**HERSCHEL / PLANCK**

# Planck PLM Thermal Analyses

## H-P-3-ASPI-AN-0330

## Product Code : 22000

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## ENREGISTREMENT DES EVOLUTIONS / *CHANGE RECORDS*

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# 1. INTRODUCTION

## 1.1 Scope

This document is intended to present the PPLM thermal analyses. Full design description is given in [RD**2**].

## 1.2 Applicable and Reference Documents

### *1.2.1 Applicable documents*

| Ref. | No. | Issue/date | Title |
|---|---|---|---|
| AD 1 | SCI-PT-RS-05991 | Latest issue | H/P System requirement specifications |
| AD 2 | H-P-3-ASPI-SP-0274 | Latest issue | Planck telescope Optical and RF system specifications |
| AD 3 | H-P-3-ASPI-IS-070 | Latest issue | Planck PLM Interface and Applicability specification |
| AD 4 | PL-LFI-PST-ID-002 | I3R0 | PLANCK SORPTION COOLER ICD |
| AD 5 | SCI- PT-IIDB/LFI-04142 | I2R1 | Instrument Interface Document PART B INSTRUMENT “LFI” |
| AD 6 | SCI-PT-IIDB-HFI-04141 | I3R1 | Instrument Interface Document PART B INSTRUMENT “HFI” |
| AD 7 | SCI-PT-RS-07422 | I5R4 | Planck Telescope – Primary Reflector / Secondary Reflector Specification |

### *1.2.2 Reference documents*

| Ref. | No. | Issue/date | Title |
|---|---|---|---|
| RD 1 | H-P-3-ASP-ID-0550 | I2R0 | PPLM EICD |
| RD 2 | H-P-3-ASPI-RP-0313 | I2 | Planck PLM Design Report |
| RD 3 | H-P-3-CSAG-TR-0002 | I2R2 | Planck Telescope & Cryo-structure Thermal Conductivity Evaluation Report |
| RD 4 | H-P-3-CSAG-TR-0006 | I1R0 | Planck Telescope & Cryo-structure Selection of High Emissivity Coating – Phase 2 Report |
| RD 5 | H-P-3-CSAG-TR-0008 | I1R2 | Planck Telescope & Cryo-structure Interface Thermal Conductance Test Report |
| RD 6 | H-P-3-CSAG-TR-0009 | I1R0 | Planck Telescope & Cryo-structure Thermo-optical Properties Evaluation Report |

| Ref. | No. | Issue/date | Title |
|---|---|---|---|
| RD 7 | H-P-3-CSAG-AN-0003 | I2R2 | Planck Telescope & Cryo-structure Thermal Design & Analysis Report |
| RD 8 | H-P-3-CSAG-AN-0006 | I1R0 | Planck Telescope & Cryo-structure Thermo-optical Design & Analysis Report |
| RD 9 | H-P-3-CSAG-TR-0103 | I1R0 | Planck Telescope & Cryo Structure - Delta Qualification Test Report Low Emissivity Coatings (LEC) |
| RD 10 | H-P-1-ASP-LI-0279 | I3R0 | Declared material List ( DML ) |
| RD 11 | 5C LCSE R – 7100 13 | | Détermination de la conductivité thermique d'un alliage d'aluminium 5056 entre 4-50K et 77-160K |
| RD 12 | H-P-3-ASP-AN-0657 | I1R0 | Planck CQM Cryo-Chain Thermal Mathematical Model Description |
| RD 13 | PLA-ASED-RP-014 | I1R0 | Transient Thermal Analysis Report for the Primary and Secondary Reflector |
| RD 14 | H-P-1-ASPI-AN-0269 | I3R0 | End of Life cleanliness analysis |
| RD 15 | H-P-3-ASPI-BT-0275 | I2R0 | PPLM MCI budgets |
| RD 16 | H-P-1-ASPI-TN-0216 | Issue 1 | Radiometric environment hypothesis for straylight assessment |
| RD 17 | H-P-3-ASPI-AN-0323 | Issue 1 | PPLM RF Analysis |
| RD 18 | H-P-3-ASPI-SP-0004 | Latest issue | Planck telescope specification |
| RD 19 | H-P-3-ASPI-SP-0021 | Latest issue | Cryo-structure and telescope baffle specification |

## 1.3 Acronyms

| | |
|---|---|
| AD | Applicable Document |
| CFRP | Carbon Fiber Reinforced Plastic |
| CTE | Coefficient of thermal expansion |
| BOL | Beginning of Life |
| EOL | End of Life |
| EP | Entrance Pupil |
| FPA | Focal Plane Assembly |
| FOV | Field-of-view |
| PPLM | Planck Payload Module |
| HFI | High Frequency Instrument |
| LFI | Low Frequency Instrument |
| LOS | Line Of Sight |
| MOS | Margin of Safety |
| N/A | Not applicable |
| PA | Product Assurance |
| PLM | Payload Module |
| PR | Primary Reflector |
| PtV | Pic to valley |
| RD | Reference Document |
| RH | Relative Humidity |
| RMS | Root Mean Square |
| S/C | Spacecraft |
| SR | Secondary Reflector |
| TA | Telescope Assembly |
| TBC | To be confirmed |
| TBD | To be determined |
| WFE | Wave Front Error |
| wrt | With Regards To |
| PPLM | Cryo-Structure and Telescope |

# 2. REVIEW OF PPLM STRUCTURE THERMAL REQUIREMENTS

## 2.1 Performance requirements at interfaces with Instruments and Reflectors

### *2.1.1 Operational mode*

The PPLM structure must ensure, at Instruments Interfaces, max temperatures compatible with the cryo-chain functioning.

Table 2.1-1 presents a synthesis of requirements in operating mode.

| *Operating mode* | | Min T (K) | Max T (K) | Location at which the required temperature must be guaranteed |
|---|---|---|---|---|
| LFI WG | VG1 | N/A | 170 | on interface shield side |
| | VG2 | N/A | 120 | |
| | VG3 | N/A | 60 | |
| Sorption Cooler | VG1 | 150 | 170 | at exchangers and on exchangers side (at exchanger 3C on shield 3) |
| | VG2 | 100 | 120 | |
| | VG3 | 45 | 60 | |
| JFET box | | 40 | 60 | on PR panel side |
| LFI FPU | | 40 | 65 | on PR panel side |
| Primary Reflector | | 30 | 50 | average PR temperature |
| Secondary Reflector | | 30 | 50 | average SR temperature |

**Table 2.1-1 : Operational interface temperature requirements**

### *2.1.2 Non-operational mode*

Table 2.1-2 presents a synthesis of requirements in non-operating mode.

| *Non operating mode* | | Min T (K) | Max T (K) | Location at which the required temperature must be guaranteed |
|---|---|---|---|---|
| LFI WG | VG1 | N/A | N/A | on interface shield side |
| | VG2 | N/A | N/A | |
| | VG3 | N/A | N/A | |
| Sorption Cooler | VG1 | 150 | 323 | at exchangers and on exchangers side |
| | VG2 | 100 | 323 | |
| | VG3 | 40 | 323 | |
| JFET box | | 30 | 333 | on PR panel side |
| LFI FPU | | N/A | 323 | on PR panel side |
| Primary Reflector | | 30 | 323 | average PR temperature |
| Secondary Reflector | | 30 | 323 | average SR temperature |

**Table 2.1-2 : Non-operational interface temperature requirements**

## 2.2 Performance requirements issued from straylight analysis

As described in Table 2.2-1, straygligtht concerns require stability on a selection of PPLM elements.

| *PPLM thermal stability requirements* | | Max amplitude (µK) | Comments |
|---|---|---|---|
| Primary Reflector | Circular central part | 1 | active face |
| | Moon illuminated part | 15 | |
| | Circular outer part | 3 | |
| Secondary Reflector | | 1 | active face |
| Baffle | | 100 | internal surface |
| Shield 3 (internal) | | 100 | inside of optical enclosure |
| Shield 3 (external) | | 13 | outside of optical enclosure |

**Table 2.2-1 : Thermal stability requirements**

The stability requirements are derived from straylight requirements (see [RD**17**]). The specified max amplitude corresponds to the 1/60 Hz frequency.

## 2.3 Telescope and Cryo-structure qualification temperature range

Table 2.3-1 is extracted from [RD**18**] and [RD**19**].

| *Items* | Qualification | | Acceptance | |
|---|---|---|---|---|
| | Min | Max | Min | Max |
| Material & Process (sample) | 30 K | 85 °C | / | / |
| Telescope & Cryo-Structure | 40 K | 85 °C | 45 K | 80 °C |

**Table 2.3-1 : Qualification temperature range**

## 2.4 Review of Interface specifications

### *2.4.1 Instruments & coolers I/F heat loads allocation*

Table 2.4-1 to Table 2.4-3 present heat loads allocations at Instruments interfaces.

| *Sorption Cooler I/F Heat Loads* | T reference (K) | Allocated load (mW) | Margin | Max load (mW) |
|---|---|---|---|---|
| Shield 3 | 58.5/56.3/52.3 | 1175 | 10% | 1293 |
| Shield 2 | 108 | 447 | 20% | 531 |
| Shield 1 | 158 | 566 | 20% | 673 |

**Table 2.4-1 : Sorption Cooler I/F heat loads allocations**

| *LFI RAA I/F Heat Loads* | T reference (K) | Allocated load (mW) | Margin | Max load (mW) |
|---|---|---|---|---|
| Shield 3 | 51.4/57.6 | 710 | 20% | 852 |
| Shield 2 | 106 | 560 | 20% | 672 |
| Shield 1 | 166 | 5370 | 20% | 6444 |

**Table 2.4-2 : LFI RAA I/F heat loads allocations**

| *HFI I/F Heat Loads* | T reference (K) | Allocated load (mW) | Margin | Max load (mW) |
|---|---|---|---|---|
| Shield3+telescope | 50 | 620 | 20% | 744 |
| Shield2+struts | 110 | 20 | 20% | 24 |
| Shield 1 | 165 | 50 | 20% | 60 |

**Table 2.4-3 : HFI I/F heat loads allocations**

### *2.4.2 Planck PLM I/F specification*

❑ SVM interface IR thermo-optical properties

- $\varepsilon$=0.05
- $\tau_{IR}$ = 90%

❑ SVM MLI outer layer temperature

- Upper closure panels and subplatform : 220K
- Solar array : 300K
- BEU & PAU : 235K

❑ PLM struts conductive interface : 310K (stability ±0.02K over [1/5000Hz, 1/60Hz])

❑ Heat loads from electronic boxes

| *Electronic boxes I/F Heat Loads* | T reference (K) | Allocated load (mW) | Margin | Max load (mW) |
|---|---|---|---|---|
| PAU&BEU→Shield1 | 166 | 2300 | 20% | 2760 |

**Table 2.4-4 : Electronic boxes I/F heat loads allocations**

# 3. P-PLM STRUCTURE THERMAL MATHEMATICAL MODEL DESCRIPTION

## 3.1 Method and software

The PPLM structure thermal modelling is based on nodal method and uses Esarad and Esatan respectively to compute radiative couplings and to set up and solve the nodal network.

Esarad runs a Monte-Carlo ray-tracing; in order to ensure radiative computation precision (generally mandatory for passive coolers performance accurate estimation), the minimum number of rays emitted by each radiating face is fixed approximately at 10000 (drawn from specific sensitivity study).

Esatan is used to set up the nodal network (radiative and conductive couplings, dissipations, boundary conditions, thermal capacitances), to solve the hence built thermal system and to output the yielded temperatures and exchanged fluxes.

Attention is paid to set the computation parameters at proper values in order to ensure, for steady and transient runs, the solving algorithms full convergence.

## 3.2 General presentation

### *3.2.1 Contents*

The global TMM takes into account :

- ☐ The P-PLM structure, i.e
    - ✓ the 12 cryo struts (including inner foam and attachment blades) and the bracing struts,
    - ✓ the 3 shields of the V-Groove system,
    - ✓ the telescope structure (frame, reflectors panels, struts and brackets),
    - ✓ the baffle,
    - ✓ the primary and secondary reflectors,
    - ✓ the thermal braids,
- ☐ The P-PLM active control harness
- ☐ The SVM interfaces
- ☐ The Instruments & Coolers TMM (as described in [RD**12**] for HFI & Sorption Cooler)

The Figure 3-1 displays an overview of PPLM geometrical model.

The model (nominal case) is referenced under H-P-ASPI-DD-1568 I2.

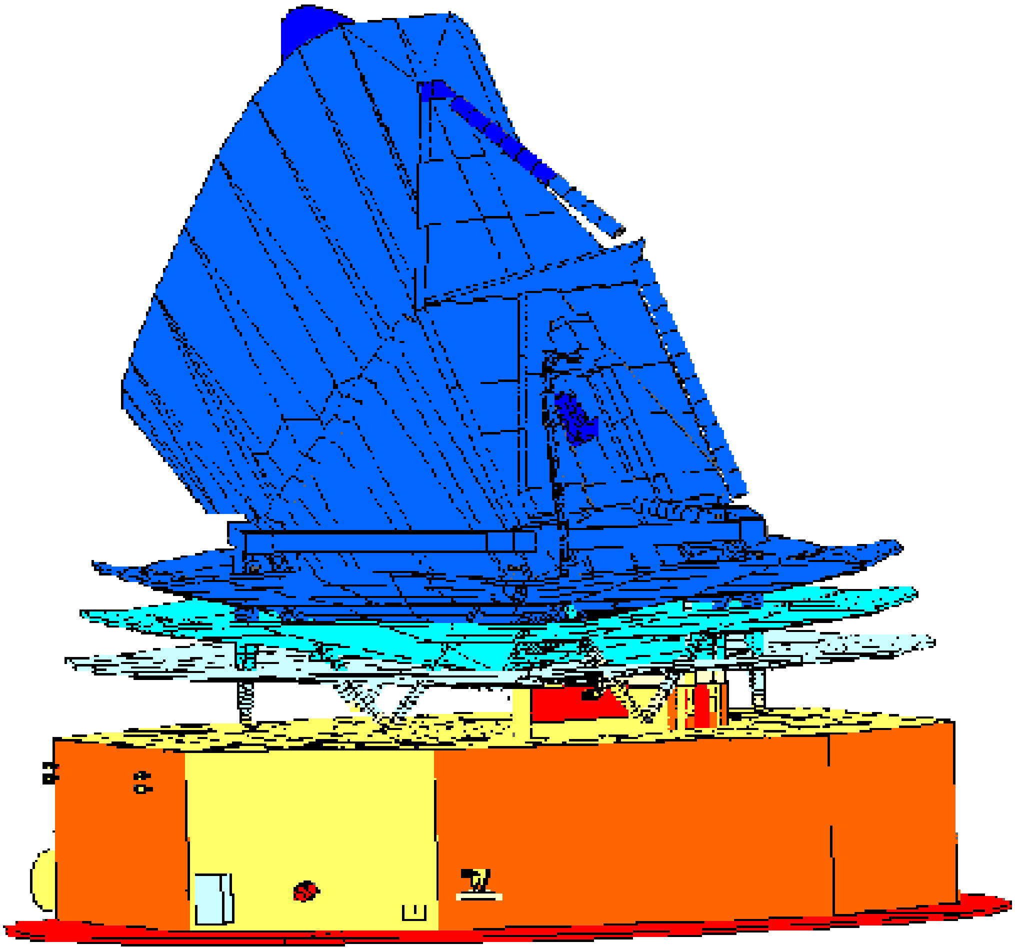


Figure 3-1 : PPLM geometrical model overview

### 3.2.2 Radiative model

#### 3.2.2.1 ESARAD structure

Esarad files architecture is displayed in Figure 3-2.

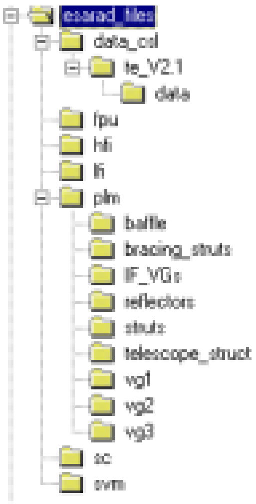


**Figure 3-2 : ESARAD structure**

### 3.2.2.2 Radiative parameters

The available radiative properties parameters are :

| *Radiative properties* | IR spectrum | Solar spectrum |
|---|---|---|
| Emission | $\varepsilon$ | - |
| Absorption | $\varepsilon$ | $\alpha$ |
| Specular reflectivity | $\rho_{S\ IR}$ | $\rho_{S\ sol}$ |
| Diffuse reflectivity | $\rho_{D\ IR}$ | $\rho_{D\ sol}$ |
| Transmittivity | $T_{IR}$ | $T_{sol}$ |

**Table 3.2-1 : Radiative properties parameters**

Note :

- The reflectance Specularity can also be characterised by the Specularity rate $\tau_S = \rho_{S\ IR}/(\rho_{S\ IR} + \rho_{D\ IR})$.
- IR parameters are linked by the relation $\varepsilon + \rho_{S\ IR} + \rho_{D\ IR} + T_{IR} = 1$ .
- These parameters characterise macroscopic properties of extent areas (defined by radiative surfaces) and thus may represent not only ideal coatings behaviour but also the influence of potential defaults inherent to actual design (shapes inaccuracies, singularities, …).
- Only cases without solar illumination are studied, for which only IR parameters are relevant, hence the presentation in this document of IR coefficients only.

### 3.2.2.3 Geometrical representativity

The P-PLM structure geometry definition is based on CSAG CDR engineering drawings. It corresponds therefore to the estimated ideal shapes at operational temperature.

Sensitivities have been performed to check the influence of shields distortion (due to thermo-elastic effect) on the performance (perturbation of V-Groove efficiency). Figure 3-3 and Figure 3-4 show typical shield shapes before and after deformation (scale exaggerated × 100 for visibility).

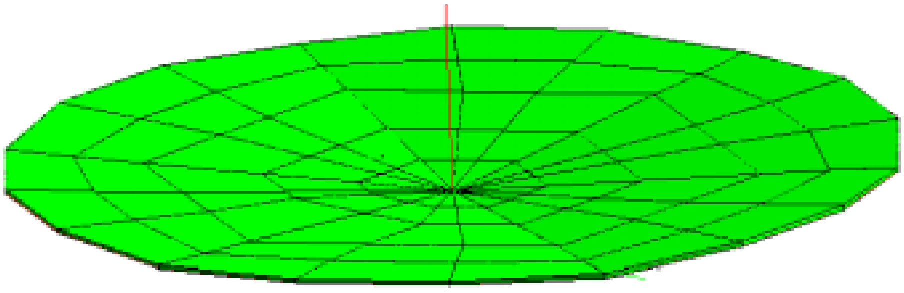


**Figure 3-3 : Shield shape before deformation**

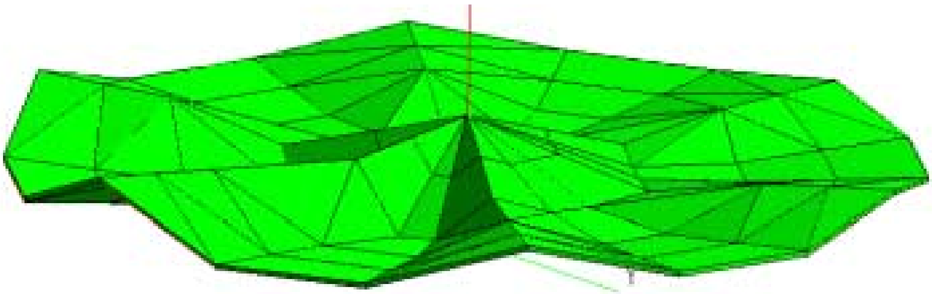


**Figure 3-4 : Shield shape after deformation**

Computations show that such displacements have :

- ✓ visible though small impact on shields 1&2 (<1K)
- ✓ no impact on shield 3 (<0.1K)

The ideal geometry has therefore been used for GMM and this potential low error source has been considered as included in the 2K mathematical uncertainty.

### *3.2.3 Nodal network set-up presentation*

#### 3.2.3.1 ESATAN structure

Esatan files architecture is displayed in Figure 3-5.

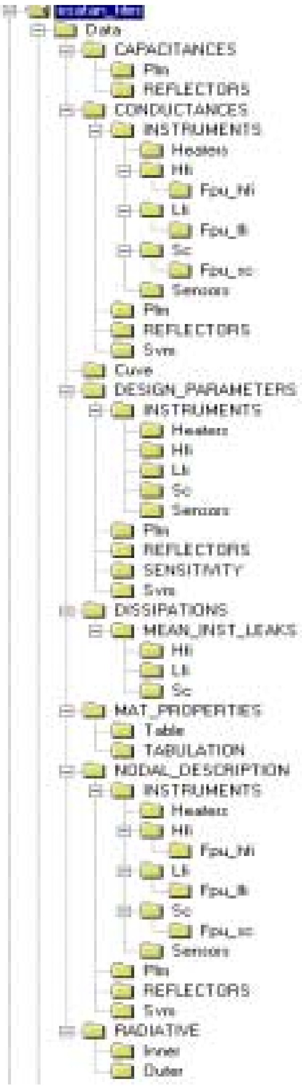


**Figure 3-5 : ESATAN model architecture**

### 3.2.3.2 Nodal breakdown

The nodal breakdown is described in Table 3.2-2.

| | | | |
|---|---|---|---|
| **PPLM**<br>**1677 nodes**<br>**(30000-39999)**<br>**(50000-79999)**<br>**model cool down**<br>**405 nodes** | Primary Reflector | (33000-33999) | **75 nodes**<br>Front : 33000-33076<br>Rear : 33100-33176<br>Thermal foil : 33200<br>Heater and inner MLI cover : 33311-33376<br>outer MLI cover foil : 33411-33476 |
| | Secondary Reflector | (34000-34999) | **75 nodes**<br>Front : 34000-34076<br>Rear : 34100-34176<br>Thermal foil : 34200<br>Heater and inner MLI cover : 34311-34376<br>outer MLI cover foil : 34411-34476 |
| | Baffle | (30000-30999) | **12 nodes**<br>30000-30005<br>30500-30505 |
| | VG1 | (50000-59999) | **198 nodes**<br>50110-50184, 51110-51184<br>50210-50236, 51210-51236<br>50310-50236, 51310-51336<br>50410-50236, 51410-51436<br>50510-50236, 51510-51536<br>50610-50684, 51610-51684<br>52100-52602 |
| | VG2 | (60000-69999) | **198 nodes**<br>60110-60184, 61110-61184<br>60210-60236, 61210-61236<br>60310-60236, 61310-61336<br>60410-60236, 61410-61436<br>60510-60236, 61510-61536<br>60610-60684, 61610-61684<br>62100-62602 |
| | VG3 | (70000-79999) | ***270* nodes**<br>70110-70189, 71110-71189<br>70210-70278, 71210-71278<br>70310-70337, 71310-71337<br>70410-70437, 71410-71437<br>70510-70578, 71510-71578<br>70610-70689, 71610-71689<br>72003, 72013<br>72100-72602 |
| | FRAME | (35000-35999) | **96 nodes**<br>35000-35173<br>35210-35263 |
| | PR structure | (31000-31699) | **30 nodes**<br>Main panel<br>31000-31008, 31100-31108<br>31009-31033, 31109-31133 |
| | | | **20 nodes**<br>Doubler Panel<br>31203-31208, 31303-31308<br>31220-31223,31320-31323 |
| | | | **2 nodes**<br>Triangle panel : 31500, 31501 |
| | | | **2 nodes**<br>Dismountable beam : 31400, 31401 |
| | | | **20 nodes**<br>Main panel struts<br>31600-31609, 31610-31619 |
| | | | **10 nodes**<br>Bottom strut<br>31620-31629 |
| | | | **10 nodes**<br>Back strut<br>31630-31639 |
| | | | **10 nodes**<br>Top strut<br>31640-31649 |
| | SR structure | (31700-31899) | **14 nodes**<br>SR panel<br>31700-31706, 31710-31716 |

**Table 3.2-2 : TMM nodal breakdown**

## 3.3 Modelling assumptions

### *3.3.1 General rules*

### 3.3.1.1 PPLM structure modelling

The PPLM structure modelling is based on :

- ☐ Detailed analytical studies

  These detailed studies aim at providing the global TMM with consolidated assumptions (open honeycomb performance, thermal coupling between shield 3 and Sorption Cooler exchanger …)

- ☐ Experimental data issued from intensive materials and coating characterisation

  Assumptions take into account data drawn from latest measurements, including HEC emittance, processed by ASP and compared to CSAG assessments (see appendixes 1&2)

- ☐ CSAG CDR definition

  All geometrical parameters have been updated according to CDR engineering drawings

- ☐ Observations on CQM hardware

  Actual CQM coating detailed definition (open honeycomb covering) has been taken into account after observations on specimen

All modelling parameters are given with uncertainty through (min – nom – max) values in order to build the (cold – nom – hot) global TMM cases.

<u>Notes</u> :

- The optical closures (SLI skirts) between Baffle & Shield 3 and PR Panel & FPU are not included in radiative model because of their negligible influence on the thermal performance.
- The modelling parameters uncertainty is defined after materials characteristic uncertainty, the latter being generally much higher than geometrical parameters (thickness …) tolerances.

### 3.3.1.2 Heat allocations for Instruments interfaces

The PPLM TMM takes into account nominal Instruments modelling. The instruments modelling is not described in this document, only the resulting loads are of interest for the passive performance demonstration.

These nominal Instruments TMM will be used for cold and nominal operating cases definition. Since the corresponding interface heat loads should be inferior to the allocated ones, the hot case will use fixed extra power in order to reach allocated values.

If,

- ✓ $\varphi(T)$ is the I/F allocated load at temperature T,
- ✓ Q(T) is the I/F heat load resulting from the use of the Instrument model,
- ✓ $T_c$ is the computed I/F temperature with the Instrument model,

the extra power $\delta Q$ injected at I/F will be written : $\delta Q = \varphi(T_c) - Q(T_c)$.

The hence “modified” Instrument modelling therefore produces $Q'(T_c) = \varphi(T_c)$ at I/F.

Note that non-operating case will take into account nominal Instruments TMM in OFF mode i.e without any fluidic dissipation at PPLM interfaces.

### 3.3.1.3 SVM interface

The SVM interfaces are taken into account by using a temperature boundary SVM model. Three cases are used at SVM level:

- Hot case : SVM TCS temperatures "EOL + uncertainties" ⊕ Degraded thermo-optical parameters
- Nom case : SVM TCS temperatures "EOL + uncertainties" ⊕ Nominal thermo-optical parameters
- Safe : SVM TCS temperatures "BOL survival – uncertainties" ⊕ Nominal thermo-optical parameters

Details about interface definition are given in §3.3.4.3.

## *3.3.2 Analysis cases definition*

### 3.3.2.1 Operational cases

Three operational cases are studied. The macroscopic definition of these cases is given in Table 3.3-1.

| *Operational cases* | PPLM structure | Instruments I/F | SVM I/F | Operating Sorption Cooler |
|---|---|---|---|---|
| Nominal | *Nominal* | *Nominal* | *Nominal* | *Nominal* |
| Hot | *Hot* | *Allocations* | *Hot* | *Redundant* |
| Cold | *Cold* | *Nominal* | *Nominal* | *Nominal* |

**Table 3.3-1 : Operational cases definition**

Notes :

- ✓ Redundant Sorption Cooler is considered for hot case because its position leads to hotter configuration
- ✓ Nominal Instruments TMM are used in cold case because no other models are available
- ✓ Nominal SVM I/F conditions are used in cold case for simplification sake (weak sensitivity)

### 3.3.2.2 Non-operational case

One very cold case is studied, as defined in Table 3.3-2.

| *Non-operational case* | PPLM structure | Instruments I/F | SVM I/F |
|---|---|---|---|
| Safe cold | *Cold* | *OFF* | *Safe* |

**Table 3.3-2 : Non-operational case definition**

### *3.3.3 P-PLM Design parameters*

### 3.3.3.1 Thermo-optical parameters

#### *3.3.3.1.1 TMM parameters estimation process*

The parameters ($\varepsilon^{mod}$, $\tau_S^{mod}$) integrate all information related to :

- The coating in its clean and perfect condition
  For example, the MIRO sheet perfectly flat and clean.
  This state is considered as the one corresponding to the measurements.

- The potential contamination (ground&flight)
  The contamination levels are drawn from [RD**14**]. Note that only the particular contamination (5000ppm) may have a noticeable influence on the thermo-optical characteristics.

- The potential presence of interfering substance on the coating
  Some glue, covering part of the open honeycomb cells, may typically reduce the emittance.

- The non-perfect surfaces geometry
  Mainly for highly Specular surfaces (Miro sheets), for which degradation of the flatness may decrease the Specularity. Note that, in order keep modelling close to the physical system, only "small scale" effects can be integrated in the thermo-optical parameters.

- The presence of objects and structure elements perturbing the ideal coating
  Either for high or low emissive coatings, the presence of screws, pipes, supports … will modify (i.e degrade in a conservative approach) the coating properties.

The rational estimation of all these degradation sources allow to define, for each characteristic area of the structure, dedicated properties.

Note :

- Thermal cycling and cleaning process are assumed, as shown by [RD9], to have no influence on LEC thermo-optical properties.

##### *3.3.3.1.1.1 Initial measurement data*

❑ LEC (MIRO)

Measurements have been performed on MIRO sheets.

Measurement data used as inputs for TMM are :

✓ Specular reflectance measurement (LEMTA)

✓ Direct measurements (EADS)

Results are shown in Appendix 2.

- ❑ HEC (PUK on substrate)

  Measurements have been performed on flat Aluminium samples. Extrapolation to open HC coating needs analytical processing (see §3.3.3.1.2)

  Measurement data used as inputs for TMM are :

  - ✓ Specular reflectance measurement (LEMTA)
  - ✓ Direct measurements (LEEE)

  Results are shown in Appendix 2.

### *3.3.3.1.1.2 Estimation of contamination influence*

A specific tool has been developed in order to estimate the influence of contaminant deposit on surfaces, mainly low emissive ones.

This tool uses as inputs absorption indices of main contaminants ($H_2$0 & $NH_3$) and derives emissivity degradation as a function of contaminant thickness and substrate temperature.

