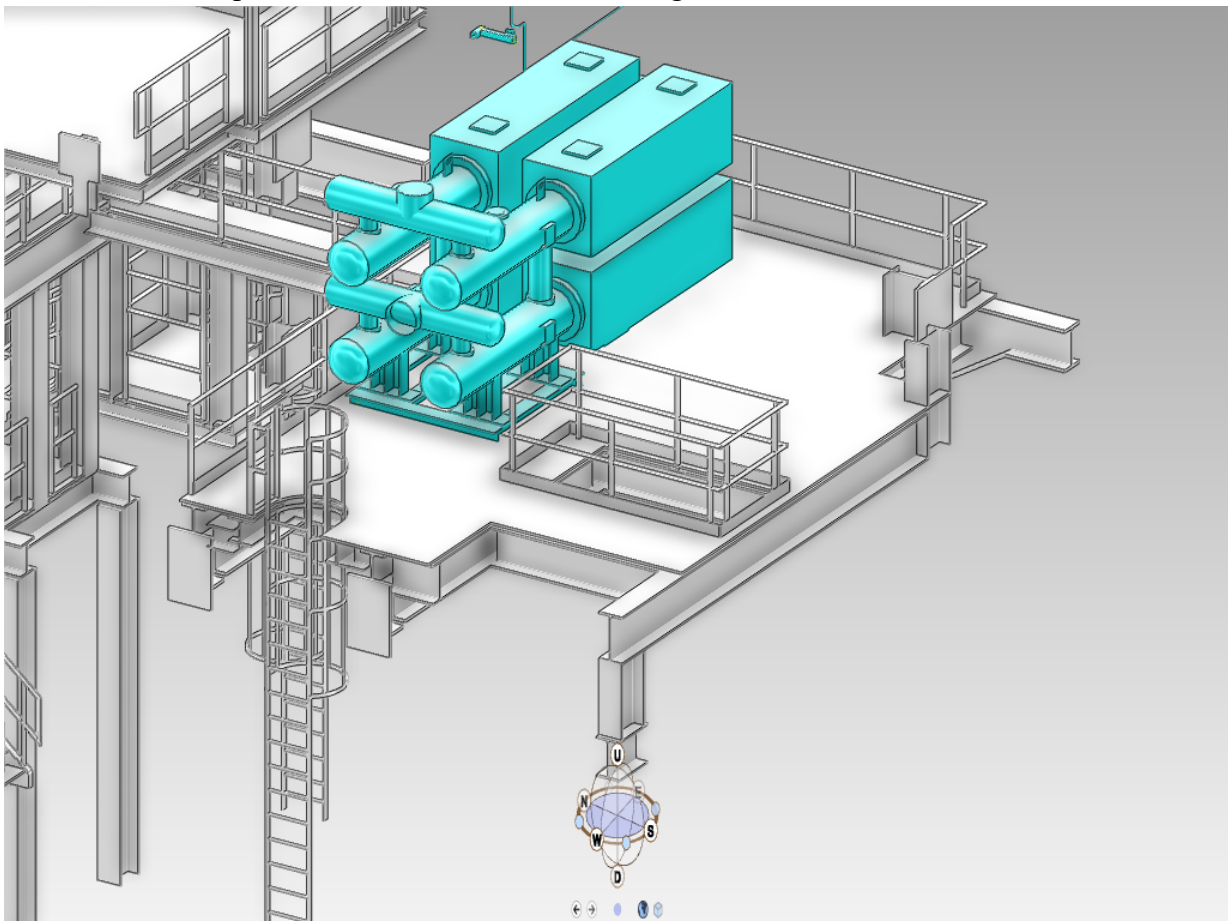
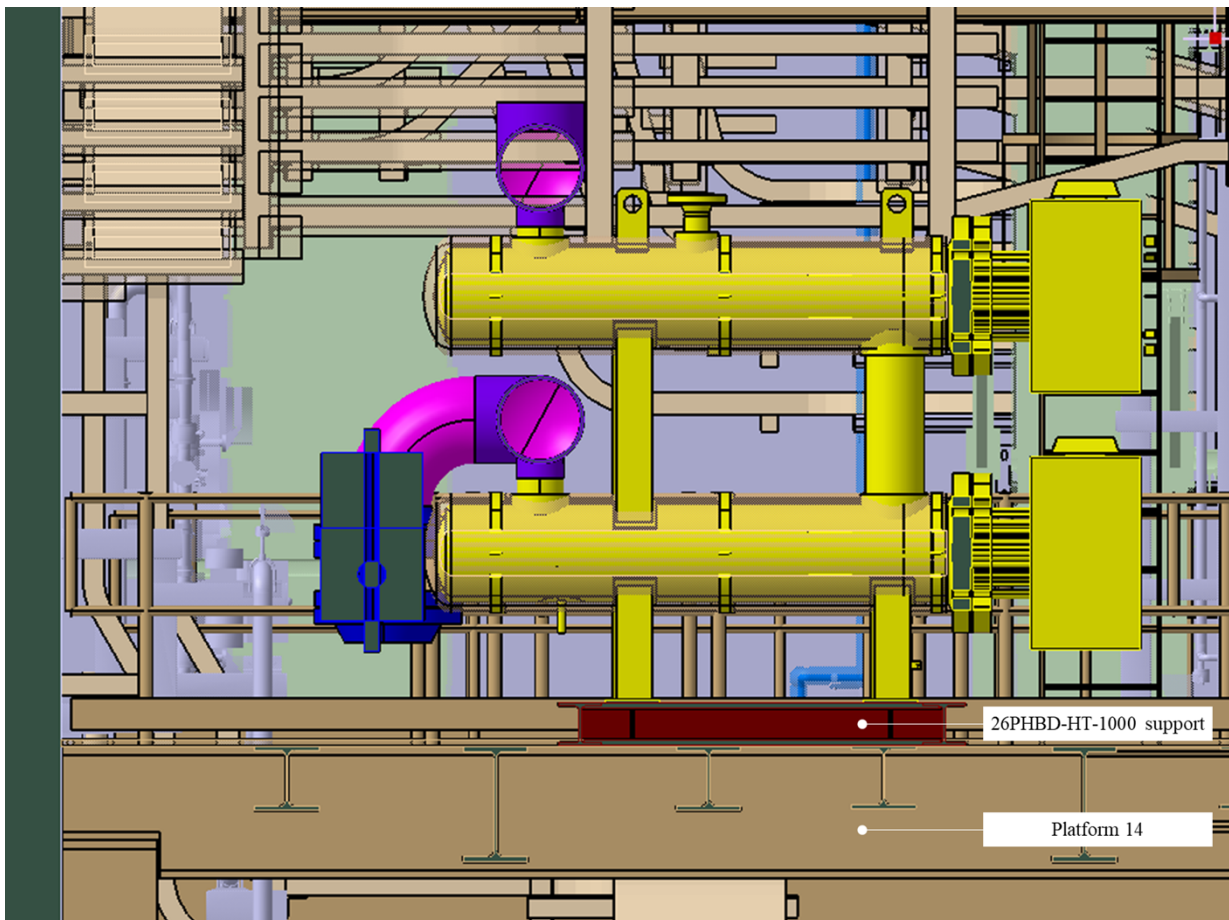


Figure 8 – Platform 14*Figure 9 – Side view between 26PHBD-HT-1000 and platform 14*

5.1.3.26 Handling/lifting lugs and trunnions

The 26PHBD-HT-1000 shall be equipped with handling/lifting lug(s) and trunnions in accordance with the code chosen and designed to support all the handling, lifting loads.

The handling/lifting lug(s) or trunnion shall be clearly identified.

The handling/lifting lugs and trunnions shall be located away from welds and nozzles.

The material requirements for the lifting lugs shall be equivalent to those of the pressure boundary materials.

The lifting could be performed with vertical slings or slings making an angle which must be defined by the Contractor, calculated in a design report, and indicated in the Installation Manual.

5.1.3.27 Nameplate

26PHBD-HT-1000 shall have a nameplate marked with the unique identification number supplied by the IO as TAG number “26PHBD-HT-1000” and a PNI number that will be defined later. A metal nameplate, suitable for the intended service and at least 0.5 mm thick, shall be permanently attached to a bracket that is permanently attached to the baking heater and long enough to be visible with the insulation. The nameplate shall be visible and accessible in the room after the baking heater installation. The nameplate and attachment shall be such that removal shall require the wilful destruction of the nameplate or its attachment. The attachment weld to the baking heater shall not adversely affect the integrity of the equipment.

The nameplate shall be performed according to the requirements defined in the PED [2] and ESPN [3] following the template provided in [64] and shall be made in austenitic stainless steel.

Safety signs and safety information in French related to the residual risks from the Hazards and Risks Analysis shall be indicated in warning labels on the equipment.

5.1.4 Heater control cubicle

26PHBD-HT-1000 heater control cubicles shall be designed, manufactured, assembled, tested, and qualified as per [74].

Table 4 – LV Electrical Motor Control Cubicle load list

Description of Equipment	Equipment Number	Cubicle	Starter type	Cubicle Location	SIC or Non - SIC	KW rating	QC
IBED baking heater	26PHBD-HT-1000	26PHBD-CMC-1009	SCR/DOL	11-R1-01E	Non-SIC	1000	2
IBED baking heater	26PHBD-HT-1000	26PHBD-CMC-1010	SCR/DOL	11-R1-01E	Non-SIC	1000	2
IBED baking heater	26PHBD-HT-1000	26PHBD-CMC-1011	SCR/DOL	11-R1-01E	Non-SIC	1000	2
IBED baking heater	26PHBD-HT-1000	26PHBD-CMC-1012	SCR/DOL	11-R1-01E	Non-SIC	1000	2

Cubicles are fixed to the platform (B11_R1_PLATFORM_18), see Figure 10.

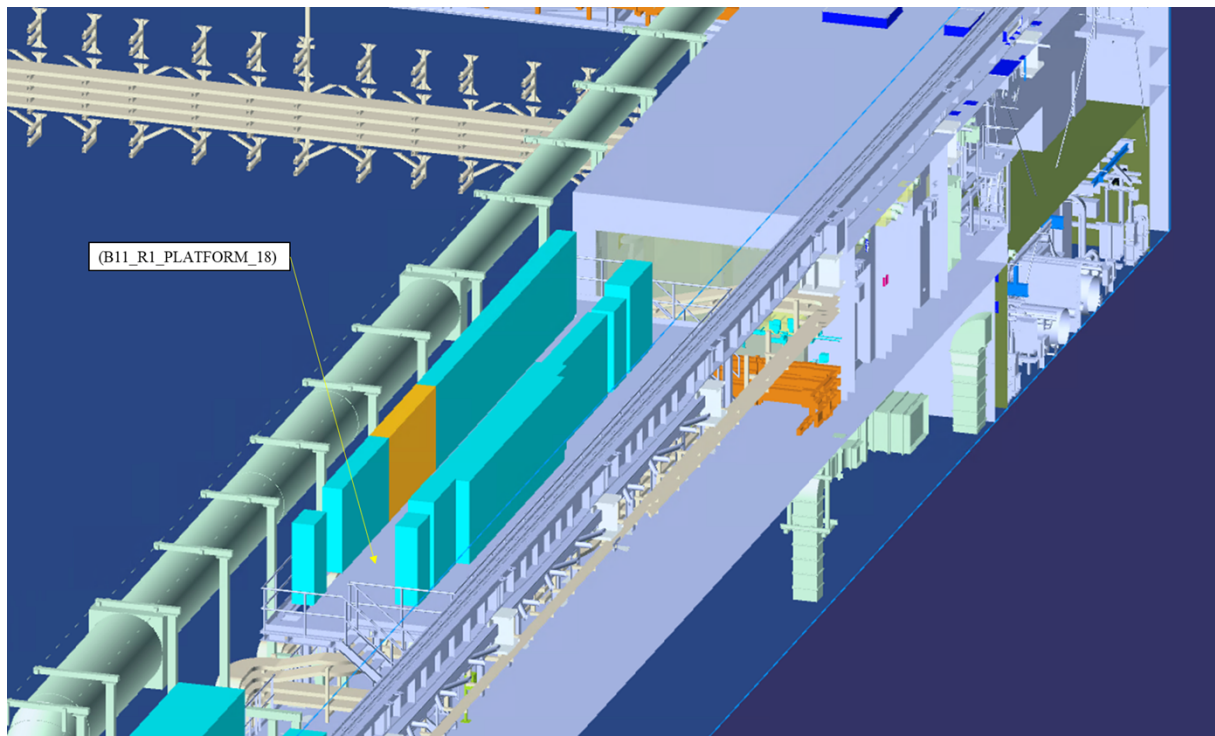


Figure 10 – Platform 18 at R1

- 5.1.4.1 The IBED Baking Heater temperature controller shall be a variable full silicon-controlled rectifier (SCR) system with a process temperature controller utilizing a process variable feed-back control loop.
- 5.1.4.2 The process variable shall be continuously fed to the process temperature controller and the controller then sends a signal to the SCR for the required power output to maintain the requested set-point.
- 5.1.4.3 The heater controller shall be configured and wired to allow the starting of the heater in either REMOTE or LOCAL mode.
- 5.1.4.4 The selection of REMOTE or LOCAL mode shall be done with a hardware REMOTE/LOCAL selector switch mounted on the exterior of the heater cubicle. Hardwired interlocks shall prevent the selection of the operating mode by any other means than the selector switch.
- 5.1.4.5 Individual LED indicator lights on the front panel of the heater cubicle shall be provided to indicate the operation mode of the heater control circuit (REMOTE or LOCAL) with additional hardware auxiliary contacts (NO/NC) provided to indicate the operational mode to the TCWS PLC.
- 5.1.4.6 A START hardware pushbutton mounted on the heater cubicle shall START the heater when the system is in LOCAL operation mode.
- 5.1.4.7 A STOP hardware pushbutton mounted on the heater cubicle shall STOP the heater regardless of operating mode. This interface shall be hardwired (non-software).
- 5.1.4.8 When the heater control system is in LOCAL mode it will control to a LOCAL SETPOINT entered at the heater control cubicle.
- 5.1.4.9 This LOCAL SETPOINT shall be entered at an interface on the outside of the cubicle and shall not be remotely accessible.
- 5.1.4.10 When the heater control system is in REMOTE mode it shall control to a REMOTE SETPOINT received from the TCWS PLC via a 4-20 mA signal.
- 5.1.4.11 The heater control system shall be capable of receiving a process variable temperature signal (PV) from the TCWS PLC in the form of a 4-20 mA signal.
- 5.1.4.12 The heater control system shall also be capable of receiving a process variable temperature signal (PV) from a RTD sensor.
- 5.1.4.13 The heater control system shall be configured to select either of the process variable temperature (PV) signals for controlling the temperature.
- 5.1.4.14 An EMERGENCY STOP pushbutton provided by the manufacturer and mounted on the exterior of the control cubicle, if activated, shall immediately open the power circuit regardless of operating mode. The interface to this EMERGENCY STOP shall be hardwired (non-software).

- 5.1.4.15 In addition, provisions for a remotely mounted EMERGENCY STOP (provide by others) to immediately open the power circuit regardless of operating mode shall be provided. The interface to this EMERGENCY STOP shall be hardwired (no software).
- 5.1.4.16 At least two separate means of over temperature protection shall be utilized for the system.
- 5.1.4.17 The manufacturer shall supply all hardware components for the over-temperature protection device including required sensors.
- 5.1.4.18 The over-temperature protection device shall have a high temperature limit set at a temperature slightly higher than the estimated sheath temperature. This set-point shall be field adjustable.
- 5.1.4.19 Remote reset of the over-temperature device shall not be allowed. The overtemperature device must be reset at the heater control cubicle.
- 5.1.4.20 Heater control cubicles shall have temperature displays available on the outside of the cubicle for all monitored temperatures.
- 5.1.4.21 Heater control cubicles shall have displays available on the outside of the cubicle for indicating the value of the selected SETPOINT and selected PROCESS VARIABLE.
- 5.1.4.22 Heater control cubicles shall have indicating lights on the outside of the cubicle to signify ALARMS, REMOTE/MANUAL mode of operation, and POWER ENABLED (ON/OFF) status with additional hardware auxiliary contacts provided to indicate the status to the TCWS PLC.
- 5.1.4.23 All local controls and interfaces shall be available without opening the heater control cubicle door.
- 5.1.4.24 The heater control cubicle shall be lockable.
- 5.1.4.25 The heater control system shall have the capability to transmit all monitored analogue signals to the plant control system in the form of 4-20 mA signals.
- 5.1.4.26 The heater control system shall have the capability to receive a "START" and "STOP" hardwired digital command from a remote source. The "START" command will only be valid when the heater control system is in REMOTE mode.
- 5.1.4.27 The STOP command will always be operational.
- 5.1.4.28 The heater control system shall have the capability to transmit a digital signal indicating ON or OFF status. A dry auxiliary contact will be made available for this purpose.
- 5.1.4.29 The heater control system shall have the capability to transmit a digital signal indicating LOCAL or REMOTE status. A dry auxiliary contact will be made available for this purpose.

5.1.4.30 The heater control system shall have the capability to transmit a minimum of two (2) user defined ALARMS in a digital signal format through the use of dry auxiliary contacts.

5.1.4.31 The heater control system shall have the capability to transmit instantaneous current usage for each heater circuit in the form of 4-20 mA signals.

5.1.4.32 The heater control system shall have the capability (software and/or hardware) to communicate with a Siemens Profinet protocol and shall include the following parameters at a minimum:

Bit Parameters:

- Communication Status
- Controller Status
- Auto/Manual Mode Status
- Alarm 1 Status
- Alarm 2 Status
- Setpoint Ramping Active

Word Parameters:

- Setpoint Ramping Active
- Current value of Process Variable
- Value of selected setpoint
- Maximum setpoint value
- Minimum setpoint value
- Output Power (%)
- Deviation – Difference between Process Variable and Setpoint
- Instantaneous Current Usage for Each Heater Circuit
- Alarm 1 Status
- Alarm 2 Status
- Alarm Dead band

- 5.1.4.33 Heater control cubicles shall allow for continuous detection of welded magnetic contactors.
- 5.1.4.34 Heater control cubicles shall be complete with an incoming TP&N (4- pole) circuit breaker.
- 5.1.4.35 The heater control cubicle's main incoming circuit breaker shall include a lockable operating mechanism (OPEN/CLOSE) available on the cubicle door. Entry into the cubicle will not be required to OPEN or CLOSE the breaker.
- 5.1.4.36 The main circuit breaker shall have an over-current trip with auxiliary dry contacts to indicate if the circuit breaker is OPEN, CLOSED, or TRIPPED.
- 5.1.4.37 Each heater control cubicle heater element circuit shall include an individual MCCB if it's load is greater than or equal to 63 A, or a MCB if it's load is less than 63 A.
- 5.1.4.38 These devices shall provide protection adequately rated for the load and provide overload, short circuit protection and selectivity for each individual circuit.
- 5.1.4.39 Each heater control cubicle circuit shall also include a 30 mA residual current device with an adequate thermal rating for the load and anticipated fault currents.
- 5.1.4.40 If the heater control cubicles has multiple circuits and an SCR short occurs, the control cubicle will open the magnetic contactor on that circuit and send a common alarm signal. The control cubicle will continue to function without the failed circuit.
- 5.1.4.41 If multiple heater circuits are provided, the number one (1) circuit shall have the overtemperature sensors. The over-temperature controller shall always be connected to the number one circuit. If the number one circuit is shorted, then power shall be disconnected by the main circuit breaker and the magnetic contactors.
- 5.1.4.42 Multiple circuit heaters (the final number of circuits is determined by the manufacturer) shall incorporate a Load Management System (LMS) designed such that full power is not required for high turndowns. Sequential circuit ramp-up shall not be used as the LMS.
- 5.1.4.43 Heater control cubicles shall meet or exceed the Kilo-Amperes Interrupting Capacity (KAIC) rating specified in the associated SLD.
- 5.1.4.44 SCR shall be zero crossover fired (burst firing). The system shall have SCR short circuit detection and alarm capability.
- 5.1.4.45 Short circuit protection shall be fast-acting current limiting semi-conductor fuses.

5.1.5 Material, Welding and Fabrication Requirements

5.1.5.1 Stainless steel

26PHBD-HT-1000 shall be austenitic stainless-steel 304L and shall comply with the additional composition requirements shown in ref. [43] and recalled in the tables 5.1.4.1 and 5.1.4.2 below.

The requirement for the Cobalt, Niobium and Tantalum content limitation is for the full equipment including pressure retaining parts and wetted surfaces parts.

Table 5 – Stainless-Steel Composition - pressure retaining parts and wetted surfaces parts.

Component	Content (wt%)
Cobalt	<0.05
Niobium	<0.10
Tantalum	<0.04

For the primary support and secondary supports (beams, plates...), the Cobalt limitation is 0.20%, while the Niobium and Tantalum content limitation is still 0.10%.

Table 6 – Stainless-Steel Composition - primary and secondary supports.

Component	Content (wt%)
Cobalt	<0.20
Niobium	<0.10
Tantalum	<0.04

For the small items also called COTS (bolts, nuts, gaskets, screws, plugs, washers...) these Co/Ta/Nb impurities requirements can be not applied.

- 5.1.5.2 For the material composing pressure parts PP, MPBP and parts contributing to pressure resistance CCPR, inspection certificates as per EN 10204:2004 ref. [15] shall be provided by the Contractor and shall be consistent with the NPMA and this technical Specification (see CLAP File X141 ref. [23]). NPMA shall be referenced in the material certificates. The editions of the material standards specified in the certificates shall be the same as specified in the NPMA.

- 5.1.5.3 When the materials manufacturer has an appropriate quality assurance system of at least EN ISO 9001 certified by a competent body established within the European Community, and having undergone a specific assessment for materials, an inspection document from the manufacturer is appropriate. The specific assessment of the quality system shall properly cover all the relevant processes and material properties referred to in the material specifications and attested in the material certificates. In this case, material manufacturer can issue material certificate type 3.1 according to EN 10204:2004 ref. [15] in any other case material certificate type 3.2 can only be issued. Gaskets shall be provided with certificates type 2.2.
- 5.1.5.4 The 26PHBD-HT-1000 is ESPN level N3, therefore following ESPN ref.[3] , base material shall be sufficiently ductile with elongation after rupture not less than 14%, performed with a tensile test carried out by a standard procedure. In addition, the base material bending rupture energy measured on an ISO V test-piece is not less 27 J at the minimal allowable temperature 5°C.
- 5.1.5.5 The selection of the material in the NPMA shall demonstrate the compliance with the radioprotection guide ref. [39] as well as the ESR from PED [1] and ESPN [3].
- 5.1.5.6 The NPMA shall reflect the requirement to get the yield strength Rp1.0 and Rp0.2 and the tensile strength Rm at room temperature. These tests at the temperature TS of 270°C shall be provided. These values shall be recorded in the material certificates of PP, MPBP and CCPR to comply with the allowable stress comparison presented in ref. [44].
- 5.1.5.7 All water used for cleaning and hydrotesting shall meet the requirements in Table 7 in accordance with ASME NQA-1, Part II, Subpart 2.1, Section 304.1, *Water* ref. [12]for hydrotesting and Grade A water quality from RCC-M 2012, Annex F-III ref. [11] for cleaning.

Table 7 – Water Quality

Parameter	Requirement	
	Cleaning	Hydrotesting
pH at 25°C (77°F)	6.0 – 8.0 ⁽¹⁾	6.5 – 8.0
Specific conductivity at 25°C (77°F), $\mu\text{S}/\text{cm}$	<2	–
Chloride, ppm	<0.15	<250
Fluoride, ppm	<0.15	<2
Sulfide, ppm	n/a	<1
Silica, ppm	<0.1	–
Total solids, ppm	<0.1 (suspended)	<500 (dissolved)

(1) a drop in the minimum pH level to 5.5 is permissible on the condition that it can be shown that the drop in pH is effectively due to the carbonation of the water.

- 5.1.5.8 The design shall address the *ITER Radiation Protection Guidelines* ref. [39] for the design and manufacturing of nuclear pressure equipment.
- 5.1.5.9 Following requirement of ref.[3], the choice of materials is made considering the possible activation and release of corrosion products that may, after activation, require protective measures in operation. The water chemistry requirements are given in the chapter 5.1.2.2 and the radiological requirements are given in the chapter 5.1.3.15. The fluid radioactivity concentration is given in the ref.[47].
- 5.1.5.10 Welding materials shall meet the requirements of the *Code of Construction*. Welding materials shall comply with the additional composition requirements shown in Table 6. Additionally, manufacturers of welding consumables shall provide test report “Type 2.2” as an inspection document in accordance with the standard EN 10204 ref.[15]. To comply with the traceability requirement of PED, Annex I, Section 3.1.5 ref.[1] for welding consumables, the Contractor shall be able to demonstrate in the procedures, test records, drawings, list of welders, WPS, WPQR and welding lists that the traceability is maintained during the manufacture.
- 5.1.5.11 If heterogeneous welds are present (stainless steel vs carbon steel), it shall be considered between these two materials. Galvanic corrosion shall be limited.

- 5.1.5.12 The bolts for flange connections shall be made with the grade A453 gr 660B or other ASME grades with similar or better material properties. These bolts shall be compatible to be in contact with the 304 L stainless steel flange without risk of galvanic corrosion. Bolts of flanges are classified as PP (pressure parts) and dedicated NPMA shall be issued including the specific requirements for ESPN level N3 bolts material following [3].
- 5.1.5.13 Every activity of manufacturing managed by the material supplier as tube bending shall be clearly requested in the material purchase specification and identified in the material certificates. Dimensions of raw material shall be detailed in the material certificates.
- 5.1.5.14 The 26PHBD-HT-1000 shall be fabricated in accordance with requirements of the *Code of Construction*, the ESPN ref.[3], the PED ref. [1] and project-specific quality requirements per this Specification. Any conflicts between conformance with required codes and standards and this Specification shall be brought to the attention of IO for resolution. No irreversible steps in design or manufacturing shall be taken before resolution in writing of the conflict by IO.
- 5.1.5.15 Thermal arc gouging processes are prohibited.
- 5.1.5.16 Any heat treatments performed during fabrication or after welding shall be duplicated on the qualification test coupon(s) and are subject to ANB approval before acceptance for use.

