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EXTERNAL REFERENCE / VERSION

System Load Specifications

Loads Case Specification VVPSS -RL

This document contains all relevant structural and thermal loads acting on the ITER VVPSS Relief Lines.
It is based on the "Guideline for ITER System Load Specifications", [R19].
This document is consistent with the "New VVPSS Design Proposal", [R29]

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Hall C.**	**11 Feb 2020:signed**	**IO/DG/CNST/PLD/MID**
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Approver	**Sarkar B.**	**30 Mar 2020:approved**	**IO/DG/CNST/PLD/MID**
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Change Log			
Loads Case Specification VVPSS -RL (UXX829)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	Signed	03 Oct 2017	
v2.0	Revision Required	02 Jul 2018	This document specifies the single load types and load combinations to be applied in the structural analysis of the relief lines considering latest process requirements.
v2.1	Revision Required	31 May 2019	The new version include the following clarification and updated input data: - Integrity load case considering safety requirements of 30 Bar_a @ maximum design condition in service level A; - BDBA cases for fail to close scenario of the non-reverse flow valve in both cases combustion / explosion; - ICDs and ISs reference information included; - PE/NPE classification of the load cases in line with ASN guideline; - Clarification of the loads condition included; - Updated reference and justification for fire loads; - Updated reference and justification for reverse flow loads.
v2.2	Signed	04 Sep 2019	Significant editing to improve the readability of the document without changing the intention. Nominal Pressure rating of piping used to be minimum of 30 bar to ensure conservative design. PS clarified as 15 bar_a for relief line up to rupture disk / bleed valve assy, 6 bar_a between VV and RD / BV. Load Case DW+LOCA PC III+ICE II added in line with comments. Integrity Load Case removed. Reverse Flow section updated and now makes reference to separate report on reverse flow. Load case 9 changed from Service Level C to A to ensure all Cat. III events are Service A Load Case 19 changed from Service Level B to C as is combined SL3 + Cat V LOCA Other comments from previous version addressed.
v2.3	Approved	16 Oct 2019	Includes 30 bar(a) requirement as Service Level D for Relief Line - changed from Nominal Pressure Changes VVICE V + SL3 from service level C to B
v2.4	Signed	27 Jan 2020	Combined SL3 AND VVICE V Load Case changed from Service Level B to Level C acceptance limits as agreed with SRO. Inconsistencies with design temperature corrected - design temperature remains 250°C. Expansion bellows data removed from document to avoid duplication with references. Format improvements.
v2.5	Approved	11 Feb 2020	Change of Load Case 19 (SL3 and co-incident VVICE V) acceptance criteria from Service Level B to C. This change is made to avoid over-conservatism of using normal operational limits for co-incident Beyond Design Basis Events. Several minor internal inconsistencies have been corrected.

Table of Contents

1 Introduction

1.1 Purpose

The main purpose of load specification is to provide detailed requirements to be considered in the design and in the qualification activities for the relief lines system between the VSTs tanks located in DTR and VV.

Relief lines system shall be designed considering all loads and load combinations as defined in this document. This load specification has been prepared following ref. [R19].

1.2 Scope of Reviewers

Table 1-1 – List and scope of reviewers

Reviewers	Scope of review
A. Vaccaro	Check the compliance with the guidelines for ITER System Load Specification and the requirements for undertaking structural analysis
M. Olcese	Check the contents of this specification and consistency with functional specification.
C. Seropian	Check compliance with safety requirements
P. Vertongen	Check that the list of reviewers and the chosen approver of this document are appropriate. Check that this document is written following quality assurance requirements.
P. Teissier	Check compliance with the requirements of ESPN
B Sarkar	Approver

1.3 Scope of Load Specification

This document specifies the individual loads and load combinations to be applied in the structural analysis of the VVPSS relief lines.

The scope of the system load specification includes:

- The description of all states of the system and its components during its life.
- The safety, quality and seismic classification;
- The relevant design codes and standards;
- The description of all load events in each state (including normal, incidental and accidental conditions).
- The list of all single loads and load combinations to be considered to verify the structural integrity of the system and the load category of all load combinations.
- The specification of load values to be considered to verify the structural integrity of the system.
- The number of occurrence of each event during the life of the system and the number of load cycles.

The analysis shall also fulfil the procedural requirements for the structural analysis instruction and guidelines as indicated in ref. [R45], [R46], [R47] and [R48].

1.4 Codes and standards

The design criteria for the relief piping system between VV and VSTs are defined by ASME B31.3 -Ed 2016 (Category M fluid service) ref. [A1].

The analysis criteria for fatigue are defined by ASME BPVC VIII Div. 2 ref. [A4] for simplified analysis and respectively EN13480-3 ref. [A12] for detail analysis.

The selected criteria for analysis are based on studies documented in ref. [R8], [R12] and [R13].

1.5 System Classification

The classification of VVPSS relief piping system is defined in SRD-24-VP, ref. [R58].

The relief lines components and corresponding functions are PIC/SIC-1.

The seismic class of piping system is SC-1 based on requirement that the VVPSS be able to function during and after seismic events up to SL2.

The justification for this selection is driven by two main factors, see ref. [R58]:

- Primary confinement of radioactive materials;
- Over-pressure protection of the ITER Vacuum Vessel

The VVPSS Relief lines are Hard Core Components, ref. [R21] and [R34], and shall therefore remain functional following an SL3 seismic event.

The relief line has two main vacuum classifications (See Vacuum Handbook [R9]):

- Upstream of the RD/BL assembly is an extension of the VV and thus part of the high vacuum boundary area
- Downstream line of the RD/BL assembly is an auxiliary vacuum system with a consideration that in the case of an over pressure event the entire system shall become primary confinement boundary space.

The relief line system between the VV and non-reverse flow valves (NRVs) is not required to be classified as pressure equipment or ESPN ref. [R63], [R64] and [R65]) due to the fact that maximal pressure will never exceed 0.5 bar_g up to category III events (operational events for VVPSS relief lines piping system).

The relief lines between the NRVs and VSTs are classified as pressure components under ESPN considering that the maximum pressure will exceed 0.5 bar_g due to the controlled combustion of hydrogen in to VSTs.

The auto-combustion of non-condensable gases is negligible and coincides with an event cat V (BDBA) considering that the H_2 concentration in relief line is below the flammability limit.

Considering the above requirements the relief line components can be defined as part of one of three main functional areas as indicated in table 1-2. Refer also to Figure 1-2.

Table 1-2 System classification

Components Area	PIC / Safety class	Quality Class	Pressure Class	ESPN Class	Seismic Class	Vacuum Class	Tritium Class	RH* Class
1. VV to RD/BV	PIC/SIC-1	QC1	N/A	N/A	SC1	VQC-1A	TC2A	N/A
2. RD/BV to NRVs	PIC/SIC-1	QC1	N/A	N/A	SC1	VQC-3A	TC2A	N/A
3. NRVs to VSTs	PIC/SIC-1	QC1	III	N2	SC1	VQC-3A	TC2A	N/A

**The RD/BV complete assemblies' are removable parts that required maintenance. The Bleed valve and rupture discs Loads are detailed in a separate document.*

1.6 Units

The units used in this analysis are the standard SI base and derived units as listed in Table 1-3 below:

Table 1-3 - Units

Quantity	Unit Name	Unit Symbol
Length	Meter	m
Mass	Kilogram	kg
Temperature	Centigrade	°C
Force	Newton	N
Moment	Newton-meter	N.m
Pressure	Pascal	N.m-2

1.7 Coordinate System

Otherwise specified, this document uses the ITER Tokamak Global Coordinate System which is defined on Figure 1-1. The loads specification of the relief piping system uses the Global Coordinate System for ITER site. The system is referring to the "Tokamak Global Coordinate System" (TGCS) which has the origin in the nominal centre of the Tokamak machine.

These coordinate are clear defined in additional report by ITER Design Office. They are defined by a translation (in the X, Y and Z Directions) and a plane rotation (measured in degrees, clockwise direction) with respect to the TGCS.

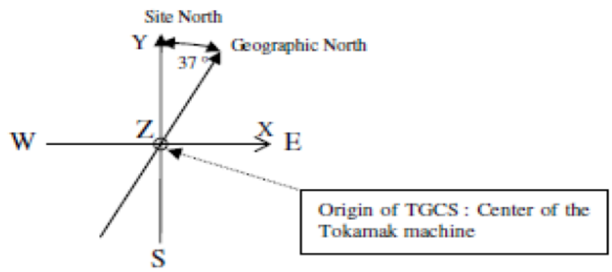


Figure 1-1 TGCS with respect to the Geographic North

The TCGS origin coordinate can be translated in to French Lambert III and NGF-IGN69 coordinate system as follow:

Table 1-4 Coordinate systems

Coordinate	ITER TGCS [m]	Lambert III and NGF-IGN69 [m]
X	0	877220.16
Y	0	162276.39
Z	0	316.68

Note: The Z coordinate in TGCS system will represent the vertical positive axis.

The TGCS coordinate is rotated on the Z axis in counter clockwise direction precisely by 37 degree relative to the Geographic North direction.

In the TGCS, the X coordinate will correspond to the "East" side of the site and the Y axis direction indicates the "North" of the site.

1.8 Abbreviations

Table 1-5 Abbreviations

For a complete list of ITER abbreviations see: ITER Abbreviations, ref [R2].

AAR	Accident Analysis Report
ASME	American Society of Mechanical Engineers
BL	Bleed Valve
BDBA	Beyond Design Basis Accident
DTR	Drain Tank Room
ESP	Equipment manufactured in compliance with Directive 2014/68.
ESPN	Equipment manufactured in compliance French order dated December 30, 2015 related to the manufacture of Nuclear Pressure Equipment (NPE) modified by French order 03/09/2018
FRS	Floor Response Spectra
HMS	Hydrogen Mitigation System
ICE	Ingress of Coolant Event
LLT	Large LOCA Tank
LOCA	Loss of Coolant Accident
LOVA	Loss of Vacuum Accident
NRV	Non-Return Valve
PED	Pressure Equipment Directive (Directive 2014/68/UE)
RD	Rupture Discs
RH	Remote Handling
RL	Relief Line
RPrS	Preliminary Safety Report (Rapport Préliminaire de Sûreté)
SC	Seismic Class
SIC	Safety Importance Class (-1)
SL-1	Seismic Level 1 – Defined by ITER for investment protection
SL-2	Seismic Level 2 – equivalent to Safe Shutdown Earthquake
SL-3	SL-3 or SND Seismic Noyau Dur
SLT	Small LOCA Tank
SMHV	Séismes Maximaux Historiquement Vraisemblables = Maximum Historically Probable Earthquake
SRSS	Square Root of Sum of Square
ST-VS	Suppression Tank – Venting System
VST	Vapour Suppression Tank
VV	Vacuum Vessel
VVPSS	Vacuum Vessel Pressure Suppression System

1.9 VVPSS Relief Lines System Description

The Vacuum Vessel Pressure Suppression System (VVPSS) is designed to protect the ITER Vacuum Vessel (VV) against over pressure in case of an in-vessel LOCA.

The VVPSS is also designed to provide dynamic confinement of the VV in the event of a Loss Of Vacuum Accident (LOVA), which leads to a connection of the VV volume with the Port-Cell volume. Maintaining the VV below the port-cell pressure in case of LOVA prevents the contamination of the port-cell.

The following Process Flow Diagram gives an overview of VVPSS, and highlights the three relief line functional areas:

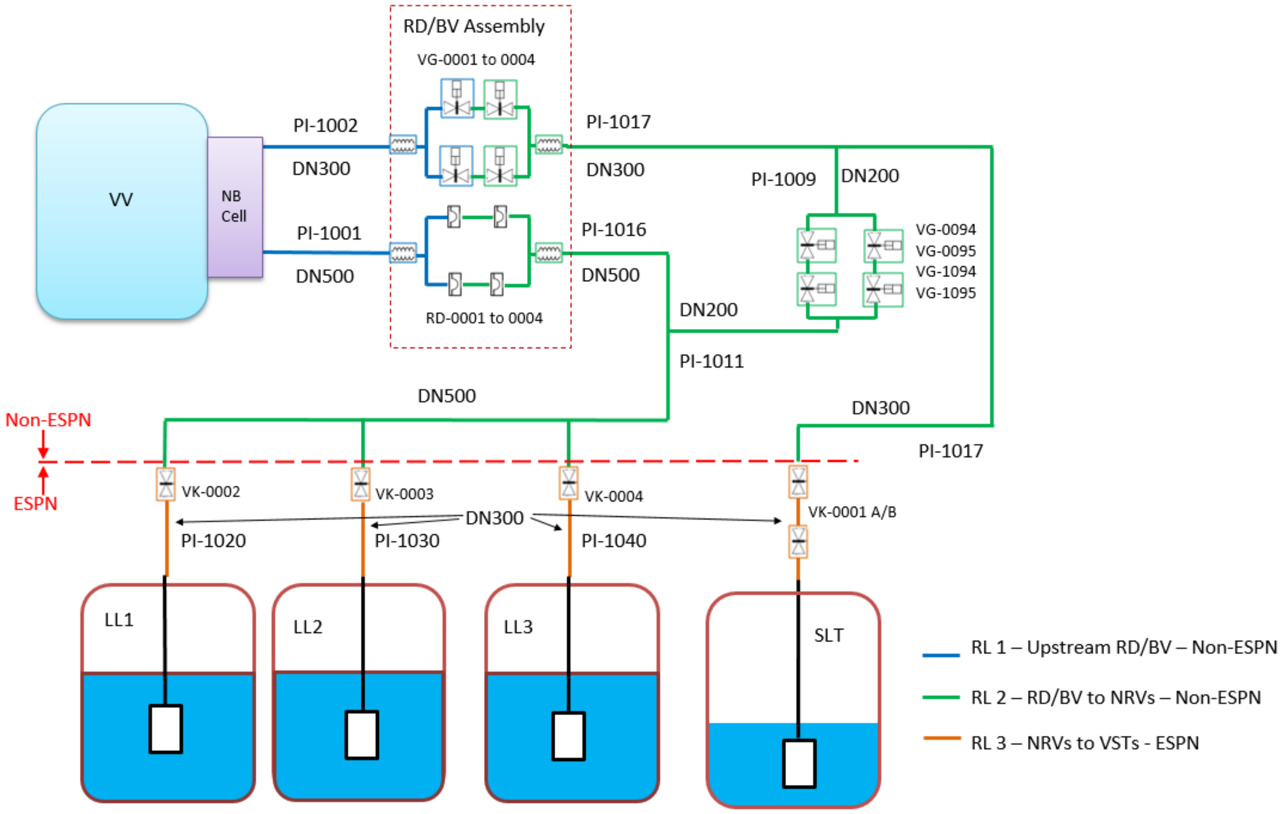


Figure 1-2 PFD of the VVPSS relief line

The RL-1 section of the relief line is connected to the VV via two Neutral Beam Injector ports.

The RL-1 defined as plasma operation section of the relief lines delimited by VV -VVPSS box connection upstream and boundary RD/BV assemblies;

The RL-2 and RL-3 sections are defined as accidental / incidental sections of the relief line delimited upstream by the RD/BV assemblies and downstream by VSTs.

2 Structural analysis requirements

2.1 Loads Type

The loads applicable for the relief piping system are divided in the below categories:

- Inertia loads – The loads described in this category are defined and caused by the gravity and acceleration due seismic events.
- Assembly and pretension loads – The loads include the remote handling operation during VVPSS Box maintenance or replacement of the components within RD/BV assemblies.
- Pressure loads - The pressure loads include the complete spectrum of internal / external pressure, from vacuum condition to slightly pressure state during LOCA/LOVA and flooding.
- Thermal loads – The thermal loads are caused by temperature gradients in the relief piping components, this can occur during operation, in accidental condition following baking or accidentally by large volume of gas/steam during LOCA / LOVA.
- Interface loads – The interface loads generally are defined as relative displacements between supporting structures, stiffness of supporting structure, thermal displacement of the interface equipment, any other loads that may affect the structural stability of the piping system

2.2 Loads Category

The ITER loading conditions are categorised, into four classes based on the expectation of occurrence, see ref. [R3]:

- Category I: Operational Loading Conditions
- Category II: Likely Loading Conditions Frequency f>10-2y^{-1}
- Category III: Unlikely Conditions Frequency 10-2y^{-1}>f>10-4y^{-1}
- Category IV: Extremely Unlikely Conditions Frequency 10-4y^{-1}>f>10-6y^{-1}

Other events or events combinations that are beyond design basis has been classified in an additional category (category V) and represent extreme unlikely events.

The typical process to establish the component design involves the following steps:

- Identify the initial design condition (e.g. seismic, gravity, thermal);
- Identify and categorise the applicable combination condition (e.g. seismic + thermal);
- Determine the acceptable damage limit for each combination condition (e.g. Normal, Upset, Emergency or Fault) based on the component safety importance criteria in the functionality of the VVPSS.
- Determine the structural service criteria for each damage limit.
- Compare the calculated stresses against the established criteria defined by the calculation methodology.

The relief lines are designed for the over pressure protection function of the Vacuum Vessel and accidental condition considered for VV shall be considered as normal operating condition for the relief line.

To ensure a conservative approach for the design of relief line, all loading conditions in Categories I-III shall be assessed against service limits for level A (normal operation).

Relief lines shall perform safety function confinement under all accident conditions.

Due to the confinement safety function, general deformations shall also be limited in Category IV Events. Therefore, Category IV events shall be assessed against service levels C and D.

The VVPSS Relief Lines are defined as Hard Core Components (HCC). L'évaluation complémentaire de la sûreté d'ITER [R44] identifies two scenarios that relate to the VVPSS, scenarios 8 and 11. The scenarios required the designation of the VVPSS relief line between VV and the VVPSS Discharge Tank as essential equipment to prevent the dispersal of radioactive material in the VV to the galleries via the broken VVPSS relief line.
The re-designed VVPSS, maintains all parts of the VVPSS within the C3 envelope and removes all equipment from the Galleries, effectively preventing the two identified scenarios and thus removing the need for the VVPSS to be designated as HCC. However, it has been decided, as a defence in depth measure that the VVPSS relief lines, rupture disk assembly and Vapour Suppression Tanks will be retained as HCC.

2.3 Path of Main Loads

The relief line the general layout of the system described below.
The two relief lines indicated in system description chapter 1.8 are connected via VVPSS Box and duct expansion joints to Neutral Beam Ducts.
The design of the VVPSS box joint has been develop considering no thermal and seismic movement of the VV impact the relief line system.
During baking, normal operation or accidental case of VV a thermal expansion will occur between the fix support of VVPSS Box and the interface with the relief line, this displacement shall be considered in the relief piping stress analysis.
The present design of VVPSS box has been included in section 3.10.
Parts of the relief line components (rupture discs and bleed valves) considered in the analysis are subject to future R&D study.
The schematic path of the main loads has been summarised in figure 2-1.

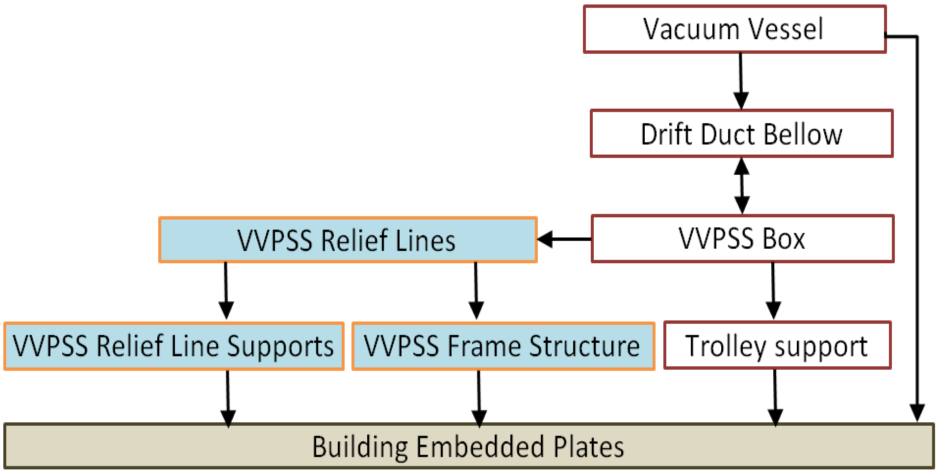


Figure 2-1 Paths of the main loads

2.4 Main Loads

The applicable loads and their combinations are applied to design of both piping and their supports according to the basic requirements for ITER safety and investment protection, ref. [R3], [R4], [R13].

The correspondence of the load combinations for VVPSS reference [R4] and their event categories with the service levels, shown in Tables 2.1, 2.3 and 2.4, shall guarantee the requested safety functions defined in the safety analysis.

All the loads, according to the likelihood occurrence are divided in events category (I, II, III, IV and V) with the corresponding service levels (A, B, C and D) as reported in Tables 2.3 and 2.4. Reference has been made to the Qualification Roombook [R68] to ensure that all loads defined in this load specification meet or exceed the defined loads.

The main loads defined by the process simulation, project and safety requirements are summarised in the table 2.1:

Table 2.1 Main Loads Case

Load Case	Chapter	Characteristic Loads
Piping system mass	**3.1**	Weight (Pipe ~250kN, Insulation ~35kN)
Assembly and lifting	**3.1**	During lifting and installation the piping spool are subject to deflection and large movement.
Hydraulic Test	**3.2**	Hydrostatic pressure test shall be perform for relief lines, considering limitation defined in section 3.2 Pt= max(1.43Ps;1.25*Pd*fa/ft).
SL-1		SL-2*0.34
SMHV		SL-2*0.73 (depending on frequency and damping factor, see reference [A5], [A6], [R7]
SL-2	**3.3**	Accelerations vary per location. See Appendix 1 for detailed information about FRS used. Envelope FRS documents, see [R6], [R7], [R12]
SL-3		According to [R16].
ICE II	**3.4**	Bleed Valves open and steam is released and condensed in the SLT. In particular case in all VSTs.
ICEIII / ICE IV	**3.4**	Bleed Valves and Rupture Disks open and steam is condensed in all VSTs.
ICE any category + VV-LOVA	**3.4**	Steam condense in one of the ICE incident mentioned above, the H2 + air accumulated in the free volume will be burned by ignitors. During this process the pressure will rise and may reach a peak of 3.5 bar_g.
H2 Explosion	**3.4**	Considering ref. [R28] the ESPN section of RL has been designed for the same internal pressure as VSTs assuming service level D for internal pressure at 30 bar(a).

