

Date:

Technical Note

Operational regimes of LSS vacuum warm modules

Abstract:

This document presents operational regime of Warm Modules that are installed in the LHC.

Prepared by :
Viktoras Arapoglou

Data contributed by:
Piotr Mieczyslaw Gebolis
Jose Maria Martin Ruiz
Florian De Simone

Checked by :

Josef Sestak
Julien Finelle

Approved by :

Giuseppe Bregliozzi

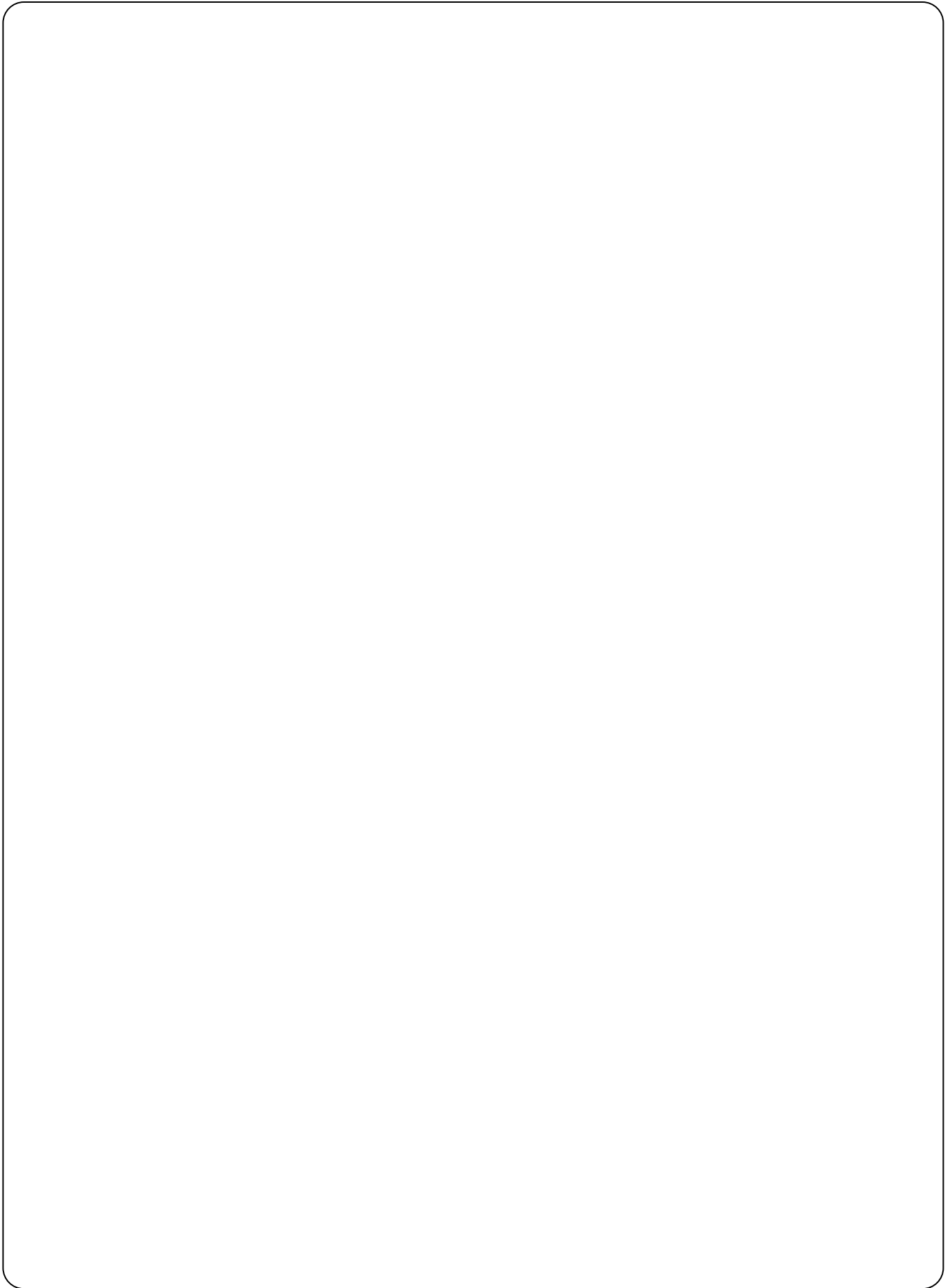


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1. INTRODUCTION

The purpose of this study was to define the operational range, for approximately ≈ 1500 circular RF bridges that are installed in the LHC. The mapping was based on the geometrical characteristics of the modules. The results obtained by this study describe the operating regimes for the majority of modules that are currently installed within the LHC room temperature sectors.

2. DESCRIPTION OF LHC VACUUM WARM MODULE

2.1 FUNCTIONAL DESCRIPTION

The LHC vacuum warm modules with circular RF Bridges can be found with different length, diameter and/or inner aperture. Their main function is to ensure a good electrical continuity between the contiguous vacuum chambers after the bake-out process. This achieved when the electrical current passing from the RF fingers to the transition tube without presenting geometrical discontinuities. As a result, large local impedances and electrical breakdowns are avoided in the LHC during the beam circulation [1].

2.2 GEOMETRY & DESIGN

During the tests, circular RF bridges with different geometrical characteristics were tested to define the operational range. Figure 1, shows an example of the drawing with the most common type of warm module with circular RF Bridge, VMAAB numbering 178 occurrences.

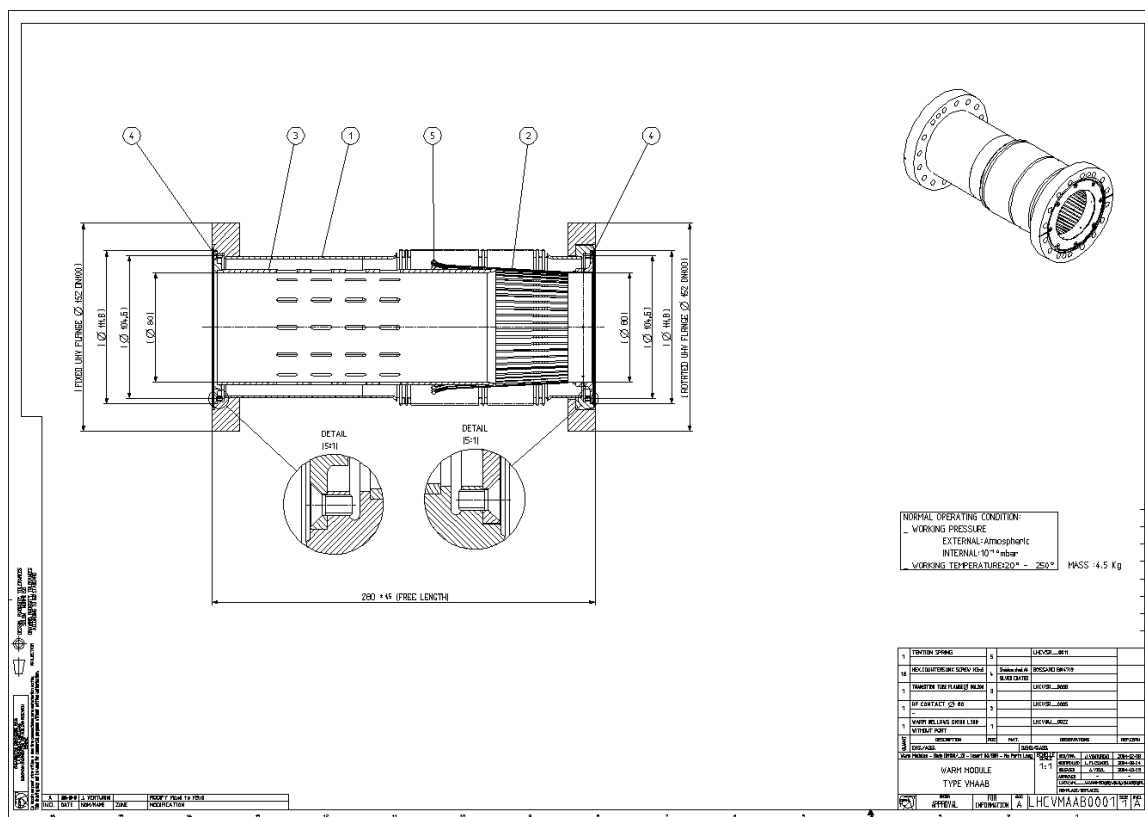


Figure 1: Assembly drawing of ID80 vacuum warm module.

The assembly consists of the RF Contact, Transition Tube insert, Vacuum Bellow and the tension spring (Figure 2.).