- 5.1.5.17 Following PED ref. [1], preparation of the component parts as forming, bending, machining activities or heat treatment must not give changes in the mechanical characteristics likely to be detrimental to the safety of the pressure equipment. Specific qualifications proposed by the Contractor and approved first by IO shall be performed after forming and bending activities to ensure the material properties of the base material are not modified. Forming and bending ratio shall be provided in the forming and bending procedure. If cold bending or cold forming is used and the deformation ratio is higher than 20% (see ref. [68]), specific means like heat treatment shall be put in place to avoid stress corrosion cracking.
- 5.1.5.18 Grinding, lapping, and surfacing equipment and abrasives for use on corrosion resistant materials shall be new or not previously used on carbon steel or other metals or alloys so contamination of the finished surfaces is completely avoided. All grinding or lapping on base material or welded metal shall be performed with one of the following: carbide or aluminium oxide burrs, silicon carbide, zirconia, or alumina grinding and lapping wheels. All grinding material shall be free of halogens. Any type of grinding wheel bonded with a resin, rubber, or silicate must be submitted for review and written approval of chemical content by the IO. Excessive pressure that may result in localized heating or smearing of the surface that can invalidate a subsequent liquid penetrant examination shall be avoided.
- 5.1.5.19 Wire brushes used for cleaning austenitic stainless-steel or nickel-based alloy materials or welds shall be made from stainless-steel and shall not have previously been used on carbon steel.
- 5.1.5.20 For the purposes of this Specification an expendable material is defined as a non-permanent material that comes in contact with the 26PHBD-HT-1000 during the manufacture or storage activities. Such items or products shall not cause degradation of the baking heater. All expendable materials shall be free of halogens. Use of expendable material shall be controlled by written procedure, which shall be approved by IO and the ANB prior to use of such materials.
- 5.1.5.21 A list of all the product in contact with the surface of the 26PHBD-HT-1000 shall be provided by the Contractor.

5.1.5.22 For the surface finish, all internal wetted surfaces of the 26PHBD-HT-1000, including the internal surface of the tubes and the welds, shall have a surface finish smoother than 1.6 µm roughness. Interior welds shall be ground flush to meet surface finish requirements.

The external weld seams shall have a surface finish of 12.5 µm or better if stringent criteria are needed for NDT. Surface finish shall extend a minimum distance from the edge of the weld to a distance whichever the greater is of:

- twice the base plate thickness plus 100 mm
- 150 mm.

All burrs and rough edges shall be removed.

5.1.5.23 Marking

Marking paint or ink shall not contain harmful amounts of chlorides, metals, or metallic salt, such as zinc or copper that can cause corrosive attack on heating. The IO review and approval is required prior to use of any marking paint or ink. Stamping shall not introduce a notching effect, therefore low stress stamping with round edges is recommended. If any method of marking other than hard-stamping or engraving is used, the Contractor shall ensure that confusion between different materials is not possible, e.g. by separate handling (time and/or place) or stamped bands.

The labels shall be placed in a visible location on the components.

5.1.5.24 Welding and other permanent joining

Welding shall be performed in accordance with the requirements of the *Code of Construction*, as defined in Section 5.1.3.3, the ESPN, and PED (insofar as it is called upon by the ESPN).

Each weld shall be identified with a unique weld identification number on the weld control record or equivalent. Weld numbers and weld location shall be shown on the Contractor's drawings.

For pressure boundary parts, drawings that show fabrication by welding shall indicate the joints, together with the joint geometry and welding process and welding procedure(s).

Weld seams shall not intersect nozzles or access opening locations.

Following ESPN appendix II for material ESPN level 3, pressure boundary welds including the common wall between two compartments are 100% volumetric controlled. Welded joints shall be full penetration welded.

Temporary weld attachments shall be removed upon completion of their intended purpose. Removal shall be documented and included in a document provided by the Contractor. If thermal cutting is used, the attachment shall be cut no closer than 8 mm from the surface to which it is attached, and the balance material shall be removed by mechanical means.

Tack welds to be incorporated into the final weld shall have a contour suitable for fusion with the root pass. Tack welds that become part of the finished weld shall be performed by a qualified welder, using a qualified procedure and filler material, and visually examined. Tack welds that have cracked or are defective shall be removed, and the area re-tacked prior to welding. Tack welds in grooves shall be kept to a minimum.

Weld joint preparation shall not be performed by thermal processes.

Welding procedure and welder performance qualification shall be in accordance with the codes, standards and requirements indicated in Section 5.1.3.3 and with ESR from PED ref. [1] and ESPN ref. [3]. Welding procedure qualification records and welder performance qualification shall be approved by a notified body and shall be verified by IO and the ANB as part of the conformity assessment.

Other permanent joining as tube expansion shall follow the same requirements as the welding.

The location, depth and area size of all weld repairs, regardless of the depth of the repair, shall be documented in accordance with the Contractor's quality program with the IO approval. When base metal is repaired by weld (i.e. cosmetic, buttering or build-up) shall be specified in the as-built drawing with its location and size.

5.1.5.25 Personnel for non-destructive examination (NDE) must be approved by a Notified Body or a third-party recognized by a Member State. All NDE personnel qualifications shall conform to the following requirements:

- Personnel shall be qualified in accordance with NF EN ISO 9712 ref.[18] and approved by either a Notified Body or a Recognized Third Party Organization as per [2] art R557.4.2 point 11.a).i or 11.a).ii.
- the IO and ANB shall check that the qualifications of the personnel responsible for NDE are valid in terms of time and appropriateness for the work to be carried out.
- All non-destructive procedures shall be validated by personnel level III

- 5.1.5.26 All heat treatment equipment shall be calibrated and all personnel performing heat treatment shall be qualified to do so. Heat treatment procedure shall include operating method, and position of the thermocouple.
- 5.1.5.27 Pickling and Passivation procedures shall be submitted to the IO for review and acceptance prior to the start of production and shall follow the rules of ref.[16]. All stainless-steel internal and external surfaces of the baking shall be passivated including the internal surfaces of the tubes.
- 5.1.5.28 Stainless steel surfaces shall not be coated but shall be clean metal and free of weld spatter, oil, dirt, and grease.

5.1.6 Quality Controls Provisions

- 5.1.6.1 The Contractor shall provide the Quality Assurance Program (QAP) under this Specification prior to Contract implementation at least 2 weeks before the KOM. The Contractor shall ensure that their subcontractors follow the QA requirements under the relevant QA classifications (see section 9).
- 5.1.6.2 The Quality Plan shall identify:
- The critical quality activities
 - The specific allocation of resources, duties, responsibilities, and authority
 - The details of all suppliers/subcontractors and how interfaces will be managed.
 - The specific procedures, methods and work instructions to be applied.
 - The specific methods of communication, both formal and informal, to be established between working groups.

The Quality Plan can be updated during the project to include additional requirements related to the design, the procurement, the manufacturing, or the controls.

- 5.1.6.3 Quality requirements to supplement the design and construction code are itemized in the appendix 2 of ref.[45] to ensure conformance with the project-specific standards for the Quality class indicated in Table 2.
- 5.1.6.4 Cross-contamination of stainless steel and carbon steel is prohibited. The Contractor shall prepare a documented plan and implementing procedures employing the best practices of ASTM A380 ref.[16], §8.1 for minimizing iron contamination of stainless steels. This plan and implementing procedures are to be submitted to IO for review and approval. Manufacturing work on this contract may not begin until the plan and implementing procedures are approved.
- 5.1.6.5 26PHBD-HT-1000 shall meet the cleanliness requirements set forth in the ASTM A380 ref.[16] §7.2.1. 26PHBD-HT-1000 shall meet the cleanliness requirements of ASME NQA-1 Subpart 2.1 ref. [12] Cleanliness Class B for the internal surfaces and Class C for external surfaces.
- 5.1.6.6 In progress and at the end of the production of the 26PHBD-HT-1000, all the operations are carried out making it possible to check the dimensions and their compatibility with the tolerances indicated on the plans. Dimensional and geometric controls allow establish the plan "as-built" of the 5.1.5.5 26PHBD-HT-1000.
- 5.1.6.7 The 26PHBD-HT-1000 shall be subject to a load test of the handling/lifting lugs with empty baking heater in accordance with the mechanical design report to ensure that no modification of the dimensions nor permanent deformation occur during the test.
- 5.1.6.8 All instruments used in the testing shall have a recent calibration sheet and shall have an evaluation of the measurement accuracy following *Test Uncertainty*, ASME PTC 19.1 ref.[17]. Another equivalent measurement uncertainty standard can be used subject to prior acceptance by the IO.

5.1.7 Spare parts

26PHBD-HT-1000 shall be delivered with additional full set of gaskets as spare parts in addition of the gasket installed on the flange.

Bolts and nuts for flanges or for supports shall be provided with 10% as spare parts in addition of the items already mounted on the 5.1.5.5 26PHBD-HT-1000.

5.1.8 PED/ESPN regulation requirements

- 5.1.8.1 The 26PHBD-HT-1000 shall be delivered with a Conformity Assessment under Module G. The Contractor as Manufacturer shall hire an Agreed Notify Body (ANB) to perform this conformity assessment.
- 5.1.8.2 The documents needed for the module G shall be forwarded to the ANB after approval from IO. If after ANB review, the documents are requested to be updated, they shall be re-submitted to IO in their last version informing the reviewers the new version is only related to the ANB review.
- 5.1.8.3 All the formal reports issued by the ANB for the design, manufacture, and controls of the 26PHBD-HT-1000 shall be submitted to IO for information through IDM.
- 5.1.8.4 The ESR gap analysis summarizes all the harmonised standards and solutions adopted to meet the requirements of the directive ref. [1], ESPN ref. [3] (codes, technical standards, etc.) and radioprotection guide [39]. The Contractor will adapt the gap analysis ref. [66] between the construction code ref. [7] (or other codes if not harmonized) and the requirements of the PED ref. [1] and ESPN ref. [3].
- 5.1.8.5 The Final Inspection using the as-built drawings shall be performed according to a procedure established by the contractor and approved by IO prior to hydrostatic testing. The purpose is to assure the conformity of the 26PHBD-HT-1000 to all specified requirements before the Declaration of Conformity is issued. All internal and external surfaces shall be visually inspected. If some areas cannot be inspected during the Final Visual Inspection (shell surface covered with pad, internal welds of a nozzle for example), they shall be identified at the design phase and identified in the MIP. IO and the ANB shall be notified to inspect these areas as part of the formal visual inspection and the results shall be recorded in visual inspection reports.

- 5.1.8.6 Proof testing (i.e., hydrostatic testing) shall be conducted on the 26PHBD-HT-1000 in the Contractor's workshop before the shipping with the presence of the IO representative and the ANB with the value indicated in the appendix B. The Proof testing shall be conducted in accordance with a procedure established by the contractor that meet the requirements defined by the IO and approved by IO and the ANB. The hydrostatic test shall be performed with all covers and counter-flanges in place and bolts fastened with the prescribed torque or with caps welded on the nozzle pipes. Covers and counter-flanges shall be the ones that will be delivered with the 26PHBD-HT-1000. If covers or counter-flanges need to be disassembled after the hydrostatic test, they will be reinstalled with new gaskets. Pressure accessories shall be used during the hydrostatic test to ensure that the value of P_{test} is not exceeded during the whole test duration. The hydrostatic test shall be carried out separately on both compartments (shell side and tube side) while the other compartment is empty.
- 5.1.8.7 The hydrostatic test procedure shall be approved at the design stage if the equipment due to its size or production mode cannot be subject to the entire pressure resistance test.
- 5.1.8.8 All the approved formal reports issued by the ANB for the design, manufacture, and controls of the equipment shall be submitted to IO for information through IDM. The Contractor shall present the ANB review status progress during the project meetings with IO and ensure the ANB review progress does not impact the project schedule.

5.1.9 Packing, preservation & shipping

- 5.1.9.1 The 26PHBD-HT-1000 packaging shall meet the minimum requirements in ASME NQA-1, Level C ref. [12] for overseas shipment and the additional requirements stated in this technical specification.
- 5.1.9.2 The 26PHBD-HT-1000 internals shall be preserved with a nitrogen gas purge and pressurization in accordance with ASME NQA-1, Part II, Subpart 2.2, Section 304.2, *Inert Gas Blankets* ref. [12]. The pressure of the nitrogen shall stay lower than 0.5 bar g during the transport and the storage. The initial value shall be selected to ensure that with slight pressure variations, the pressure will not exceed 0.5 bar g. A local manometer shall be provided and connected to allow periodic monitoring of the blanket nitrogen. Range of the manometer shall be at least 1.5* the desired pressure and no more than 3* the desired pressure with an accuracy not higher than 5%. The 26PHBD-HT-1000 shall be kept under nitrogen since the end of the hydrostatic test in factory until its installation and connection to its final location.
- 5.1.9.3 The protection of the surfaces of the various parts is ensured during manufacture and during storage before shipment. The provisions are taken to ensure the preservation of protection under nitrogen and coatings during transport and handling.

- 5.1.9.4 Materials intended for use in preservation, packaging and shipping such as tape, wood, plastic caps, sheet, vapour corrosion inhibitor (VCI) coverings or other covers which are applied directly to stainless steel shall be compatible with the materials to which they are applied.
- 5.1.9.5 During transportation, it is forbidden to let the 26PHBD-HT-1000 touch with materials containing Halogens. Other materials, including Cu, Pb, Zn, and carbon steel, shall not touch the 26PHBD-HT-1000 as well even during the lifting.
- 5.1.9.6 Pictograms on all sides of the packaged the 26PHBD-HT-1000 shall be indicated to ensure the good means to transport and lift it.
- 5.1.9.7 It is the responsibility of the Contractor to take any other precautions required to ensure that the 26PHBD-HT-1000 arrive at the jobsite undamaged.
- 5.1.9.8 Weld nozzles shall be fitted with a welded cap for transportation. The nozzles shall have sufficient extra straight length to allow for the removal of the cap at the site and prepare the nozzle end for welding. Caps shall be designed and calculated for hydrostatic test and transportation loads and must be removed during installation.
- 5.1.9.9 The shipping and storage of the 26PHBD-HT-1000 shall occur only after the completion of the conformity assessment.
- 5.1.9.10 The Contractor shall provide in the instruction manual all the provisions to ensure the regulatory requirements are respected during transportation, installation, and commissioning of the 26PHBD-HT-1000.
- 5.1.9.11 The 26PHBD-HT-1000 is PIC, no deformations are authorized during the transportation from the manufacture phase to the delivery to IO site. Accelerometers shall be fixed on the HT during the transport to record the accelerations. They shall be supported on a rigid part of the 26PHBD-HT-1000. A maximal acceleration shall be set for the transport and confirmed by calculation in the 3 directions. A dedicated transport calculation including the means of fixation during the transport and a static acceleration acting simultaneously in the 3 directions shall be provided as deliverable to ensure the design of the 26PHBD-HT-1000. Initially, this acceleration value is set at 3G in the 3 directions, but another value can be decided by the Contractor with IO approval.
- 5.1.9.12 The transport of the 26PHBD-HT-1000 shall be the responsibility of the Contractor. The delivery shall be performed as DAP Incoterms 2010 ref. [22] at ITER site. The final delivery location of the 26PHBD-HT-1000 is IO site:

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5.1.9.13 The place of storage on site of the 26PHBD-HT-1000 between the delivery phase and the installation phase will be the Storage Area at the IO. The Contractor shall consider storage inside buildings. The 26PHBD-HT-1000 will be delivered with a packaging to withstand the usual weather (wind / snow) during transport provided in 5.1.3.6.

5.1.10 Installation and assembly

- 5.1.10.1 The transport of the 26PHBD-HT-1000 from the storage area to the assembly area is not included in this Contract. Nevertheless, the Contractor shall provide specific means as temporary supports to ensure the transportation of the 26PHBD-HT-1000 which are compatible with the constraints of the site and shall describe the procedure for the in-site transportation and installation operations in an installation manual. Specific supports shall be manufactured for the transport as lugs or trunnions to lift, pull or push the 26PHBD-HT-1000 for their installation. Dedicated supports to use jack system for the transport may be implemented. Transport supports shall be fully designed, manufactured, controlled, and delivered to IO.
- 5.1.10.2 As optional requirement, the Contractor will assist the IO during the in-site transportation phase. Specific quotation shall be provided for this activity.
- 5.1.10.3 For the paired 26PHBD-HT-1000, the welds between the two heaters can only be performed on IO work site. These welds will be managed by IO as an installation activity.
- 5.1.10.4 No items or devices will be manufactured on the IO site. The assembly is not included in this contract. Nevertheless, the Contractor shall provide an assembly guideline in the installation manual of the 26PHBD-HT-1000 especially for the support anchoring and shall implement the needed protection to allow the good assembly achievement. The Contractor shall also provide recommendations for on-site commissioning tests needed to verify the correct operation of the 26PHBD-HT-1000 after installation in the instruction manual.
- 5.1.10.5 The installation step shall be included in the design (stress report) of the 26PHBD-HT-1000 considering the bending moments and loads induced in the equipment and its supports. In the appendix F, pictures of a preliminary study of installation are presented. The Contractor shall include a full installation study and installation manual for the 26PHBD-HT-1000.

5.1.11 Maintenance and Inspection Requirements

- 5.1.11.1 The 26PHBD-HT-1000 shall be designed to allow for removal of the heater bundle(s). The 26PHBD-HT-1000 parts requiring adjustment, inspection or repair shall be accessible and able to be conveniently removed, cleaned, replaced, or repaired.
- 5.1.11.2 The 26PHBD-HT-1000 and nozzle connections shall be designed to meet the in-service-inspection requirements of the ESPN level N3 described in [3]. In-service Inspection drawing with indication and justification of the most vulnerable areas shall be approved by IO before starting the manufacture of the 26PHBD-HT-1000.
- 5.1.11.3 An in-service inspection up to 40 months following initial commission and every 40 months then shall be performed. Visual inspection of all pressure bearing parts of the pressure vessel, for internal and external surface including tube bundle shall be carried out during these inspections.
- 5.1.11.4 Periodic requalification including a visual inspection of all pressure bearing parts of the pressure vessel, for internal and external surface including tube bundle and a pressure test with $Prequal=120\%*PS$ shall occur every 10 years. This requalification pressure test shall be included in the design of the 26PHBD-HT-1000.
- 5.1.11.5 Welds of all pressure bearing parts shall be controlled volumetrically without exception, this requirement shall be included from the design phase.
- 5.1.11.6 The tube bundle if it cannot be directly visually inspected goes through Non-Destructive Testing using an automatic Eddy Current Testing device – Note that other techniques such as Ultrasonic, Magnetic Flux Leakage, Laser Optic, etc. may also be acceptable if agreed with IO and ANB and described in the Instruction Manual.

5.1.12 Insulation and sheathing

- 5.1.12.1 The 26PHBD-HT-1000 design shall include the means for application of insulation on the heater and the support saddles.
- 5.1.12.2 The design of supports for the installation of the insulation and sheathing is included in the design and construction of the 26PHBD-HT-1000.
- 5.1.12.3 The expected insulation shall have the same characteristics (thermal conductivity and density) as PROMAT Microtherm Overstitch 1000 in order reduce the thickness of insulation to the minimum. Other insulation material can be used subject to written approval IO prior to use.

- 5.1.12.4 The insulation thickness shall be designed and the material insulation shall be selected to resist fire and limit the metal temperature under the insulation to maximum 263°C (T_{sat} at 5.5 MPa abs_a see appendix A) for all fire loads during 2h following Eurocode 1 ref. [19] which provides a peak air temperature of 1050°C. The thickness of the insulation shall be the minimum possible due to space requirements around the 26PHBD-HT-1000.
- 5.1.12.5 The thermal insulation of the 26PHBD-HT-1000, as well as the sheathing, is chemically neutral with respect to the walls to be protected. The sheathing shall be stainless steel sheet.
- 5.1.12.6 The density of the insulating material and its thickness shall be considered in the weight of the 26PHBD-HT-1000 for the design and calculations.
- 5.1.12.7 Insulation supports shall be designed such that the insulation remains in place during a SL-2 earthquake.
- 5.1.12.8 The insulation shall be tested and qualified for these different requirements:
- Chemical analysis: Co, Ta and Nb shall be in the limits indicated in the chapter 5.1.5.1 for the insulation product and the sheathing.
 - Free of Halogens (Chlorine, Fluorine, Bromine) for the insulation product and the sheathing
 - Landa test (thermal conductivity) following ASTM C177
 - Density following ASTM C303
 - Flammability resistance: minimum classification A2L s3 d0 according to EN 13501-1. The flammability performance shall be equivalent or better than the mentioned classification in other recognized standards (as ASTM E84).
 - Resistance to seismic event SL-2
 - Radiation ageing qualification will be performed later by IO: coupons shall be sent by the Contractor done in the same batch of the insulation of the 26PHBD-HT-1000 and provided in the same preservation conditions as the insulation itself.

5.1.13 Software requirements

- 5.1.13.1 The use of computer software to perform a safety basis task activity such as analysis and/or modelling, etc. shall be reviewed and approved by the IO prior to its use, providing the software V&V following qualification Policy ref. [65]
- 5.1.13.2 The software V&V shall include test cases encompassing the range of intended use for the new or revised software. Qualification testing shall be taken into consideration to demonstrate that software meets its specifications and is ready for use in its target environment or integration with its containing system.
- 5.1.13.3 Where necessary to evaluate technical adequacy for verification, the V&V shall indicate how the results are to be evaluated. For example, the results may be compared to results from alternative methods such as:
- Analysis without computer assistance
 - Other qualified software
 - Experiments and tests
 - Standard problems with known solutions
 - Confirmed publications or correlations.
- 5.1.13.4 The following software and versions shall be used by the supplier:
- For thermal calculation: HTRI Xchanger Suite 8 or more recent or other equivalent software after IO approval
 - For CFD thermal hydraulic analyses: Ansys workbench 19.2 – Fluent 19.2 or more recent
 - For mechanical structural analysis: Ansys workbench 19.2 – Mechanical 19.2 or more recent after IO approval
 - For design calculation: PV Elite 2018 or more recent or other equivalent software after IO approval
 - For flange calculation: TEMES 9.0.21 or more recent or other equivalent software after IO approval

5.1.13.5 GM3S ref. [25] states that the models shall be provided in a ready-to-run state. Any manual operation that is required to rerun the analyses shall be described either in the analysis report or in a document attached to the model.

5.1.13.6 Excel spreadsheet can be used for calculation by formula but the native files shall be provided and the formula shall be readable for review.

5.1.14 Delivery time

5.1.14.1 The maximum expected duration from the contract signature to the supply of the scope of work is 2 years (24 months).

5.1.14.2 The design of 26PHBD-HT-1000 shall be fully completed withing 10 months after the KOM.

D No.	Description	Due date, months
D01	Quality Plan (approved)	T0 + 2
D02	MIP/MRR	T0 + 5
D03	Fabrication report	T0 + 10
D04	Factory acceptance test (inspection/audit)	T0 + 16
D05	Delivery to IO site (CRN, RN, DR, MTC's)	T0 + 23

T0 – signature of the contract

6 Location for Scope of Work Execution

The Contractor will perform the work at their own location from the KOM to the shipment of the 26PHBD-HT-1000. The list of main manufacturing activity locations shall be communicated to IO in the qualified supplier list. Change of one of location shall be timely notified to IO.

7 IO Documents

Under this scope of work, IO will deliver the following documents by the stated date:

Table 8 – IO documents

Ref	Title	Doc ID	Expected date
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1	As-built position of the platform	Drawing	KOM
2	Installation study	Presentation	KOM
3	Maintenance space reservation	Drawings	KOM
4	Integration studies	Presentation	after 26PHBD-HT-1000 drawing submission
5	Verification Compliance Matrix	Table	MRR
6	List of clarifications	List	MRR

- 1- Drawings with as-built position of the platform will be provided by IO to ensure the supporting structure can be designed accordingly. These drawings will be submitted for the KOM as a design input.
- 2- Installation study will be provided by IO with the detailed path of transport inside the Tokamak building and as-built dimensions of the final space reservation for 26PHBD-HT-1000. This study will be submitted for the KOM to design the temporary supports and transport/lifting items.
- 3- Drawings for the space around the 26PHBD-HT-1000 to be used for the in-service inspection will be provided by IO for 26PHBD-HT-1000 to ensure the equipment can be designed and inspected accordingly. These drawings will be submitted for the KOM as a design input.
- 4- After submission of assembly drawings of 26PHBD-HT-1000 by the Contractor, IO verify the potential clashes using the step file of the pressure equipment attached with the drawing. An integration study is created with the 26PHBD-HT-1000 in its environment to verify the accessibility and the remaining space to the other items in the vicinity of the HT.
- 5- For the MRR, the IO will provide the Verification Compliance Matrix part 1 which lists all the main requirements from this Technical Specification and GM3S ref. [25]. The requests of clarifications raised by the Contractor and answered by IO during the design phase are also listed in this Verification Compliance Matrix.
The Contractor shall fill the part 2 and 3 of this document for the end of the Contract and provide it as a deliverable.

- 6- The list of clarifications is updated during the design phase by IO to record all the requests of clarifications from the Contractor and the answers from IO to complete the Technical Specifications requirements. This list is completed for the MRR.

8 List of deliverables

The Contractor shall provide IO with the documents and data required in the application of this technical specification, the GM3S Ref [25] and any other requirement derived from the application of the contract. Some other documents can be identified during the kick-off Meeting or during the project and will be added to the list presented in the appendix G.

Supplier shall prepare their document schedule based on the list in the appendix G and using the template available in the GM3S Ref [25] appendix II.

9 Quality Assurance requirements

26PHBD-HT-1000 must function to achieve plasma operation, all components and equipment of it become Quality Class 1.

Consequently, the Quality class under this contract is QC-1, GM3S section 8 ref. [25] applies in line with the defined Quality Class.

The Contractor's QAP shall be applied to the entire Product under this Specification and shall be submit to the IO.

10 Safety requirements

TCWS IBED PHTS is a SIC-1 system according to Safety Important Functions and Components Classification Criteria and Methodology from Ref [33].

The scope under this contract covers for PIC and/or PIA and/or PE/NPE components, GM3S section 5.3 ref. [25] applies.