Load Case	Chapter	Characteristic Loads

Thermal	**3.5**	Temperature of incoming gas mixture is up to 285°C during accident. Conservatively design temperature for RL has been selected: Upstream RD/BV =250°C Downstream RD/BV =250°C Baking temperature is 200°C Temperature cycle during VV normal operation is 20-110°C, conservatively assumed 115°C.
External Pressure	**3.6**	Up to 200kPa in case of VV-PHTS LOCA in the DTR or NB Cell.
Fatigue	**3.7**	Fatigue analysis for the load cycle corresponding to each case as indicated in the section 2.5. Detail fatigue analysis shall be performed according ref.[A7]
Fire	**3.8**	External explosion / fire will be assessed according to the fire load methodology specified in ref. [A12], [R24], [R31] & [R32].
Surge combustion	**3.9**	Deflagration of H2 inside VSTs will create a reverse flow (slug/water hammer effect) in RL.
Surge explosion	**3.9**	Detonation of H2 inside VSTs will create a reverse flow (slug/water hammer effect) in RL.
Interface Loads	**3.10**	Displacement of the VVPSS box and RD/BV interface.

Note: Limited acceleration and movement to be considered during lifting of large spools of pipes. Loads case has been considered in line with ITER guideline for loads specification, ref. [R19].

2.5 Non-Relevant Load Cases

Table 2.2 Non-Relevant Loads Cases for Relief Lines

Non Relevant Load Case	Justification, see reference [R5], [R7] and [R44]
Magnet fast discharge (MFD)	No significant loads occur due to major disruptions on components outside the magnet system.
Major disruption (MD)	No significant loads occur due to major disruptions on components outside the magnet system. The VV displacement caused by MD has been considered in design of the interface components, see ref. [R66].
Vertical displacement event (VDE)	No significant loads occur due to VDEs on components outside the magnet system. The VDE has been considered in design of the interface components, see ref. [R66].
Cr ICE	Not in contact with VV chamber volume.
Cr LOVA III	Not in contact with VV chamber volume.
Helium leak in the galleries	Not in contact with the gallery volume.

Large DV ex-vessel Coolant Pipe Break	In such an event, coolant will be discharged at a high rate into the TCWS (Tokamak Cooling Water System) vault and will not enter the Vacuum Vessel.
Load drop	Appropriate measures will be taken in the design of the components in the tokamak building, the assembly and remote handling tools to ensure that all first confinement barrier components will be protected from load drop.
Damaged equipment	Appropriate measures will be taken in the design of the components in the tokamak building to ensure that a failure of a component, e.g. break of pipe; will not harm first confinement barrier components.
External fire	The external building walls are designed to withstand the specified external fire event.
External flooding / Water Table	The foundation of the tokamak building is designed to withstand the specified water table and the specified type of external flooding. For internal flooding see Table 2.1
External explosion	The external building walls are designed to withstand the specified external explosion.
Airplane crash	The external building walls are designed to withstand the specified airplane crash. However an airplane crash event can cause an internal fire event.
Accidental temperature	The tokamak building is designed for external temperatures in the range [-15°C; 40°C]. In case external temperature occur outside this range within the specified limits, only the building external walls will be affected, the building interior will remain temperature controlled, hence no excessive thermal expansion occurs at internal walls.
Transient effects during heating and cool down before and after baking.	Temperature gradients are expected to be very small due to the requirement of slow increase/decrease of the temperature of the baked components; hence the additional thermal stresses will be insignificant. The normal baking case is certainly analysed as listed above.
Electromagnetic loads	
Stray field and slow transient	The stray field is produced mainly by the poloidal coils. Considering that the VVPSS relief line is made in SS 304/304L this load is judged negligible.
Fast transient	Transient events caused by plasma disruption, vertical displacement events (VDEs) and magnet current fast discharge (MFD) induce 2 main loads on the surrounding structure: dynamic (accelerations) and electromagnetic loads (induction of currents in the conducting structures which, in turn, gives rise to significant forces and torques).
Dynamic loads:	Considering that the HNB Front End Component – VVPSS Box is separated from the VV by the mean of a Drift Duct bellows, which acts as a damper, it is assumed that the inertia loads from VDE transiting through the VVPSS Box to relief line are negligible.
Eddy current load:	Considering the distance between the VV and the VVPSS box, and the fact that relief line is outside the Bioshield, it is assumed that the various fast transient events will have a limited impact on relief line.

2.6 Load Combinations for Relief Piping System

Table 2.3 Loads Case Combination for relief piping system

No	Load case	Pint (1) Non-ESPN	Pint (2) Non-ESPN	Pint (3) ESPN	Pext (1) Non-ESPN	Pext (2) Non-ESPN	Pext (3) ESPN	Temp(1) Non-ESPN	Temp(2) Non-ESPN	Temp(3) ESPN	Plant Event Cat.	Service Level (4)	No of Events [q]	VVPS S-RL Operating Situations [n]	VST Load Case
		bar(a)	bar(a)	bar (a)	bar(a)	bar(a)	bar (a)	°C	°C	°C	-	-	-		
1	DW+ NO	0	0	0	1	1	1	115	35	35	I	A	300	NOS	1
2	Hydrostatic test [a]	N.A.	21.5	21.5	1	1	1	35	35	35	-	A	1	TEST	14
3	Lifting & Handling + SL-1 [b) p)]	1	1	1	1	1	1	35	35	35	I	A	50	NOS	18
4	Maintenance (+ Compression Loads) [b) c)]	1	1	1	1	1	1	35	35	35	I	A	50	NOS	
5	DW +TBAKING [d]	0	0	0	1	1	1	200	35	35	I	A	500	NOS	
6	DW + SL-1 + TBAKING [d]	0	0	0	1	1	1	200	35	35	I	A	50	NOS	
7	DW + VVICE II [f) g)]	1.5	1.5	1.5	1	1	1	250	250	250	II	A	15	NOS	2
8	DW + VVICE III [f) g)]	1.5	1.5	1.5	1	1	1	250	250	250	III	A	1	NOS	3
9	DW + LOCA VV-PHTS	0	0	0	2	2	2	145	145	145	III	A	1	EOS	13
10	DW+ NO + SMHV	0	0	0	1	1	1	115	35	35	III	A	50	NOS	5
11	DW +SMHV+TBAKING [d]	0	0	0	1	1	1	200	35	35	III	A	10	NOS	
12	DW +VVICE IV [f) g)]	2	2	2	1	1	1	250	250	250	IV	C	1	NOS	4
13	DW+ NO + SL-2	0	0	0	1	1	1	115	35	35	IV	C	10	EOS	6
14	DW+ VVICE V [f) g)]	2	2	2	1	1	1	250	250	250	V	C	1	EOS	7
15	DW+ SL-2 +TBAKING [d]	0	0	0	1	1	1	200	35	35	IV	C	10	EOS	

No	Load case	Pint (1)	Pint (2)	Pint (3)	Pext (1)	Pext (2)	Pext (3)	Temp(1)	Temp(2)	Temp(3)	Plant Event Cat.	Service Level (4)	No of	VVPS S-RL Operating Situations [n)]	VST Load Case
		Non-ESPN	Non-ESPN	ESPN	Non-ESPN	Non-ESPN	ESPN	Non-ESPN	Non-ESPN	ESPN			Events [q)]		
		bar(a)	bar(a)	bar (a)	bar(a)	bar(a)	bar (a)	°C	°C	°C	-	-	-		
16	DW + SL-2 [(SMHV)] + FIRE [h)]	0	0	0	1	1	1	302	252	252	IV	C	1	EOS	11
17	DW + LOVA+ VVICE+FA [f) g) i)]	1.5	1.5	5	1	1	1	250	250	250	II	A	1	NOS	9
18	DW + LOVA+ VVICE + Explosion in VSTs + FD [f) g) j)]	2	2	12	1	1	1	250	250	250	IV	D	1	HIS	10
19	DW+VVICE V+ SL3 [f) g)]	2	2	2	1	1	1	250	250	250	V	C	1	HIS	8
20	DW+VV Dust Explosion [k)]	6	6	6	1	1	1	115	35	35	V	A	1	NOS	
21	DW + LOVA+ VVICE+FA [f) l)]	2	3	5	1	1	1	250	250	250	V	D	1	HIS	
22	DW + LOVA+ VVICE + Explosion in VSTs + FD [f) m)]	2	5	12	1	1	1	250	250	250	V	Ultimate failure	1	HIS	
23	DW+LOCA PC III+ICE II	1.5	1.5	1.5	2	2	2	250	250	250	IV	D	1	HIS	

Note:

(1) - Section 1 defined between VVPSS Box and including RD/BV;

(2) - Section 2 defined between RD/BV and up to NRV;

(3) - Section 3 defined between /including NRVs and VSTs;

(4) - Following Allowable value and limit in service C and D for ITER mechanical component (Section 0)

a. See section 3.2 for the applicability of hydrostatic test.

b. The acceleration during lifting, assembly and maintenance shall be considered conservatively as the SL-1 seismic acceleration.

c. The need to perform maintenance of the RD/BV, bypass valves and non-reverse flow valves requires the axial force needed to compress the bellow or to remove the components to be considered.

According to the current design configuration the following axial loads shall be to be applied to the piping during the maintenance operation:

Table 2-4 Maintenance Loads

Area	Tag	Estimated Axial Compression [kN]
NB Cell	RD	~26.4
NB Cell	BV	~16.4
NB Cell	VG	To be calculated.*
DTR	VK	To be calculated.*

- The preliminary estimation of the required clearance to replace the valves is ~10 mm.

d. The 200 °C baking is applicable for piping between VVPSS Box and RD/BV assemblies (included).

e. N/A

f. During LOCA event it is assumed relief line reaches maximum steam temperature of 250°C.

g. During LOCA the structural integrity analysis of the RD and BV module shall be performed assuming the following thermal/pressure code cases:

- Both train of RD and BV are opened simultaneously
- Only one train of the RD and BV open at the time (see figure 2.2)

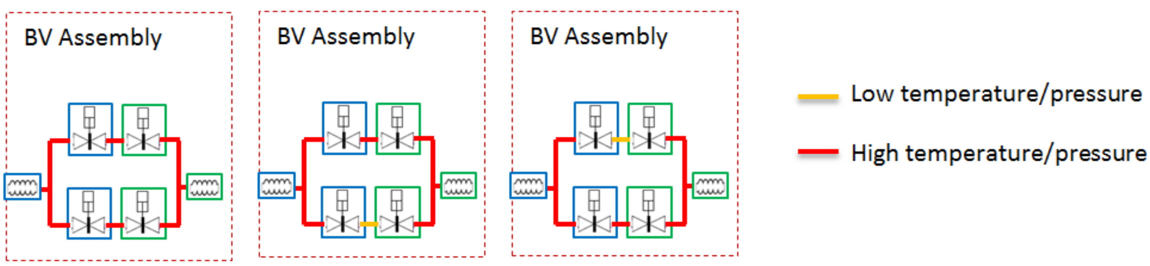


Figure 2.2 Thermal / pressure on BV assemblies

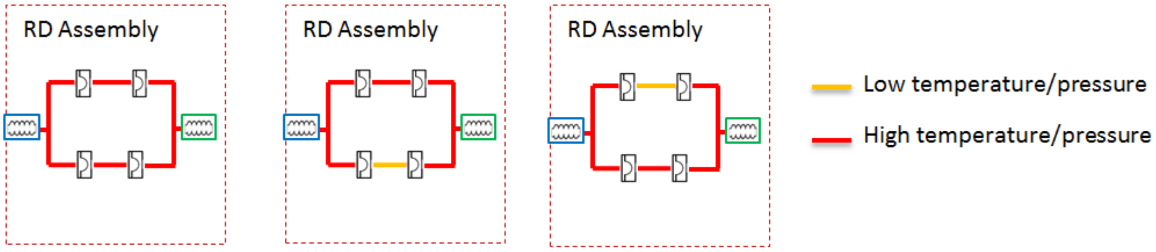


Figure 2-3 Thermal / pressure on RD assemblies

As low temperature it shall be considered the temperature of the relief line section according to load case 1.upstream NO of the VV, normal operating load case (see load case 1).

h. Fire load can be a consequence of a SL2 seismic event and therefore shall be considered as concatenated but not concomitant. However the fire event shall be considered as concomitant with an SMHV seismic replica.

The increasing pressure in the NB cell during fire is limited~5kPa and therefore negligible.

The fire analysis shall be performed assuming the piping temperature as indicated in table 3-9.

The detail of the fire analysis temperature has been included in Appendix 2.

The relief lines shall be fire protected, see detail explanation in section 3.8 and 4.2 of present report.

i. Case related to H2 deflagration (combustion) induced by the ignitors in VSTs. The increase in pressure will push the water from VSTs tanks back into the relief line piping and then the back flow is assumed to be stopped by the closure of the non-return valve.

Due to the 1.3 meter of water head in the VSTs above the sparger holes there is no risk of propagation of flammable gases into the relief lines.

A conservative hydrogen explosion pressure of 4.58 bar(a) is assumed to be reached in the VSTs.

Therefore a 5 bar(a) maximum pressure shall be considered in the piping between VSTs and NRV for this load case during normal service condition.

In addition to this pressure load, the force generated by the dynamic effect due to the water front travelling back in the relief lines has to be applied to each elbow of the relief line between the sparger and the NRV.

j. Case related to worst case H2 explosion in VSTs the increase in pressure will reverse the water from VSTs tanks back in the relief line piping and then the back flow is assumed to be stopped by the closure of the non-return valve.

A conservative hydrogen explosion pressure of 11.72 bar(a) is assumed to be reached in the VSTs. Therefore a 12 bar(a) maximum pressure shall be considered in the section of the relief line between VSTs and NRV.

In addition to this load, the force generated by the dynamic effect due to the water front travelling back in the relief lines has to be applied to each elbow of the relief line between the sparger and the NRV as shown in figure 1-2 and according to the profiles defined in Section 3.9.

The water hammer effect associated to the closure of the non-return valve shall also be considered as function of the closure time of the selected valve assuming that such a valve will close in liquid phase.

The reverse flow due to explosion event has been considered a highly improbable event category IV under Service Level D.

The load profiles of section 3.9 have been determined at the sparger hole of the VSTs and they shall be applied to each elbow considering the time delay due to the propagation of the water back flow into the relief line.

This delay has been determined based on the velocity (v) and line routing profile.

k. The accident is defined in [R5] and is considered as a consequence of a VV LOVA, which leads to mobilisation of hydrogen isotopes and deflagration, which then triggers a dust explosion. Whilst the event is considered beyond design basis, due to the proximity of the relief line to the North Wall of the Tokamak Complex, this event will be conservatively assessed against Service Level A requirements.

The overpressure generated by such event is up to 6 bar(a).

The complete VVPSS relief lines system is assumed to be affected by this accidental case.

l. Beyond design basis accidental scenario assuming the non-reverse flow valves "fail to close" and hence fail to stop the back flow in the relief lines following a deflagration induced by ignitors (combustion) event in the VSTs.

The water back flow will generate dynamic loads only on the bends up to:

- The VV for the DN 300 relief line connected to the VST1 (SLT)
- The relief line manifold connected to the VST2, 3 and 4.

In both cases, the verification of the dynamic effects on the relief line piping has to be performed considering the loads as described in (i) and assuming service level D limits.

m. Beyond design basis accidental scenario assuming the non-reverse flow valves "fail to close" and hence fail to stop the back flow generated by the worst-case H2 explosion in VSTs.

The verification of the relief line structural integrity will be performed following the approach described in (m) but assuming as failure criteria the ultimate limit state of the piping.

n. ESPN Case definition;

NOS – normal operating situation,

EOS –exceptional operating situation,

HIS – highly improbable situations

o. The flooding will produce a buoyancy force on the lower piping in DTR corresponding to the estimated water level in the DTR, 3.13 m ref. [R18]. This will not be applicable for relief lines due to the current level of the piping components.

p. The loads during transportation, handling and lifting will be verified to remain within the acceptance limit.
Lifting and handling of the piping components should be performed in order to not introduce additional stress in the system.

q. Unless a detailed dynamic analysis is performed and the number of cycles per event is directly calculated, according ref. [R3] it is recommended to assume for each seismic event 10 equivalent maximum stress cycles whenever a fatigue or a cyclic load analysis is required. Category III events and combinations shall be assumed to occur once in the machine life unless otherwise specified.

r. There are no other anticipated external loads than mentioned above.

2.7 Acceptance Criteria for Relief Piping System

The acceptance criteria for the relief piping analysis are listed [A1] and [R10] considering the following paragraphs.

Design Code ASME B31.3 ref. [A1] for piping provides only acceptance criteria for sustained loads, occasional loads and for displacement range (expansion); however it does not consider something such as "operating stress". Therefore the acceptance criterion to be used is that for sustained loads (that consider the pipe at operating temperature), which can be combined with occasional loads that depend on the event category.

Furthermore ASME B31.3 ref. [A1] doesn't provide 4 service levels as ASME BPVC ref. [A4] does.
To cope with this, ITER document reference [R10] assigns acceptance criteria to service levels C and D for piping design under ASME B31.3, ref. [A1].

Applicable acceptance criteria for the relief piping components has been summarised in table 2.5 below.

Table 2.5 Acceptance Criteria for Analysis

Event Category	Service	Acceptance Criteria (ITER design)
I	A	$[(PD_0 \div 4t) + (IM_{SUS} \div Z)] \leq 1{,}0Sh$
II	B	$[(PD_0 \div 4t) + I(M_{SUS} + M_{OCC}) \div Z] \leq 1{,}0Sh$
III	C	$[(PD_0 \div 4t) + I(M_{SUS} + M_{OCC}) \div Z] \leq 1{,}5Sh$
IV	D	$[(PD_0 \div 4t) + I(M_{SUS} + M_{OCC}) \div Z] \leq 2.0Sh$

Note:

- Primary stresses calculated for service levels C and D should not exceed 1.5 and 2 times the basic allowable stress respectively [R10];
- Secondary stresses calculated for service levels C and D shall not exceed 4.2 and 6 times the basic allowable stress respectively; furthermore the axial stresses for purely secondary cases shall not exceed 0.7 and 1.0 times the basic allowable stress respectively [R10];
- Calculated stresses due to hydro test should not exceed 1.5 times the basic allowable stress [A1];
- It is not necessary to consider other occasional loads, such as earthquake occurring concurrently with test loads;
- Ultimate limit state of the piping system is described as ultimate tensile stress capability of the components under accidental scenario. The method shall be used for beyond design basis accidental scenario assuming the non-reverse flow valve "fail to close" and hence fail to stop the back flow generated by the worst case H2 explosion in VSTs.

2.8 Interfaces

The complete list of interface documents is provided in the PBS24VP-SRD ref. [R58].

In general the interface loads that other PBS will affect the stability and integrity of relief lines, such as thermal displacement, maintenance scenario has been summarised in section 3.10 of the present specification and are properly considered in the terminal ends or supports which are connected to the relevant component of the system.

In table 2.6 are defined the main system that will affect the integrity of the relief lines.

Table 2.6 List of ICD & IS

PBS	UIMIDM
PBS 23 - Remote Handling System	
ICD PBS 23 – PBS 24VP	ITER_D_9AYLJJ - ICD-PBS 23 Remote Handling Systems - PBS 24 VVPSS
IS PBS 23 – PBS 24VP	ITER_D_LZNFH5 - IS-23-24.VP-001 Interface between Rupture Disk Assembly and RH System
IS PBS 23 – PBS 24VP	ITER_D_LZU7Q6 - IS-23-24.VP-002 Interface between Bleed Line Valve Assembly and RH System
IS PBS 23 – PBS 24VP	ITER_D_LZYKNJ - IS-23-24.VP-003 Interface between Relief lines and RH System
PBS 15 - Vacuum Vessel	
ICD PBS 15 – PBS 24	ITER_D_2NRU42 - ICD-15-24 Interface Control Document for Vacuum Vessel (PBS 15) and Cryostat (PBS 24)
PBS 31 - Vacuum	
ICD PBS 31 – PBS 24VP	ITER_D_45LXKT - ICD-24.VP-31 Interface Control Document between Vacuum Vessel Pressure Suppression System (PBS 24.VP) – Vacuum Pumping (PBS 31)
IS PBS 31 – PBS 24VP	ITER_D_9KAGSU - IS 24 VP-31-001 - Interface between VVPSS and Service Vacuum System
IS PBS 31 – PBS 24VP	ITER_D_9MUWQ9 - IS-24.VP-31-002 Interface between VVPSS and Vacuum Control system
PBS 53 – Neutral Beam	
ICD PBS 53 – PBS 24VP	ITER_D_3V8PBR - Interface Control Document (ICD) between Cryostat VVPSS (PBS 24) - NB HCD (PBS 53)
IS PBS 53 – PBS 24VP	ITER_D_BFAXLN - IS 24- 53
PBS 62 - Reinforced Concrete Buildings	
ICD PBS 62 – PBS 24VP	*No IS*

3 Single Load Cases

3.1 Dead Weight

The dead weight of the components has been included in all loads cases condition as indicated in the table 2.1.
The masses of the piping components can be found in the approved Enovia models under configuration management.

The masses reported in this document are correct as of the date of the revision.

Table 3.1 Weight data for components

Component	Supplier	Weight (Estimated weight)
Item/Tag	**-**	**-Kg**
DN200 flange	~ Estimate single flange / assembly	35/ 70
DN300 flange	~ Estimate single flange / assembly	30 / 65
DN500 flange	~ Estimate single flange / assembly	60 / 130
DN200 Valve	~ Estimate welds /flange conn. (unit)	350 / 300
DN300 Valve	~ Estimate BV welds conn. (unit)	340
DN500 RD	~ Estimate RD & holders (unit)	350
DN350 VK	~ Estimate NRV flanged (unit)	320
DN350 EN-Flange	~ Estimate flange EN1092-PN25	50

3.2 Testing Loads

The relief piping system shall be designed, constructed, and tested in accordance with the ASME B31.3 Ed.2016, ref. [A1] and shall be consistent with ESPN regulation ref. [R63], [R64] and [R65].

Separate hydrostatic tests may be performed for individual parts of the piping system due to the phased installation of the relief lines.

For hydrostatic testing purpose the relief lines between NRVs and VSTs have been classified as pressure components under ESPN requirements.

An individual spool test shall be performing for the piping system between the NRVs and RD/BV and respectively RD/BV and VVPSS Box.

Due to sensitive components and consideration that hydrostatic test will damage the components; the RD shall not be hydro tested.

The ESPN section shall be hydrostatic tested as part of ESPN requirements considering the standard test pressure according to ref. ref. [A1] and consistent with ref. [R63], [R64] and [R65].

Hydrostatic pressure considered in design is: Pht= max (1.43Ps;1.25*Pd*fa/ft)bar(a).

