"QUICK MAINTENANCE FOR HIGH VOLTAGE EQUIPMENT WITH THE NEW NOT TOXIC BORON NITRIDE POWDER (BN100) SUPERIOR THERMAL CONDUCTIVE AND LIGHTWEIGHT FILLER"

ESA CONTRACT 18697/04/NL/MV

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ABSTRACT: *Maintenance of high voltage equipment is since ever a critical point that, with the increasing cost of high graded components, can well reduce the margin of profit of Industry when repairing must occur. The BN100 superior thermal conductive and lightweight filler technology is a new filler technology, that not only lets Users a full access for maintenance because cure-free being compounded by loose Boron Nitride powder mechanically compressed and without resin, but also permits to much increase the thermal dissipation because of a K value of about 10 W/mK. Under this ESA contract we have demonstrated that hot spot temperatures can drop as much as 20°-50° depending on the power, opening a new way for more compacted packaging, higher power density PCBs and COTS acceptance in Space missions.*

This "Proof of Concept" program aimed at demonstrating the thermo-mechanical and electrical performance of the BN100 filler technology in typical Space equipment was based in the accomplishment of the following activities:

1 - TEST OF A HIGH VOLTAGE COMPONENT

The activity is aimed at identifying the possibility to use the BN100 as high dielectric constant filler in high voltage component.

To this purpose a high voltage component mock up has been manufactured. It is made of two parallel aluminium plates, in order to get a well defined and controlled electric field.

5 samples, made as shown in Figure 1-1, have been prepared by using the ARTHE Automatic Filling Equipment (AFE):

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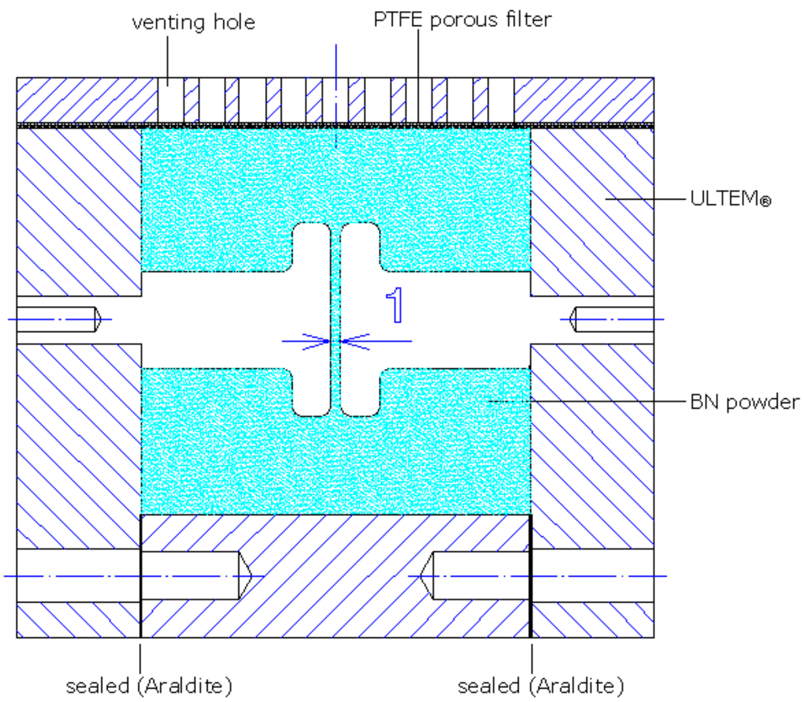


Figure 1-1

1.1 -HV samples preparation

Any of the 5 samples was prepared by using the following procedure:

- After the housing assembly has taken place, a dummy Plexiglas cover is put in place of the original one. This will permit to check the powder distribution during the filling process. The screws on the housing have been used only to withstand the compressive loads during the filling process and, apart from the 4 screws on the cover, they have been removed after the filling not to interfere with the electrical test field.

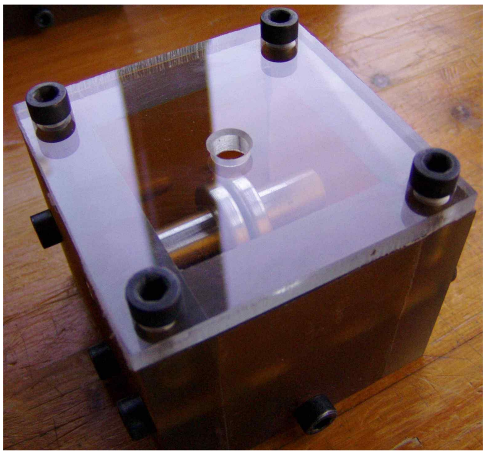


Figure 1-2

- The sample is then put on the Automatic Filling Equipment table developed by ARTHE and filled. In Figure 1-3 the sequence of the filling process is shown.

Figure 1-3

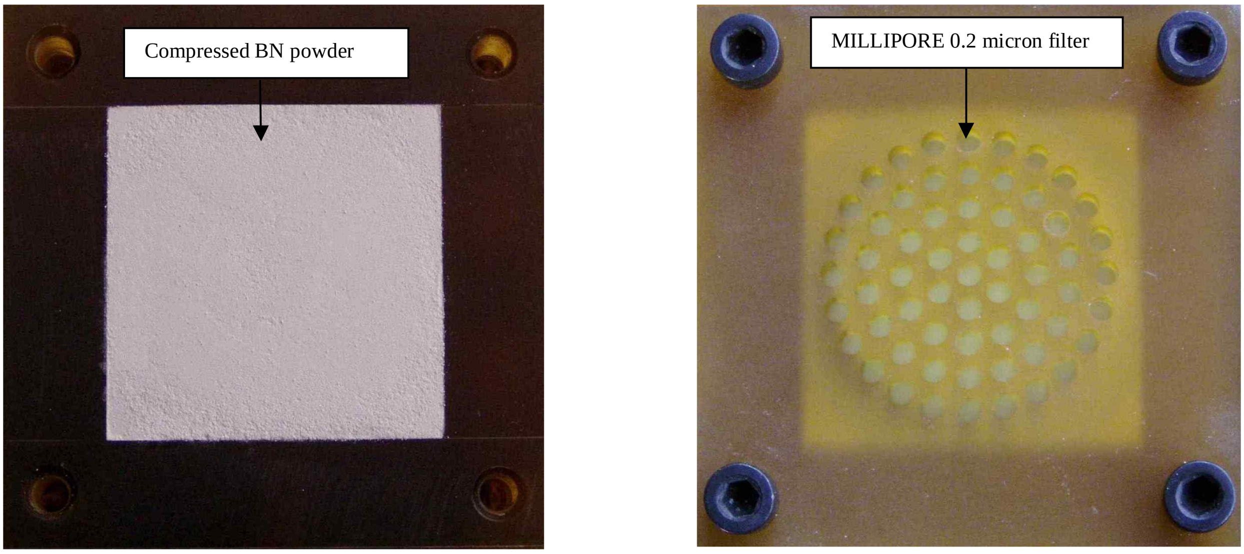


Figure 1-4

The filling process, that lasts about 1 min, is checked by weighting the sample before and after filling. These are the results:

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Empty weight (gr)	284	284	284	284	284
Full weight (gr)	329	330	329	330	330

Table 1-1

Being the internal volume equal to 59597 mm^3 the average filler density results to be **0.77 g/cm^3**. This value is indicative of the mass competitive characteristics of the BN100 filler compared to traditional ones (for instance the density of Conathane EN11 is 1 g/cm^3).

1.2 -Test in vacuum chamber

The tests have been carried out at the GALILEO AVIONICA Facilities. The samples were undergoing the following tests:

- measurement of the DC leakage current
- measurement of the high voltage breakdown in thermal vacuum conditions

1.2.1 - Test set up

The following test set up has been used:

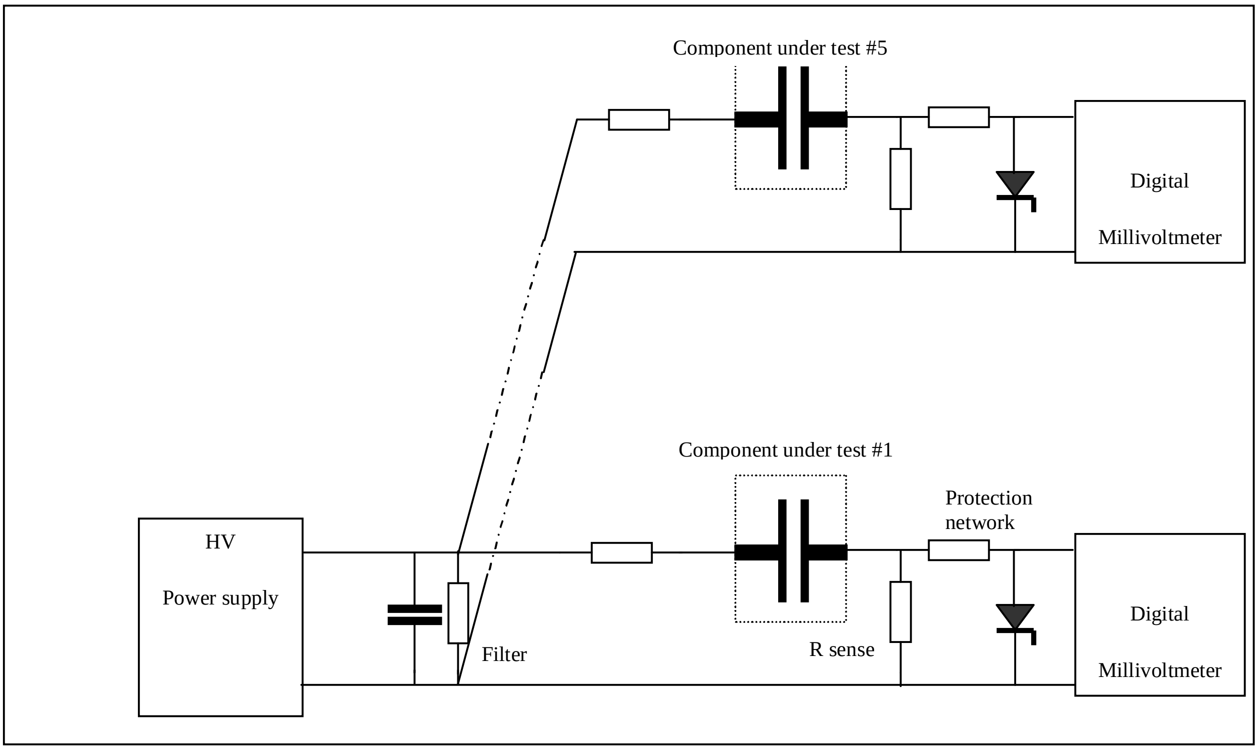


Figure 1-5

The 5 components under test have been mounted into a thermal vacuum chamber at the GALILEO AVIONICA Facilities.