Under French Order 7 February 2012 ref.[4], the PICs require control and guaranty of the quality of the PICs during the design and manufacturing phase to ensure its safety functions can be maintained in all postulated situations. This is accomplished through the guidelines provided for in the Management of Propagation of Nuclear Safety Requirements in the Contractor Chain ref. [35] regarding:

- Policy on Protection of the Interests
- Quality management system
- Supervision
- Execution and supervision of the PIA

- Skills and qualification of the interveners
- Records
- Non-conformities
- Lesson learned
- Safety demonstration

In the contracts passed down to the subcontractors, it is clearly stated that in addition to technical requirements, defined requirements on Protection Important Components (PIC) and Protection Important Activities (PIA) must be monitored by the IO. The subcontractor must possess a quality system in agreement with the importance of the equipment being delivered and for the follow-up of the PIA corresponding to the PIC to be provided under the contract. This system shall be included in the MIP or Quality Plan.

The system requirements applicable to 26PHBD-HT-1000 are presented in the Appendix H.

11 Specific General Management requirements

Requirement for ref. [25] GM3S section 6 applies in full and is completed with the below specific requirements.

11.1 Contract Gates

The contract gates as defined in ref. [25] section 6.1.5. The Manufacturing Readiness Review (MRR) can be split in different sub-MRR to authorize the partial manufacture of the equipment. The purpose is to ensure that if the procedures are approved, raw materials received and certificates approved, some parts of the pressure equipment can be authorized to be manufactured. These sub-MRR gates are formalized in the MRR report.

11.2 Meeting Schedule

A progress review meeting is to be held on a weekly basis between the Contractor representative and CRO with the appropriate support of relevant stakeholders.

The Contractor shall ensure the timely submission of the Progress Report during the progress meeting.

The Contractor shall create and maintain a list of open action items assigned to the Contractor or the IO. The list shall identify the action to be taken, category (critical or non-critical), responsible Party or individual, and the date the required action is to be completed. Due dates shall be met to maintain project schedules and proper work sequence.

11.3 CAD design requirements

This contract requires CAD activities, GM3S Section 6.2.2.2 applies, [25].

The step files of the pressure equipment and supports shall always been attached to the drawings submitted to IO.

11.4 Subcontracting

GM3S ref. [25] chapter 6.4 applies. When a document is sub-contracted, there is no maximal versions of the documents before IO approval. The Contractor shall ensure his sub-contractor perform the work assigned with the best quality to reduce the number of versions.

11.5 Documents

All the manuals (Instruction Manual, Installation Manual, Transport Manual...) shall be written in French and in English.

All documents shall be clean and legible white prints with uniform background density suitable for electronic scanning and subsequent reproduction from an electronic format. Insofar as practical, documentation shall be typed and arranged in a neat and professional manner. Handwritten documents shall conform to the legibility requirements and quality requirements of this section. Any pen and ink changes necessary after printing will be performed by drawing a single strike through line, preserving the original information, with neat ink text initialled and dated. Material certificates with white correction fluids on it will not be accepted.

Documents not meeting the quality requirements specified herein will be returned to the Contractor without IO review for correction and resubmission. Rejected documents will not be a basis for approving schedule extensions or cost increases.

All documents shall use SI units as primary dimensions. Drawings shall follow all normal ISO conventions and standards, in particular those standards used in the power industry, for orientation and rotation of drawings, plan views, dimensioning, symbols, etc.

Appendix A: Process loading conditions.

A.1. Process loading conditions.

The process loading conditions of the 26PHBD-HT-1000 are provided hereafter and can be extracted from the IBED process loading ref. [59], zone PT2. These loading conditions shall be combined with mechanical loading conditions according to TCWS Load Specification ref.[46] as seismic effect and nozzle loads (Appendix B: Loads combinations).

The fatigue analysis shall include the number of cycles as per Table 9. The thermal conditions indicated in this appendix can be used for the fatigue analysis to optimise the design and the minimum required thickness.

A.2. Environmental conditions

Dose rate (kGy/h)	≤ 0.1
Integrated Dose Rate 20 yrs. (kGy)	10
Magnetic Field (mT)	84
Normal temperature (°C)	5-35
Normal Humidity (%)	≤ 65
Normal Pressure relative to atm. (kPa)	-0.14
Accidental Temperature (°C)	400*
Accidental Pressure relative to atm. (kPa)	-5/100
Accidental Humidity (%)	100

- Fire case

Case	Loading Conditions	Number of Cycles	PT2 = Baking Loop	Comment
I.S0	Design Conditions	-	5.0 MPa 270 °C	
I.S1	Standby Mode (Low Flow)	-	2.2 MPa Tamb	no flow
I.S2	Water Baking Operation at 240 °C	-	4.4 MPa 240 °C	full flow rate
I.S3	Idle Mode	-	1.4 MPa Tccws	low flow rate
I.S4	Off Mode	-	0.6 MPa Tamb	no flow
I.S5	Maintenance Mode	-	0.1 MPa Tamb	no flow
I.S6	Standby Mode (Nominal Flow)	-	4.3 MPa Tamb	no flow
I.S8	Water Baking Operation at 18 °C	-	4.4 MPa 18 °C	full flow rate
I.S9	First Plasma Gas Baking Operation at 240 °C	-	3.2 MPa 240 °C	full flow rate
I.T1	Plasma Operation	30000	4.3 MPa Tamb	no flow
I.T2	Standby Mode (Low Flow) to Water Baking Operation	500	[0.1, 4.4] MPa [18, 240] °C	transient, from pump stopped to full flow
I.T14	Idle Mode to Water Baking Operation		[1.4, 4.4] MPa [10, 240] °C	transient, from no flow to full flow
I.T3	Water Baking Operation to Standby Mode (Low Flow)	500	[2.2, 4.4] MPa [18, 240] °C	transient, from full flow to no flow
I.T15	Water Baking Operation to Idle Mode		[1.4, 4.4] MPa [10, 240] °C	transient, from full flow to no flow
I.T4	Standby Mode (Low Flow) to Idle Mode	500	[0.1, 1.4] MPa [10, 35] °C	transient, from low flow to no flow
I.T5	Idle Mode to Standby Mode (Low Flow)	500		

Case	Loading Conditions	Number of Cycles	PT2 = Baking Loop	Comment
I.T6	Off Mode to Maintenance Mode	500	[0.1, 0.6] MPa T_{amb}	no flow
I.T7	Maintenance Mode to Off Mode	500		
I.T8	Off Mode to Idle Mode	500	[0.6, 1.4] MPa [10, 35]	transient, from no flow to no flow
I.T9	Idle Mode to Off Mode	500		
I.T10	Clients Dryout during Maintenance Mode	50	0.1 MPa T_{amb}	no flow
I.T11	Clients Blowout during Maintenance Mode	See comment	0.1 MPa T_{amb}	no flow
I.T16	Standby Mode (Low Flow) to Standby Mode (Nominal Flow)	4000	[2.2, 4.3] MPa T_{amb}	no flow
I.T17	Standby Mode (Nom. Flow) to Standby Mode (Low Flow)	4000		
II.S1	DEG1 Degraded Environmental Conditions	-	Environmental pressure: [95, 200] kPa Environmental temperature: [5, 100] °C Environmental air humidity: [0, 100] %	
II.T1	Short-Term LOOP	50	[4.4, 5.0] MPa [10, 240] °C	No Flow
II.T2	Cat. II Break within In-Vessel LOCA Boundaries	50	[4.4, 5.0] MPa 18 °C	
II.T4	Loss of HVAC Incident	50	[-0.2] MPa [18, 100] °C	
II.T5	SL-1 Seismic Event	50	4.4 MPa 240 °C	
II.T6	WH Pump Trip	50	Baking pump: I.S2 + PL-1900 trip (Impulse case 5 from 8RF7N6 v5.1)	
II.T9	WH Spurious LOCA Isolation Valve Closure	5	For ex-vessel and in-vessel LOCA valves closure: During baking: I.S2 + simultaneous closure of in-vessel LOCA isolation valves (Impulse case 1C1 from 8RF7N6 v5.1)	

Case	Loading Conditions	Number of Cycles	PT2 = Baking Loop	Comment
II.WH	Bounding Case for Category II Water Hammer Events (II.T6 & II.T9)	55	[4.4, 5.0] MPa 240 °C	100% design pressure is never exceeded for category II water hammer events (II.T6 & II.T9). Their initial operating conditions are based on I.S2 & I.T1. A bounding case is thus defined based on sudden pressure variation from lowest operating pressure to design pressure at constant highest operational temperature, and vice-versa.
II.T11	OPP Category II	50	[0.6, 5.0] MPa 270 °C	
III.S1	DEG2 Highly Degraded Environmental Conditions	-	Environmental pressure: [95, 200] kPa Environmental temperature: [5, 130] °C Environmental air humidity: [0, 100] %	
III.T1	Long-Term LOOP (32hr) + Failure of DHR Operation	1	4.4 → 5.0 → 4.4 MPa 240 → 10 → 240 °C	no flow
III.T2	Short-Term LOOP + Loss of HVAC Incident	1	II.T1 → II.T1 + II.S1 → II.T1	This loading condition is covered by the bounding case suggested for loss of HVAC incident (II.T4), and the bounding case for short-term LOOP (II.T1).
III.T3	LOCA Outside Cryostat	1	[-0.2] MPa 18 → 130 → 18 °C	Only impact on environmental conditions
III.T4	WH Pump Seizure	1	Baking pump: I.S2 + 1 ms PL-1900 seizure (Impulse case 6A from 8RF7N6 v5.1)	
III.T5	SMHV Seismic Event	1	4.4 MPa 240 °C	SMHV is cumulated to this bounding case.
III.T9	WH Break Propagation	1	Pipe Break for Plasma and Baking: From Table 1-3 for baking part (2PW8D3). All category III cases	These pipe breaks should not result in damaging: * piping inside cryostat. * piping across any ex-vessel LOCA isolation valve.

Case	Loading Conditions	Number of Cycles	PT2 = Baking Loop	Comment
III.T10	OPP Category III	1	0.6 → 5.5 MPa 270 °C	
III.T11	WH Spurious & Simultaneous LOCA Isolation Valves Closure with a Single Failure	1	I.T1 + simultaneous closure of all LOCA isolation valves except one: Hydraulic loads for baking in 8RF7N6 v5.1	
III.WH	Bounding Case for Category III Water Hammer Events (III.T4 & III.T11)	1	4.4 → 5.5 → 4.4 MPa 240 °C	110% design pressure is never exceeded for category III water hammer events (III.T4 & III.T11). Their initial operating conditions are based on I.S2 & I.T1. A bounding case is thus defined based on sudden pressure variation from lowest operating pressure to design pressure at constant highest operational temperature, and vice-versa.
III.T12	Cat. III Pipe Break within In-Vessel LOCA Boundaries	1	4.4 → 5.5 → 4.4 MPa 18 °C	
N.A	Combination III.WH + III.T5 = SMHV + WH Cat. II or III	1	4.4 → 5.5 → 4.4 MPa 240 °C	SMHV is cumulated to bounding case III.WH. Note that this covers any combination of category II / III water hammer events with SMHV.
IV.S1	Fire Design Basis	1	The fire design basis event is based on Eurocode 1 EN 1991-1-2:2002. Environmental temperature increases up to 1049 °C for a fire duration of 2 hr. IBED PHTS fire insulation is sized to ensure that the maximum process temperature in case of fire never exceeds the saturation temperature at design pressure.	
IV.T1	Fire Exposure	1	0.6 → 5.5 → 0.6 MPa 18 → 263 → 18 °C	
IV.T2	SL-2 Seismic Event	1	4.4 MPa 240 °C	SL-2 is cumulated to this bounding case.

Case	Loading Conditions	Number of Cycles	PT2 = Baking Loop	Comment
IV.T5	Cat. IV Pipe Break within In-Vessel LOCA Boundaries	1	4.4 → 6.0 → 4.4 MPa 18 °C	
IV.T6	WH Severe Pump Seizure	1	Pump Seizure in Plasma: Case 4 (3S3YGB v7) Pump Seizure in Baking: Case 6B (8RF7N6 v5.1)	
IV.WH	Bounding Case for WH Severe Pump Seizure (IV.T6)	1	4.4 → 6.0 → 4.4 MPa 240 °C	120% design pressure is never exceeded for WH severe pump seizures (IV.T6). Their initial operating conditions are based on I.S2.A bounding case is thus defined based on sudden pressure variation from lowest operating pressure to design pressure at constant highest operational temperature, and vice-versa.
N.A	Combination IV.WH + IV.T2 = SL-2 + WH Cat. II, III, or IV	1	4.4 → 6.0 → 4.4 MPa 240 °C	SL-2 is cumulated to bounding case IV.WH. Note that this covers any combination of category II / III / IV water hammer events with SL-2.
U.S1	Storage Env. Conditions	-	<p>OUTDOORS</p> <p>Environmental pressure: atmospheric Environmental temperature: [-25, 45] °C Environmental air humidity: 30 g/kg (=> 100% at 32 °C and 50% at 45 °C) Extreme winds up to 166 km/hr Maximum mass of snow: 150 daN/m²</p> <p>INDOORS</p> <p>Environmental pressure: atmospheric Environmental temperature: [-8, 45] °C Environmental air humidity: 30 g/kg (=> 100% at 32 °C and 50% at 45 °C)</p>	
U.T1	Hydrostatic Pressure Test	10	TBD by manufacturer (ESPN) Suggestion: 0.1 → 8.6 → 0.1 MPa [5, 45] °C	

Case	Loading Conditions	Number of Cycles	PT2 = Baking Loop	Comment
U.T2	Containment Leak-Tightness Test	10	Environmental pressure: [95, 200] kPa Environmental temperature: [18, 35] °C Environmental air humidity: [0, 60] %	

Table 9 – Loading conditions (fatigue).

CAT I – II	Loading condition	Cycles	P MPa	T °C
I	Plasma Operation	30000	4.3	Tamb.
I	Standby Mode (Low Flow) to Water Baking Operation	500	[0.1, 4.4]	[18, 240]
I	Idle Mode to Water Baking Operation	500	[1.4, 4.4]	[10, 240]
I	Water Baking Operation to Standby Mode (Low Flow)	500	[2.2, 4.4]	[18, 240]
I	Water Baking Operation to Idle Mode	500	[1.4, 4.4]	[10, 240]
I	Standby Mode (Low Flow) to Idle Mode	500	[0.1, 1.4]	[10, 35]
I	Idle Mode to Standby Mode (Low Flow)	500	[0.1, 1.4]	[10, 35]
I	Off Mode to Maintenance Mode	500	[0.1, 0.6]	Tamb.
I	Maintenance Mode to Off Mode	500	[0.1, 0.6]	Tamb.
I	Off Mode to Idle Mode	500	[0.6, 1.4]	[10, 35]
I	Idle Mode to Off Mode	500	[0.6, 1.4]	[10, 35]
I	Clients Dry out during Maintenance Mode	50	0.1	Tamb.
I	Standby Mode (Low Flow) to Standby Mode (Nominal Flow)	4000	[2.2, 4.3]	Tamb.
I	Standby Mode (Nom. Flow) to Standby Mode (Low Flow)	4000	[2.2, 4.3]	Tamb.
II	Short-Term LOOP	50	[4.4, 5.0]	[10, 240]
II	Cat. II Break within In-Vessel LOCA Boundaries	50	[4.4, 5.0]	18
II	Loss of HVAC Incident	50	-0.2	[18, 100]
II	SL-1 Seismic Event	50	4.4	240
II	Bounding Case for Category II Water Hammer Events (II.T6 & II.T9)	55	[4.4, 5.0]	240
II	OPP Category II	50	[0.6, 5.0]	270
U.T1	Hydrostatic Pressure Test	10	[0.1, 8.6]	[5, 45]
U.T2	Containment Leak-Tightness Test	10	[0.095, 0.2]	[18, 35]

Appendix B: Loads combinations

B.1. Classification

This appendix describes all the combinations of loads to be used for the normal, exceptional, and highly improbable conditions needed for the design of the 26PHBD-HT-1000.

The 26PHBD-HT-1000 safety important classification is SIC-1 as per ref. [46], loading conditions from categories I & II shall remain within normal damage limits (service level = A), loading conditions from category III shall remain within emergency damage limits (service level = C) with the allowable values from ref. [40], and loading conditions from category IV shall remain within faulted damage (service level = D) with the allowable values from ref. [40].

From the ESPN classifications, according to the ASN guide 19 ref. [6] the events are classified into 4 categories:

- Normal operating conditions (corresponding to cat I and II),
- exceptional situations (cat III)
- highly improbable situations (cat IV)
- testing conditions

Table 10 below summarizes the classification and the requirements and criteria for the maximum allowable pressure and the maximum allowable temperature.

Table 10 – Situations Classification and associated requirements

classification of the situation following the harmonised standards			PS/TS
conditions of use which can be reasonably foreseen	normal situations	normal situations during normal operating conditions	T ≤ TS P ≤ PS
		situations corresponding to usual operational incidents	
	exceptional situations		P ≤ 110%PS and short time excess - verification of the equipment (except if adequate design defined) - adequate protection device when T > TS
test situations		Proof test pressure carried out at the final assessment (envelop of all the pressure tests during operation)	
highly improbable situations			avoid the risk of loss of integrity in case of excess of PS ad TS related to the requirements defined in the safety report.

B.2. Units

The following units are used:

- Pressures, stresses are given in kPa abs, MPa abs and bar g
- Temperatures are given in Celsius degrees °C
- Dimensions and displacements are in meters or mm
- Mass is in kilograms kg
- Acceleration is in m/s^2 or in g

B.3. Coordinate system

The ITER global reference axes is used for the global reference coordinate system of the 26PHBD-HT-1000:

For the ITER plant the reference axes are:

- X = East
- Y = North
- Z = Vertical

B.4. Loads

The loads acting on the 26PHBD-HT-1000 can be divided into 5 independent categories:

- Pressure loads: these include the internal pressure and the water height pressure on the vessel.
- Inertial loads: these are caused by accelerations due to gravity and seismic events on the equipment itself, the internals and on the contained water (sloshing).
- Thermal loads: stresses caused by fluctuations of temperature applied to the vessel and its support and stresses caused by temperature differences including transient conditions and by differences in coefficients of thermal expansion.
- Nozzle loads: the connected pipes provide loads at the connection nozzles.
- Maintenance loads: the transportation, lifting, installation and in-site inspection during the lifetime of the pressure equipment provides additional loads and stresses.

The TCWS Load specification ref. [46] indicates many types of loads for the TCWS systems. However, the 26PHBD-HT-1000 is not subject to the following loads:

- Vertical displacements events
- Major disruptions
- Helium leak outside cryostat
- CrICE event (leak of Cryogenic pipes inside Cryostat)
- VV ICE (ingress of coolant inside the Vacuum vessel)

B.5. Nozzle Loads

See Table 14.

B.6. Seismic Loads

Following the loads specification ref. [46], the 26PHBD-HT-1000 is subject to seismic loads. Three different seismic events must be considered for the 26PHBD-HT-1000:

- SL-1 (event category II)
- SMHV (event category III)
- SL-2 (event category IV)

The numbers of occurrences for the seism events during the lifetime of the 26PHBD-HT-1000 are (see Appendix A):

- 50 for SL1,
- 1 for SMHV,
- 1 for SL2.

The values for the Floor Response Spectra are provided in Appendix D: Platform Response Spectra.

B.7. Fire case

Fire is a cat. IV event (service level D).

The 26PHBD-HT-1000 and their supports are insulated.

The fire design basis event is based on Eurocode 1 EN 1991-1-2:2002 ref. [19]. Environmental temperature increases up to 1049 °C for a fire duration of 2 hours.

IBED PHTS fire insulation is sized to ensure that the maximum process temperature in case of fire never exceeds the saturation temperature at design pressure which is 263°C (see case IV. T1 in appendix A).

Per reference [46], a seism SL-2 can trigger a fire which is not concomitant, should occur as an event category IV (highly improbable situation). Then, a replica SMHV concomitant to the fire shall occur.

When the fire is cumulated with SMHV, it shall be verified that, after the deformations, the nozzles can withstand the service level C nozzles loads provided in the Appendix C.

B.8 Summary of the loading combinations

The individual load cases are listed in B-2 while the load combinations to consider for the 26PHBD-HT-1000 design are listed in B-3 and B-4.

Table 11 – individual load cases

Load	Description
P	Internal and external specified pressure (including static height pressure from liquid)
Ptest	Test Pressure
Dw	Dead weight including all sustained loads (piping, insulation, stainless steel jacket, fluid, etc)
Dt	Same as Dw, except for conditions during pressure test. This can be different from Dw in case of no insulation during the test
T	Temperature or Thermal Loads due to: <ul style="list-style-type: none"> - piping thermal expansion/contraction when subjected to maximum temperature differences between the fluid and the surrounding environment, - anchor movements due to thermal movements of the equipment - thermal expansion
SL1	Seismic event level 2 due to operating basis earthquake, SL-2 x 0.34
SMHV	Seismic event level 3 due to operating basis earthquake, SL-2 x 0.73
SL2	Seismic event level 4 due to safe shutdown earthquake
Nozzle loads	The nozzle loads at the flange with the pipe connected provided for the levels A/ B (normal situation), C (exceptional situations) D (highly improbable situations).

Table 12 – Heater loads for Normal Operation (I, II) and Exceptional situations (III, IV)

LOADS	NORMAL SITUATION		EXEPTIONAL SITUATION	HIGHLY IMPROBABLE SITUATION	HIGHLY IMPROBABLE SITUATION	NORMAL SITUATION	LIFTING CASE
	CATI/II	CATII	CATIII	CATIV	CATIV	TEST	TEST
Dead weight	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pressure, Mpa	5	⁽⁴⁾ -0.2	5.5	5.5	6	8.6	0
⁽¹⁾ Temperature (internal) °C	270	240	270	263	240	45	T _{amb}
⁽²⁾ Temperature (external) °C	T _{amb}	100	T _{amb}	263	T _{amb}	T _{amb}	T _{amb}
Temperature (supports) °C	See ⁽³⁾	See ⁽³⁾	See ⁽³⁾	263	See ⁽³⁾	N/A	N/A
Dynamic (seismic)	SL-1	SL-1	SMHV	SMHV	SL-2	N/A	N/A
Nozzle loads	A/B	B	C	D	D	N/A	N/A
Operational state	Yes	Yes	Yes	No	No	N/A	N/A
Confinement state	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fatigue	Appendix A	Appendix A	N/A	N/A	N/A	N/A	N/A

- (1) Internal temperature of the heater.
- (2) Outside temperature in the room.
- (3) Supporting structure temperature to be calculated with consideration of convection.
- (4) External pressure.

Note:

- the pressure test shall be confirmed by the Contractor. It is stated in this table following the document ref. [67]
- The wet dead weight is considered for each loading combination (including thermal insulation). For the lifting case, 125% of the dry weight is considered (including thermal insulation).

Table 13 – Environmental conditions for cubicles

		ITER_UID
Location	11-R1-01E (Crane Hall R1 Area)	N/A
(Platform)	B11_R1_PLATFORM_18	37NDX4_v2
Confinement zone	Confinement zone 11-None (Building 11)	Y4YGUZ v2.0
Magnetic field, [mT]	21	Y4YGUZ v2.0
Seismic	See ITER_UID for details	TK2PJZ v1.2
Spectra/Nodes	Nodes: 86991/86391/ 86517	3F4X5L v3.0
Radiation, [Gy]	<100@4700 h	RJLLFY v2.1 3Q3E5Z v1.4 3YVVKU v1.0
Humidity, [%]	60% RH	Y4YGUZ v2.0

Notes:

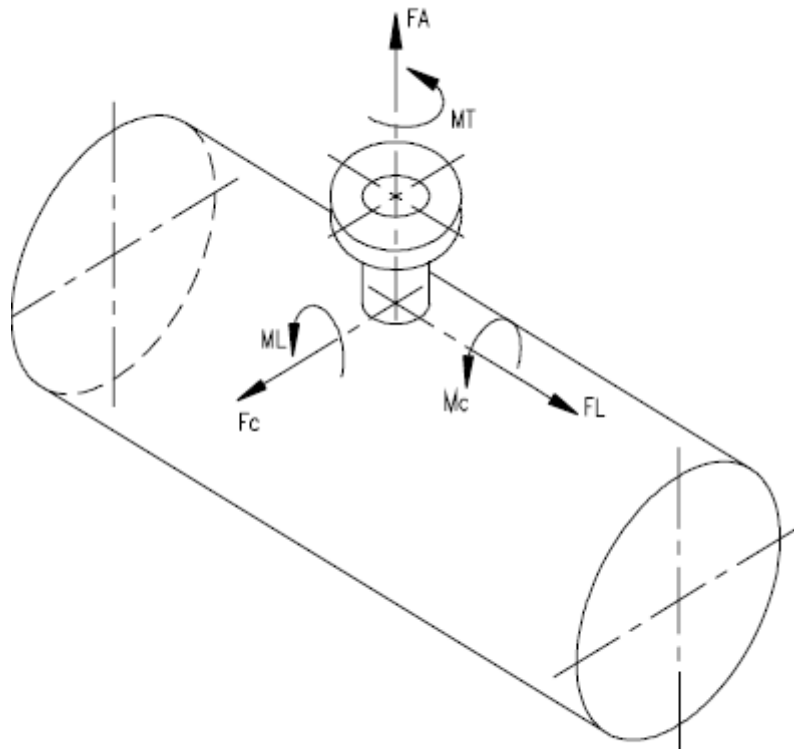
- LOCA, LOVA or Helium Leak are not applicable to this area, as per [54].