Design pressure Ps is detailed in section 3.4 of the specification.

3.3 Seismic Loads

Seismic events shall be considered to occur assuming the machine in the worst foreseeable conditions.

For each system and component the worst foreseeable condition has to be identified. It has to be considered that for different systems or parts of a system the worst condition can be represented by different conditions or machine status.

Seismic load excitation corresponds to the specific selected site for the ITER construction (Cadarache) for buildings and equipment that are classified in seismic class 1 and 2 (SC1 and SC2) three levels (SL-2, SMHV and SL-1) of ground motion are considered.

Mandatory requirements for ITER Hard Core Component are described in reference [R21] and [R33] in which damping factor and reduction factor are given and reminded below for pipework components.

Table 3-2 Damping factors Service Level C and D

Component	Damping factor	Reduction factor*	
	-	Level C	Level D
Valves / Socket pipe	5%	1.25	1.5
But welded pipe	5%	1.5	**1.5**
Supports	5%	1.5	**1.5**

Note: * For mechanical equipment and distribution systems located inside the Tokamak complex (generally in buildings equipped with seismic isolator systems) the value has to be limited to 1.5, according to EN 1998-1 - Eurocode 8, see ref. [A5]
All active components with operability requirements after the earthquake have to be qualified considering reduction factor **F=1**.

Seismic Analysis

Seismic analysis shall comply with the ITER guidelines and specification as well with the standard code specific applicable for the current design indicated is section "Reference & Applicable Documents "indicated at the end of present specification.
Detail information regarding applicable FRS for VVPSS has been indicated in Appendix 1.
The seismic analysis methodology and modelling principle is based on the detailed methodology provided in ref. [R48] and [R49].
The response spectra indicated in Appendix 1 which correspond to the damping ratio indicated in table 3-3 shall be combined following the below proposed method in order to provide the maximum response of the piping system.
The Square Root of Sum of Square (SRSS) has been selected as preferred option for the seismic response due to the fact that the result represents the maximum response to a component.

$$R = \sqrt{R_x^2 + R_y^2 + R_z^2}$$

The Newmark beta method is considered optional due to the fact that requires more simulation cases:

- +/-100% Rx :+/-40% Ry : +/-40% Rz
- +/-40% Rx : +/-100% Ry : +/-40% Rz
- +/-40% Rx : +/-40% Ry : +/-100% Rz

Simplified this can be considered assumed as:

$$R = \max(|Rx| + 0.4|Ry| + 0.4|Rz|; |Ry| + 0.4|Rz| + 0.4|Rx|; |Rz| + 0.4|Rx| + 0.4|Ry|)$$

$$= 0.6 * \max(|Rx|; |Ry|; |Rz|) + 0.4 * (|Rx| + |Ry| + |Rz|)$$, ref. [R49]

Seismic Event Level SL-1

SL-1 corresponds to the SL-2 event multiplied by the factor of 0.34. The SL-1 is a lower category (Category II) of event, and as such is accompanied by lower allowable stresses and different damping factors as indicated in table 3.3 and represents an investment protection earthquake level.
The equipment which is SIC has to be designed to restart and operate after an SL-1 without special maintenance or test.
SL-1 has lower return periods (~100 years) than the earthquakes that are typically considered in ASME assessments (500 years). SL1 loads are therefore treated as live loads (L) instead of earthquake loads I for conservatism.

Seismic Event Level SMHV

The SMHV loading, accelerations are determined by applying a factor of 0.73 to the SL-2 loading determined from FRS diagram at 4% damping corresponding to the Natural frequency analysis.

Seismic Event Level SL-2

SL-2 corresponds to the seismic level required by French nuclear practice (RFS 2001/01).
The SL-2 loading, accelerations are determined from FRS diagram at 4% damping corresponding to the Natural frequency analysis.
SL2 and SMHV have higher return periods (more than 1000 years) than the earthquakes that are typically considered in ASME assessments (500 years). SL2 and SMHV loads are therefore treated as earthquake loads I.

Seismic Event Level SL-3

According to stress test methodology for HCC on ITER plant, a seismic event of a magnitude 1.5 times the SL-2 has been defined as SL-3 and shall be considered in combination with normal plasma operation, see ref. [R20].
The SL-3 seismic event will be assessed against Service Level B.
The SL-3 loading, accelerations are determined from FRS diagram at 5% damping corresponding to the Natural frequency analysis, see ref. [R16] and [R49].

Seismic Relative Displacement

The seismic relative displacement has been implemented in the piping stress analysis for the relevant system application according study performed by the building engineering as documented in ref. [R37]. The stress results considered in structural analysis shall include the relative displacements if these are considered relevant for analysis.
The relative displacement indicated in ref. [R37] has been determined for the SL-2 seismic case. Interpolation in line with above factored FRS has been formulated for all seismic cases.

VV Seismic Response

The response of VV seismic and thermal displacement due to irregular ports has been considered in design of the VVPSS Box and corresponding expansion joints, see ref. [R38].

The VV seismic response will not affect the relief piping system and implicit the support structure.

Seismic Response Spectra

Seismic response spectra are specified based on [R7] and calculated by [R16] and [R6] shall be applied to the piping system.
The tabular form of this data is available and shall be used for analysis. An Envelop of seismic response spectra from [R7] shall be used for analyses.
The correct damping factors from the table below shall be used to determine which part of the provided floor response spectra shall be used.
The seismic floor response spectra (FRS) for the seismic analyses of the VVPSS system have been derived from reference [R7] by obtaining the envelope of all the locations where FRS are provided within the Drain Tank Room (DTR) at level B2 and L1 levels of the Tokamak Building, see Appendix1 of present specification.
Appendix 1 includes the seismic FRS monitoring point’s relative position and FRS envelope (figure and tables) for the horizontal and vertical directions applicable for relief lines VVPSS.

Table 3-3 Summary of Damping Value (for reference and guidance, see [R19])

System	Description	SL-1	SMHV and SL-2	SL-3
General	Welded steel or bolted steel with friction connection	3%	4%	5%
	Bolted steel with bearing connection	5%	7%	7%
Piping	Piping system	3%	4%	5%
Electrical distribution	Cable tray system – Maximum cable loading	7%	10%	15%
	Cable tray - Empty	5%	7%	
	Conduit system – Maximum fill	5%	7%	-
	Conduit system - Empty	3%	7%	
Mechanical and electrical components	Motors, Fans, protection housing, Pumps	2%	3%	3%
	Pressure vessels, Heat exchangers and Valve Bodies	2%	3%	5%
	Electrical cabinets, Panels, Motor Control Centres	2%	3%	5%
	Metal Atmospheric Storage Tanks – Impulsive mode (containment, protection)	2%	3%	3to5%
	Metal Atmospheric Storage Tanks – Convective mode (Sloshing) (containment, protection)	0.5%	0.5%	0.5%

3.4 Pressure Loads

The Accident Analysis Report, ref. [R5], [R54], [R55] and [R56] has postulated several levels of coolant leaks. The following are the estimated pressure loads of these postulated events.
The summarised pressure loads have been included in table 3.4. It should be noted that all design basis LOCA, LOVA and combined LOCA+LOVA events are considered as normal operation for the VVPSS.

3.4.1 Vacuum Vessel Ingress of Coolant Event Cat II (ICEII)

The ICE II event is initiated by a failure 1 or 10 first wall cooling pipes, resulting in water ingress into the vacuum vessel, which causes a plasma disruption. The small steam generation is managed by the operation of the Small LOCA Tank and the pressure in the VV and relief line remains below 1 bar(a). Conservatively an internal pressure of 1.5 bar(a) will be assumed to be experienced by the relief line.

3.4.2 Vacuum Vessel Ingress of Coolant Event Cat III (ICEIII)

The ICE III event is the worst conditions correspond to a discharge from multiple coolant channels affecting 1 PHTS loop of the First Wall cooling system (e.g. caused by runaway electron initiated damage) or 1-2 coolant channels of divertor and other in-vessel components.
This event is expected to occur no more than once in the machine life. An ICEIII will cause pressurisation of the VV leading to bursting of the Rupture Discs at 1.1 bar(a) followed by depressurisation as steam flows to the VVPSS. An internal pressure of 1.5 bar(a) will be assumed to be experienced by the relief line.

3.4.3 Vacuum Vessel Ingress of Coolant Event Cat IV (ICEIV)

The ICE IV event is considered the worst VV ICE event corresponds to a multiple (>100) break of FW cooling tubes with total break size of 0.02 m2, resulting in the three FW/BLK cooling loops spilling water inside the VV. An internal pressure of up to 2.0 bar(a) could be experienced by the relief line.

3.4.4 Vacuum Vessel Ingress of Coolant Event Cat V (ICE V)

The ICE V event corresponds to a total break size the same as ICE IV, but is coincident with failure of the VV PHTS isolation valves, which extends the duration of the event and the quantity of water drained into the VV.
The ICE V can lead to a saturation of the condensation capacity within the VSTs. In this event pressure would build until 1.8 bar(a), at which point emergency relief valves located on each VST open to release the pressure to the DTR. An internal pressure of 2 bar(a) within the relief line will be assumed to be created in ICE V.

3.4.5 Loss of Vacuum in the VV (LOVA)

This postulated event is a loss of vacuum through one Vacuum Vessel (VV) /cryostat penetration line.
Air ingress through one horizontal VV/cryostat penetration line causes pressurization in the VV. Fusion power will be terminated by the air ingress, triggering a disruption. The VV primary heat transport system (VV PHTS) maintains its decay heat removal function. In the first phase, air rapidly ingresses into the VV, until the pressure inside the VV and port cell is almost equal. After pressure equilibrium, the air inside the VV is heated by hot plasma-facing components, and flows by natural convection, stirring the air and the mobilized materials inside the VV. Once the air inside the VV is sufficiently heated up, an overpressure will be created.

3.4.6 Loss of Flow (LOFA) – Pump seizure in Divertor PHTS

The postulated event is a pump seizure in a cooling loop of the Divertor Primary Heat Transfer System during a plasma burn. This event leads to a quasi-instantaneous coolant flow reduction in the divertor primary cooling loop. When the coolant in the failed loop has drops to 80% of its nominal value, the Fusion Power Termination System (FPTS) will stop plasma burn in three seconds. At indicated time, the VV pressure reaches 50 kPa the VVPSS bleed line valves open.

3.4.7 LOCA in NB Cell

The postulated initiating event is here a double ended pipe rupture of the largest diameter (Ø66mm) cooling pipe of the PHTS inside of the port cell.
This event will discharge coolant from a pipe that has the highest coolant enthalpy during full power operation (500 MW of fusion power), directly into the Port Cell creating an overpressure condition.
The (external) pressure rises to 200kPa, the set point pressure of the relief panels in the cell.

3.4.8 VV Dust Explosion

The postulated event occurs due to a failure of the confinement barrier inside the penetration line between the VV and port cell, resulting in air ingress into the VV causing VV pressurisation and mobilisation of the dust and hydrogen isotopes with formation of the hydrogen / air explosive mixture.
The pressure load of 600 kPa is considered for the normal design condition of the relief lines components following VV dust explosion.
The design condition has been determined in order to protect the integrity of the building and the surrounding components in NB Cell.

3.4.9 VSTs Hydrogen Combustion & Explosion

The postulated events occur due to the operating or accidental mode of hydrogen combustion inside the VSTs.
Due to the high level of the water inside VSTs during explosion & combustion event, the gas flames will not propagate thru the piping system.
During combustion event the pressure wave generated inside VSTs will push the water from the VSTs between the water level and sparger holes (1000mm level = 30m^3) back to relief piping system.
Increased pressure due to internal combustion in VSTs has been evaluated in ref. [R62].
The conservatively estimative value of the pressure rise in VSTs due to internal combustion has been considered **458 kPa.**
The conservatively estimative value of the pressure rise in VSTs due to internal explosion has been considered **1172 kPa.**

Considering the rising pressure due to VSTs combustion a number of safety devices have been considered in order to limit the pressure load propagation into the complete relief piping system.
The optimal safety device for the current design has been determined to be a non-reverse flow valve (NRV) installed as close as possible to the VST sparger nozzle.

The piping sections between the VST nozzles up to and including the NRV have been classified as ESPN, with requirements replicating the VSTs, ref. [R63], [R64] and [R65].

The impulsive pressure loads generated by the reverse flow from VSTs to VV are subject to a separate detail investigation.

A summary of the combustion, respectively explosion water hammer condition that occur due to the VSTs internal detonation / combustion is described in chapter 3.9.

3.4.10 Relief Line Maximum Operating and Design Pressures

Table 3.4 Pressure loads

Item/Case	Max Operating Pressure		Design Pressure	
	Internal	External	Internal	External
	-kPa		-kPa	
ICE II	50	100	150	100
ICE III	110	100	150	100
ICE IV	145	100	150	100
ICE V	180	100	200	100
LOVA	100	100	150	100
LOFA	94	100	150	100
LOCA NB/DTR	0	200	100	200
VV Dust Explosion	565	100	600	100
VSTs Deflagration	458	100	500	100
VSTs Detonation	1172	100	1200	100

Table 3.5 Relief Line Designated Ps

Ps relates to the maximum operating pressure in Reasonably Foreseeable Events (up to Category III) as defined by the Pressure Equipment Directive.

Relief Line Section	Ps (Bar(g))
1. VVPSS Box to RD/BV	0.5
2. RD/BV to NRV	0.5
3. NRV to VST	15

In order to guaranty the VSTs structural integrity, the design pressure is specified as 15 bar, however, the tanks are qualified to 30 bar in service level D. In order to ensure a similarly robust design of the relief line, the same approach will be followed to **verify the relief line at 30 bar using Service Level D**. The goal of this verification is to ensure the robustness of the relief line to the effects of a dust explosion within the VV, therefore the assessment of the relief line will be undertaken using the maximum temperature experienced by the Relief Line following a VV dust explosion, namely 120°C.

3.5 Thermal Loads

3.5.1 Normal Operation: Plasma

During normal plasma operation and also during the stand by between pulse, the temperature of upstream section of the relief lines between RD/BV complete assemblies and VV (VVPSS Box) shall be controlled using electrical tracers, at 100 °C (variability ±10 °C with an accuracy of ±2 %). This has been conservatively assumed 115°C.
Following the increase from 20 to 100 (115) °C an estimated of 30000 thermal cycle will occur during ITER VV lifetime. From these only 300 thermal cycles has been considered relevant for VV thermal displacement on the upstream section of relief lines.

3.5.2 Normal Operation: Baking

The baking temperature of 200 °C shall be considered for the upstream section of the RD/BV complete assemblies.
During baking, the upstream section of relief line will be subject to around 500 thermal cycles.
The baking will apply to the section between VVPSS Box up to and including RD/BV.

3.5.3 Accidental cases

The accidental thermal loads defined for the relief piping system refer to the changes in the operation temperature during ICE events.

In the long term following ingress of coolant event, it is calculated in the Accident Analysis Report ref. [R5], that the maximum temperature from the plasma chamber could be as high as 245°C.

The design temperature for the plasma chamber section has been considered 250°C.

The design temperature for other section of relief piping has been considered 250°C.

These thermal loads acting on different parts of the relief lines will cause thermal expansion and thermal stress depending on the specifics of the support structure.
Sliding support elements and flexible sections, such as bellows has been used to accommodate the thermal expansion and lower the thermal stresses accordingly.
The following thermal loads shall be applied to the model and be used to verify the structural integrity of the design.
The ITER approved strength- temperature curve and property data has been used in the detailed analysis. Material property, strength and chemical composition has been summarised in the Memorandum Note ITER_D_ RBFN56, see reference [R26].

ICE II

During the ICE II incident, considered as maximum 10 tube failure, the below temperature load in relief lines has been defined.
For conservativism the 250°C has been used as reference design temperature loads for this case.

ICE III

The thermal profile of the temperature distribution can be considered conservative as uniform on complete relief line as temperature of the NB Cell connection box.
During AAR simulation, ref. [R54] & [R55], the temperature loads for ICE III has been indicated below 200 °C.
For conservativism 250°C has been used as reference design temperature loads for this case.

ICE IV

This accident describes the consequences of a multiple rupture of FW cooling tubes belonging to three FW/BLK cooling loops
During AAR simulation, ref. [R55], the temperature loads for ICE IV has been indicated below 200 °C.
For conservativism 250°C has been used as reference design temperature loads for this case.

LOVA

Due to postulated event of loss of vacuum through one VV line the temperature transient diagram has been indicated below.
The temperature loads for LOVA has been indicated below 200 °C.
For conservativism 250°C has been used as reference design temperature loads for this case.

Loss of Flow (LOFA) – Pump seizure in Divertor PHTS

The postulated event is a pump seizure in a cooling loop of the Divertor Primary Heat Transfer System during a plasma burn.
The temperature loads for LOFA has been indicated below 200 °C.
For conservativism 250°C has been used as reference design temperature loads for this case.

Large DV ex-vessel Coolant Pipe Break (LOCA)

The accident postulated is a double ended rupture of a large diameter cooling pipe, downstream of the pump of the PHTS primary coolant loop during normal operation.
The temperature loads for LOCA has been indicated below 200 °C.
For conservativism 250°C has been used as reference design temperature loads for this case.

LOCA in Port Cell/ NB Cell

Temperature rises only during a short period. The related thermal cycle loads do not need to be considered, see reference [R22].

VV Dust Explosion

The VV internal hydrogen detonation has been considered a BDBA event for VV and normal operating case for relief lines in line with the functionality of the piping components.

The conservativism in the VV dust explosion refers to the integrity of piping components to outstand limited plastic deformation and ensures the functionality of the system during and after detonation event.

The dust explosions occur at the end of a normal operating condition in VV due to a combined event.

Considering instantaneous impact to the relief piping, the temperature load for the VV dust explosion case is considered the normal operating temperature as indicated in para.3.5.1.

Fire curve

Assuming the current development stage of the equipment inside DTR/NB cell the fire load defined for analysis has been considered as indicated in section 3.8.

VSTs Hydrogen Combustion & Explosion

The temperature loads considered for the VSTs hydrogen combustion and explosion has been considered for conservativism as similar with the accidental case, the 300°C for upstream section and respectively 250°C for downstream section of relief pipes.

Table 3.6 Temperature loads

Item/Case	Operating Temperature		Design Temperature	
	Upstream of RD/BV	Downstream of RD/BV	Upstream of RD/BV	Downstream of RD/BV
	-°C		-°C	
Ambient	12-35	12-35	35	35
NO	90-110	12-35	115	35
Lifting/ maintenance	12-35	12-35	35	35
Baking	200	12-35	200	35
ICE II	215	215	250	250
ICE III	245	245	250	250
ICE IV	245	245	250	250
ICE V	245	245	250	250
LOVA	200	200	250	250
LOFA	200	200	250	250
LOCA NB/DTR	145	145	145	145
DUST Expl	20-110	12-35	115	35
VSTs Comb	200	200	250	250
VSTs Expl	200	200	250	250

Table 3.7 Maximum Temperature Conditions

Item Section	Max Design Temperature
	°C
Upstream pipe of RD/BV	250
RD/BV Internal/ External Bellows	250
Pipe components part of RD/BV	250
Downstream pipe of RD/BV	250

3.6 External Pressure Loads

The pressure loads can be summarised in three main group of analysis.

3.6.1 Differential pressure

The piping will be designed to avoid collapse due to vacuum conditions.

3.6.2 Overpressure in DTR

The pressure may rise in NB/DTR up to 200kPa due to the VV-PHTS LOCA incident.

The temperature may also rise for a short period of time during PHTS LOCA incident according safety simulation; see ref. [R21], [R27] and [R29].

Table 3-8 Overpressures during LOCA in DTR

DTR Pressure Loads	Load Name	Cat.	Value [kPa]	Application
External pressure	Leak in DTR	III	200	Outer shell

3.6.3 Overpressure due to fire

According the Safety Requirements Roombook, document ref. [R22] the differential pressure in NB cell due to internal fire event has been considered: ΔP=+/- 5kPa.

3.7 Fatigue Analysis

During lifetime the relief piping system will undergo a number of the load cycle caused by different functional condition (operational, transient, seismic, accidental...).

For each functional condition described an associated load cycle has been defined in order to perform a structural integrity calculation. The loads cycle considered has been included in the loads case combination table 2-1.

According to designed code for structural integrity analysis of relief line, the ASME B31.3, ref. [A1] the fatigue strength shall be performed according to methodology stipulated in ASME VIII Div. 2 Annex 3.F table 3.F.3 and shall been used in for simplified analysis, see for ref. [A4].

Considering the simplicity of the fatigue analysis indicated in the ASME B31.3 Ed. 2016 ref. [A1] the methodology for fatigue analysis indicated in EN13480-3. [A7] shall be used to determine the acceptable changes in pressure, temperature and external loading that can cause the damage by fatigue cracking in components.

<u>Detail fatigue analysis</u>

In condition of impossibility to demonstrate the integrity of piping system using the preliminary methodology described in EN13480-3 Ed. 2012, ref. [A7] the detail assessment of the fatigue life shall be performed in line with EN13445-3 Ed. 2014 ref. [A8] requirements.

3.8 Fire Inside Tokamak Building

The severity of the event of an internal fire has been specified individually for each room following an adequate assessment of the materials present in each room. The severity of a fire event is defined by the expected maximum temperature and the duration of the event.

Simultaneous fire in more than one room does not need to be considered.

A special attention has been allocated to all SIC components, as relief lines, because of their important safety functions.

In fact a strategy aiming at protecting SIC components might not directly reduce the fire risk but would improve their resistance to fire events and in conclusion improve the safe functioning of the IO machine.

Considering this is therefore necessary to analyse all occurrences of potential fire aggression to SIC components and segregate them, whenever possible, from fire sources and loads.

For conservativism in evaluation of fire aggression, sources and loads the ISO standard curve indicated below has been considered in analysis of the piping system.