Inputs, in term of contaminants amount, are drawn from [RD**14**]. Next tables show the resulting degradation.

***Molecular***

| Density (g/cm3) | **H20** | **Groove 1** | **Groove 2** | **Groove 3** |
|---|---|---|---|---|
| 1 | Surf density (g/cm²) | 2.89E-07 | 1.76E-05 | 1.45E-05 |
| | Thickness (µm) | 2.9E-03 | 1.8E-01 | 1.5E-01 |
| | Emiss degradation | **2.0E-06** | **1.0E-04** | **1.0E-05** |

| Density (g/cm3) | **NH3** | **Groove 1** | **Groove 2** | **Groove 3** |
|---|---|---|---|---|
| 1 | Surf density (g/cm²) | 2.94E-18 | 4.29E-08 | 0 |
| | Thickness (µm) | 2.9E-14 | 4.3E-04 | 0.0E+00 |
| | Emiss degradation | **0.0E+00** | **2.0E-06** | **0.0E+00** |

| Density (g/cm3) | **Other contaminants** | **Groove 1** | **Groove 2** | **Groove 3** |
|---|---|---|---|---|
| 1 | Surf density (g/cm²) | 1.83E-06 | 1.83E-06 | 1.83E-06 |
| | Thickness (µm) | 1.8E-02 | 1.8E-02 | 1.8E-02 |
| | Emiss degradation | **1.8E-06** | **1.8E-06** | **1.8E-06** |

***Particular***

| Emissivity p | - | **Groove 1** | **Groove 2** | **Groove 3** |
|---|---|---|---|---|
| 0.8 | ppm | 5000 | 5000 | 5000 |
| | Emiss degradation | **4.0E-03** | **4.0E-03** | **4.0E-03** |

***Global emissivity degradation***

| - | **Groove 1** | **Groove 2** | **Groove 3** |
|---|---|---|---|
| Emiss degradation | **4.0E-03** | **4.1E-03** | **4.0E-03** |

**Table 3.3-3 : Contamination of low emissive surface**

This shows that only the particulate contamination may have an influence on low emissive surfaces.

Note that, though the same approach could be applied to Specularity degradation, the contamination has been considered as having no significant influence on Specularity rate. The uncertainty existing on the Specular reflection is indeed much larger (#5%) than its potential degradation (0.5%) by particles scattering, whereas the emissivity degradation (0.004) is comparable to the measurement uncertainty (0.006).

Influence of contamination on high emissive coating is assessed by reducing 0.5% to the “clean” value :

$$\varepsilon_{contaminated} = \varepsilon_{clean} \times (1\text{-}5000ppm)$$

#### *3.3.3.1.1.3 Parasitic substance on coating*

Observations show glue traces on the open honeycomb cells surface.

The covered surface has been estimated equal to 33mm². Consistent with observations, this represents a 1mm bandwidth along the perimeter of the cell bottom.

The emissivity value assumed for this area is 0.1 which, along with the corresponding surface, allows to determine the flat coating emittance degradation.

#### *3.3.3.1.1.4 Geometry degradation*

Geometry degradation will affect primarily highly Specular surfaces, very sensitive to any defaults. The most widespread default on shields is the facesheet quilting effect.

This default profile can be modelled as following (drawn from [RD**8**]) :

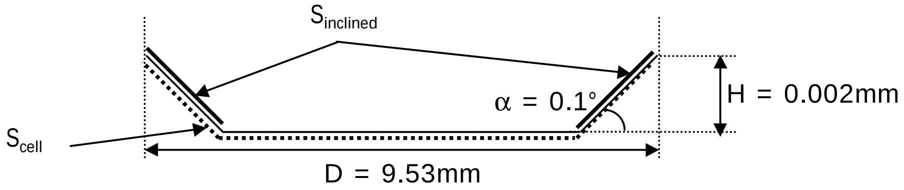


**Figure 3-6 : Quilting effect detailed modelling**

This is represented in global TMM by a flat surface with adapted thermo-optical coefficients.

- Emissivity degradation

The ratio of the developed surface and the projected one (as modelled in global TMM) is $< 1+10^{-4}$. The emissivity increase due to geometry effect is then assumed to be negligible ($<10^{-4}$).

- Specular rate degradation

The flat modelled surface must represent the reflection deviation induced by the inclined parts of the real surface. This deviation has to be integrated in the diffuse reflection coefficient $\rho_{diff}{}^{q}$.

The $\rho_{diff}$ coefficient characterising a reflection over a $2\pi$ radians solid angle, the quilted surface diffuse reflection can be written :

$$\rho_{diff}{}^{q} = \rho_{diff}{}^{Miro} + \rho_{spec}{}^{Miro} \times (S_{inclined}/S_{cell}) \times (1-\cos(2\alpha))$$

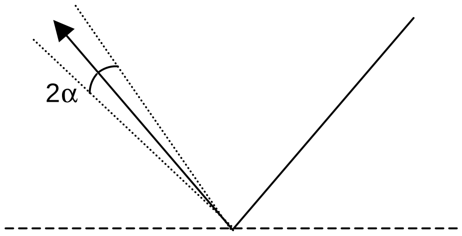


**Figure 3-7 : Quilting effect : reflection cone**

Note :

- $\rho_{diff}^{Miro}$ and $\rho_{spec}^{Miro}$ represent the measured Diffuse and Specular reflection without quilting.

Results are presented in Table 3.3-4. A sensitivity has been performed by exaggerating the defaults.

| *Quilting* | $(\rho_{diff}^{\ q} - \rho_{diff}^{Miro})/\rho_{diff}^{Miro}$ |
|---|---|
| $\alpha$ = 0.1° & H = 0.002mm | $5\ 10^{-5}$ |
| $\alpha$ = 1° & H = 0.02mm | $2.5\ 10^{-4}$ |

**Table 3.3-4 : Miro facesheet quilting effect on Specular reflection**

The results show that the quilting effect has no significant influence. The taking into account of this effect is nonetheless included in coating specular reflectance evaluation for the hot case.

### *3.3.3.1.1.5 Perturbing elements*

A collection of supports, holes, screws are spread over the shields, with different densities according to the considered areas. A detailed work has been performed to count down the surfaces corresponding to all these elements. These surfaces, associated to elements thermo-optical assumptions, lead to substrate coating degradation.

Note that the influence is taken into account only for low emissive areas; the elements developed area is generally much more important than the supporting surface and modelling only the flat surfaces, for HEC, can then be considered as a conservative approach.

The elements emissivity and Specular rate are respectively considered as equal to 0.5 and 0%, whatever the position or the temperature.

The definition of most important radiative areas are presented in appendix 3.

Note that the exact coating definition is also taken into account. For example, the baffle HEC coating is composed of black painted open honeycomb and black flat surfaces. The equivalent average emittance is assessed from the surface weighing of the corresponding surfaces.

### *3.3.3.1.2 High emissivity coating (PUK) characterisation*

#### *3.3.3.1.2.1 Flat coating*

The emissivity values for all PUK coated flat surfaces are drawn from LEEE measurements on Aluminium coating (conservative approach wrt min values).

The following scheme gives a synthesis of the way the flat PUK coated surfaces emittance is estimated in all cases (hot/nom/cold) :

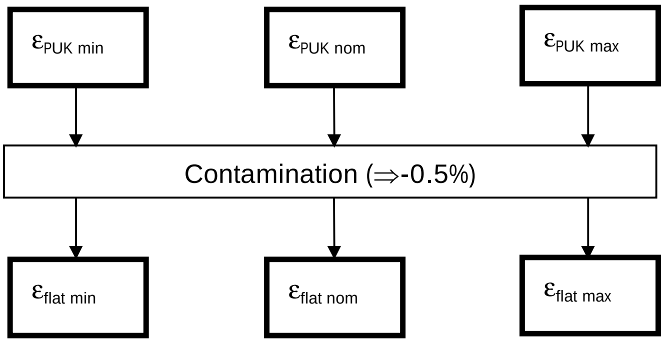


**Figure 3-8 : Flat PUK emittance estimation flowchart**

See Appendix 2 for emittance curve.

<u>Note</u> :

The contamination influence is estimated with following assumptions :

- ✓ 5000 ppm particulate contamination (molecular influence negligible)
- ✓ Particles emissivity = 0

#### *3.3.3.1.2.2 Open honeycomb*

The open honeycomb is aimed at increasing the flat coating emissivity by geometrical effect.

The apparent emittance of the projected flat surface (as modelled in the global TMM) is computed from flat coating properties and geometry by using a detailed dedicated radiative model (THERMICA, Monte Carlo method).

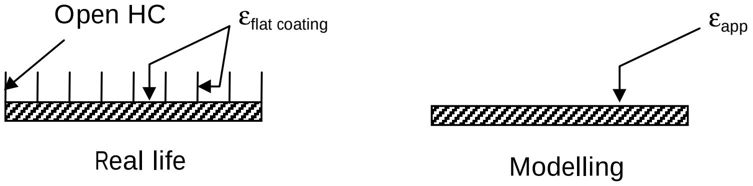


**Figure 3-9 : Modelling of surfaces equipped with open honeycomb**

The modelling presented in Figure 3-9 is theoretically valid only in case of perfect temperature homogeneity in the open HC height. The max gradient estimated @60K between the facesheet and the honeycomb upper extremity is 0.3K, meaning that the mean radiative temperature of the coating (composed by both facesheet and honeycomb) will be ≈0.15K higher than the facesheet itself. This gradient did not justify the implementation of extra nodes in the detailed TMM and is considered to be covered by the 2K mathematical uncertainty.

A view of the detailed open HC radiative model is presented by Figure 3-10. The modelled cells are consistent with the design (3/8'' / 14.3 mm).

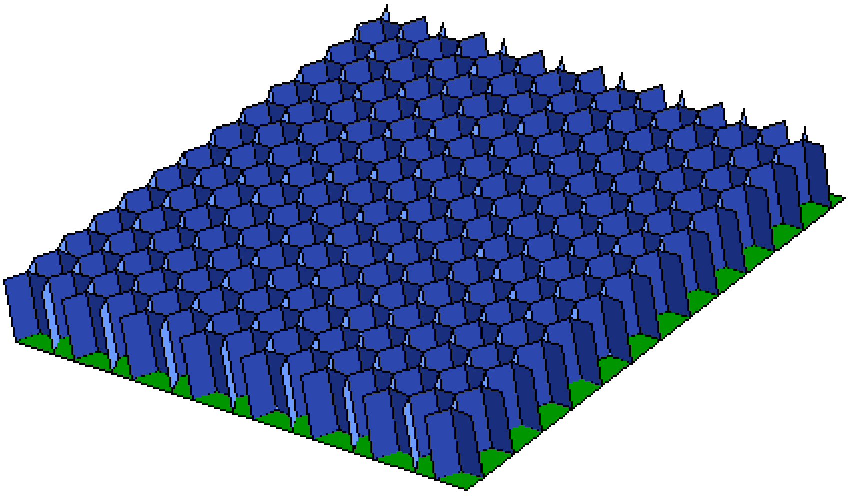


**Figure 3-10 : Open honeycomb detailed radiative model**

The detailed open HC radiative model allows to define a relation g() : $\varepsilon_{app} = g(\varepsilon_{flat\ coating})$

The hence assessed relation is presented in Figure 3-11.

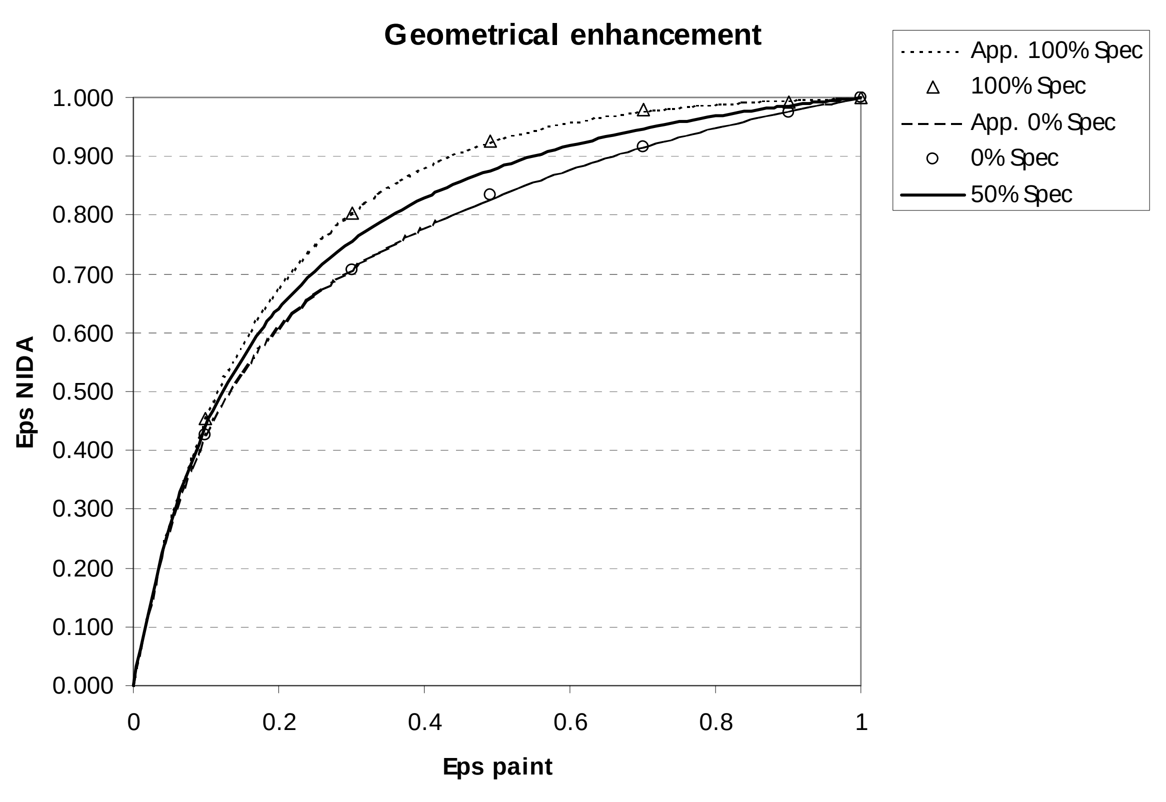


**Figure 3-11 : Emissivity geometric enhancement**

The characteristic points are computed with the detailed model and mathematical extrapolations are afterwards applied to obtain continuous curves. The two extreme curves correspond to pure Specular or Diffuse flat coatings. It is important to notice that the higher Specularity rate the better the geometrical enhancement.

Considering the 0% Spec as a worst case (the Specular ratio tends to increase with increasing wavelengths and then with decreasing temperature), the nominal geometric effect is considered as the median one (50% Specular ratio).

The relation g() is valid for monochromatic assessment on the whole interesting range (sufficient size difference between cells size and wavelength).

According to the total emissivity definition $\varepsilon_T = \frac{\int \varepsilon_{(\lambda,T)}\, L^0(\lambda,T)\, d\lambda}{\int L^0(\lambda,T)\, d\lambda}$, and because of the relation g() strong non-linearity, the relation $g(\varepsilon_T) = \frac{\int g(\varepsilon_{(\lambda,T)})\, L^0(\lambda,T)\, d\lambda}{\int L^0(\lambda,T)\, d\lambda}$ cannot be written, hence the need to know the $\varepsilon_\lambda$ profile versus wavelength in order to estimate the parameter $\varepsilon_{\mathrm{app}\ T} = \frac{\int g(\varepsilon_{(\lambda,T)})\, L^0(\lambda,T)\, d\lambda}{\int L^0(\lambda,T)\, d\lambda}$.

At the time this report is written, the $\varepsilon_\lambda$ profile is not determined, only total values being assessed. Nonetheless, monochromatic behaviour can be estimated from Specular reflectance measurements performed at LEMTA.

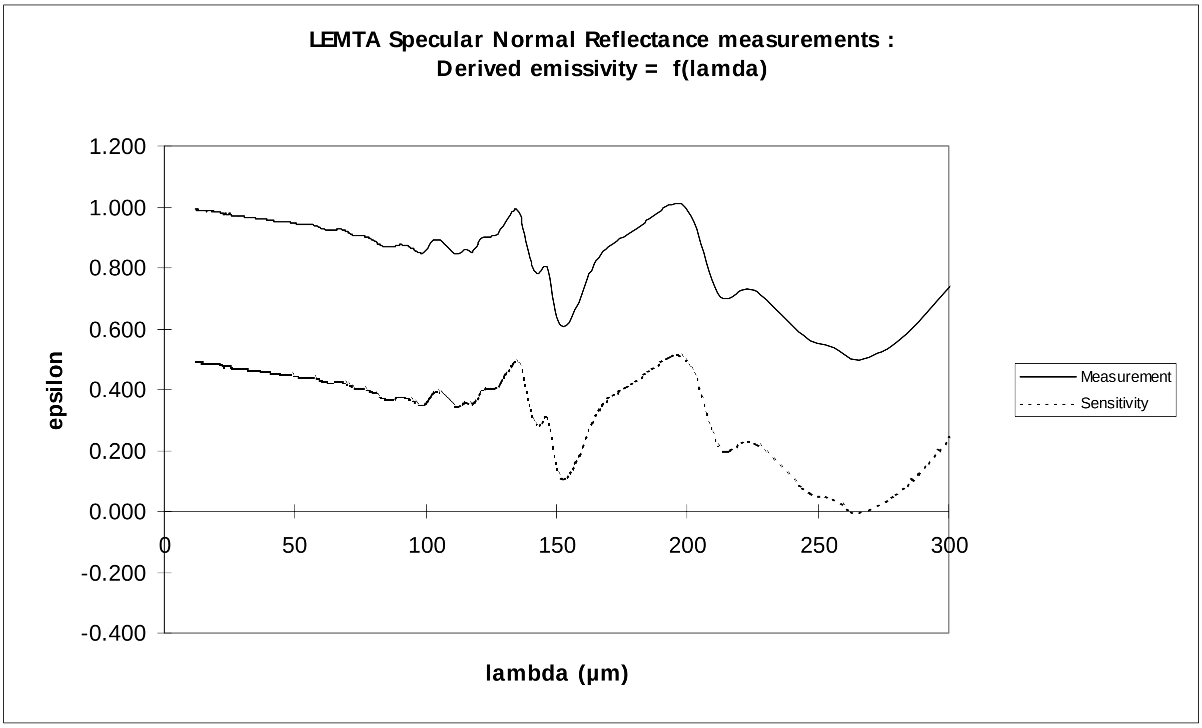


**Figure 3-12 : PUK emissivity monochromatic behaviour (LEMTA measurements)**

As shown in Figure 3-13, the interesting bandwidth is [0; 300µm] through which Figure 3-12 shows large derived emissivity variations.

Knowing that :

- Specular reflectance measurements systematically over-estimate the emissivity,
- the g() relation non-linearity effect is all the more important that the emissivity is low,

it is necessary to check the influence of the curve level.

In order to be as representative as possible to the “real” emissivity profile, the initial data are translated down to values yielding integrated emittance (@50K) close to min estimated value (#0.4). The curve named “sensitivity” is the resulting curve, hence giving an estimation of the “worst” (or lowest) monochromatic profile.

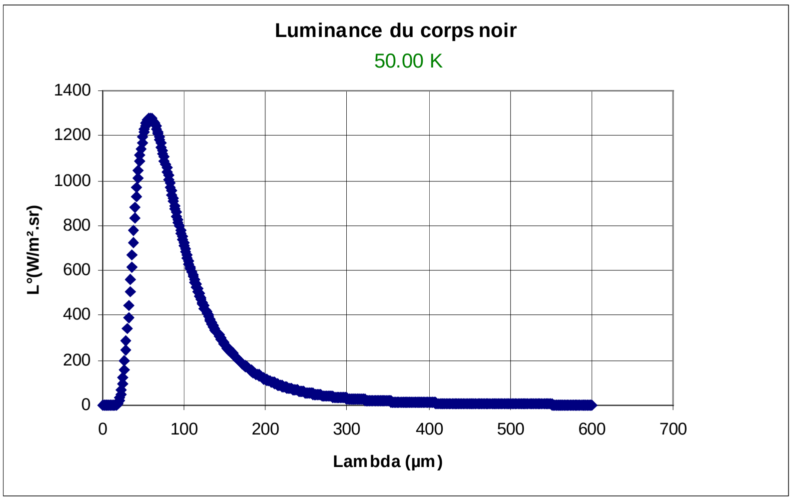


**Figure 3-13 : Blackbody emission profile @ 50K**

Computations have been made in order to compare, with both profiles, the results obtained when using both methods to compute apparent emitance :

M1 $$\varepsilon_{\text{app T}} = \frac{\int g(\varepsilon_{(\lambda,T)})\, L^0(\lambda,T)\, d\lambda}{\int L^0(\lambda,T)\, d\lambda}$$

M2 $\varepsilon_{\text{app T}} = g(\varepsilon_T)$

The results are presented in Table 3.3-5.

| | | | 0% Specular | | | 100% Specular | | |
|---|---|---|---|---|---|---|---|---|
| *Curve* | T (K) | $\varepsilon_{\text{flat T}}$ | $\varepsilon_{\text{app T}}$ (M2) | $\varepsilon_{\text{app T}}$ (M1) | Delta (M1-M2) | $\varepsilon_{\text{app T}}$ (M2) | $\varepsilon_{\text{app T}}$ (M1) | Delta (M1-M2) |
| *Degraded profile* | 50 | 0.411 | 0.784 | 0.748 | **-0.036** | 0.886 | 0.840 | **-0.046** |
| *Degraded profile* | 100 | 0.470 | 0.817 | 0.811 | -0.007 | 0.916 | 0.907 | -0.009 |
| *Initial profile* | 50 | 0.881 | 0.971 | 0.969 | -0.003 | 0.994 | 0.991 | -0.003 |

**Table 3.3-5 : Sensitivity on apparent emittance evaluation**

It can be noted that :

- The non-linearity effect is more important for the Specular behaviour than for the diffuse one.
- The non-linearity effect is more important at low temperature (linked to the considered monochromatic values).

Considering the results obtained @50K with the degraded profile as a worst case, a fixed 2% deviation will be applied to all values, in addition to a 3% uncertainty for hot and cold cases.

The following scheme gives a synthesis of the way the open HC emittance is estimated in all cases (hot/nom/cold) :

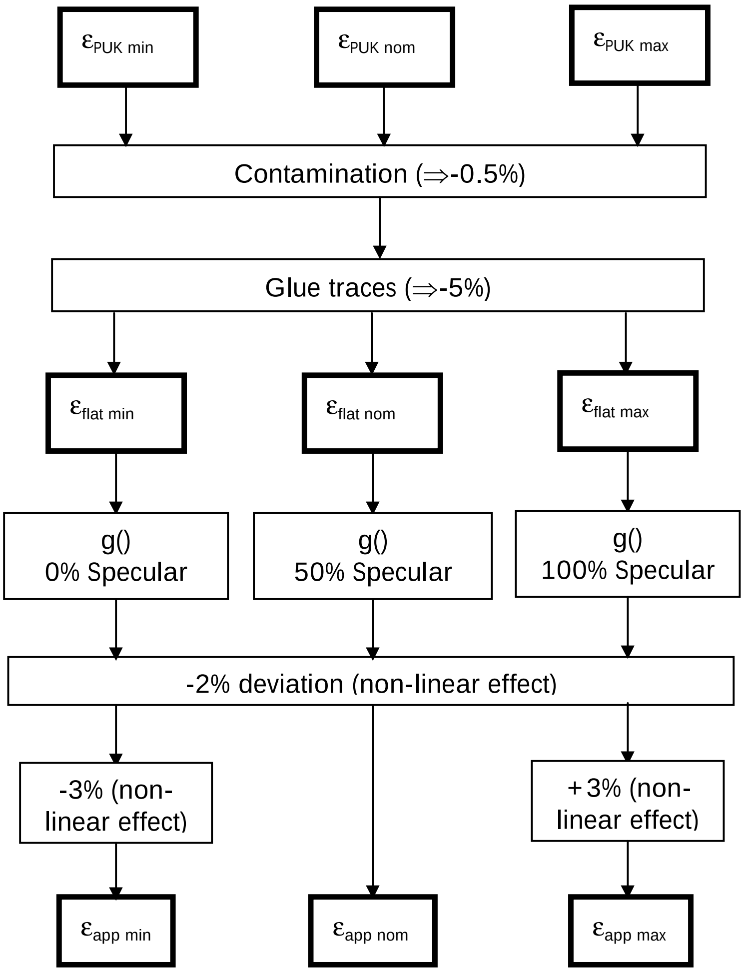


**Figure 3-14 : Open HC emittance estimation flowchart**

Notes :

- The contamination influence is estimated with following assumptions :
  - ✓ 5000 ppm particulate contamination (molecular influence negligible)
  - ✓ Particles emissivity = 0
- The glue traces influence is estimated with following assumptions :
  - ✓ Covered surface = 33mm² (#1mm bandwidth around cell)
  - ✓ Emissivity of covered surface = 0.1

The results are presented here below :

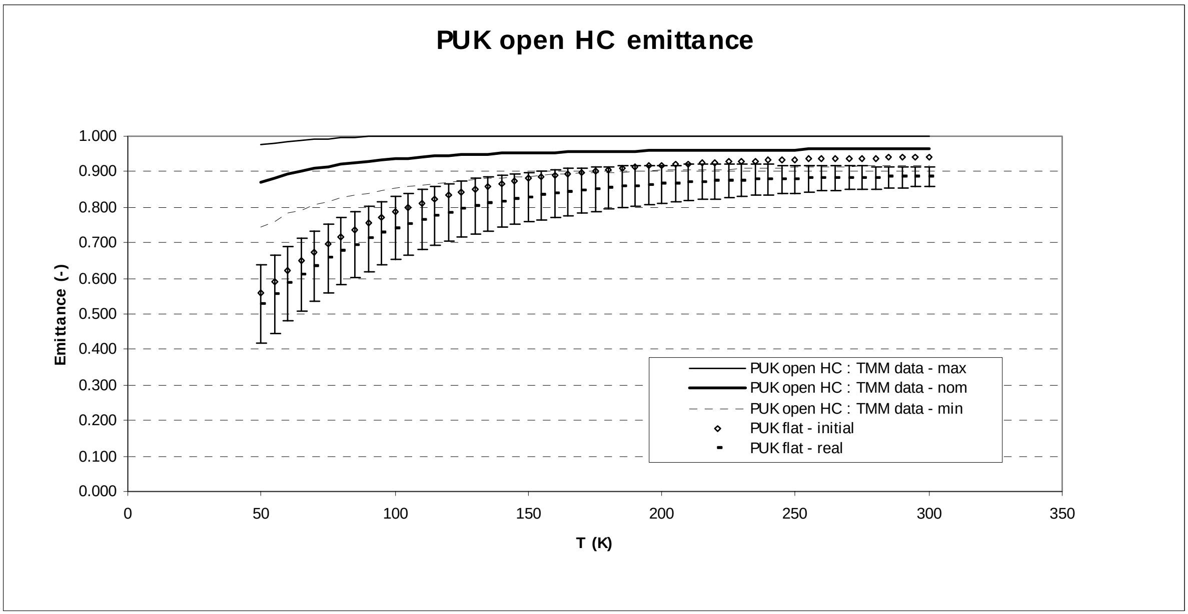


**Figure 3-15 : PUK open HC emittance**

Data on PUK measurements are also presented in Appendix 2.

### *3.3.3.1.3 Low emissivity coating (MIRO) characterisation*

The MIRO thermo-optical values are drawn from LEMTA and EADS measurements (see Appendix 2).

Unlike HEC, LEC will be very sensitive to parasitics on the coating. Details about defaults surface estimation are reported in Appendix 3.

The Figure 3-16 gives a synthesis of the way the LEC thermo-optical properties are estimated in all cases (hot/nom/cold) :

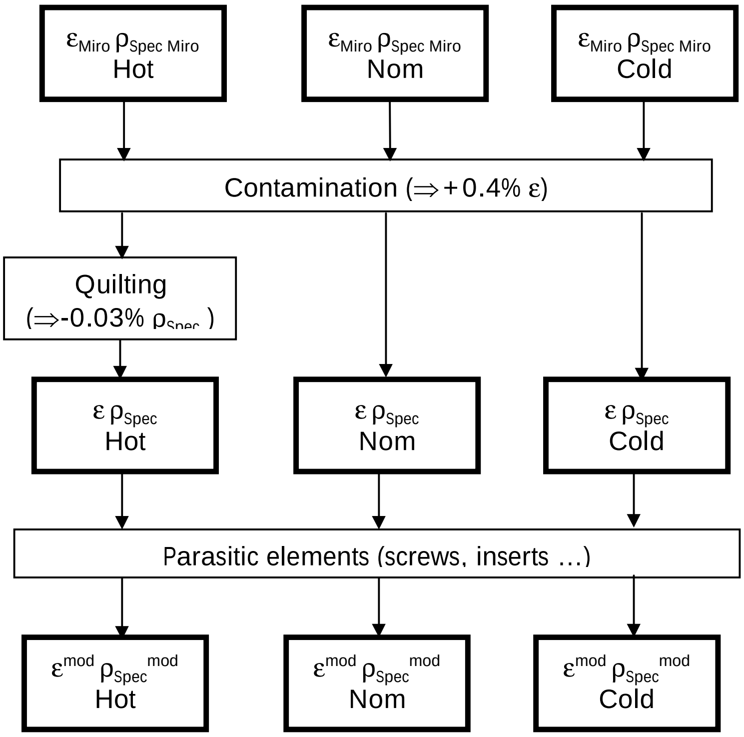


**Figure 3-16 : LEC emittance estimation flowchart**

### 3.3.3.1.4 *Shields holes*

Holes, through which struts and pipes cross the shields, modify the ideal Miro thermo-optical properties in the sense they increase the object transmittance. Though initially taken into account by locally modifying shield transmittance, it has afterwards been decided to insert “real” holes. The closure around cryo-struts being expected to present the more difficulties, only the holes around the struts are modelled.