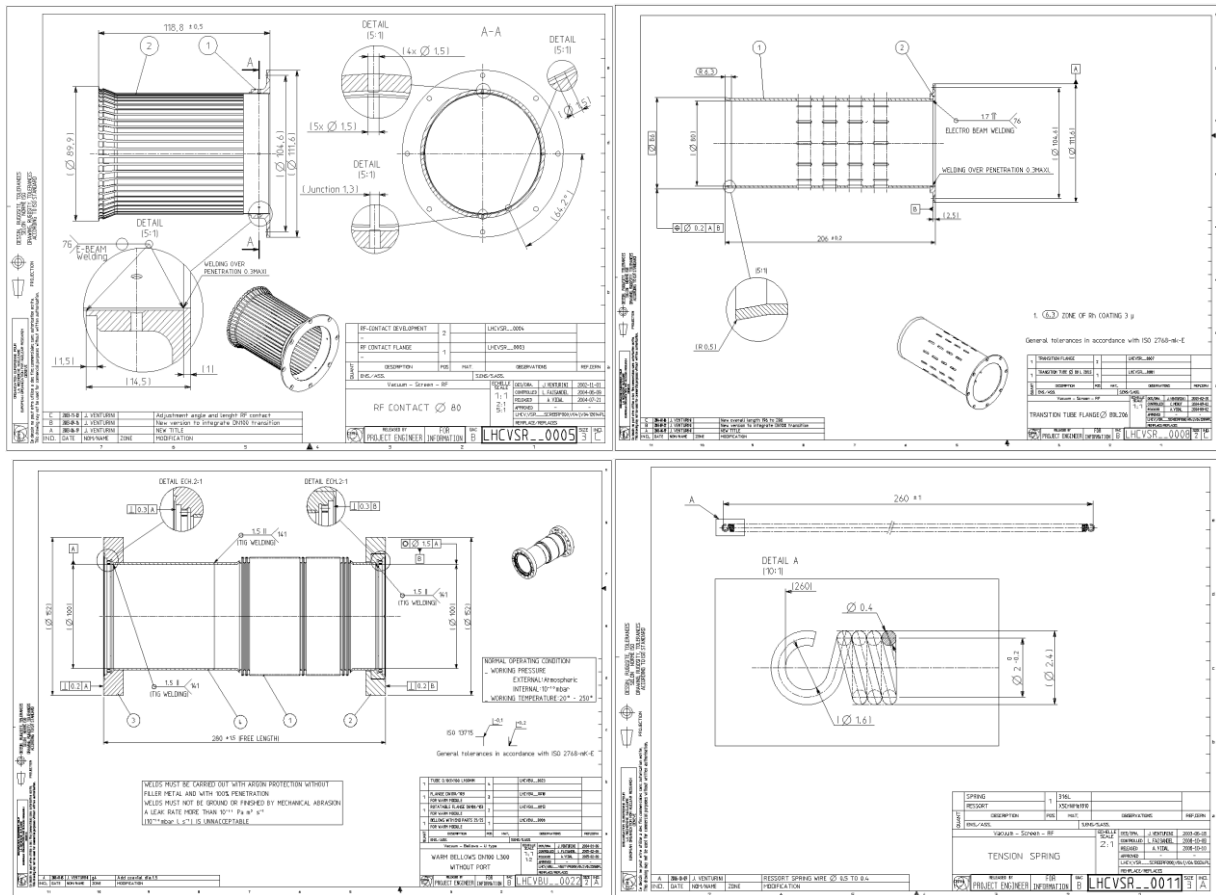


Figure 2: Assembly components of the VMAAB drawing.

The geometry of each of the above-mentioned parts varies, depending on the sector that the beam is passing through.

2.3 OPERATIONAL CONDITIONS

The operational conditions for the tests were set according to the installed length of the modules in the machine and the mechanical tolerances of the vacuum bellows. The drawing in the next page (Figure 3.) presents a vacuum bellow which shows the axial and radial tolerances. The limits are $\pm 20\text{mm}$ in the axial and $\pm 2\text{mm}$ in radial range (Figure 4.). Although, during the experimental measurements the radial limits were purposely exceeded (set to $\pm 5\text{mm}$) to provide a better understanding of the operational regime.

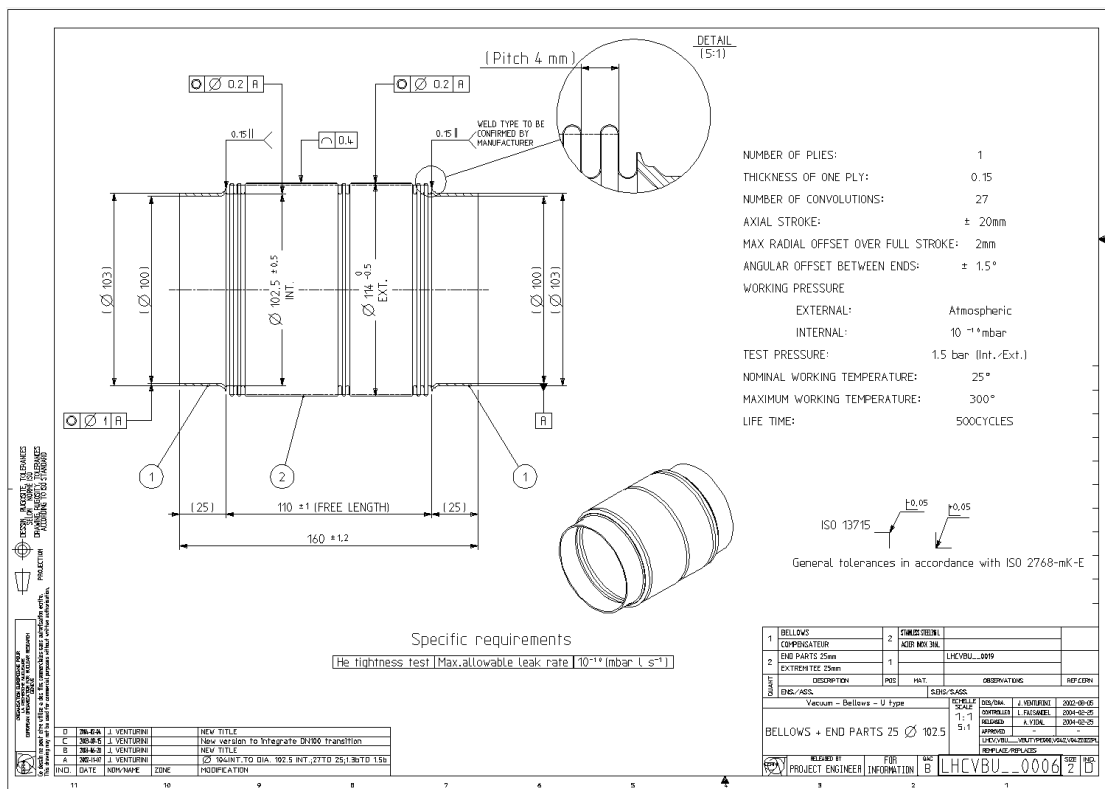


Figure 3: Vacuum Bellow drawing with its mechanical tolerances

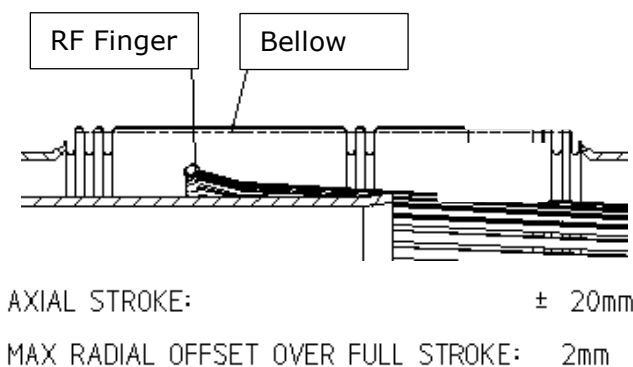


Figure 4: ID80 Vacuum bellow with mechanical tolerances.

2.4 OBSERVED NON-CONFORMITIES

For the proper validation of the measurements, a reference to the most commonly observed non-conformities was done. The purpose is to highlight the main factors which are responsible for the presence of local impedances and electrical breakdowns.

1. When the length L of the RF fingers is $L \leq 0$ (Figure 5.) the installed length of the Warm module is considered non-conform [2] (Figure 6. left).
2. When the RF fingers interfere with the vacuum bellow and buckle (Figure 6. right).

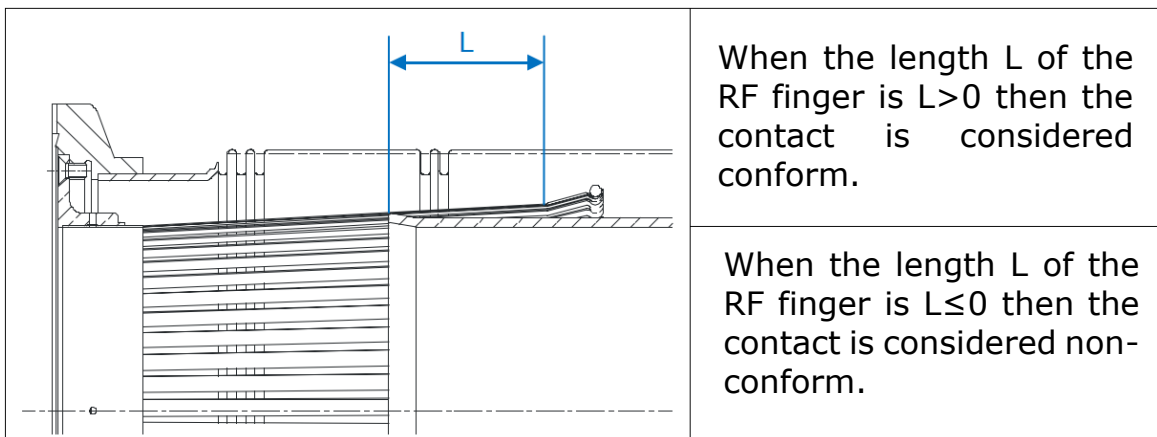


Figure 5: RF fingers conformity constraint.