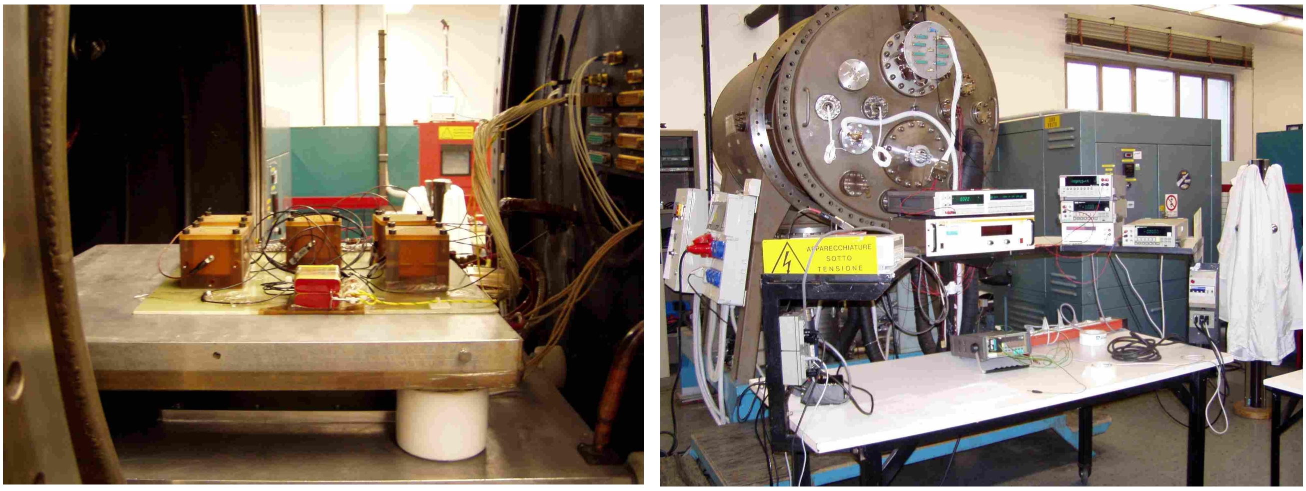


Figure 1-6

<u>With the plates distance set to 1 mm no breakdown was recorded up to 10kV.</u>

<u>It must be pointed out that also the leakage current was lower than the sensitivity of the measurement set up (1 nA) as shown in Figure 1-7.</u>

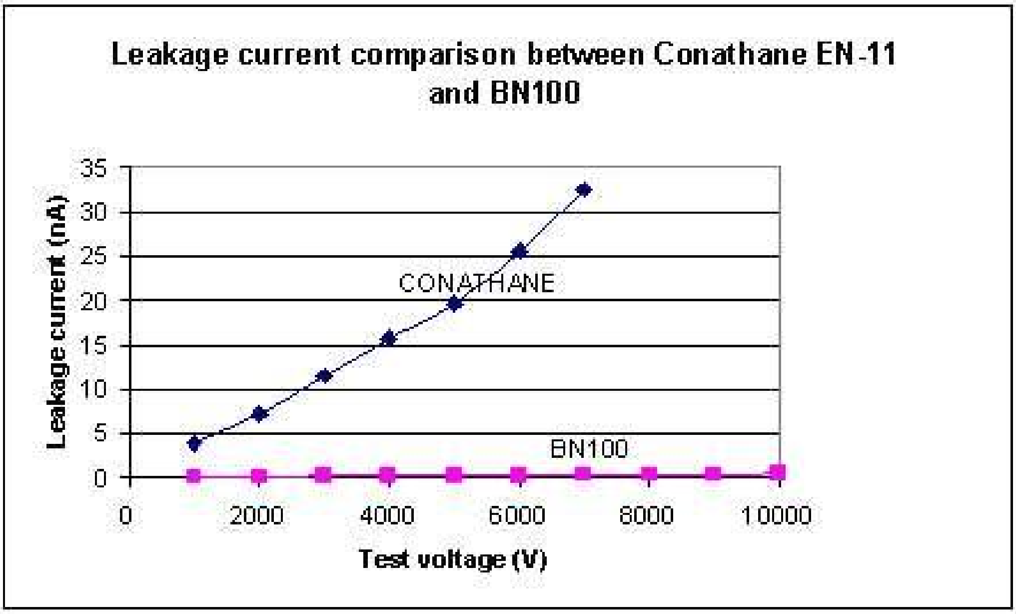


Figure 1-7

<u>The data reported show the measured leakage current, compared with the same measurement performed on a sample with the same geometry but filled with Conathane EN11 encapsulant.</u>

In order to increase the range of the exploited electric field it has been decided to decrease the distance between the sample plates to 0.25 mm, before, and then, 0.4 mm, by putting dedicating shims between plates and ULTEM walls.

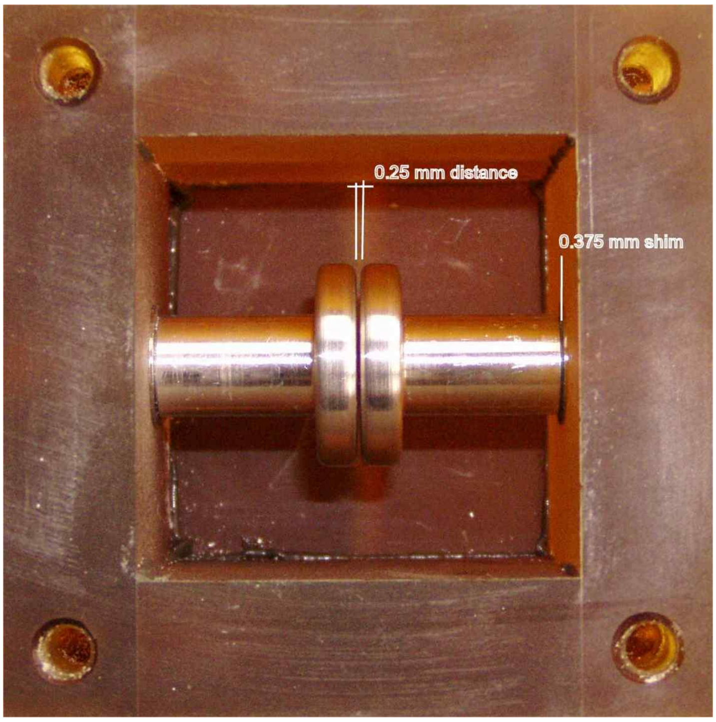


Figure 1-8

After filling with plates distance set to 0.25mm, the HV samples were mounted into the thermal vacuum chamber and, after a stable vacuum condition was reached, they have been supplied with increasing voltage, while monitoring the leakage current (by a digital multimeter).

<u>It is worth noting that the measured leakage current confirmed the above quoted results, i.e. it was lower than the sensitivity of the measurement set up (1 nA), until the breakdown occurred.</u>

When breakdown was detected to occur in a sample, the latter were disconnected from the power supply and the test kept on going with the other.

The results are summarized in the following table:

Sample	Test voltage for breakdown (V)	Equivalent breakdown test voltage (kV/mm)
# 1	6375	25.5
# 2	5375	21.5
# 3	5500	22.0
# 4	5875	23.5
# 5	4250	17.0

Table 1-2

The results give an average breakdown voltage of **21.9 kV/mm.** It is to be noted that the recorded variance between the samples (particularly the 5^{th}) can well be due to the fact the powder particles size distribution is not far from the plates distance of 0.25 mm as shown in Figure 9. The closer is the plates distance to the particles size the higher will be the variance of the filling characteristics among the samples.

In order to minimise the effect of the powder size distribution a new test campaign with the plates set to 0.4 mm was carried out, a distance more than 6 times the largest particle size and 20 times the average particle size.

1.3 -Test campaign N°2: sample plates at 0.4 mm

The additional investigation is mainly addressed to:

- verify that the recorded variance between the samples breakdown voltage is due to the plates distance (the closer is the plates distance to the particles size, the higher is the variance of the filling characteristics among the samples). To this purpose the plates distance has been increased to 0.4 mm.

- evaluate the time taken by the samples to evacuate the air. As far as this issue is concerned, it is worth mentioning that voids are intrinsic in this filler technology, intended as the space among the BN particles. BN100 is then not considered the ideal high voltage filler for ambient or critical pressure conditions, but it is very attractive as far as its thermal conductivity is concerned, and it could be effectively used in vacuum condition where high voltage and high power dissipation are present if it can be demonstrated that the filler will not affect the dielectric characteristic of the vacuum condition due to its micro-impurity or the presence of trapped air/humidity.

Before starting with the vacuum test, measurement of the AC corona inception voltage (CIV) at ambient condition has been carried out to record the homogeneity of the filler between the different samples.

The measurement was carried out at ambient condition since the available facility does not allow to perform the test in vacuum.

Results of the test are:

Sample		**CIV (V)**	**Normalized AC electric field (V/mm)**
# 1	with BN100	2000	5000
# 2	with BN100	2000	5000
# 3	with BN100	2100	5250
# 4	with BN100	2000	5000

Table 1-3

Partial discharges were not appreciable until the CIV, after which threshold they exceeded 100pC.The test showed that the samples behaves very similarly.

1.3.1 - Measurement of the high voltage breakdown in vacuum conditions

The test was aimed at detecting the high voltage breakdown threshold of the samples filled with BN100 and the necessary time to evacuate the trapped air.

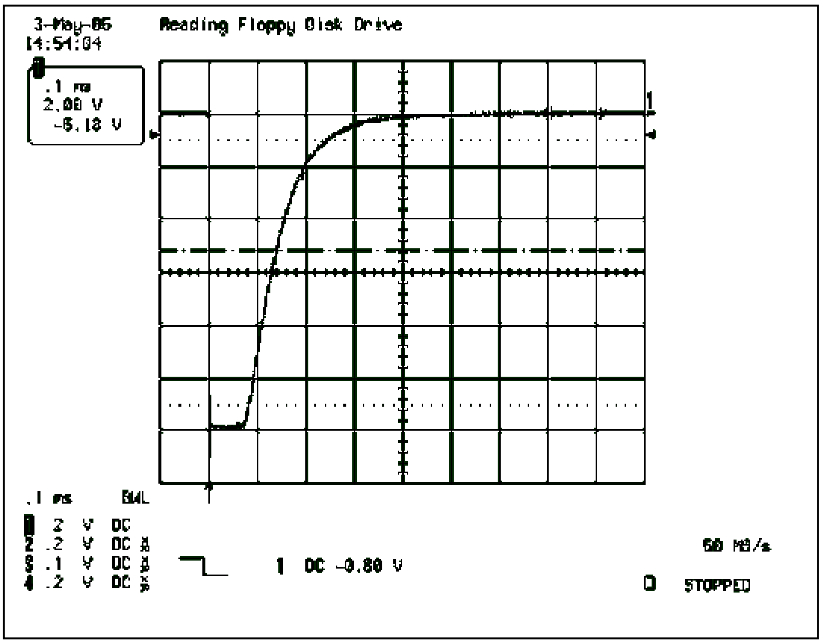
To do so the chamber pressure was rapidly pumped down and the test started when the chamber pressure was lower than 1×10^{-3} torr. One empty sample without BN100 is included into the set up and its dielectric strength is measured and used as a reference for the other samples.

High voltage discharges between the plates are detected by an oscilloscope.

The results are summarized in Table 1-4:

Time	**Chamber pressure (torr)**	**Sample #5**		**Sample #1 to #4**			
		Test voltage for 1st transient breakdown (V)	**Equivalent breakdown voltage (V/mm)**	**Test voltage for 1st transient breakdown (V)**	**Equivalent breakdown voltage (V/mm)**	**Test voltage for permanent breakdown (V)**	**Equivalent breakdown voltage (V/mm)**
14.45	ambient						
14.54	1×10^{-3}	6000	15000	6000	15000		
14.58	7×10^{-4}	6300	15750	6400	16000		
15.10	5×10^{-4}	6500	16250	6400	16000		
15.35	4×10^{-4}	6500	16250	6400	16000		
15.55	2.5×10^{-5}	6800	17000	6800	17000		
16.34	2×10^{-5}	7000	17500	7100	17750		
18:44	1.5×10^{-5}					10000	25000

Table 1-4



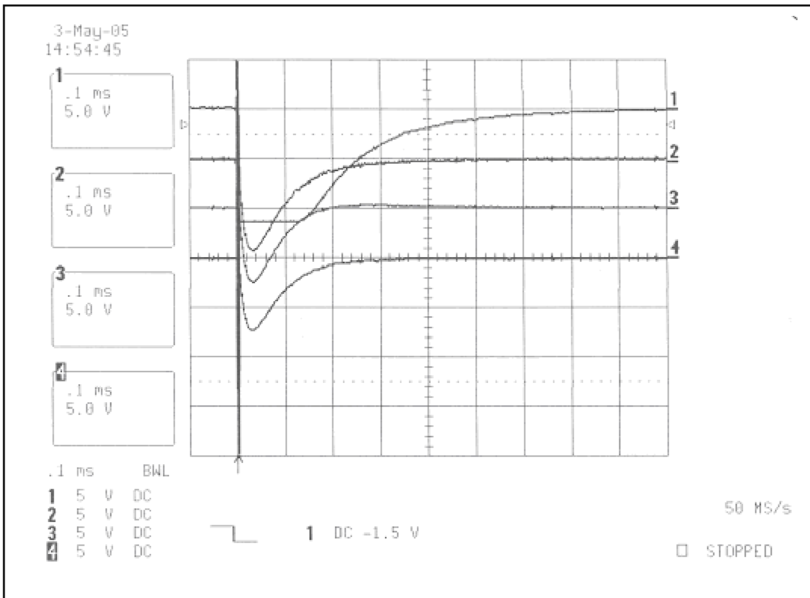
Sample #5 (empty)

Breakdown transient

Chamber pressure 1×10^{-3} torr

Test voltage 6000 V

Figure 1-9



Sample #1 to #4 (with BN100)

Breakdown transient

Chamber pressure 1×10^{-3} torr

Test voltage 6000 V

Note: Breakdown occurred on sample#1

Figure 1-10

As shown in the previous plots, after each discharge, the samples recovered the dielectric isolation such that the test could continue. This was done increasing the test voltage up to the occurrence of a permanent breakdown on the samples with BN100.