Along with the hot/nom/cold cases definition, several configurations are modelled. Table 3.3-6 presents the cases definition.

| *Diam hole (mm)* | Nom | Hot | Cold |
|---|---|---|---|
| Diam Strut + | 2.5 | 10 | 2.5 |

**Table 3.3-6 : Shields holes / cases definition**

Figure 3-17 and Figure 3-18 show the holes position and the whole assembly struts + shields.

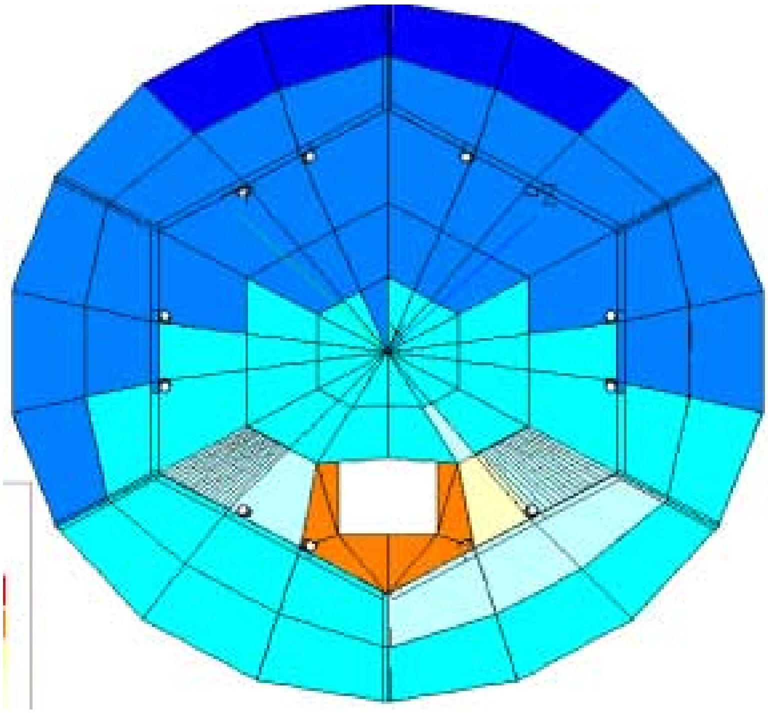


**Figure 3-17 : Struts holes**

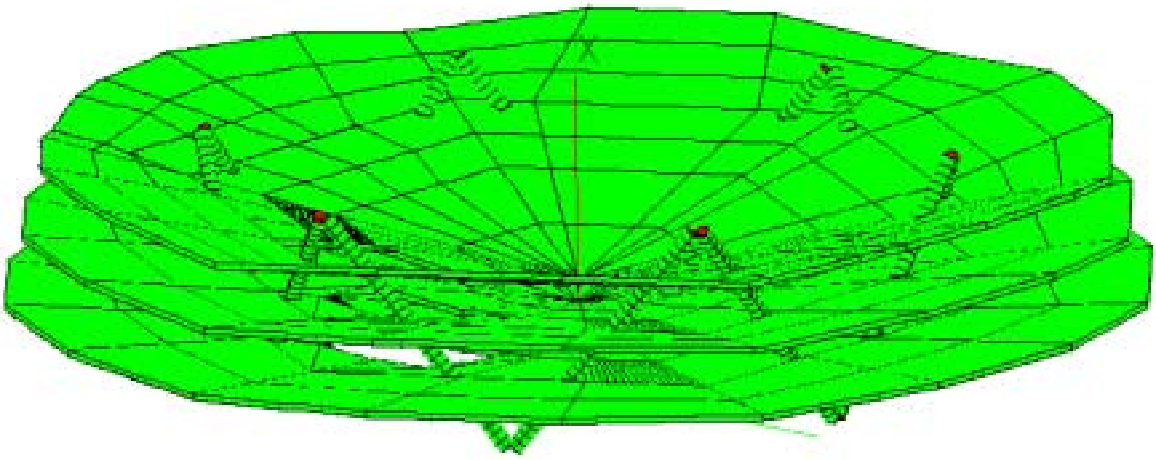


**Figure 3-18 : Struts – shields crossing**

#### *3.3.3.1.5 Comparison of thermo-optical parameters with initial requirements*

Table 3.3-7 is aimed at comparing the initial main required values with the estimated worst properties of actual design.

The displayed values are averaged on each object (Shield1 …) and take into account all degradations presented in §3.3.3.1.1. It can be seen that most significant deviations concern high emissivity coatings, while low emissive properties are globally as initially expected.

| *Shields* | Shield 1 ± X faces | | Shield 1 edge | | Shield 2 ± X faces | | Shield 2 edge | | Shield 3 face –X | | Shield 3 face +X outside baffle | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Comp model/req | model "hot" | req | model "hot" | req | model "hot" | req | model "hot" | req | model "hot" | req | model "hot" | req |
| $\varepsilon$ | 0.06 | ≤ 0.05 | 0.8 | ≥ 0.8 | 0.06 | ≤ 0.05 | 0.7 | ≥ 0.8 | 0.06 | ≤ 0.05 | 0.68 | ≥ 0.9 |
| $\tau_S$ | 0.94 | ≥ 0.9 | 0 | 0 | 0.94 | ≥ 0.9 | 0 | 0 | 0.93 | ≥ 0.9 | 0 | 0 |
| $T_{IR}$ | 0 * | 0 | 0 | N/A | 0 * | 0 | 0 | N/A | 0 * | 0 | 0 | N/A |

| *Baffle & Tel. structure* | Baffle Inner side | | Baffle Outer side | | Telescope Frame | | PR panel Outer space side | |
|---|---|---|---|---|---|---|---|---|
| Comp model/req | model "hot" | req | model "hot" | req | model "hot" | req | model "hot" | req |
| $\varepsilon$ | 0.05 | ≤ 0.05 | 0.68 | ≥ 0.9 | 0.43 | ≥ 0.85 | 0.64 | ≥ 0.9 |
| $\tau_S$ | 0.9 | ≥ 0.9 | 0 | 0 | 0 | 0 | 0 | 0 |
| $T_{IR}$ | 0 | N/A | 0 | N/A | 0 | N/A | 0 | N/A |

| *Struts* | Struts | |
|---|---|---|
| Comp model/req | model "hot" | req |
| $\varepsilon$ | 0.44-0.89 | ≥ 0.85 |
| $\tau_S$ | 0 | 0 |
| $T_{IR}$ | 0 | N/A |

**Table 3.3-7 : P-PLM worst radiative properties / comparison with initial requirements**

* Though the closures of shields holes may be not perfect, the equivalent transmittance value, when averaged on shield total surface, is expected to be very small.

### 3.3.3.2 Conductive parameters

#### *3.3.3.2.1 Parasitic conduction through PPLM CTA harness*

Two sets of harness are mounted on the PPLM, for both functions :

- ✓ Power injection (decontamination)
- ✓ Temperature acquisition

Details about harness design description and justification are given in Appendix 4.

- Power injection harness

All wires are AWG24 Brass, with exact following characteristics (supplier data) :

  - ✓ Conductor cross section : 0.239 mm²
  - ✓ Brass type : 64/36

- Temperature acquisition harness

All wires are AWG28 Brass, with exact following characteristics (supplier data) :

  - ✓ Conductor cross section : 0.0882 mm²
  - ✓ Brass type : 64/36

The number of wires reaching each stage is shown in Table 3.3-8.

| *Wires number* | Wires number |
|---|---|
| Shield 1 | 112 |
| Shield 2 | 100 |
| Shield 3 & Telescope | 92 |

**Table 3.3-8 : PPLM CTA harness**

No dedicated device is used to heat sink the P-PLM harness to the intermediate shields. Though the harness, routing along the struts, will obviously be linearly heat sinked, the conservative assumption is made according to which the PPLM parts are linked, through the harness, directly to the 300K SVM parts.

The harness is moreover conductively connected to the sandwich area closest to the strut along which the wires are routed. This assumption is not only expected to be representative to reality (strong mechanical coupling at shieds exit) but also tends to locate the input heat loads which is, for shield rejection concerns, conservative.

Note that the presented conservative assumptions constitute the single set of parameters used for all nom/hot/cold global TMM cases.

#### *3.3.3.2.2 Conduction along Struts*

Both cryo and bracing struts are considered.

### *3.3.3.2.2.1 Cryo-Struts*

Struts are made of GFRP (R-Glass / Epoxy composite), the conductivity of which has been characterised by intensive measurements. Measurement bench at CEA Grenoble has been the subject of ASP analytical studies which have corrected the now reliable test set-up. Measured values as well as TMM data used in nom/cold/hot TMM cases definition are presented in Appendix 1.

In line with CSAG design, the struts are modelled with next main parameters :

- GFRP length = 860mm
- Outer diameter = 50mm
- Inner diameter = 46.9mm

Cryo-struts are moreover filled with foam (ECCOSTOCK SH # 16kg/m$^3$). The parasitic conductive coupling is modelled with the 300K foam conductivity value (conservative approach) = 0.02W/mK.

Note that the modelling also takes into account the Aluminium collars on which the interface blades are fixed (total aluminium height per strut # 120mm).

### *3.3.3.2.2.2 Bracing struts*

Bracing struts are modelled between SVM and Groove 1 with same material properties than cryo-struts, and following parameters :

- GFRP length = 190mm
- Outer diameter = 11mm
- Inner diameter = 10mm

Bracing struts between Shield 3 and Telescope are not modelled (thermally neutral).

### *3.3.3.2.3 Couplings through “Struts–Shields” blades*

The couplings are computed by ASP after AA7075 blade and copper braids geometry and material properties (see Appendix 1). The results are shown in Figure 3-19 and compared to CSAG assessment (see [RD**7**]) and available measurement data.

It can be noted that ASP assessment, though pessimistic when compared to measurements data (the latter corresponding to an optimistic ASP assessment wrt uncertainties), is optimistic wrt CSAG. This discrepancy is explained by a computation mistake found lately in CSAG assessment.

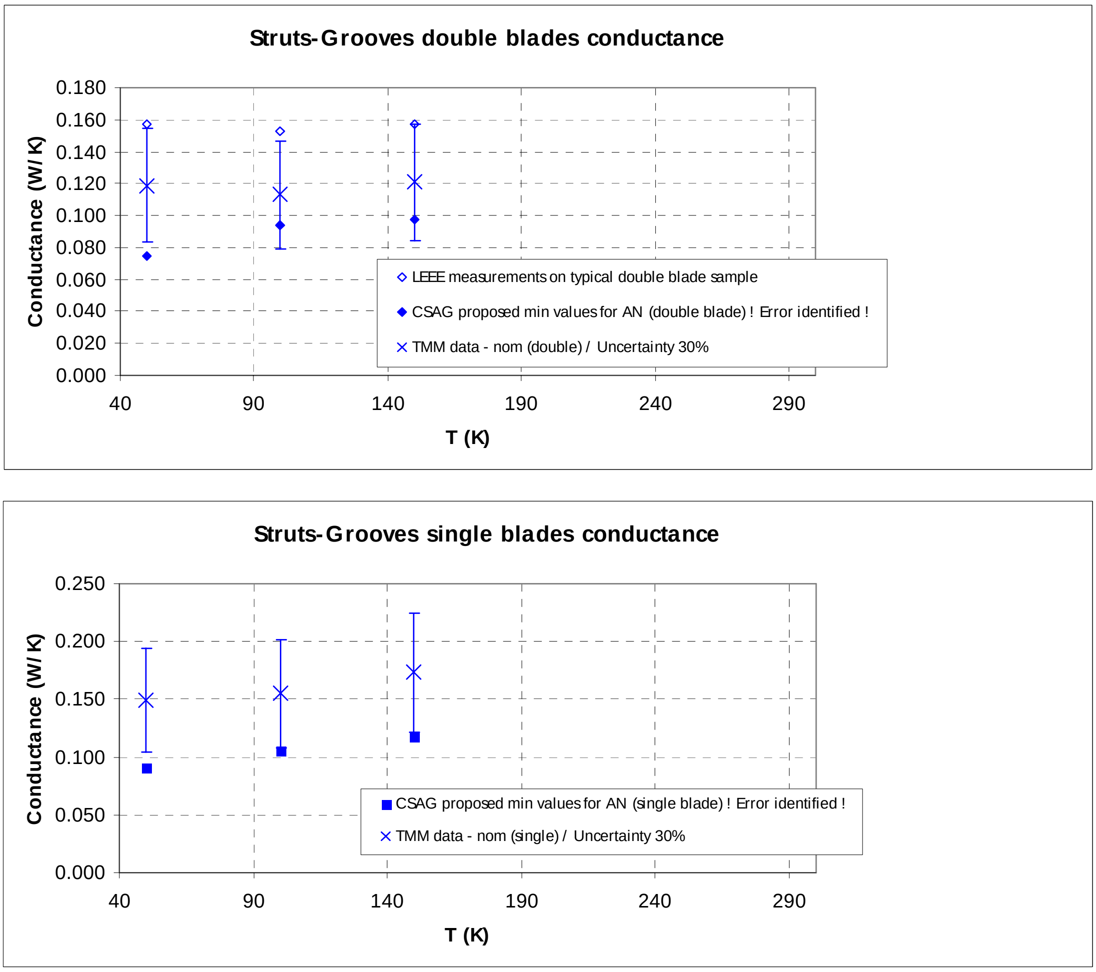


**Figure 3-19 : Struts-Shields blades conductance**

Nom/min/max values are used for nom/hot/cold cases definition.

### *3.3.3.2.4 Couplings within shields*

#### *3.3.3.2.4.1 Transversal couplings*

The shields transversal conductance (through the thickness) is based on the following considerations :

- ✓ Sandwich thickness = 20mm (internal petals) & 17mm (external petals)
- ✓ AA5056 honeycomb (see Appendix 1 for conductivity values)
- ✓ Different honeycomb densities according to the areas (taken into account as best as possible according to radiative meshing).

Nom/min/max AA5056 conductivity values are used for nom/hot/cold cases definition.

#### *3.3.3.2.4.2 In-plane couplings*

The shields "in-plane" conductances are characterised by intra-petals couplings and by contacts between petals.

### *3.3.3.2.4.2.1 Intra-petals couplings*

Theses coupling are based on the following considerations :

- ✓ Sheet thickness = 0.25mm
- ✓ Sandwich thickness = 20mm (internal petals) & 17mm (external petals)
- ✓ Miro27 for sheets conductivity (see Appendix 1 for values)
- ✓ AA5056 for honeycomb in-plane conductivity (see Appendix 1 for values)

Nom/min/max AA5056 & Miro conductivity values are used for nom/hot/cold cases definition.

Note that the couplings between the sandwich nodes and the edges (black painted and used as radiator) are modelled according to Figure 3-20.

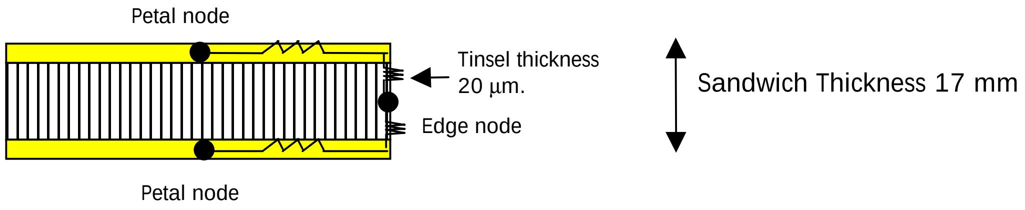


**Figure 3-20 : Coupling with shields edge**

### *3.3.3.2.4.2.2 Inter-petals couplings*

Interface conductances have been measured by ASP at operational temperature on representative samples for internal-external and external-external links. The resulting values, extrapolated by ASP to provide continuous data over the temperature range, are presented in Appendix 1 along with TMM assumptions.

Offering more margin, the internal-internal interface is analytically studied (see Appendix 1 for values).

Nom/min/max values are used for nom/hot/cold cases definition

### *3.3.3.2.5 Couplings within Baffle*

### *3.3.3.2.5.1 Transversal couplings*

The shields transversal conductance (through the thickness) is based on the following considerations :

- ✓ Sandwich thickness = 20mm
- ✓ AA5056 honeycomb (see Appendix 1 for conductivity values)
- ✓ Different honeycomb densities according to the areas (taken into account as best as possible according to radiative meshing)

Nom/min/max AA5056 conductivity values are used for nom/hot/cold cases definition.

### *3.3.3.2.5.2 In-plane couplings*

The baffle “in-plane” conductances are characterised by couplings within each part and by contacts between the two baffle parts.

### *3.3.3.2.5.2.1 Couplings within each part*

Theses coupling are based on the following considerations :

- ✓ Sheet thickness = 0.25mm
- ✓ Sandwich thickness = 20mm
- ✓ Miro27 for sheets conductivity (see Appendix 1 for values)
- ✓ AA5056 for honeycomb in-plane conductivity (see Appendix 1 for values)

Nom/min/max AA5056 & Miro conductivity values are used for nom/hot/cold cases definition.

### *3.3.3.2.5.2.2 Couplings between two Baffle parts*

Baffle parts interface being similar to shields internal-external interface, the associated performance is derived from measured data (see Appendix 1 for values).

Nom/min/max values are used for nom/hot/cold cases definition.

### *3.3.3.2.6 Couplings through thermal braids*

Thermal braids are made of several elementary braids. These elementary braids are all of the same type :

- Cross section = 3mm²
- Material = Copper RRR56 (see Appendix 1 for conductivity values)

Notes:

- Cross section has been assessed by ASP from CEA Saclay measurements on actual hardware and differ slightly from CSAG statements (section should be 3.4mm² according to supplier). The origin of this discrepancy is under discussion with CSAG. It has been preferred to rely on ASP assessed cross section, based on measurements, which is besides conservative wrt CSAG value.
- The braids are modelled as pure conductive couplings.

Review of different braids assemblies :

- ☐ Baffle – Shield 3
  - CSAG braids
    - ✓ 64 elementary braids
    - ✓ Average length = 100mm

    Figure 3-21 shows the coupling through a 8-braid assembly (as modelled) compared to measurements. Note that assumptions differ from CSAG assessment; measured values were indeed considered as more reliable.

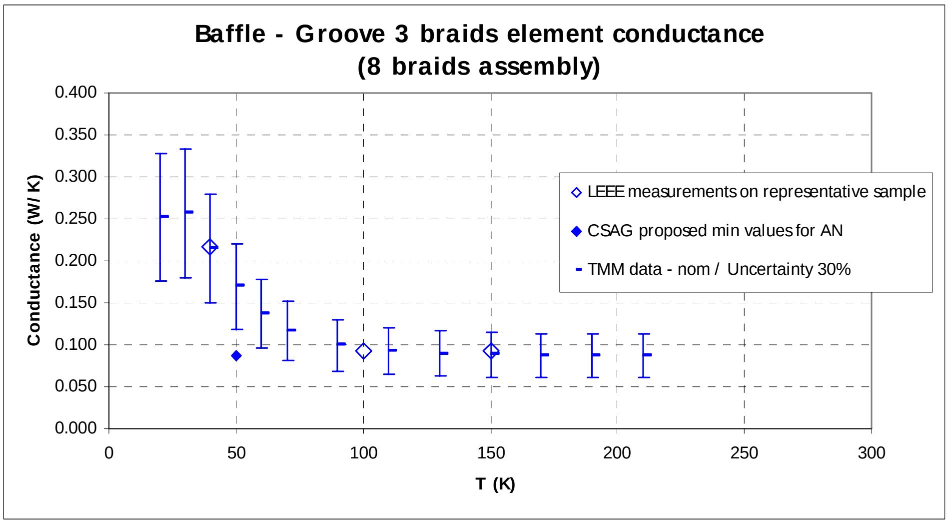


**Figure 3-21 : Coupling through one Baffle-Shield3 braid**

- ASP braids
  - ✓ 120 elementary braids
  - ✓ Average length = 350mm
- ❑ Baffle – PR Panel (ASP braids)
  - 40 elementary braids
  - Average length = 120mm
- ❑ Frame – PR Panel
  - 8 elementary braids
  - Average length = 50mm
- ❑ Frame – SR Panel
  - 2 elementary braids
  - Average length = 50mm

For all braids, nom/min/max copper conductivity values are used for nom/hot/cold cases definition.

### *3.3.3.2.7 Couplings in Telescope structure*

#### *3.3.3.2.7.1 PR&SR panels*

Both panels sandwiches are made of :

- CFRP (M55J/Cyanate) skins
- AA5056 honeycomb

Conductivity values are reported in Appendix 1. Note that CFRP conductivity values are based on measurements as well as ASP data processing.

The model meshing allows to accurately take into account extra thickness (and hence conductivity) brought by PR Panel doublers.

All panels interface elements are also part of the model :

- Brackets
- Struts
- Triangle panel
- Lower and FPU beams

### *3.3.3.2.7.2 Frame*

The frame is modelled as CFRP (same as panels) skin (2.5mm thick) with local reinforcements, consistently with the design.
Links with Baffle through brackets are also taken into account.

### *3.3.3.2.8 Comparison of conductive parameters with initial requirements*

Table 3.3-9 to Table 3.3-12 are aimed at comparing the initial main required values with the estimated worst properties of actual design.

Many deviations from initial requirements can be noted. These deviations are though compensated by MIRO high conductivity, especially at cold temperature, which improves significantly the radiative areas efficiency.

| *Shields* | Shield 1 Central part (@150 K) | | Shield 1 External part (@150 K) | | Shield 2 Central part (@100 K) | | Shield 2 External part (@100 K) | | Shield 3 Central part (@50 K) | | Shield 3 External part (@50 K) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Comp mod/req | mod “hot” | req | mod “hot” | req | mod “hot” | req | mod “hot” | req | mod “hot” | req | mod “hot” | req |
| In-plane sheet conductance λ.e (W/K) | 0.04 | > 0.03 | 0.04 | > 0.02 | 0.05 | > 0.03 | 0.05 | > 0.02 | 0.08 | > 0.03 | 0.08 | > 0.03 |
| In-plane honeycomb conductance λ.e (W/K) | $3.10^{-3}$ | > $9.10^{-3}$ | $3.10^{-3}$ | > $5.10^{-3}$ | $2.10^{-3}$ | > $9.10^{-3}$ | $2.10^{-3}$ | > $5.10^{-3}$ | $1.10^{-3}$ | > $9.10^{-3}$ | $1.10^{-3}$ | > $9.10^{-3}$ |
| Transversal conductance λ/L (W/m².K) | 18 | > 19 | 21 | > 11 | 14 | > 19 | 16 | > 11 | 9 | > 19 | 10 | > 19 |
| Conductive couplings between two petals (W/K) | 3.6 | > 1.4 | 0.4 | > 0.4 (*) | 3.8 | > 1.4 | 0.3 | > 0.45 (*) | 5 | > 1.4 | 0.5 | > 0.5 (*) |

| *Shields* | Shield1 (@150 K) | | Shield2 (@100 K) | | Shield3 (@50 K) | |
|---|---|---|---|---|---|---|
| Comp mod/req | mod “hot” | req | mod “hot” | req | mod “hot” | req |
| Conductive couplings between central and external facets (W/K) | 0.8 | > 0.6(*) | 0.8 | > 0.7(*) | 1 | > 0.8(*) |

**Table 3.3-9 : P-PLM shields conductive properties / comparison with initial requirements**

(*) Requirement has been re-formulated to be directly comparable with performed measurements; it lies now between two reference lines separated by 64mm.

| *Baffle & Tel. structure* | Baffle (@40 K) | | PR support panel (@40 K) | | Telescope Frame (@40 K) | |
|---|---|---|---|---|---|---|
| Comp mod/req | mod "hot" | req | mod "hot" | req | mod "hot" | req |
| In-plane sheet conductance $\lambda$.e (W/K) | 0.08 | > 0.02 | $8.10^{-4}$ | > $5.10^{-3}$ | $2.10^{-3}$ (1) | > $1.10^{-2}$ |
| In-plane honeycomb conductance $\lambda$.e (W/K) | $1.3\ 10^{-3}$ | > $9.10^{-3}$ | $6.10^{-3}$ | > 0.02 | N/A | N/A |
| Transversal conductance : $\lambda$/L (W/m$^2$.K) | 7.6 | > 19 | 6 | > 7 | N/A | N/A |
| Conductive couplings between two parts (W/K) | 0.6 | >0.6 | N/A | N/A | N/A | N/A |

**Table 3.3-10 : P-PLM Baffle and Tel. structure conductive properties / comparison with initial requirements**

| *Struts* | Struts (@50 K) | |
|---|---|---|
| Comp mod/req | mod "hot" | req |
| $\lambda$S/L (W/K) | $1.2\ 10^{-4}$ (2) | < $1\ 10^{-4}$ |

**Table 3.3-11 : P-PLM Struts conductive properties / comparison with initial requirements**

| *Thermal braids Couplings (W/K)* | PR Panel and Frame | | PR Panel and Baffle | | Baffle and Shield 3 | | SR Panel and Frame | |
|---|---|---|---|---|---|---|---|---|
| Comp mod/req | mod "hot" | req | mod "hot" | req | mod "hot" | req | mod "hot" | req |
| T = 50 K | 0.25 | > 0.4 | 0.5 | N/A | 1.3 (3) | > 1 | 0.07 | > 0.1 |
| T = 100 K | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| T = 150 K | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |

**Table 3.3-12 : P-PLM thermal braids conductive properties / comparison with initial requirements**

(1) Doublers not included

(2) Foam not included; parasitic conductance induced by foam ≈ $4.10^{-5}$ W/K

(3) ASP + CSAG braids conductance; extra braids between baffle&Shield 3 and Baffle&PR Panel have replaced those between PR Panel and Shield 3

#### 3.3.3.3 Thermal inertia parameters

The PPLM structure thermal inertia computation is based on :

- ☐ CSAG CDR mass budget (see [RD**15**])

Table 3.3-13 shows the differences between the mathematical mass (model weight) and the actual mass drawn from budgets.

| Global Budget verification | | TMM Mass | Design Mass w ctg | Deviation |
|---|---|---|---|---|
| Groove 1 | | 35.79 | 36.50 | -2% |
| Groove 2 | | 32.08 | 32.60 | -2% |
| Groove 3 | | 45.19 | 45.70 | -1% |
| Cryo Struts | | 25.03 | 25.30 | -1% |
| Brace Strut | | 0.40 | 0.40 | 0% |
| Telescope | Frame | 23.13 | 23.70 | -2% |
| | SR Panel | 6.57 | 6.70 | -2% |
| | PR Panel | 50.04 | 50.90 | -2% |
| Baffle | | 35.81 | 35.90 | 0% |
| Total Cryo Structure & Telescope | | 254.04 | 257.70 | -1% |

**Table 3.3-13 : Model weight**

The mass input for thermal inertia computation is very close to reality.

- ☐ Materials heat capacitances

Except for composites, the capacitances of which have been measured at ITMO, all data are drawn from bibliographic studies.

Heat capacitances values are reported in Appendix 1.

### *3.3.4 PPLM structure interfaces*

#### 3.3.4.1 Interfaces with Instruments and coolers

Details about Instruments&coolers models (except LFI RAA) included in global TMM are reported in [RD**12**].

##### *3.3.4.1.1 Interfaces with HFI*

Interfaces with HFI are identified as :

- ☐ 4K Cooler assembly

No radiative interaction between 4K Cooler piping and shields (screening effect) is taken into account. Though optimistic, this assumption is justified by the 4K pipes small dimensions and thus by their a priori low influence, when compared, for instance, to the wave-guides.

Interfaces are located to the Shield 3 heat sink.

- 0.1K Cooler pipes

  No radiative interaction between the 0.1K Cooler piping and the shields (screening effect) is taken into account. Though optimistic, this assumption is justified by the 0.1K pipes small dimensions and thus by their a priori low influence, when compared, for instance, to the wave-guides.

  Interfaces are located to the 3 Shields heat sinks.

- Bellow+harness & JFET

  The model takes into account radiative and conductive connections with the structure consistently with the provided HFI models and defined interfaces.

- HFI FPU

  Radiative interactions between the PPLM optical cavity and the HFI FPU are implicitly taken into account by global modelling.

### *3.3.4.1.2 Interfaces with LFI*

The LFI RAA model taken into account is the one delivered on 06/2003 by Laben under the reference LFI_CQM_212. This version is the latest available and corresponds to the closest modelling of current design.

### *3.3.4.1.3 Interfaces with Sorption Cooler*

#### *3.3.4.1.3.1 General rules*

The interfaces with the Sorption Cooler are limited to the heat exchangers located on the three shields :

- No radiative interaction between the Sorption piping, routing between different shields, and the shields (screening effect) is taken into account. Though optimistic, this assumption is justified by the Sorption pipes small dimensions and thus by their low influence when compared, for instance, to the wave-guides. Note that perturbations of shields thermo-optical properties induced by the pipes routing on the shields, as well as pipes supports, are taken into account in the shields emissivity and specular ratio degradation (see Appendix 3).
- The sorption cooler exchangers are radiatively modelled (boxes on the shields) in order to take into account associated perturbation.
- No internal design of Sorption exchangers is modelled in P-PLM TMM. Only the thermal contact between the exchanger fitting and the shield is defined after design characteristics. The so-called “interface temperature” is on the exchanger’s side of the contact.
- The power distribution on Shield 3 is spread on the three exchangers according to JPL equations; 72% on 3A, 19% on 3B and 9% on 3C.

#### *3.3.4.1.3.2 Thermal Exchangers heat sinking*

The 3 shields are used as pre-cooling stages for Sorption Cooler, requiring good heat sinking at each exchanger.

### *3.3.4.1.3.2.1 Exchanger 3C*

The efficiency of the heat sink between the exchanger and the shield is of major importance for the performance (requirement to be verified on exchanger contact plane). A specific detailed study has then been performed in order to consolidate the assumptions used in global TMM.

#### *3.3.4.1.3.2.1.1 Detailed model*

The exchanger surrounding area has been modelled by a 400 node detailed TMM. The detailed geometrical model is presented in Figure 3-22.