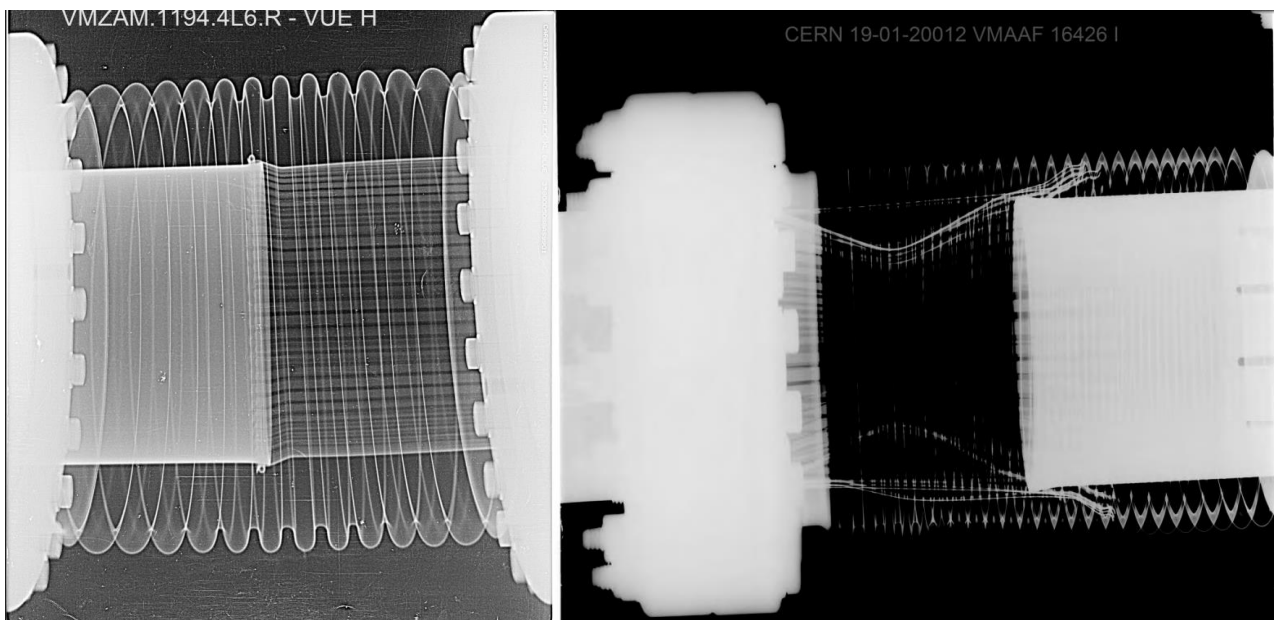


Figure 6: two most common non-conformities .

3. WARM MODULES CONSOLIDATION STUDY

For the consolidation study, data from the Layout database [3] and the CERN Drawing Directory [4] were collected and processed. The main parameters that defined the final number of contact force tests were (Figure 7.):

1. RF Contact geometry (Figure 8.)
 - diameter
 - RF contact length
 - RF Fingers shape
2. Transition Tube geometry (Figure 9.)
3. Length of the tension spring
4. Installed length
5. Bellow limits

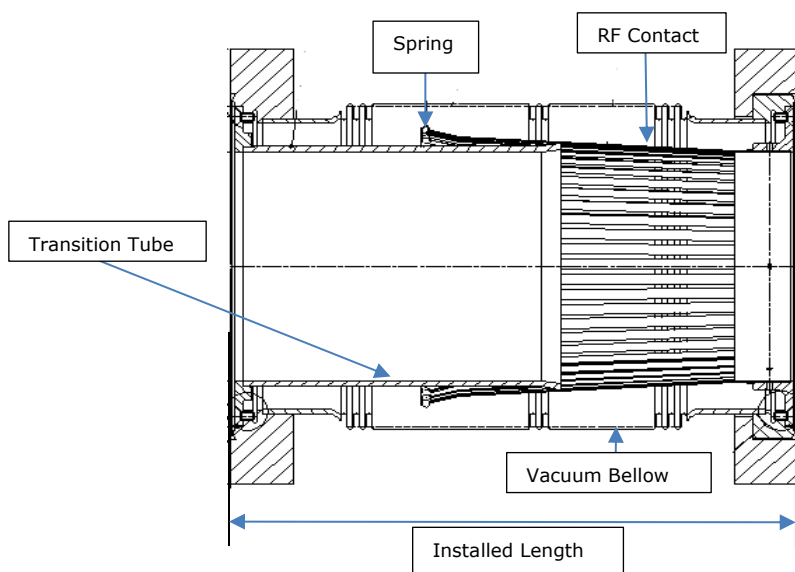


Figure 7: ID80 Warm Module lay-out.

Inside the machine, there are various types of circular RF Contacts that have different RF Fingers length, shape, and aperture size which varies from 57 up to 212mm diameter. Figure 7, showcases an example of two RF contacts that have the same aperture size (80mm) but different shape and length of the RF fingers. This played a major role in the definition of the final number of tests that are described in the next paragraph.

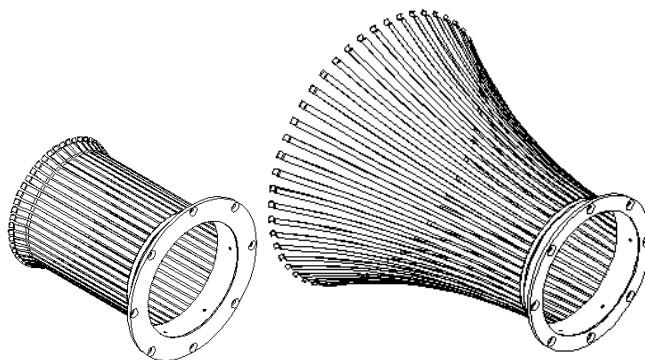


Figure 8: Layout of different types of ID80 RF Contact.

In addition, the parameter that was taken into consideration during the consolidation and measurement process of the transition tubes was the size of the upstream aperture. Figure 8, displays two types of tubes that have the same upstream (80/80) but different downstream aperture size (80/63). For simplification reasons, the downstream aperture size was excluded.

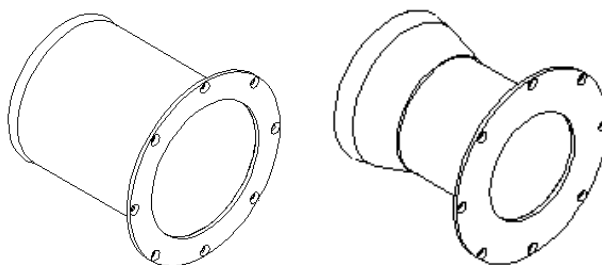


Figure 9: Layout of different types of ID80 Transition tube.

After a careful review of the parameters, Table 1 was created. It shows that 15 contact force tests were adequate to provide representative results to cover the entire number of modules. It also presents the test plan overview including important parameters such as RF contact type, Transition tube, tension spring length and the total number of installed modules per WM type that were used to determine the final number of tests. The number of tests that carried out was 11, covering more than 99% of the total number of circular RF Bridges.

Test number	RF Contact	Number installed in the LHC	Transition Tube	Nominal Tension Spring length (mm)	Status
1	ID80 L1	857	ID 80	260	Tested on 6/12/2018
2	ID63 L1	230	ID 63	215	Tested on 13/12/2018
3	ID80 L2	205	ID 80	260	Tested on 7/12/2018
4	ID212 L1	69	ID 212	660	Tested on 23/1/2019
5	ID130	40	ID 130	400	Tested on 24/1/2019
6	ID100	35	ID 100	320	Tested on 24/1/2019
7	ID63 L2	34	ID 63	215	Tested on 6/2/2019
8	ID66	33	ID 66	230	Tested on 5/2/2019
9	ID60 L1	24	ID 60	190	Tested on 6/2/2019
10	ID60 L2	12	ID 60	190	Tested on 7/2/2019
11	ID57	8	ID 57	185	Tested on 1/11/2018
12	ID212 L2	2	ID 212	660	Not Tested
13	ID90	2	ID 90	290	Not Tested
14	ID196	2	ID196	580	Not Tested
15	ID52	0	ID 52	ID52	Not Tested
Tested Modules		1553			

Table 1: Contact force test overview.

The priority order that was set for the tests is according to the installation occurrences of each type of modules.

4. TEST PROCEDURE

The point where the contact force was measured is located between the transition tube and the RF fingers and it can be clearly seen in Figure 3. Contact that may be present outside the "Contact Point" area is considered non-conform.

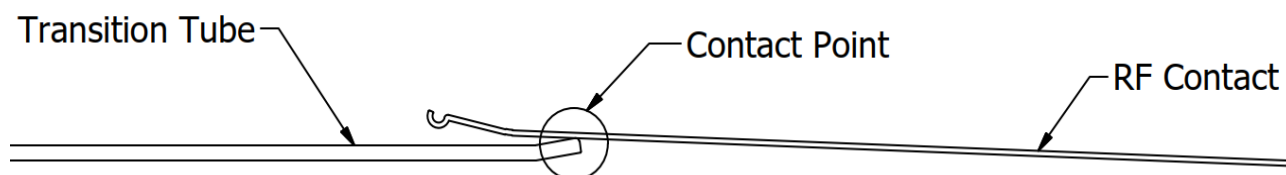


Figure 3: Contact point.