This is reported in the following plots, showing the performances of samples #1 to #4 at 10000 V test voltage (corresponding to 25000 V/mm) , when the sample #3 reached a permanent short condition.

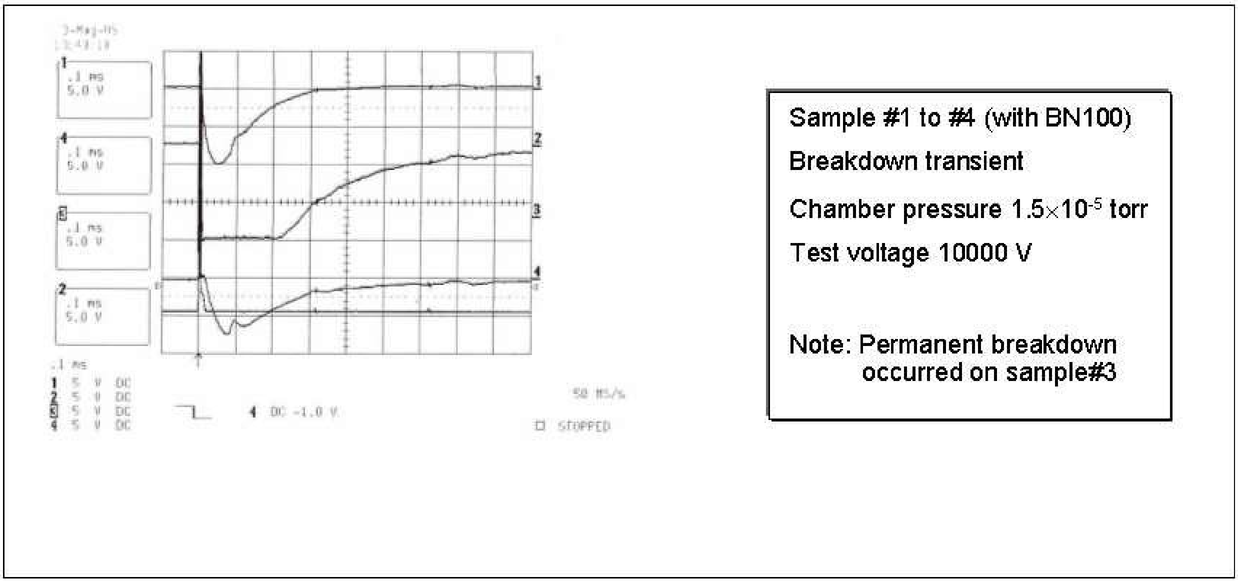


Figure 1-11

1.4 -Conclusions on the electrical test campaign

The HV samples test campaign was aimed to get a preliminary evaluation of the capability of the BN100 to be used as a filler in high voltage components and modules.

Intrinsically this filler technology has voids, not internally the material itself but among the BN particles, which raise concern about its use in HV modules at ambient and, mainly, at critical pressure conditions.

Nevertheless the test campaign provided indeed some encouraging results, such as:

1. the dielectric strength of the BN100, even if lower than the material intrinsic one (78,7 kV/mm) due to the powder particles surface micro impurity, is very good. The spread detected in the first test run has been improved by a more uniform size distribution as explained above.
2. the material leakage current is extremely low, at least two order of magnitude better than a traditional high voltage potting.
3. the samples have shown a kind of "self healing" characteristic, i.e. after the breakdown and the removal of the test voltage, it was possible to repeat the test. This is most likely due to the very high temperature limit of the BN (about 2000 °C).
4. the air evacuation of the filler is very fast; by comparison with the empty sample characteristic, it fundamentally follows the chamber pressure decay.
5. being the BN100 dielectric strength properties basically determined by the voids internal pressure, the measurement obtained in on-Ground verification are conservative and a warranty with respect to the Space conditions.

As a conclusion, despite the limit of the present "Proof of Concept" program, we consider that the recorded data confirm the claims addressed to the BN100 filler to be used in high voltage component application, where strong benefits could derive from its unique characteristics of high thermal conductivity combined to either an high dielectric strength and an easy reworkability.

Of course this issue should be deeply investigated to define and validate design and process technology capable to get over the filler limit at ambient conditions. Investigation area concerning this issue could be addressed either to the use of dedicated cautions during on-Ground test, like use of high dielectric electronic liquid, and specific design and process technology like the use of conformal coating, high rigidity painting, etc..

2 - MECHANICAL DYNAMIC TEST ON THE THERMAL BREADBOARD

The test breadboard used for the either mechanical and thermal test campaign is the EQM of a battery discharge regulator (BDR) module used in a Main Bus Regulator Unit (MRU), GALILEO AVIONICA has kindly lent to analyse the thermal and mechanical performance of the BN100 filler technology.

Reasons for the choice are the availability of the BDR thermal characteristics (thermal map) and its power handling capability (up to 400 W).

2.1 -The BN100-based BDR thermal breadboard

A case has been designed around the BDR module to host the PCB, the electrical connectors and the filler.

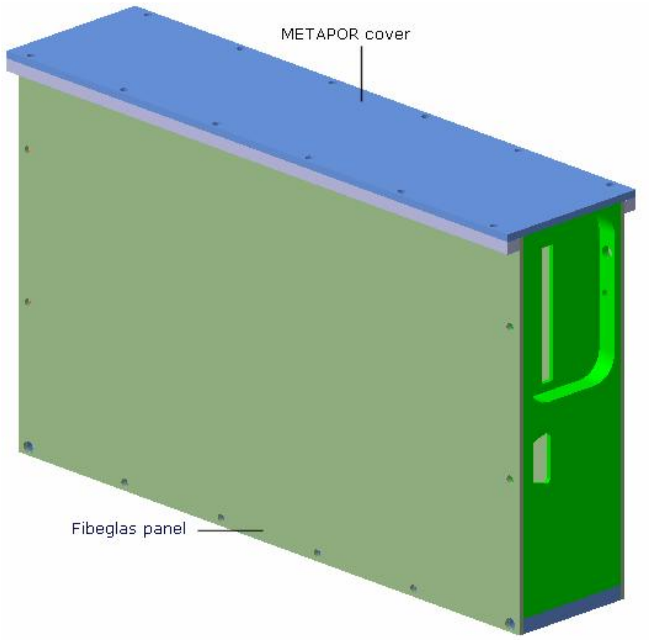


Figure 2-1

It is here to be pointed out that the powder containment solution that will permit air to freely move out of the casing is to use as a cover a METAPOR® -based plate 3 mm thick that coincide from a mass viewpoint as to have an Al plate of 2 mm thickness. The porous characteristics of the METAPOR® will permit air to get away along the total cross sectional area of the casing, a condition certainly optimising to reduce at a negligible factor the ΔP during the depressurisation phase.

The casing lateral panels are made of Fiberglas to simulate the presence of other PCBs around the BDR module. The breadboard is just representative of a configuration in which it is possible to analyse the impact of the BN100 filler in the central portion of a multi-PCB unit. If the filler will proof to be effective in this unit area at good reason we can consider it will be effective in the portions closer to the case walls.

The other casing parts are machined in Al6082 T6 and black anodised, with the exception of the 3 mm thick cover panel made in METAPOR®. This solution will permit air to move out of the casing and contain the BN fine particles.

According to the BN100 design rules the walls are foreseen to be mated one another by interposing a thin layer of DOW CORNING® to assure a full powder containment, as well as for the connector feed troughs and instrumentation cut out.

2.2 -The BDR-BN100 breadboard preparation

The BDR breadboard was just prepared as per the following figures.

2.2.1 - Instrumentation integration

2 accelerometers have been integrated on one side of the BDR module. 9 Thermocouples have been integrated on the opposite side of the BDR module (see Figure 2-2).

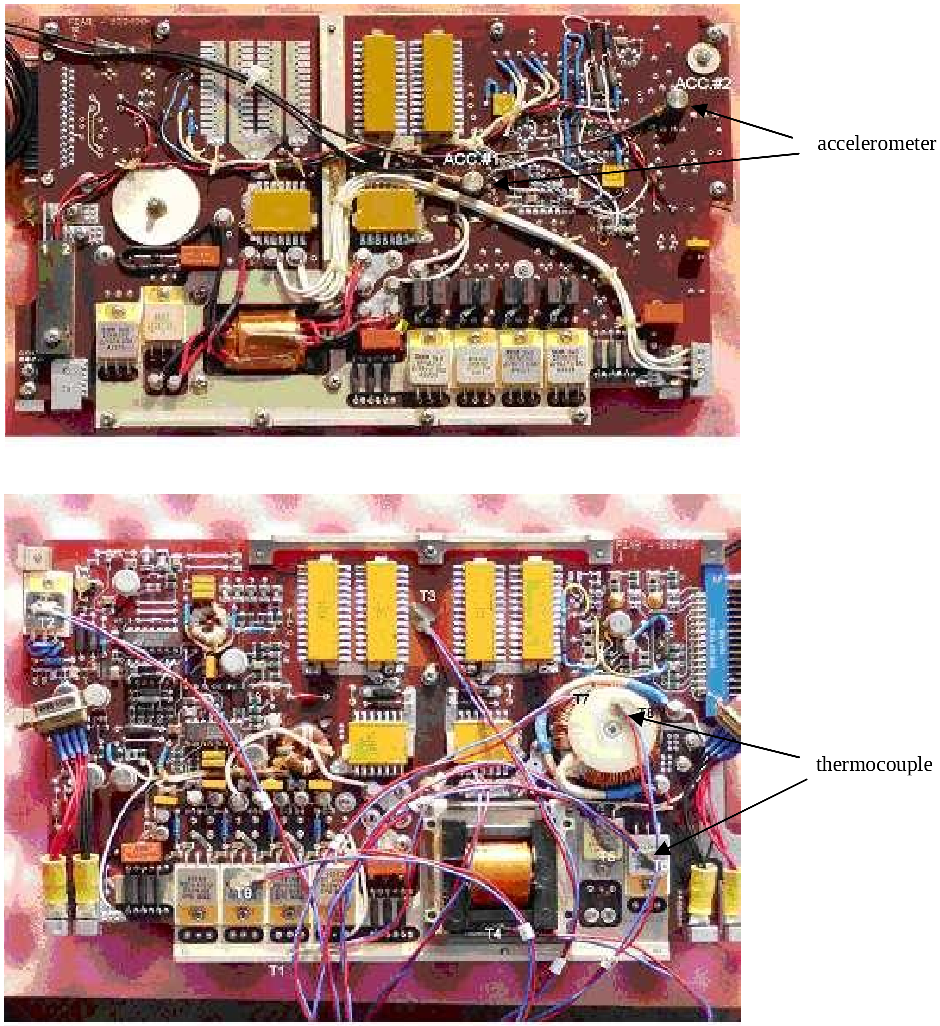


Figure 2-2

2.2.2 - Casing assembly

After mating the BDR module to the baseplate, the front and back panels have been assembled to the baseplate without any contact with the module if not for the 2 Canon connectors. The lateral fixations points of the BDR module have then not been used.