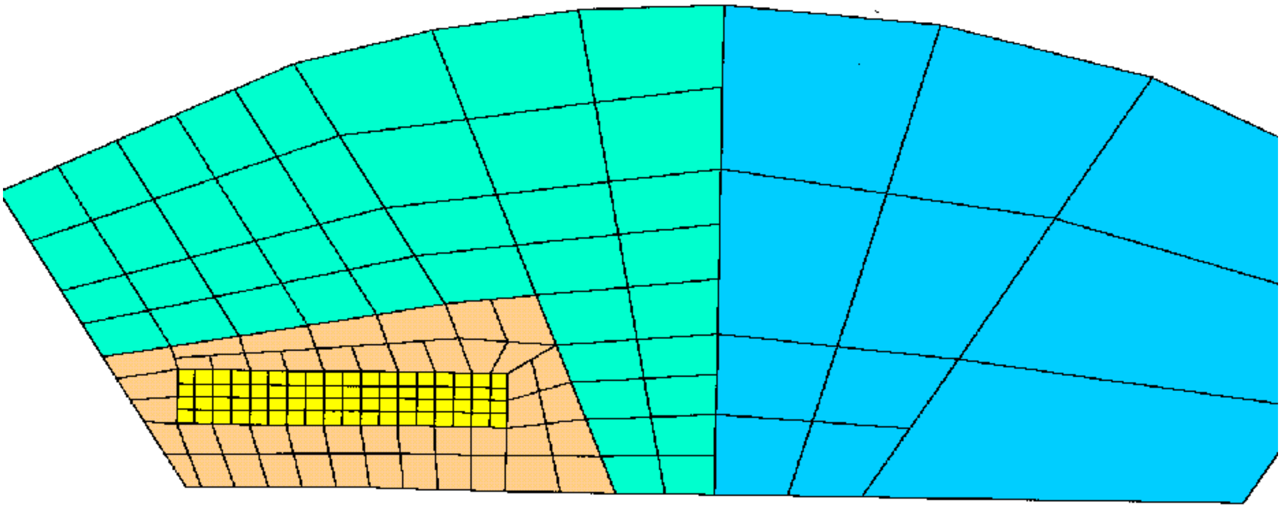


**Figure 3-22 : Detailed SC 3C interface TMM**

This detailed TMM is afterwards simplified (see Figure 3-23) in order to be included into the global TMM.

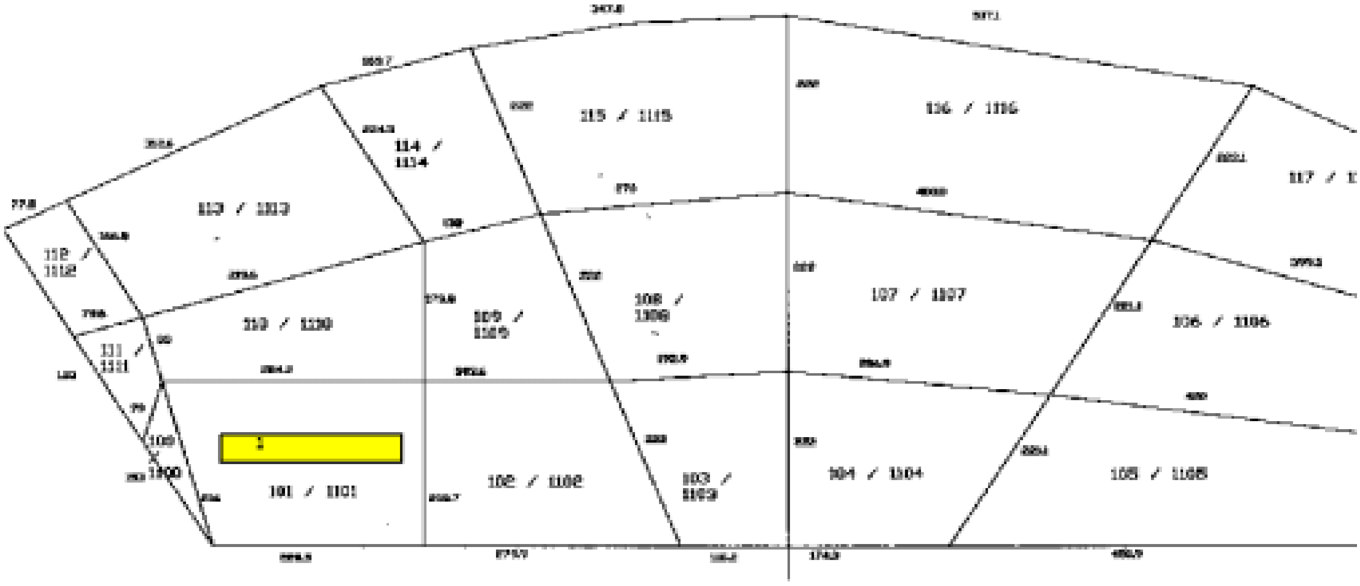


**Figure 3-23 : Simplified SC 3C interface TMM**

### *3.3.4.1.3.2.1.2 Identification of thermal paths*

The main thermal paths to be considered are :

- ✓ Contact exchanger – facesheet (dry)
- ✓ Contact exchanger – inserts (dry)
- ✓ Coupling insert – facesheets (through the glue)

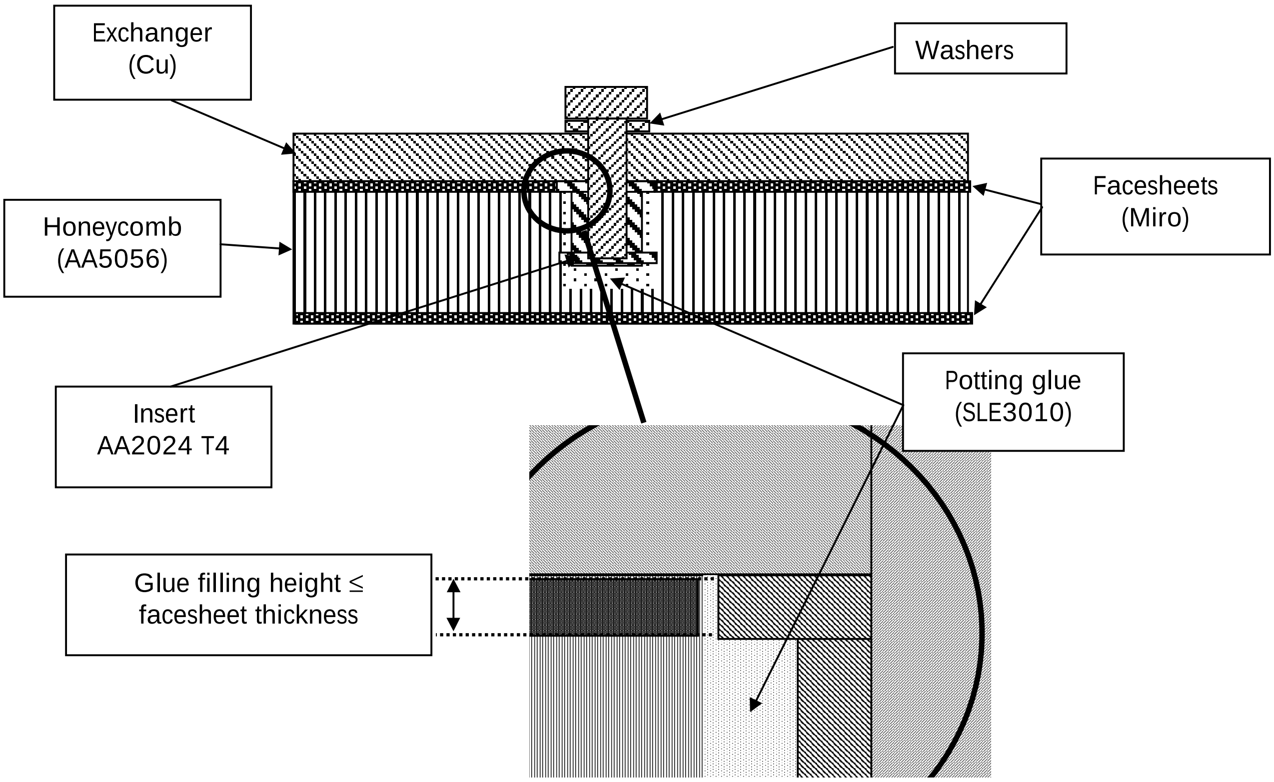


**Figure 3-24 : Detailed modelling of conduction through insert**

The coupling insert – facesheet has been estimated by use of another 30 node detailed model (see Appendix 6); this model allows to refine the estimation of how the heat is conducted within the insert and then propagated through the glue layer to the facesheets.

The physical parameters used to support the modelling are :

- ✓ The copper – aluminium dry contact

  Bibliography study, associated to estimation of the contact pressure, lead to the following assumptions :

  - Optimistic evaluation : $B_c$ = 3800 W/m²K
  - Pessimistic evaluation : $B_c$ = 440 W/m²K

  Note that the contact between exchanger and facesheet is expected to be quite poor. Indeed, the potential insert displacements, combined with relatively poor surface flatness under the exchanger, are expected to decrease significantly the contact efficiency.

- ✓ The conduction within the insert

  A 40 W/mK value is assumed @50K for the aluminium conductivity.

✓ The conduction within the glue

A 0.12 W/mK value is assumed @50K for the glue conductivity.

The way the room between the insert and the sandwich is filled up with glue (up to the facesheet upper surface or not, see Figure 3-24) is also of much importance. Two assumptions are made as extreme optimistic and conservative :

- Optimistic evaluation : Glue filling up to 100% facesheet thickness (glue spilling out insert-facesheet inter-space)
- Pessimistic evaluation : Glue filling up to 10% facesheet thickness

### *3.3.4.1.3.2.1.3 Sensitivities and results*

The sensitivity cases are based on main parameters :

- ❖ Contact Exchanger-Insert : $B_c$ = 440 W/m²K // 3800 W/m²K
- ❖ Contact Exchanger-Facesheet : $B_c$ = 0 W/m²K // 440 W/m²K // 3800 W/m²K
- ❖ Conduction between insert and facesheet : glue filling 10% or 100%

Results are presented in Table 3.3-14 in term of temperature gradient between the exchanger and the shield.

| *ΔT* *Exchanger - Shield* | $B_c$ Exch-insert 440 W/m²K | $B_c$ Exch-insert 3800 W/m²K | $B_c$ Exch-Miro 0 W/m²K | $B_c$ Exch-Miro 440 W/m²K | $B_c$ Exch-Miro 3800 W/m²K | Filling 10% | Filling 100% |
|---|---|---|---|---|---|---|---|
| Ref | | **X** | | | **X** | | **X** |
| +0.1K | **X** | | | **X** | | | **X** |
| +0.1K | **X** | | | **X** | | **X** | |
| +1K | | **X** | **X** | | | | **X** |
| +1K | **X** | | **X** | | | | **X** |
| +2K | **X** | | **X** | | | **X** | |

**Table 3.3-14 : SC 3C heat sinking / sensitivity study**

Table 3.3-14 shows that, in case of a poor contact between exchanger and facesheet, the thermal sinking is very sensitive to the glue filling. Note that the presented sensitivities are over-estimated because computed with fixed Sorption Cooler dissipation, though the latter normally varies according to I/F temperature.

Due to the difficult control of both flatness and glue filling, it has been decided to build up global TMM hot case with an unambiguous conservative approach :

- ❑ Hot case :
  - Contact Exchanger-Insert : $B_c$ = 440 W/m²K
  - Contact Exchanger-Facesheet : $B_c$ = 0 W/m²K
  - Conduction between insert and facesheet : glue filling 10%

Other cases are based on more optimistic values :

- ❑ Nominal case :
  - Contact Exchanger-Insert : $B_c$ = 3800 W/m²K
  - Contact Exchanger-Facesheet : $B_c$ = 440 W/m²K
  - Conduction between insert and facesheet : glue filling 100%
- ❑ Cold case :
  - Contact Exchanger-Insert : $B_c$ = 3800 W/m²K
  - Contact Exchanger-Facesheet : $B_c$ = 3800 W/m²K
  - Conduction between insert and facesheet : glue filling 100%

### *3.3.4.1.3.2.2 Exchangers 1-2-3A&3B*

Being less sensitive parameters, the thermal interfaces between the Sorption exchangers and the shields are more classically modelled by contact conductances (W/m².K) determined after design parameters such as the number/type of screws.

The main design parameters of Sorption exchangers are :

| *Sorption Cooler exchangers characteristics* | Unit | Groove 1 (warmest) | Groove 2 (interm.) | Groove 3 (coldest) |
|---|---|---|---|---|
| Nb. of exchangers | - | 1 | 1 | 2 |
| Length | mm | 350 | 350 | 196 |
| Width | mm | 35 | 35 | 35 |
| Material | - | Copper | Copper | Copper |
| Nb. of screws per unit | - | 2 x 16 M4 | 2 x 16 M4 | 2 x 9 M4 |
| Op. temperature | K | 150 | 100 | 50 |

**Table 3.3-15 : Sorption Cooler exchangers design parameters**

Note : Parameters given for one (either nominal or redundant) Sorption Cooler.

As a conservative approach, the thermal conductance through each interface is estimated considering an effective thermal contact only under each screw head which corresponds approximately, for M4 screws, to a 38 mm² contact surface per screw.

The nominal contact conductance ($B_c^{loc}$), locally to the screws, is taken equal to # 3000 W/m².K. This value, valid only where the contact pressure is ensured, is based on ASP experience for low temperature applications.

The contact is then spread all over the actual exchanger interface area in order to define the TMM parameter $B_c$ which, consistently with the interface total area, is used to model this interface.

The Table 3.3-16 gives a synthesis of the thermal contact assumptions for different nom/hot/cold cases :

| *Sorption Cooler* | Bc **nom** (W/m².K) | Bc **hot** (W/m².K) | Bc **cold** (W/m².K) | $S_c$ (spread) (mm²) | Materials (-) |
|---|---|---|---|---|---|
| VG3 | | | | | |
| I/F A | 300 | 150 | 300 | 6860 | Copper / Alu |
| I/F B | 300 | 150 | 300 | 6860 | Copper / Alu |
| VG2 | 300 | 150 | 300 | 12250 | Copper / Alu |
| VG1 | 300 | 150 | 300 | 12250 | Copper / Alu |

**Table 3.3-16 : Sorption Cooler exchangers I/F thermal contact assumptions**

### 3.3.4.2 Interfaces with Reflectors

The reflectors model used in global TMM is the one delivered by ASED and described in [RD**13**].

### 3.3.4.3 Interfaces with SVM

- Temperatures

In order to keep as close as possible to current design, the SVM structure temperatures are drawn from latest SVM TCS results (see Appendix 5) and the MLI upper layer temperatures are re-computed in PPLM TMM. The resulting MLI outer temperatures being slightly lower than those from PLM IF specification, a sensitivity is performed (see §4.5) to check the performance delta when using one (SVM TCS analyses results) or the other (PLM I/F spec) assumptions.

- Thermo-optical properties

The thermo-optical description of SVM interfaces is reported in Table 3.3-17 :

| *SVM interfaces* | MLI on Solar Array +X side | | Aluminised MLI on Sub-platform | | Aluminised MLI on upper closure Panels | |
|---|---|---|---|---|---|---|
| nom / degraded | nom | deg | nom | deg | nom | deg |
| $\varepsilon$ | 0.05 | 0.1 | 0.05 | 0.1 | 0.05 | 0.1 |
| $\tau_S$ | 0.9 | 0.5 | 0.9 | 0.5 | 0.9 | 0.5 |
| $T_{IR}$ | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 3.3-17 : SVM interfaces thermo-optical properties**

Note that the hot case is defined after parameters degraded wrt specified ones for conservative reasons.

- Interface fluxes

The BEU & PAU models, though not in line with latest design (1 box design for BEU for instance), provide radiative interfaces (flux & geometry) which largely cover I/F flux specification (see §4.2.3). The radiating areas temperatures are moreover drawn from latest SVM TCS.

- Temperature fluctuations

The inputs for stability analyses (see §6.1) are drawn from SVM TCS CDR results and cover PLM I/F specification.

# 4. STEADY STATES ANALYSES RESULTS

Four steady states are studied :

- ❑ Operating modes
  - Nominal case related to typical assumptions
  - Hot case related to pessimistic assumptions
  - Cold case related to optimistic assumptions
- ❑ Non-operating mode
  - Cold case related to optimistic assumptions

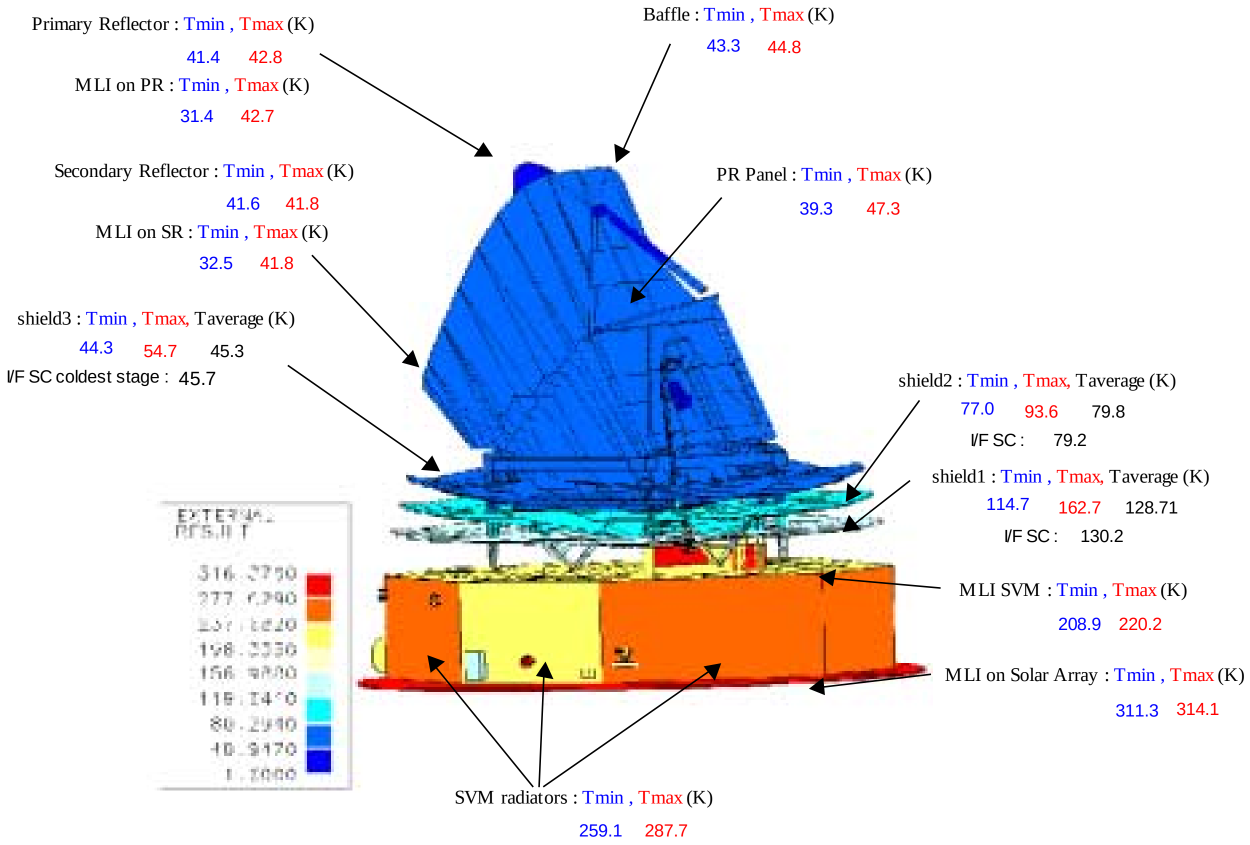
Notes :

- An assumption is said optimistic when it tends to lower the shield 3 temperature
- The different configurations are explained in §3.3.1.

## 4.1 PPLM Steady state results – Nominal operating case

### *4.1.1 Temperature cartography*

Figure 4-1 shows the PPLM nominal temperature cartography.



Primary Reflector : Tmin , Tmax (K)
41.4 42.8
MLI on PR : Tmin , Tmax (K)
31.4 42.7

Baffle : Tmin , Tmax (K)
43.3 44.8

Secondary Reflector : Tmin , Tmax (K)
41.6 41.8
MLI on SR : Tmin , Tmax (K)
32.5 41.8

PR Panel : Tmin , Tmax (K)
39.3 47.3

shield3 : Tmin , Tmax, Taverage (K)
44.3 54.7 45.3
I/F SC coldest stage : 45.7

shield2 : Tmin , Tmax, Taverage (K)
77.0 93.6 79.8
I/F SC : 79.2

shield1 : Tmin , Tmax, Taverage (K)
114.7 162.7 128.71
I/F SC : 130.2

MLI SVM : Tmin , Tmax (K)
208.9 220.2

MLI on Solar Array : Tmin , Tmax (K)
311.3 314.1

SVM radiators : Tmin , Tmax (K)
259.1 287.7

**Figure 4-1 : Nominal PPLM temperature cartography**

Table 4.1-1 presents a summary of PPLM / Instruments interfaces temperatures in nominal case. Note that a complete temperatures listing is given in Appendix 8.

| *PPLM interfaces temperatures* | | Computed temperatures **Nominal case** (K) |
|---|---|---|
| LFI WG | I/F with VG1 | 138.3 – 142.8 |
| | I/F with VG2 | 79.9 - 83.1 |
| | I/F with VG3 | 46.0 – 47.2 |
| Sorption Cooler | I/F with VG1 | 136.5 |
| | I/F with VG2 | 83.3 |
| | I/F with VG3 | 49.8 / 47.5 / 45.7 |
| 4K Cooler coldest exchanger | | 45.8 |
| 0.1K Cooler coldest exchanger | | 46.2 |
| JFET box | | 47.3 |
| FPU interface | | [41.9 - 44.9] |
| Primary Reflector | | [41.4 – 42.8] |
| Secondary Reflector | | [41.6 – 41.8] |

**Table 4.1-1 : PPLM / Instruments nominal interfaces temperatures**

### *4.1.2 Evolutions since PDR*

Next table shows main model evolutions PDR → CDR as well as associated impact on computed nominal performance. Note that Instruments modelling evolutions are also taken into account (nominal performance assessment).

| *TMM evolutions* | Impact on Sorption Cooler 3C I/F Temperature (K) | Comments |
|---|---|---|
| LFI RAA TMM | -1.8 | 100GHz removed |
| Sorption Cooler TMM | -2.8 | New equations (*) |
| Cryo Struts | -0.4 | Meshing and materials assumption |
| External petals contact | -1.2 | Zero contact initially assumed |
| MIRO and copper conductivity | -0.6 | From measurements |
| New braids | -0.2 | New Baffle – Shield3 link |
| ATC harness | +0.3 | None initially included |

* Global heat load on shield 3 has not changed significantly with latest equations. However, the distribution of this load on the three shield 3 precooler is now such that the coldest one (3C), which is the most important one wrt performance, receives only 9% of the global load. This explains why the equations update, with no shield 3 global load modification, leads to a colder Sorption Cooler 3C interface.

## 4.2 PPLM Steady state results – Worst Hot operating case

### *4.2.1 Worst hot case definition*

The worst hot case corresponds to the hot configuration (as presented in §3.3.2) degraded by mathematical uncertainty (2K) :

- $T_{\text{worst hot}} = T_{\text{hot}} + 2K = f(Pi_{\text{degraded}}) + 2K$

where $Pi_{\text{degraded}}$ are representative of the degraded (i.e hot) PPLM thermal functioning, including Instruments overloads in line with system margin.

*Note that this hot case is assessed with redundant Sorption Cooler ON.*

### *4.2.2 Temperature cartography*

Figure 4-2 shows the PPLM “hot” temperature cartography.

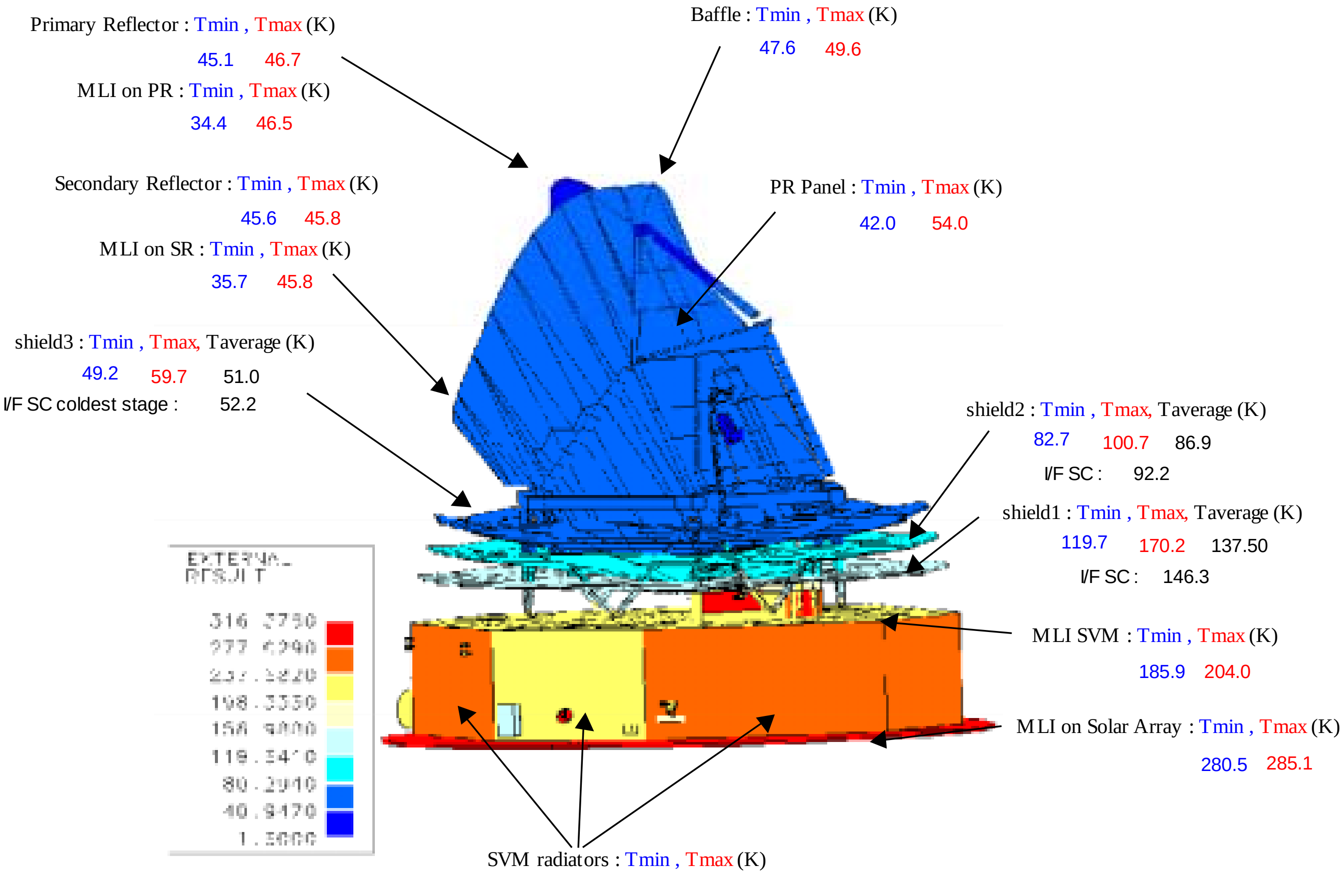


**Figure 4-2 : “hot” PPLM temperature cartography**

Table 4.2-1 presents a summary of PPLM / Instruments interfaces temperatures in worst hot case. Note that a complete temperatures listing is given in Appendix 7.

| *PPLM worst hot interfaces temperatures* | | Computed temperatures **hot case** (K) | Mathematical uncertainty (K) | Worst hot temperatures (K) | Max T (K) |
|---|---|---|---|---|---|
| LFI WG | I/F with VG1 | 155.6 – 156.8 | + 2 | 157.6 – 158.8 | 170 |
| | I/F with VG2 | 89.1 – 91.1 | + 2 | 91.1 – 93.1 | 120 |
| | I/F with VG3 | 54.1 – 55.0 | + 2 | 56.1 – 57.0 | 60 |
| Sorption Cooler | I/F with VG1 | 146.3 | + 2 | 148.3 | 170 |
| | I/F with VG2 | 92.2 | + 2 | 94.2 | 120 |
| | I/F with VG3 (3C) | 52.2 | + 2 | 54.2 | 60 |
| 4K Cooler coldest exchanger | | 53.1 | + 2 | 55.1 | - |
| 0.1K Cooler coldest exchanger | | 51.3 | + 2 | 53.1 | - |
| JFET box | | 54 | + 2 | 56 | 60 |
| FPU | | [45.4 – 50.1] | + 2 | [47.4 – 52.1] | 65 |
| Primary Reflector | | [45.1 – 46.7] | + 2 | [47.1 – 48.7] | 50 |
| Secondary Reflector | | [45.6 – 45.8] | + 2 | [47.6 – 47.8] | 50 |

**Table 4.2-1 : PPLM / Instruments worst hot interfaces temperatures**

The passive radiator performance is compliant with specifications for all interfaces.

### *4.2.3 Interface Heat Loads review*

As explained in §3.3.1.2 extra loads are injected at main Instruments interfaces in order to reach allocated values.