The test-bench used for the measurements is presented in Figure 7. It is made with three manual linear translation stages which allow the movements in 3 axes [5]. On one side of the test-bench, the insert with the RF contact is attached while the transition tube is attached to the other side.

The method that was followed to measure the contact force is:

1. The RF Contact and Transition Tube were set in the nominal installed position (Installed length), the spring was placed on the RF Contact and the thread was attached on one RF Finger that was in contact with the transition tube.
2. A low electrical current (1A indication) was set to pass from RF Contact to the Transition tube.
3. The RF finger was pulled up until the circuit was opened (0A indication).
4. Read the indication of the force gauge (measured in g).

The above procedure was followed in both axial (2mm step) and radial (0.5mm step) direction emulating the operational conditions of the module. The mean value of three individual measurements with different RF Contact orientation (different RF Finger in each measurement) defined the final operational range of the RF Bridges (Mapping).

A more detailed step-by-step description of the installation and measurement procedure is given in the document: "Warm Modules contact force test procedure" [5].

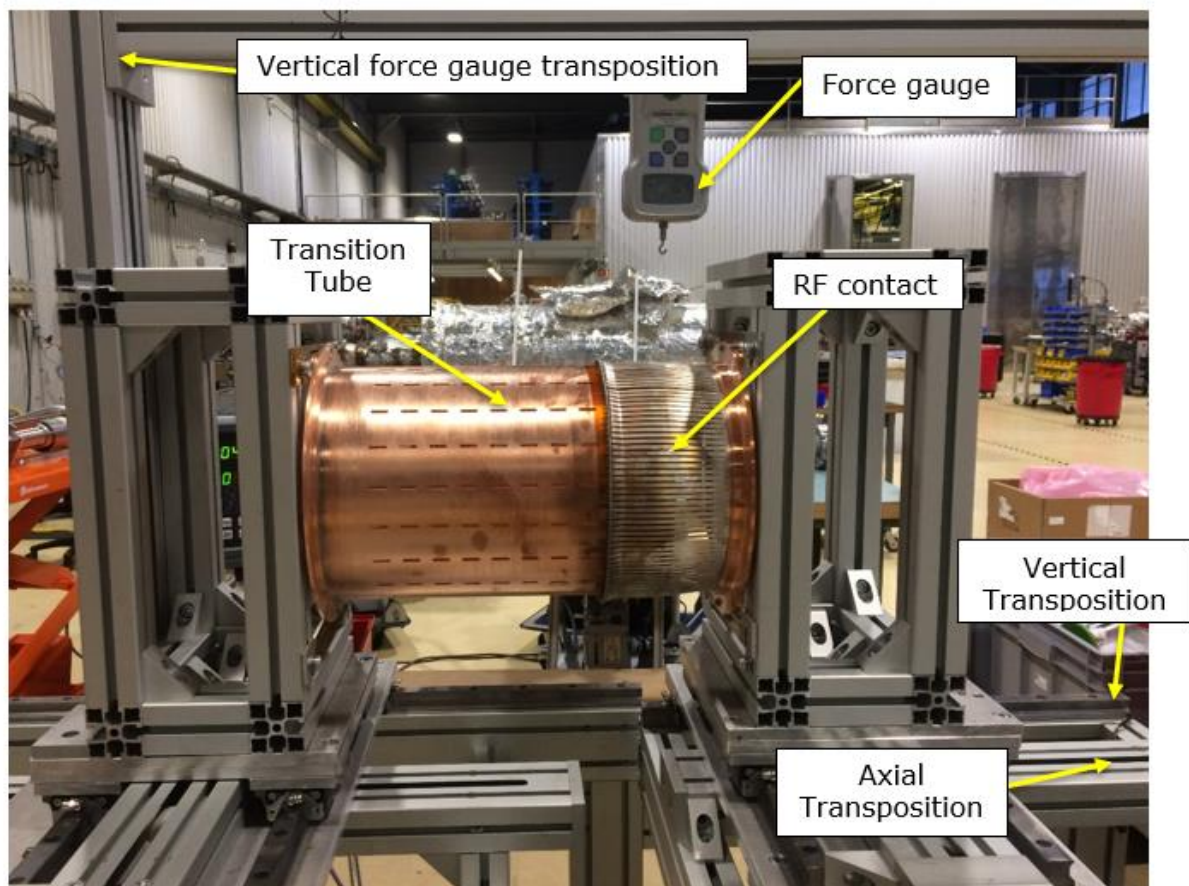


Figure 7: Test-Bench.

5. CONTACT FORCE TEST RESULTS

Table 2, is part of APPENDIX A and represents the Layout of the operational regime map for the ID80 warm modules with installed length 300mm. It also displays the three positions that the module obtains during its operation. In the center of the table, the nominal installed position can be clearly seen along with the Operational Range which is constrained by the bellow in the radial direction. In addition, the position that the module can obtain during the bake-out is presented. The conformity table[6] indicates the areas where the contact force was conform, in the transitional region and non-conform. The radial displacement occurred by moving the RF Contact in the opposite direction of the force applied by the fingers. Then using symmetry assumption, considering that on the other side the bottom finger will have the same behaviour during the deviation, the measured value was mirrored on the radial displacement.

ID80 with installed length 300mm

Installed L (mm)		300														
Axial range(mm)		-8	-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20
Radial Displacement	5	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4.5	10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	13.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3.5	16.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	19.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2.5	22.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	26.0	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0
	1.5	30.1	9.6	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	33.4	19.1	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.5	37.2	25.5	8.8	0	0	0	0	0	0	0	0	0	0	0	0
	0	39.7	33.6	16.8	3	0	0	0	0	0	0	0	0	0	0	0
	-0.5	37.2	25.5	8.8	0	0	0	0	0	0	0	0	0	0	0	0
	-1	33.4	19.1	0	0	0	0	0	0	0	0	0	0	0	0	0
	-1.5	30.1	9.6	0	0	0	0	0	0	0	0	0	0	0	0	0
	-2	26.0	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0
	-2.5	22.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-3	19.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-3.5	16.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4	13.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4.5	10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-5	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table 2: Operational range of ID80 warm modules with installed length 300mm

Conform:	x ≥ 10g
Transitional region:	5 ≤ x < 10g
Non-conform:	x < 5g

Warm Module type

VMAAB	VMAAF	VMHAB	VMACB	VMACE	VMACK	VMANC	VMANE	VMZAF
VMAAE	VMGAB	VMJAE	VMACD	VMACF	VMANB	VMAND	VMZAE	VMZBA

It is clear that the contact force in the nominal position is in the non-conform regime. This shows that the specific family of warm modules requires further study in order to improve the operational conformity.

6. REFERENCES

- [1] LHC Design Report
- [2] A. Vidal, A-M. Piguiet, Module d'interconnexion dans less LSS "Warm Module" en 5L6 et 4L6, (2012).
- [3] CERN Layout Database.
- [4] CERN Drawing Directory.
- [5] V. Arapoglou, Warm Module contact force test procedure, (2019).
- [6] C. Blanch, CERN, EDMS 1391490

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P. Gebolis, CERN, Geneva. RF Clamp for spring support in LHC Vacuum warm modules, 2017.

F. De Simone, CERN, Geneva. Etude du comportement des différents modules de transitions du LHC, 2015.

8. APPENDIX A: EXPERIMENTAL RESULTS

8.1 ID80 OPERATIONAL RANGE

ID80 with installed length 300mm

Installed L (mm)					300											
Axial range(mm)	-8	-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20	
5	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
4.5	10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
4	13.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
3.5	16.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
3	19.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2.5	22.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2	26.0	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	
1.5	30.1	9.6	0	0	0	0	0	0	0	0	0	0	0	0	0	
1	33.4	19.1	0	0	0	0	0	0	0	0	0	0	0	0	0	
0.5	37.2	25.5	8.8	0	0	0	0	0	0	0	0	0	0	0	0	
0	39.7	33.6	16.8	3	0	0	0	0	0	0	0	0	0	0	0	
-0.5	37.2	25.5	8.8	0	0	0	0	0	0	0	0	0	0	0	0	
-1	33.4	19.1	0	0	0	0	0	0	0	0	0	0	0	0	0	
-1.5	30.1	9.6	0	0	0	0	0	0	0	0	0	0	0	0	0	
-2	26.0	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	
-2.5	22.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-3	19.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-3.5	16.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-4	13.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-4.5	10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
-5	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table A.1: Map ID80 with nominal length 300mm.