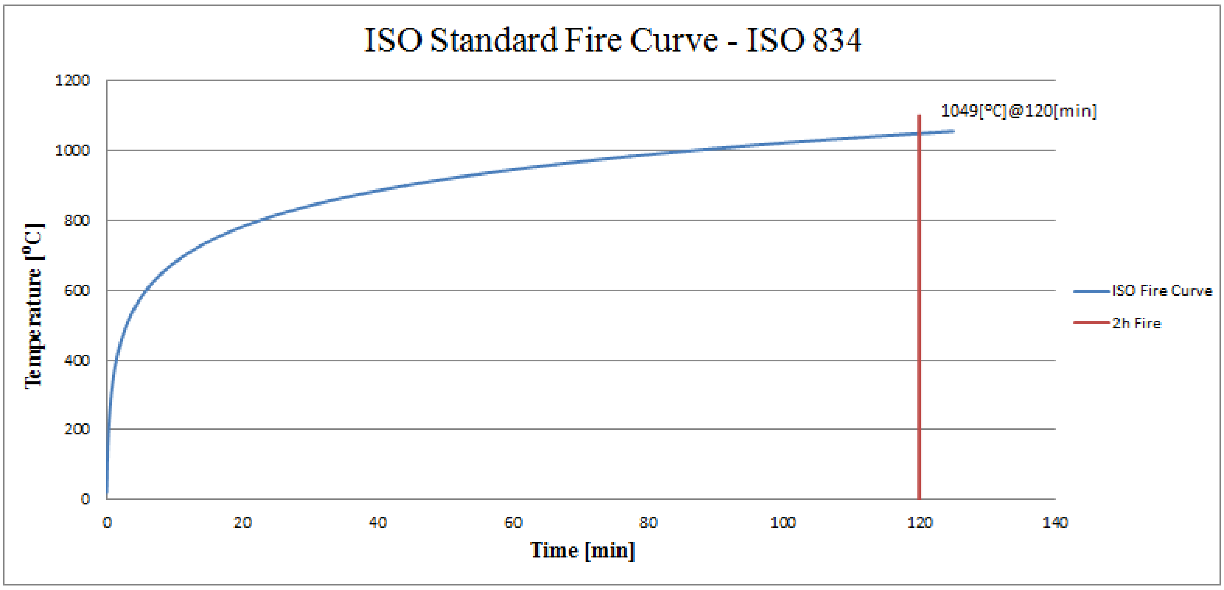


Figure 3-2 ISO Standard Fire Curve

Note:

The temperature development of the Hydrocarbon fire curve is described by the following equation:

$$T = 20 + 345 \log_{10} (8\,t + 1)\ [°C]$$

Note: Considering the above formula defined by ISO 834 [A13] the maximum temperature load develop during 120 minutes of fire is approximate 1050°C.

Applicable Fire loads for RL

In order to evaluate the impact of the fire to the piping system has been assumed below methodology.

Fire load can be a consequence of a seismic failure of components inside DTR or NB Cell and shall not be considered concomitant, but shall be investigated adequately.

The aftershock evaluation of relief piping integrity consider that the temperature of pipe steel external surface will reach a temperature as indicated in table 3.9 considering the ISO fire simulation for the corresponding pipe section and shall be compared with the allowable stress given by the code for service level C.

The detail calculation of the fire load temperature of the piping system has been summarised in Appendix 2.

The pipe wall temperature after 2 hours exposure to the fire induced temperatures described in table 3-9 and Appendix 2 has been calculated by carrying out a transient heat transfer analysis.

The calculation has been performed with Quickfield, finite element analysis software used for transient heat transfer analysis.

The input data consider two process scenarios in piping system during fire, steam or empty inside of pipe.

A steady state calculation was used as input point to start the transient analysis, for the convection coefficient assuming steam inside the pipe has been use the Dittus Boelter correlation and for empty pipe inside the natural convection outside pipe I used to calculate Nu for air flow on cylinders.

The analysis has been carried out considering an emissivity factor e=0.8, value suggested by Eurocode 1 [A12] which can be representative of the external surface of the pipe cladding.

The external temperature is calculated for the worst case, according to ISO-834 ref. [A13] nominal time-temperature curve.

Table 3-9 Fire Loads on Relief Lines

PBS24 – ISO Curve Fire Simulation Results			
DN	**Final temperature after 2hrs ISO-834 (steam inside)**	**Final temperature after 2hrs ISO-834 (empty inside)**	**Note**
	[C]	[C]	Area
DN200	252	73	NB Cell
DN300	251	67	Down RD/BV
DN350	252	61	Down RD/BV
DN500	252	60	Down RD/BV
DN300	302	67	Up RD/BV
DN500	301	60	Up RD/BV

Justification Note for Fire Loads

The temperature specify in table 3-9 for relief lines piping external steel layer has been considered appropriate for the current analysis of piping system fire protected with 50 mm (MICROTHERM® MPS) as indicated in section 4.2., see ref. [R59].

The thermal fire insulation has been considered SIC1 component and shall not fail as consequence of seismic loads.

3.9 VSTs Reverse Flow – Surge Analysis

The consequence of controlled hydrogen combustion inside VSTs is the production of high pressure that creates a reverse flow of water from the tanks.

In order to prevent the reverse flow, which could send water back to the VV and will deplete the condensation capacity of the affected VST, a non-reverse flow valve has been specified for each relief line as close as possible to VSTs. The selected non-reverse flow valves allows isolation of the VSTs from the relief line preventing contaminated water and dust to return to the VV.

Due to the speed of pressure rise inside the VSTs, the reverse flow will act as a slug of water, creating a hammer effect onto the piping components. The NRV will limit this hammer effect to only those components between the VST and the NRV (Load Cases 17 and 18), however, in the event that the NRV fails to close (Beyond design basis events – Load Cases 21 and 22), the slug of water will impact all the relief line piping components. An assessment of the propagation of the water slug has been made assuming failure of the NRV to operate [R69]. The velocity of the water slug and the timing of its arrival has been determined at each node in the system. These calculated velocities and timing at each bend in the system shall be used in the determination of the reaction loads and hence the stresses associated with Load Cases 17, 18, 21 & 22.

3.10 Interface Loads

3.10.1 Interface Loads VVPSS Box

At the interface between the VV and the VVPSS system each relief line will be connected to a separate interface box as indicated in figure 3-4.

The interface box, named VVPSS Box, will be subject to additional displacement caused by thermal loads during operation, baking and accidental scenario.
Current configuration used in analysis has been simplified in the below figures to serve as base of the analysis and shall be reviewed after the interface connection box has been analysed.

The current design of the VVPSS Box interface with VV as indicated in the ref. [R66] will not provide any impact from VV ports to VVPSS relief piping system.

The thermal displacement and movement of VV will be compensated by the Drift Ducts bellows located upstream of VVPSS box.

Any normal operating case, incident / accidents or baking of the VVPSS Box shall be considered as input load to the relief lines system.

As required condition, the VVPSS Box shall be considered in to the VVPSS - RL stress calculation.

The fixation frame of the VVPSS Box trolley shall be considered as anchoring point in the stress evaluation, see for ref. figure 3-5.

The VVPSS Box trolley is a fixing point during operation and is used only for maintenance operations to allow the replacement and accessibility of the components.

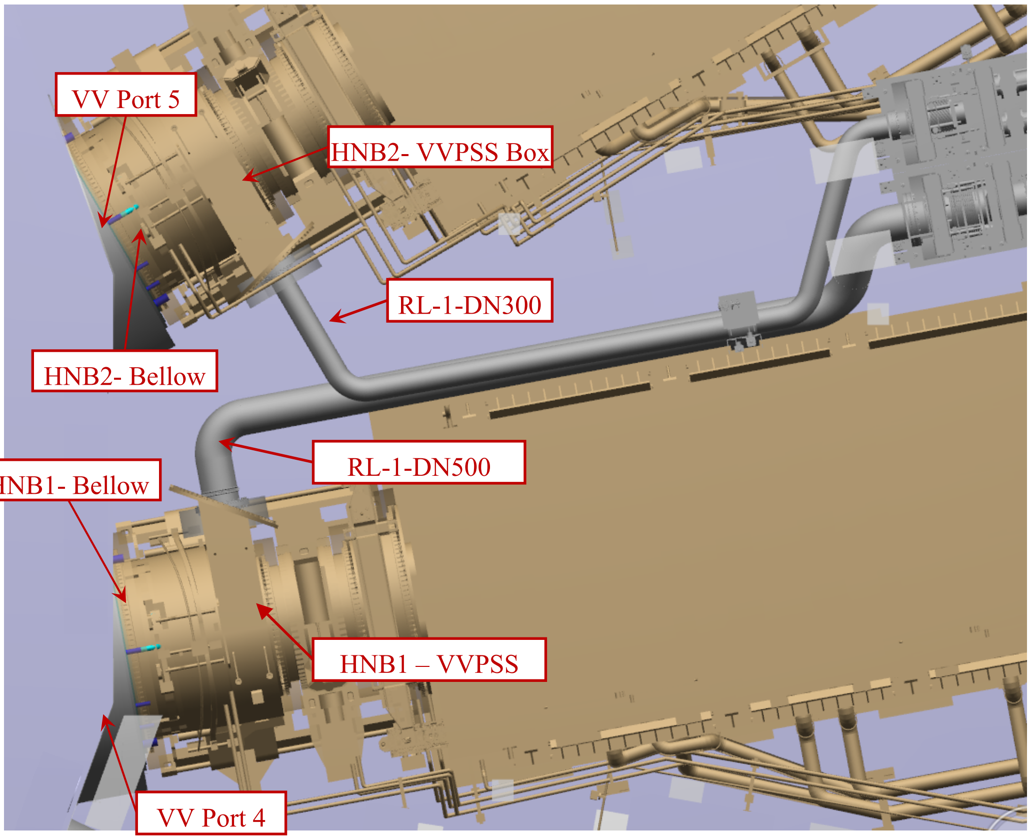


Figure 3-4 Layouts VV Ports - VVPSS Box – VVPSS RL

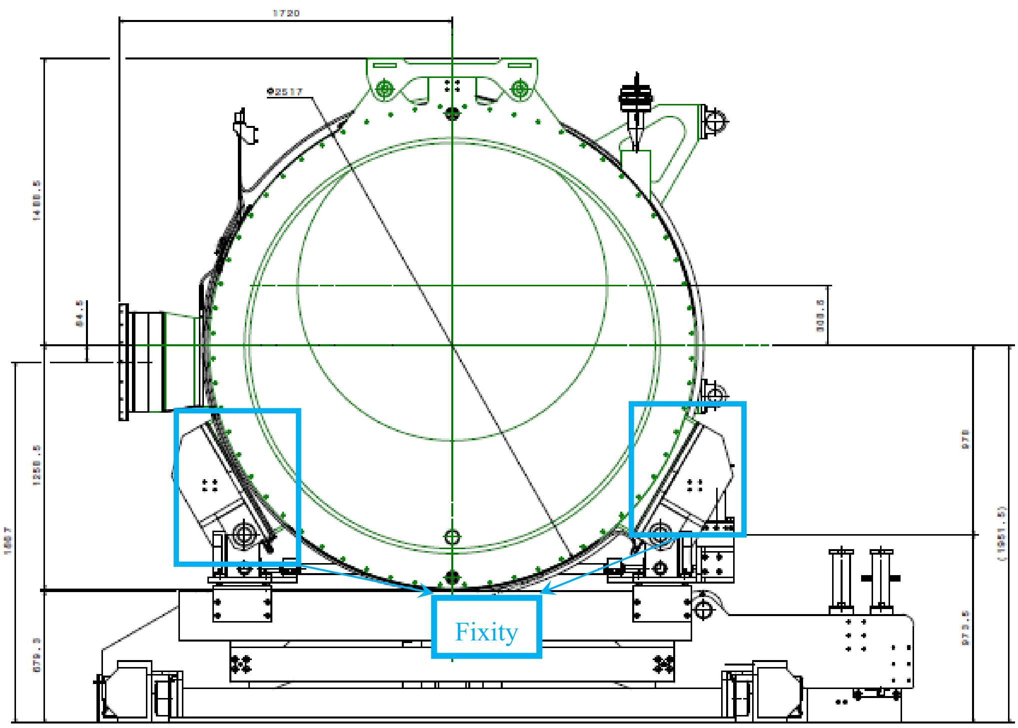


Figure 3-5 Boundary condition of VVPSS Box

3.10.2 Interface with Rupture Discs and Bleed Valve Assemblies Structure

The relief lines piping systems between VV and VSTs include the rupture discs and bleed valve (RD/BV) assemblies as intermediary components.

Considering the complexity of the RD/BV assemblies, remote handling components and support frame, the decision has been take to analyse these in a separate dedicated model.

Due to interface condition of the components, the assemblies have been summary modelled, design and analyse in relief lines analysis model as indicated in figure 3-6.

This analysis will be strict refer to the thermal and pressure effect of the relief lines to the assemblies components, in particular to the expansion bellow used in the design.

The expansion joint configuration shall be design and analysed based on the displacement generate by the loads cases considered in this specification and summarised below for this application.

Due to the current design condition, the below configuration has been considered in the piping stress analysis with the indicated constrain and limitations.

Boundary conditions of RD/BV structure:

- For conservativism the support frame of the RD/BV assembly has been considered sufficient rigid and no deflection shall be transferred to the piping system or subcomponents of the assembly RD or BLV.
- The fixity support (anchor) of the RD/BV at the indicated position as indicated in figure 3-6 and 3-7 has been considered with infinite stiffness.
- The guided support of the RD/BV assembly has been considered having the below permissible displacement by using a bolted slotted assembly support configuration, see table 3-11 for detail.

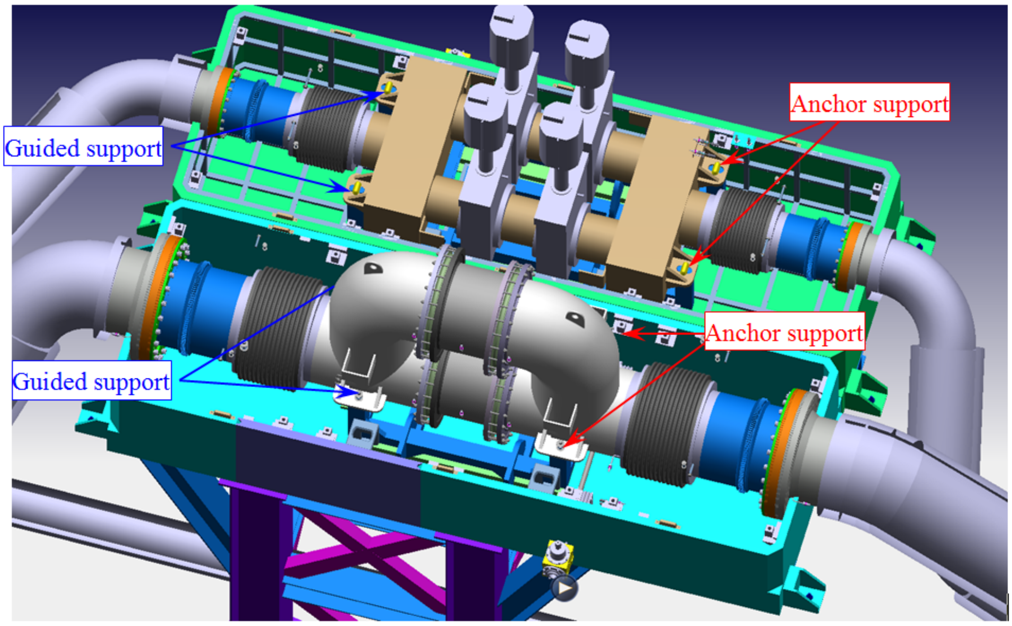


Figure 3-6 RD/BV Assemblies - Design boundary conditions

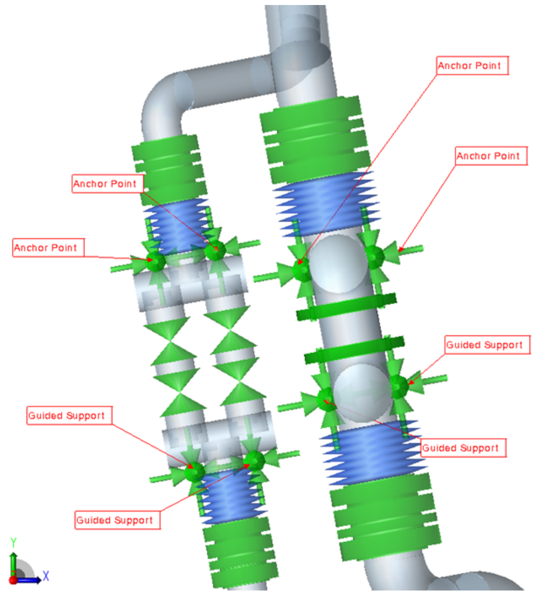


Figure 3-7 RD/BV – Analysis model boundary conditions

In later design phase the deflection resulted from structural analysis of the RD/BV frame shall be included in the final assessment of the relief line assembly if this is relevant for analysis.

Table 3-11 Permissible displacement in RD/BV support frame

Relief line	Permissible displacement at RD/BV guided support		
	Axial	Lateral	Vertical
	[mm]	[mm]	[mm]
DN500	±10	±1.0	±0
DN300	±10	±1.0	±0

Standard manufacturing tolerances are acceptable at the anchor support boundary.

Note: Maximum permissible displacement at anchor support ±1.0 mm in lateral directions, to allow thermal movement of the assembly.

3.10.3 Interface with RD/BV Assemblies Double Bellows

The loads case specification and requirements for RD/BV Double Bellows have been indicated in ref. [R52].

The technical information, type dimensional data and mechanical property, has been based on the standard components information included in potential manufacturer manual for expansion joints, ref. [R57].

Conceptual design of the bellows assemblies has been indicated in the figure 3-8 below:

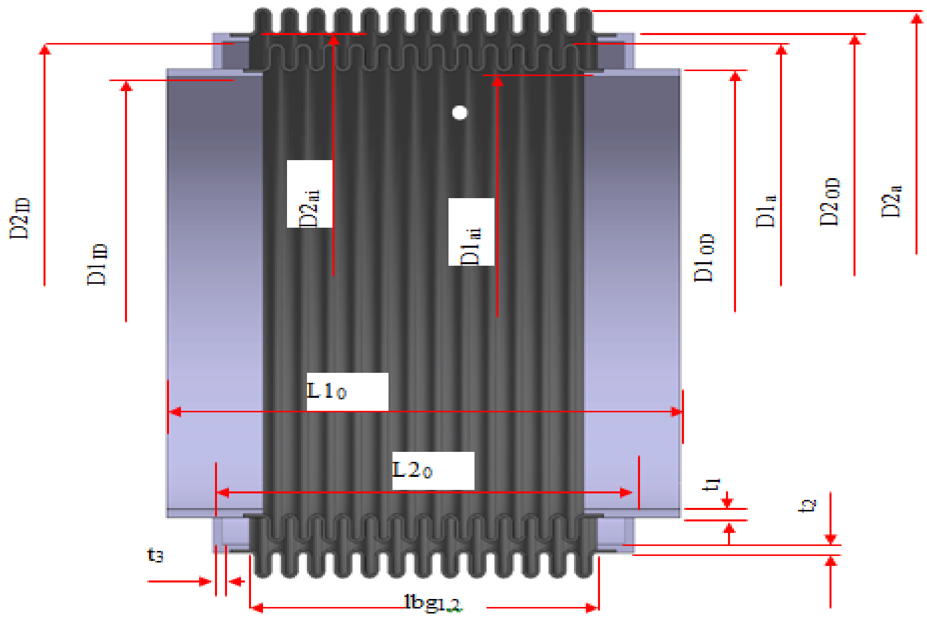


Figure 3-8 Double bellow assembly for RD/BV Assemblies

Preliminary design input

The configuration of two type assembly bellows indicated in figure 3-8 above shall be used as preliminary input for the stress analysis.

The preliminary manufacturer selection data has been taken from [R57]

- Bellows double assembly DN500/DN600 for the relief line DN500 with two pressure boundary conditions:
  - Design pressure inner bellow 600 kPa (Service Level A);
  - Design pressure outer bellow 250 kPa (Service Level A);

- Bellows double assembly DN300/DN400 for the relief line DN300 with two pressure boundary conditions:
  - Design pressure inner bellow 600 kPa (Service Level A);
  - Design pressure outer bellow 250 kPa (Service Level A);

The maximum allowable compression load of the RH tool is assumed as 30kN, considering 3 compressions tools positioned at 120 deg with a capacity of 10 kN as defined in table 2-6 , ICD Interface with RH.

3.10.4 Interface with Structural Frame Support

The piping stress analysis of the relief lines considers in the pre-analysis phase that the structural support frame as well as individual support and other structure support has infinite stiffness to support the piping system. This approach shall be verified after the structural analysis of the support frame has been design.

If the stiffness of the structure due to relief piping loads is considered relevant for analysis, this shall be included in re-evaluation of the piping system.

The specification for analysis of the piping supports and frame structure has been detailed in ref. [R60].

The mentioned specification includes the relevant design information, support assessment and load combination that shall be considered in evaluation of piping support for the VVPSS.

4 Material Property

4.1 Piping Materials

The detail specification of the piping material used in structural analysis and also the chemical composition has been detailed in the ref. [R26].

Summary material properties of the piping and mechanical structure are given in Table 4-1.

Table 4-1 Material Property at Elevated Temperature

Steel Number	WT	Tensile strength		Allowable stress Sm [MPa]						
		Yield Strength		at derating temperature						
-	[mm]	Rm [MPa]	Sy [MPa]	<40 °C	100°C	125°C	150°C	200°C	250°C	300°C
SA-240 (plate) 304/304L	≤100	515	205	138	113	108	103	96	90	86
SA-312 304/304L (seamless)	≤125	515	205	138	138	138	138	129	122	116
SA-182 304/304L (forging)	≤100	515	205	138	113	108	103	96	90	86

Note: Allowable stresses indicated in table 4-1 have been derivate from the below mentioned standards:

- For ASME type materials see ref. [A2];
- For EN type materials see ref. [A9].

The technical piping specification for the relief lines system ref. [R30], include detailed material guideline and applicable standards for all piping components as well as requirements for the recommended thickness based on the analytical evaluation according ASME B31.3, ref. [A1].

4.2 Thermal Fire Insulation

Boundary condition

Insulation shall be provided for all piping components unless is explicit mentioned.

As preliminary design consideration the insulation shall cover the whole external surface of the components exposed to the environment of DTR or NB Cell.

The specific area of RD/BV assemblies will be subject to a specific thermal insulation configuration due to the requirements for remote handling operation.

The loads case specification for RD and respectively BV will include detailed configuration of the thermal insulation applicable for these components.

Design condition

The design temperature of the piping components considered for the selection of insulation has been indicated in table 3-6, 3-7 and 3-9 with thermal cycles between 10°C and 250°C, respectively 300°C as indicated in table 2.3.

In case of fire in DTR or NB Cell level, the thermal insulation will be exposed to a maximum temperature of 1050°C as defined in section3.8 of the present specification.

Mechanical design condition

Insulation shall meet the below requirements:

- Thickness of 50mm (considered as base data in the current design).
- Insulation and support element shall perform function in case of normal and accidental condition (earthquakes), calculation shall be provided by supplier;
- Removable components to permit accessibility for inspection and maintenance;
- Lightweight capability due to strict requirements for the embedded capacity loads;
- Support shall be design to outstand capacity 125% of the insulation load.