This is obviously possible only when nominal Instruments lead to heat fluxes lower than allocated. Two exceptions have been found :

- PAU&BEU boxes : Incident heat loads are much higher than allocated

  ⇒ no modification of computed loads (conservative approach)
- HFI : Loads on intermediate shields and struts are much higher than allocated (mainly due to Harness+Bellow)

  ⇒ computed loads increased by 20% on shields 1 & 2 (system margin wrt current HFI design)

Extra loads are located at following interfaces :

- Sorption Cooler (Redundant)
  - ❖ Shield 3 ($\delta Q_{SC}{}^{3}$)
    - @ Exchanger 3A (72% $\delta Q_{SC}{}^{3}$)
    - @ Exchanger 3B (19% $\delta Q_{SC}{}^{3}$)
    - @ Exchanger 3C (9% $\delta Q_{SC}{}^{3}$)

  - ❖ Shield 2 @ Exchanger 2
  - ❖ Shield 1 @ Exchanger 1
- LFI RAA
  - ❖ Shield 3 @ Wave Guides interfaces (symmetrical)
  - ❖ Shield 2 @ Wave Guides interfaces (symmetrical)
  - ❖ Shield 1 @ Wave Guides interfaces (symmetrical)
- HFI
  - ❖ Shield 3 @ 4K and JFET interfaces
  - ❖ Shield 2 @ Dilution Cooler interface
  - ❖ Shield 1 @ Dilution Cooler interface

Figure 4-3 allows to compare :

- Interface heat loads allocations (φ)
- Heat loads as computed by Instruments models (Q)
- Loads actually injected (Q + δQ) to be compared with allocations (Q + δQ ≥ φ)

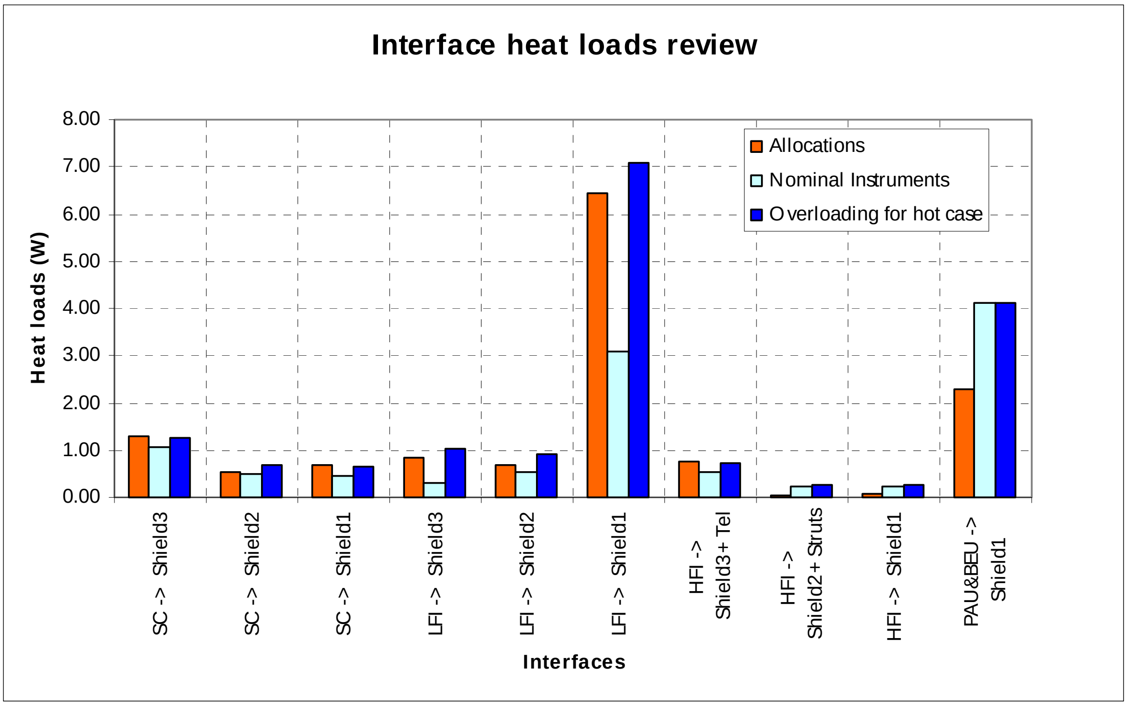


**Figure 4-3 : Interface Heat Loads review / hot case**

Effective heat loads are superior or equal to allocations for all interfaces.

Table 4.2-2 gives a comparison between the reference temperatures at which the allocations are given and the ones computed with heat loads presented before.

| *Interface* | | T ref allocation (K) | T computed (K) |
|---|---|---|---|
| Sorption Cooler | Shield3 | 52 | 52 |
| | Shield2 | 108 | 92 |
| | Shield1 | 158 | 146 |
| LFI RAA | Shield3 | 54.5 | 54 |
| | Shield2 | 106 | 90 |
| | Shield1 | 166 | 156 |
| HFI | Shield3+Tel | 50 | 53 |
| | Shield2+Struts | 110 | 87 |
| | Shield1 | 165 | 145 |

**Table 4.2-2 : Interfaces temperatures**

The temperatures are consistent with reference ones on Shield3 but not on Shields1&2. However, knowing that the budget on Shield3 is the most important, and that Q + $\delta$Q is generally superior to $\varphi$, it can be considered that the obtained interfaces status is conservative wrt allocations.

### 4.2.4 Heat flows

Figure 4-4, Figure 4-5 and Figure 4-6 present the three shields “hot” heat budgets.

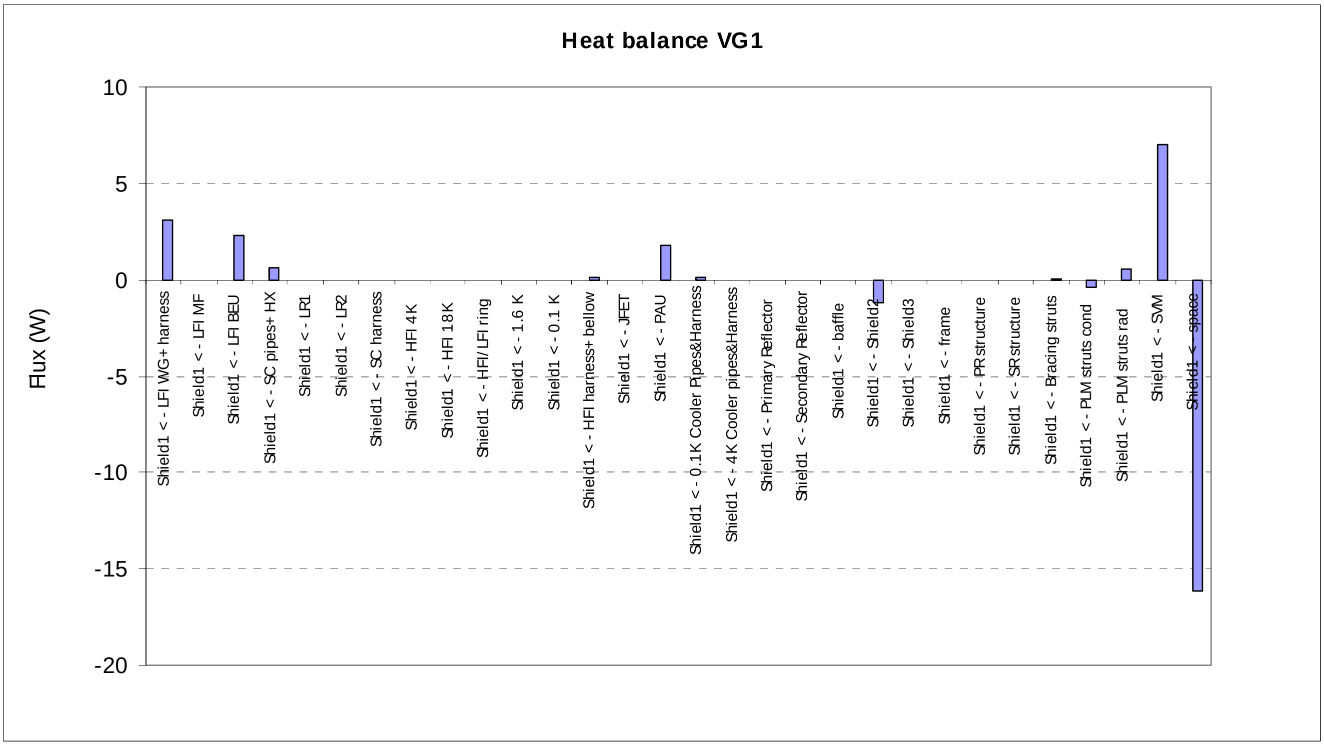


**Figure 4-4 : Shield 1 “hot” heat budget**

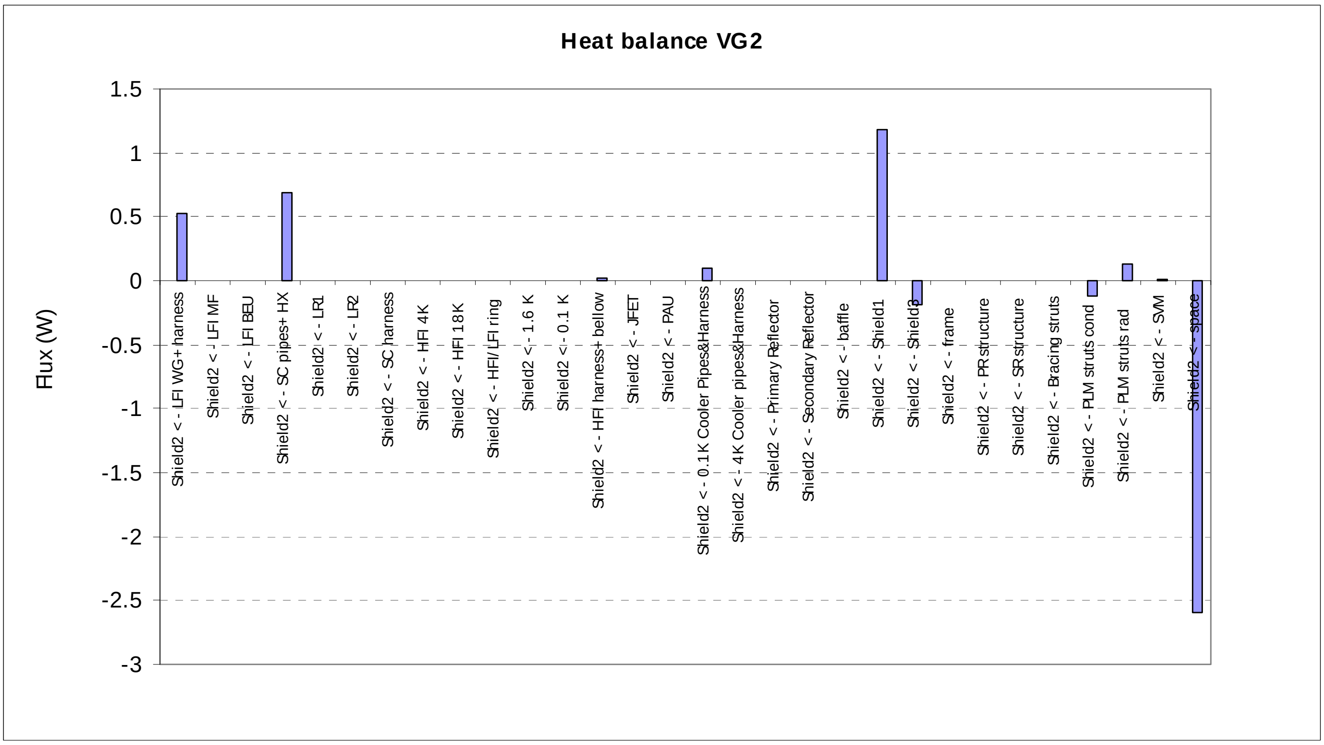


Figure 4-5 : Shield 2 “hot” heat budget

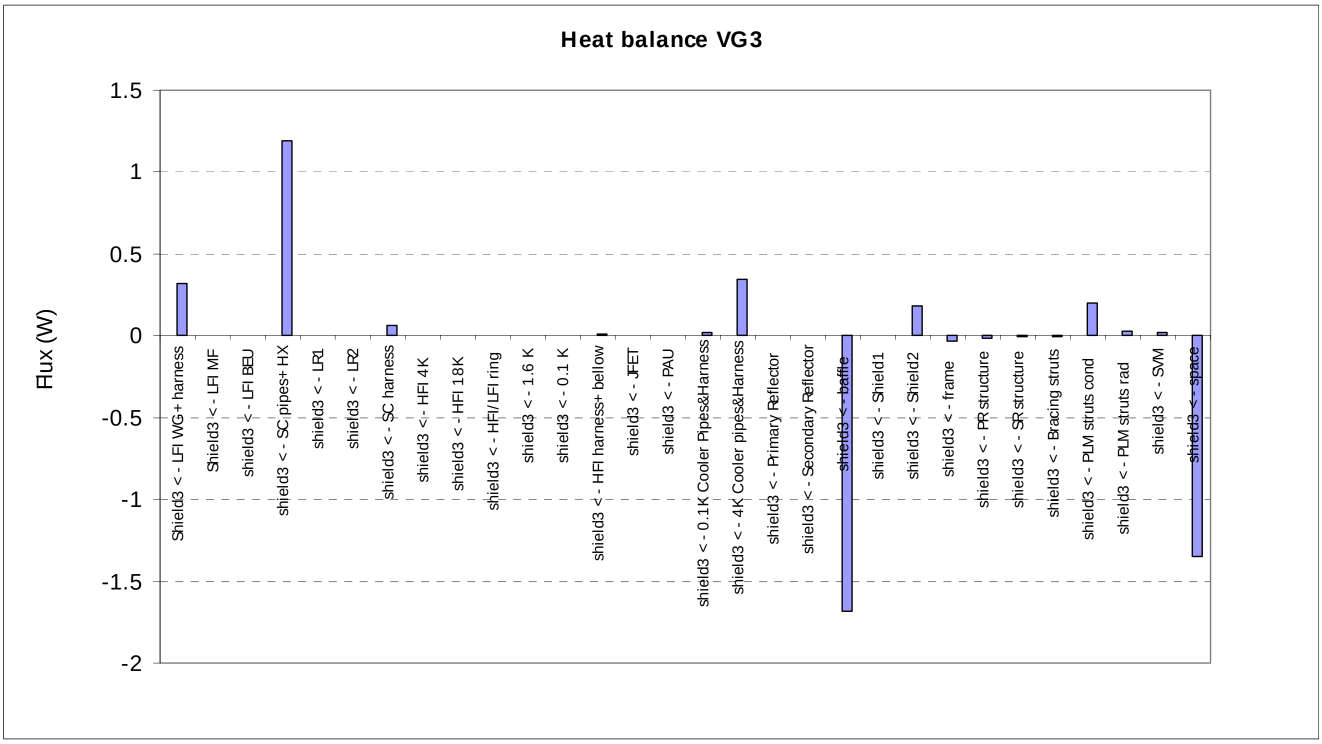


Figure 4-6 : Shield 3 “hot” heat budget

Next figures show Instruments heat loads on PPLM (extra loads δQ not included).

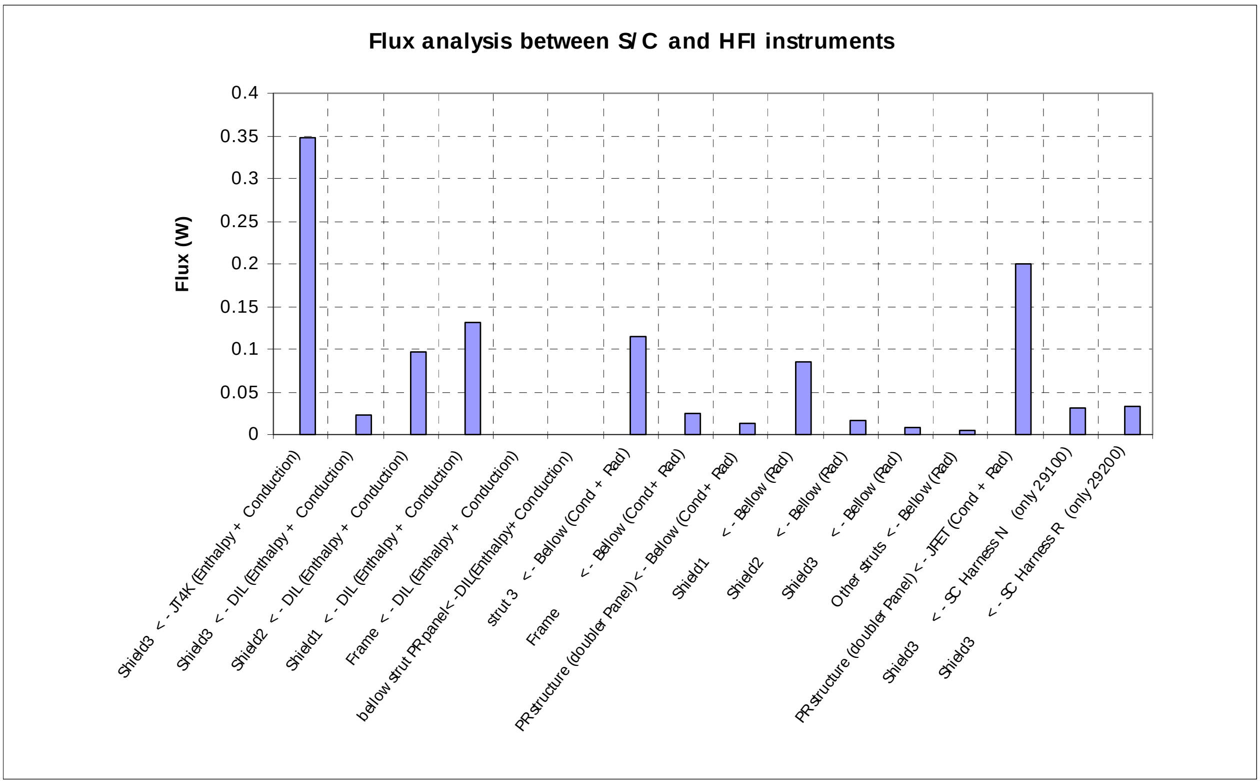


Figure 4-7 : Interfaces with HFI

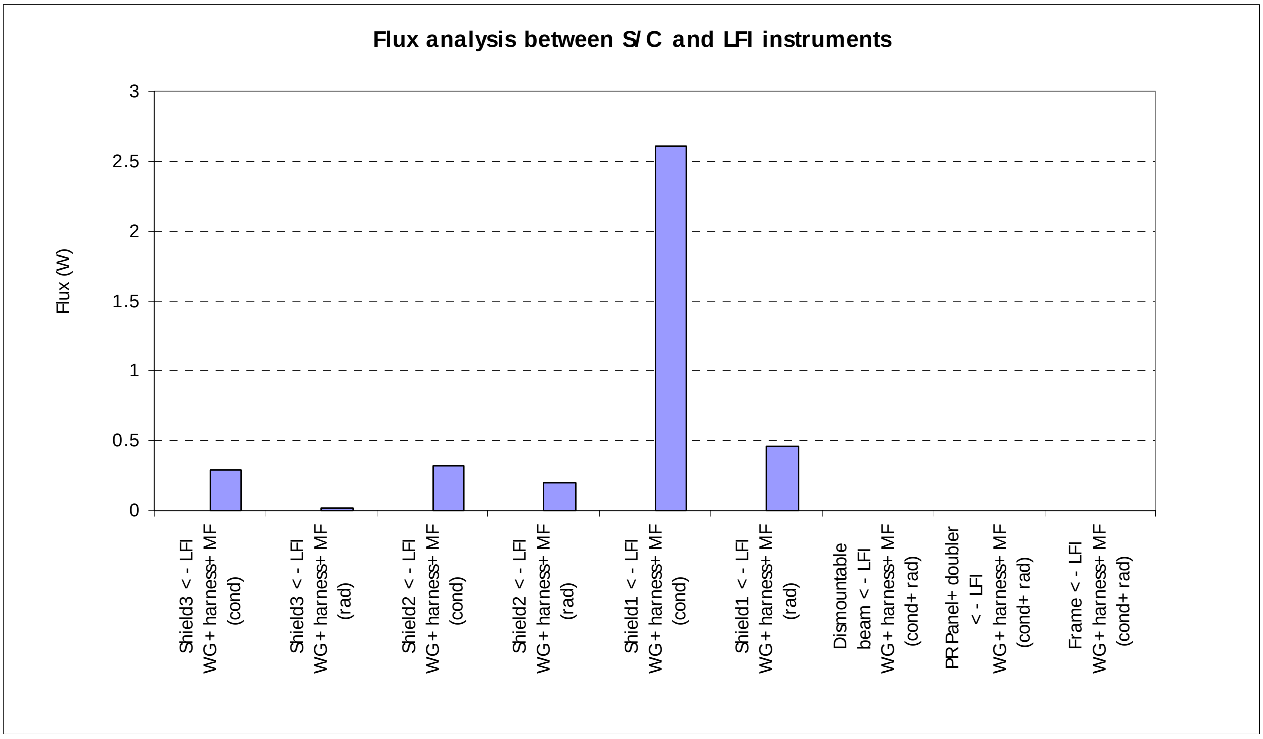


Figure 4-8 : Interfaces with LFI

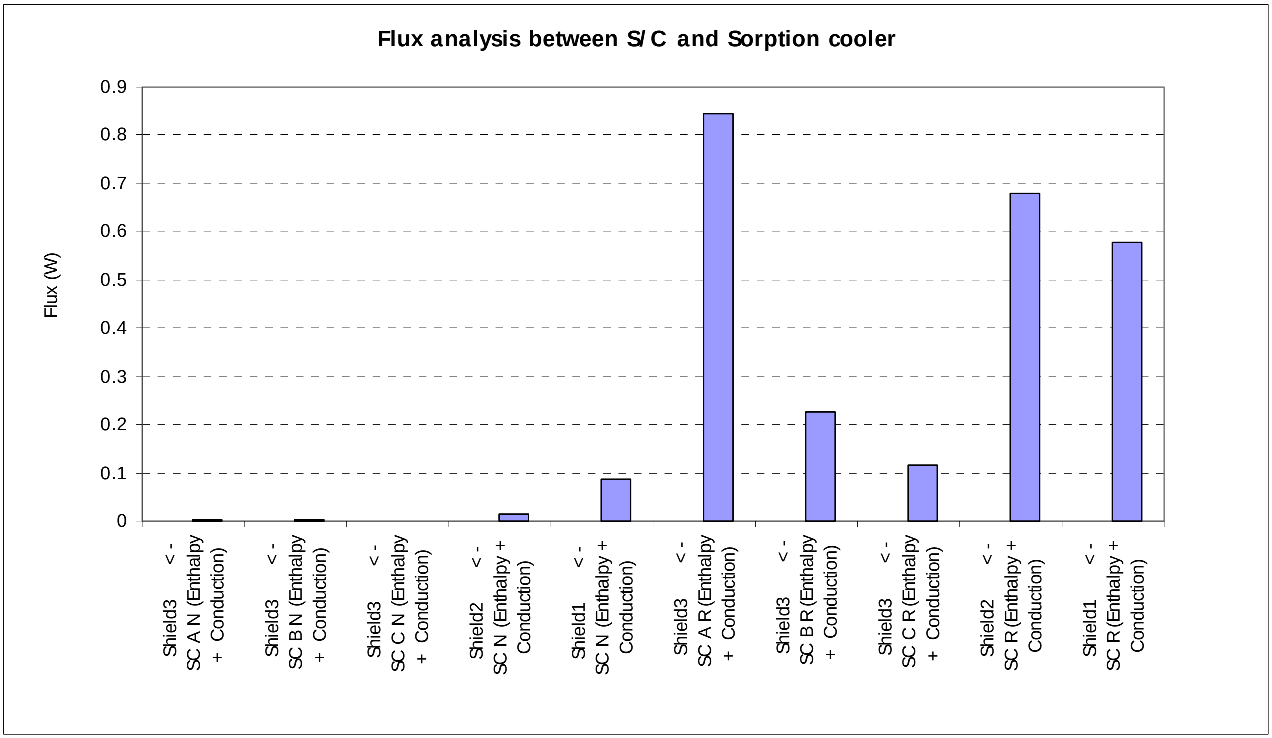


**Figure 4-9 : Interfaces with Sorption Cooler**

## *4.2.5 Hot performance with nominal environment*

The case “Hot PLM”, as described in Table 4.2-3, has been studied for comparison with 50K goal only.

| *50K Goal* | PPLM structure | Instruments I/F | SVM I/F | Operating Sorption Cooler |
|---|---|---|---|---|
| Hot PLM | *Hot* | *Nominal* | *Hot* | *Nominal* |

**Table 4.2-3 : “Hot PLM” case definition**

The computed Sorption Cooler I/F 3C temperature is 48K, leading to 50K when including mathematical uncertainties.

The goal is then achieved with Instruments interfaces as currently modelled.

## 4.3 PPLM Steady state results – Worst Cold operating case

### *4.3.1 Worst Cold operating case definition*

The worst operating cold case corresponds to the cold operating configuration (as presented in §3.3.2.2) including mathematical uncertainty :

- $T_{\text{worst cold}} = T_{\text{op cold}} - 2K$

*Note that this cold case is assessed with nominal Sorption Cooler ON.*

### *4.3.2 Temperature cartography*

Figure 4-10 shows the PPLM cold operating temperature cartography.

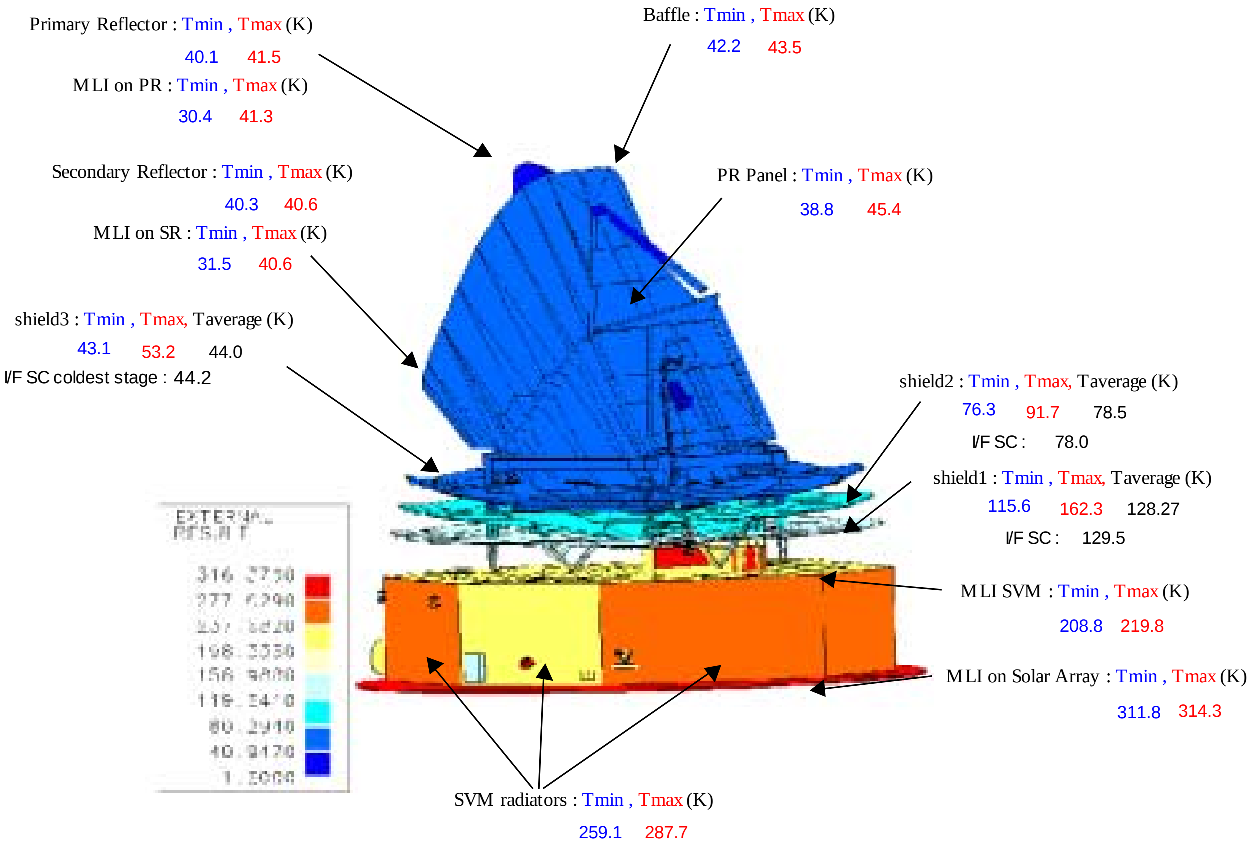


**Figure 4-10 : Cold operating PPLM temperature cartography**

Table 4.3-1 presents a summary of PPLM / Instruments interfaces temperatures in worst cold operating case.

| *PPLM worst cold interfaces temperatures (operating)* | | Computed temperatures **cold operating case** (K) | Mathematical uncertainty (K) | Worst cold operating temperatures (K) | Min T (K) |
|---|---|---|---|---|---|
| LFI WG | I/F with VG1 | 136.5 – 140.7 | - 2 | 134.5 – 138.7 | - |
| | I/F with VG2 | 78.6 – 81.3 | - 2 | 76.6 – 79.3 | - |
| | I/F with VG3 | 44.5 – 45.7 | - 2 | 42.5 – 43.7 | - |
| Sorption Cooler | I/F with VG1 | 135.1 | - 2 | **133.1** | **150** |
| | I/F with VG2 | 81.7 | - 2 | **79.7** | **100** |
| | I/F with VG3 | 44.2 | - 2 | **42.2** | **45** |
| 4K Cooler coldest exchanger | | 44.5 | - 2 | 42.5 | - |
| 0.1K Cooler coldest exchanger | | 44.8 | - 2 | 42.8 | - |
| JFET box | | 45.4 | - 2 | 43.4 | 40 |
| FPU | | [40.7 – 43.4] | - 2 | [**38.7** – 41.4] | **40** |
| Primary Reflector | | [40.1 – 41.5] | - 2 | [38.1 – 39.5] | 30 |
| Secondary Reflector | | [40.3 – 40.6] | - 2 | [38.3 – 38.6] | 30 |

**Table 4.3-1 : PPLM / Instruments worst cold operating interfaces temperatures**

Deviations have to be noted wrt cold operating conditions, mainly at Sorption Cooler interfaces

## 4.4 PPLM Steady state results – Worst Cold non-operating case

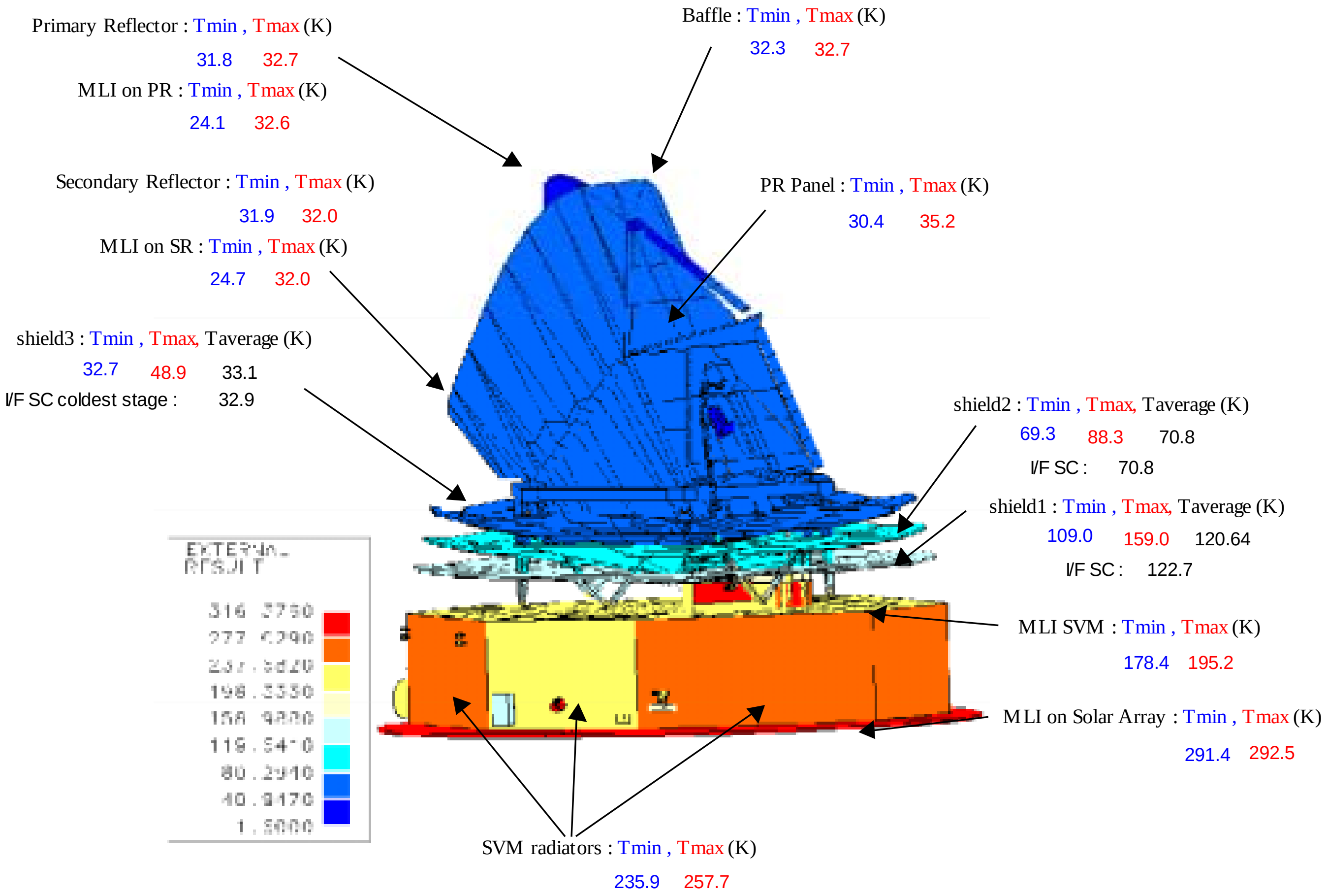
### *4.4.1 Worst Cold non-operating case definition*

The worst non-operating cold case corresponds to the cold non-operating configuration (as presented in §3.3.2.2) including mathematical uncertainty :

- $T_{worst\ cold} = T_{non\ op\ cold} - 2K$

### *4.4.2 Temperature cartography*

Figure 4-11 shows the PPLM cold non-operating temperature cartography.