Testing and inspection requirements:

- The examination, testing, and inspection of all pressure retaining and integrally attached materials shall meet the requirements of ASME BPVC Section VIII, Division 2 [Ref. 2.3.5], ESPN, ESP/PED, and the additional requirements stated herein. When no code or standard applies, the acceptance criteria shall be the manufacturer's standard and of proven suitability for the service.
- A visual inspection in accordance with ASN Guide 8 [Ref. 2.3.22] shall be completed prior to hydrostatic testing.
- Proof testing (hydrostatic test) shall be conducted on the HT in accordance with the Code of Construction, as defined in Section 3.1.2 and approved by the ANB. The selected code shall be harmonized with the PED hydrostatic testing requirements. The hydrostatic test shall be performed with all covers and counter-flanges as described in Section 3.2.1.b&c in place and bolts fastened with the prescribed torque. Covers, counter-flanges and gaskets shall be the ones that will be delivered with the HT. If covers or counter-flanges need to be disassembled after the hydrostatic test, they will be reinstalled with new gaskets.
- The HT shall be fully filled with water and completely drained. Any water that appears to have pooled or collected in the HT shall be clearly indicated on the test report. The inspection may be performed while draining the HT after completion of the proof testing.
- The HT control system factory acceptance testing shall be in accordance with Technical Specification for Control System FAT/SAT for the 2nd Plasma Sub-Systems [Ref. 2.1.16].
- The HT checklist shall include megger check, continuity check, and power check for the heater bundle, and I/O check, loop check, and logic check for the heater control cubicle.
- The HT shall be filled with water, heated under power to design temperature listed in HT DS (Appendix A), and tested for insulation resistance. The HT shall be tested for wattage and dielectric strength.
- The HT shall be subject to a load test of the handling/lifting lugs with empty heater.
- The verification of design and performance of the heater control cubicle shall be performed in accordance with the Technical Specification for Electrical Cubicles and Systems for LV for IBED PHTS, CVCS, NBI PHTS [Ref. 2.1.10].
- Any additional testing required shall be noted on the HT DS (Appendix A).
- A final visual inspection shall be completed to assure the conformity of the HT to all specified requirements before the Certificate of Conformity is issued.
- All instruments used in the testing shall have a recent calibration sheet and shall have an evaluation of the measurement accuracy following Test Uncertainty, ASME PTC 19.1 [Ref. 2.3.10]. Another equivalent measurement uncertainty standard can be used subject to prior acceptance by IO.

Appendix C- nozzle Loads

The nozzle loads are located at the connection nozzle with the pipe connected (not at the connection nozzle / vessel).



Nozzles on Cylindrical Shells

Figure 11 – localization of the load application for a nozzle on a cylindrical shell

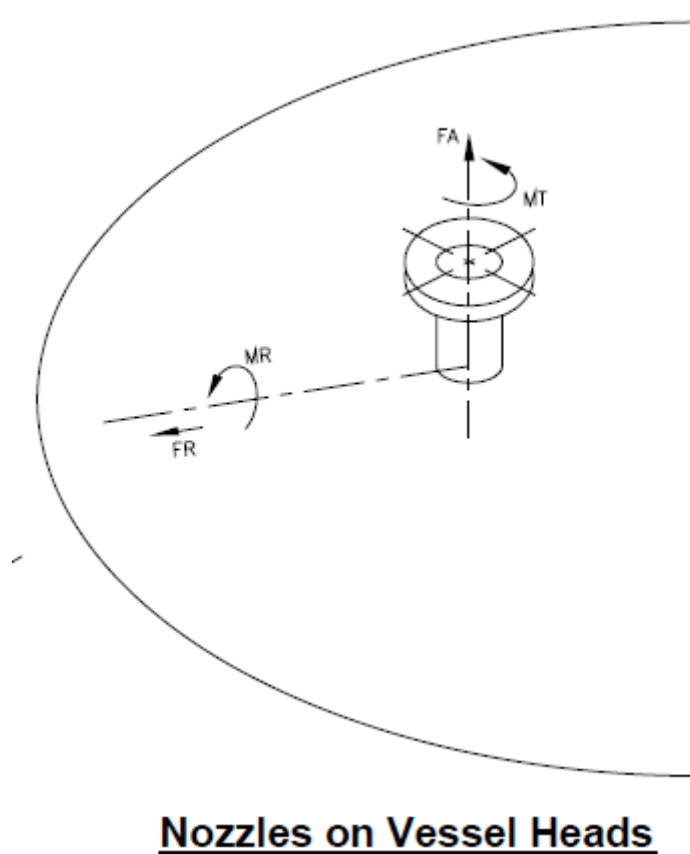


Figure 12 – localization of the load application for a nozzle on a spherical head

The values are provided for the situation's A/B (cat I and II normal situations), C (cat III exceptional situations) and D (IV highly improbable situations).

C-1 Nozzle loads for 26PHBD-HT-1000

Estimated loads on the nozzles N1 and N2 are provided in the table below as per WRC107. These are preliminary values of the expected loads, not fixed values.

Table 14 – Allowable nozzle loads, CAT I – IV (see 5.1.3.22)

CAT	F_L	F_A	F_C	M_C	M_T	M_L
I - IV	KN	KN	KN	KNm	KNm	KNm
I	23.25	38.40	23.25	35.10	49.50	35.10
II	34.88	57.60	34.88	52.65	74.25	52.65
III	69.75	115.20	69.75	105.30	148.50	105.30
IV	69.75	115.20	69.75	105.30	148.50	105.30

Appendix D: Platform Response Spectra

The floor response spectra are provided in the Design Seismic Floor Response Spectra in the Tokamak Complex [57]. These spectra are enveloped for the data points adjacent to the HT

locations. The floor response may be amplified by any supporting structure between the HT and the platform.

The damping value for the heater is 3% for SL-2 and SMHV and 2% for SL1 according to the Load Specification [46].

The 3% damping values ($a_{3\%}$) can be calculated from available 2% and 4% damping values ($a_{2\%}$ and $a_{4\%}$), using the following equation:

$$a_{3\%} = a_{2\%} - (a_{2\%} - a_{4\%}) * [\ln(2/3)] / [\ln(2/4)]$$

Since the orientation of the heater may vary, the X & Y spectra are grouped and shall be used for both horizontal directions. The Z-spectra are the vertical floor responses.

SL-1 can be taken as 0.34 times SL-2 (calculated with 3% damping) and SMHV is 0.73 times SL-2 (calculated with 3% damping).

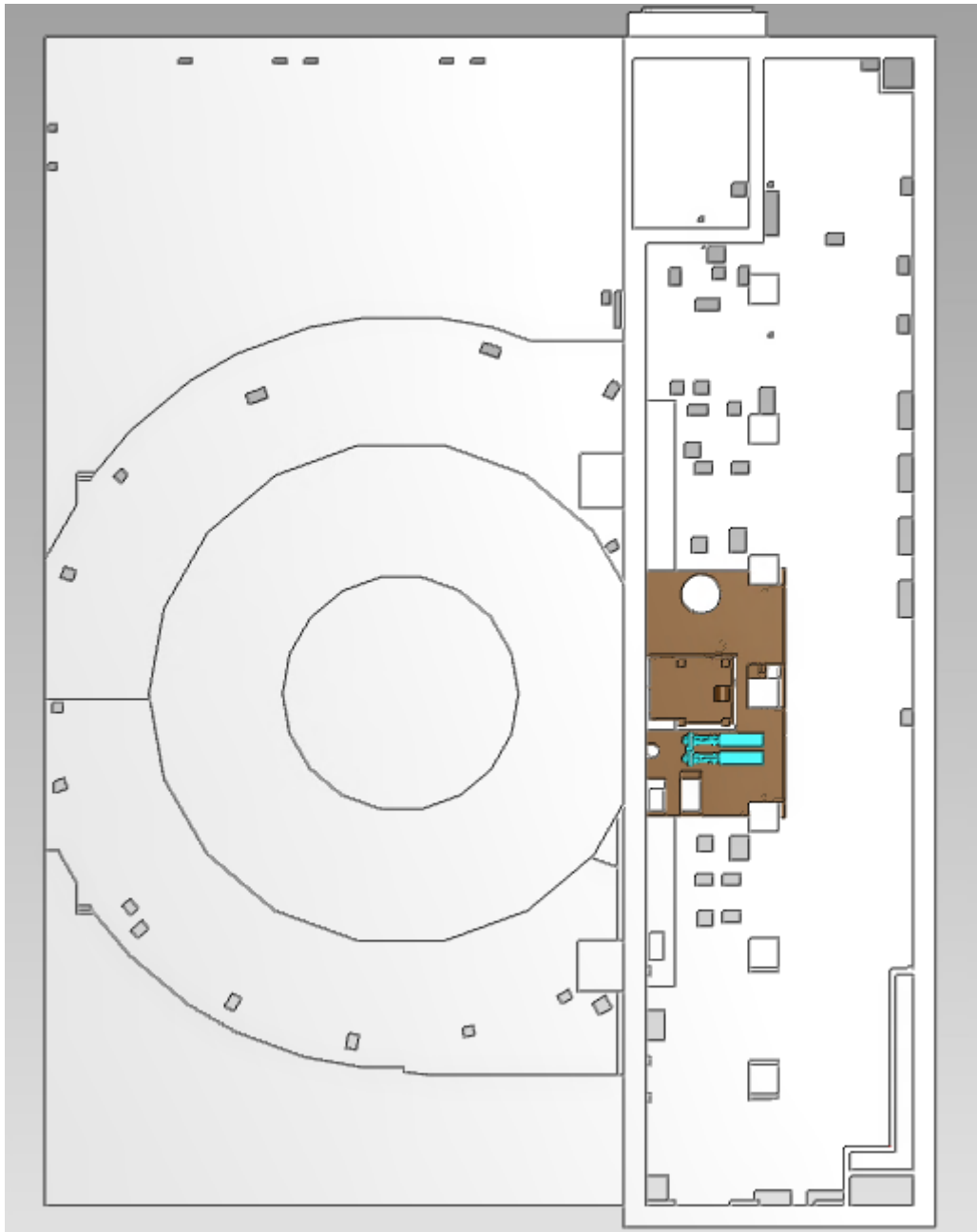


Figure 13 – Location of 26PHBD-HT-1000

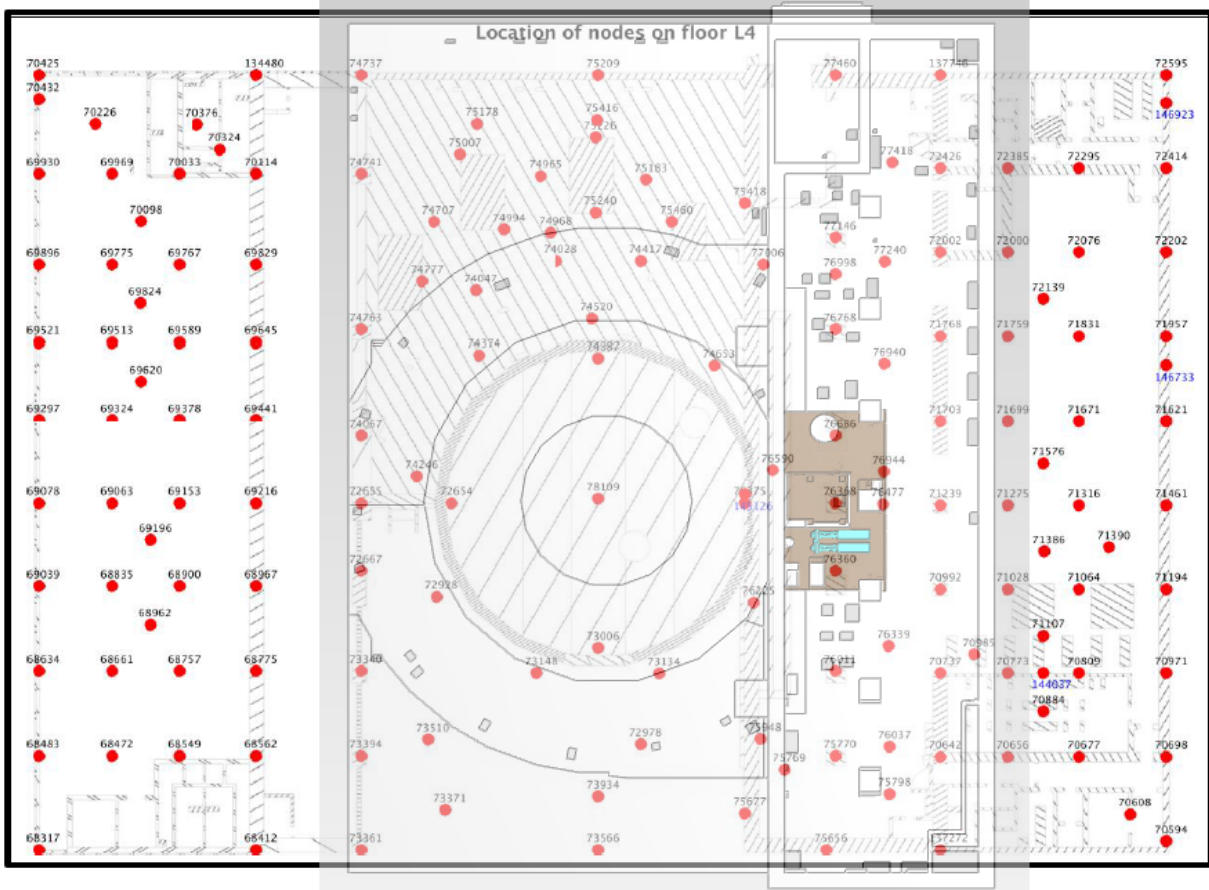


Figure 14 – Overlay of 26PHBD-HT-1000 on FRS nodes

Global view with connecting points of platform 14 is presented below:

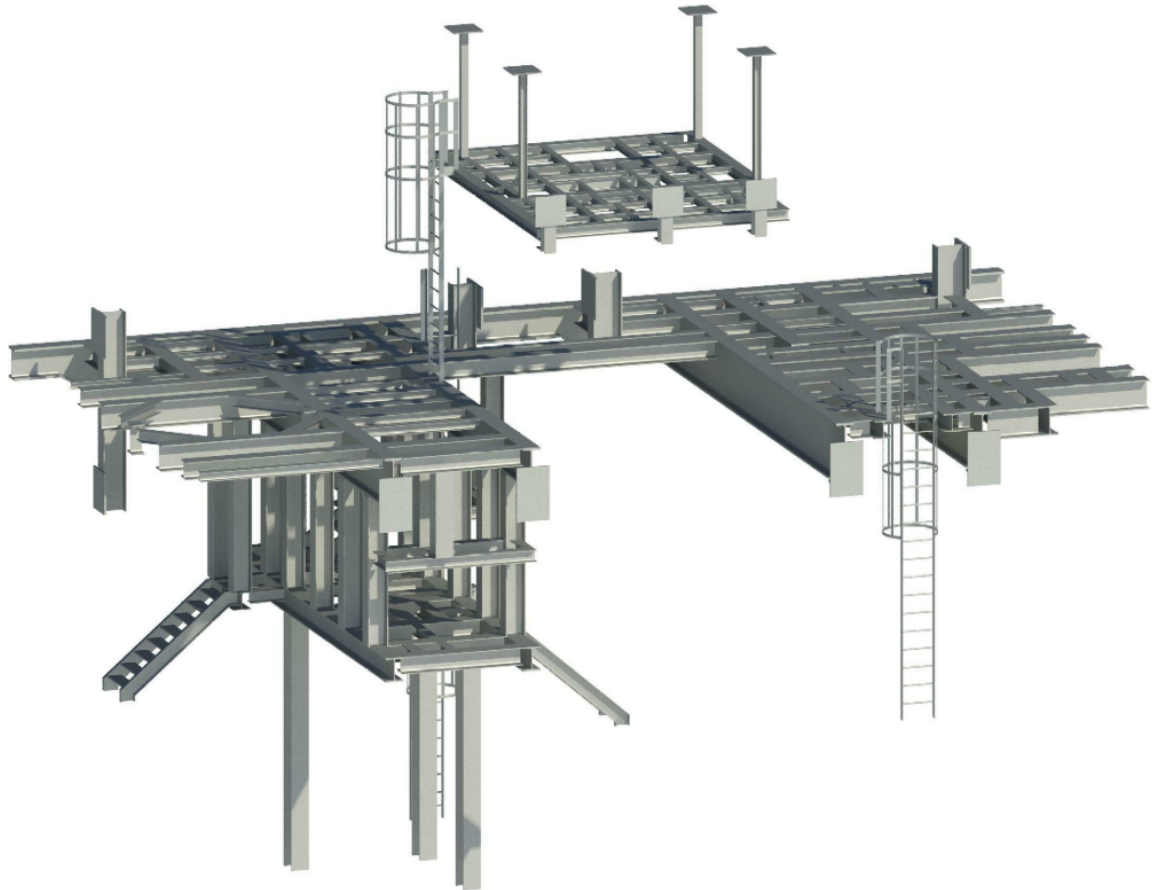


Figure 15 – Platform 14 with connection points

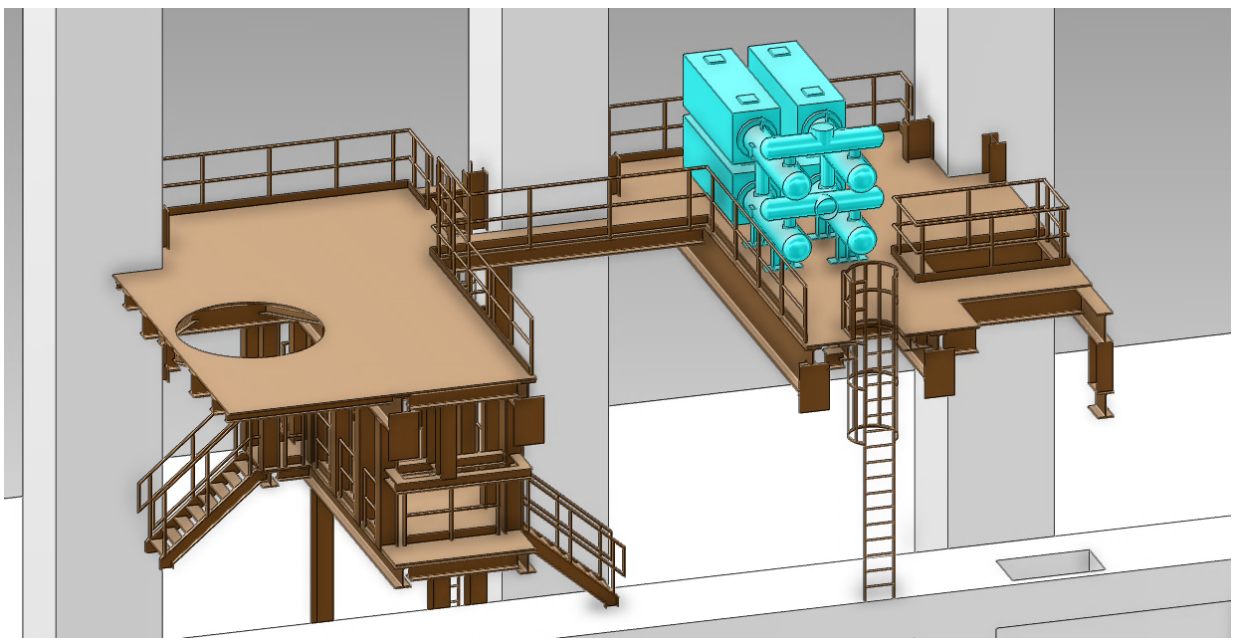


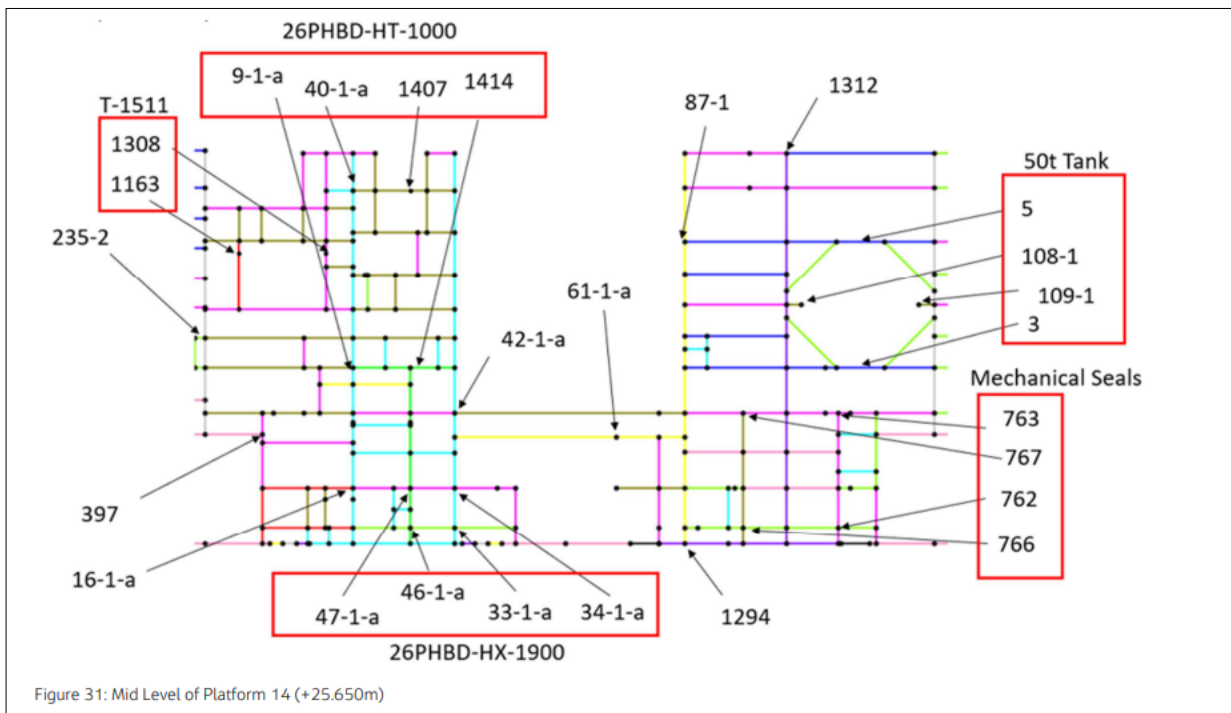
Figure 16 – Location details of 26PHBD-HT-1000

As per [73], chapter 5, the following nodes are used for the FRS values:

Table 15: Equipment Nodes and General Nodes in SAP Model (Platform 14, 16 and 17)

Platform No.	Equipment No.		SAP Model Nodes
14	26PHBD-HT-1000		40-1-a; 1407; 9-1-a; 1414
14	26PHBD-HX-1900	Heat Exchanger	33-1-a; 34-1-a; 46-1-a; 47-1-a
14	Mechanical Seals (PL14)		762; 763; 766; 767
14	50t Tank (PL14)		3; 5; 108-1; 109-1
14	T-1511	Pipe Support	1308; 1163
14	Platform 14 General (+25.650m)		42-1-a; 397; 16-1-a; 1294; 235-2; 87-1; 1312; 61-1-a

These nodes are located as per diagram below:



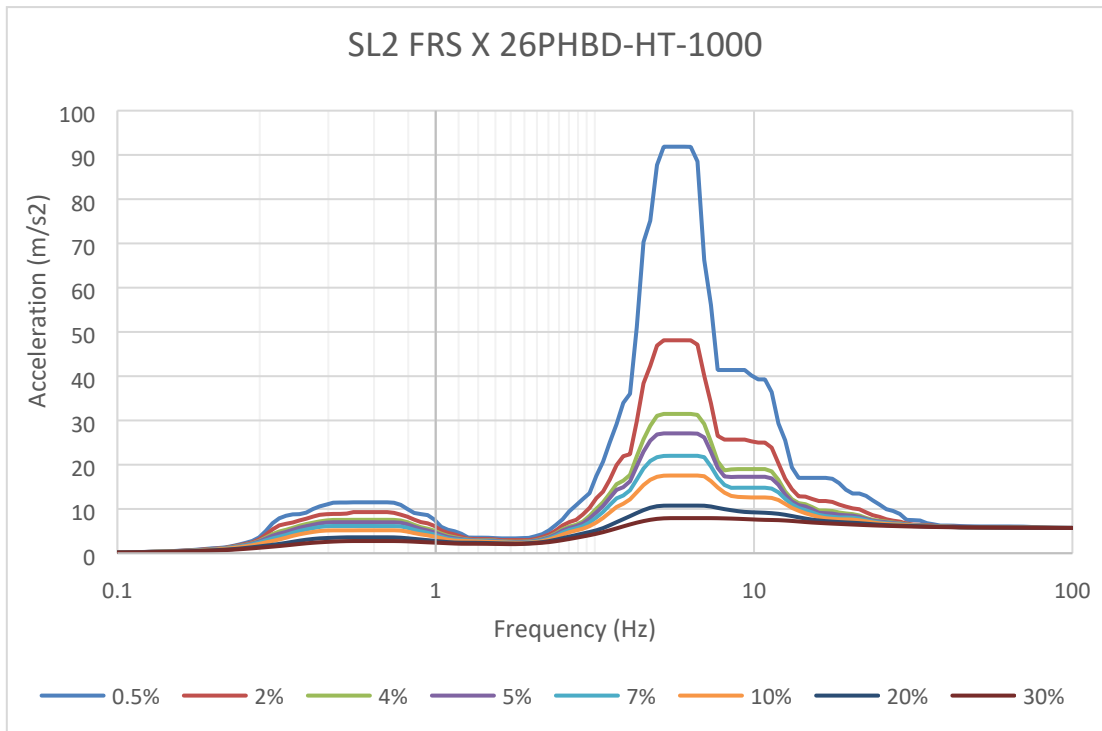


Figure 17 – SL2 FRS X 26PHBD-HT-1000

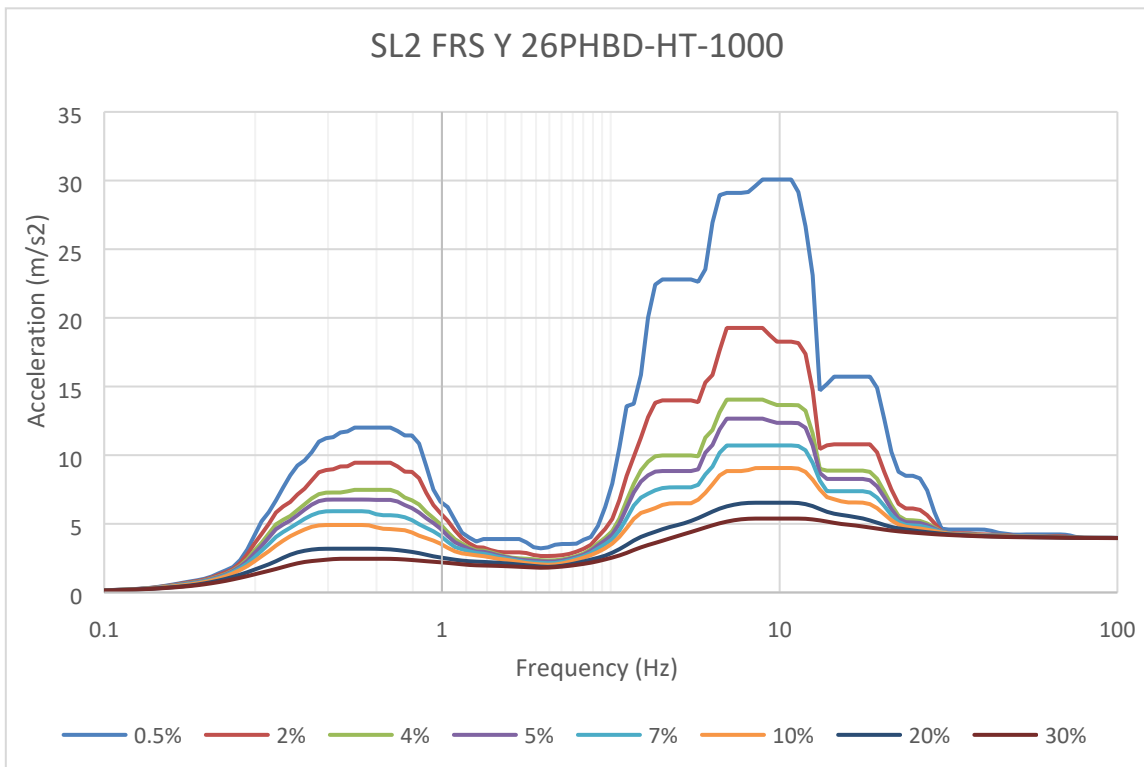


Figure 18 – SL2 FRS Y 26PHBD-HT-1000

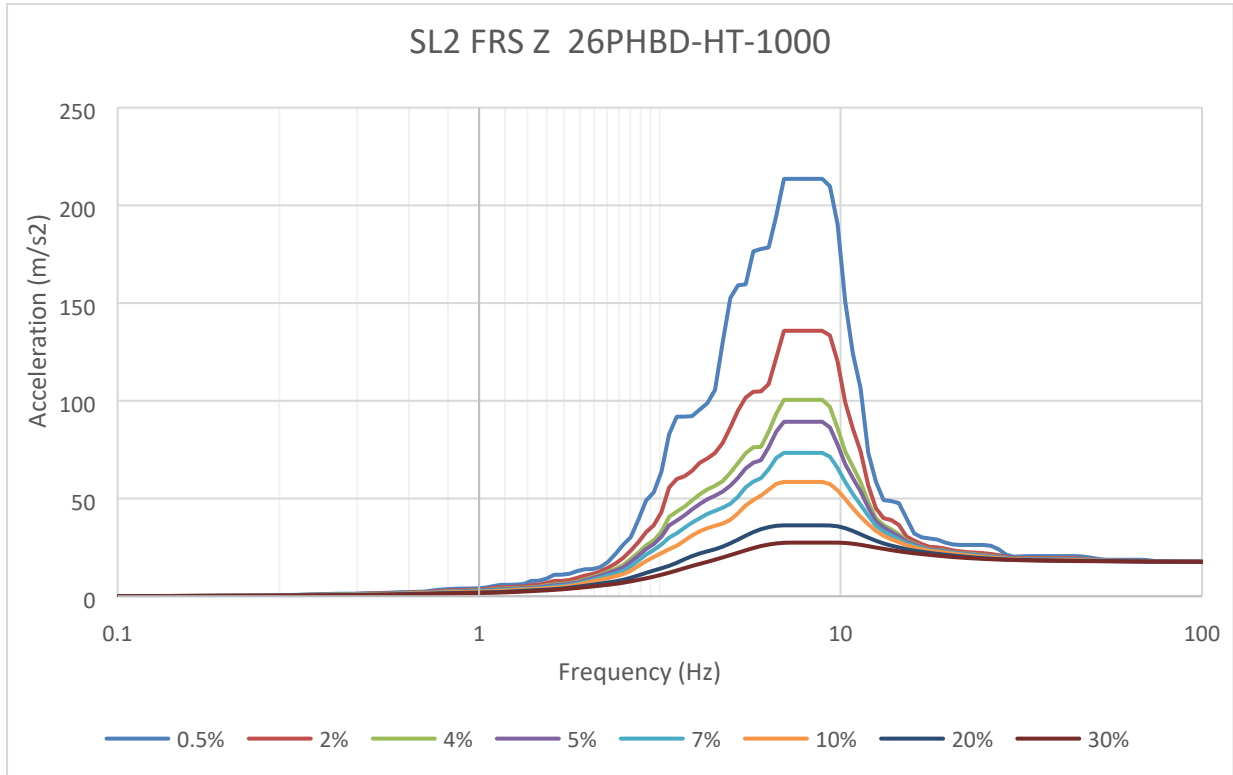


Figure 19 – SL2 FRS Z 26PHBD-HT-1000

Table 15 – FRS X with damping values

Damping Levels	0.5%	2%	4%	5%	7%	10%	20%	30%
Freq (Hz)	Accelerations (m/s²)							
0.1	0.2176458	0.2113678	0.2039201	0.2005593	0.194349	0.1861117	0.1650495	0.1500092
0.105	0.2325992	0.2264811	0.2192799	0.2159733	0.2098528	0.2016967	0.1804181	0.1647293
0.11025	0.2440852	0.2388139	0.2324424	0.2294979	0.2240208	0.2166351	0.1964457	0.1802591
0.11576	0.2567735	0.2520984	0.2463402	0.2437017	0.2389794	0.2328849	0.2140508	0.1972303
0.12155	0.2841612	0.278245	0.2708979	0.2675949	0.2620087	0.2554042	0.2349741	0.2164884
0.12763	0.328399	0.3206728	0.3110743	0.3065484	0.2979933	0.2862637	0.2582496	0.2381315
0.13401	0.3743622	0.3641448	0.3516427	0.3458205	0.3349359	0.3202681	0.2844127	0.2624904
0.14071	0.4170412	0.4048113	0.3899895	0.38314	0.3704158	0.3535948	0.3133466	0.2893021
0.14775	0.467355	0.4479026	0.4301806	0.4224033	0.4083523	0.3899356	0.3461132	0.3187288
0.15513	0.5466899	0.5146053	0.4850184	0.4723621	0.4531612	0.4315735	0.3836679	0.3512041
0.16289	0.6309346	0.5896448	0.5459016	0.5268617	0.4977344	0.4752032	0.4253565	0.3874047
0.17103	0.7149683	0.6649735	0.610237	0.5873267	0.552582	0.5261276	0.4713259	0.427484
0.17959	0.8239067	0.7574685	0.6854879	0.6605191	0.6242648	0.5883259	0.5222393	0.4719249
0.18857	0.9634	0.8714029	0.7743926	0.7466675	0.7081891	0.6634146	0.5782179	0.5210645
0.19799	1.0963623	0.9821887	0.8745561	0.8466818	0.8054199	0.7557985	0.6417603	0.5752932
0.20789	1.1816456	1.0760093	0.995271	0.9708868	0.9265389	0.8699439	0.718134	0.6357903
0.21829	1.3165065	1.2293554	1.162682	1.1334283	1.0777819	1.0036512	0.8074065	0.7065666
0.2292	1.6043399	1.4961051	1.3861595	1.3414174	1.2605899	1.1598587	0.9095283	0.7908679
0.24066	1.9446534	1.7961645	1.6508574	1.5892728	1.4812992	1.3478174	1.036231	0.8863244
0.2527	2.3310978	2.0955908	1.9190236	1.8443662	1.7122591	1.5493158	1.1852442	0.9923672

0.26533	2.7776978	2.4474314	2.2431896	2.1608776	2.0032399	1.7891762	1.3486351	1.1076215
0.2786	3.5590012	3.1145029	2.7778583	2.6483841	2.4079295	2.0945719	1.5268135	1.230887
0.29253	5.0056588	4.1754245	3.5411406	3.3034919	2.9023832	2.4415459	1.7056899	1.3595981
0.30715	6.7661919	5.3842775	4.3310216	3.9522084	3.3534946	2.7647063	1.8901961	1.4886656
0.32251	7.8918641	6.2909749	4.9121664	4.4254013	3.7203017	3.1104029	2.1015555	1.6242698
0.33864	8.4636275	6.6450074	5.2883346	4.8011248	4.1194794	3.4979833	2.3315598	1.7749927
0.35557	8.780153	6.9426972	5.7363896	5.2886834	4.6114155	3.9241346	2.5854839	1.9319715
0.37335	8.8264932	7.4073005	6.2245047	5.7611752	5.0386614	4.2764621	2.8339572	2.091565
0.39201	9.1707294	7.7991088	6.5942396	6.1052715	5.359807	4.558083	3.0493193	2.2388615
0.41161	9.9863566	8.2729298	6.9016951	6.4238481	5.6648312	4.8113842	3.2267717	2.3640313
0.43219	10.585152	8.6771691	7.1893404	6.7296389	5.9436441	5.0165596	3.3559476	2.46762
0.4538	10.993939	8.8147984	7.4096859	6.923393	6.1022107	5.132917	3.4312749	2.5567562
0.47649	11.415292	8.8764996	7.5202042	6.9929071	6.1480446	5.1673582	3.485735	2.6358298
0.50032	11.455266	8.8819597	7.5289977	6.9978054	6.1509339	5.1695438	3.5457342	2.6980607
0.52534	11.45627	8.9579672	7.5294195	6.9978054	6.1509339	5.1695438	3.5858814	2.7379292
0.5516	11.501903	9.2914108	7.548588	6.9978054	6.1509339	5.1707821	3.5912891	2.7543729
0.57918	11.501903	9.2914108	7.548588	6.9978054	6.1509339	5.1851178	3.5912891	2.7543729
0.60814	11.501903	9.2914108	7.548588	6.9978054	6.1509339	5.1851178	3.5912891	2.7543729
0.63855	11.501903	9.2914108	7.548588	6.9930697	6.1469627	5.1851178	3.5912891	2.7543729
0.67048	11.501903	9.2914108	7.548588	6.9792583	6.1353812	5.1851178	3.5912891	2.7543729
0.704	11.501903	9.2914108	7.548588	6.9792583	6.1353812	5.1851178	3.5912891	2.7543729
0.7392	11.407399	9.1222217	7.5295918	6.9792583	6.1353812	5.1851178	3.5738346	2.7509299
0.77616	10.931805	8.717751	7.3943974	6.8898027	6.0590179	5.1208208	3.5041876	2.7303616
0.81497	9.9870196	8.2534835	7.0106171	6.5368904	5.7526082	4.8826569	3.3809911	2.6814259
0.85572	9.100524	7.5959945	6.4113052	5.9847606	5.2953077	4.5437051	3.2355724	2.6111352
0.8985	8.8374813	7.0315933	5.8774521	5.4953785	4.9208556	4.2675422	3.0926526	2.5337737
0.94343	8.6118249	6.7550003	5.5439655	5.1326763	4.6117488	4.0384818	2.9459689	2.461307
0.9906	7.5791031	6.1724368	5.0978801	4.7115708	4.2155715	3.7481659	2.7972697	2.3968345
1.0401	5.9659947	5.1442028	4.4226332	4.1535544	3.750332	3.4031855	2.6518472	2.3294749
1.0921	5.3008255	4.5868619	3.9194112	3.6647777	3.3323988	3.0608542	2.510055	2.2583781
1.1467	4.9533378	4.2175395	3.6090338	3.3975439	3.1216277	2.8423549	2.4056095	2.1902895
1.2041	4.3940196	3.7268415	3.3050124	3.1843777	2.983516	2.7807817	2.373513	2.1465926
1.2643	3.5411851	3.2710179	3.0738386	3.0138257	2.9004626	2.7459081	2.3650223	2.1404332
1.3275	3.5163028	3.2065469	2.957836	2.9076108	2.8175269	2.6864413	2.3582325	2.1393828
1.3939	3.5163028	3.2065469	2.9467559	2.858702	2.7534494	2.6285542	2.3360285	2.1326913
1.4636	3.4958948	3.2009617	2.943162	2.8449601	2.6892263	2.5637862	2.3004845	2.1198735
1.5367	3.4102805	3.1113174	2.8683621	2.7817685	2.6417578	2.5145086	2.2578045	2.101247
1.6136	3.3505984	2.9602943	2.6983099	2.6441225	2.563442	2.4631018	2.2223013	2.0779565
1.6943	3.3533158	2.9661952	2.6216684	2.5459037	2.4823958	2.4000306	2.1952388	2.0540003
1.779	3.3533158	2.9661952	2.5955917	2.4729957	2.3963489	2.3328697	2.1642203	2.0546691
1.8679	3.4154538	2.9661952	2.6104623	2.5076289	2.4019134	2.3280453	2.1795092	2.0956433
1.9613	3.4638769	2.9661952	2.6753559	2.6032782	2.4906498	2.391014	2.2550284	2.1616331
2.0594	3.8549793	3.2269268	2.9011456	2.8044262	2.6548691	2.5084211	2.3589368	2.2493242
2.1624	4.3131965	3.6684774	3.2748025	3.1386783	2.9329389	2.7285325	2.5074335	2.3631144
2.2705	5.1749833	4.2198367	3.7268741	3.5680383	3.3248009	3.0814553	2.7369445	2.5153109

2.384	6.3736143	5.147545	4.4794426	4.2659664	3.9376391	3.6033955	3.0488554	2.7174292
2.5032	7.6576352	6.2779858	5.4254301	5.1261469	4.6822799	4.2199671	3.3988996	2.9578356
2.6284	9.4821685	7.0349029	6.0349874	5.7118865	5.2475755	4.7474749	3.7506578	3.2168945
2.7598	10.835616	7.5322283	6.422762	6.1148822	5.6462619	5.140569	4.0954739	3.491907
2.8978	12.226604	8.7490302	7.1404911	6.7239493	6.1163023	5.5269736	4.4431917	3.7756755
3.0426	13.564251	10.240414	8.432442	7.8398578	6.9531491	6.1188419	4.7878475	4.0722168
3.1948	17.452421	12.413781	10.01448	9.2229153	8.0637791	6.9437521	5.1695221	4.3961071
3.3545	20.669889	13.911515	11.510859	10.666414	9.3373385	7.9674837	5.6666367	4.7596455
3.5222	25.045101	16.627226	13.4941	12.480652	10.908021	9.2033403	6.3145176	5.1765434
3.6984	29.146232	19.902125	15.595966	14.311439	12.394556	10.439885	7.0136846	5.6128895
3.8833	33.966093	21.921361	16.395305	14.924206	13.038474	11.182348	7.6951403	6.0637382
4.0774	36.028061	22.371898	17.693813	16.250076	14.229507	12.169735	8.3760989	6.5017083
4.2813	51.03342	29.787504	21.885906	19.660816	16.657696	13.767275	9.0825895	6.9062404
4.4954	70.32153	38.388675	25.717548	22.951868	19.143299	15.397651	9.7379375	7.2602083
4.7201	75.132156	42.326521	28.780151	25.431119	20.838292	16.589514	10.275885	7.5518253
4.9561	87.719904	46.914177	31.044584	26.835933	21.696228	17.266588	10.618794	7.7635656
5.204	91.854486	48.109906	31.475195	27.074821	21.9795	17.523481	10.742085	7.8842124
5.4642	91.854486	48.109906	31.475195	27.074821	22.010065	17.553492	10.75537	7.9270076
5.7374	91.854486	48.109906	31.475195	27.074821	22.010065	17.553492	10.75537	7.9306429
6.0242	91.854486	48.109906	31.475195	27.074821	22.010065	17.553492	10.75537	7.9306429
6.3254	91.818309	48.099317	31.472746	27.074219	22.010065	17.553492	10.75537	7.9306429
6.6417	88.526911	47.135891	31.249949	27.019405	22.010065	17.553492	10.75537	7.9306429
6.9738	66.262294	40.111307	29.205033	26.165577	21.701193	17.39426	10.732495	7.9306429
7.3225	56.069855	33.848597	25.145277	22.874773	19.604176	16.293142	10.554333	7.9279742
7.6886	41.394757	26.505563	20.76489	19.29743	17.086512	14.854029	10.246699	7.9087774
8.073	41.394757	25.673641	18.712421	17.347717	15.427037	13.686408	9.9590097	7.871252
8.4767	41.394757	25.673641	18.942645	17.220863	14.772939	12.94612	9.7216498	7.8299209
8.9005	41.394757	25.673641	19.008924	17.271422	14.79747	12.726829	9.502373	7.7767745
9.3456	41.394757	25.673641	19.008924	17.271422	14.79747	12.660459	9.3332775	7.7155688
9.8128	40.160116	25.279434	19.008924	17.271422	14.79747	12.600319	9.2546064	7.6500725
10.304	39.280893	24.998709	19.008924	17.271422	14.79747	12.600319	9.2051423	7.5836799
10.819	39.280893	24.998709	19.008924	17.271422	14.79747	12.600319	9.1444377	7.5351484
11.36	36.400212	23.853758	18.49496	16.909575	14.605026	12.495929	9.0484123	7.5086508
11.928	29.319733	20.304816	16.576213	15.450778	13.760193	12.027054	8.9039205	7.4715958
12.524	25.520998	16.839264	13.947165	13.233798	12.290257	11.147015	8.683043	7.3924433
13.15	19.383959	14.461168	12.1997	11.702614	11.041438	10.246705	8.4030215	7.2930553
13.808	17.024554	12.856625	11.316397	10.855323	10.214263	9.5974246	8.1155121	7.1736599
14.498	17.024554	12.788475	11.07298	10.546758	9.7336261	9.0342334	7.8314217	7.0502264
15.223	17.024554	12.257746	10.42501	9.9211233	9.2112782	8.5971997	7.5831465	6.9377621
15.984	17.024554	11.795068	9.6521925	9.1256607	8.6608973	8.1795723	7.3894902	6.8511091
16.783	17.024554	11.795068	9.6521925	9.0339055	8.387093	7.9079443	7.2434127	6.7671673
17.622	16.81512	11.58517	9.5393781	8.9410952	8.2218621	7.7645176	7.1339785	6.691408
18.504	15.837562	10.993442	9.1956092	8.677047	8.0714815	7.6585194	7.0399665	6.6233641
19.429	14.352396	10.534893	8.9881343	8.5726304	8.0705568	7.640137	6.9555142	6.5535828
20.4	13.489329	10.13706	8.83238	8.4792612	8.0160509	7.5932167	6.8831151	6.4836639

21.42	13.489329	9.9315247	8.533488	8.211409	7.8153778	7.4375158	6.7930244	6.4170573
22.491	12.955365	9.2263387	7.9737772	7.7486983	7.4832641	7.2013158	6.6736592	6.3513944
23.616	11.920048	8.5786528	7.5293655	7.3608573	7.1547872	6.9515138	6.548172	6.2885821
24.797	10.977189	8.2047352	7.3456018	7.1625113	6.9344923	6.7514198	6.4359312	6.2354028
26.036	9.950862	7.6715749	7.1387095	6.9906001	6.7816866	6.6152698	6.3465577	6.1899236
27.338	9.5464203	7.3546893	6.9256275	6.8268115	6.6798856	6.5284328	6.2821309	6.1471624
28.705	8.87663	7.1420842	6.7692441	6.6840378	6.5677819	6.4455161	6.2293217	6.1035481
30.14	7.5351672	6.7104306	6.514407	6.4674488	6.4085344	6.3450404	6.1810487	6.0617083
31.647	7.4764657	6.4771856	6.3295675	6.3073996	6.2860626	6.2532687	6.1393964	6.0226118
33.23	7.3907207	6.4277605	6.2725243	6.2480402	6.2045184	6.1816319	6.0952909	5.988099
34.891	6.7933507	6.3749205	6.2333592	6.1920315	6.1428029	6.1192201	6.0510478	5.9612609
36.636	6.5311769	6.2349576	6.1318639	6.1083596	6.0768735	6.0595166	6.0086701	5.9357179
38.468	6.2465473	6.0715131	6.042185	6.0348029	6.0234561	6.0067911	5.9698852	5.9104801
40.391	6.2465473	6.0375094	5.9995595	5.9882569	5.9758333	5.9603029	5.9338967	5.8870174
42.411	6.2203377	6.0058704	5.9484102	5.9365465	5.9234416	5.9145814	5.902066	5.8658235
44.531	6.1375667	5.9567601	5.8920825	5.8829243	5.8755667	5.8789507	5.8766853	5.8481661
46.758	6.0868544	5.9508643	5.8786101	5.8664681	5.8560059	5.8597593	5.8581506	5.834201
49.095	6.0629166	5.9225409	5.8709525	5.8622649	5.8529114	5.8503993	5.8437387	5.8222945
51.432	6.0430255	5.8893896	5.8556886	5.8523926	5.847389	5.8431129	5.8323819	5.812116
53.769	6.0430255	5.8817105	5.8447955	5.8430323	5.8401685	5.8361034	5.8230696	5.803193
56.106	6.0430255	5.8817105	5.8413136	5.837284	5.8340238	5.8296344	5.8148661	5.7952231
58.443	6.0430255	5.8817105	5.8413136	5.834552	5.8294621	5.8236256	5.8071156	5.7880453
60.78	6.0430255	5.8817105	5.8413136	5.8336192	5.8260595	5.818217	5.7994676	5.7814737
63.117	6.0428786	5.8817105	5.8413136	5.8335455	5.8239881	5.8139667	5.7917244	5.7752355
65.454	6.0267354	5.8817105	5.8413136	5.8330047	5.8216469	5.8093596	5.7848161	5.7691956
67.791	6.0224848	5.876862	5.8340171	5.8261387	5.8153203	5.8029155	5.7782108	5.7633054
70.128	6.0070594	5.8729416	5.8281172	5.8190745	5.8066781	5.7943742	5.7714563	5.75758
72.465	5.9687723	5.8725673	5.8279228	5.8149339	5.7967084	5.7837036	5.7643271	5.7520228
74.802	5.9157904	5.8316996	5.8066925	5.7983184	5.7851559	5.7722905	5.7577071	5.7469038
77.139	5.8506742	5.7946748	5.7830504	5.7788193	5.7712472	5.7609909	5.7512178	5.7420594
79.476	5.7767522	5.7612591	5.7576835	5.7571307	5.7554751	5.7498178	5.7448461	5.7374507
81.813	5.7662082	5.7513505	5.7462534	5.7453666	5.743853	5.7403948	5.7390035	5.7333424
84.15	5.7551223	5.7402546	5.735292	5.7345514	5.733549	5.7322442	5.7335403	5.7294737
86.487	5.7432776	5.7274961	5.7249869	5.7250647	5.725091	5.7258753	5.7286084	5.7259405
88.824	5.7401891	5.7198976	5.7189231	5.7193462	5.7199365	5.7210271	5.7242632	5.7227211
91.161	5.7401891	5.7141192	5.7143553	5.7149567	5.7159472	5.7167152	5.7201249	5.7196125
93.498	5.7351684	5.713671	5.7125066	5.7127658	5.7134604	5.7142956	5.7167831	5.7168994
95.835	5.7307939	5.713338	5.7108022	5.710743	5.7111214	5.7119505	5.7135523	5.7142331
98.172	5.7307939	5.7131377	5.709675	5.7094932	5.7095071	5.7098532	5.7109002	5.7118046
99.5	5.7307939	5.7130239	5.7090345	5.708783	5.7085898	5.7086615	5.7093932	5.7104247
100	5.7307939	5.712981	5.7087933	5.7085157	5.7082444	5.7082128	5.7088258	5.7099051

Table 16 – FRS Y with damping values

Damping Levels	0.5%	2%	4%	5%	7%	10%	20%	30%
Freq (Hz)	Accelerations (m/s ²)							
0.1	0.1605315	0.1587308	0.1565026	0.1554578	0.1534926	0.1508214	0.1436481	0.1380307
0.105	0.1779837	0.175549	0.1726311	0.1713071	0.1688904	0.1657028	0.1575899	0.1514906
0.11025	0.1957704	0.1928997	0.1895329	0.1880583	0.185428	0.1820297	0.1736276	0.1673084
0.11576	0.2154977	0.2121366	0.2081955	0.2065936	0.2038244	0.200366	0.1916401	0.1847541
0.12155	0.2399989	0.2352603	0.2295807	0.22741	0.2243842	0.2208109	0.2113746	0.2040397
0.12763	0.2738056	0.2670893	0.2589019	0.2553857	0.2511554	0.2460914	0.2337349	0.2254496
0.13401	0.3150785	0.3051673	0.2941183	0.2896018	0.2826723	0.2749287	0.2601836	0.2493736
0.14071	0.3702466	0.3562184	0.3413738	0.3348565	0.3230442	0.3112497	0.2903415	0.2762895
0.14775	0.4440977	0.424436	0.4024126	0.3926754	0.3759249	0.3595175	0.3238219	0.3066035
0.15513	0.5261887	0.4918264	0.4651146	0.453927	0.4348166	0.4131558	0.361572	0.3406751
0.16289	0.613863	0.570986	0.5373324	0.5232524	0.4982173	0.4671927	0.4045027	0.3790365
0.17103	0.7106206	0.6666657	0.6208784	0.6010281	0.5660189	0.5232394	0.4532706	0.4220428
0.17959	0.8020677	0.7530959	0.6992257	0.6756912	0.6342953	0.5852924	0.5093672	0.4705918
0.18857	0.8880951	0.8297494	0.7746574	0.7515271	0.7096856	0.6615009	0.5772543	0.5281575
0.19799	0.99541	0.9328086	0.8745924	0.8499049	0.8069724	0.7561644	0.6603472	0.5960696
0.20789	1.1603007	1.089427	1.0130509	0.9796115	0.9249467	0.8696006	0.7572887	0.672566
0.21829	1.396605	1.2867568	1.1724287	1.1267502	1.0663438	1.0090748	0.866599	0.7568885
0.2292	1.6169227	1.4763562	1.3541636	1.3066895	1.2544192	1.1827579	0.9920807	0.8507103
0.24066	1.8551133	1.7073243	1.6100211	1.5693771	1.4945812	1.3948104	1.1392905	0.9570976
0.2527	2.3595723	2.1425732	1.9502751	1.8814685	1.7749054	1.6388527	1.2997878	1.0709012
0.26533	3.1326958	2.7780973	2.4233787	2.2930081	2.1147195	1.9195152	1.4723345	1.1913207
0.2786	4.1641296	3.5641032	3.0548032	2.8624635	2.5667298	2.2700789	1.6647147	1.3205265
0.29253	5.1891379	4.2651481	3.6240821	3.3907968	3.0431652	2.64257	1.8575034	1.4501792
0.30715	5.8476087	4.9917411	4.2860713	3.9958184	3.5249567	3.0065938	2.051359	1.5776649
0.32251	6.70411	5.8205613	4.9594249	4.6088407	4.0442156	3.4125403	2.2764129	1.7103665
0.33864	7.6414673	6.2616356	5.2891355	4.9511659	4.4037935	3.7729183	2.5274807	1.853844
0.35557	8.5311943	6.5931851	5.5689759	5.2393514	4.7127512	4.0970025	2.7490738	1.9958408
0.37335	9.2411243	7.1319056	5.9974938	5.6262272	5.0356027	4.3535123	2.9213232	2.1226623
0.39201	9.6145997	7.5611762	6.4209898	6.0321429	5.3621194	4.5887636	3.0386482	2.2222337
0.41161	10.209423	8.1628093	6.8471743	6.3966463	5.6333782	4.7827308	3.1214721	2.2884597
0.43219	10.983187	8.7552668	7.1614273	6.6551836	5.8245428	4.8846238	3.1709416	2.3366246
0.4538	11.234642	8.9149266	7.2699377	6.7564774	5.9089212	4.9124084	3.1852086	2.3854752
0.47649	11.313206	8.9746635	7.2798497	6.766836	5.9182687	4.914697	3.1882339	2.4297014
0.50032	11.650444	9.1755283	7.2798497	6.766836	5.9182687	4.914697	3.1884417	2.4520297
0.52534	11.730106	9.1890936	7.365519	6.766836	5.9182687	4.914697	3.1884417	2.4532592
0.5516	12.008147	9.4507555	7.4742399	6.766836	5.9182687	4.914697	3.1884417	2.4532592
0.57918	12.008147	9.4507555	7.4742399	6.766836	5.9182687	4.914697	3.1884417	2.4532592
0.60814	12.008147	9.4507555	7.4742399	6.7620197	5.8802898	4.8897285	3.1884417	2.4532592
0.63855	12.008147	9.4507555	7.4742399	6.7423269	5.6997236	4.7497875	3.1819513	2.4532592
0.67048	12.008147	9.4507555	7.4742399	6.7423269	5.626005	4.6393156	3.1595261	2.4532592
0.704	12.008147	9.4507555	7.4742399	6.7423269	5.626005	4.6200193	3.1373113	2.4491288
0.7392	11.760924	9.1761695	7.2964608	6.6260817	5.5877122	4.5771717	3.0875909	2.4320523
0.77616	11.436448	8.8001387	6.915038	6.3659802	5.4798021	4.5321794	3.0247255	2.4023526
0.81497	11.436448	8.7839765	6.7135546	6.1448747	5.2710865	4.3704135	2.95425	2.3644967
0.85572	10.844396	8.3237159	6.4083868	5.8226141	4.9691634	4.1349221	2.8631376	2.3221376
0.8985	9.2076156	7.2593553	5.8598603	5.4108295	4.7065827	3.9587765	2.7483882	2.2786673
0.94343	7.4922161	6.3665296	5.421001	5.0587306	4.4530115	3.7777639	2.6345447	2.2383574
0.9906	6.6064083	5.7704507	4.9611888	4.6466194	4.1245536	3.5510193	2.5464569	2.198322
1.0401	6.2200629	5.2245402	4.3912459	4.1194659	3.6922244	3.2529745	2.4670588	2.1539268