Material condition

Material used for insulation shall not be harmful with the equipment and with auxiliary components in contact. All metallic material used for supporting or fixation of insulation shall be 304 type stainless steel or equivalent.

Preliminary compatible material

The below insulation material, ref. [R59] has been indicated in current design phase as suitable for VVPSS system application.

Standard piping shapes

Type - MICROTHERM® MPS (Moulded Pipe Section)

- Class temperature 1000°C
- Density **320** kg/m^3
- Thermal conductivity 0.034 W/mK at 800°C, according ASTM C-177 / ISO8302, ref. [A10] and [A11].

Non-standard piping shape

Type - MICROTHERM® OVERSTITCHED 1000R HY - High temperature flexible microporous insulation panel – hydrophobic type

- Class temperature 1000°C
- Density 260 kg/m3
- Thermal conductivity 0.049 W/mK at 800°C, according ASTM C-177 / ISO8302, ref. [A10] and [A11].

5 Future evaluation

5.1 HELB Evaluation

The definition of the HELB (High Energy Line Break) lines in ITER safety reports refer to lines carrying fluid under operating pressure above 20 bar_g or operating temperature above 100 deg C, see for ref. [R61].
Considering the second aspect, operating temperature, the relief lines shall be considered and evaluated as High Energy Line based on the single load definition mentioned in chapter 3.

Considering the current maturity of the system, the HELB evaluation methodology shall be provided in a separated strategy guideline.

6 References & Applicable Documents

6.1 List of Applicable Codes and Standards

[A1] ASME B31.3 – 2016 ASME Process Piping

[A2] ASME BPVC II A Ed.2017 BPVC Section II-Materials-Part A-Ferrous Materials Specifications

[A3] ASME BPVC Sect V Ed.2017BPVC Section V-Non-destructive Examination

[A4] ASME BPVC Sect.VIII Div.2 – Ed.2017 Rules for the Construction of Pressure Vessels, Alternative Rules

[A5] EN 1998-1Ed.2006 Eurocode 8 Part 1 - Design of structures for earthquake resistance. General rules, seismic actions and rules for buildings.

[A6] EN 1998-4 Ed.2006 Eurocode 8 Part 4 - Design of Structure for Earthquake Resistance. Silos, tanks and pipelines.

[A7] EN 13480-3 Ed. 2012 Metallic Industrial Piping

[A8] EN 13445-3 Ed. 2014 Unfired pressure vessels

[A9] EN10088-3 Ed. 2014 Technical delivery conditions for semi-finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purposes

[A10] ASTM C177 - 13Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus

[A11] ISO 8302:1991 Thermal insulation -- Determination of steady-state thermal resistance and related properties -- Guarded hot plate apparatus

[A12] Eurocode 1: Actions on structures – Part 1-2: General actions – Actions on structures exposed to fire

[A13] ISO 834-1:1999 - Fire-resistance tests. Elements of building construction – Part 1: General requirements

6.2 ITER Reference Documents

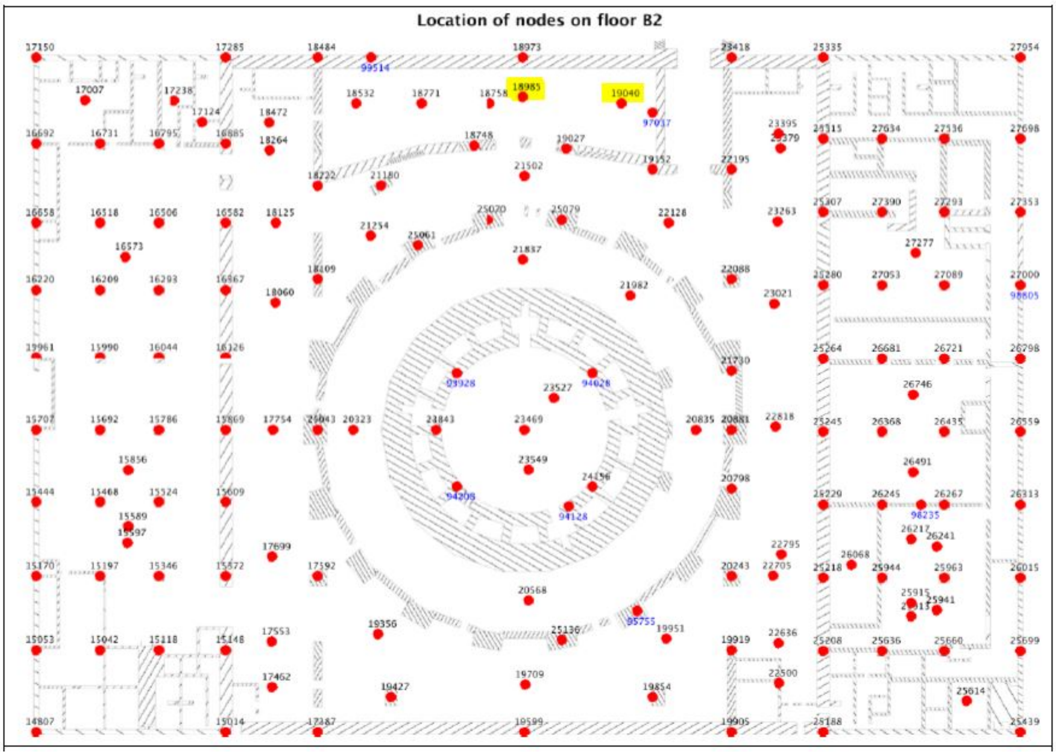
[R1] ITER_D_27ZRW8 v5.3 Project Requirements (PR)
[R2] ITER_D_2MU6W5 v1.16 ITER Abbreviations
[R3] ITER _D_222QGL v6.2 Loads Specifications (LS)
[R4] ITER _D_34Q3WT v1.6 Loads Specification for the VVPSS
[R5] ITER_D_2ZTMLF Accident Analysis Report (AAR)
[R6] ITER_D_2DRVPE v1.6 ITER Seismic Nuclear Safety Approach
[R7] ITER_D_SVBRJZ v1.1 Design Seismic Floor Response Spectra in the Tokamak Complex
[R8] ITER_D_25EW4K v4.0 Codes and Standards for ITER Mechanical Components
[R9] ITER_D_2EZ9UM v2.3 ITER Vacuum Handbook
[R10] ITER_D_3G3SYJ v3.1 Allowable Value and Limits in Service Level C and D for ITER Mechanical Components
[R11] ITER_D_35QTKD v1.2 Guidelines for Structural Integrity Report
[R12] ITER_D_7J4HVC v2.0 VVPSS selection of C&S and compliance with requirements
[R13] ITER_D_6U532P v1.1 ASME Code Justification for VVPSS
[R14] ITER_D_T2Y36A v3.6 Technical Specification for Vapour Suppression Tanks Manufacturing Design and Procurement
[R15] ITER_D_PQK3RF v1.3 CDI evaluation for PIC component
[R16] ITER_D_SFSN7Q v2.0 SL-3 Floor Response Spectra for Tokamak Complex
[R17] ITER_D_2LAJTW v1.4 Tritium Handbook
[R18] ITER_D_QV4FYF v7.0 Construction design – Tokamak complex – PBS 62.11, 62.14 and 62.74 - Internal flooding – ENG_50_CR_110004_CW
[R19] ITER_D_33TTPJ v2.5 Guideline for ITER Load Specifications
[R20] ITER_D_R5389R v2.1 Stress Test Detailed Methodology for Hard Core Components on ITER Plant
[R21] ITER_D_PJK22L v1.1 Hard Core Components for PBS-24 VVPSS
[R22] ITER_D_KF63PB v2.11 Safety requirements Roombook
[R23] ITER_D_3E4KSJ v4.4 Safety requirements for ITER Facility Building
[R24] ITER_D_UC3Z56 v1.0 Fire Loads associated within Tokamak Complex Building
[R25] ITER_D_RTHD44 v2.0 Relief Line Stress Analysis
[R26] ITER_D_RBFN56 v1.1 VVPSS Material Data Summary for Structural Analysis
[R27] ITER_D_E9FQ24 v1.1 TKM B1: Safety requirements study for TB03/TB04 Integration
[R28] ITER_D_TU72QM v2.1 System Load Specification for the Vapour Suppression Tanks
[R29] ITER_D_PX64Q7 v2.3 New VVPSS Design Proposal – Description
[R30] ITER_D_URET8B v3.2 Piping Specification VVPSS –RL
[R31] ITER_D_RT9U7W v1.3 Fire loads methodology
[R32] ITER_D_U2BR7J v1.1 Fire load assessment for PBS-24VP
[R33] ITER_D_PQR228 v1.1 ITER Hard Core Components - Summary Report
[R34] ITER_D_UC6CRR v1.1 Modification des Systemes VVPSS et TCWS
[R35] ITER_D_X27HTG v1.0 VST Process Instrumentation Diagrams

[R36] ITER_D_UBFQ6C v2.1 Fire risk assessment for NB cell cryostat circular and rectangular bellows
[R37] ITER_D_KWXL6B v1.0 Seismic Relative Displacements between the Building Floors
[R38] ITER_D_TP9QBH v2.1 Impact on VV Seismic response due to Irregular Ports
[R39] ITER_D_L9VRZK v2.2 Thermal relative displacements of the ITER Vacuum Vessel Port Flanges & Connecting Ducts (VV PHTS temperature effect)
[R40] ITER_D_2F52JY v.3.4 ITER Vacuum Vessel Load Specification
[R41] ITER_D_2FMAJY v1.6 ITER Remote Maintenance Management System
[R42] ITER_D_UX5JAF v1.0 Final report of the most unfavourable fire event with FDS
[R43] ITER_D_SQPZM7 v2.7 Design and qualification of the rupture disc complete assembly for the ITER Vacuum Vessel Pressure Suppression System
[R44] ITER_D_QRVGWD v1.0 Evaluation Complementaire De La Surete ITER English
[R45] ITER_D_22MAL7 v5.1 Procedure for Analyses and Calculations
[R46] ITER_D_35BVV3 v2.0 Instructions for Structural Analyses
[R47] ITER_D_U34WF3 v1.2 Instructions for the Storage of Analysis Models
[R48] ITER_D_SKH4UV v1.0 F4E_D_26R65J_Guidelines for seismic design, analysis and qualification of complex industrial and nuclear facilities against seismic hazard
[R49] ITER_D_VT29D6 v1.1 Instructions for Seismic Analyses
[R50] ITER_D_TXRGCC v1.2 Fire Loads Commitment #18.3 for bldg. 11 & 14 - Data collection
[R51] ITER_D_TMQNZY v3.0 Fire load assessment for PBS-26
[R52] ITER_D_V3J32M v2.0 Loads Specification for Bellows for the VVPSS Relief Lines
[R53] ITER_D_SECRZD v2.2 VVPSS Building Interface Drawing
[R54] ITER_D_2DPVGT v1.4 Accident Analysis Report (AAR) Volume I - Event Identification and Selection
[R55] ITER_D_2DJFX3 v4.10 Accident Analysis Report (AAR) Volume II - Reference Event Analysis
[R56] ITER_D_2E2XAM v4.9 Accident Analysis Report (AAR) Volume III - Hypothetical Event Analysis
[R57] Witzenmann HYDRA Expansion Joint Manual
[R58] ITER_D_28B2U6 v4.2 - SRD-24-VP (VVPSS)
[R59] MICROTHERM® MPS (Moulded Pipe Section) / OVERSTITCHED - High temperature microporous insulation;
[R60] ITER_D_V3P8R7 v2.0 Specification for VVPSS Support Design and Analysis
[R61] ITER_D_3ZR2NC v3.0 Preliminary Safety Report (RPrS)
[R62] ITER_D_UMW9TD v1.0 CFD Analyses and thermal mechanical simulations of the nozzle tank –sparger-venting joint loaded by hydrogen explosion and repeated scenarios of hydrogen combustions
[R63] December 30th 2015 ESPN French Ministry Order
[R64] December 12th 2005 ESPN French Ministry Order
[R65] Order of 7th February 2012 establishing the general rules for basic nuclear installations
[R66] ITER_D_434QCS v10.1 - Loads specification for VVPSS box
[R67] Pressure Equipment Directive 2014/68/EU

[R68] ITER_D_YMVZN5 - Qualification Roombook
[R69] ITER_D_YK6RCP - Small LOCA Tank Reverse Flow Modelling

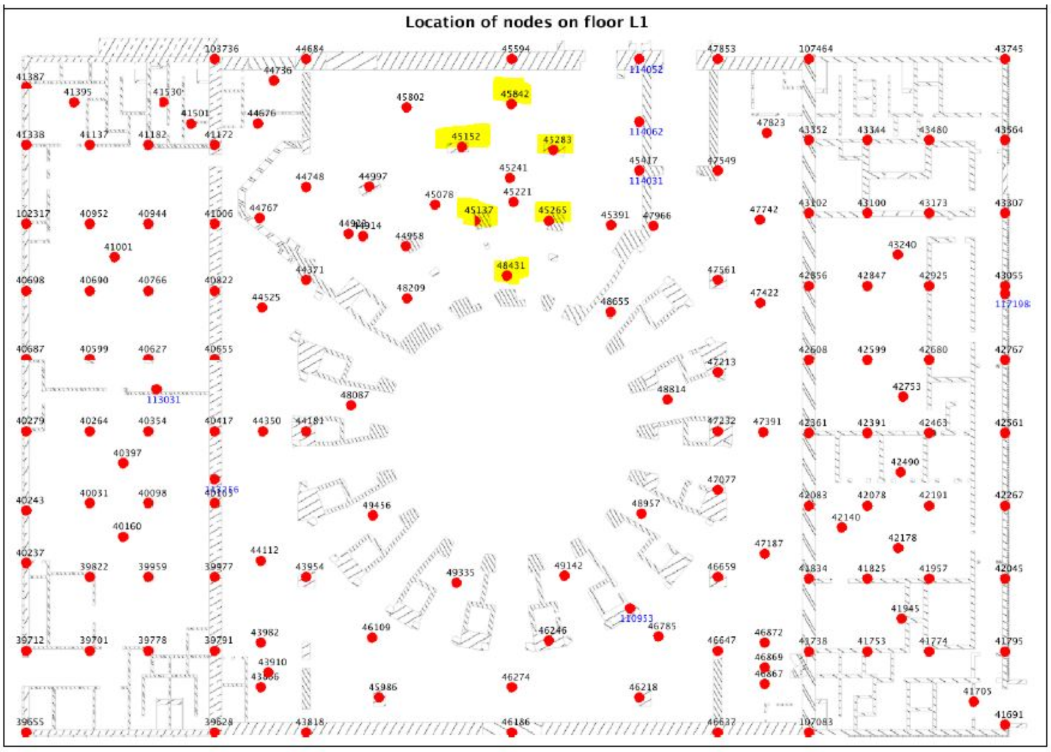
Appendix 1 – FRS for VVPSS Relief Lines

Seismic Response Spectra for VVPSS Relief Lines (DTR and NB Cell)



a)

Note: Nodes monitoring FRS: 18985 and 19040.



b)

Note: Nodes monitoring FRS: 45283, 45265, 48431,45152, 45842 and 45137.

Figure I-1(a, b)– Location of monitoring seismic nodes for VVPSS RL

- Level B2 – For interconnected pipe around VSTs
- Level L1 – For upward piping on structural frame and connection to NB Cell