Primary Reflector : Tmin , Tmax (K)
31.8 32.7
MLI on PR : Tmin , Tmax (K)
24.1 32.6

Baffle : Tmin , Tmax (K)
32.3 32.7

Secondary Reflector : Tmin , Tmax (K)
31.9 32.0
MLI on SR : Tmin , Tmax (K)
24.7 32.0

PR Panel : Tmin , Tmax (K)
30.4 35.2

shield3 : Tmin , Tmax, Taverage (K)
32.7 48.9 33.1
I/F SC coldest stage : 32.9

shield2 : Tmin , Tmax, Taverage (K)
69.3 88.3 70.8
I/F SC : 70.8

shield1 : Tmin , Tmax, Taverage (K)
109.0 159.0 120.64
I/F SC : 122.7

MLI SVM : Tmin , Tmax (K)
178.4 195.2

MLI on Solar Array : Tmin , Tmax (K)
291.4 292.5

SVM radiators : Tmin , Tmax (K)
235.9 257.7

**Figure 4-11 : Cold non operating PPLM temperature cartography**

Table 4.4-1 presents a summary of PPLM / Instruments interfaces temperatures in worst non-operating cold case.

| *PPLM worst cold interfaces temperatures (non-operating)* | | Computed temperatures **Cold non operating case** (K) | Mathematical uncertainty (K) | Worst non-operating cold temperatures (K) | Min T (K) |
|---|---|---|---|---|---|
| LFI WG | I/F with VG1 | 130.1 – 134.1 | - 2 | 128.1 – 132.1 | - |
| | I/F with VG2 | 71.4 – 72.4 | - 2 | 69.4 – 70.4 | - |
| | I/F with VG3 | 33.8 – 34.1 | - 2 | 31.8 – 32.1 | - |
| Sorption Cooler | I/F with VG1 | 123 | - 2 | **121** | **150** |
| | I/F with VG2 | 71 | - 2 | **69** | **100** |
| | I/F with VG3 | 33 | - 2 | **31** | **40** |
| 4K Cooler coldest exchanger | | 33 | - 2 | 31 | - |
| 0.1K Cooler coldest exchanger | | 33 | - 2 | 31 | - |
| JFET box | | 32 | - 2 | 30 | 30 |
| FPU | | 32 | - 2 | 30 | - |
| Primary Reflector | | 32 | - 2 | 30 | 30 |
| Secondary Reflector | | 32 | - 2 | 30 | 30 |

**Table 4.4-1 : PPLM / Instruments worst non-operating cold interfaces temperatures**

As for operating case, deviations have to noted at Sorption Cooler interfaces.

It is also to be noticed that Shield3 and Telescope predicted min average temperatures are close to 30K (lower materials&process qualification range), the coldest parts belonging to PR panel and reaching 28K.

## 4.5 Sensitivity analyses

Sensitivity studies have been performed and are reported in Table 4.5-1.

| *Sensitivities* | Deviation | Impact at Sorption Cooler coldest I/F (3C) | Comments |
|---|---|---|---|
| In-plane Shields and Baffle sheet conductance | -15% | +0.15 K | |
| Shields and Baffle honeycomb conductance | -30% | +0.04 K | |
| SC1&2&3A&3B contact conductance | -50% | +0.03 K | |
| Copper braids conductance | -30% | +0.10 K | |
| Copper braids conductance | -100% | +4.7 K | Braids removed |
| Shields petals Interface conductance | -30% | +0.10 K | |
| Cryo-Struts conductance | +30% | +0.23 K | |
| ATC harness conductance | +20% | +0.06 K | |
| SC 3C heat sink | "nom → hot" | +0.38 K | See §3.3.4.1.3 for deviation detailed description |
| LEC properties ($\varepsilon$, $\rho_S$) | "nom → hot" on all LEC surfaces | +0.4 K | See §3.3.3.1.3 for deviation detailed description |
| HEC properties ($\varepsilon$) | "nom → hot" on all HEC surfaces | +1 K | See §3.3.3.1.2 for deviation detailed description |
| SVM I/f temperatures | TCS results → PLM I/F spec | +0.1 K | |

**Table 4.5-1 : Sensitivity studies**

# 5. COOL DOWN ANALYSES

A passive cool down has been studied. The profiles of shields and reflectors average temperatures are presented in Figure 5-1.

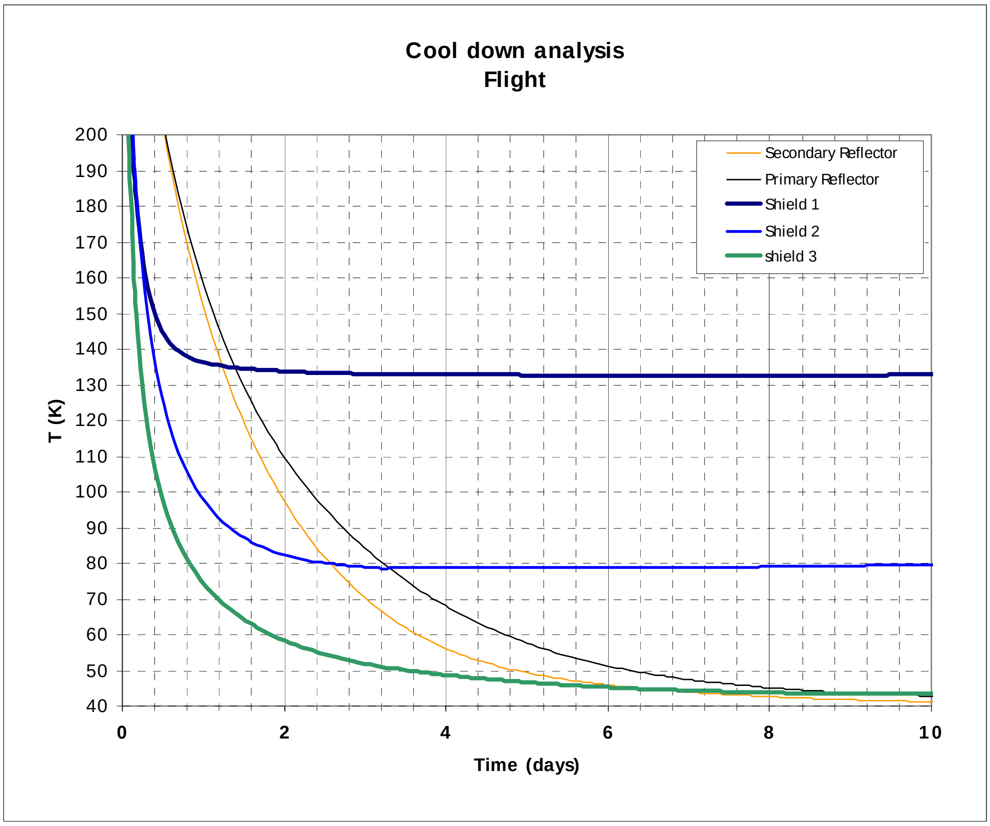


**Figure 5-1 : Cool down analysis**

Note that this cool-down corresponds to a nominal case.

# 6. PPLM THERMAL STABILITY STUDY

This study is aimed at providing thermal inputs necessary for straylight analysis.

The thermal perturbations are listed according to the position of the sources :

- SVM temperatures fluctuation
  - ✓ Occurring at PPLM / SVM conductive and radiative interfaces
- Sorption Cooler dissipation on shields 1&2&3
  - ✓ Occurring at Sorption exchangers on shields
- Moon illumination
  - ✓ Occurring on primary mirror and baffle

The PPLM thermal stability is analysed through the study of the following elements :

- Shield 3 upper parts (internal and external parts)
- Baffle internal faces
- Primary and secondary reflectors

Notes :

- ✓ The selected elements are the most sensitive ones regarding straylight concerns.
- ✓ The **reference temperatures** for the stability study are the elements **average** ones.

The transient analyses presented in §6.1 and §6.2 are performed with global PPLM TMM.

The analyses presented in §6.3 are based on local models independent of PPLM global TMM.

In both studies, attention has been paid to choose computation parameters (time step < CSGMIN) ensuring the convergence of ESATAN resolution routines.

## 6.1 SVM temperatures fluctuation

The SVM reference temperatures taken into account correspond to the following interfaces :

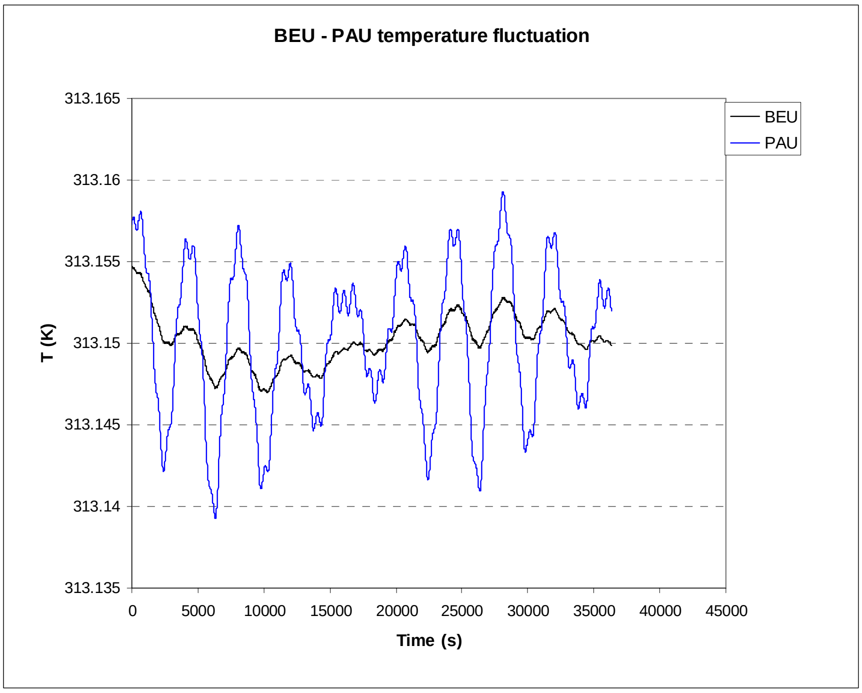
- BEU and PAU radiative areas
- External faces of PPLM sub-platform and SVM upper closer panel MLI (including BEU and PAU MLI)
- External face of the solar array MLI
- PPLM struts conductive interface

### *6.1.1 Thermal perturbations inputs*

The inputs are drawn from SVM TCS CDR results on which a ×10 margin is taken into account.

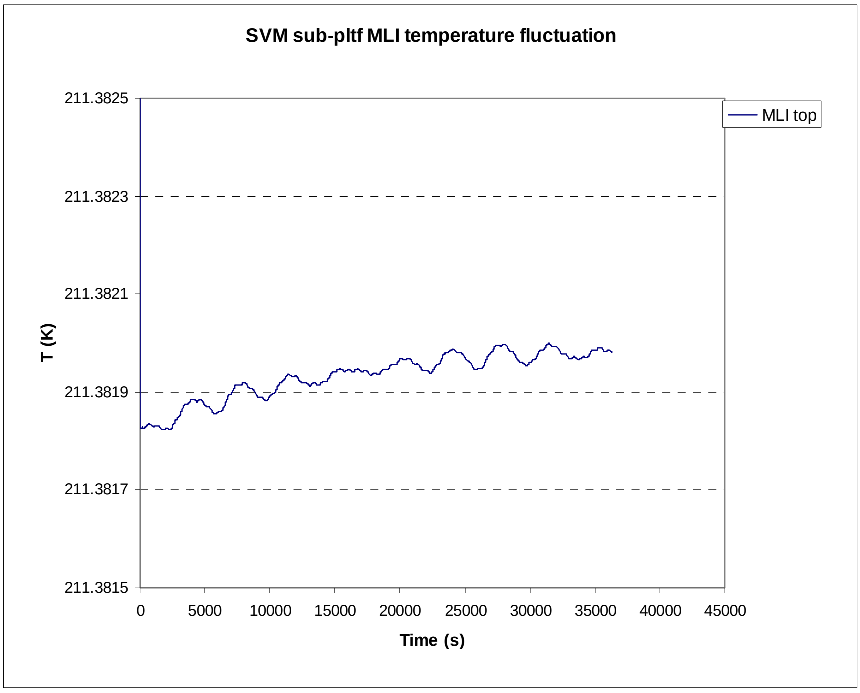
Note that the PPLM global TMM used to assess the effect of these fluctuations is not the one in line with CDR steady state analyses but is an older version; this less detailed and hence lighter version gives conservative results.

SVM amplified fluctuations are presented in the following graphs :



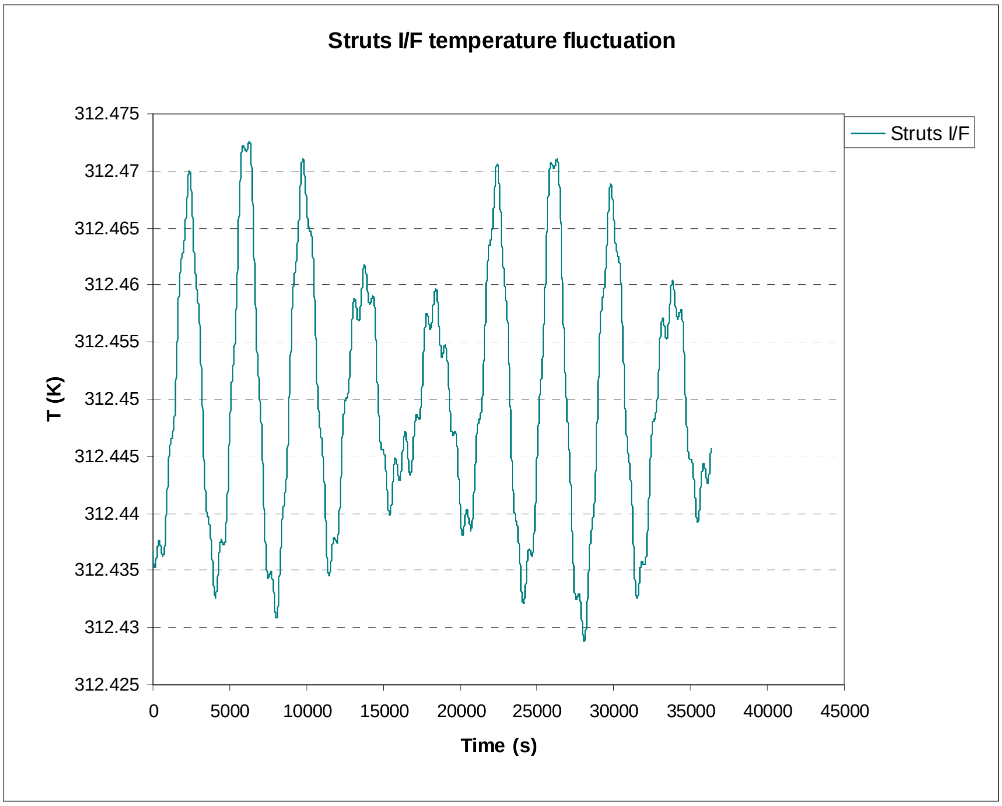
PTV ≈ 15 mK

Figure 6-1 : BEU – PAU temperature fluctuations / amplified amplitudes



PTV ≈ 0.05 mK

Figure 6-2 : SVM sub-platform MLI temperature fluctuations / amplified amplitudes



PTV ≈ 40 mK

**Figure 6-3 : Struts I/F temperature fluctuations / amplified amplitudes**

Note : MLI BEU-PAU and MLI SA fluctuations are not presented because they are of the same order as MLI sub - pltf.

### 6.1.2 *Resulting PPLM temperature fluctuation*

The fluctuations resulting from the perturbations presented in §6.1.1 are reported in the following graphs.

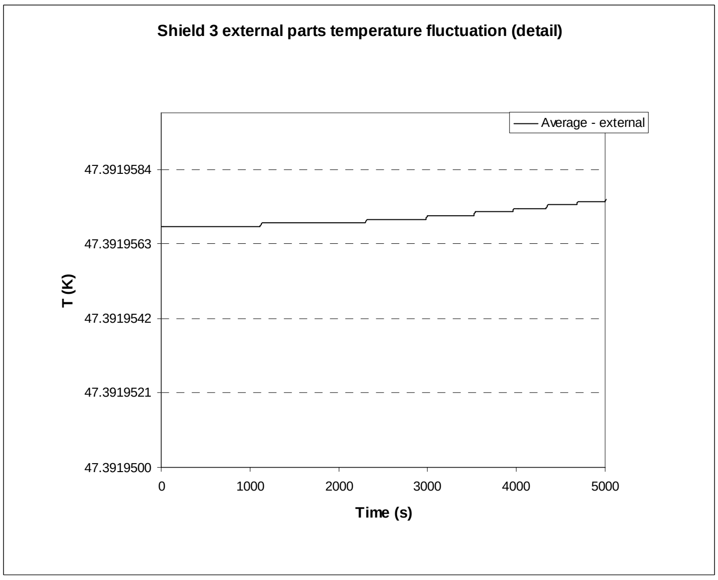


**Figure 6-4 : Shield 3 external parts fluctuation / SVM perturbation**

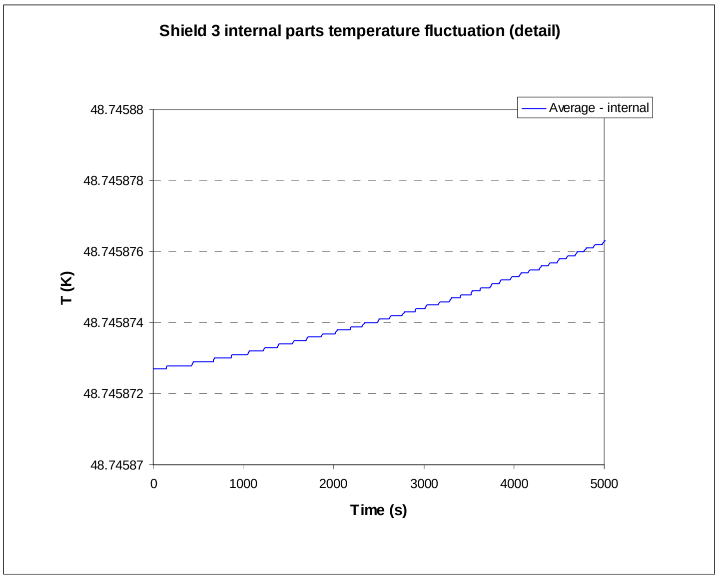


Figure 6-5 : Shield 3 internal parts fluctuation / SVM perturbation

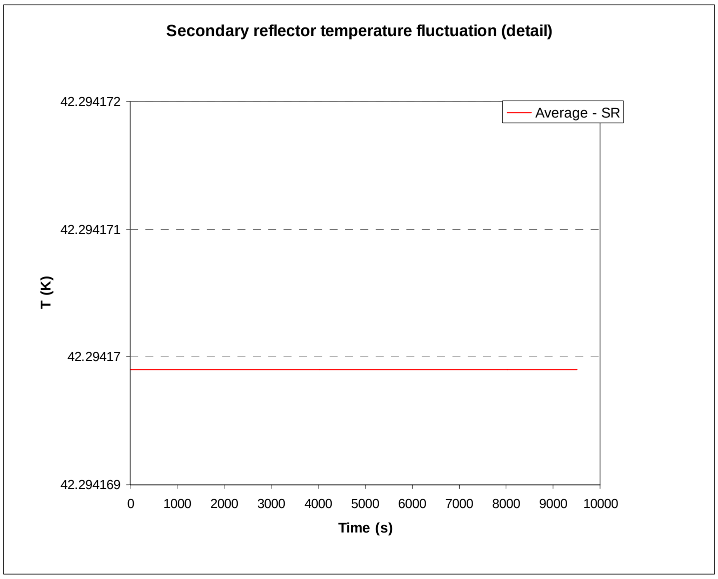


Figure 6-6 : Secondary reflector fluctuation / SVM perturbation

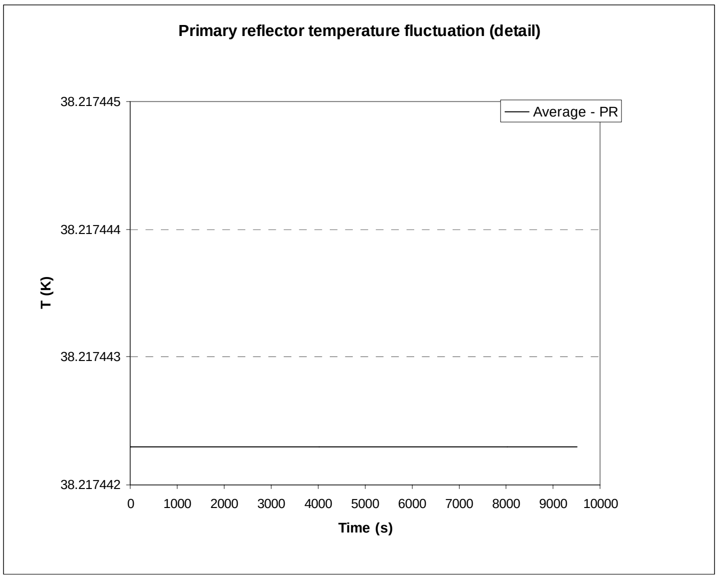


Figure 6-7 : Primary reflector fluctuation / SVM perturbation

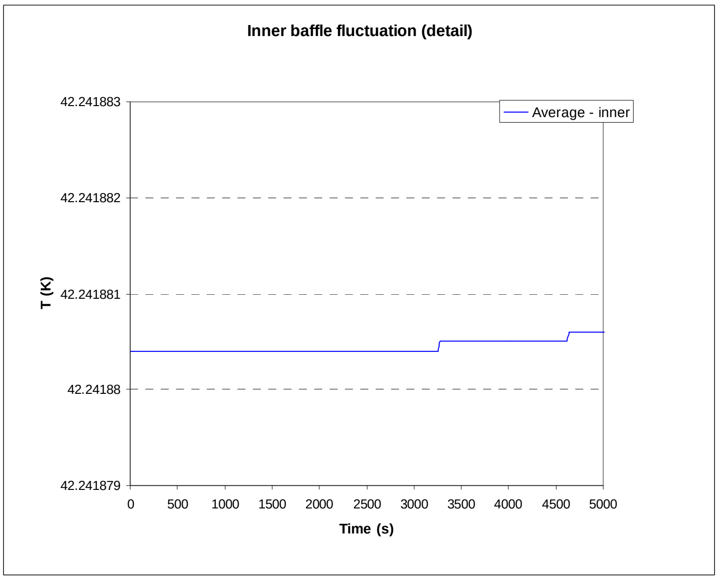


Figure 6-8 : Inner baffle fluctuation / SVM perturbation

Notes:

- The presented fluctuations are only due to the SVM fluctuations (no Sorption Cooler dissipation variations).
- The observed drift on shield 3 and baffle is due to a slight change of the injected mean values after amplification of the SVM fluctuations.

It can be stated from these different results that SVM I/F fluctuations, even when amplified by a factor of 10, lead to no significant thermal fluctuations upon PPLM sensitive elements.

As shown in §6.2, the Sorption Cooler variable dissipation on shields is the major contributor to PPLM thermal instability.

## 6.2 Sorption Cooler dissipations on shields

The Sorption Cooler pipes being pre-cooled on the three shields induce a fluctuating dissipation, on each shield, tuned on the cooler functioning profile.

### *6.2.1 Thermal perturbations inputs*

Two kinds of inputs are studied :

- JPL inputs dating from 1999
- JPL latest provided inputs (06/2002)

As shown in next two paragraphs, these two sets of inputs present quite different profiles which may lead to different PPLM thermal responses.

Note : In order to use provided fluctuation data (dissipation profile Q = f(t)) for any shields temperatures and then for several values of average dissipation $Q_{mean}$, the initial data have been turned into $Q/Q_{mean}$ profiles.

#### 6.2.1.1 JPL 1999 inputs

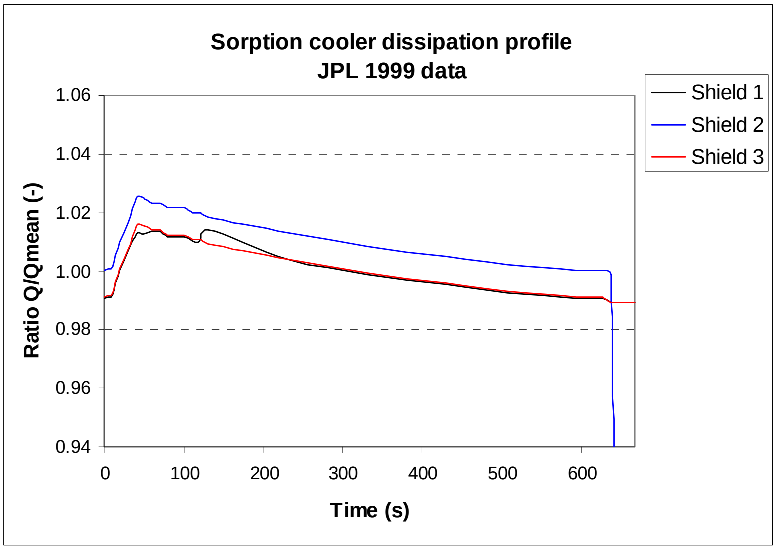


**Figure 6-9 : Sorption Cooler dissipation profiles # $Q/Q_{mean}$**
**JPL 1999 data**

The three profiles are 667s periodic functions. Only one period is presented in the Figure 6-9.

It can be remarked that, excepted for Shield 2, the dissipation fluctuations remain approximately within ± 2% of the mean value.

A sensitivity study has been performed on the basis of the nominal profile amplitudes amplified by a factor of 10.