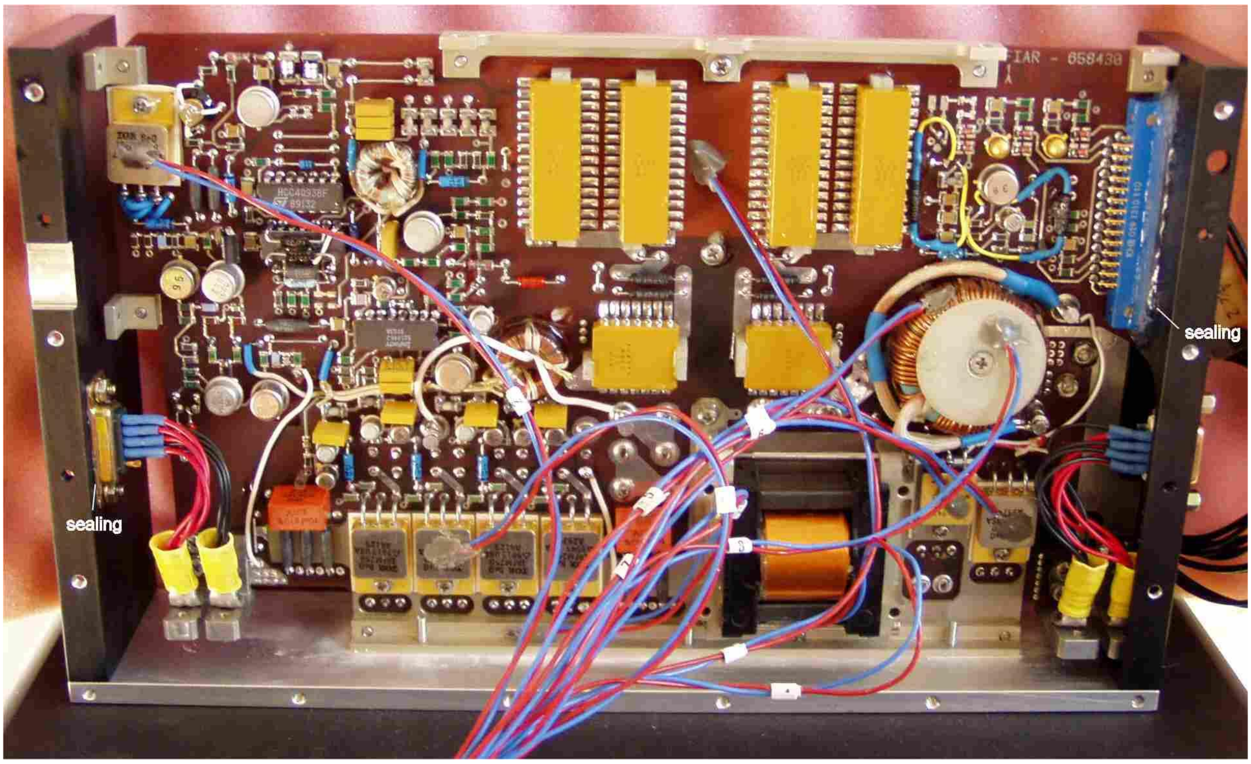


Figure 2-3

2.2.3 - The filling process

The breadboard with the BDR module inside, despite it is a 1 single PCB configuration, is typical of a multi-PCB layout, having the PCB mounted vertically on the baseplate. Our breadboard presents in fact only 1 PCB but located in the middle of the casing expressly configured as if it were a portion of a multi-PCB unit to simulate the same thermal conditions of the original MRU unit.

The filling process, for a multi-PCB configuration, is rather different from the one discussed before because the filling cannot be realised evenly through 1 single hole. To arrive to compress the powder uniformly across the PCB plane an important step is needed before using the Automatic Filling Equipment that is effective when all the H/W parts are rigidly fixed.

This step consists in executing a preliminary filling process that eliminates the risk to overload the PCB, by compacting the powder with the cover removed and with the powder introduced on the upper part of the casing. This process is accompanied by a progressive escalation of vibration loads carried out by a shaker. The vibration environment is responsible to compact the powder equally distributed around each component that will be loaded much less than if we directly introduced the powder through a single hole on one side of the PCB as it would be with the AFE.

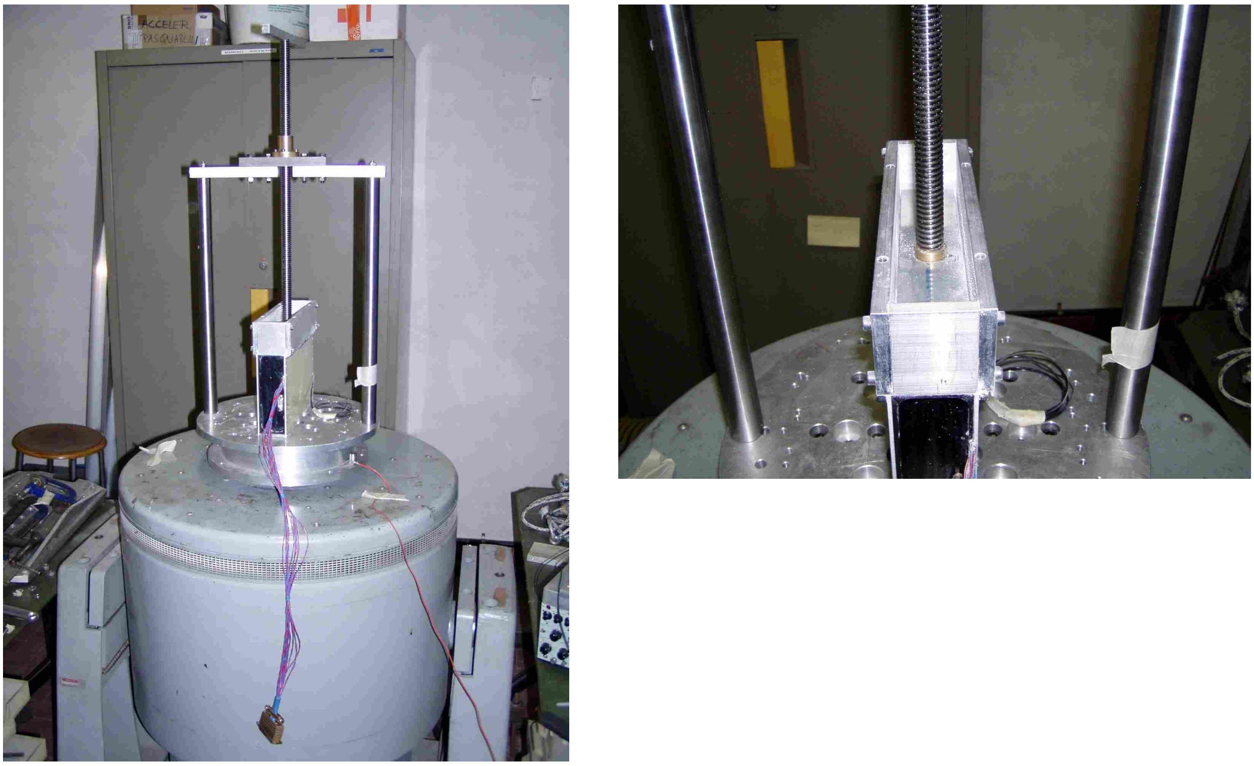


Figure 2-4

This part of the process, shown in Figure 2-4, is carried out also by using a simple press device mechanism that increase the powder compression inside the casing along with the vibration escalation with the result to evenly compress the powder over the entire unit envelope.

The amount of compression used cannot be quantified as in the case of the Automatic Filling Equipment, but this part of the process is only needed to evenly constrain the PCB around its ideal and natural location.

Once the PCB is well constrained in its ideal position by means of the partial compressed powder, a dummy Plexiglas cover is fastened to the housing and the breadboard can be farther filled by using the AFE up to the final compression.

This second step is carried out alternatively through 2 holes located on the opposite side of the PCB similarly as already shown in Figure 1-3 for the electrical samples.

2.3 -Mechanical test campaign

The tests have been carried out at the POLYTECHNIC OF TURIN, Mechanical Department.

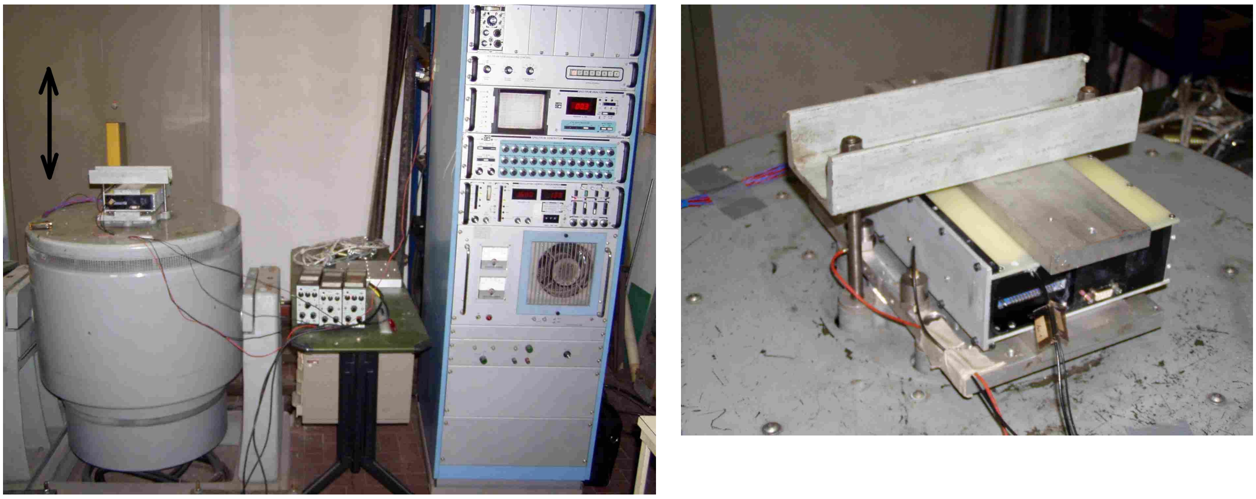


Figure 2-5

2.3.1 - Test specification

The frequency response function (FRF) has been calculated from the sine signals taken from the reference point, on the fixture with the Brüel&Kjær accelerometers mod. 4370, and the Unit response points. The resonance search was carried out with the following parameters:

- frequency range	20-2000 Hz
- frequency change rate	1 octave per minute
- sweep time	7 min.
- acceleration amplitude	$a = 0.5\ g_{pk}$

The Random vibration test, any of the duration of 2 minutes for a total elapsed time of 10 minutes, was based on the following PSD levels:

20 Hz	0.01006 g2/Hz
20 – 85 Hz	6 dB/Oct
85 – 250 Hz	0.18 g2/Hz
250 – 315 Hz	-9 dB/Oct
315 – 700 Hz	0.09 g2/Hz
700 – 2000 Hz	-3 dB/Oct
2000 Hz	0.03161 g2/Hz
TOT	**12 gRMS**

The required PSD shape has been obtained using the shaker analogue random control unit, with its 36 bands control: the random signal amplitude has been determined and tested for each band, to obtain the requested shape and the total RMS value.

2.4 -Test results

The typical output result (measured amplification) is reported in Figure 2-6.

For the 1st resonance the level of amplification at the related frequency are reported in Table 2-1.

	Acc.#1 ampl. / frequency (Hz)	Acc.#2 ampl. / frequency (Hz)
Res. Search 1	2.38 / 575	4.36 / 575
Res. Search 2	2.20 / 575	4.19 / 575
Res. Search 3	2.17 / 570	4.11 / 575
Res. Search 4	2.18 / 570	4.07 / 575
Res. Search 5	2.20 / 570	4.05 / 575
Res. Search 6	2.16 / 570	3.75 / 575

Table 2-1

The replication of the output amplification that appear in any graphic and from the above table is the necessary and sufficient condition to assure that the compression of the BN100 is maintained all along the vibration environment.

The rather high frequency at which any amplification occur is relevant of the overall increase of the packaging stiffness due to the filler pre-compression.

The recorded low amplification values are also the demonstration that the BN particles micro-frictions that occur during the vibration loads are an outstanding damping factor.

In the following figures the results are shown in its time sequence:

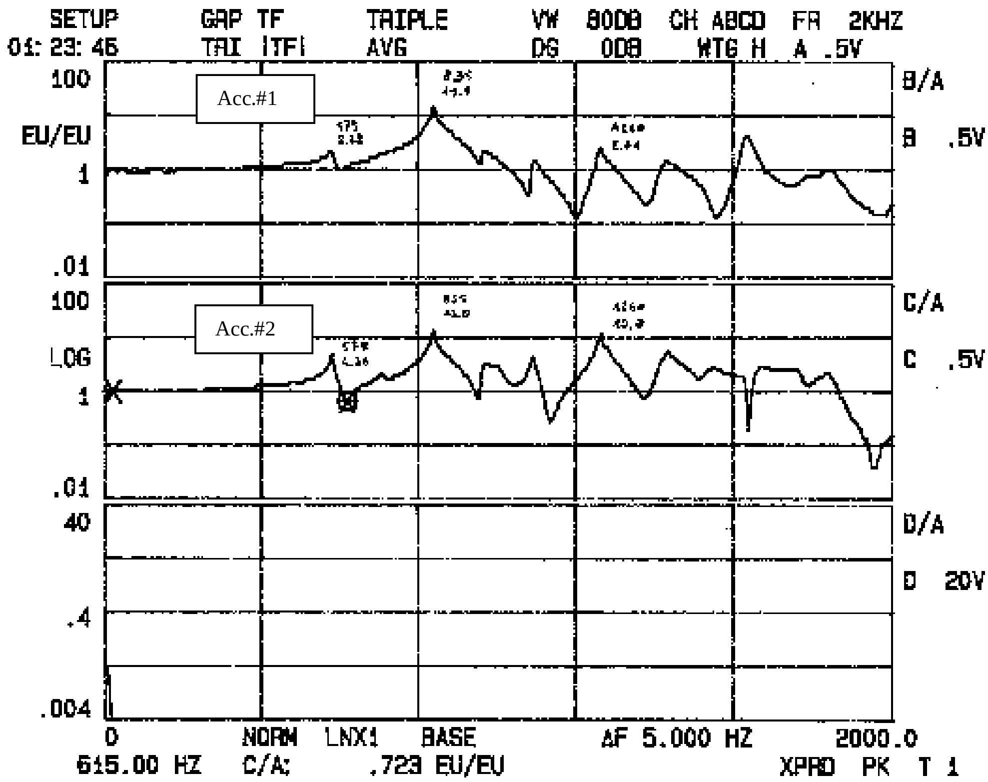


Figure 2-6

3 - THERMAL TEST ON THE BDR BREADBOARD

The test campaign is aimed at demonstrating the superior characteristics in terms of thermal dissipation offered by a filler having 10-14 W/mK of thermal conductivity depending on the housing rigidity.