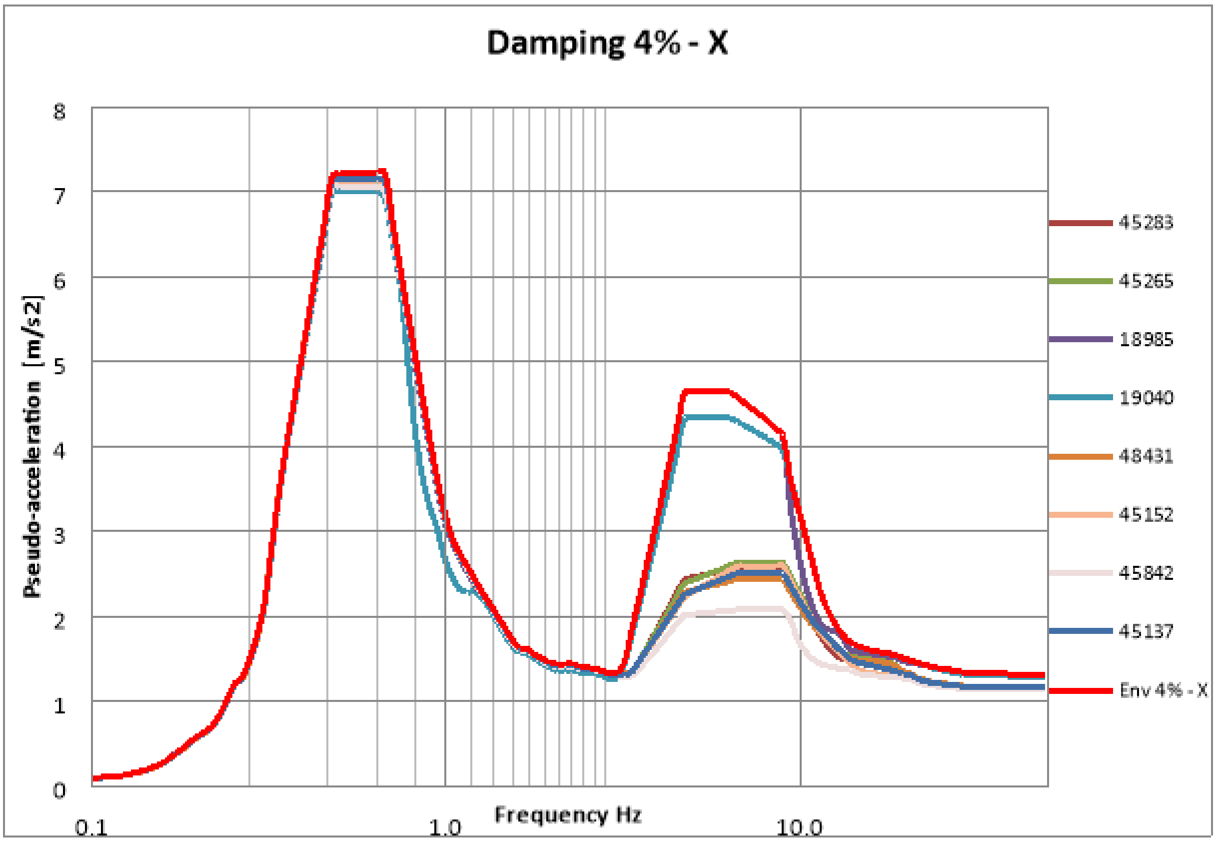


Figure I-2 Horizontal (X direction) seismic FRS 4% RL

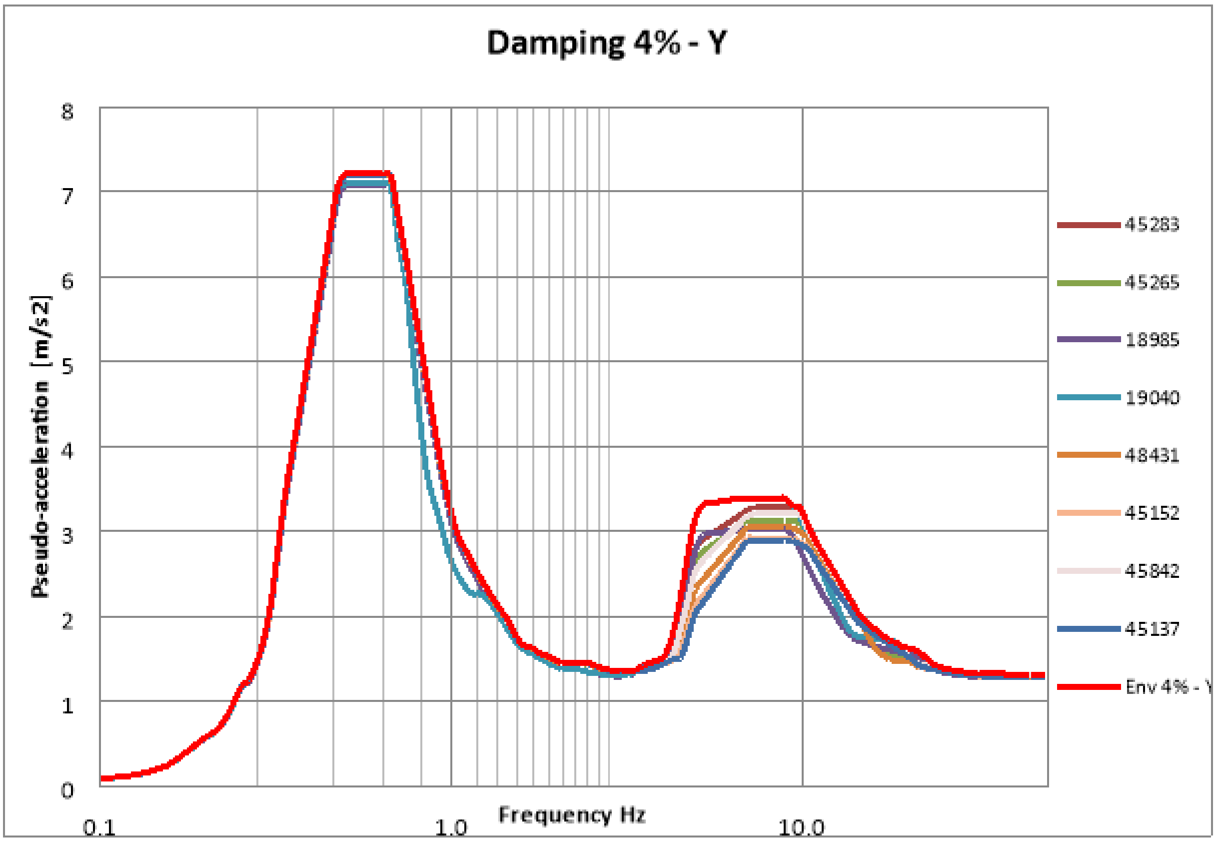


Figure I-3 Horizontal (Y direction) seismic FRS 4% RL

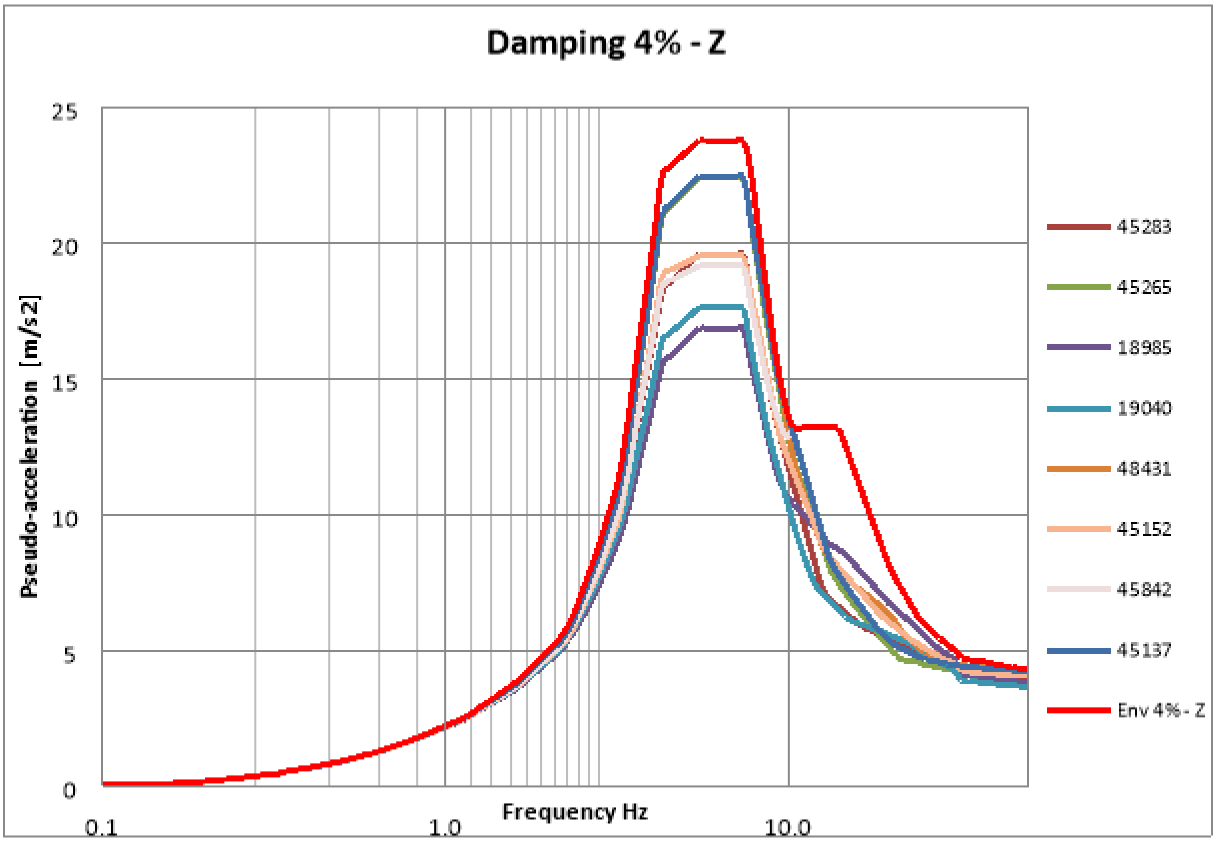


Figure I-4 Vertical (Z direction) seismic FRS 4% RL

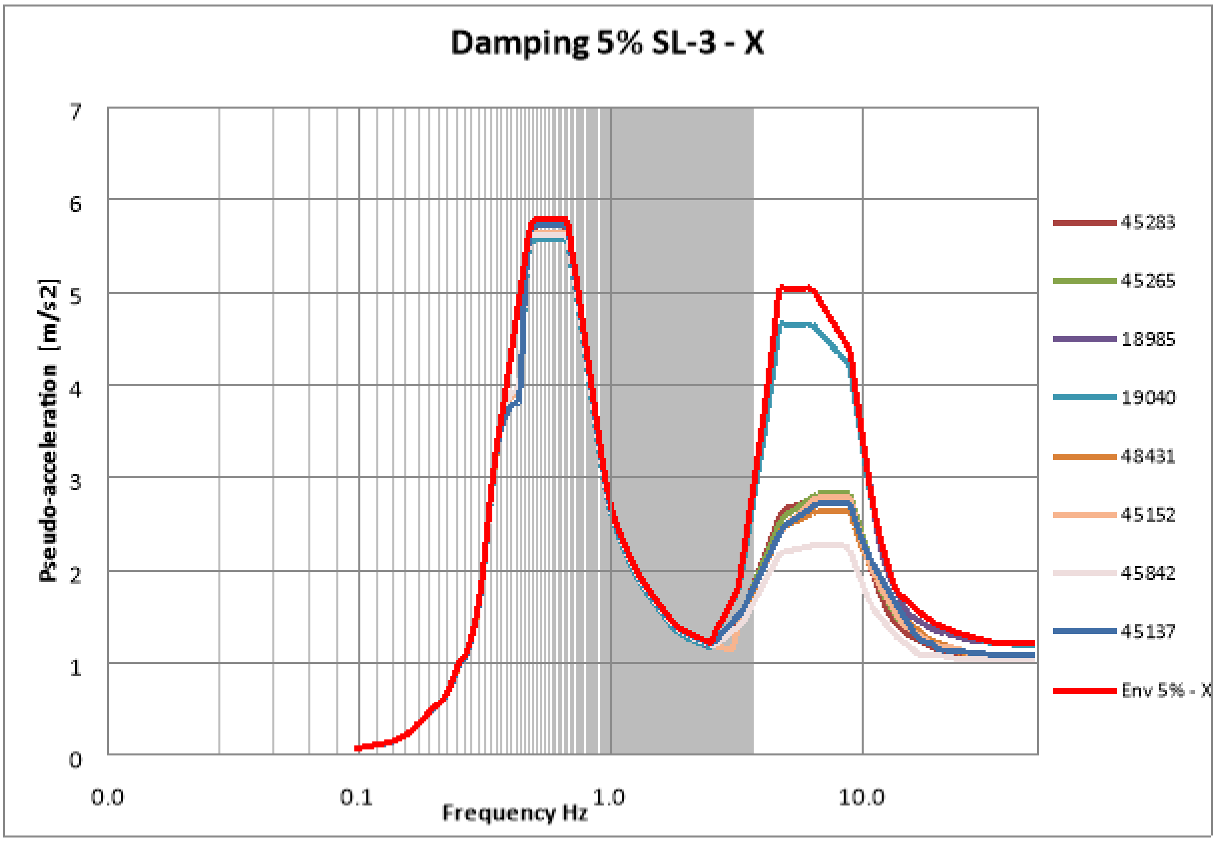


Figure I-5 Horizontal (X direction) seismic FRS 5% RL

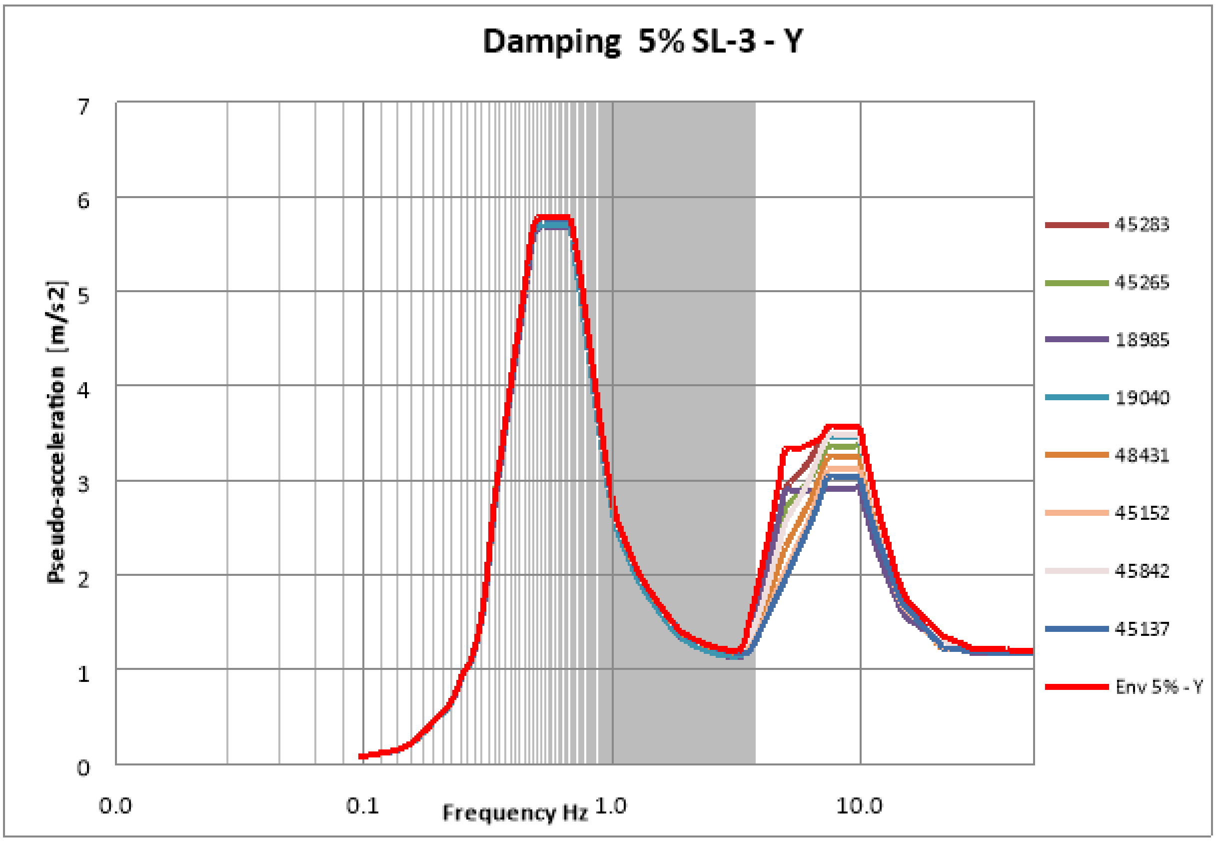


Figure I-6 Horizontal (Y direction) seismic FRS 5% RL

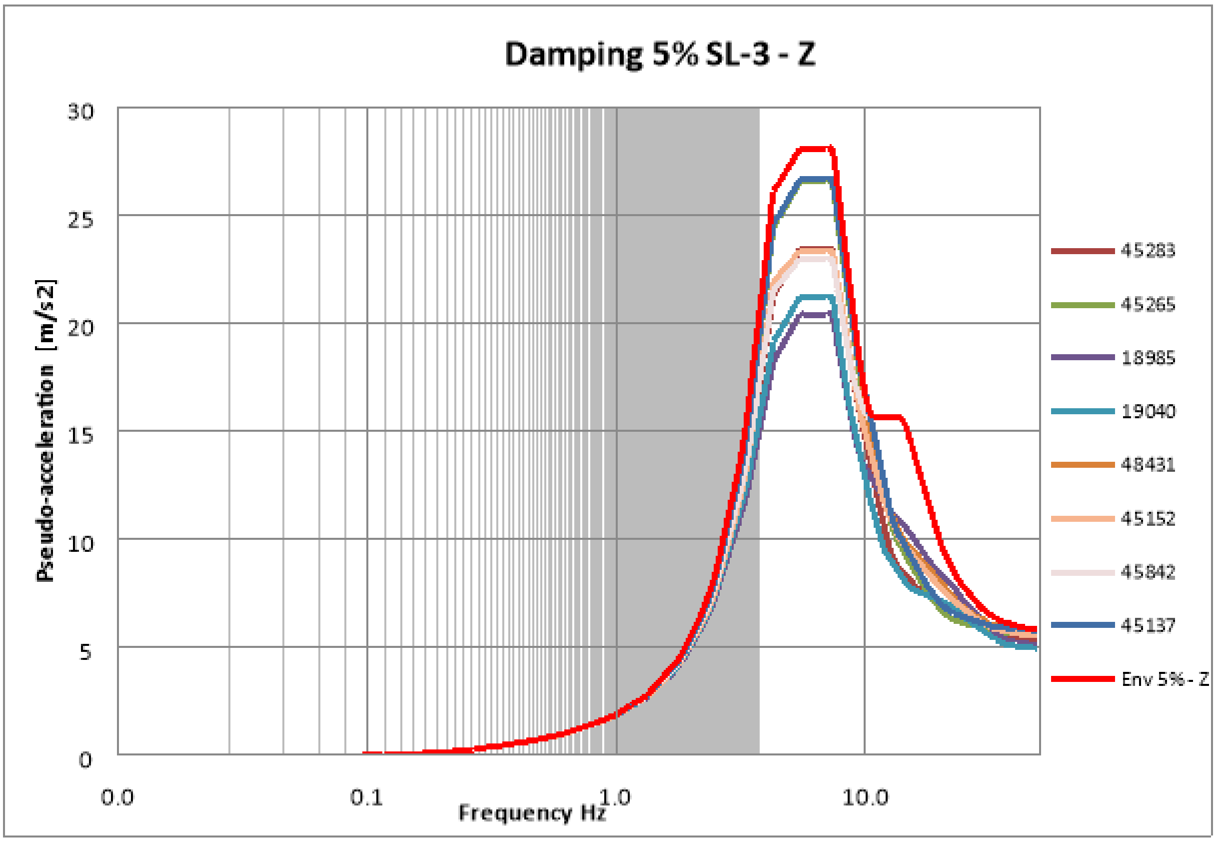


Figure I-7 Vertical (Z direction) seismic FRS 5% RL

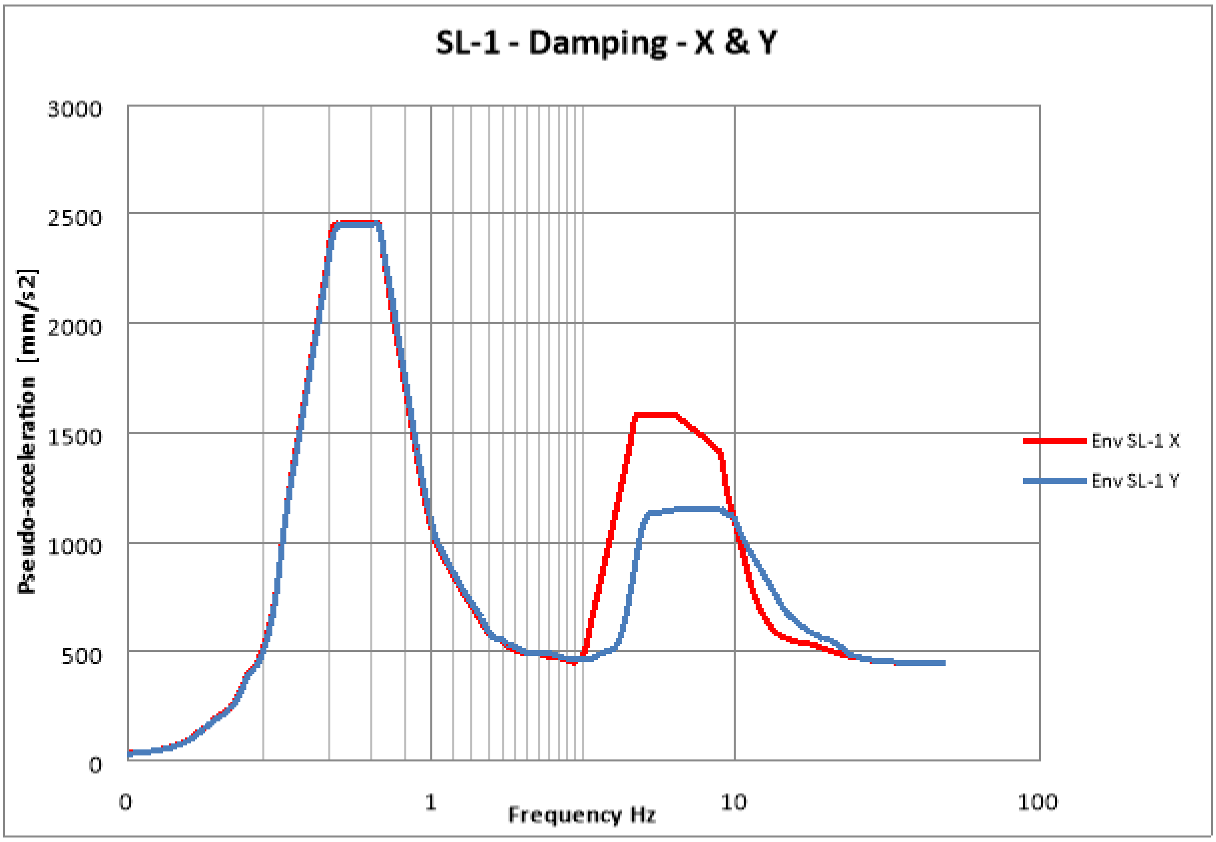


Figure I-8 Horizontal (X&Y direction) seismic FRS RL- SL-1

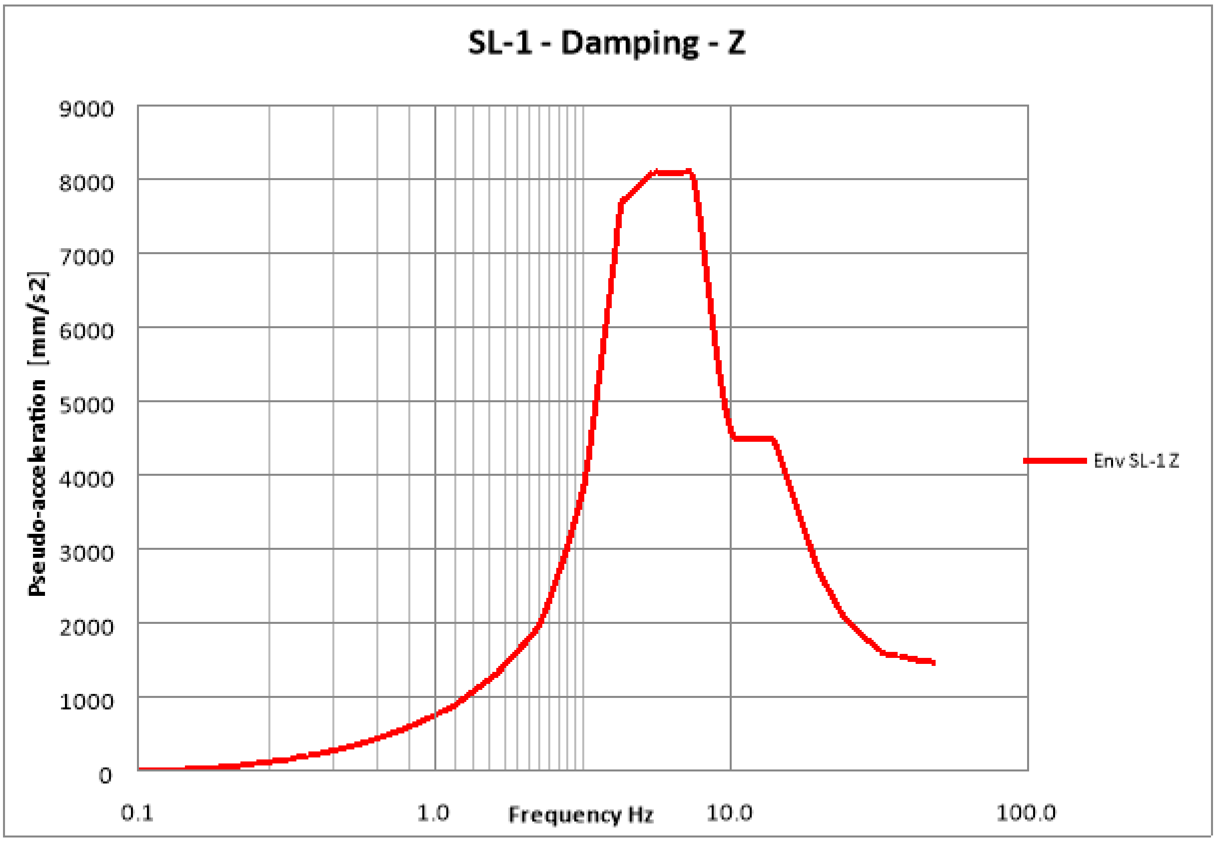


Figure I-9 Vertical (Z direction) seismic FRS RL- SL-1

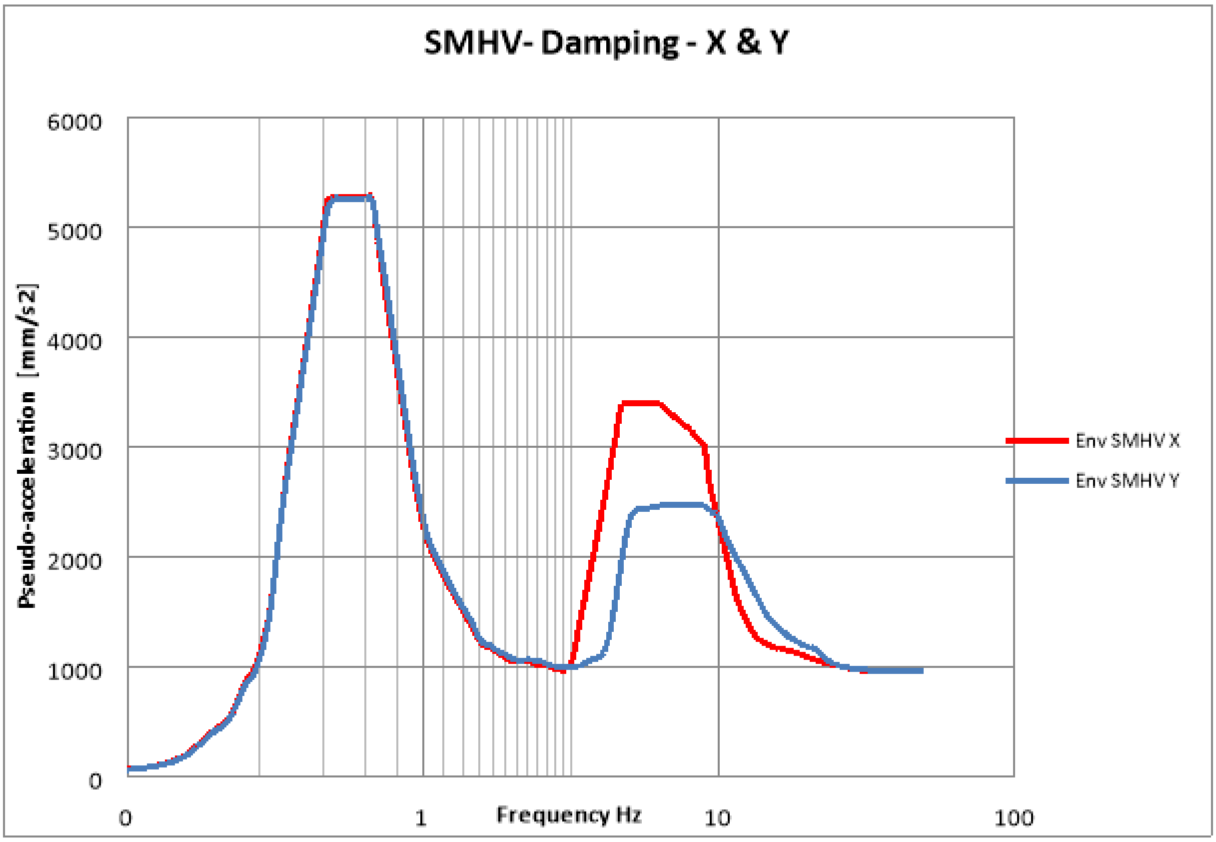


Figure I-10 Horizontal (X&Y direction) seismic FRS RL- SMHV

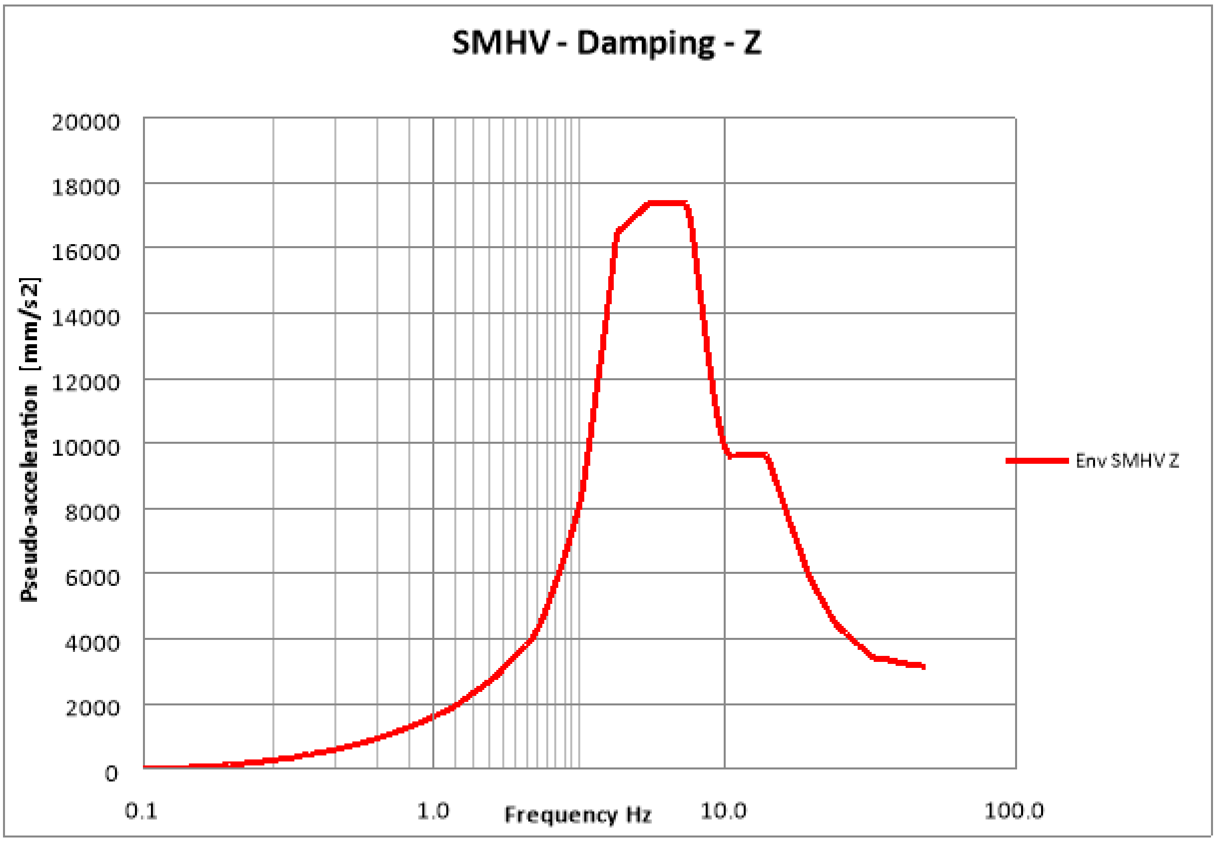


Figure I-11 Vertical (Z direction) seismic FRS RL– SMHV

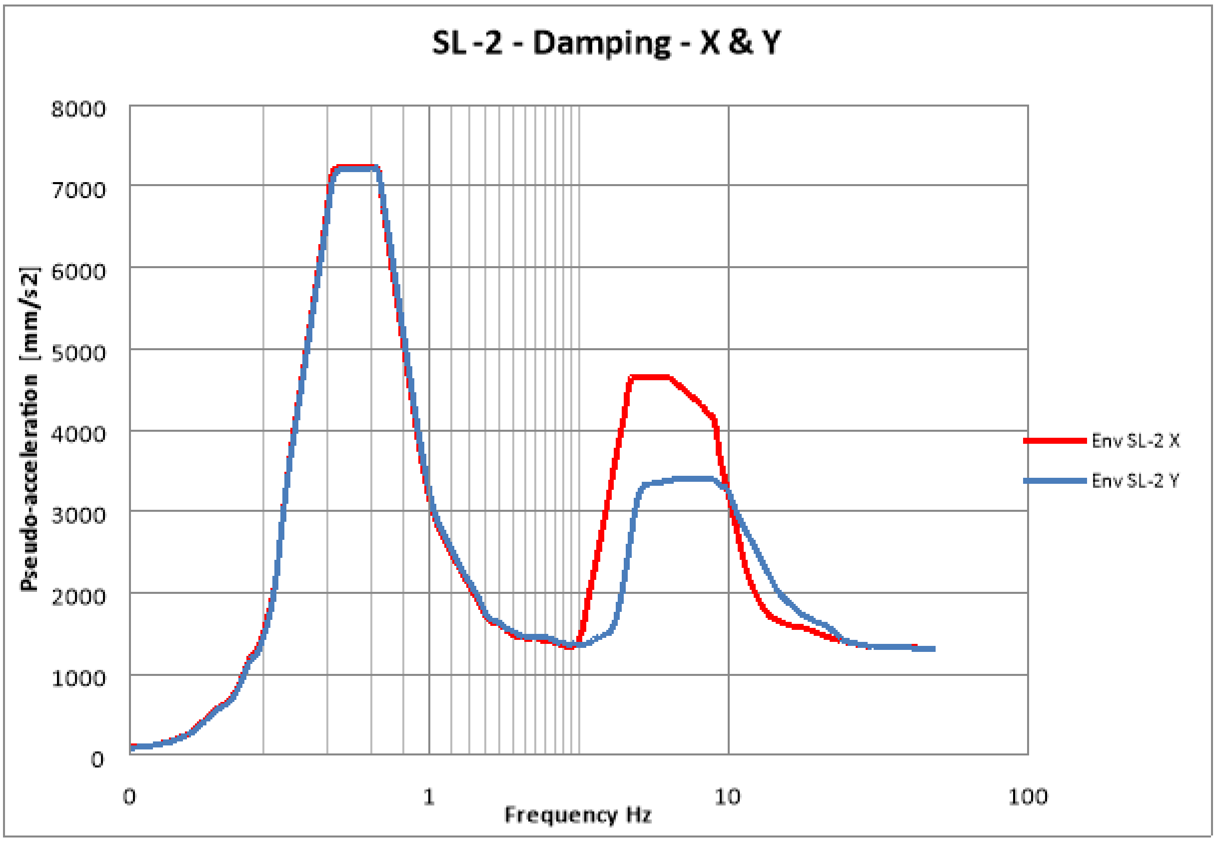


Figure I-12 Horizontal (X&Y direction) seismic FRS RL- SL-2

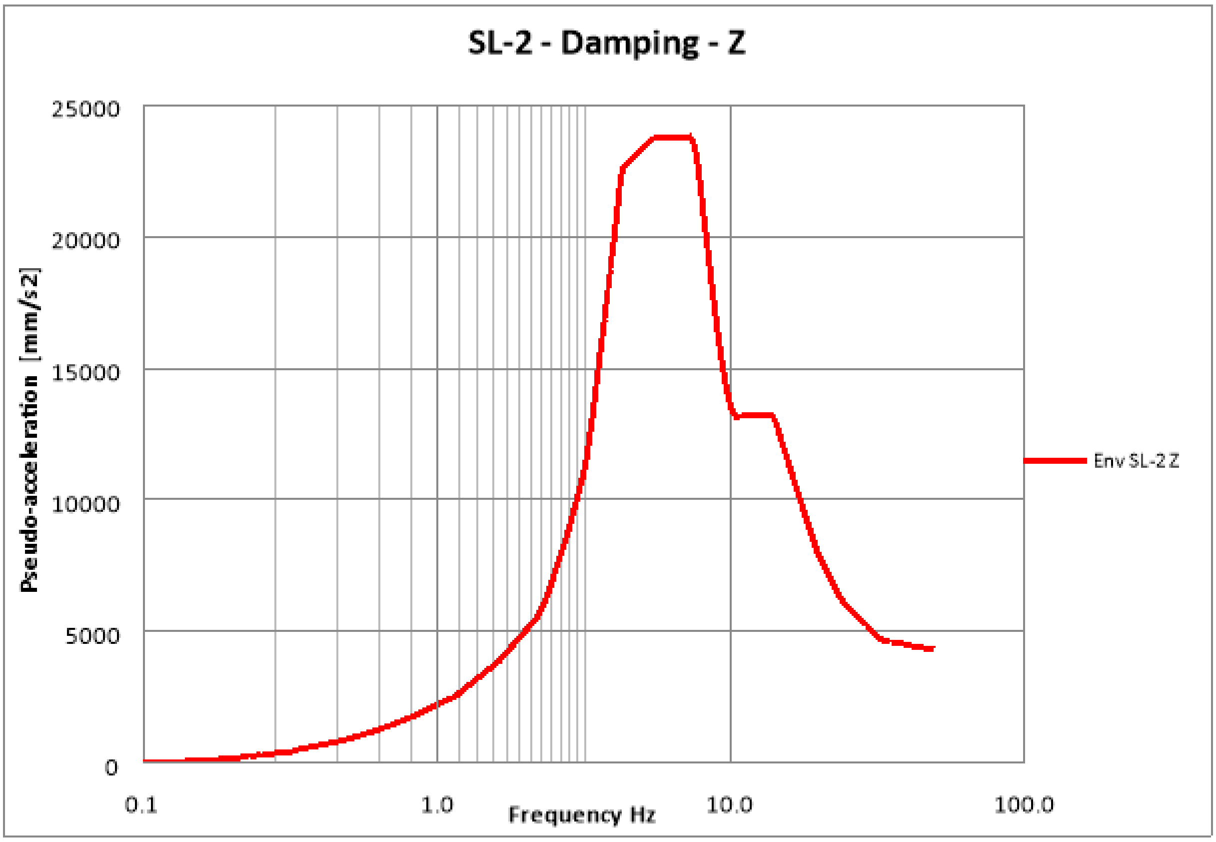


Figure I-13 Vertical (Z direction) seismic FRS RL- SL-2

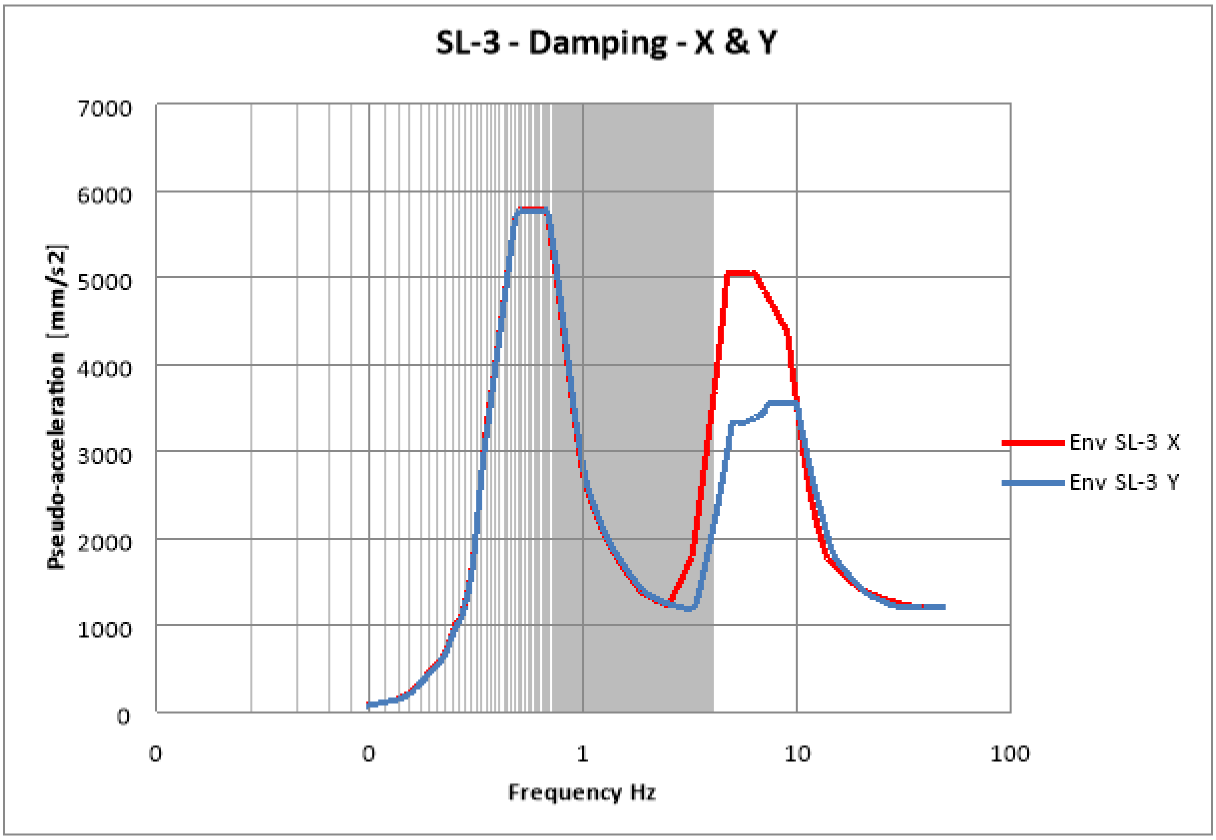


Figure I-14 Horizontal (X&Y direction) seismic FRS RL- SL-3

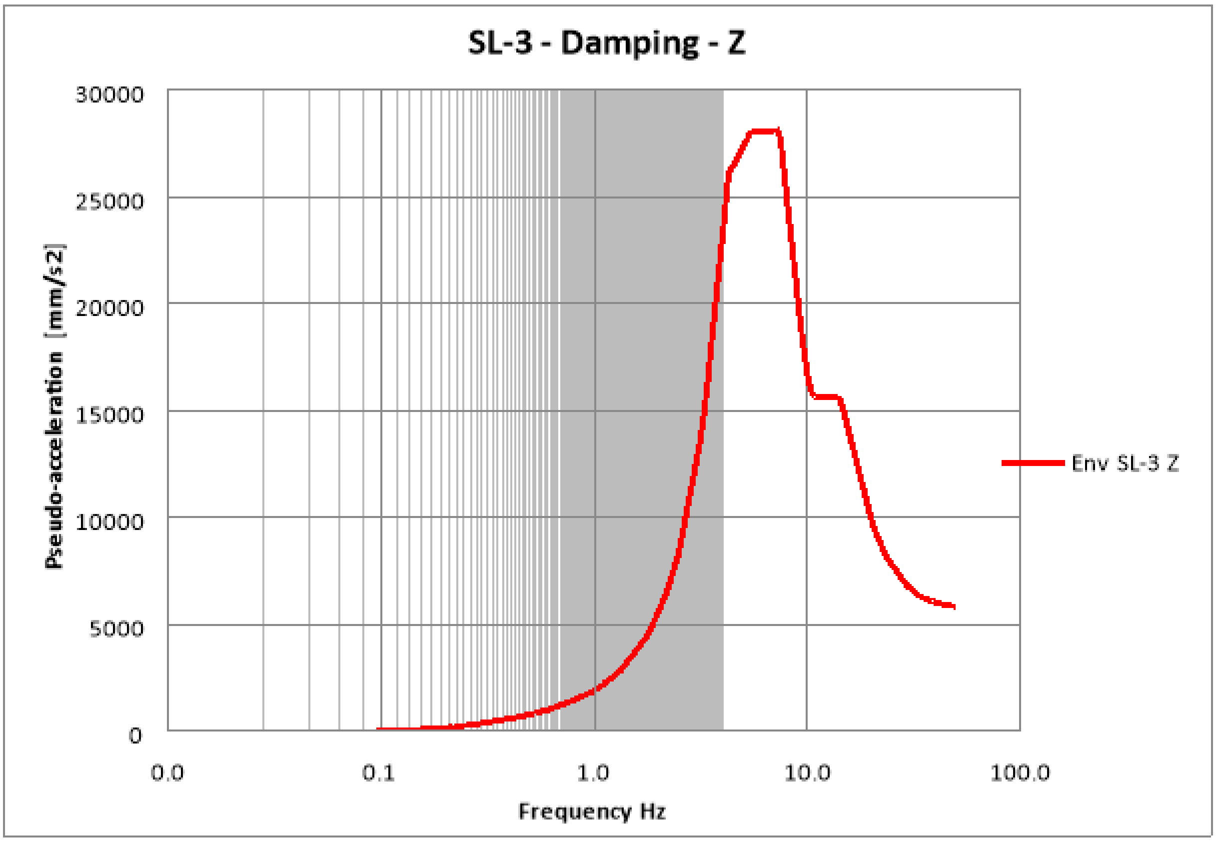


Figure I-15 Vertical (Z direction) seismic FRS RL- SL-3

Table I - 1 FRS of VVPSS RL – SL-1 and SMHV spectrum

Frequency	SL-1 Design FRS			Frequency	SMHV Design FRS		
Hz	X[mm/s2]	Y[mm/s2]	Z[mm/s2]	Hz	X[mm/s2]	Y[mm/s2]	Z[mm/s2]
0.10000	31.662	30.038	9.989	0.10000	67.979	64.492	21.447
0.10500	34.796	33.074	11.187	0.10500	74.709	71.012	24.020
0.11025	37.345	35.425	12.292	0.11025	80.181	76.059	26.392
0.11576	38.905	38.546	13.341	0.11576	83.531	82.761	28.643
0.12155	42.785	42.546	14.907	0.12155	91.863	91.349	32.006
0.12763	49.338	48.579	19.179	0.12763	105.932	104.301	41.179
0.13401	56.379	53.412	21.888	0.13401	121.049	114.680	46.996
0.14071	64.168	61.759	24.197	0.14071	137.772	132.601	51.952
0.14775	75.355	72.346	28.670	0.14775	161.791	155.331	61.556
0.15513	86.629	83.037	31.579	0.15513	185.999	178.286	67.803