The resulting amplified profiles are presented here below :

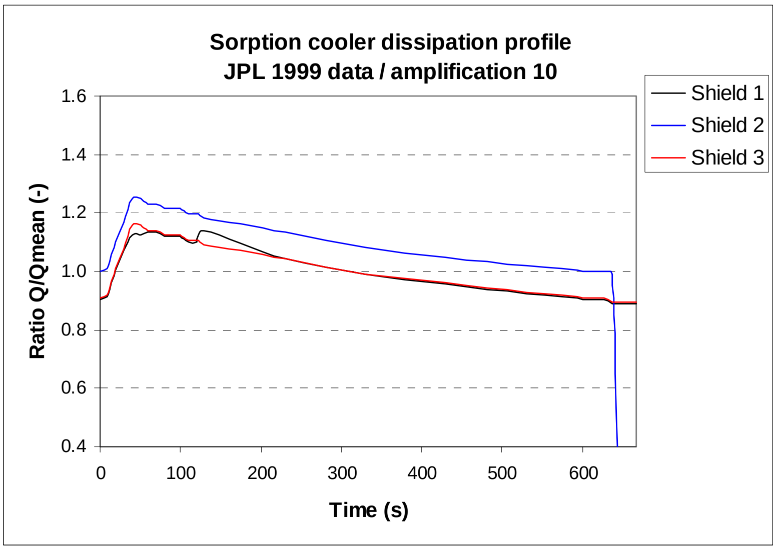


**Figure 6-10 : Sorption Cooler dissipation profiles # Q/Q$_{mean}$ JPL 1999 data / amplification 10**

### 6.2.1.2 New JPL inputs

The profiles given by JPL are reported hereafter :

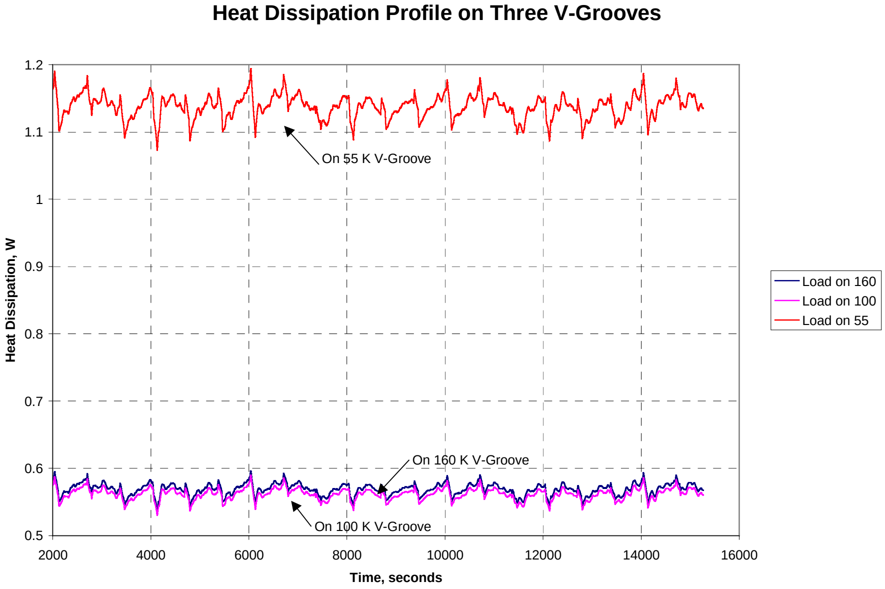


**Figure 6-11 : Sorption Cooler dissipation profiles # Q (W) new JPL data**

A period of approximately 4000 s (# 6×667 s) can be drawn.

These profiles, turned into $Q/Q_{mean}$ ratio curves, are presented over a period :

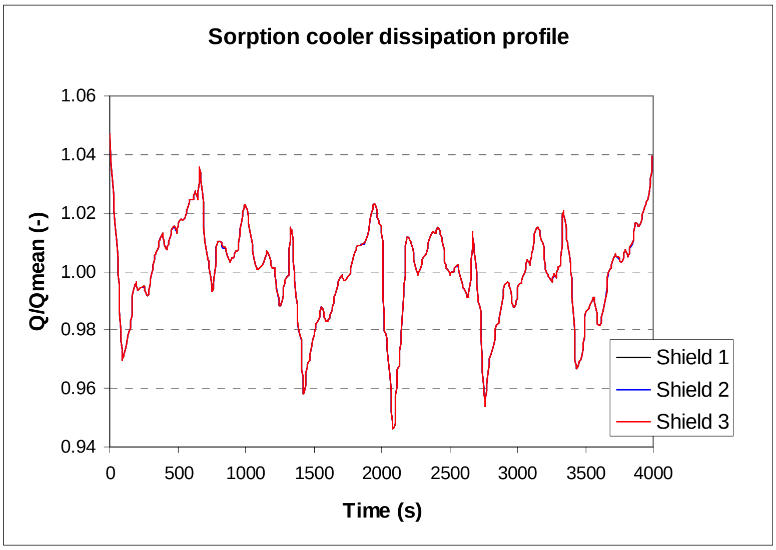


**Figure 6-12 : Sorption Cooler dissipation profiles # $Q/Q_{mean}$ (new JPL data)**

The Figure 6-12 shows the three profiles, in term of $Q/Q_{mean}$ ratio, are identical.

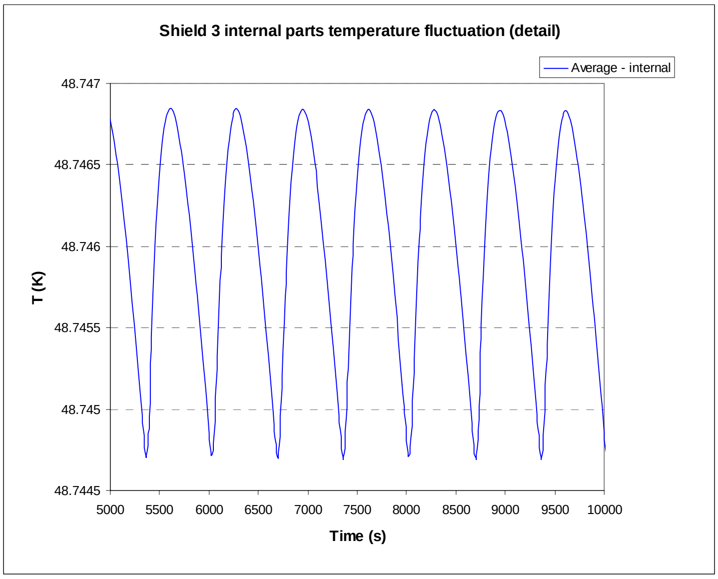
It can moreover be noted that, even though this profile can hardly be compared to the 1999 data one (see §6.2.1.1), the fluctuations amplitudes seem to be twice as big as the previous ones (± 4 % instead of ± 2 %).

### *6.2.2 Resulting PPLM temperature fluctuation*

The fluctuations resulting from the perturbations presented in §6.2.1 are reported in the following graphs.

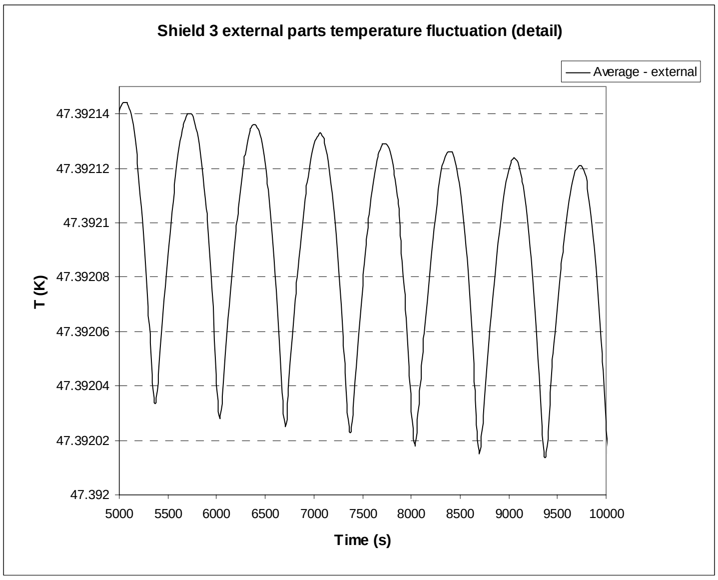
### 6.2.2.1 Results with JPL 1999 inputs

#### *6.2.2.1.1 Nominal amplitudes*



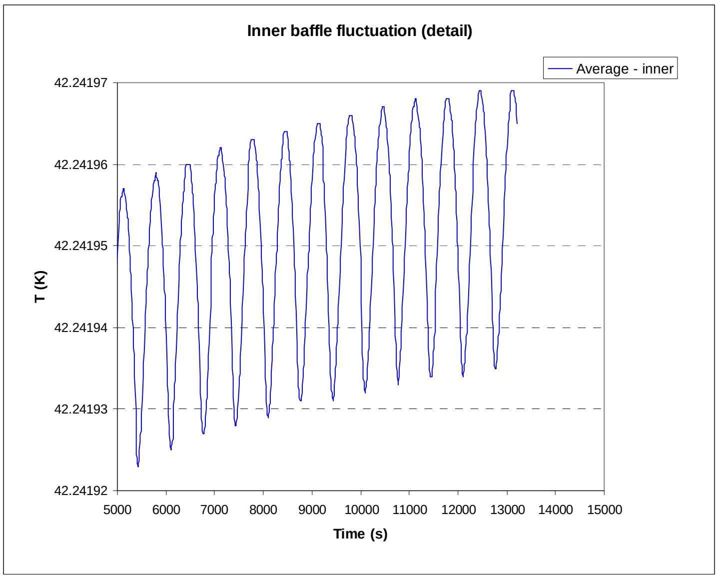
PTV ≈ 2 mK

**Figure 6-13 : Shield 3 internal parts fluctuation / Sorption Cooler nominal perturbation JPL 1999 inputs**



PTV ≈ 0.1 mK

**Figure 6-14 : Shield 3 external parts fluctuation / Sorption Cooler nominal perturbation JPL 1999 inputs**

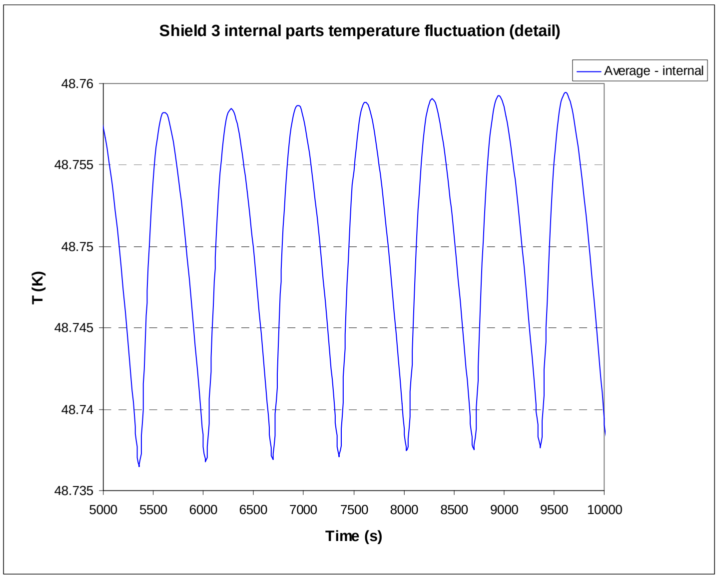


PTV ≈ 0.030 mK

**Figure 6-15 : Inner baffle fluctuation / Sorption Cooler nominal perturbation JPL 1999 inputs**

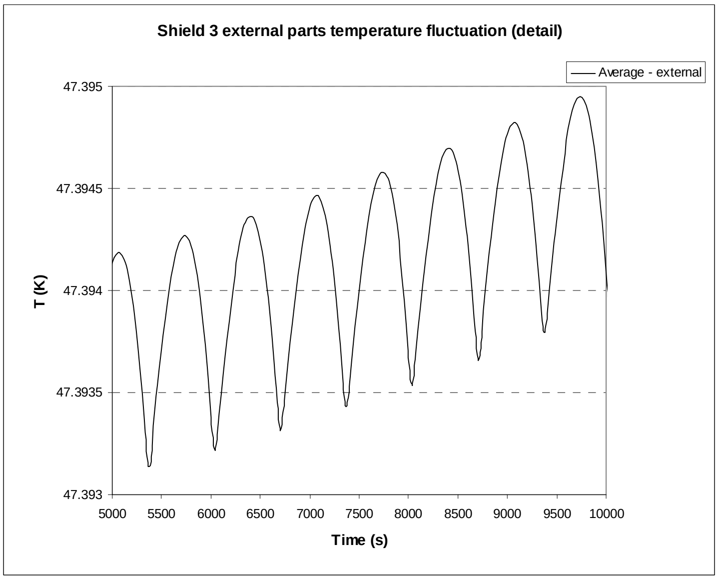
The mirrors fluctuations are not presented because of their very weak fluctuations (not detectable). See §6.2.2.1.2 for amplified fluctuations.

#### *6.2.2.1.2 Amplified perturbations (×10)*



PTV ≈ 21 mK

**Figure 6-16 : Shield 3 internal parts fluctuation / Sorption Cooler amplified perturbation**



PTV ≈ 1.1 mK

Figure 6-17 : Shield 3 external parts fluctuation / Sorption Cooler amplified perturbation

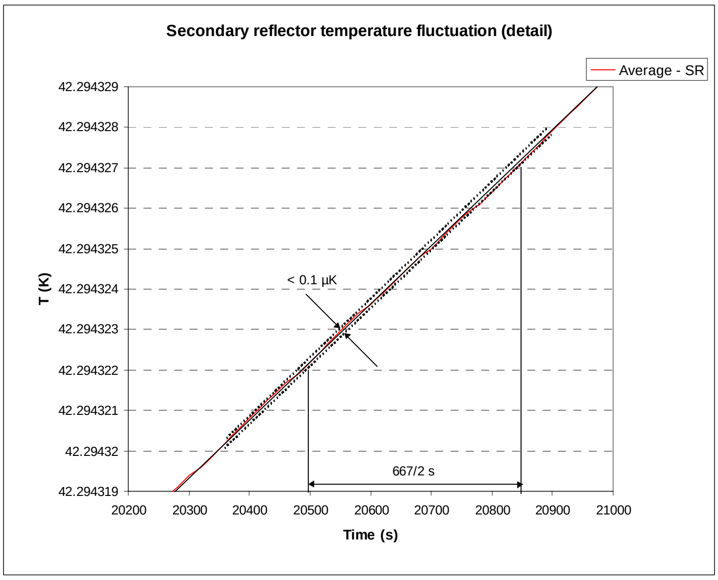


Figure 6-18 : Secondary reflector fluctuation / Sorption Cooler amplified perturbation

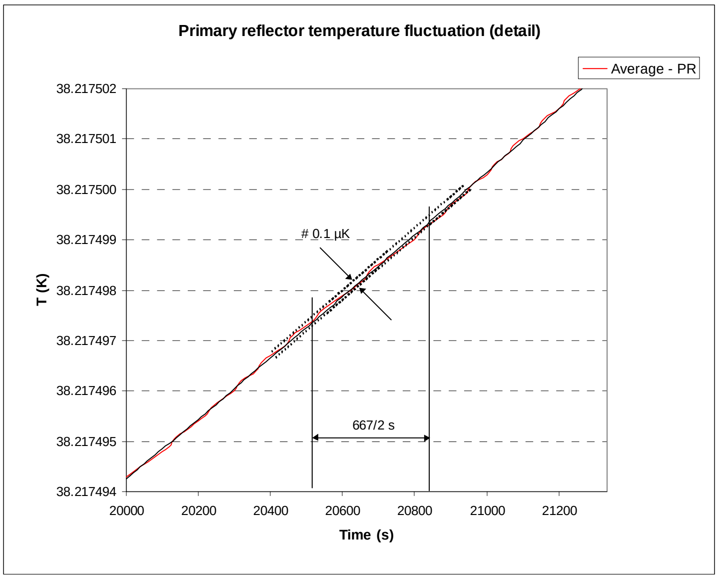
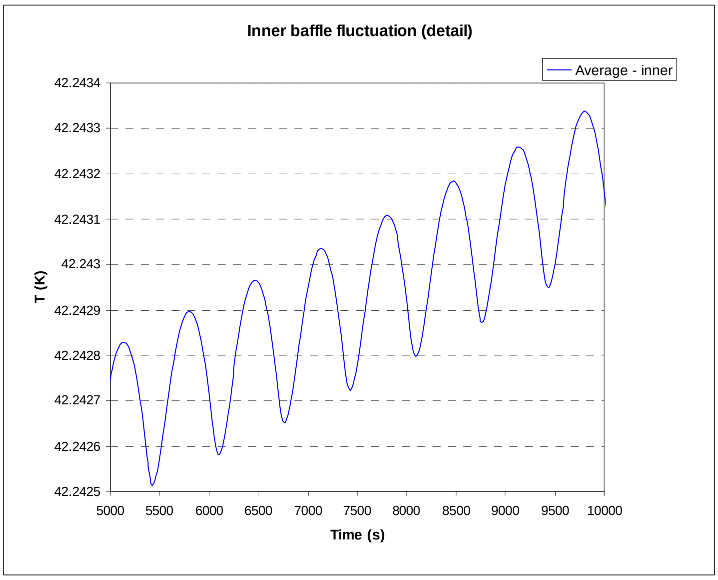


**Figure 6-19 : Primary reflector fluctuation / Sorption Cooler amplified perturbation**

The mirrors fluctuation can hardly be detected (#0.1µK), even with amplified perturbations.

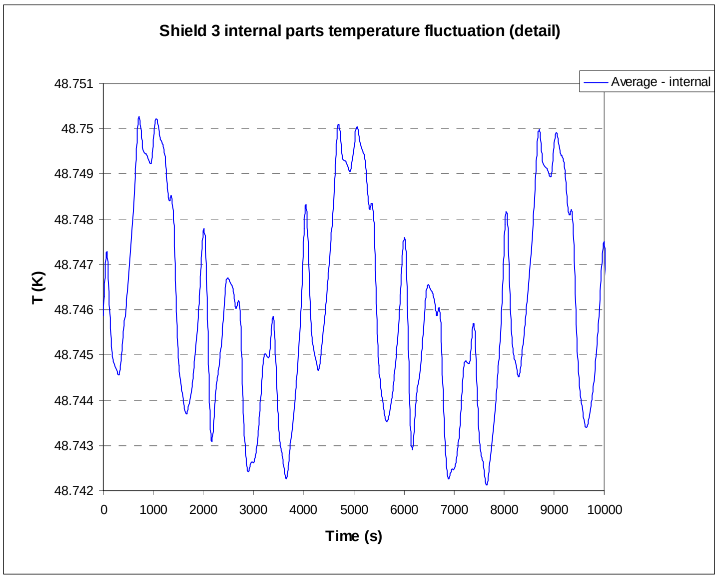


PTV ≈ 0.3 mK

**Figure 6-20 : Inner baffle fluctuation / Sorption Cooler amplified perturbation**

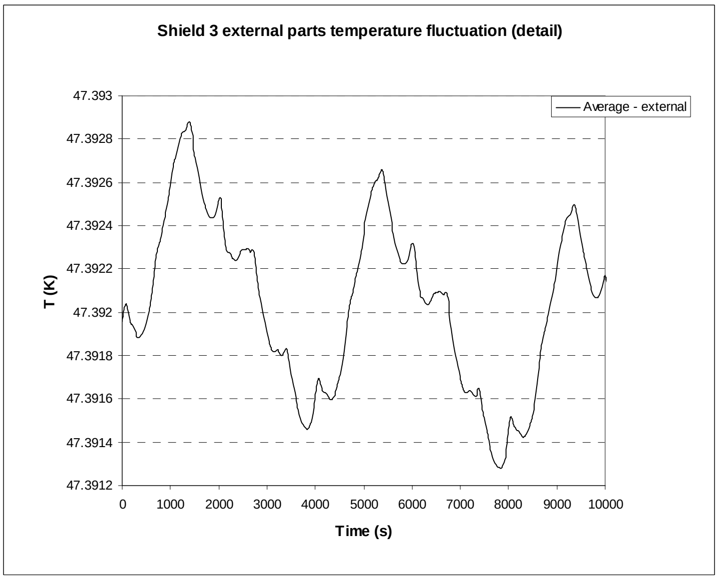
Note : The observed drift on all elements is due to a slight change of the injected mean values after amplification of the fluctuations.

### 6.2.2.2 Results with JPL 2002 inputs



PTV ≈ 8 mK

**Figure 6-21 : Shield 3 internal parts fluctuation / Sorption Cooler perturbation JPL 2002 inputs**



PTV ≈ 1.2 mK

**Figure 6-22 : Shield 3 external parts fluctuation / Sorption Cooler perturbation JPL 2002 inputs**

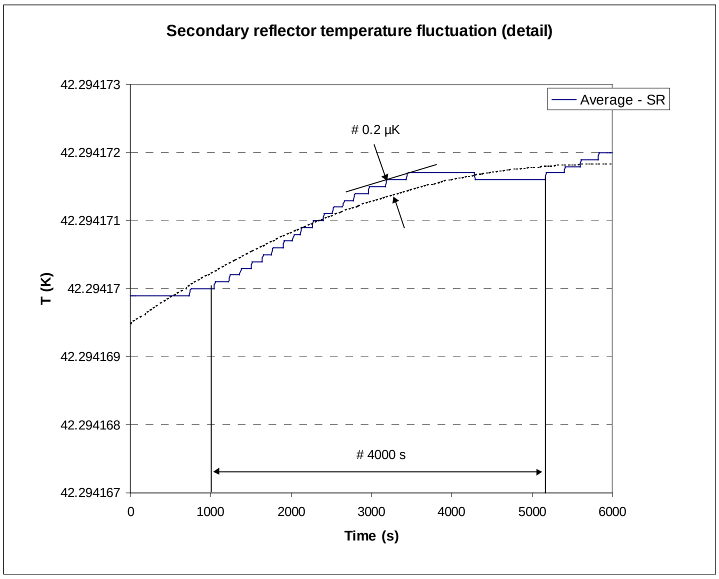


**Figure 6-23 : Secondary reflector fluctuation / Sorption Cooler perturbation JPL 2002 inputs**

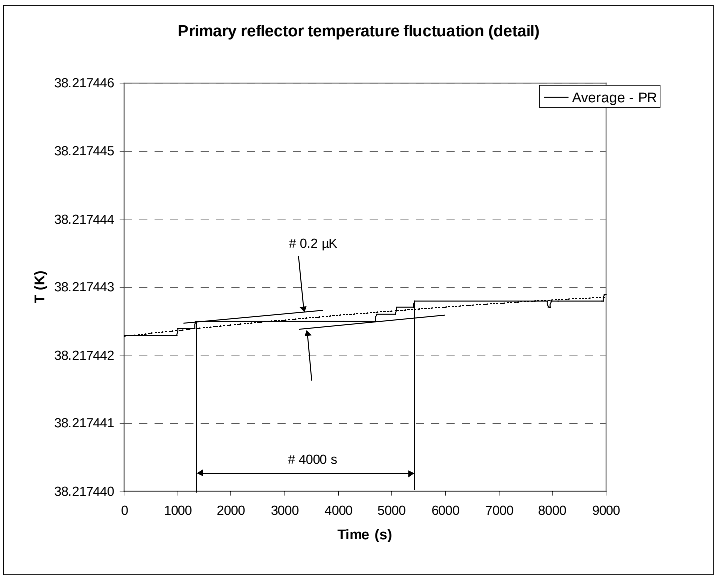
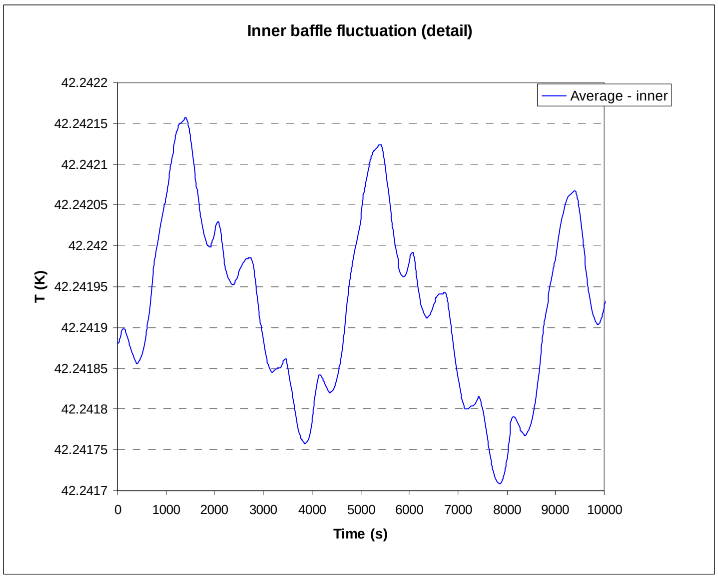


**Figure 6-24 : Primary reflector fluctuation / Sorption Cooler perturbation JPL 2002 inputs**



PTV ≈ 0.4 mK

**Figure 6-25 : Inner baffle fluctuation / Sorption Cooler perturbation JPL 2002 inputs**

### 6.2.2.3 Synthesis of thermal perturbations due to the Sorption Cooler

| ***Thermal fluctuations due to Sorption Cooler*** | Sorption Cooler JPL 1999 data | | Sorption Cooler JPL 1999 data ⊗ 10 | | Sorption Cooler JPL 2002 data | |
|---|---|---|---|---|---|---|
| | Amplitude | Period | Amplitude | Period | Amplitude | Period |
| Shield 3 internal | 2130 µK | # 667 s | 20960 µK | # 667 s | 7880 µK<br>4088 µK | # 4000 s<br># 667 s |
| Shield 3 external | 110 µK | # 667 s | 1039 µK | # 667 s | 1200 µK<br># 100 µK | # 4000 s<br># 667 s |
| Sec. Reflector | negligible | - | < 0.1 µK | # 667 s | # 0.4 µK<br>negligible | # 4000 s<br># 667 s |
| Prim. Reflector | negligible | - | 0.1 µK | # 667 s | # 0.2 µK<br>negligible | # 4000 s<br># 667 s |
| Baffle internal | 30 µK | # 667 s | 300 µK | # 667 s | 400 µK<br># 30 µK | # 4000 s<br># 667 s |

**Table 6.2-1 : Synthesis of the thermal fluctuations due to the Sorption Cooler**

Note that amplitudes and periods are difficult to extract from the results computed after JPL 2002 data.

## 6.3 Direct Moon illumination

### *6.3.1 Thermal fluctuations of the PR*

#### 6.3.1.1 Introduction

This paragraph is intended to present the results achieved about the PR temperature fluctuation when submitted to direct Moon illumination.

In order to avoid huge time consuming 3D or 2D approaches, a 1D model of PR thickness has firstly been created; any incoming perturbation on PR (external Moon illumination) is fully transmitted through PR thickness, without any 2D damping, thus leading to the maximum PR active face local temperature fluctuation.

The 1D results are afterwards processed by a simple inertia approach in order to estimate the PR active face temperature fluctuations as a function of the considered area.

#### 6.3.1.2 PR 1D modelling

##### *6.3.1.2.1 Reflector design*

The description of the reflector is given hereafter :

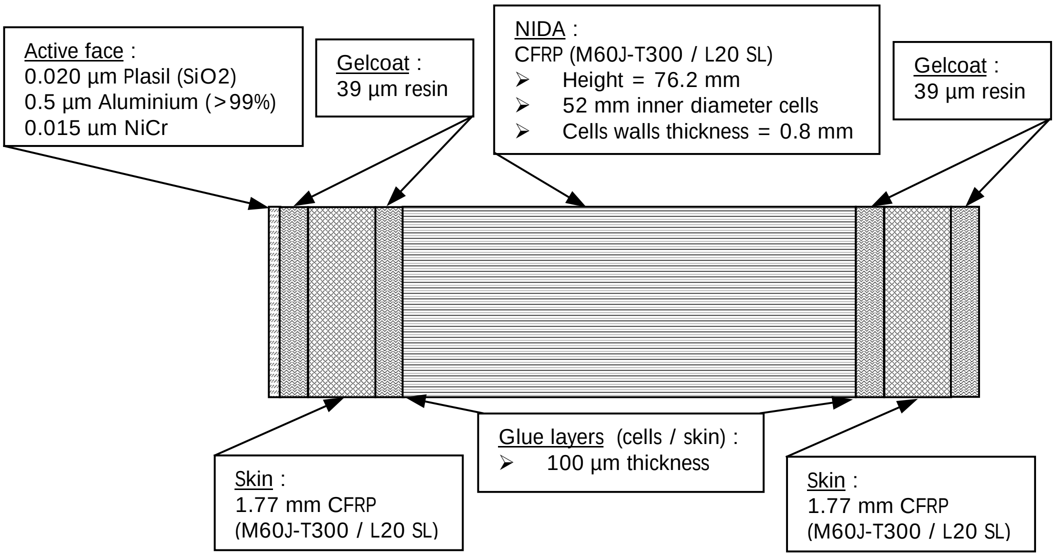
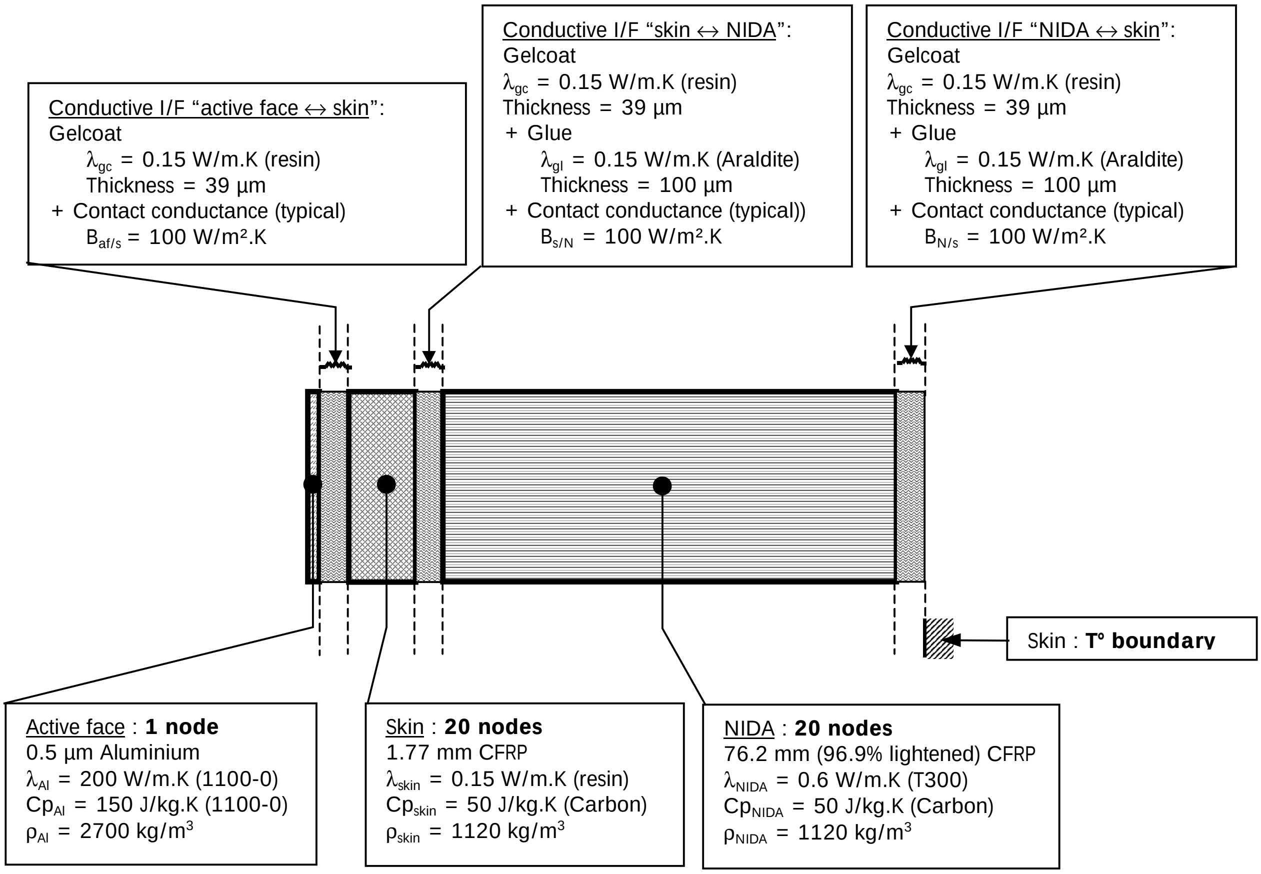


**Figure 6-26 : Primary Reflector description**

##### *6.3.1.2.2 Reflector modelling*

The 1D reflector modelling of the presented design is shown here below :



Conductive I/F "active face ↔ skin":
Gelcoat
$\lambda_{gc}$ = 0.15 W/m.K (resin)
Thickness = 39 µm
+ Contact conductance (typical)
$B_{af/s}$ = 100 W/m².K

Conductive I/F "skin ↔ NIDA":
Gelcoat
$\lambda_{gc}$ = 0.15 W/m.K (resin)
Thickness = 39 µm
+ Glue
$\lambda_{gl}$ = 0.15 W/m.K (Araldite)
Thickness = 100 µm
+ Contact conductance (typical))
$B_{s/N}$ = 100 W/m².K

Conductive I/F "NIDA ↔ skin":
Gelcoat
$\lambda_{gc}$ = 0.15 W/m.K (resin)
Thickness = 39 µm
+ Glue
$\lambda_{gl}$ = 0.15 W/m.K (Araldite)
Thickness = 100 µm
+ Contact conductance (typical)
$B_{N/s}$ = 100 W/m².K

Skin : **T° boundary**

Active face : **1 node**
0.5 µm Aluminium
$\lambda_{Al}$ = 200 W/m.K (1100-0)
$Cp_{Al}$ = 150 J/kg.K (1100-0)
$\rho_{Al}$ = 2700 kg/m$^3$

Skin : **20 nodes**
1.77 mm CFRP
$\lambda_{skin}$ = 0.15 W/m.K (resin)
$Cp_{skin}$ = 50 J/kg.K (Carbon)
$\rho_{skin}$ = 1120 kg/m$^3$

NIDA : **20 nodes**
76.2 mm (96.9% lightened) CFRP
$\lambda_{NIDA}$ = 0.6 W/m.K (T300)
$Cp_{NIDA}$ = 50 J/kg.K (Carbon)
$\rho_{NIDA}$ = 1120 kg/m$^3$

**Figure 6-27 : Primary Reflector modelling**

### *6.3.1.2.2.1 Physical parameters assumptions*

All assumptions are made in order to :

- Minimise the thermal inertia of different parts.