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

Warm module type

VMAAB	VMAAF	VMHAB	VMACB	VMACE	VMACK	VMANC	VMANE	VMZAF	VMZBA	VMJND
VMAAE	VMGAB	VMJAE	VMACD	VMACF	VMANB	VMAND	VMANF	VMZAE	VMJNC	

ID80 with installed length 200mm

Installed L (mm)		200													
Axial range(mm)		-4	-2	0	2	4	6	8	10	12	14	16	18	20	
Radial Displacement	5	8.9	0	0	0	0	0	0	0	0	0	0	0	0	
	4.5	10.4	0	0	0	0	0	0	0	0	0	0	0	0	
	4	13.8	0	0	0	0	0	0	0	0	0	0	0	0	
	3.5	16.3	0	0	0	0	0	0	0	0	0	0	0	0	
	3	19.7	0	0	0	0	0	0	0	0	0	0	0	0	
	2.5	22.7	0	0	0	0	0	0	0	0	0	0	0	0	
	2	26.0	5.5	0	0	0	0	0	0	0	0	0	0	0	
	1.5	30.1	9.6	0	0	0	0	0	0	0	0	0	0	0	
	1	33.4	19.1	0	0	0	0	0	0	0	0	0	0	0	
	0.5	37.2	25.5	8.8	0	0	0	0	0	0	0	0	0	0	
	0	39.7	33.6	16.8	3.0	0	0	0	0	0	0	0	0	0	
	-0.5	37.2	25.5	8.8	0	0	0	0	0	0	0	0	0	0	
	-1	33.4	19.1	0	0	0	0	0	0	0	0	0	0	0	
	-1.5	30.1	9.6	0	0	0	0	0	0	0	0	0	0	0	
	-2	26.0	5.5	0	0	0	0	0	0	0	0	0	0	0	
	-2.5	22.7	0	0	0	0	0	0	0	0	0	0	0	0	
	-3	19.7	0	0	0	0	0	0	0	0	0	0	0	0	
	-3.5	16.3	0	0	0	0	0	0	0	0	0	0	0	0	
	-4	13.8	0	0	0	0	0	0	0	0	0	0	0	0	
	-4.5	10.4	0	0	0	0	0	0	0	0	0	0	0	0	
-5	8.9	0	0	0	0	0	0	0	0	0	0	0	0		

Table A.2: Map ID80 with nominal length 200mm.

Warm module type

VMAAA	VMHAA	VMANA
VMAAQ	VMACQ	VMACA

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

ID80 with installed length 290mm

Installed L (mm)		290																			
Axial range(mm)		-18	-16	-14	-12	-10	-8	-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20
Radial Displacement	5	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4.5	10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	13.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3.5	16.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	19.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2.5	22.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	26.0	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1.5	30.1	9.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	33.4	19.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9
	0.5	37.2	25.5	8.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	1.8	4.1
	0	39.7	33.6	16.8	3.0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	3.9	6.0	10.0
	-0.5	37.2	25.5	8.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	1.8	4.1
	-1	33.4	19.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9
	-1.5	30.1	9.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-2	26.0	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-2.5	22.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-3	19.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-3.5	16.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4	13.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4.5	10.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-5	8.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.3: Map ID80 with nominal length 290mm.

Warm module type

- VMAAP
- VMAAC

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

ID80 with installed length 400mm

Installed L (mm)		400																				
Axial range(mm)		-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20
Radial Displacement	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	1.9	2.5	4.4
	0.5	8.8	0	0	0	0	0	0	0	0	0	0	0	0	0.9	1.8	4.1	5.2	9.6	12.5	20.4	12.5
	0	16.8	3	0	0	0	0	0	0	0	0	0	0	0.9	3.9	6.0	10.0	12.6	16.8	20.4	12.5	12.5
	-0.5	8.8	0	0	0	0	0	0	0	0	0	0	0	0	0.9	1.8	4.1	5.2	9.6	12.5	20.4	12.5
	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.9	1.9	2.5	4.4
	-1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.3
	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table A.4: Map ID80 with nominal length 400mm.

Warm module type

- VMIAA
- VMIAL

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non-conform:	$x < 5g$

ID80 with installed length 220mm

Installed L (mm)		220											
Axial range(mm)		-2	0	2	4	6	8	10	12	14	16	18	20
Radial Displacement	5	8.9	0	0	0	0	0	0	0	0	0	0	0
	4.5	10.4	0	0	0	0	0	0	0	0	0	0	0
	4	13.8	0	0	0	0	0	0	0	0	0	0	0
	3.5	16.3	0	0	0	0	0	0	0	0	0	0	0
	3	19.7	0	0	0	0	0	0	0	0	0	0	0
	2.5	22.7	0	0	0	0	0	0	0	0	0	0	0
	2	26.0	5.5	0	0	0	0	0	0	0	0	0	0
	1.5	30.1	9.6	0	0	0	0	0	0	0	0	0	0
	1	33.4	19.1	0	0	0	0	0	0	0	0	0	0
	0.5	37.2	25.5	8.8	0	0	0	0	0	0	0	0	0
	0	39.7	33.6	16.8	3.0	0	0	0	0	0	0	0	0
	-0.5	37.2	25.5	8.8	0	0	0	0	0	0	0	0	0
	-1	33.4	19.1	0	0	0	0	0	0	0	0	0	0
	-1.5	30.1	9.6	0	0	0	0	0	0	0	0	0	0
	-2	26.0	5.5	0	0	0	0	0	0	0	0	0	0
	-2.5	22.7	0	0	0	0	0	0	0	0	0	0	0
	-3	19.7	0	0	0	0	0	0	0	0	0	0	0
	-3.5	16.3	0	0	0	0	0	0	0	0	0	0	0
	-4	13.8	0	0	0	0	0	0	0	0	0	0	0
	-4.5	10.4	0	0	0	0	0	0	0	0	0	0	0
-5	8.9	0	0	0	0	0	0	0	0	0	0	0	

Table A.5: Map ID80 with nominal length 220mm.

Warm Module type

- VMTBA
- VMTBG

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

8.2 ID63 OPERATIONAL RANGE

ID63 with installed length 260mm (Cold sector)

	Installed L (mm)	260												
	Axial range(mm)	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0	2	4
Radial Displacement	5	0	0	0	0	0	0	0	0	0	0	0	0	0
	4.5	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0
	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0
	2.5	0	0	0	0	0	0	0	0	0	0	1.3	2.5	3.3
	2	0	0	0	0	0	0	1.0	1.5	2.5	3.4	6.8	7.7	11.2
	1.5	0.6	0.9	0.7	0.4	1.3	2.4	3.3	5.1	6.7	8.7	12.7	16.6	21.8
	1	1.9	1.5	1.8	2.5	3.9	6.1	7.2	9.9	12.0	16.9	22.4	28.0	33.7
	0.5	3.0	4.1	4.8	5.7	7.5	10.3	13.2	16.5	20.8	26.3	33.9	39.2	50.1
	0	7.0	8.7	10.2	11.6	13.8	18.2	20.8	25.4	30.6	35.9	43.2	53.4	64.1
	-0.5	3.0	4.1	4.8	5.7	7.5	10.3	13.2	16.5	20.8	26.3	33.9	39.2	50.1
	-1	1.9	1.5	1.8	2.5	3.9	6.1	7.2	9.9	12.0	16.9	22.4	28.0	33.7
	-1.5	0.6	0.9	0.7	0.4	1.3	2.4	3.3	5.1	6.7	8.7	12.7	16.6	21.8
	-2	0	0	0	0	0	0	1.0	1.5	2.5	3.4	6.8	7.7	11.2
	-2.5	0	0	0	0	0	0	0	0	0	0	1.3	2.5	3.3
	-3	0	0	0	0	0	0	0	0	0	0	0	0	0
	-3.5	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4.5	0	0	0	0	0	0	0	0	0	0	0	0	0
-5	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table A.6: Map ID63 with nominal length 260mm.

Warm module type

VMABC260	VMAOC260
VMABD260	VMAOD260

Conform:	x≥10g
Transitional region:	5≤x<10g
Non- conform:	x< 5g

ID63 with installed length 200mm

Radial Displacement	Installed L (mm)			200										
	Axial range(mm)	-4	-2	0	2	4	6	8	10	12	14	16	18	20
	5	5.7	0	0	0	0	0	0	0	0	0	0	0	0
	4.5	8.7	0	0	0	0	0	0	0	0	0	0	0	0
	4	11.3	0	0	0	0	0	0	0	0	0	0	0	0
	3.5	15.6	0	0	0	0	0	0	0	0	0	0	0	0
	3	19.2	2	0	0	0	0	0	0	0	0	0	0	0
	2.5	22.8	4.2	0	0	0	0	0	0	0	0	0	0	0
	2	26.7	6.6	0	0	0	0	0	0	0	0	0	0	0
	1.5	29.2	7.9	0	0	0	0	0	0	0	0	0	0	0
	1	33.2	10.8	0	0	0	0	0	0	0	0	0	0	0.7
	0.5	39.1	12.6	0	0	0	0	0	0	0	0	0	1.5	1.8
	0	40.6	17.4	0	0	0	0	0	0	0	0	1.5	2.5	3.5
	-0.5	39.1	12.6	0	0	0	0	0	0	0	0	0	1.5	1.8
	-1	33.2	10.8	0	0	0	0	0	0	0	0	0	0	0.7
	-1.5	29.2	7.9	0	0	0	0	0	0	0	0	0	0	0
	-2	26.7	6.6	0	0	0	0	0	0	0	0	0	0	0
	-2.5	22.8	4.2	0	0	0	0	0	0	0	0	0	0	0
	-3	19.2	1.8	0	0	0	0	0	0	0	0	0	0	0
	-3.5	15.6	0.0	0	0	0	0	0	0	0	0	0	0	0
	-4	11.3	0	0	0	0	0	0	0	0	0	0	0	0
	-4.5	8.7	0	0	0	0	0	0	0	0	0	0	0	0
	-5	5.7	0	0	0	0	0	0	0	0	0	0	0	0

Table A.7: Map ID63 with nominal length 200mm.