0.16289	105.362	101.132	35.941	0.16289	226.219	217.137	77.167
0.17103	130.095	125.561	40.395	0.17103	279.322	269.587	86.731
0.17959	149.619	145.005	47.924	0.17959	321.240	311.335	102.896
0.18857	176.576	170.683	54.991	0.18857	379.118	366.466	118.069
0.19799	199.840	193.228	60.179	0.19799	429.067	414.871	129.208
0.20789	216.926	209.810	68.835	0.20789	465.752	450.475	147.793
0.21829	240.128	233.892	76.807	0.21829	515.568	502.179	164.910
0.22920	284.566	276.250	85.927	0.22920	610.980	593.124	184.491
0.24066	346.343	336.544	99.645	0.24066	743.619	722.580	213.943
0.25270	411.147	401.086	107.923	0.25270	882.757	861.155	231.718
0.26533	436.806	425.017	111.389	0.26533	937.848	912.536	239.159
0.27860	509.262	492.272	124.638	0.27860	1093.414	1056.938	267.605
0.29253	602.217	584.306	139.344	0.29253	1292.995	1254.540	299.179
0.30715	736.680	734.543	141.901	0.30715	1581.696	1577.107	304.671
0.32251	966.649	966.607	151.664	0.32251	2075.452	2075.362	325.631
0.33864	1192.487	1186.992	182.163	0.33864	2560.339	2548.542	391.116
0.35557	1382.334	1361.332	197.542	0.35557	2967.952	2922.860	424.134
0.37335	1552.285	1535.672	212.092	0.37335	3332.847	3297.178	455.373
0.39201	1727.401	1710.012	226.641	0.39201	3708.831	3671.496	486.612
0.41161	1905.705	1884.352	241.191	0.41161	4091.661	4045.814	517.851
0.43219	2084.010	2058.692	259.066	0.43219	4474.491	4420.132	556.231
0.45380	2262.314	2233.032	276.942	0.45380	4857.322	4794.450	594.611
0.47649	2440.619	2407.371	294.818	0.47649	5240.152	5168.768	632.991
0.50032	2458.293	2451.055	316.553	0.50032	5278.099	5262.559	679.659
0.52534	2458.293	2451.055	340.026	0.52534	5278.099	5262.559	730.057
0.55160	2458.293	2451.055	363.499	0.55160	5278.099	5262.559	780.455
0.57918	2458.293	2451.055	386.972	0.57918	5278.099	5262.559	830.853
0.60814	2458.293	2451.055	410.445	0.60814	5278.099	5262.559	881.250
0.63855	2458.293	2451.055	440.310	0.63855	5278.099	5262.559	945.371
0.67048	2458.293	2451.055	470.174	0.67048	5278.099	5262.559	1009.492
0.70400	2272.421	2293.637	500.039	0.70400	4879.021	4924.574	1073.613
0.73920	2086.548	2136.220	529.903	0.73920	4479.942	4586.589	1137.734