1.0921	5.2767438	4.5253809	3.8841787	3.6593188	3.3128287	2.9967916	2.3865079	2.1047916
1.1467	4.3534706	3.9522391	3.562226	3.4049945	3.142315	2.8487953	2.3201965	2.0535665
1.2041	4.0003768	3.5735294	3.2683645	3.1723272	3.0016968	2.7782561	2.2760169	2.0072281
1.2643	3.7105505	3.2974599	3.0636366	2.9785523	2.8761091	2.7061748	2.2458927	1.9802335
1.3275	3.8915125	3.2707677	3.0478937	2.9645512	2.8236206	2.6457075	2.2250923	1.9645766
1.3939	3.8915125	3.0871022	2.9271791	2.8546972	2.7236024	2.5572669	2.1974625	1.9518931
1.4636	3.8915125	2.9570148	2.774587	2.7086939	2.5944951	2.4543396	2.1636657	1.9371659
1.5367	3.8915125	2.9238129	2.6353052	2.5842244	2.4973892	2.3885798	2.1242177	1.9186192
1.6136	3.8915125	2.9238129	2.5339314	2.4835815	2.4069301	2.3123115	2.0796032	1.8967427
1.6943	3.8915125	2.9238129	2.4854821	2.3990732	2.3109032	2.2229608	2.0303869	1.8726671
1.779	3.6491425	2.8720984	2.4563982	2.3452796	2.2303559	2.1387679	1.9800833	1.8480343
1.8679	3.3001761	2.7293332	2.416878	2.3151447	2.1866003	2.0784761	1.9323764	1.8246761
1.9613	3.214823	2.6578915	2.3536878	2.2700381	2.1604892	2.0436385	1.8862919	1.8026432
2.0594	3.2840798	2.6538552	2.3336886	2.2522892	2.1339432	2.0149777	1.8624518	1.8112029
2.1624	3.4763579	2.6726325	2.3462581	2.2592883	2.1464258	2.0385066	1.8896652	1.8444131
2.2705	3.5318646	2.7181085	2.4098161	2.3287964	2.2261883	2.1172696	1.9477667	1.8869409
2.384	3.5318646	2.809158	2.5150184	2.4453117	2.3457132	2.230603	2.0333012	1.9426245
2.5032	3.5556449	2.9726028	2.6572905	2.5833369	2.4867618	2.3735684	2.1407484	2.0110012
2.6284	3.8425998	3.1828815	2.8411249	2.751291	2.6453147	2.5343025	2.2608214	2.085683
2.7598	4.038934	3.4722093	3.1438748	3.0402055	2.8767862	2.7190814	2.3920887	2.1720776
2.8978	4.8507069	4.0595336	3.579036	3.4340241	3.2027222	2.9457674	2.5256048	2.2804233
3.0426	6.2169562	4.6210998	3.9852876	3.7937237	3.5192971	3.2199477	2.6813895	2.4081458
3.1948	7.9303881	5.3570768	4.4731988	4.2231781	3.8871945	3.5652969	2.8954541	2.5445301
3.3545	10.572977	6.7393697	5.3808779	5.0229578	4.5153411	4.0533654	3.1565721	2.6971429
3.5222	13.56705	8.4875764	6.6841551	6.1570765	5.3908106	4.6833464	3.4599877	2.8806726
3.6984	13.742708	9.8874694	7.908491	7.2835939	6.3317842	5.3633182	3.7827495	3.09186
3.8833	15.841836	11.275582	8.8959641	8.0764091	6.9065889	5.7926202	4.0470987	3.2854604
4.0774	20.031722	12.771693	9.5232484	8.5326068	7.195059	5.9612268	4.2442702	3.4559748
4.2813	22.422114	13.814862	9.9159537	8.8012738	7.4434791	6.1469533	4.4227184	3.6085389
4.4954	22.796574	13.990165	9.9812639	8.8454038	7.6030332	6.3748309	4.6057455	3.7668143
4.7201	22.796574	13.990165	9.9812639	8.8454038	7.6527727	6.4817865	4.7638298	3.9303346
4.9561	22.796574	13.990165	9.9812639	8.8454038	7.6584421	6.4978337	4.8943497	4.091186
5.204	22.796574	13.990165	9.9812639	8.8454038	7.6584421	6.4978337	5.034926	4.2499931
5.4642	22.796574	13.990165	9.9812639	8.8454038	7.6584421	6.4978337	5.2108594	4.4058402
5.7374	22.627818	13.861571	9.9155442	8.966657	7.8401033	6.7588361	5.4181052	4.5665549
6.0242	23.532754	15.292265	11.279054	10.178771	8.5950363	7.2546002	5.6539334	4.732
6.3254	26.938186	15.842055	11.832812	10.742616	9.1649103	7.8699924	5.892149	4.8910504
6.6417	28.938501	17.632099	13.12783	11.878119	10.17693	8.5230789	6.1071361	5.038837
6.9738	29.100505	19.26597	14.046766	12.660303	10.704421	8.842154	6.272252	5.1600289
7.3225	29.100505	19.26597	14.046766	12.660303	10.704421	8.842154	6.3923186	5.2598121
7.6886	29.100505	19.26597	14.046766	12.660303	10.704421	8.842154	6.4795172	5.3297272
8.073	29.165821	19.26597	14.046766	12.660303	10.704421	8.9142992	6.5236634	5.3675137
8.4767	29.608665	19.26597	14.046766	12.660303	10.706176	9.0560433	6.5357432	5.3816485
8.9005	30.076788	19.26597	14.046766	12.660303	10.708747	9.0643668	6.5363981	5.3824157
9.3456	30.076788	18.741521	13.839506	12.500447	10.708747	9.0643668	6.5363981	5.3824157
9.8128	30.076788	18.2663	13.6517	12.355597	10.708747	9.0643668	6.5363981	5.3824157
10.304	30.076788	18.2663	13.6517	12.355597	10.708747	9.0643668	6.5363981	5.3824157
10.819	30.076788	18.2663	13.6517	12.355597	10.708747	9.0643668	6.5363981	5.3824157
11.36	29.158932	18.162426	13.635213	12.33343	10.666717	9.0200637	6.5150954	5.3815297
11.928	26.663457	17.371418	13.237561	11.996814	10.355757	8.7797294	6.4339182	5.3675305
12.524	23.101378	14.722767	11.579963	10.701925	9.440415	8.216117	6.2899623	5.3199241
13.15	14.712451	10.452211	8.9992451	8.7038601	8.1504711	7.4990922	6.078868	5.2516666
13.808	15.178193	10.716524	8.8753953	8.2694896	7.3760245	6.9456662	5.874443	5.1623573
14.498	15.717481	10.789925	8.8753953	8.2694896	7.3760245	6.7879911	5.7367894	5.070495
15.223	15.717481	10.789925	8.8753953	8.2694896	7.3760245	6.638078	5.6495851	4.9884325

15.984	15.717481	10.789925	8.8753953	8.2694896	7.3760245	6.5565188	5.5739822	4.9334037
16.783	15.717481	10.789925	8.8753953	8.2694896	7.3760245	6.5565188	5.4838096	4.8767724
17.622	15.717481	10.789925	8.8753953	8.2694896	7.3760245	6.5425573	5.39058	4.8052957
18.504	15.717481	10.789925	8.7829379	8.1730884	7.2816779	6.4338472	5.24796	4.7306719
19.429	14.90185	10.205131	8.2818877	7.7254261	6.9072099	6.1413749	5.085375	4.6557682
20.4	12.641703	8.7883956	7.3577957	6.9385179	6.3079669	5.701489	4.9213555	4.5790612
21.42	10.238145	7.5019849	6.3777463	6.0666083	5.6380058	5.2553896	4.7740822	4.5105507
22.491	8.7908342	6.4582324	5.579732	5.3787248	5.1382661	4.9511703	4.6686086	4.4529134
23.616	8.4971116	6.117943	5.2781302	5.1202791	4.9194351	4.7888353	4.5911611	4.4040574
24.797	8.4971116	6.117943	5.2565163	5.0975163	4.8819198	4.708371	4.5193777	4.3625385
26.036	8.3052579	6.0129566	5.209255	5.0573571	4.8493195	4.6579547	4.4505617	4.3225091
27.338	7.4348203	5.6301945	5.0264996	4.9018886	4.731923	4.5692479	4.3893744	4.2827406
28.705	5.8728877	5.0612741	4.7370606	4.6615013	4.5684814	4.471603	4.3335582	4.2451476
30.14	4.6474829	4.4639442	4.4408657	4.4296516	4.4043837	4.3667674	4.2798225	4.2141606
31.647	4.5850649	4.3212903	4.3036266	4.2988572	4.2927964	4.2840509	4.2379275	4.1879786
33.23	4.5850649	4.3153054	4.2454574	4.2435158	4.2415105	4.238577	4.2039266	4.1635478
34.891	4.5850649	4.3153054	4.2378173	4.2222354	4.2146796	4.2099681	4.1745398	4.1409095
36.636	4.5850649	4.3023553	4.2331531	4.2188251	4.2038614	4.1895116	4.1483412	4.1199986
38.468	4.5850649	4.2453567	4.2079862	4.1981289	4.182916	4.166547	4.1256029	4.1004632
40.391	4.5772664	4.2326357	4.1847071	4.1735202	4.1584339	4.1452916	4.1073542	4.0826978
42.411	4.4876969	4.2123789	4.1632082	4.1563107	4.1447773	4.1316004	4.0940588	4.0676993
44.531	4.3416255	4.1985471	4.1516992	4.1454687	4.1341941	4.1191274	4.0824089	4.0546656
46.758	4.2775372	4.1771486	4.1357421	4.1280509	4.1175786	4.1044724	4.0707789	4.0429087
49.095	4.2124431	4.1287195	4.0984728	4.0961573	4.0931499	4.0865985	4.0592539	4.0328506
51.432	4.2099033	4.1072047	4.0791748	4.0757062	4.0740003	4.0713211	4.0491345	4.0251874
53.769	4.2272905	4.1072047	4.0779703	4.0713069	4.0655907	4.0619948	4.0407481	4.0187257
56.106	4.2272905	4.1072047	4.0779481	4.0713069	4.063236	4.0570022	4.0339699	4.0127966
58.443	4.2272905	4.1047825	4.0763123	4.0700128	4.0614331	4.0530365	4.0282858	4.0073797
60.78	4.2272905	4.0992554	4.0701107	4.0649328	4.0569986	4.0477671	4.0229808	4.0024938
63.117	4.2272905	4.0964167	4.056976	4.0539279	4.0481788	4.0402941	4.0174266	3.9980598
65.454	4.2272905	4.0964167	4.0504672	4.0441179	4.0385624	4.0311838	4.0114934	3.9939627
67.791	4.2272905	4.0964167	4.0487535	4.0396102	4.0304802	4.0218574	4.0054315	3.990043
70.128	4.2056676	4.0811356	4.0399518	4.0311449	4.0206299	4.0118563	3.9994062	3.9863169
72.465	4.1518365	4.0433281	4.0181597	4.0140194	4.007342	4.0009835	3.9935095	3.9827867
74.802	4.0599324	4.0041122	3.9938693	3.9927977	3.9913547	3.9910209	3.9883649	3.9797207
77.139	4.0067913	3.9837615	3.9800254	3.9797847	3.9803867	3.9833237	3.9837657	3.9769139
79.476	3.985983	3.9790448	3.9748863	3.9736513	3.9736637	3.9775476	3.9796376	3.9743287
81.813	3.985983	3.9790448	3.9748863	3.9736513	3.9727412	3.9746603	3.9766566	3.9721664
84.15	3.985983	3.9790448	3.9748863	3.9736513	3.972203	3.9727295	3.9741095	3.9701826
86.487	3.985983	3.9790448	3.9748863	3.9736513	3.972203	3.9721384	3.9721699	3.9684489
88.824	3.985983	3.9790448	3.9748863	3.9736513	3.97219	3.971693	3.9706275	3.9669215
91.161	3.985983	3.9790448	3.9748863	3.9736513	3.9721724	3.9712992	3.9692253	3.9654668
93.498	3.985983	3.9788689	3.9745885	3.9733163	3.9717029	3.9704859	3.9679948	3.9642426
95.835	3.985269	3.9781064	3.9739441	3.9726958	3.9710449	3.9695868	3.9667764	3.9630435
98.172	3.980299	3.9738651	3.9712649	3.9704089	3.9693099	3.968219	3.9656115	3.9619697
99.5	3.9774748	3.971455	3.9697424	3.9691094	3.9683239	3.9674418	3.9649496	3.9613595
100	3.9764115	3.9705476	3.9691692	3.9686201	3.9679527	3.9671492	3.9647003	3.9611297

Table 17 – FRS Z with damping values

Damping Levels	0.5%	2%	4%	5%	7%	10%	20%	30%
Freq (Hz)	Accelerations (m/s ²)							
0.1	0.0745926	0.0724123	0.0697432	0.068468	0.066024	0.0628177	0.0542785	0.0476463
0.105	0.0809858	0.0785787	0.0757703	0.0744431	0.0718954	0.0684376	0.0587409	0.0512518
0.11025	0.0878417	0.0852962	0.0821999	0.0807435	0.0779463	0.0740241	0.0630383	0.054909
0.11576	0.0959576	0.0929723	0.0892933	0.087537	0.0841811	0.0795161	0.067054	0.0586098
0.12155	0.1064884	0.10266	0.0979185	0.095673	0.0914139	0.0855615	0.0709526	0.0623456
0.12763	0.1166532	0.1118284	0.1063287	0.1037362	0.0988412	0.0922121	0.0757274	0.0665564
0.13401	0.1268811	0.1202152	0.1136275	0.1105734	0.105197	0.0984144	0.0819753	0.0720932
0.14071	0.1412994	0.1330912	0.1248059	0.1210045	0.1148033	0.1079468	0.0896773	0.0785674
0.14775	0.1627114	0.1520537	0.1424311	0.1379507	0.1303543	0.122096	0.0991703	0.0862302
0.15513	0.1837216	0.1712663	0.1596301	0.1545633	0.1462613	0.1362764	0.1091517	0.0946184
0.16289	0.2064215	0.1930872	0.1779544	0.1718719	0.1625402	0.1501099	0.1193202	0.1036331
0.17103	0.2345467	0.2185681	0.1996727	0.1917042	0.1789562	0.1638784	0.1291469	0.1136999
0.17959	0.263095	0.2426279	0.2192889	0.2105545	0.1956472	0.1780273	0.1399261	0.1248494
0.18857	0.2905149	0.2651541	0.2373585	0.2284191	0.2126744	0.1920714	0.1529552	0.1367579
0.19799	0.3239779	0.293122	0.2638575	0.2534348	0.2349293	0.2106381	0.1683182	0.149822
0.20789	0.3616324	0.3292963	0.2996426	0.2873059	0.2652513	0.236936	0.186397	0.1648936
0.21829	0.399311	0.3683755	0.3346815	0.3205787	0.2953318	0.2642142	0.2068784	0.1817498
0.2292	0.4423419	0.4029305	0.3623005	0.3463364	0.3196789	0.2890763	0.2287813	0.1996157
0.24066	0.4867532	0.4314265	0.3851521	0.3686056	0.3428517	0.3140064	0.2523169	0.219815
0.2527	0.5330981	0.455845	0.4082125	0.393014	0.367399	0.3372549	0.2779824	0.244234
0.26533	0.5488342	0.4744907	0.4326756	0.4172766	0.3929281	0.3650356	0.3066921	0.2705992
0.2786	0.5538464	0.4937971	0.461919	0.4471021	0.4204263	0.395632	0.3377029	0.2973388
0.29253	0.5884303	0.5190169	0.4920642	0.4786496	0.4546777	0.4295336	0.3689543	0.32409
0.30715	0.6737694	0.5817729	0.5412394	0.5239809	0.494072	0.4644058	0.3992252	0.3504989
0.32251	0.7915507	0.6766479	0.6075206	0.5831296	0.5436562	0.5047443	0.428218	0.3763327
0.33864	0.8884176	0.7672971	0.6743921	0.647317	0.6031351	0.5561977	0.4557895	0.4013879
0.35557	0.9693756	0.8314429	0.7406617	0.7122716	0.6631741	0.6048397	0.4816291	0.4253992
0.37335	1.0805685	0.9149446	0.8084832	0.7686507	0.7120123	0.6444219	0.506519	0.4481917
0.39201	1.2088	1.0149485	0.866711	0.8110373	0.7485308	0.6776394	0.5303912	0.4704328
0.41161	1.2789427	1.0665727	0.9023258	0.8461901	0.7810941	0.7061142	0.5536359	0.4961489
0.43219	1.2905223	1.0772356	0.9395073	0.8909854	0.8199098	0.7367397	0.5833228	0.5261649
0.4538	1.2925818	1.1570637	1.0219063	0.9667975	0.872748	0.7741052	0.6227628	0.5605486
0.47649	1.4367472	1.2912308	1.1284254	1.0584975	0.9365921	0.8229974	0.6672064	0.6019869
0.50032	1.5585857	1.3912215	1.2076338	1.1293474	0.9947874	0.8800659	0.7171457	0.6495407
0.52534	1.6443462	1.4443991	1.2513409	1.1702697	1.0403313	0.9363208	0.7771863	0.7000134
0.5516	1.7375024	1.4572639	1.2616313	1.1998241	1.1038694	1.0223755	0.8510332	0.7538969
0.57918	1.9054137	1.6255228	1.4005464	1.3366544	1.2456597	1.1577153	0.9451807	0.817189
0.60814	2.0542551	1.7685604	1.54372	1.4714883	1.3902107	1.292271	1.043404	0.8919319
0.63855	2.155102	1.8601134	1.6499446	1.5983717	1.518821	1.411376	1.1355692	0.9671355
0.67048	2.2384478	1.8791086	1.7553429	1.7103593	1.6257221	1.5112352	1.2188997	1.0394203
0.704	2.3810533	2.0232622	1.8666391	1.8193288	1.7302333	1.6090488	1.2993713	1.1066862
0.7392	2.8752853	2.3701763	2.0512498	1.9849213	1.8676204	1.7359688	1.3919888	1.1716762
0.77616	3.3370616	2.7050907	2.2789217	2.1688482	2.00906	1.8626112	1.48675	1.2375748
0.81497	3.5884333	2.9012788	2.4468986	2.3059534	2.1254814	1.9617941	1.5677285	1.3062976
0.85572	3.8096615	3.0725073	2.5837	2.428558	2.2277011	2.0442732	1.6498015	1.3866003
0.8985	3.9318067	3.1802962	2.7039895	2.5418453	2.3259321	2.1236897	1.7366864	1.4729959

0.94343	3.9530739	3.2509931	2.8419461	2.6849468	2.4521344	2.2199575	1.8143797	1.5557048
0.9906	4.0312525	3.3909057	3.0219959	2.870796	2.6121114	2.3281533	1.8826944	1.637077
1.0401	4.39739	3.624792	3.1884967	3.0160888	2.7230102	2.4055057	1.9501289	1.7225531
1.0921	5.1382013	4.145212	3.4763489	3.2399885	2.875912	2.516101	2.0315755	1.8157374
1.1467	5.8111373	4.6869308	3.8794444	3.597127	3.1629373	2.7368912	2.1618764	1.9195135
1.2041	5.8323796	4.7056421	4.0174471	3.7606919	3.3581356	2.9704341	2.3565194	2.0408509
1.2643	5.942345	4.8370185	4.1210162	3.8832678	3.5344663	3.1949218	2.5585915	2.20234
1.3275	6.2254016	4.9652062	4.3345754	4.1169921	3.7873464	3.4277349	2.7581263	2.4021368
1.3939	7.8448778	5.698618	4.5176212	4.2365702	3.8798361	3.5547133	2.9688842	2.6043028
1.4636	7.911805	5.8628616	4.8242584	4.5652052	4.1615718	3.7757478	3.1680213	2.8093875
1.5367	9.0157306	6.8002649	5.562763	5.1728674	4.6368969	4.0909556	3.3701008	3.0221327
1.6136	10.974592	7.8343147	6.0611388	5.6196238	4.9604249	4.3239827	3.6066189	3.2601233
1.6943	11.043653	7.8707707	6.3611027	5.9383113	5.2763275	4.6626602	3.9301167	3.5438998
1.779	11.496884	8.2966087	6.7033343	6.3054855	5.6862009	5.1666823	4.3564475	3.8670943
1.8679	12.879937	9.4200087	7.4327857	7.0011724	6.4227061	5.8711181	4.8436544	4.2233359
1.9613	13.799866	10.524758	8.6208708	8.1467286	7.4709363	6.7158533	5.3592647	4.6087394
2.0594	13.916074	11.383361	9.7858179	9.2622206	8.4107323	7.5303707	5.8829233	5.0116894
2.1624	14.898386	12.672576	11.034854	10.426239	9.4022845	8.3758137	6.4369334	5.4248216
2.2705	17.466088	14.551065	12.581583	11.833279	10.580934	9.2799974	7.0160306	5.8448036
2.384	21.638693	16.696207	14.032641	13.08636	11.624589	10.194491	7.6165961	6.3152974
2.5032	26.33015	19.594271	15.969835	14.732544	12.957822	11.330722	8.3932457	6.9118081
2.6284	30.241121	23.363274	19.087366	17.556669	15.296049	13.071955	9.4466221	7.6186242
2.7598	39.214819	27.692734	22.315002	20.716497	18.246831	15.514535	10.659777	8.3633997
2.8978	48.971081	32.783888	26.015388	24.122187	21.267414	18.02938	11.954317	9.1534223
3.0426	53.153555	36.293254	28.581089	26.607989	23.678075	20.096243	13.158302	10.019233
3.1948	63.662168	43.049017	32.945384	30.456894	26.497996	22.077189	14.305592	10.991591
3.3545	82.827492	55.614585	40.628269	36.219459	29.980849	24.041429	15.557902	12.039141
3.5222	91.893151	59.959839	43.292836	38.707936	32.190265	25.829846	17.088143	13.168145
3.6984	91.893151	61.381963	45.796953	41.343892	35.006298	28.422057	18.908199	14.357569
3.8833	92.16645	64.167592	49.040982	44.432634	37.65687	31.093512	20.518349	15.493242
4.0774	95.469791	68.29542	52.136433	47.1701	39.894423	33.233193	21.88741	16.551022
4.2813	98.806295	70.487928	54.677377	49.617815	42.112809	34.831813	22.982702	17.592386
4.4954	105.58782	73.324891	56.5034	51.44267	43.6967	36.025442	24.031608	18.702955
4.7201	129.9404	78.432114	58.883801	53.558586	45.298694	37.191886	25.387707	19.867366
4.9561	152.64992	86.429378	63.156356	56.607135	47.317201	39.090626	27.080198	21.051941
5.204	159.10246	95.013747	68.122026	60.589164	50.899228	42.475485	28.978443	22.263625
5.4642	159.56168	101.64728	73.173352	65.393993	55.735419	46.453259	30.967866	23.489896
5.7374	176.4869	104.64413	76.239739	68.334817	58.656601	49.253863	32.831842	24.663667
6.0242	177.67586	104.8026	76.412883	69.596446	60.417579	51.480695	34.311339	25.677073
6.3254	178.45911	108.53034	84.17822	76.226103	64.96446	54.50815	35.351262	26.45278
6.6417	194.75601	122.11053	93.44869	84.263991	70.767529	57.485441	36.056571	27.026732
6.9738	213.56461	135.82933	100.5062	89.276501	73.354148	58.48569	36.27158	27.359262
7.3225	213.56461	135.82933	100.5062	89.276501	73.354148	58.48569	36.27158	27.441391
7.6886	213.56461	135.82933	100.5062	89.276501	73.354148	58.48569	36.27158	27.441391
8.073	213.56461	135.82933	100.5062	89.276501	73.354148	58.48569	36.27158	27.441391
8.4767	213.56461	135.82933	100.5062	89.276501	73.354148	58.48569	36.27158	27.441391
8.9005	213.56461	135.82933	100.5062	89.276501	73.354148	58.48569	36.27158	27.441391
9.3456	209.77406	133.43263	96.899934	86.402727	71.397861	57.408455	36.197735	27.441391
9.8128	190.3684	120.08662	85.958223	77.640979	65.636197	54.191532	35.788928	27.420767
10.304	150.67875	99.155922	74.013646	67.560749	58.469221	49.736231	34.82959	27.259918
10.819	124.11964	85.684685	66.32446	60.39312	52.239563	45.01461	33.387304	26.872816
11.36	106.40359	74.191854	58.38969	53.620956	46.807258	40.672062	31.686659	26.318526
11.928	73.491824	56.794483	48.220961	45.457956	41.191918	36.853047	29.984655	25.627546
12.524	58.669496	45.032476	39.938004	38.408197	36.083642	33.427883	28.389715	24.918321
13.15	49.176026	39.9292	36.401946	35.195244	33.187246	30.969755	27.007531	24.259336