Traditional potting fillers are in fact absolutely thermal insulated materials and a much complicated filling process associated to a poor reliability have to be paid to render them somehow thermal conductive, an effort that can permit to reach at maximum a 1-3 W/mK of thermal conductivity.

3.1 -Thermal budget of the BDR module

The max power dissipation hereunder given is relevant to Vmb=42.5, Vbat=23V, Pout = 400W.

Compon.	Type	Pd (W)
C1,C2,C57,C58	CH72	4 x 0.077
F10 ÷ F13	P600L	4 x 0.004
F1 ÷ F8	P600L	8 x 0.136
R142 ÷ R143	RWR80	2 x 0.073
Q25-Q26	JANS2N7268	2 x 1.79
Q17 ÷ Q24	JANS2N7269	8 x 1.27
CR19	1N6659	3.53
CR24	SSR2010CTM	2.94
R79 ÷ R82	RWR80	4 x 0.122
R8 ÷ R13, R126 ÷ R131	RWR80	12 x 0.11
TS2 (coil)	ETD34	0.97
TS2 (core)	ETD34	0.97
PCB electr.	various	0.6 (spread)
RS1 sensing	mangan.	0.574
LS2	Induct.	0.486
Q31	2N3700	0.168
Q30	JANS2N7268	0.2
TOTAL		**27.554**

Figure 3-1

3.1.1 - Test instrumentation

9 thermocouples have been integrated internally the BDR breadboard as per Figure 2-2.

3.1.2 - Test Specification

To resume the differences between a Unit filled with the BN100 filler and an equivalent empty one, that is, either without filler or with a traditional thermally insulated filler, the Campaign has been carried out in 2 phases:

- Tests with BN100 filler, with and without MLI.
- Tests without BN100 filler after having removed it out of the Unit.

Even if it exists a thermal map of the BDR module inside the original MRU unit it has been preferred to redo the test without filler with the current configuration of our BDR breadboard in which no other modules are present (while in the MRU unit the other PCBs affected the BDR thermal behaviour).

In this way only the filler makes a difference between the 2 systems.

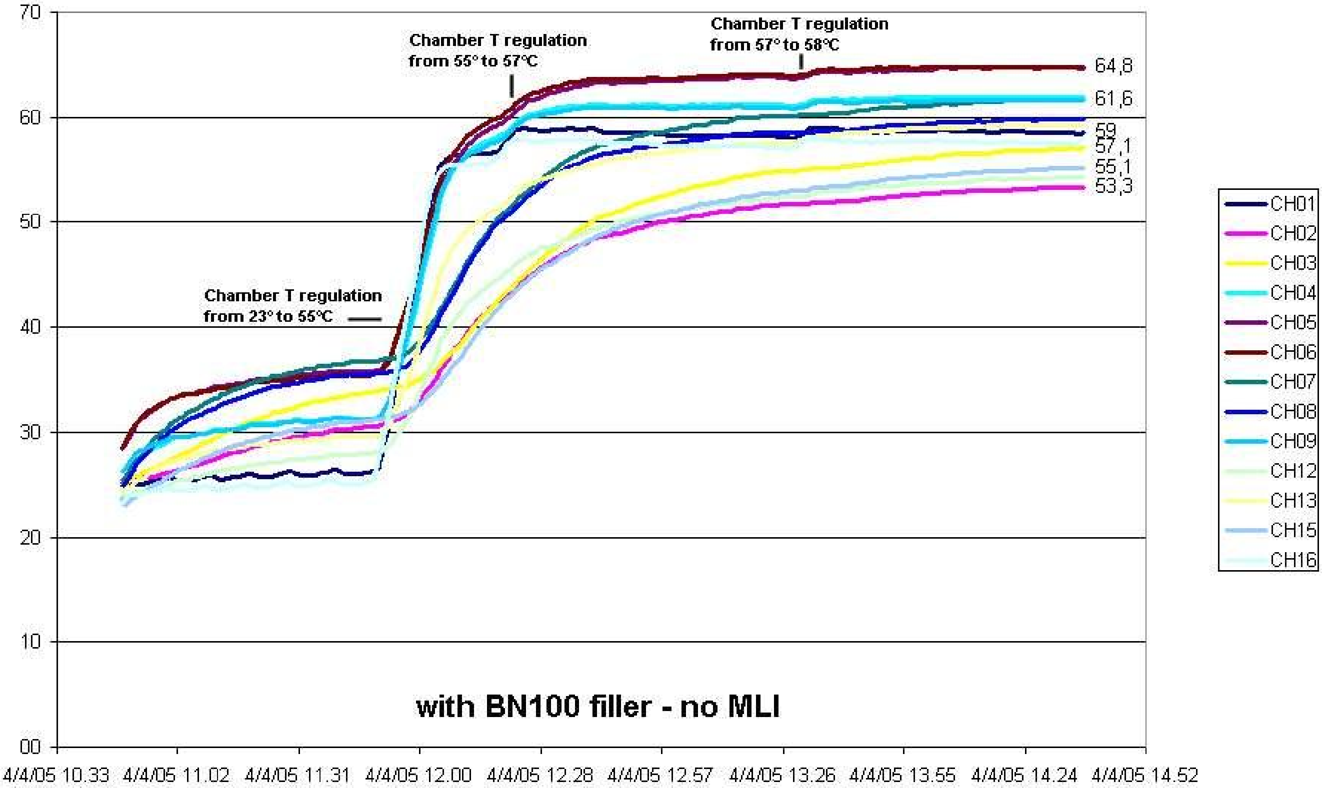
The Chamber baseplate ambient temperature has been set to 58°C for all the tests. No control was done on the shroud.

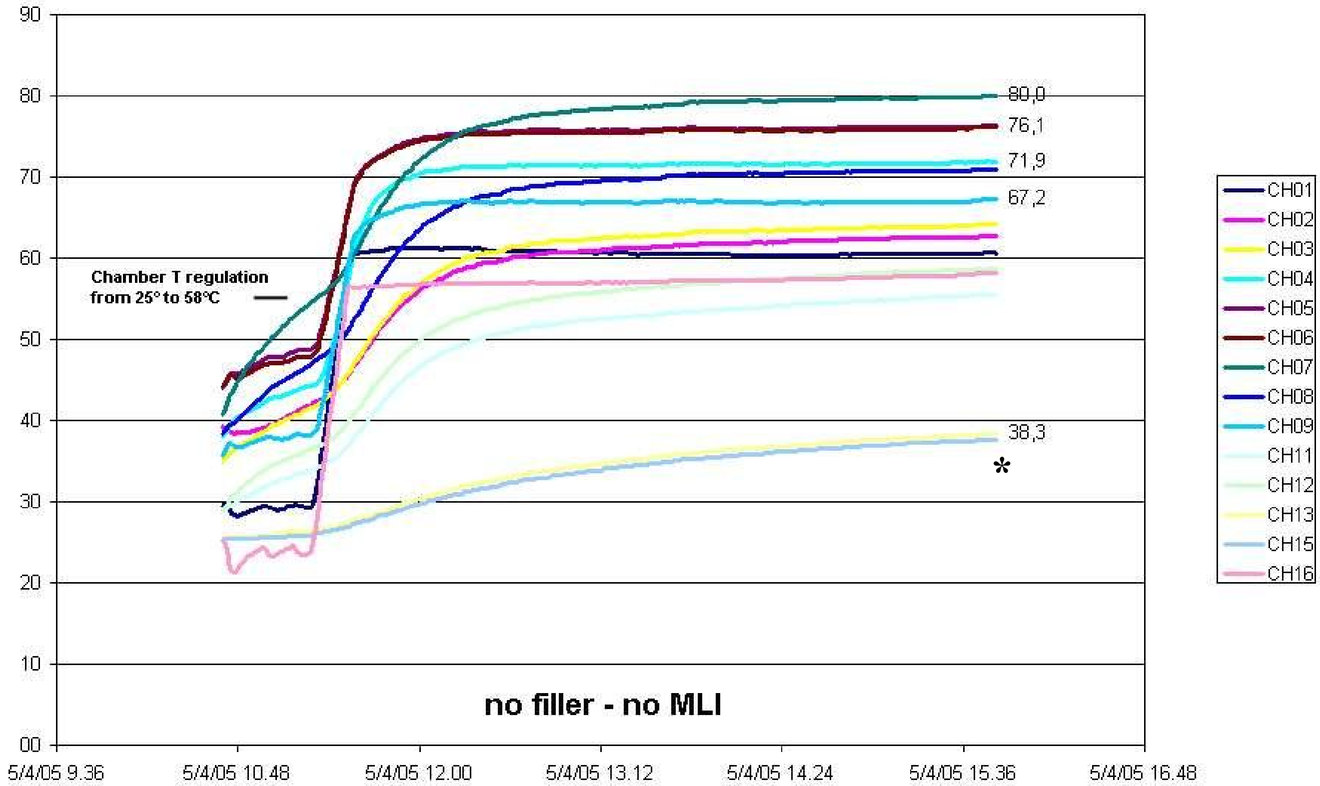
3.2 -Test results

The tests have been carried out at the GALILEO AVIONICA Facilities.