Warm module type

VMABA	VMAOA
VMGBA	

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

ID63 with installed length 300mm

Installed L (mm)		300													
Axial range(mm)		-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20
Radial Displacement	5	5.7	0	0	0	0	0	0	0	0	0	0	0	0	0
	4.5	8.7	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	11.3	0	0	0	0	0	0	0	0	0	0	0	0	0
	3.5	15.6	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	19.2	2	0	0	0	0	0	0	0	0	0	0	0	0
	2.5	22.8	4.2	0	0	0	0	0	0	0	0	0	0	0	0
	2	26.7	6.6	0	0	0	0	0	0	0	0	0	0	0	0
	1.5	29.2	7.9	0	0	0	0	0	0	0	0	0	0	0	0.6
	1	33.2	10.8	0	0	0	0	0	0	0	0	0	0	0.7	1.9
	0.5	39.1	12.6	0	0	0	0	0	0	0	0	0	1.5	1.8	3.0
	0	40.6	17.4	0	0	0	0	0	0	0	0	1.5	2.5	3.5	7.0
	-0.5	39.1	12.6	0	0	0	0	0	0	0	0	0	1.5	1.8	3.0
	-1	33.2	10.8	0	0	0	0	0	0	0	0	0	0	0.7	1.9
	-1.5	29.2	7.9	0	0	0	0	0	0	0	0	0	0	0	0.6
	-2	26.7	6.6	0	0	0	0	0	0	0	0	0	0	0	0
	-2.5	22.8	4.2	0	0	0	0	0	0	0	0	0	0	0	0
	-3	19.2	1.8	0	0	0	0	0	0	0	0	0	0	0	0
	-3.5	15.6	0.0	0	0	0	0	0	0	0	0	0	0	0	0
	-4	11.3	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4.5	8.7	0	0	0	0	0	0	0	0	0	0	0	0	0
-5	5.7	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table A.8: Map ID63 with nominal length 300mm.

Warm module type

VMABC	VMABF	VMAD E	VMGDB
VMABE	VMABD	VMADF	VMAOB

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

8.3 ID80 (L=181) OPERATIONAL RANGE

ID80 (L=181) with installed length 460,520mm

Installed L (mm)		460,520																	
Axial range (mm)		-10	-8	-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20	14	16
Radial Displacement	5	2.8	3.7	3.6	3.4	3.3	3.1	3.4	3.2	3.1	2.8	2.7	2.7	2.7	2.5	2.5	2.4	2.4	1.9
	4.5	4.0	4.6	4.7	4.4	4.3	4.2	4.0	3.9	3.8	3.5	3.3	3.3	3.2	3.1	3.0	2.8	3.0	2.8
	4	4.8	5.0	5.3	5.2	4.9	4.9	4.6	4.4	4.4	4.0	3.8	3.8	3.8	3.7	3.7	3.1	3.6	3.3
	3.5	5.7	5.7	5.8	6.0	5.6	5.5	5.3	5.1	5.0	4.7	4.5	4.5	4.4	4.2	4.2	3.7	3.9	3.7
	3	6.6	6.3	6.5	6.6	6.2	5.9	5.8	5.7	5.5	5.2	5.1	5.0	5.1	4.9	4.7	4.2	4.3	4.1
	2.5	7.3	6.9	7.1	7.0	6.9	6.6	6.3	6.3	6.1	5.8	5.8	5.3	5.4	5.2	4.8	4.7	5.2	4.6
	2	7.9	7.7	7.9	7.6	7.5	7.3	6.9	6.9	6.7	6.4	6.3	5.9	5.9	5.8	5.7	5.8	5.9	5.4
	1.5	8.7	8.5	8.6	8.5	8.5	7.9	7.7	7.7	7.5	7.2	7.0	6.4	6.9	6.4	6.6	6.3	6.3	5.9
	1	9.1	8.7	8.7	8.6	8.5	8.1	7.9	7.6	7.5	7.3	7.0	6.9	6.8	6.7	6.7	6.6	6.3	6.3
	0.5	9.9	9.7	9.7	9.3	9.4	8.8	8.7	8.7	8.5	8.2	8.2	8.0	7.8	7.4	7.5	7.1	7.1	6.9
	0	10.9	10.2	10.5	10.2	10.0	9.8	9.5	9.1	9.2	8.8	8.5	8.4	8.2	7.8	7.8	7.6	7.5	7.2
	-0.5	9.9	9.7	9.7	9.3	9.4	8.8	8.7	8.7	8.5	8.2	8.2	8.0	7.8	7.4	7.5	7.1	7.1	6.9
	-1	9.1	8.9	9.0	8.9	8.9	8.3	8.0	7.9	7.7	7.5	7.3	7.1	7.3	6.9	6.9	6.7	6.6	6.3
	-1.5	8.7	8.4	8.3	8.2	8.1	7.7	7.5	7.5	7.2	7.0	6.7	6.3	6.4	6.2	6.4	6.2	6.0	5.9
	-2	7.9	7.7	7.9	7.6	7.5	7.3	6.9	6.9	6.7	6.4	6.3	5.9	5.9	5.8	5.7	5.8	5.9	5.4
	-2.5	7.3	6.9	7.1	7.0	6.9	6.6	6.3	6.3	6.1	5.8	5.8	5.3	5.4	5.2	4.8	4.7	5.2	4.6
	-3	6.6	6.3	6.5	6.6	6.2	5.9	5.8	5.7	5.5	5.2	5.1	5.0	5.1	4.9	4.7	4.2	4.3	4.1
	-3.5	5.7	5.7	5.8	6.0	5.6	5.5	5.3	5.1	5.0	4.7	4.5	4.5	4.4	4.2	4.2	3.7	3.9	3.7
	-4	4.8	5.0	5.3	5.2	4.9	4.9	4.6	4.4	4.4	4.0	3.8	3.8	3.8	3.7	3.7	3.1	3.6	3.3
	-4.5	4.0	4.6	4.7	4.4	4.3	4.2	4.0	3.9	3.8	3.5	3.3	3.3	3.2	3.1	3.0	2.8	3.0	2.8
-5	2.8	3.7	3.6	3.4	3.3	3.1	3.4	3.2	3.1	2.8	2.7	2.7	2.7	2.5	2.5	2.4	2.4	1.9	

Table A.9: Map ID80 L=181 with nominal length 460,520mm.

Warm module type

VMTNA	VMTQA	VMTQC	VMTQE	VMTIA	VMTND
VMTNB	VMTQB	VMTQD	VMTQF	VMTNC	

Conform:	x≥10g
Transitional region:	5≤x<10g
Non- conform:	x< 5g

8.4 ID212 OPERATIONAL RANGE

ID212 with installed length 400mm

	Installed L (mm)	400											
	Axial range(mm)	-2	0	2	4	6	8	10	12	14	16	18	20
Radial Displacement	5	5.7	6.1	6.6	6.9	7.1	7.2	7.3	7.1	6.4	4.1	3.1	1.8
	4.5	6.5	7.0	7.6	7.7	8.3	8.4	8.7	9.0	9.0	7.9	7.1	6.1
	4	7.3	8.0	8.5	9.5	9.2	9.6	10.5	10.6	10.8	10.9	10.2	10.0
	3.5	8.2	9.0	9.6	10.5	10.7	10.9	12.1	12.1	12.7	12.9	13.2	13.0
	3	8.8	9.9	10.8	11.1	12.0	12.4	13.3	13.8	14.4	14.7	15.2	15.7
	2.5	9.9	10.9	11.9	12.7	13.1	14.1	14.7	15.3	15.9	16.8	17.5	17.9
	2	10.9	12.0	13.0	13.9	14.6	15.1	16.3	16.9	17.9	18.6	19.6	20.2
	1.5	11.9	13.1	14.3	14.8	15.9	16.7	17.6	18.5	19.6	20.6	21.5	22.4
	1	12.5	14.1	15.3	16.2	17.1	18.2	19.0	20.2	21.4	22.3	23.2	24.1
	0.5	13.5	15.1	16.5	17.4	18.5	19.4	20.4	22.0	23.1	23.9	25.3	26.5
	0	14.3	16.0	17.0	18.3	16.4	20.4	21.6	23.2	24.2	24.7	27.0	27.8
	-0.5	13.5	15.1	16.5	17.4	18.5	19.4	20.4	22.0	23.1	23.9	25.3	26.5
	-1	12.5	14.1	15.3	16.2	17.1	18.2	19.0	20.2	21.4	22.3	23.2	24.1
	-1.5	11.9	13.1	14.3	14.8	15.9	16.7	17.6	18.5	19.6	20.6	21.5	22.4
	-2	10.9	12.0	13.0	13.9	14.6	15.1	16.3	16.9	17.9	18.6	19.6	20.2
	-2.5	9.9	10.9	11.9	12.7	13.1	14.1	14.7	15.3	15.9	16.8	17.5	17.9
	-3	8.8	9.9	10.8	11.1	12.0	12.4	13.3	13.8	14.4	14.7	15.2	15.7
	-3.5	8.2	9.0	9.6	10.5	10.7	10.9	12.1	12.1	12.7	12.9	13.2	13.0
	-4	7.3	8.0	8.5	9.5	9.2	9.6	10.5	10.6	10.8	10.9	10.2	10.0
	-4.5	6.5	7.0	7.6	7.7	8.3	8.4	8.7	9.0	9.0	7.9	7.1	6.1
-5	5.7	6.1	6.6	6.9	7.1	7.2	7.3	7.1	6.4	4.1	3.1	1.8	

Table A.10: Map ID212 with nominal length 400mm.