13.808	48.678478	39.003496	34.23373	32.985826	31.114249	29.171451	25.911779	23.606498
14.498	47.665531	36.495539	31.758059	30.629834	29.10535	27.656011	24.96549	22.98503
15.223	39.843696	30.493856	28.365011	27.866781	27.055138	26.150425	24.058846	22.438642
15.984	32.126007	28.476005	26.974101	26.504877	25.798411	25.026813	23.325156	21.977295
16.783	30.122619	26.676758	25.326395	24.995776	24.525919	24.009697	22.725252	21.564859
17.622	29.554401	25.262163	24.011254	23.80512	23.521317	23.230411	22.196758	21.166198
18.504	29.017098	25.016128	23.697371	23.447255	23.117061	22.768449	21.71611	20.78049
19.429	27.536594	24.405097	23.32571	23.039421	22.689104	22.313306	21.269862	20.420235
20.4	26.541127	23.474777	22.624937	22.409044	22.138147	21.803155	20.861435	20.088921
21.42	26.240696	22.951197	22.174875	21.972367	21.678406	21.333026	20.46872	19.794486
22.491	26.240696	22.546322	21.837274	21.613823	21.271966	20.89582	20.097687	19.538086
23.616	26.240696	22.278852	21.44548	21.210472	20.851579	20.468817	19.775036	19.314842
24.797	26.240696	22.052681	21.061551	20.80214	20.433639	20.081219	19.499024	19.116411
26.036	25.82839	21.594468	20.574189	20.356614	20.051508	19.760821	19.250958	18.935427
27.338	24.07618	21.061498	20.229962	20.017689	19.742889	19.482738	19.022189	18.771892
28.705	21.296848	20.092521	19.732557	19.594478	19.387645	19.19167	18.827881	18.633496
30.14	20.21114	19.572239	19.247219	19.171442	19.057176	18.953157	18.695996	18.528924
31.647	20.441234	19.596677	19.188304	19.057318	18.850214	18.755372	18.593789	18.437207
33.23	20.544098	19.612039	19.188304	19.057318	18.850214	18.656002	18.507595	18.354329
34.891	20.544098	19.612039	19.188304	19.057318	18.850214	18.626751	18.430961	18.282222
36.636	20.544098	19.612039	19.188304	19.057318	18.850214	18.626751	18.369596	18.219274
38.468	20.544098	19.612039	19.188304	19.057318	18.850214	18.626751	18.31628	18.158954
40.391	20.544098	19.612039	19.187314	19.053277	18.840402	18.613586	18.251499	18.100319
42.411	20.544098	19.612039	19.173254	19.028685	18.799687	18.562235	18.190713	18.047141
44.531	20.526382	19.501169	19.084634	18.946095	18.729204	18.499051	18.153674	18.005365
46.758	20.325634	19.16699	18.86542	18.76566	18.604919	18.42212	18.123233	17.974492
49.095	19.775298	18.824427	18.610309	18.549128	18.448694	18.326251	18.086593	17.944906
51.432	19.123745	18.58761	18.426724	18.385021	18.316682	18.236128	18.046567	17.916559
53.769	18.745106	18.398194	18.292319	18.262041	18.20966	18.152896	18.005974	17.890191
56.106	18.653298	18.260419	18.186363	18.164147	18.123264	18.075892	17.964815	17.864707
58.443	18.653298	18.18166	18.117242	18.09706	18.059939	18.013873	17.923889	17.839668
60.78	18.653298	18.132461	18.079211	18.057655	18.018092	17.972855	17.88478	17.815396
63.117	18.653298	18.085436	18.042299	18.025057	17.991069	17.948414	17.848251	17.791967
65.454	18.653298	18.080404	18.017108	17.99887	17.964934	17.920619	17.816671	17.770243
67.791	18.653298	18.076472	17.98711	17.963934	17.927457	17.885192	17.790526	17.750032
70.128	18.520744	18.027049	17.926146	17.904498	17.873875	17.843003	17.76765	17.731213
72.465	18.19397	17.910422	17.822671	17.81401	17.802833	17.795006	17.746739	17.713669
74.802	17.982871	17.836749	17.781539	17.770327	17.763365	17.761524	17.727387	17.698291
77.139	17.887505	17.803467	17.762958	17.750594	17.741594	17.737216	17.709165	17.68382
79.476	17.887443	17.803293	17.762832	17.750462	17.73437	17.720568	17.691925	17.67012
81.813	17.884115	17.793867	17.756033	17.743355	17.725174	17.709296	17.677328	17.657643
84.15	17.873246	17.782895	17.748894	17.736399	17.71697	17.699177	17.665247	17.646096
86.487	17.851818	17.769758	17.741278	17.729652	17.710158	17.690672	17.656687	17.635853
88.824	17.827227	17.766332	17.739292	17.727893	17.708381	17.687294	17.648928	17.627729
91.161	17.801522	17.766332	17.739292	17.727893	17.708381	17.685725	17.641451	17.620352
93.498	17.7995	17.760429	17.736631	17.726067	17.707391	17.684557	17.636297	17.613589
95.835	17.798124	17.754487	17.733237	17.7236	17.705851	17.682945	17.631201	17.606906
98.172	17.798124	17.748929	17.725747	17.717502	17.701132	17.678651	17.626211	17.600634
99.5	17.798124	17.745771	17.721491	17.714038	17.69845	17.67621	17.623375	17.597069
100	17.798124	17.744582	17.719889	17.712733	17.69744	17.675291	17.622308	17.595727

Spectral input for cubicles at 11-R1-01E

Three main nodes are used to collect the spectra, see Figure 20.

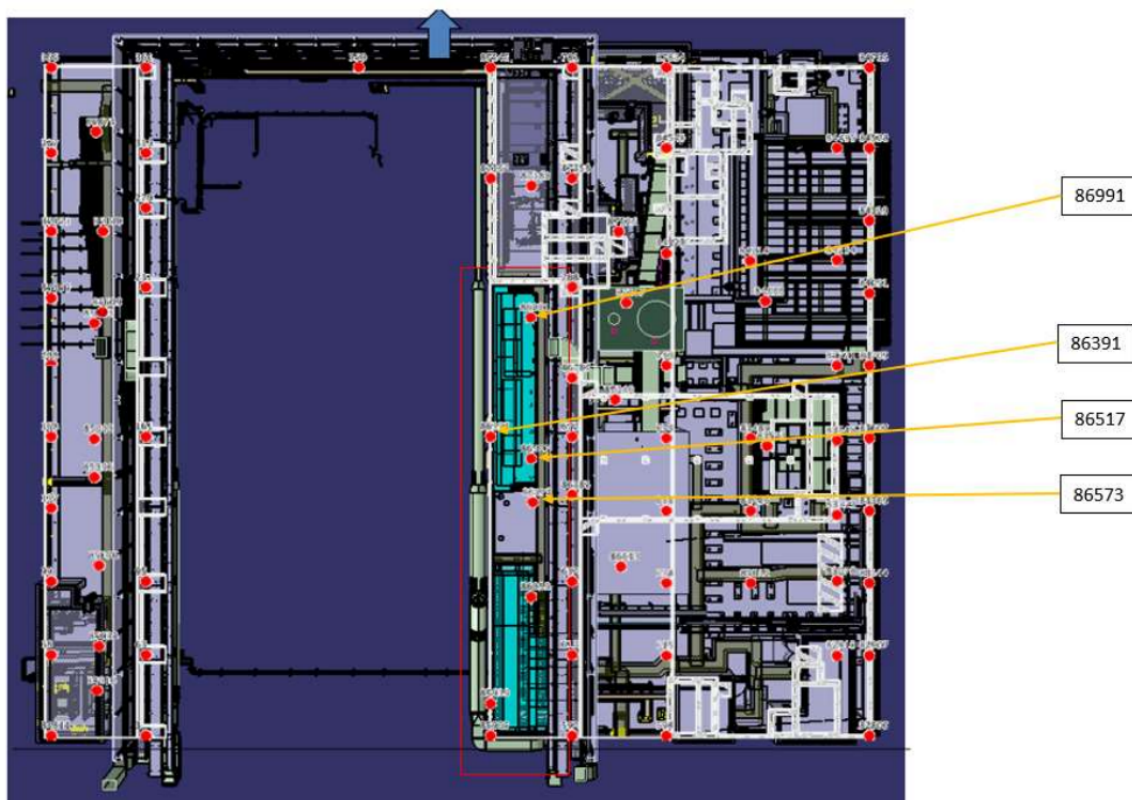
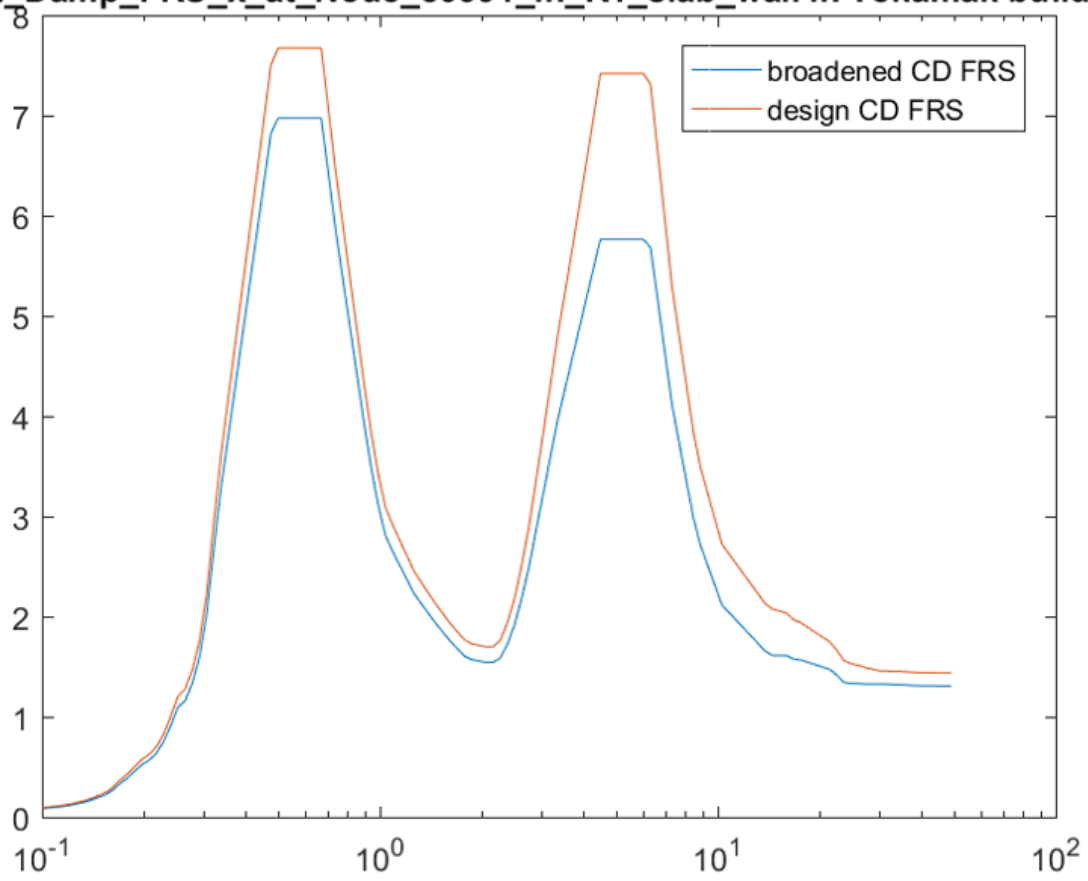


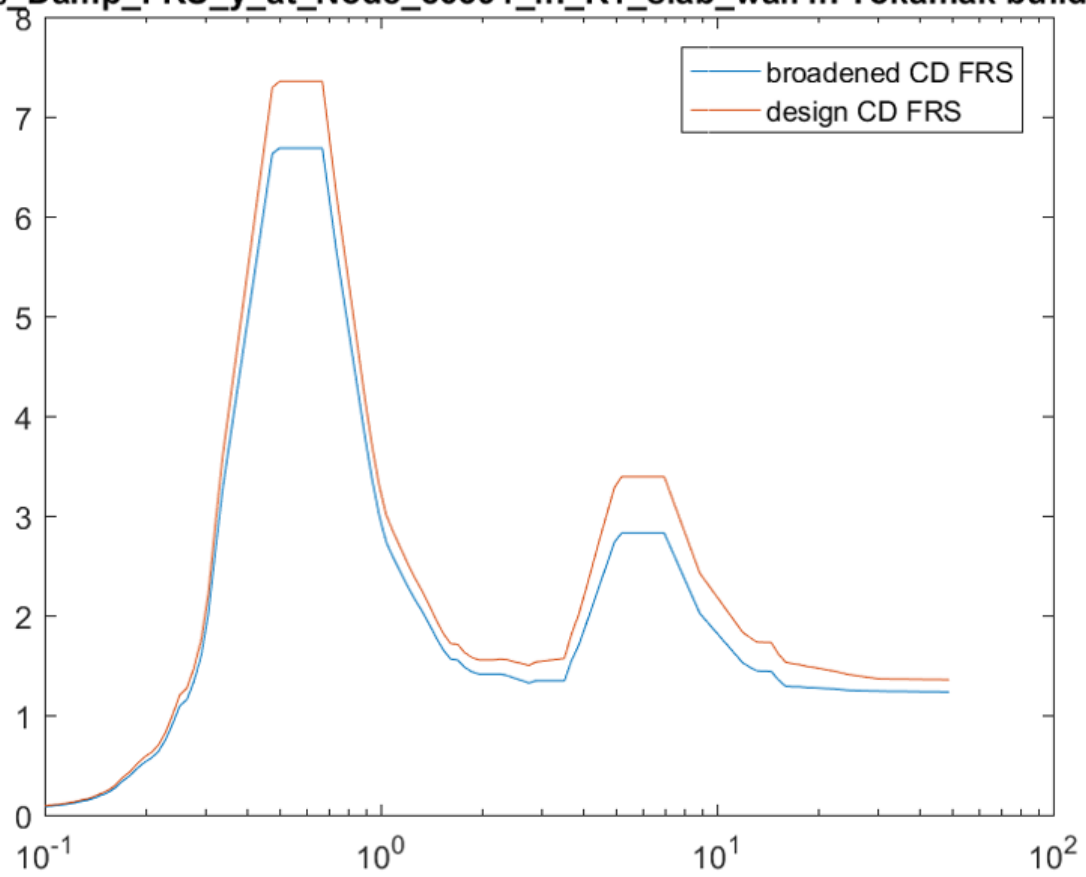
Figure 20 – Spectral input for cubicles

A separate file with X, Y, Z accelerations for three nodes will be provided for the ease of use and application.

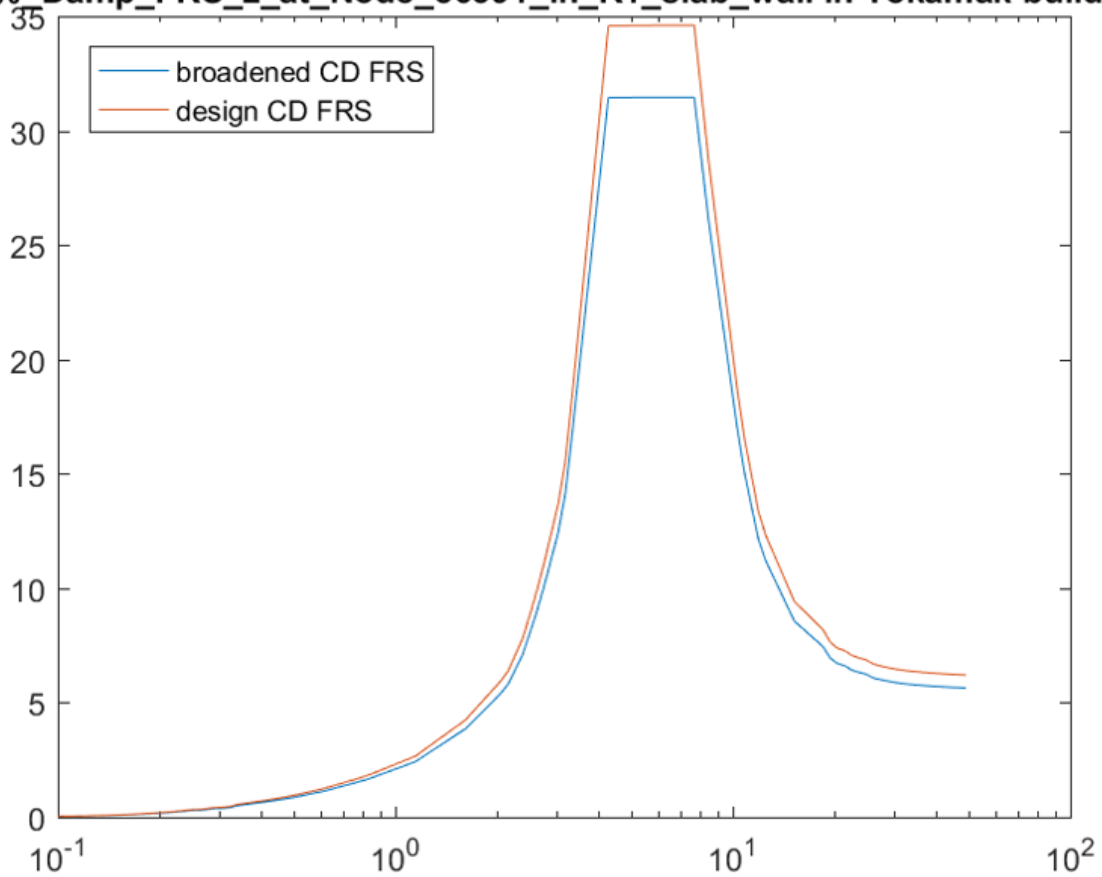
4% Damp_FRS_x_at_Node_86391_in_R1_slab_wall in Tokamak building



4% Damp_FRS_y_at_Node_86391_in_R1_slab_wall in Tokamak building



4% Damp_FRS_z_at_Node_86391_in_R1_slab_wall in Tokamak building



Appendix F: installation

The installation of the 26PHBD-HT-1000 is an important stage and requires precise attention during the transportation to level L4.

The following figures present the 26PHBD-HT-1000 installation in context. However, this study is preliminary, and the Contractor shall include a detailed study of installation in the installation manual.

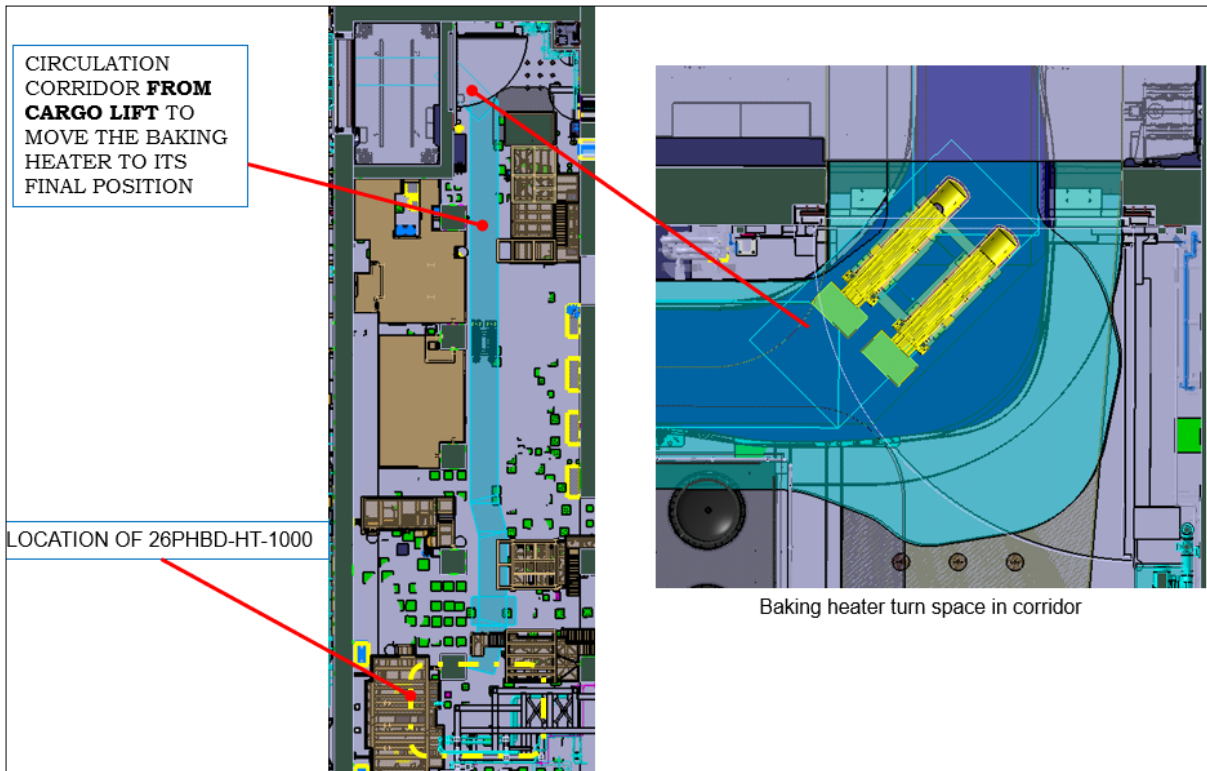


Figure 21 – Proposed installation sequence and spacing

As shown in Figure 22, supplier shall design and validate lifting lugs and assess options for transportation, use either current or propose others.

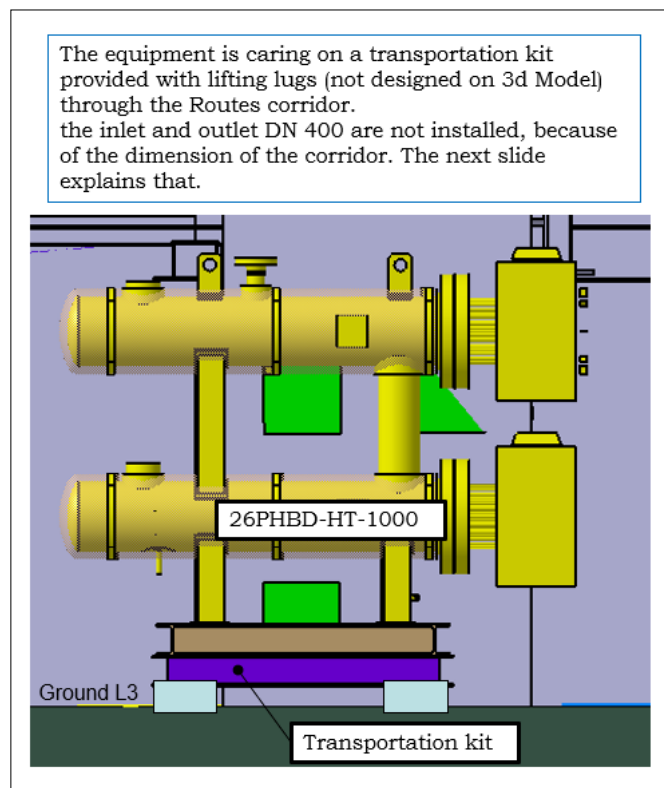


Figure 22 – Handling and transportation options

Moving the 26PHBD-HT-1000 thru the available space is bounded by the dimensions of the corridor, as shown in Figure 23. Maximum space can be 2200 x 3100 mm.

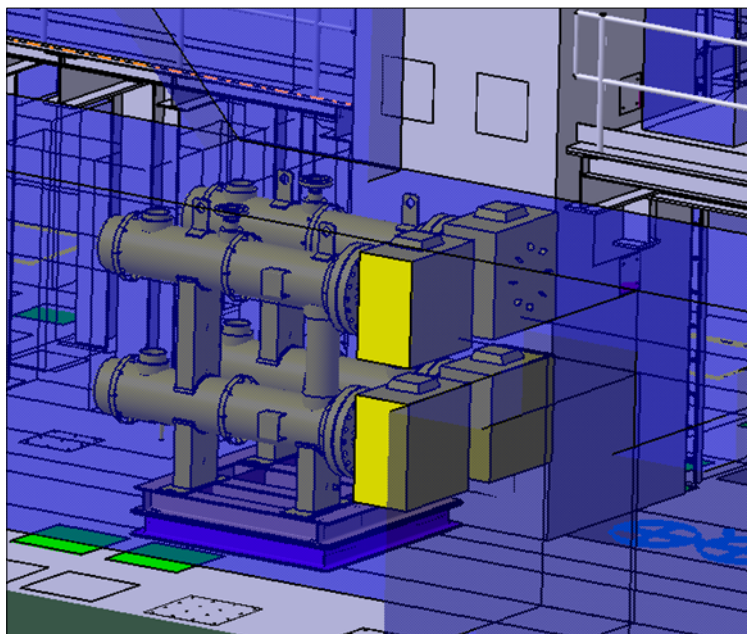


Figure 23 – Corridor and boundaries

Heater is placed in the final position on the platform 14 with space reservation on the right side to perform maintenance of the tube bundles, which is to be specified by the supplier and later checked internally for sufficient spacing in the model.