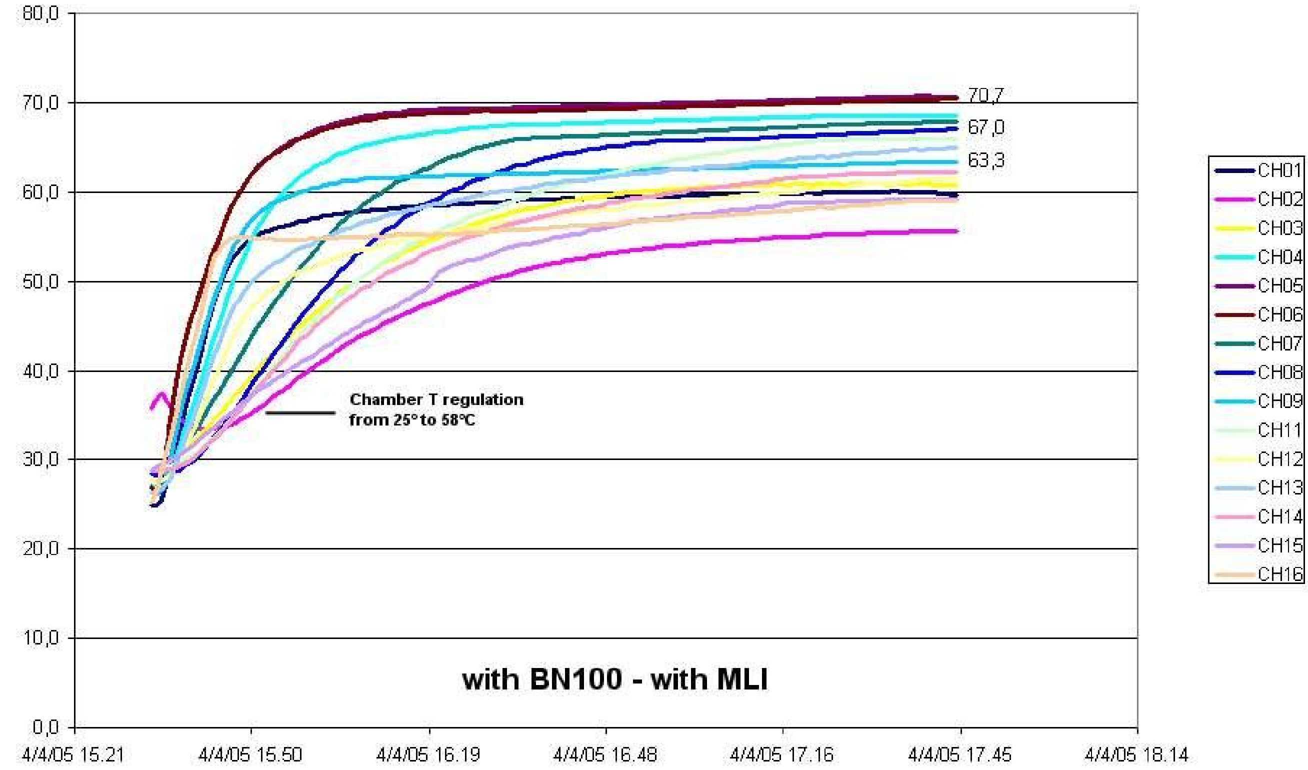
Figure 3-2

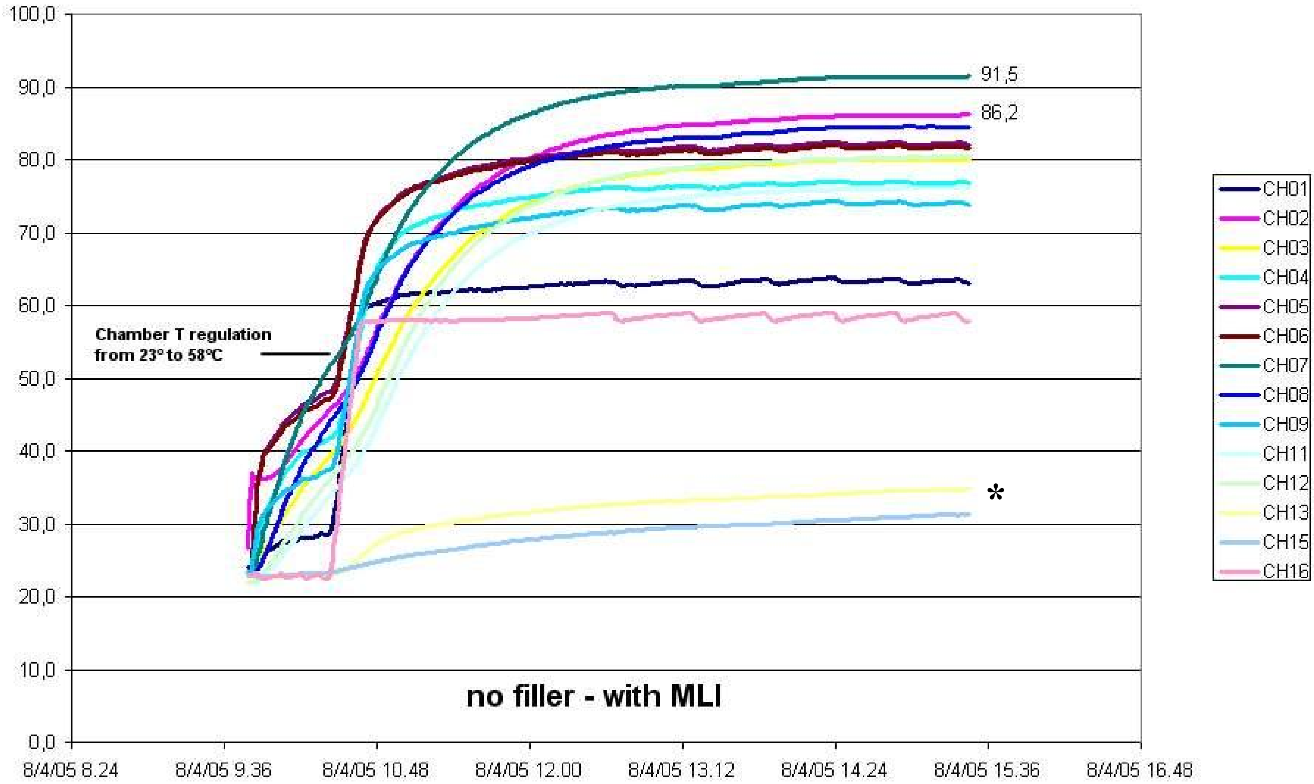
The results are reported in the following plots and resumed in Table 3-1.





* *thermocouples CH13 and CH15 have been put on the Chamber walls*





* *thermocouples CH13 and CH15 have been put on the Chamber walls*

Figure 3-3

3.3 -Conclusions on the thermal test campaign

The results resumed in Table 3-1 show a wide difference in terms of thermal dissipation in favour of the case with BN100 filler with respect to the one without/or with a traditional filler.

	Max T (°C)	**Thermocouple**	**Component**	**Power**	**$T_{difference}$ with T_{amb}**	**$T_{difference}$ between 2 sys**
with BN100 No MLI	64.8	T6	Q26	1.79	**+6.8**	
Empty No MLI	80.0	T7	LS2	0.423	**+22**	**+15.2**
With BN100 with MLI	70.7	T5	CR24	2.94	**+12.7**	
Empty with MLI	91.5	T7	LS2	0.423	**+33.5**	**+20.8**

Table 3-1

If we compare the 2 systems with MLI, in particular, it appears how important is to have a thermal conductive filler that permits to dissipate towards the baseplate with additional thermal paths other than the PCB ones.

Plus in detail it can be said that the components mounted outside the heat sink (that increases dissipation in the lower part of the PCB) and upon which the most powered components are located, such as CR19, CR24, Q25 and Q26, mainly benefit by the presence of a thermal conductive filler such as the BN100.

The component LS2 that has a thermal dissipation of only 0.486 W is in fact located outside the heat sink area but it is the item that has recorded the highest temperature in the case no filler was used, 91.5 °C: <u>this temperature has been reduced to only 67.8°C when the BN100 filler was used.</u>

This T difference of 23.7°C is significant of the fact that with the BN100 filler all the PCB area can in principle be exploited and a much higher power density can be hosted and designed on the PCB.

We will see in the next chapter, when some thermal simulations will be carried out on the FEM model tuned up with these results, that, <u>by increasing the thermal power of the LS2 component, the case with no filler will soon reach prohibitive temperatures while the case with the BN100 filler is able to host 12 times more power before arriving at the T recorded in empty conditions or with a traditional filler.</u>

4 - THERMAL FEM MODELLING ON THE BDR BREADBOARD

A thermal FEM model has been built to analyse in details the performance of the BDR breadboard with BN100 filler.

The thermal analysis is composed of a steady state analysis, to evaluate the equilibrium temperature of all the nodes of the model.

The FEM Thermal model has been built up by doing mapped divisions on the PCB surface, mid-surfacing each zone to get rectangular trimmed surfaces and successively meshed them with plate elements. The method has been extended also to the baseplate (see Figure 4-1).

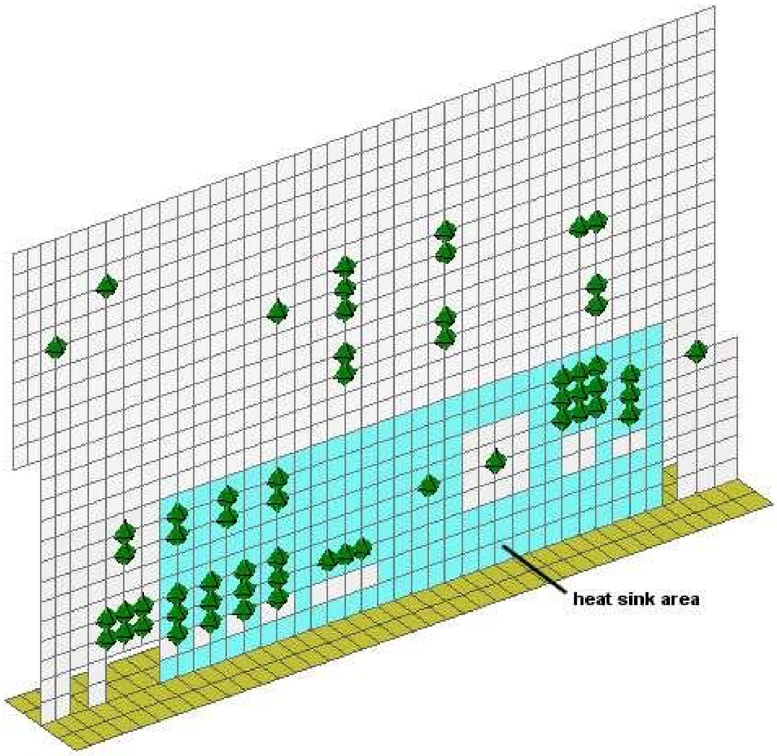


Figure 4-1

Taking as a basis the information of the thermal model of the BDR module, the FEM model has been realised with FEMAP and NASTRAN as pre- and post-processor respectively.

These information have further been tuned up <u>to obtain the same recorded values of the BDR breadboard without filler and with MLI</u>, a case that is not affected by other parameters such as radiation.

Starting from the Chamber baseplate temperature of 58°C set to the BDR breadboard, the analysis of the BDR module has been performed setting this result as the temperature constraint and introducing the heat power sources (shown in Figure 3-1) set on the nodes in their effective nodal locations as per Figure 4-1.

The FEM model is shown in Figure 4-1. The thermal analysis is shown in Figure 4-2 and complies with the BDR test results at ± 1°C.

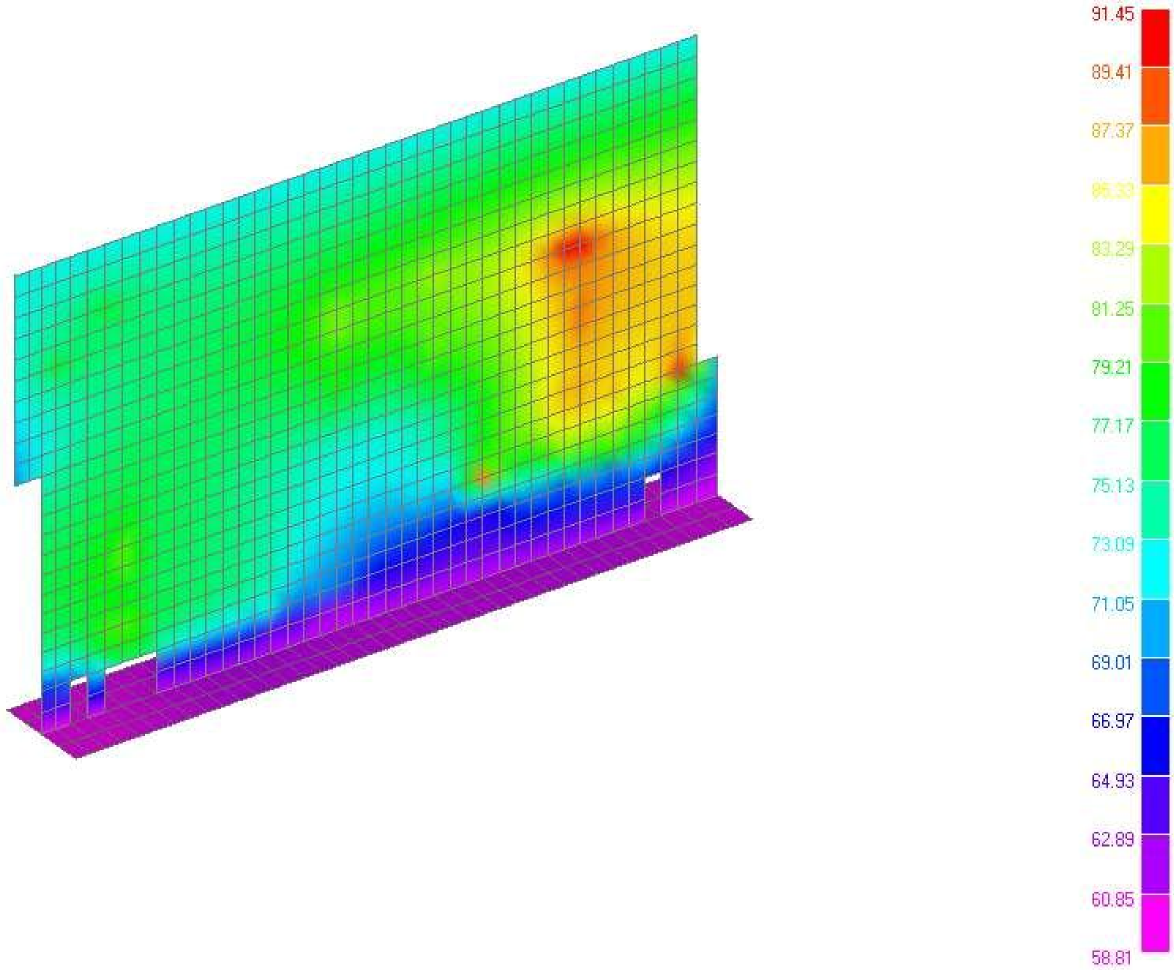


Figure 4-2

4.1 -The BDR Module with the BN100 filler

The previous FEM model with no filler has been used. The filler has been modelled by creating solid elements correspondents to the existent mesh nodes.