0.77616	1912.540	1958.575	560.488	0.77616	4106.337	4205.175	1203.401
0.81497	1738.532	1780.930	595.631	0.81497	3732.731	3823.761	1278.855
0.85572	1564.525	1603.285	630.774	0.85572	3359.126	3442.347	1354.309
0.89850	1390.517	1425.640	668.623	0.89850	2985.521	3060.933	1435.573
0.94343	1229.546	1263.861	708.119	0.94343	2639.908	2713.584	1520.372
0.99060	1093.084	1124.093	747.614	0.99060	2346.915	2413.494	1605.171
1.04013	994.213	1011.524	787.109	1.04013	2134.634	2171.802	1689.970
1.09213	933.451	951.263	826.605	1.09213	2004.175	2042.417	1774.769
1.14674	880.865	896.352	866.100	1.14674	1891.270	1924.522	1859.569
1.20408	828.279	841.442	930.323	1.20408	1778.365	1806.626	1997.459
1.26428	776.912	790.554	994.546	1.26428	1668.076	1697.365	2135.349
1.32749	731.767	744.288	1058.769	1.32749	1571.146	1598.030	2273.240
1.39387	683.855	700.473	1122.992	1.39387	1468.277	1503.956	2411.130
1.46356	636.837	654.686	1187.215	1.46356	1367.326	1405.650	2549.021
1.53674	587.183	595.405	1251.438	1.53674	1260.715	1278.369	2686.911
1.61358	555.665	562.882	1315.661	1.61358	1193.045	1208.541	2824.802
1.69426	551.833	558.720	1407.824	1.69426	1184.817	1199.604	3022.682
1.77897	527.026	534.538	1499.988	1.77897	1131.556	1147.684	3220.562
1.86792	511.835	525.009	1592.151	1.86792	1098.941	1127.224	3418.442
1.96131	496.092	509.270	1684.315	1.96131	1065.139	1093.432	3616.323
2.05938	490.588	495.439	1776.478	2.05938	1053.321	1063.737	3814.203
2.16235	490.588	495.439	1868.642	2.16235	1053.321	1063.737	4012.083
2.27047	493.561	498.442	2014.223	2.27047	1059.705	1070.184	4324.655
2.38399	479.192	495.792	2207.081	2.38399	1028.854	1064.494	4738.732
2.50319	477.249	491.014	2453.356	2.50319	1024.682	1054.235	5267.500
2.62835	472.557	478.389	2699.632	2.62835	1014.608	1027.128	5796.269
2.75977	463.076	468.834	2949.476	2.75977	994.252	1006.614	6332.699
2.89775	453.266	465.687	3244.567	2.89775	973.188	999.857	6966.276
3.04264	454.963	467.420	3539.658	3.04264	976.832	1003.578	7599.853
3.19477	450.986	464.584	3883.666	3.19477	968.293	997.489	8338.460
3.35451	462.222	467.269	4449.347	3.35451	992.419	1003.255	9553.010
3.52224	507.080	469.955	5093.731	3.52224	1088.731	1009.021	10936.540
3.69835	558.667	485.349	5738.115	3.69835	1199.491	1042.073	12320.071
3.88327	612.678	490.936	6382.499	3.88327	1315.455	1054.070	13703.601
4.07743	667.263	504.969	7026.883	4.07743	1432.653	1084.198	15087.131
4.28130	722.422	583.548	7671.267	4.28130	1551.084	1252.911	16470.661
4.49537	778.156	700.541	7753.842	4.49537	1670.748	1504.102	16647.954
4.72014	829.855	821.784	7836.416	4.72014	1781.747	1764.419	16825.246
4.95614	836.835	950.737	7918.991	4.95614	1796.734	2041.287	17002.539
5.20395	843.816	987.935	8001.565	5.20395	1811.722	2121.154	17179.831
5.46415	850.796	1007.487	8084.139	5.46415	1826.710	2163.134	17357.123
5.73736	860.541	1027.039	8084.139	5.73736	1847.632	2205.114	17357.123
6.02422	872.333	1046.592	8084.139	6.02422	1872.950	2247.094	17357.123
6.32544	884.125	1066.144	8084.139	6.32544	1898.268	2289.074	17357.123
6.64171	895.917	1085.696	8084.139	6.64171	1923.587	2331.054	17357.123

6.97379	895.917	1105.249	8084.139	6.97379	1923.587	2373.034	17357.123
7.32248	895.917	1117.649	8084.139	7.32248	1923.587	2399.658	17357.123
7.68861	895.917	1117.649	7740.842	7.68861	1923.587	2399.658	16620.043
8.07304	895.917	1117.649	7063.745	8.07304	1923.587	2399.658	15166.275
8.47669	895.917	1117.649	6386.647	8.47669	1923.587	2399.658	13712.507
8.90052	895.917	1117.649	5709.550	8.90052	1923.587	2399.658	12258.739
9.34555	842.319	1117.649	5142.188	9.34555	1808.509	2399.658	11040.580
9.81283	788.722	1117.649	4713.132	9.81283	1693.432	2399.658	10119.371
10.30350	735.124	1052.321	4485.660	10.30350	1578.355	2259.394	9630.976
10.81860	681.527	991.013	4485.660	10.81860	1463.278	2127.764	9630.976
11.35960	630.982	940.633	4485.660	11.35960	1354.755	2019.594	9630.976
11.92760	598.515	890.252	4485.660	11.92760	1285.046	1911.424	9630.976
12.52390	566.048	839.872	4485.660	12.52390	1215.337	1803.254	9630.976
13.15010	536.390	789.491	4485.660	13.15010	1151.662	1695.085	9630.976
13.80760	523.485	739.111	4485.660	13.80760	1123.953	1586.915	9630.976
14.49800	517.674	688.730	4282.448	14.49800	1111.477	1478.745	9194.667
15.22290	512.183	657.642	4026.930	15.22290	1099.687	1411.996	8646.055
15.98410	507.915	632.916	3771.412	15.98410	1090.523	1358.907	8097.444
16.78330	503.663	608.426	3515.895	16.78330	1081.394	1306.327	7548.833
17.62240	499.426	584.173	3267.754	17.62240	1072.298	1254.254	7016.060
18.50350	485.135	560.157	3023.002	18.50350	1041.614	1202.689	6490.564
19.42870	462.242	536.377	2778.251	19.42870	992.461	1151.633	5965.068
20.40020	453.211	512.833	2594.188	20.40020	973.072	1101.084	5569.875
21.42020	434.760	500.031	2439.246	21.42020	933.454	1073.597	5237.205
22.49120	426.539	497.124	2284.305	22.49120	915.803	1067.355	4904.536
23.61570	418.238	486.040	2129.363	23.61570	897.981	1043.556	4571.867
24.79650	414.298	476.629	2021.734	24.79650	889.522	1023.351	4340.783
26.03630	410.865	469.759	1940.986	26.03630	882.152	1008.600	4167.411
27.33820	407.455	464.431	1860.238	27.33820	874.829	997.160	3994.040
28.70510	404.174	459.503	1779.489	28.70510	867.786	986.579	3820.668
30.14030	401.740	455.325	1713.428	30.14030	862.559	977.609	3678.830
31.64730	401.740	454.362	1617.992	31.64730	862.559	975.543	3473.925
33.22970	400.913	452.992	1589.964	33.22970	860.785	972.601	3413.747
34.89120	400.573	451.435	1566.468	34.89120	860.053	969.257	3363.299
36.63580	400.421	451.435	1566.468	36.63580	859.728	969.257	3363.299
38.46750	400.096	450.567	1542.312	38.46750	859.029	967.394	3311.436
40.39090	399.911	449.973	1525.321	40.39090	858.633	966.120	3274.954
42.41050	399.752	449.295	1506.322	42.41050	858.291	964.662	3234.161
44.53100	399.584	448.936	1495.306	44.53100	857.931	963.891	3210.510
46.75750	399.505	448.421	1483.287	46.75750	857.761	962.785	3184.704
49.09540	399.396	448.118	1474.835	49.09540	857.526	962.136	3166.558

Table I - 2 FRS of VVPSS RL – SL-2 and SL-3 spectrum

Frequency	SL-2 Design FRS			Frequency	SL-3 Design FRS		
Hz	X[mm/s2]	Y[mm/s2]	Z[mm/s2]	Hz	X[mm/s2]	Y[mm/s2]	Z[mm/s2]
0.10000	93.122	88.346	29.380	0.095238	74.457	72.228	24.702
0.10500	102.341	97.276	32.904	0.1	83.013	81.784	27.688
0.11025	109.837	104.190	36.153	0.105	92.569	92.019	31.132
0.11576	114.426	113.371	39.237	0.11025	103.008	102.423	34.867
0.12155	125.839	125.136	43.844	0.115763	112.997	112.370	38.577
0.12763	145.113	142.879	56.409	0.121551	122.085	121.388	43.474
0.13401	165.820	157.095	64.378	0.127628	132.240	131.097	50.509
0.14071	188.729	181.645	71.168	0.13401	145.766	143.414	57.804
0.14775	221.631	212.782	84.323	0.14071	167.861	160.934	63.751
0.15513	254.793	244.228	92.881	0.147746	197.079	188.982	71.635
0.16289	309.889	297.448	105.709	0.155133	226.953	219.914	80.724
0.17103	382.633	369.297	118.810	0.162889	278.569	267.187	91.417
0.17959	440.055	426.486	140.954	0.171034	340.918	328.724	103.382
0.18857	519.340	502.008	161.738	0.179586	389.918	377.105	122.267
0.19799	587.764	568.317	176.998	0.188565	456.941	441.183	139.656
0.20789	638.017	617.088	202.456	0.197993	519.546	501.681	151.170
0.21829	706.258	687.917	225.904	0.207893	566.541	547.284	172.777
0.22920	836.959	812.499	252.727	0.218287	627.881	610.852	191.450
0.24066	1018.656	989.836	293.073	0.229202	737.802	714.844	212.254
0.25270	1209.256	1179.665	317.422	0.240662	886.098	858.922	245.949
0.26533	1284.724	1250.049	327.615	0.252695	1030.837	994.055	270.482
0.27860	1497.828	1447.860	366.582	0.26533	1091.551	1066.347	277.371
0.29253	1771.226	1718.548	409.834	0.278596	1264.227	1243.636	311.556
0.30715	2166.707	2160.420	417.357	0.292526	1505.252	1478.700	362.076
0.32251	2843.085	2842.961	446.071	0.307152	1861.127	1847.374	392.607
0.33864	3507.314	3491.153	535.775	0.32251	2406.982	2402.063	423.138
0.35557	4065.688	4003.918	581.006	0.338635	2948.831	2928.358	455.131
0.37335	4565.544	4516.682	623.799	0.355567	3403.099	3296.710	491.798
0.39201	5080.590	5029.447	666.592	0.373346	3742.768	3711.683	528.465
0.41161	5605.015	5542.211	709.384	0.392013	4129.423	4103.346	565.132
0.43219	6129.440	6054.975	761.960	0.411614	4516.078	4495.009	601.798
0.45380	6653.866	6567.740	814.536	0.432194	4902.732	4886.672	645.844
0.47649	7178.291	7080.504	867.111	0.453804	5289.387	5278.335	689.890
0.50032	7230.273	7208.985	931.039	0.476494	5676.042	5669.998	733.935
0.52534	7230.273	7208.985	1000.078	0.500319	5780.228	5775.522	777.981
0.55160	7230.273	7208.985	1069.116	0.525335	5780.228	5775.522	831.945
0.57918	7230.273	7208.985	1138.154	0.551602	5780.228	5775.522	887.486
0.60814	7230.273	7208.985	1207.192	0.579182	5780.228	5775.522	943.027
0.63855	7230.273	7208.985	1295.029	0.608141	5780.228	5775.522	998.568
0.67048	7230.273	7208.985	1382.866	0.638548	5780.228	5775.522	1079.320
0.70400	6683.590	6745.992	1470.702	0.670475	5780.228	5775.522	1160.072
0.73920	6136.906	6282.999	1558.539	0.703999	5424.657	5513.137	1240.824

0.77616	5625.119	5760.514	1648.494	0.739199	5069.086	5168.824	1321.575
0.81497	5113.331	5238.029	1751.856	0.776159	4662.460	4756.053	1402.327
0.85572	4601.543	4715.544	1855.217	0.814967	4255.833	4343.282	1483.079
0.89850	4089.755	4193.059	1966.539	0.855715	3849.207	3930.511	1581.288
0.94343	3616.313	3717.239	2082.702	0.898501	3442.580	3517.740	1679.498
0.99060	3214.952	3306.156	2198.865	0.943426	3073.251	3159.026	1777.707
1.04013	2924.157	2975.071	2315.028	0.990597	2756.217	2834.220	1875.916
1.09213	2745.445	2797.832	2431.191	1.040127	2550.611	2592.065	2011.866
1.14674	2590.781	2636.331	2547.354	1.092133	2397.335	2443.064	2171.736
1.20408	2436.116	2474.830	2736.245	1.14674	2265.500	2305.264	2331.606
1.26428	2285.035	2325.158	2925.136	1.204077	2133.665	2167.464	2491.477
1.32749	2152.255	2189.082	3114.027	1.264281	2010.033	2044.689	2651.347
1.39387	2011.338	2060.214	3302.918	1.327495	1914.801	1941.392	2811.217
1.46356	1873.049	1925.547	3491.809	1.39387	1827.773	1853.120	3087.959
1.53674	1727.007	1751.191	3680.700	1.463563	1742.072	1774.131	3364.702
1.61358	1634.308	1655.536	3869.591	1.536741	1664.186	1696.487	3641.444
1.69426	1623.037	1643.293	4140.660	1.613578	1586.300	1618.844	3918.187
1.77897	1550.077	1572.169	4411.729	1.694257	1508.948	1545.616	4194.929
1.86792	1505.398	1544.143	4682.798	1.77897	1442.414	1477.798	4471.672
1.96131	1459.095	1497.852	4953.867	1.867919	1382.484	1409.980	4924.116
2.05938	1442.906	1457.174	5224.936	1.961315	1353.309	1372.667	5410.856
2.16235	1442.906	1457.174	5496.004	2.05938	1324.134	1344.003	5897.596
2.27047	1451.650	1466.005	5924.185	2.162349	1294.958	1315.340	6384.336
2.38399	1409.389	1458.211	6491.414	2.270467	1267.486	1290.435	7024.859
2.50319	1403.674	1444.158	7215.754	2.38399	1248.026	1266.170	7685.036
2.62835	1389.874	1407.025	7940.094	2.50319	1230.268	1247.976	8463.792
2.75977	1361.989	1378.923	8674.930	2.628349	1258.745	1232.966	9555.562
2.89775	1333.135	1369.667	9542.844	2.759766	1317.860	1218.978	10654.435
3.04264	1338.127	1374.765	10410.758	2.897755	1381.271	1207.514	11753.308
3.19477	1326.429	1366.423	11422.549	3.042643	1444.682	1196.050	12852.180
3.35451	1359.477	1374.322	13086.315	3.194775	1508.092	1194.982	14122.784
3.52224	1491.412	1382.220	14981.562	3.354513	1571.503	1253.930	15810.017
3.69835	1643.138	1427.497	16876.809	3.522239	1692.171	1422.138	17866.605
3.88327	1801.993	1443.931	18772.057	3.698351	1841.460	1554.442	19923.193
4.07743	1962.538	1485.203	20667.303	3.883269	1990.750	1754.613	21979.781
4.28130	2124.772	1716.317	22562.550	4.077432	2140.039	1963.057	24036.369
4.49537	2288.696	2060.414	22805.417	4.281304	2289.328	2171.500	26092.957
4.72014	2440.749	2417.012	23048.282	4.495369	2438.617	2410.282	26489.742
4.95614	2461.280	2796.284	23291.149	4.720137	2587.906	2660.877	26886.527
5.20395	2481.811	2905.691	23534.015	4.956144	2669.823	2911.472	27283.312
5.46415	2502.342	2963.198	23776.881	5.203951	2686.297	2974.452	27680.097
5.73736	2531.003	3020.704	23776.881	5.464149	2702.771	3037.432	28076.882
6.02422	2565.685	3078.211	23776.881	5.737356	2719.245	3100.412	28076.882
6.32544	2600.368	3135.718	23776.881	6.024224	2748.541	3163.392	28076.882
6.64171	2635.050	3193.224	23776.881	6.325435	2787.428	3243.484	28076.882

6.97379	2635.050	3250.731	23776.881	6.641707	2826.315	3350.574	28076.882
7.32248	2635.050	3287.203	23776.881	6.973792	2826.315	3457.665	28076.882
7.68861	2635.050	3287.203	22767.182	7.322482	2826.315	3564.756	28076.882
8.07304	2635.050	3287.203	20775.720	7.688606	2826.315	3564.756	26515.618
8.47669	2635.050	3287.203	18784.257	8.073037	2826.315	3564.756	24479.712
8.90052	2635.050	3287.203	16792.794	8.476688	2826.315	3564.756	22564.549
9.34555	2477.410	3287.203	15124.083	8.900523	2826.315	3564.756	20649.386
9.81283	2319.770	3287.203	13862.153	9.345549	2645.410	3564.756	18734.223
10.30350	2162.130	3095.061	13193.117	9.812826	2464.505	3564.756	17172.460
10.81860	2004.490	2914.745	13193.117	10.303468	2283.600	3323.910	16021.622
11.35960	1855.828	2766.567	13193.117	10.818641	2111.911	3083.064	15652.847
11.92760	1760.337	2618.389	13193.117	11.359573	2013.660	2842.218	15652.847
12.52390	1664.846	2470.212	13193.117	11.927552	1915.408	2609.412	15652.847
13.15010	1577.619	2322.034	13193.117	12.523929	1817.157	2414.585	15652.847
13.80760	1539.662	2173.856	13193.117	13.150126	1718.906	2219.758	15652.847
14.49800	1522.571	2025.678	12595.435	13.807632	1620.655	2024.931	15652.847
15.22290	1506.420	1934.240	11843.911	14.498014	1522.403	1866.762	15232.357
15.98410	1493.867	1861.517	11092.389	15.222914	1452.404	1750.777	14406.054
16.78330	1481.361	1789.489	10340.866	15.98406	1403.171	1671.449	13587.122
17.62240	1468.901	1718.156	9611.042	16.783263	1353.938	1592.121	12768.190
18.50350	1426.868	1647.520	8891.184	17.622426	1304.705	1517.853	11949.258
19.42870	1359.536	1577.579	8171.326	18.503548	1258.233	1457.105	11130.326
20.40020	1332.975	1508.334	7629.965	19.428725	1234.078	1410.506	10311.394
21.42020	1278.705	1470.680	7174.254	20.400161	1212.969	1363.907	9552.231
22.49120	1254.525	1462.130	6718.543	21.420169	1191.859	1327.701	9042.308
23.61570	1230.110	1429.529	6262.832	22.491178	1170.750	1293.969	8546.405
24.79650	1218.523	1401.850	5946.278	23.615737	1162.854	1260.236	8110.071
26.03630	1208.427	1381.644	5708.783	24.796523	1145.946	1247.287	7812.154
27.33820	1198.396	1365.972	5471.287	26.03635	1124.407	1237.540	7514.236
28.70510	1188.748	1351.478	5233.792	27.338167	1115.783	1230.872	7216.318
30.14030	1181.587	1339.191	5039.493	28.705075	1109.199	1225.826	6918.401
31.64730	1181.587	1336.360	4758.801	30.140329	1104.411	1221.864	6704.805
33.22970	1179.157	1332.331	4676.366	31.647346	1100.210	1218.688	6523.344
34.89120	1178.154	1327.749	4607.258	33.229713	1096.408	1215.552	6350.114
36.63580	1177.709	1327.749	4607.258	34.891199	1093.169	1211.442	6243.598
38.46750	1176.753	1325.197	4536.213	36.635758	1090.951	1210.215	6158.064
40.39090	1176.209	1323.451	4486.238	38.467546	1088.880	1209.465	6090.609
42.41050	1175.741	1321.455	4430.358	40.390924	1087.035	1207.543	6017.616
44.53100	1175.248	1320.399	4397.959	42.41047	1085.345	1206.033	5960.119
46.75750	1175.015	1318.884	4362.609	44.530993	1083.821	1204.794	5909.989
49.09540	1174.693	1317.994	4337.750	46.757543	1082.453	1203.679	5877.374
				49.09542	1081.229	1202.706	5861.536

Appendix 2 – Thermal Loads Fire Evaluation

Overheated steam (inside)																
DN	Temp	Ph	Spec Vol.	ρ	M flow	M flow	Q flow r	velocity	Dynamic viscosity	Cinematic viscosity	Re	Specific heat	λ	Pr	Nu (Dittus Boulter)	h
	C	kPa	m3/kg	kg/m3	kg/s	kg/h	m3/s	m/s	kg / m s	m2/s		J/kg K	W / m K			W / m2 K
200	250	150	1.6	0.6	22.4	80640	35.9	1113.3	1.8E-05	2.9E-05	7732683.4	1999.4	3.8E-02	0.9	7.3E+03	1390.9
300	250	150	1.6	0.6	7.5	27000	12.0	164.6	1.8E-05	2.9E-05	1720213.4	1999.4	3.8E-02	0.9	2.2E+03	277.7
350	250	150	1.6	0.6	7.5	27000	12.0	135.0	1.8E-05	2.9E-05	1558179.9	1999.4	3.8E-02	0.9	2.0E+03	232.4
500	250	150	1.6	0.6	22.4	80640	35.9	191.0	1.8E-05	2.9E-05	3203210.4	1999.4	3.8E-02	0.9	3.6E+03	284.7
300	300	150	1.8	0.6	7.5	27000	13.2	180.6	2.0E-05	3.6E-05	1544342.7	2018.5	4.4E-02	0.9	2.0E+03	289.1
500	300	150	1.8	0.6	22.4	80640	39.4	209.6	2.0E-05	3.6E-05	2875721.5	2018.5	4.4E-02	0.9	3.3E+03	296.4

Air (outside)												Analysis results	
DN	T int	Tmean	ρ	λ	Dynamic viscosity	Cinematic viscosity	Pr	β	Ra	Nu (natural convection)	h	*** Final temperature after 2hrs ISO-834 [C] (steam inside)**	*** Final temperature after 2hrs ISO-834 [C] (empty inside)**
	C	C	kg/m3	W / m K	kg / m s	m2/s		1 / K			W / m2 K		
200	35	43.5	1.11	0.0275	0.0000194	1.74775E-05	0.71	0.00315	23801903	36.590	3.742021	**250**	**73**
300	35	45	1.11	0.0275	0.0000194	1.74775E-05	0.71	0.00314	74926305	51.7908	3.80916	**251**	**67**
350	35	45	1.11	0.0275	0.0000194	1.74775E-05	0.71	0.00314	95644888	55.8088	3.783882	**252**	**61**
500	35	45	1.11	0.0275	0.0000194	1.74775E-05	0.71	0.00314	249040809	74.9709	3.694806	**252**	**60**
300	35	46.5	1.11	0.0275	0.0000194	1.74775E-05	0.71	0.00312	85760909	53.9747	3.969796	**302**	**67**
500	35	47.5	1.11	0.0275	0.0000194	1.74775E-05	0.71	0.00311	308873902	80.1565	3.95036	**301**	**60**

- Final Temperature determined using the Dittus-Boelter correlation $Nu = 0.023.Re^{0.8}.Pr^{0.4}$