Warm module type

VMBGA	VMBGD	VMEGA	VMQGG
VMBGC	VMBGG	VMEGB	

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

8.5 ID130 OPERATIONAL RANGE

ID130 with installed length 350,250mm

	Installed L (mm)				350,250				
	Axial range(mm)	-6	-4	-2	0	2	4	6	8
Radial Displacement	5	10.8	11.2	11.5	7.7	2.7	1.6	0.0	0.0
	4.5	12.0	12.7	12.5	11.1	5.5	2.9	0.7	0.0
	4	13.1	14.1	14.6	13.6	8.0	4.8	1.6	0.3
	3.5	14.8	15.7	16.0	15.8	11.2	8.6	3.6	1.3
	3	15.5	16.9	17.7	18.3	13.7	11.4	7.4	2.7
	2.5	17.5	18.3	19.6	20.1	17.0	14.0	10.8	5.7
	2	18.9	20.7	21.0	21.9	19.7	16.8	14.1	8.8
	1.5	21.8	22.7	23.4	23.6	22.5	19.7	16.9	12.2
	1	24.3	25.3	25.6	25.6	25.6	23.9	20.2	15.0
	0.5	25.3	26.3	26.8	28.0	28.6	28.2	23.7	19.0
	0	25.9	27.8	28.7	29.2	29.6	30.2	26.0	21.2
	-0.5	25.3	26.3	26.8	28.0	28.6	28.2	23.7	19.0
	-1	24.3	25.3	25.6	25.6	25.6	23.9	20.2	15.0
	-1.5	21.8	22.7	23.4	23.6	22.5	19.7	16.9	12.2
	-2	18.9	20.7	21.0	21.9	19.7	16.8	14.1	8.8
	-2.5	17.5	18.3	19.6	20.1	17.0	14.0	10.8	5.7
	-3	15.5	16.9	17.7	18.3	13.7	11.4	7.4	2.7
	-3.5	14.8	15.7	16.0	15.8	11.2	8.6	3.6	1.3
	-4	13.1	14.1	14.6	13.6	8.0	4.8	1.6	0.3
	-4.5	12.0	12.7	12.5	11.1	5.5	2.9	0.7	0.0
-5	10.8	11.2	11.5	7.7	2.7	1.6	0.0	0.0	

Table A.11: Map ID130 with nominal length 350,250mm.

Warm module type

VMZAH	VMZAL
VMZAK	VMZAN

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

8.6 ID100 OPERATIONAL RANGE

ID100 with installed length 350,206mm

Installed L (mm)		350,206											
Axial range(mm)		-2	0	2	4	6	8	10	12	14	16	18	20
Radial Displacement	5	0	0	0	0	0	0	0	0	0	0	0	0
	4.5	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0
	3.5	0	0	0	0	0	0	0	0	0	0	0	0
	3	0.7	0.0	0	0	0	0	0	0	0	0	0	0
	2.5	3.6	0.0	0	0	0	0	0	0	0	0	0	0
	2	7.3	0.8	0	0	0	0	0	0	0	0	0	0
	1.5	11.5	2.9	1.8	0.8	0.5	0.0	0	0	0	0.3	0.4	
	1	15.0	6.8	5.0	4.0	3.4	1.9	2.5	3.3	3.6	4.8	4.9	
	0.5	20.5	10.6	9.0	8.0	7.1	6.7	4.8	6.5	7.8	8.8	9.8	
	0	25.7	17.1	14.8	13.1	12.5	11.1	9.6	11.4	12.8	13.7	14.7	
	-0.5	20.5	10.6	9.0	8.0	7.1	6.7	4.8	6.5	7.8	8.8	9.8	
	-1	15.0	6.8	5.0	4.0	3.4	1.9	2.5	3.3	3.6	4.8	4.9	
	-1.5	11.5	2.9	1.8	0.8	0.5	0.0	0	0	0	0.3	0.4	
	-2	7.3	0.8	0	0	0	0	0	0	0	0.0	0	
	-2.5	3.6	0.0	0	0	0	0	0	0	0	0	0	
	-3	0.7	0.0	0	0	0	0	0	0	0	0	0	
	-3.5	0	0	0	0	0	0	0	0	0	0	0	
	-4	0	0	0	0	0	0	0	0	0	0	0	
	-4.5	0	0	0	0	0	0	0	0	0	0	0	
-5	0	0	0	0	0	0	0	0	0	0	0		

Table A.12: Map ID100 with nominal length 350,206mm.

Warm module type

VMZAC	VMZAG
VMZAD	VMZAM

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

8.7 ID63 L2 OPERATIONAL RANGE

ID63 L2 with installed length 90mm

Installed L (mm)						90	
Axial range(mm)		-8	-6	-4	-2	0	2
Radial Displacement	5	0	0	0	0	0	0
	4.5	4.8	0	0	0	0	0
	4	17.2	0	0	0	0	0
	3.5	22.3	22.2	10.3	0	0	0
	3	28.2	40.3	32.2	16.2	8.8	10.0
	2.5	34.2	55.0	54.1	43.2	37.2	41.3
	2	43.5	67.8	72.4	71.4	68.1	74.0
	1.5	53.8	81.8	87.3	93.7	99.0	109.0
	1	68.3	95.0	101.2	111.7	122.7	138.9
	0.5	78.6	110.1	117.0	128.2	144.3	161.9
	0	86.1	117.9	129.7	140.0	157.9	174.9
	-0.5	78.6	110.1	117.0	128.2	144.3	161.9
	-1	68.3	95.0	101.2	111.7	122.7	138.9
	-1.5	53.8	81.8	87.3	93.7	99.0	109.0
	-2	43.5	67.8	72.4	71.4	68.1	74.0
	-2.5	34.2	55.0	54.1	43.2	37.2	41.3
	-3	28.2	40.3	32.2	16.2	8.8	10.0
	-3.5	22.3	22.2	10.3	0	0	0
	-4	17.2	0	0	0	0	0
	-4.5	4.8	0	0	0	0	0
-5	0	0	0	0	0	0	

Table A.13: Map ID63 L2 with nominal length 90mm.

Warm module type

VMDBA

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

ID 63 L2 with installed length 100mm

Installed L (mm)					100		
Axial range(mm)		-6	-4	-2	0	2	4
Radial Displacement	5	0	0	0	0	0	0
	4.5	4.8	0	0	0	0	0
	4	17.2	0	0	0	0	0
	3.5	22.3	22.2	10.3	0	0	0
	3	28.2	40.3	32.2	16.2	8.8	10.0
	2.5	34.2	55.0	54.1	43.2	37.2	41.3
	2	43.5	67.8	72.4	71.4	68.1	74.0
	1.5	53.8	81.8	87.3	93.7	99.0	109.0
	1	68.3	95.0	101.2	111.7	122.7	138.9
	0.5	78.6	110.1	117.0	128.2	144.3	161.9
	0	86.1	117.9	129.7	140.0	157.9	174.9
	-0.5	78.6	110.1	117.0	128.2	144.3	161.9
	-1	68.3	95.0	101.2	111.7	122.7	138.9
	-1.5	53.8	81.8	87.3	93.7	99.0	109.0
	-2	43.5	67.8	72.4	71.4	68.1	74.0
	-2.5	34.2	55.0	54.1	43.2	37.2	41.3
	-3	28.2	40.3	32.2	16.2	8.8	10.0
	-3.5	22.3	22.2	10.3	0	0	0
	-4	17.2	0	0	0	0	0
	-4.5	4.8	0	0	0	0	0
-5	0	0	0	0	0	0	

Table A.14: Map ID63 L2 with nominal length 100mm.

Warm module type

VMHDA

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non-conform:	$x < 5g$

8.8 ID66 OPERATIONAL RANGE

ID 66 with installed length 260mm (Cold Sector)

Installed L (mm)											260			
Axial range(mm)	-20	-18	-16	-14	-12	-10	-8	-6	-4	-2	0	2	4	6
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2
2	0	0	0	0	0	0.4	1.4	1.9	3.1	4.5	7.7	10.1	13.7	18.1
1.5	1.7	1.8	2.8	3.4	3.9	5.9	7.7	8.5	11.0	13.4	15.7	19.5	25.4	31.6
1	5.7	6.3	7.0	7.5	8.2	10.9	13.3	15.3	18.1	20.8	26.4	30.1	37.1	47.9
0.5	9.1	9.8	10.6	12.4	14.2	16.7	19.2	22.4	24.3	28.9	34.5	44.9	49.3	61.3
0	13	14.1	15.8	17.0	19.7	22.7	24.9	28.7	33.7	38.6	43.9	52.8	59.3	69.9
-0.5	9.1	9.8	10.6	12.4	14.2	16.7	19.2	22.4	24.3	28.9	34.5	44.9	49.3	61.3
-1	5.7	6.3	7.0	7.5	8.2	10.9	13.3	15.3	18.1	20.8	26.4	30.1	37.1	47.9
-1.5	1.7	1.8	2.8	3.4	3.9	5.9	7.7	8.5	11.0	13.4	15.7	19.5	25.4	31.6
-2	0	0	0	0	0	0.4	1.4	1.9	3.1	4.5	7.7	10.1	13.7	18.1
-2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2
-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A.15: Map ID66 with nominal length 260mm.