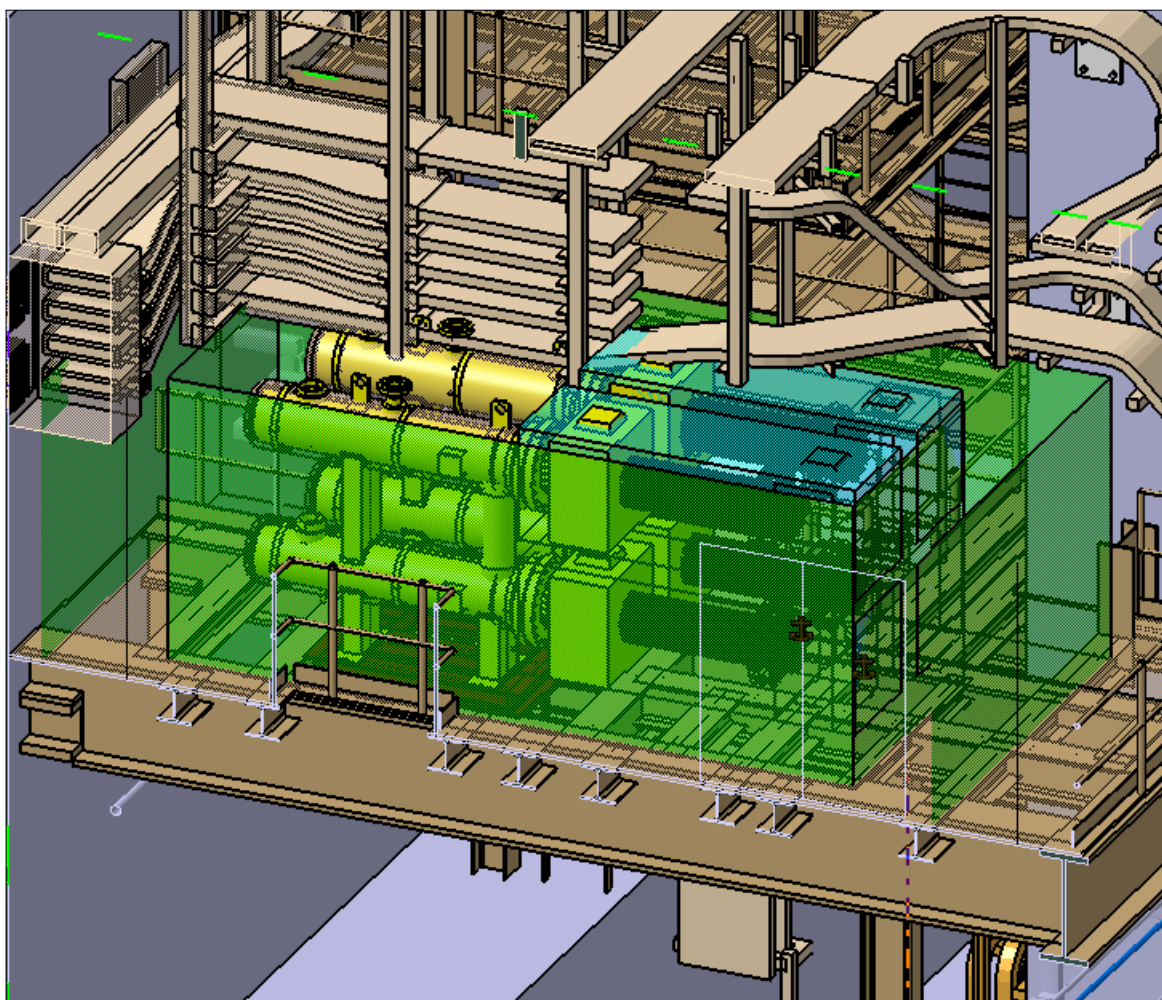
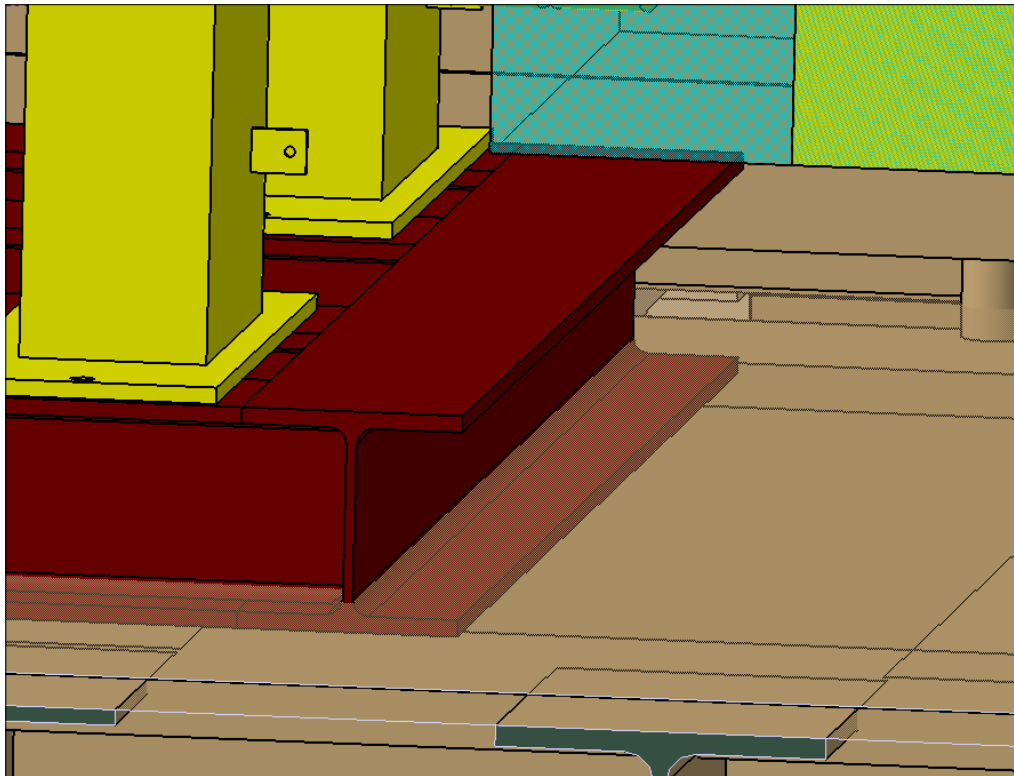


Figure 24 – Maintenance spacing and platform 14 final installation area

Fixation to the platform 14 can be performed via an intermediate structure, to be designed and verified by the supplier:



Design shall consider thermal expansion of the equipment and the supporting structure to avoid concentrated stresses at the fixation points. Model of the platform 14 with main load carrying beam elements shall be provided to the vendor for the design of the 26PHBD-HT-1000 supporting structure.

Appendix G – List of deliverables

The Contractor shall issue the documents (for IO review) indicated in the Table below. The required time for completion expressed in weeks before or after the gate will be decided during the KOM.

Additional documents can be identified during the kick-off Meeting or during the project and will be included to the list presented in this appendix.

Table 18 – applicable documents for 26PHBD-HT-1000

IO Documentation ID		Documentation Requirement	Planning
Technical Family (TDF)	Design Generic Document Title (GTD)	Gate/Stage Approved Document	Weeks before (-) or after (+) the gate
CONTRACT MANAGEMENT	Contract Management Plan	Kick off meeting	
CONTRACT MANAGEMENT	KOM Minutes	Kick off meeting	
CONTRACT MANAGEMENT	Contract Schedule	Kick off meeting	
CONTRACT MANAGEMENT	MRR plan	Kick off meeting	
CONTRACT MANAGEMENT	Bank Guarantee	Kick off meeting	
CONTRACT MANAGEMENT	List of deliverables	Kick off meeting	
DESIGN	Design Verification and Validation Plan	Design review	
DESIGN	Thermal-Hydraulic calculation report	Design review	
DESIGN	3D models	Design review	
DESIGN	Drawings (assembly and components)	Design review	
DESIGN	Design calculation sheet	Design review	
DESIGN	Stress report (FEM analysis)	Design review	
DESIGN	Fatigue analysis	Design review	

DESIGN	Software qualification	Design review	
DESIGN	Transport calculation	Design review	
DESIGN	Flanges calculation with EN1591-1	Design review	
PED/ESPN	Hazard and Risk Analysis	Design review	
PED/ESPN	Essential Safety Requirements Gap Analysis	Design review	
PED/ESPN	NPMA	Procurement review	
INSTALLATION	Installation drawing	Manufacturing Readiness Review	
INSTALLATION	Installation manual	Manufacturing Readiness Review	
DESIGN	Drawings (manufacturing)	Manufacturing Readiness Review	
DESIGN	Design Plan	Manufacturing Readiness Review	
MANUFACTURING	Hydrostatic test procedure	Manufacturing Readiness Review	
MANUFACTURING	Cleanliness control procedure	Manufacturing Readiness Review	
MANUFACTURING	Manufacturing and Inspection Plan (MIP)	Manufacturing Readiness Review	
MANUFACTURING	Manufacturing Process	Manufacturing Readiness Review	
MANUFACTURING	Lifting test procedure	Manufacturing Readiness Review	
MANUFACTURING	Expanding procedure	Manufacturing Readiness Review	
MANUFACTURING	Dimension inspection procedure	Manufacturing Readiness Review	
MANUFACTURING	Picking and passivation procedure	Manufacturing Readiness Review	
MANUFACTURING	Cleaning procedure	Manufacturing Readiness Review	
MANUFACTURING	Ultrasonic testing procedure	Manufacturing Readiness Review	
MANUFACTURING	Radiographic examination procedure	Manufacturing Readiness Review	
MANUFACTURING	Rolling and forming procedure	Manufacturing Readiness Review	

MANUFACTURING	Heat treatment procedure	Manufacturing Readiness Review	
MANUFACTURING	tooling list	Manufacturing Readiness Review	
MANUFACTURING	NDE operator list	Manufacturing Readiness Review	
MANUFACTURING	Visual examination procedure	Manufacturing Readiness Review	
MANUFACTURING	repair manufacturing procedure	Manufacturing Readiness Review	
MANUFACTURING	list of products in contact with the stainless steel	Manufacturing Readiness Review	
MATERIAL	Material Certificates	Manufacturing Readiness Review	
MATERIAL	Gasket certificates	Manufacturing Readiness Review	
PED/ESPN	DNRE drawing	Manufacturing Readiness Review	
PED/ESPN	In-service inspection drawing	Manufacturing Readiness Review	
QUALITY	Quality assurance plan	Manufacturing Readiness Review	
QUALITY	Quality plan from sub-contractors	Manufacturing Readiness Review	
QUALITY	Qualified supplier list	Manufacturing Readiness Review	
QUALITY	PIA control procedure	Manufacturing Readiness Review	
WELDING	List of qualified welders	Manufacturing Readiness Review	
WELDING	welding data package (WPS and PQR)	Manufacturing Readiness Review	
WELDING	weld defect repairing procedure	Manufacturing Readiness Review	
WELDING	welding map	Manufacturing Readiness Review	
MANUFACTURING	test records - expansion	FAT readiness review	
MANUFACTURING	test records - helium leak	FAT readiness review	
MANUFACTURING	test records - lifting test	FAT readiness review	

MANUFACTURING	test records - hydrostatic pressure test	FAT review	readiness	
MANUFACTURING	test records - surface finish test	FAT review	readiness	
MANUFACTURING	test records - dimensions and thicknesses	FAT review	readiness	
MANUFACTURING	test records - test coupon weld inspection report	FAT review	readiness	
MANUFACTURING	test records - UT	FAT review	readiness	
MANUFACTURING	test records - PT	FAT review	readiness	
MANUFACTURING	test records - RT	FAT review	readiness	
MANUFACTURING	test records - VT	FAT review	readiness	
MANUFACTURING	Test records - welding check list	FAT review	readiness	
MANUFACTURING	End of manufacturing Report (EOMR)	FAT review	readiness	
MANUFACTURING	Drawings (as-built)	FAT review	readiness	
PED/ESPN	ANB review reports (for information only)	FAT review	readiness	
QUALITY	Verification Compliance Matrix	Delivery Readiness Review (DRR)		
PED/ESPN	Instruction Manual	Delivery Readiness Review (DRR)		
PED/ESPN	Declaration of Conformity of the Manufacturer	Delivery Readiness Review (DRR)		
PED/ESPN	Certificate of Conformity from ANB	Delivery Readiness Review (DRR)		
QUALITY	Closed NCR	Delivery Readiness Review (DRR)		
QUALITY	Closed Deviation requests	Delivery Readiness Review (DRR)		
QUALITY	Contract release note	Delivery Readiness Review (DRR)		
TRANSPORT	Transportation quality plan	Delivery Readiness Review (DRR)		
TRANSPORT	package and packing list	Delivery Readiness Review (DRR)		

TRANSPORT	delivery report	Delivery Readiness Review (DRR)
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Table G-2 – applicable documents for 26PHBD-HT-1000 insulation

IO Documentation ID			Documentation Requirement	Planning
Technical Family (TDF)	Design (GTD)	Document Title	Gate/Stage Approved Document	Weeks before (-) or after (+) the gate
DESIGN		Insulation calculation sheet	Manufacturing Readiness Review	
DESIGN		Analysis report for insulation support	Manufacturing Readiness Review	
QUALITY		Quality plan for insulation	Manufacturing Readiness Review	
MATERIAL		Procurement specification of insulation	Manufacturing Readiness Review	
DESIGN		Insulation drawings	Manufacturing Readiness Review	
MANUFACTURING		MIP for insulation	Manufacturing Readiness Review	
MANUFACTURING		Dimensions inspection procedure for insulation	Manufacturing Readiness Review	
MATERIAL		Insulation material certificates	Manufacturing Readiness Review	
MANUFACTURING		Insulation qualification procedure	Manufacturing Readiness Review	
MATERIAL		Part list for insulation	Manufacturing Readiness Review	
MANUFACTURING		Insulation qualification test reports	FAT readiness review	
MANUFACTURING		Dimensions inspection reports	FAT readiness review	
MANUFACTURING		Insulation as-built drawings	FAT readiness review	
INSTALLATION		Insulation installation manual	Delivery Readiness Review (DRR)	

MANUFACTURING	EOMR for insulation	Delivery Review (DRR)	Readiness	
TRANSPORT	Transportation quality plan	Delivery Review (DRR)	Readiness	
QUALITY	Closed NCR	Delivery Review (DRR)	Readiness	
QUALITY	Closed Deviation requests	Delivery Review (DRR)	Readiness	
QUALITY	Contract release note	Delivery Review (DRR)	Readiness	
TRANSPORT	Delivery report	Delivery Review (DRR)	Readiness	

Appendix H – List of system requirements applicable to the 26PHBD-HT-1000

The TCWS SRD ref. [36] lists all the functional, design, safety, operational and quality requirements for the Tokamak Cooling Water System (TCWS).

The following system requirements are applicable to the 26PHBD-HT-1000.

H-1 Functions, basic configuration, classification, and system requirements

[26PHs12-I] The TCWS consists of three primary heat transfer systems (PHTSs), one for the VV, one integrated system (IBED) for the FW/BLK, DIV, In-Port Components and IVCs and one for the NBI. Support systems include the CVCS, DRS, and DYS. **Heat extracted in the PHTS is rejected to the Heat Rejection System (HRS) through the intermediate cooling loop (CCWS-1) at the main PHTS heat exchangers** or through the CHWS-H1 during the emergency operation of decay heat removal.

[26PHs660-R; Defined Requirement] The principle of the seismic classification of TCWS components is based on the safety objective and functional requirements in the event of an earthquake. Based on the requirements of ITER Seismic Nuclear Safety Approach ITER_D_2DRVPE, the pressure relief components, as well as other components that are required to function to maintain plant safety shall be classified as seismic class 1 (SC1) SF: Structural stability and required functional seismic safety performance maintained in the event of a safety shutdown earthquake (SSE), while all other TCWS components shall be classified as SC1 (S). Section 2.5 introduces more specific seismic requirements.

[26PHs674-R] Total maximal thermal load that will be removed using IBED PHTS is 880 MW (Table in 26PHs1321-R). A flow balancing shall ensure appropriate flow distribution between the in-vessel client systems.

H-2 Design requirements

[26PHs650-R] TCWS components in contact with cooling water provide primary confinement of radioactive inventories of tritium and ACPs. The TCWS shall facilitate leak detection and leak localization for TCWS components and client systems.

[26PHs318-I] IBED PHTS: The function of the IBED PHTS is to provide cooling water to all blanket modules, the in-port components in the upper, equatorial and lower ports, all divertor cassettes, and IVC components.

[26PHs105-R] Insulation on piping and equipment shall be determined based on industrial practice to ensure industrial safety and also the relevant metallic protective shield shall be provided around insulation.

[26PHs115-R; Defined Requirement] The TCWS shall be designed to comply with the requirements provided in the ITER Seismic Nuclear Safety Approach ITER_D_2DRVPE

[26PHs188-R] Manufacturing for the TCWS shall follow the INB order of 7th February 2012, the ESP/ESPN, and other appropriate codes and standards.

[26PHs1321-R] The thermo-hydraulic requirements of the IBED PHTS shall be in the following table:

Thermal Power Removal Requirements of IBED PHTS

Power to be removed by IBE D PHTS [MW]	Inductive Plasma Operation
FW/BLK, In-Port Components and DIV	847
IVC (ELM/VS)	12.5
Maximal Pump Heat	~ 20
Total Power	880

[26PHs326-R; Defined Requirement] The TCWS shall be designed in accordance with the Codes and Standards as established in the Codes and Standards for ITER Mechanical Components [41].

[26PHs394-R; Defined Requirement] The TCWS cooling water chemistry shall be controlled within specified limits, as detailed in the paragraphs below, for all modes of operation with water filled loops including conditioning, plasma operation, baking, and hot and cold standby states. Chemistry control shall already be available during commissioning as required by the installed parts of TCWS.

[26PHs399] Table 2.16.1: Cooling Water Chemistry Specification for Plasma Operation

Parameters	VV PHTS	IBED PHTS	NBI PHTS
Conductivity @25°C, $\mu\text{S}/\text{cm}$	≤ 1.0	≤ 0.2	≤ 0.1
pH @25°C	6.5-8.0	7.0 – 9.0	6.5-7.5
Sodium, ppb	≤ 25	≤ 5	≤ 5
Chloride, ppb	≤ 25	≤ 5	≤ 5
Hydrogen, ppb	-	≤ 80	≤ 100
Catalysed Hydrazine, ppb	-	≤ 30	-
Ammonia, ppb	≤ 300	≤ 1000	-
Oxygen, ppb	≤ 100	≤ 10	≤ 10
ORP @25°C, mV	info	(-400) – (-100)	(-400) – (-100)
Iron, ppb	≤ 12	≤ 10	≤ 10

Copper, ppb	<=10	<= 13	<=10
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[26PHs351-R] The VV and IBED PHTSs shall be designed to provide water baking conditions for the invessel components and the VV.

[26PHs352-R] The PHTSs shall be designed to maintain thermo-hydraulic conditions during all plant operational states.

[26PHs568-R; Defined Requirement] Halogenated insulating materials shall be forbidden in areas served by the detritiation systems.

[26PHs597-R] The TCWS shall be designed to maintain SIC function during and after a SL-2 seismic event.

[26PHs683-R; Defined Requirement] The design of TCWS shall accommodate nuclear shielding as to ensure that worker exposures to radiological and other hazards are ALARA during operation, maintenance, and repair.

[26PHs724-R] Electrical equipment and metallic structures susceptible to holding a fault current flow shall be earthed. The earthing conductors are interconnected to form the ITER Site Earthing Grid (ISEG). Earthing of equipment and structures shall follow the guidelines of EDH Part 5: Earthing and Lightning Protection, ITER_D_4B7ZDG

[26PHs960-R] Cooling water from the IBED PHTS shall be used to remove 12.5 MW of heat from IVC (ELM/VS) during burn periods of the inductive plasma operation as described in the following.

[26PHs968-R] Classification of the TCWS Nuclear Pressure Equipment shall be in accordance with the requirements of the French Order dated 30th December 2015 concerning Nuclear Pressure Equipment [3].

[26PHs973-R; Defined Requirement] Fire resistance material with no or low flammability shall be selected for TCWS to the extent practical.

[26PHs1246-R] At intervals prescribed by ESPN, periodic in-service inspection of the TCWS shall be performed to ensure leak tight integrity of the pressure boundary components.

[26PHs722-R] The Cooling Water System shall be designed to heat up the water from the pre-pulse temperature to baking temperature within 48 hours for both in-vessel and VV components, and to cool down in 24 hours from baking temperature to the pre-pulse temperature.

[26PHs918-R] During heat-up, the rate of change of the coolant temperature shall not be higher than 5 K/h . During cool-down the rate of change of the coolant temperature shall not be higher than -7 K/h.

H-3 Material requirements

[26PHs173-R; Defined Requirement] The main structural material for piping and equipment shall be austenitic stainless steel, with a grade appropriate for pressure and temperature of TCWS operation.

[26PHs1027-R; Defined Requirement] ESPN/ESP compliance for pressure equipment shall be assured in the TCWS design.

[26PHs1242-R; Defined Requirement] In order to minimize cobalt isotopes, components shall use steels with a low cobalt impurity level when exposed to the neutron flux (for example, maximum cobalt impurity is specified at 0.05% for stainless steel inside Cryostat) in accordance with [42]. Reducing this content has no impact on the steel properties (particularly mechanical properties) and limits the formation of these cobalt isotopes.

H-4 Construction and installation requirements

[26PHs195-R] The TCWS shall be designed to allow assembly that is consistent with the ITER construction schedule, environmental constraints, and handling, and conserve its mechanical integrity.

[26PHs1243-R] The TCWS shall be designed to allow the maximum pre-assembly at the manufacturer site, thereby minimizing the assembly work at the ITER site.

[26PHs197-R] The TCWS shall be designed to allow installation that is consistent with the ITER construction schedule, environmental constraints, and handling, and conserve its mechanical integrity.

H-5 Testing and inspection requirements

[26PHs199-R; Defined Requirement] Factory and final acceptance testing shall be specified for TCWS equipment based on relevant codes and standards.

[26PHs1228-R; Defined Requirement] All welded connections shall be inspected as required by the applicable codes and standards.

[26PHs1228-R; Defined Requirement] All welded connections shall be inspected as required by the applicable codes and standards.

[26PHs1245-R] After completion of installation, each piping system, or subsystem within the TCWS shall be pressure tested, according to the applicable rules for pressure vessels under ESPN.

[26PHs1246-R] At intervals prescribed by ESPN, periodic in-service inspection of the TCWS shall be performed to ensure leak tight integrity of the pressure boundary components.

H-6 Decommissioning requirements

[26PHs984-R; Defined Requirement] The lining of equipment that can become contaminated shall be selected to facilitate the feasibility and efficiency of decontamination operations.

[26PHs985-R; Defined Requirement] Design option shall be selected for installations (such as smooth surfaces and exemption of retention zones, continuous welds, and sumps at low points) to facilitate decontamination processes.

H-7 Other requirements

[26PHs207-R] TCWS has the primary confinement function of the ACPs and tritium. To reduce the potential risk of releasing these radioactive or hazardous material during gas phase (drying or gas baking), a gas leak test shall be performed before commissioning.

H-8 Safety requirements

[26PHs509-R; Defined Requirement] The TCWS shall provide primary confinement for tritium and ACPs in the cooling water.

[26PHs500-R; Defined Requirement] SIC SSCs shall be designed to be protected from internal and external hazards to ensure adequate performance of their safety function. SIC systems and components shall be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, hurricanes, and floods without losing the capability to perform their safety functions.

[26PHs212-R; Defined Requirement] Tritium and ACP accumulation shall be limited

[26PHs230-R; Defined Requirement] SICs shall be qualified for the seismic and environmental conditions under which they are required to perform.

[26PHs514-R; Defined Requirement] SIC systems and components shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed in accordance with the ITER Procurement Quality Requirements ITER_D_22MFMW.

[26PHs1223-R] Moreover, TCWS Items shall comply with the Requirements for Preparing and Implementing a Manufacturing and Inspection Plan ITER_D_22MDZD and the Quality Plan ITER_D_22MFMW.

[26PHs1036-R] A quality assurance program shall be established and implemented in order to provide adequate assurance that these structures, systems, and components will satisfactorily perform their safety functions.

[26PHs1037-R] Appropriate records of the design, fabrication, erection, and testing of structures, systems, and components important to safety shall be maintained by or under the control of the ITER licensee throughout the life of the plant.

[26PHs1038-R; Defined Requirement] The ALARA principle shall be considered in the system design in order to minimize radiological risks

H-9 Operation and maintenance requirements

[26PHs699-R] Any special tool and test equipment needed for maintenance of the system's equipment on site must be provided to the ITER Organization. Any such equipment, that would be additional to items delivered as manufacturing means, installation means, test and commissioning means shall be fully justified.

[26PHs700-R] Special pieces of equipment needed for packaging, handling, storage and transportation are also in the scope of the requirement. The supplier shall also state the degree of protection for any packaging equipment.

[26PHs1229-R] The ITER Numbering System for Components and Parts ITER_D_28QDBS shall be used for labelling and traceability.

H-10 Applicable codes and standards

[26PHs1226-R; Defined Requirement] The design of the ITER Site and Buildings shall be in accordance with the following codes, standards and design criteria:

- Code and standards listed in the following sections
- French standards and rules applicable or affecting:
 - Safety (nuclear and personnel safety)
 - Fire prevention, fire detection and/or fire fighting
 - Guidelines and rules for installations
 - Applicable building codes
 - The INB order of 7th February 2012
 - European Directives.
- Codes, standards and design criteria mutually agreed between the ITER Organization and the Domestic Agencies during the execution of the design work.

If a code and/or standard has been already approved by the issuing body/authority and it shall be expected to become in force during the construction phase of ITER, the ITER Organization may decide to immediately apply the new code and/or standard version.

[26PHs273-R] Pressure equipment for the TCWS shall be designed in accordance with applicable requirements in the Codes and Standards for ITER Mechanical Components [41]. The referenced codes and standards also specify requirements for in-service inspection and quality.

[26PHs1216-R; **Defined Requirement**] The TCWS shall be designed in accordance with the requirements of ESP and ESPN.