This conception is obviously well far from the reality where the components have a specific mounting offset depth normal to the PCB plane. But because of the many different components depths typical of any Ground or Space Module it has been found more attractive and much simpler modelling the filler as an homogeneous and cubic space having an average depth of TBD mm. The knowledge of the precision of the filler depth is not considered a fundamental parameter, then a wide approximation is considered acceptable.

This is shown in Figure 4-3 where only 2 ranges of solid elements have been created, what gives a filler depth of 16.7 mm.

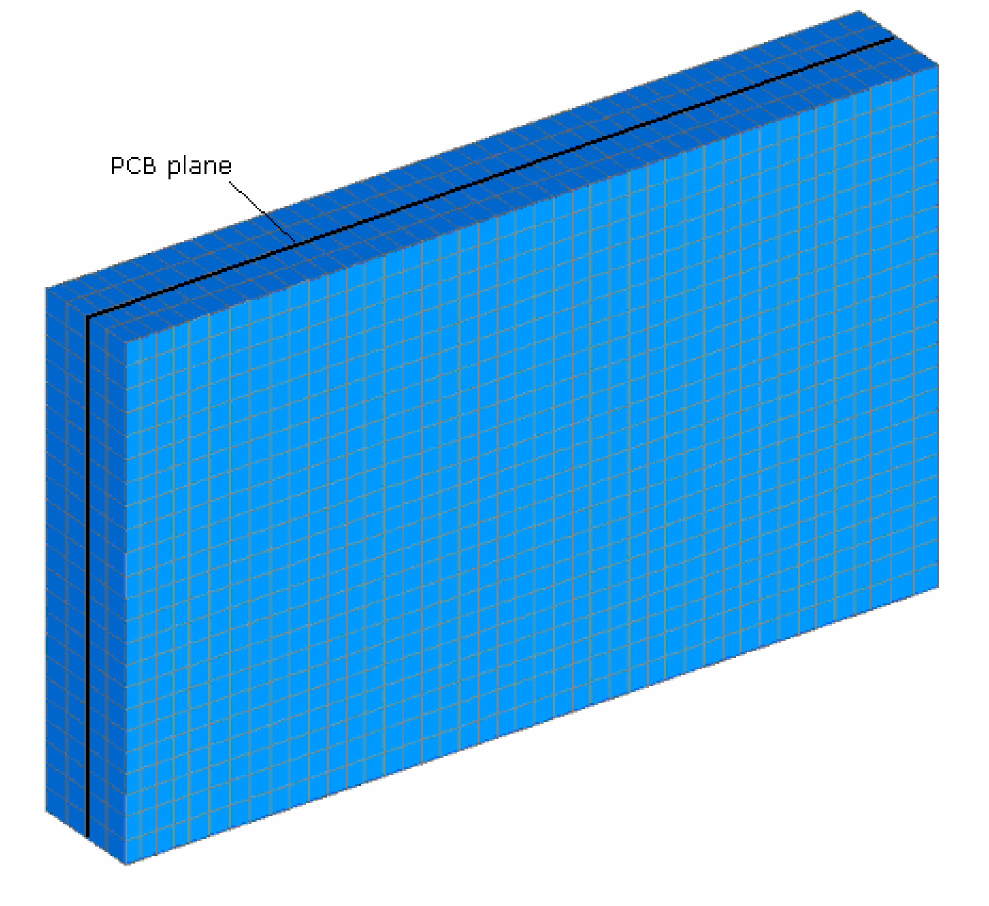


Figure 4-3

The thermal analysis results are shown in Figure 4-4 and comply with the results obtained in the breadboard test with BN100. It is to be noted that the Tmax has been recorded in correspondence of the CR24, Q26 components that are mounted on the heat sink, while the LS2 temperature benefits more of the presence of a thermal conductive filler.

The thermal analysis has been carried out approaching the matter in a straightforward way, that is, supposing to have a filler with an average isotropic thermal conductivity and varying it up to arrive to the results obtained during the test. At the end a thermal conductivity factor **K= 9 W/mK** has been the one that has given analysis results closer to the experienced ones.

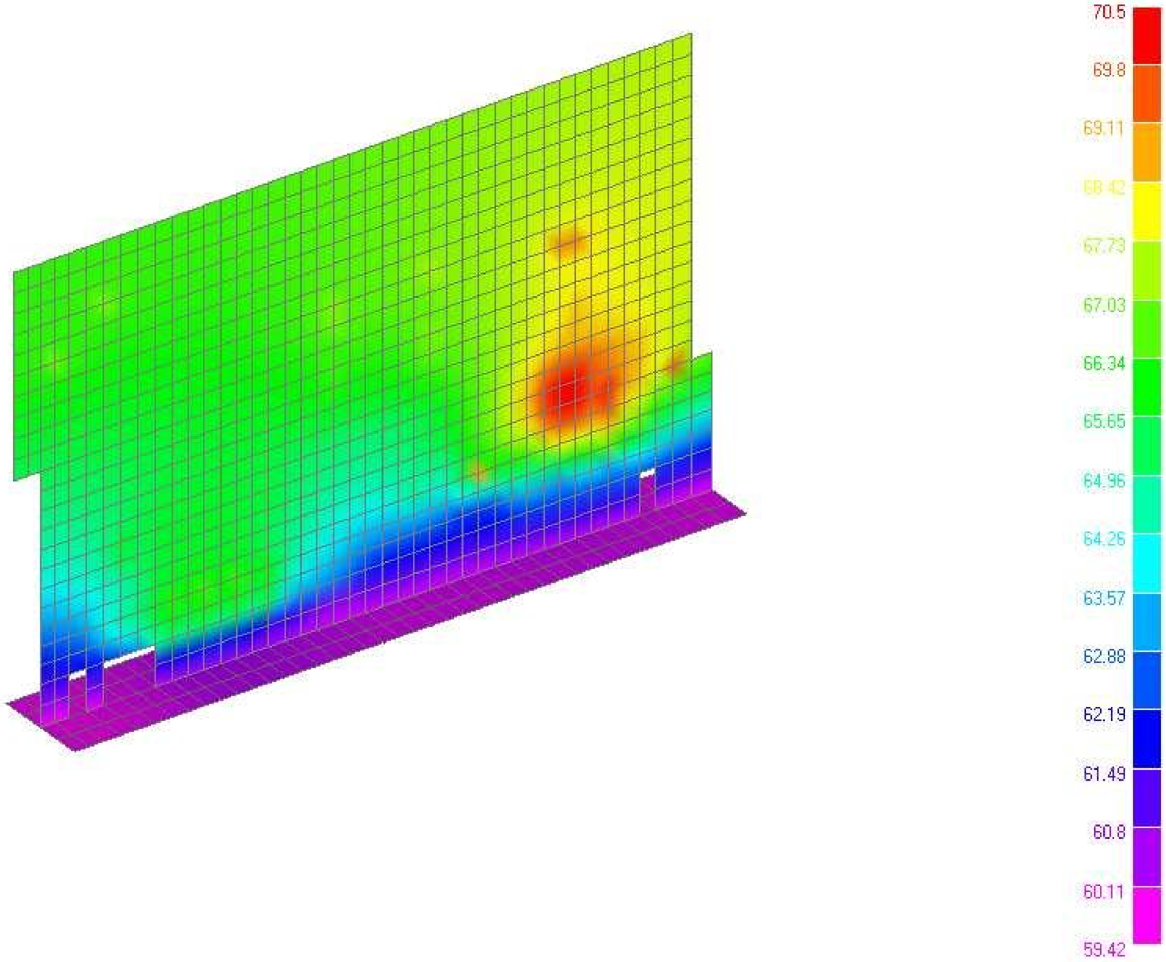


Figure 4-4

This value is lower than the one evaluated many times in on-Ground and small size applications.The reason of such a result can well be explained by the fact that:

- The lateral panels are made of Fiberglas, without any reinforcement or ribs that induce a rather low stiffness to the casing that would not permit to compress the powder at the levels normally used in on-Ground applications.
- A factor of scale that keep relatively big size units such as the breadboard from reaching the same amount of compression of small units.
- The components mounted on the PCB reduce the cross-sectional area of the powder. This aspect, that is very difficult to reproduce, has not been taken into account in the FEM model.

The already important T reduction experienced on the BDR-BN100 breadboard (more than **20°C** with MLI), not specifically developed to be structurally as much rigid as current Space units, permits to claim how much conservative are the obtained results. In future BN100-based units, an higher BN compression can be reached, with consequently even superior temperature reduction.

4.2 -Technology growth potential

The availability of a FEM model just tuned up with the results of the thermal test campaign carried out with the BDR breadboard permits to extend the obtained results to other possible thermal configuration. This will permit us to better realize the potentiality that stay behind the BN100 filler technology.

3 cases have been studied, all by varying the power of the LS2 component, the one mainly influenced by the BN100 filler:

- Case with LS2 power of 2 W
- Case with LS2 power of 4 W
- Case with LS2 power of 6 W

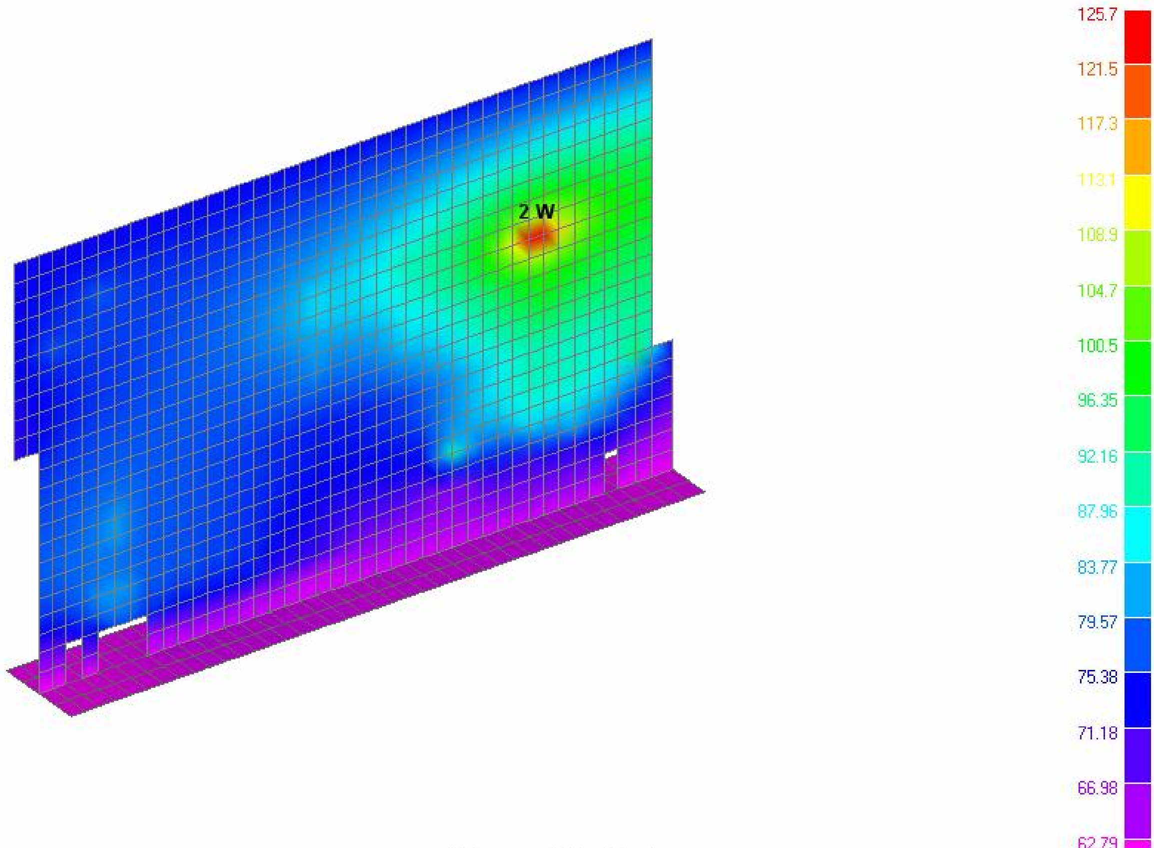
In Table 4-1and following plots the analysis results are shown:

	Max T (°C)	**T difference with T_{amb}**	**T difference between 2 systems**
Empty - P= 2W	125.7	+67.7	
With BN100 – P= 2W	76.2	+16.2	-49.5
With BN100 – P= 4W	84.6	+26.6	
With BN100 – P= 6W	93.0	+35	

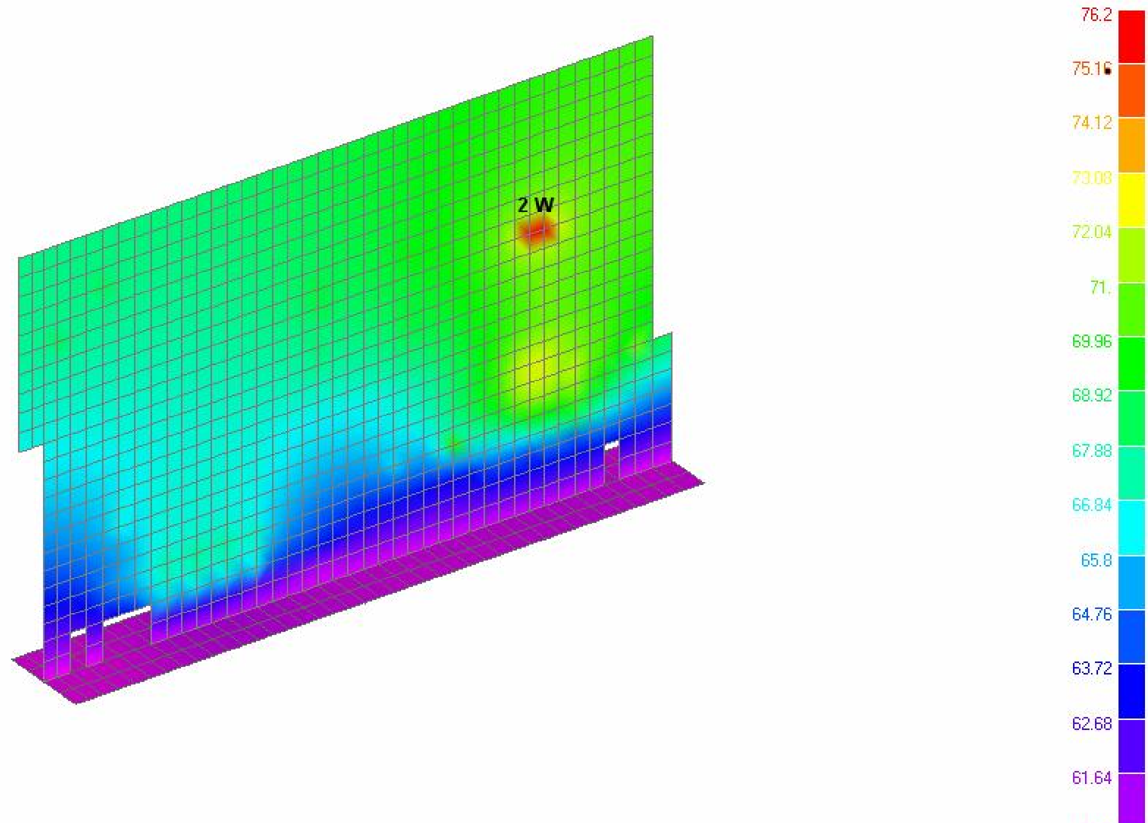
Table 4-1

<u>From the above results it appears, as a conclusion, that with the BN100 filler it is possible to host on a PCB punctual power loads 12 times the one without a thermal conductive filler.</u>

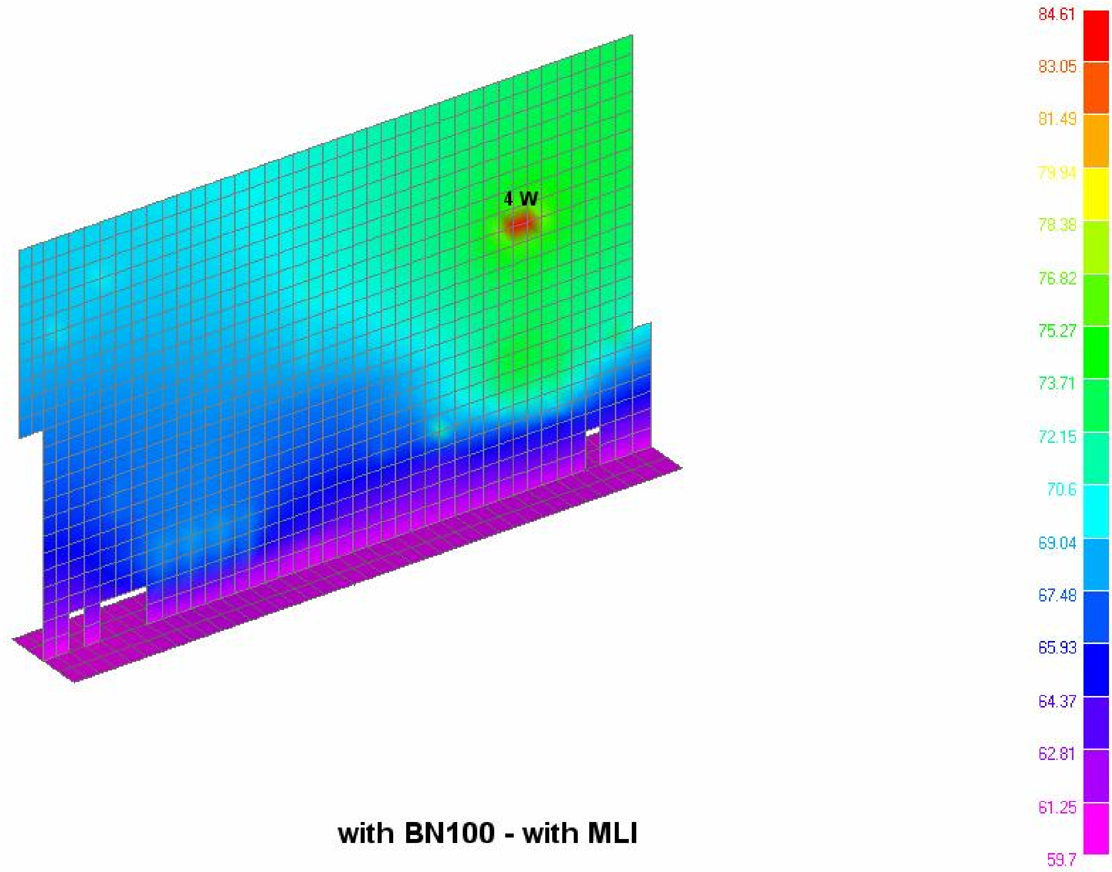
This fact has certainly an impact in the future design of a PCB that will encounter reduced environment conditions with the possibility to reduce engineering/development costs. New opportunities can also be offered to COTS that are not asked to challenge an harsh thermal environment anymore.



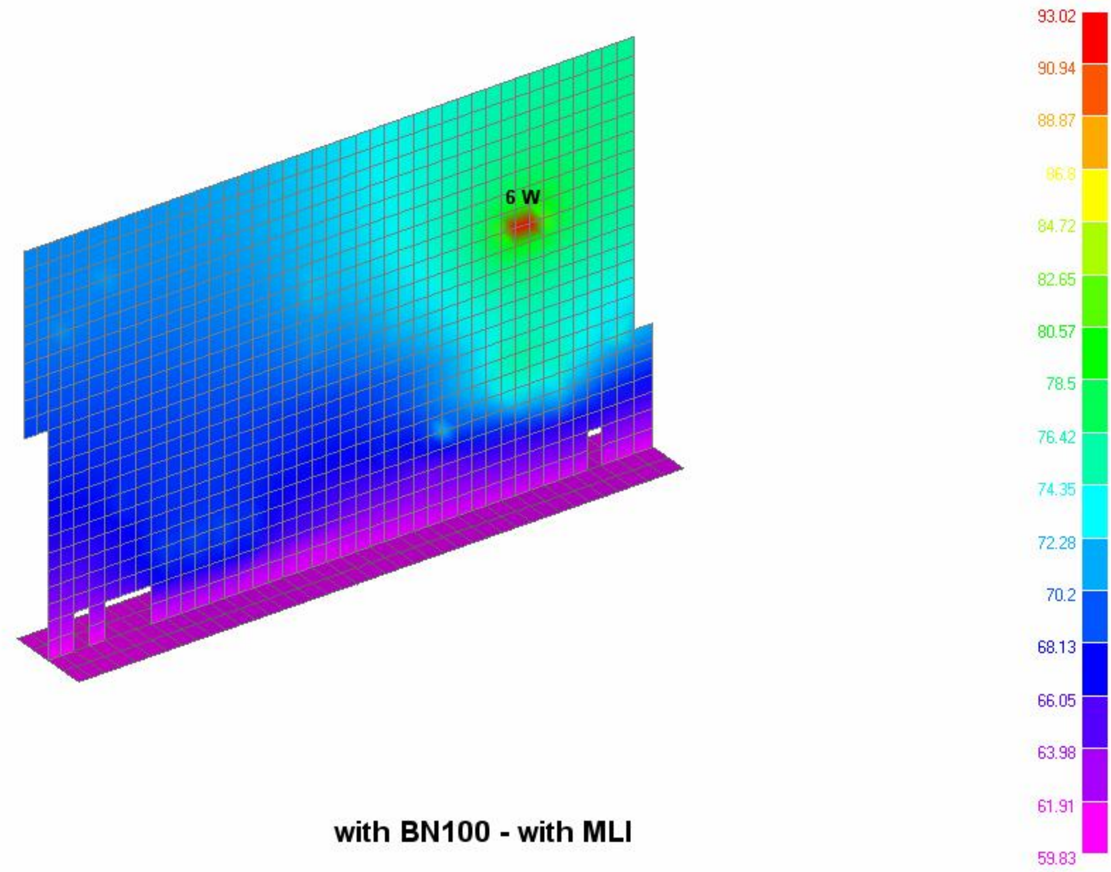
no filler - with MLI



with BN100 - with MLI



with BN100 - with MLI



with BN100 - with MLI

5 - CONCLUSIONS

From this “Proof of Concept” program aimed at verifying a possible use of the BN100 filler technology in HV equipment/component, the following fundamental results can be emphasized:

The quick maintenance has been fully demonstrated and appreciated. The cost saving deriving from this feature has not been investigated but it can be considered an added value offered by this technology.

The not toxicity of the BN is a not negligible factor of interest.

The containment aspects have been demonstrated as possible without adopting expensive design solutions.

The risks of pollution linked to handle loose BN powder has been treated as a design aspect and some solutions have been found to get it compatible with a 100.000 class clean room requirement.

The filling process has been demonstrated to be intrinsically more reliable, above all in terms of electrical characteristics, with respect to traditional polymer-based fillers. The development of the Automatic Filling Equipment has permitted to guarantee, further a quicker process, also an even filling uniformity to the Units.

The pre-compression characteristics of a BN100-based packaging increase the stiffness and damping characteristics that associated to a lower mass density permit to save mass.

The measured high dielectric strength in high vacuum conditions is demonstrated but valid solutions have to be found to carry out verification tests at ambient pressure (conformal coating, inert liquids, high rigidity painting, …).

The thermal dissipation advantages offered by the BN100 filler technology are clear and without ambiguity. Much lower temperatures and gradients are assured to the components arising then the durability. Less expensive design solutions can be applied and the use of COTS can seriously become attractive with the BN100 filler, depending on the mission.

As a conclusion, we consider this “Proof of Concept” program as successful and worthy to be pursued as driving filler technology in more specific qualification programs.

SOMMAIRE/*SUMMARY*
Poster session