Warm module type

VMARC260	VMAWC260
VMARD260	VMAWD260

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

ID 66 with installed length 300mm

Installed L (mm)		300														
Axial range(mm)		-8	-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20
Radial Displacement	5	16.8	16.4	6.8	0	0	0	0	0	0	0	0	0	0	0	0
	4.5	19.5	19.6	8.2	0	0	0	0	0	0	0	0	0	0	0	0
	4	21.7	22.6	9.5	0.4	0	0	0	0	0	0	0	0	0	0	0
	3.5	24.0	26.8	10.1	1.4	0	0	0	0	0	0	0	0	0	0	0
	3	26.7	30.7	12.8	2.5	1.2	0	0	0	0	0	0	0	0	0	0
	2.5	30.5	34.1	14.5	3.1	2.1	1.3	0	0	0	0	0	0	0	0	0
	2	34.1	36.4	16.4	3.9	3.7	2.5	1.9	0.9	0	0	0	0	0	0	0
	1.5	37.1	38.6	17.7	6.3	5.7	4.6	4.3	2.5	1.5	0.0	0.0	0.7	0.7	0.8	1.7
	1	40.1	42.2	21.1	9.7	8.3	6.8	5.8	5.6	4.6	2.9	2.3	3.4	3.9	4.7	5.7
	0.5	41.9	45.9	24.4	11.7	10.2	8.8	9.1	8.4	8.3	6.4	5.9	6.7	6.7	8.4	9.1
	0	44.3	48.8	33.5	15.6	14.3	13.0	12.2	11.7	10.6	9.9	10.2	10.7	11.6	12.0	13.0
	-0.5	41.9	45.9	24.4	11.7	10.2	8.8	9.1	8.4	8.3	6.4	5.9	6.7	6.7	8.4	9.1
	-1	40.1	42.2	21.1	9.7	8.3	6.8	5.8	5.6	4.6	2.9	2.3	3.4	3.9	4.7	5.7
	-1.5	37.1	38.6	17.7	6.3	5.7	4.6	4.3	2.5	1.5	0.0	0.0	0.7	0.7	0.8	1.7
	-2	34.1	36.4	16.4	3.9	3.7	2.5	1.9	0.9	0	0	0	0	0	0	0
	-2.5	30.5	34.1	14.5	3.1	2.1	1.3	0	0	0	0	0	0	0	0	0
	-3	26.7	30.7	12.8	2.5	1.2	0	0	0	0	0	0	0	0	0	0
	-3.5	24.0	26.8	10.1	1.4	0	0	0	0	0	0	0	0	0	0	0
	-4	21.7	22.6	9.5	0.4	0	0	0	0	0	0	0	0	0	0	0
	-4.5	19.5	19.6	8.2	0	0	0	0	0	0	0	0	0	0	0	0
-5	16.8	16.4	6.8	0	0	0	0	0	0	0	0	0	0	0	0	

Table A.16: Map ID66 with nominal length 300mm.

Warm module type

VMARC
VMARD

Conform:	x ≥ 10g
Transitional region:	5 ≤ x < 10g
Non-conform:	x < 5g

8.9 ID60 L1 OPERATIONAL RANGE

ID 60 L1 with installed length 100,120mm

Installed L (mm)	100,120							
Axial range(mm)	0	2	4	6	8	10	12	
5	0	0	0	0	0	0	0	0
4.5	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
3.5	2.1	0	0	0	0	0	0	0
3	18.1	6.1	0	0	0	0	0	0
2.5	39.8	26.7	12.3	5.1	3.5	2.7	2.3	
2	65.5	50.8	34.7	27.9	28.8	28.4	37.2	
1.5	85.2	74.2	59.5	52.8	56.2	59.5	69.7	
1	100.6	97.9	86.2	79.9	84.6	89.5	106.7	
0.5	116.1	119.2	109.6	107.4	112.0	123.6	136.9	
0	125.0	130.7	137.0	136.1	138.2	150.8	175.3	
-0.5	116.1	119.2	109.6	107.4	112.0	123.6	136.9	
-1	100.6	97.9	86.2	79.9	84.6	89.5	106.7	
-1.5	85.2	74.2	59.5	52.8	56.2	59.5	69.7	
-2	65.5	50.8	34.7	27.9	28.8	28.4	37.2	
-2.5	39.8	26.7	12.3	5.1	3.5	2.7	2.3	
-3	18.1	6.1	0	0	0	0	0	0
-3.5	2.1	0	0	0	0	0	0	0
-4	0	0	0	0	0	0	0	0
-4.5	0	0	0	0	0	0	0	0
-5	0	0	0	0	0	0	0	0

Table A.17: Map ID60 L1 with nominal length 100,120mm.

Warm module type

- VMDQA
- VMDQB

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

8.10 ID60 L2 OPERATIONAL RANGE

ID 60 L2 with installed length 400mm

Installed L (mm)					400				
Axial range(mm)		-6	-4	-2	0	2	4	6	8
Radial Displacement	5	0	0	0	0	0	0	0	0
	4.5	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0
	3.5	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0
	2.5	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0
	1.5	0	0	0	0	0	0	0	0
	1	0	0	0	0	0	0	0	2.2
	0.5	0	0	0	0	1	1.7	3.9	5.1
	0	3.2	0	3.7	4.6	5.8	7.2	8.6	9.0
	-0.5	0	0	0	0	1	1.7	3.9	5.1
	-1	0	0	0	0	0	0	0	2.2
	-1.5	0	0	0	0	0	0	0	0
	-2	0	0	0	0	0	0	0	0
	-2.5	0	0	0	0	0	0	0	0
	-3	0	0	0	0	0	0	0	0
	-3.5	0	0	0	0	0	0	0	0
	-4	0	0	0	0	0	0	0	0
	-4.5	0	0	0	0	0	0	0	0
-5	0	0	0	0	0	0	0	0	

Table A.18: Map ID60 L2 with nominal length 400mm.

Warm module type

VMKQE

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

8.11 ID57 OPERATIONAL RANGE

ID 57 with installed length 300mm

Installed L (mm)	300											
Axial range(mm)	-2	0	2	4	6	8	10	12	14	16	18	20
5	0	0	0	0	0	0	0	0	0	0	0	0
4.5	0	0	0	0	0	0	0	0	0	0	0	0
4	1.6	0	0	0	0	0	0	0	0	0	0	0
3.5	4.0	0	0	0	0	0	0	0	0	0	0	0
3	5.3	0	0	0	0	0	0	0	0	0	0	0
2.5	5.5	0	0	0	0	0	0	0	0	0	0	0
2	6.7	0	0	0	0	0	0	0	0	0	0	0
1.5	8.2	0	0	0	0	0	0	0	0	0	0	0
1	8.0	0	0	0	0	0	0	0	0	0	0	0
0.5	9.8	0.0	0	0	0	0	0	0	0	0	0	0
0	14.5	5.2	3.6	1.2	1.1	0	0	0	0	0	0	0
-0.5	9.8	0.0	0	0	0	0	0	0	0	0	0	0
-1	8.0	0	0	0	0	0	0	0	0	0	0	0
-1.5	8.2	0	0	0	0	0	0	0	0	0	0	0
-2	6.7	0	0	0	0	0	0	0	0	0	0	0
-2.5	5.5	0	0	0	0	0	0	0	0	0	0	0
-3	5.3	0	0	0	0	0	0	0	0	0	0	0
-3.5	4.0	0	0	0	0	0	0	0	0	0	0	0
-4	1.6	0	0	0	0	0	0	0	0	0	0	0
-4.5	0	0	0	0	0	0	0	0	0	0	0	0
-5	0	0	0	0	0	0	0	0	0	0	0	0

Table A.19: Map ID57 with nominal length 300mm.

Warm module type

VMAPB

Conform:	$x \geq 10g$
Transitional region:	$5 \leq x < 10g$
Non- conform:	$x < 5g$

ID 57 with installed length 186mm

Installed L (mm)		186																	
Axial range(mm)		-12	-10	-8	-6	-4	-2	0	2	4	6	8	10	12	14	16	18	20	
Radial Displacement	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	4	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	3.5	4.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	3	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	2.5	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	2	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	1.5	8.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	1	8.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	0.5	9.8	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6
	0	14.5	5.2	3.6	1.2	1.1	0	0	0	0	0	0	0	0	0	0	2.7	3.0	6.3
	-0.5	9.8	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.6
	-1	8.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-1.5	8.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-2	6.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-2.5	5.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-3	5.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-3.5	4.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table A.20: Map ID57 with nominal length 186mm.

Warm module type

VMAPA186

Conform:	x ≥ 10g
Transitional region:	5 ≤ x < 10g
Non-conform:	x < 5g