  → Only the Aluminium is taken into account for the active face.

  → Gelcoat and glue masses are neglected for the skins inertia estimation.

  → All Cp are considered at 50 K.

  → For composite material, the Cp value is, regardless of the mass ratio, this of the component which presents the lowest one.

  → The 96.9% NIDA lightening is considered for NIDA inertia evaluation.

- Minimise the thermal coupling in the PR thickness.

  → Though not taken into account for the inertia evaluation, all intermediate layers (glue, gelcoat …) are considered as insulating layers in the PR thickness.

→ All conductivity assumptions are pessimistic ones :

- $\lambda_{Al}$ is taken equal to 200 W/m.K in spite of Aluminium deposit probably high purity.
- $\lambda_{skin}$ (CFRP in thickness) is taken equal to the lowest value found in bibliography (which also corresponds to a standard Araldite resin conductivity).
- $\lambda_{NIDA}$ (CFRP in plane) is taken equal to the T300 one (much lower than the M60J one).

→ The 96.9% NIDA lightening is considered for the evaluation of the following couplings :

- Couplings through NIDA thickness.
- Couplings through "skin ↔ NIDA" glue and arbitrary contact.

Note : The model is built per surface unit.

### 6.3.1.2.2.2 Moon illumination evaluation

The incident flux on PR due to moon direct illumination is given here below :

| **PR Moon illumination** | Planck osa = 10° | Planck osa = 15° | Source |
|---|---|---|---|
| | $maa_{max}$ = 26° | $maa_{max}$ = 31° | |
| **Incident flux density on PR** | **0.13 mW/m²** | **0.18 mW/m²** | [RD**16**] |
| PR absorptance (wrt Moon radiation) | 2% | 2% | |
| ***PR absorbed flux density*** | ***2.6 µW/m²*** | ***3.6 µW/m²*** | |

For information :

| **PR Moon illumination** | Planck osa = 10° | Planck osa = 15° | Source |
|---|---|---|---|
| | $maa_{max}$ = 26° | $maa_{max}$ = 31° | |
| PR illuminated surface | 0.09 m² | 0.266 m² | [RD**16**] |
| Total PR absorbed flux | 0.23 µW | 0.96 µW | |

Note : The PR illuminated surfaces are evaluated in both cases without extended baffle. It can be noted that "osa10° (maa 26°) without extended baffle" and "osa15° (maa 31°) with extended baffle" lead to the same PR illuminated surface.

### 6.3.1.2.3 1D modelling approach results

Considering §6.3.1.2.1 assumptions, the computed PR active face temperature fluctuation is :

| *Period = 60s*<br>*No extended Baffle* | Planck osa = 10° | Planck osa = 15° |
|---|---|---|
| | $maa_{max}$ = 26° | $maa_{max}$ = 31° |
| PR temperature fluctuation | 0.2 µK | 0.3 µK |

**This amplitude is the max one seen by the PR illuminated surface** (and consequently by any area of PR active surface).

### 6.3.1.3 Overall PR active face temperature fluctuation

§6.3.1.2 has allowed to estimate fluctuation of the PR moon illuminated active face.

§6.3.1.3 is aimed at evaluating the temperature fluctuation on other areas of PR active face. As explained hereafter, the proposed method merely consists in applying, to the illuminated area temperature fluctuation, a damping factor depending of the considered surface inertia.

#### *6.3.1.3.1 Inertia damping*

The goal is to determinate the damping factor to be applied to $\Delta T_{PR}^0$ as a function of the considered surface (S). $\Delta T_{PR}^S$ will hence be all the more important as the considered surface S is small i.e. is close to the illuminated area ($S_{ill}$).

*Sizing approach* : The considered area is assumed as *thermally homogeneous*.

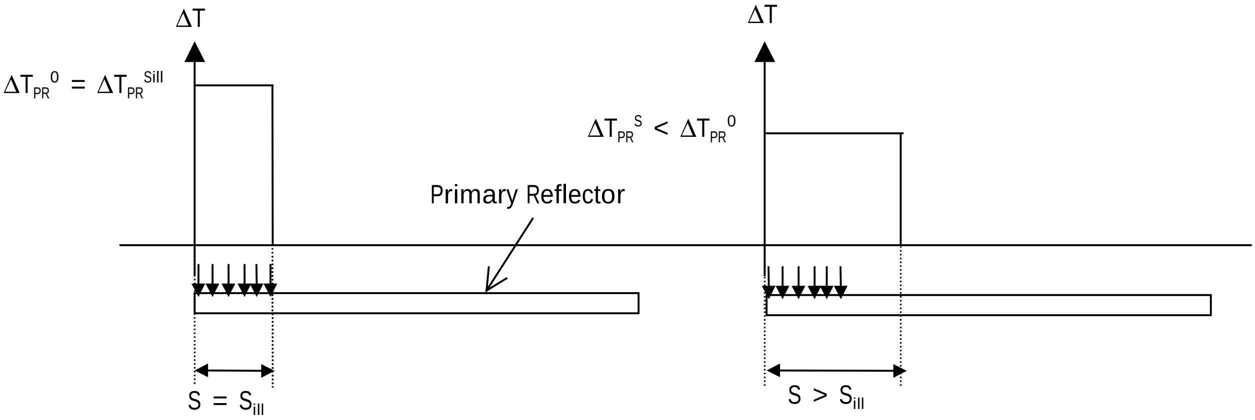


**Figure 6-28 : Inertia damping**

As shown by the 1D model results (see §4), the “Active face + skin” system is thermally homogeneous. This system (A) can the be defined by :

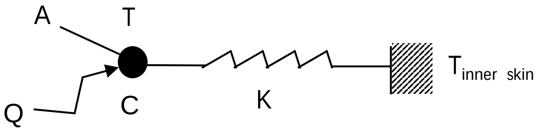


**Figure 6-29 : Modelling of the "active face + skin" system**

With :

- Q : Moon flux perturbation on (A).
- T : (A) temperature.
- C : (A) Thermal capacitance.
- K : Linear coupling with sink.

Notes :

- The radiative coupling between the PR active face and space is negligible when compared to its conductive coupling with the PR inner skin. The only considered linear coupling to a thermal sink is therefore the conductive coupling with the inner skin.
- K # 0.2 W/m².K (1D model).
- C # 90 J/K.m² (1D model).

The heat equation is : $Q + K\times(T_{\text{inner skin}} - T) = C\times dT/dt$

leading to : $\Delta T^2 = Q^2/(K^2 + C^2\times\omega^2)$

Besides, $C^2\times\omega^2 >> K^2$, so : $\Delta T \# Q/(C\times\omega)$

As a consequence, the temperature fluctuation seen by S can be extrapolated from the one seen by $S_{ill}$ through the simple formula :

$$\mathbf{\Delta T_{PR}^{S}} = \Delta T_{PR}^{Sill} \times S_{ill}/S \mathbf{= \Delta T_{PR}^{0} \times S_{ill}/S}$$

### 6.3.1.3.2 *“surface/position” correspondence*

The 0.09 m² and 0.266 m² surfaces correspond to the illuminated surfaces in both studied cases.

The thermal perturbation is assumed to propagate with a plane front. The surface to be taken into account for the inertia evaluation is therefore this of the mirror area “above” the considered point.

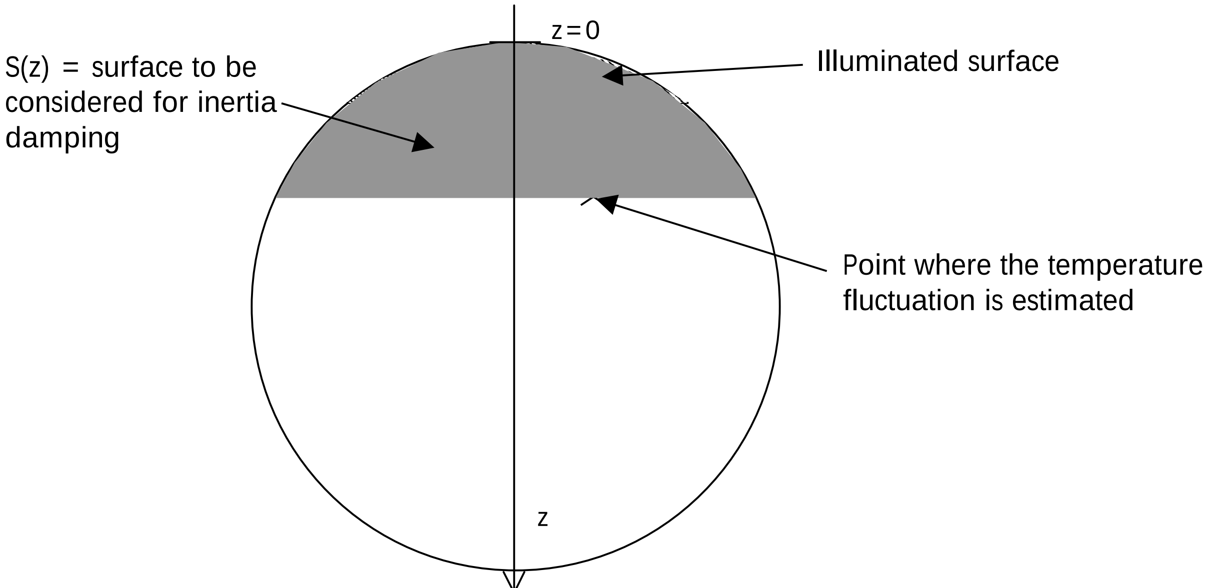


**Figure 6-30 : Correspondence : Inertia-surface / Position on PR**

The table hereafter shows the “surface/inertia” correspondence :

| z (mm) | S(z) (m²) |
|---|---|
| 188.68 | 0.125 |
| 377.36 | 0.342 |
| 566.04 | 0.604 |
| 754.72 | 0.893 |
| 943.39 | 1.194 |
| 1132.07 | 1.496 |
| 1320.75 | 1.786 |
| 1509.43 | 2.051 |
| 1698.11 | 2.272 |
| 1886.79 | 2.403 |

**Table 6.3-1 : Position / inertia correspondence for PR**

Note : The z values correspond to 10 points regularly distributed in the height.

### 6.3.1.4 PR active face temperature fluctuation results

#### *6.3.1.4.1 Typical assumptions*

##### *6.3.1.4.1.1 PR illuminated face temperature fluctuation*

Modelling assumptions, as presented in §6.3.1.2.2, lead to the following results for “osa 10° (maa 26°)” case :

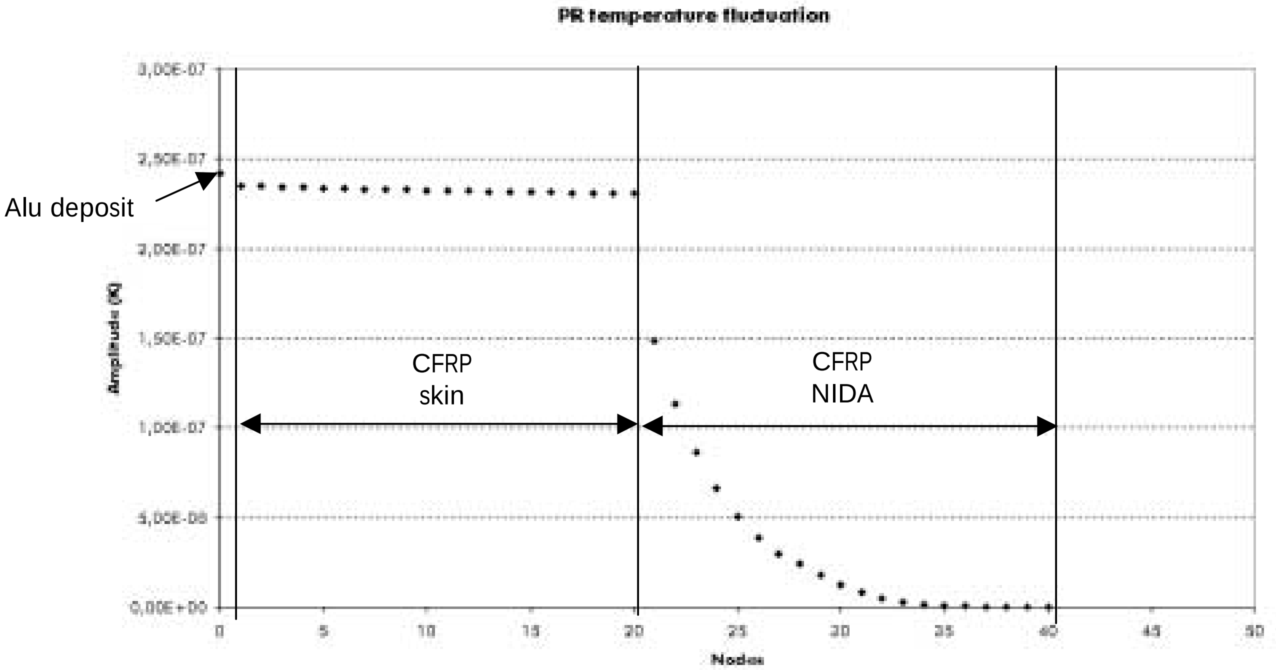


**Figure 6-31 : PR fluctuation / 1D model results / osa 10° (maa 26°)**

It is reminded that this temperature fluctuation is evaluated for the PR *illuminated face*.

<u>Note</u> : The boundary condition ($T_{inner\ skin}$ = fixed temperature) is confirmed by the results (fluctuation already negligible at node 35).

### *6.3.1.4.1.2 Effect of inertia damping*

The following curves show the damping of this fluctuation when the considered area is far from the illuminated surface.

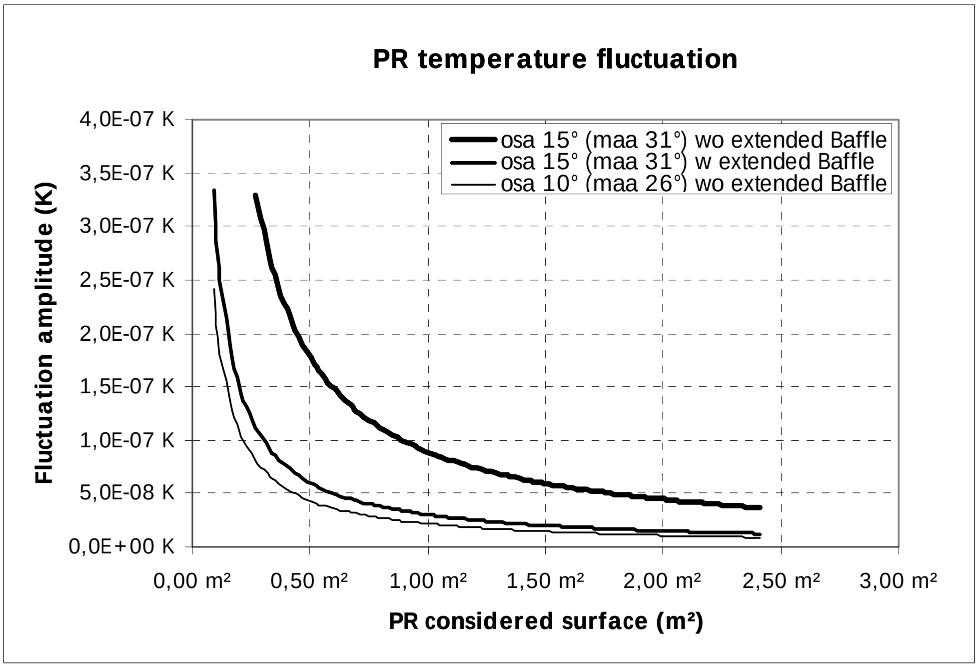


**Figure 6-32 : Inertia damping**
**Comparison of "osa 10° (maa 26°)" and "osa 15° (maa 31°)" cases**

### *6.3.1.4.2 Sensitivity analysis*

A sensitivity analysis is performed through the study of a degraded case defined as follows :

- All the parameters ($\lambda_{gc}$, $\lambda_{gl}$, $\lambda_{skin}$, $\lambda_{NIDA}$, $\lambda_{Al}$, $B_{af/s}$, $B_{s/N}$, $B_{N/s}$, $Cp_{Al}$, $Cp_{skin}$, $Cp_{NIDA}$) are divided by a factor 2 (insulation of active face and reduction of thermal inertia).
- Moon illumination amplitude multiplied by a factor 2.

### *6.3.1.4.2.1 PR illuminated face temperature fluctuation*

The modelling assumptions lead to the following results for "osa 10° (maa 26°)" case :

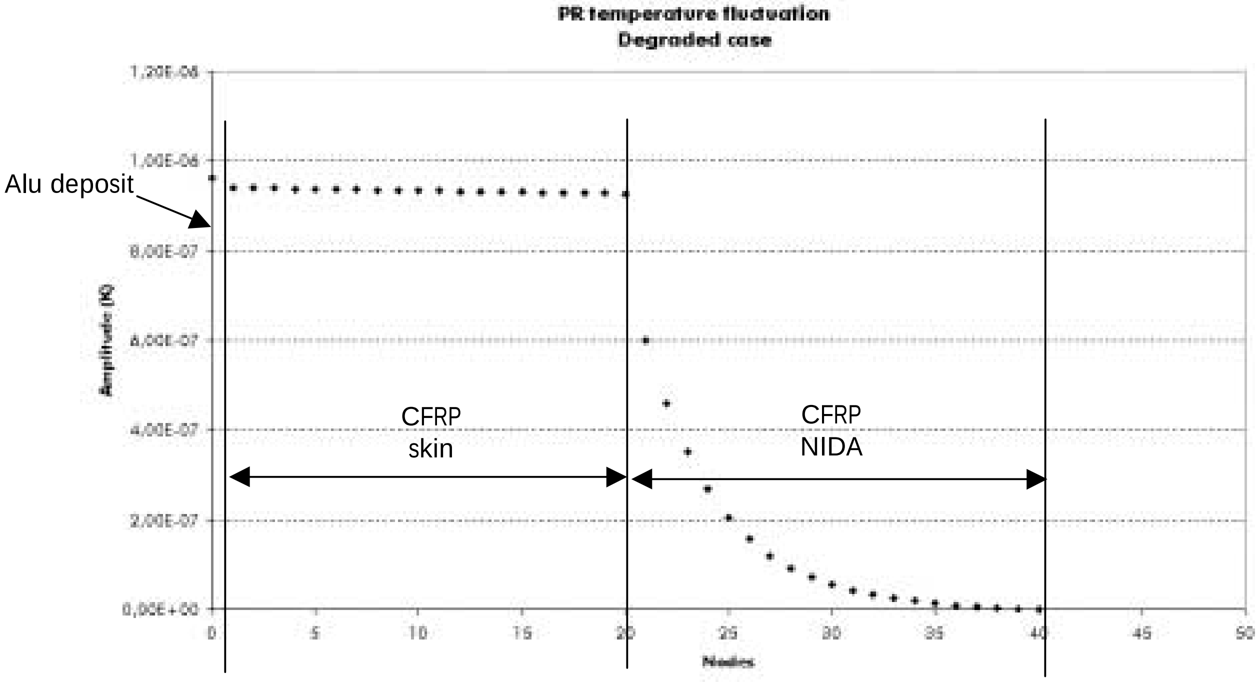


**Figure 6-33 : PR fluctuation / 1D model results / Degraded Case / osa 10° (maa 26°)**

#### *6.3.1.4.2.2 Effect of inertia damping*

The following curves show the damping of this fluctuation when the considered area is far from the illuminated surface.

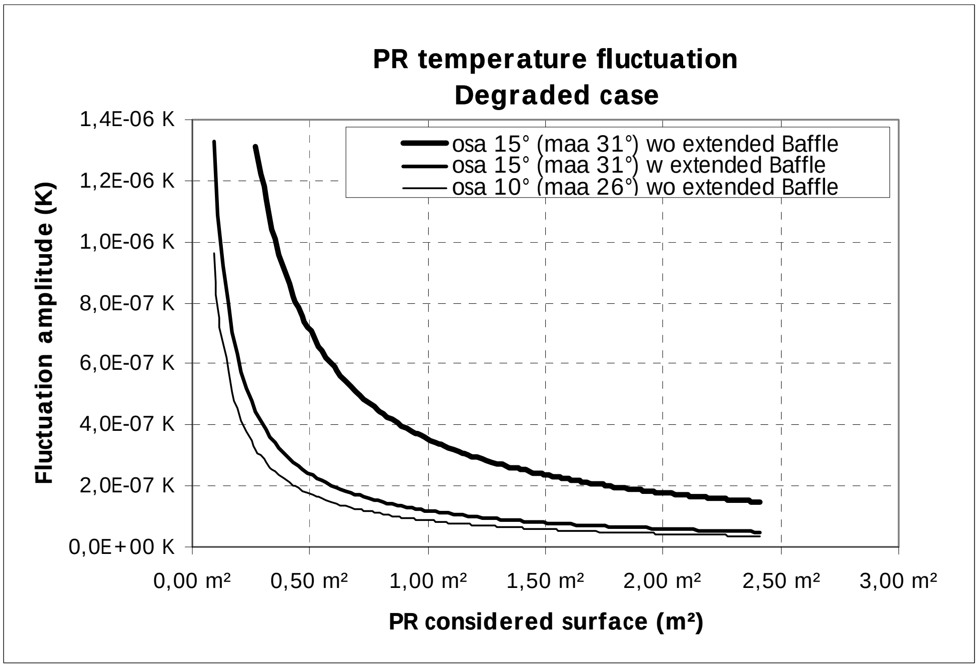


**Figure 6-34 : Inertia damping / Degraded case**
**Comparison of "osa 10° (maa 26°)" and "osa 15° (maa 31°)" cases**

### 6.3.1.5 Conclusion

Though performed through a rather simple modelling approach, the analyses allow to assess a max PR temperature fluctuation (due to Moon direct illumination) according to the considered PR area.

Indeed, considering :

- the realistic but nevertheless sizing typical assumptions,
- the results of the sensitivity analyses and the so-defined degraded case,

the max PR active face temperature fluctuation, due to direct Moon illumination, is, for all cases (osa 10°, 15° with or without extended Baffle) :

| ***Period 60 s*** | osa 10° wo ext. baffle | osa 15° wo ext. baffle | osa 15° w ext. baffle |
|---|---|---|---|
| Illuminated area | # 1 µK | # 1.3 µK | # 1.3 µK |
| Central area | # 0.1 µK | # 0.4 µK | # 0.1 µK |

The table hereafter shows, for the "osa 15° w ext. baffle" case, the fluctuation amplitude following z :

| ***osa 15°*** | z (m) | ΔT (µK) |
|---|---|---|
| Illuminated area | 0 | 1.33 |
| Circular outer part | 188.68 | 1.09 |
| | 377.36 | 0.36 |
| | 566.04 | 0.20 |
| Circular central part | 754.72 | 0.13 |
| | 943.39 | 0.10 |
| | 1132.07 | 0.08 |
| | 1320.75 | 0.07 |
| Circular outer part | 1509.43 | 0.06 |
| | 1698.11 | 0.05 |
| | 1886.79 | 0.05 |

**Table 6.3-2 : PR temperature fluctuation following position / osa 15° (maa 31°) w ext. baffle**

## *6.3.2 Thermal fluctuations of the Baffle*

### 6.3.2.1 Introduction

This paragraph is intended to present the results achieved about the baffle temperature fluctuation when submitted to direct Moon illumination.

The same approach as used for the PR has been applied to the baffle stability study; a 1D model of baffle thickness has been created. However, the baffle temperature fluctuation being a less sensitive parameter regarding straylight analysis, no inertia damping was applied to the 1D model results.

Note that the hence computed fluctuations should strictly concern only the back sides of illuminated areas. Allocating these fluctuations to the whole Baffle internal surface is a largely sizing assumption.

### 6.3.2.2 Baffle 1D modelling

#### *6.3.2.2.1 Baffle design*

The description of the baffle is given hereafter :

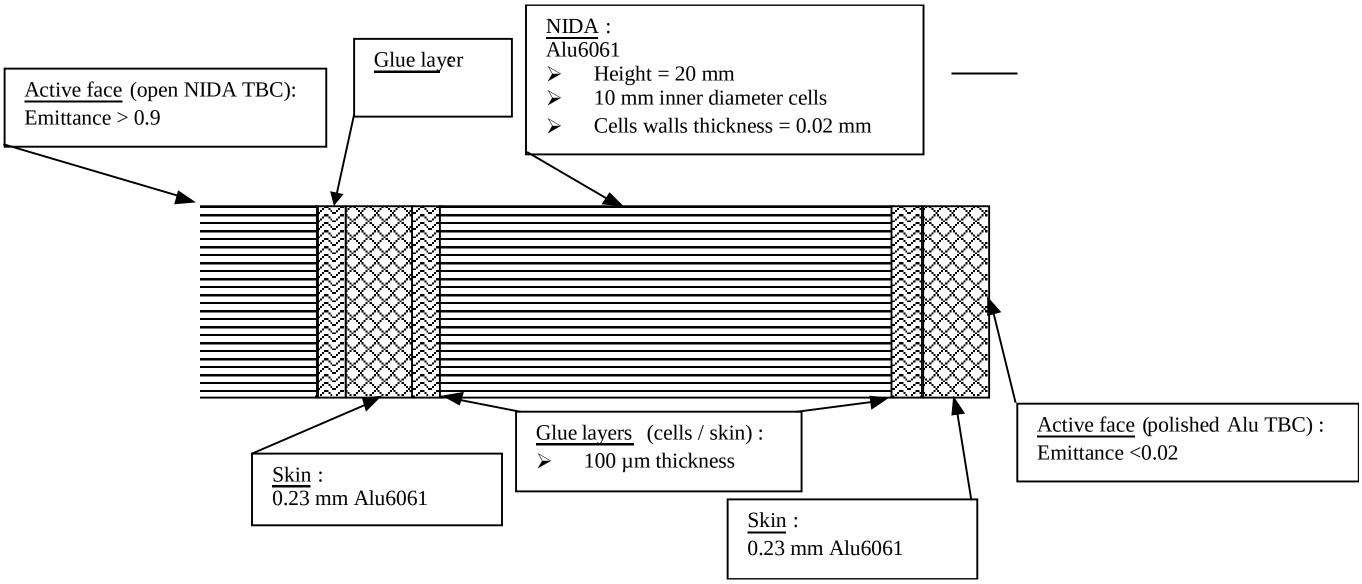


**Figure 6-35 : Baffle thickness description**

#### *6.3.2.2.2 Baffle modelling*

The 1D baffle modelling of the presented design is shown in Figure 6-36.

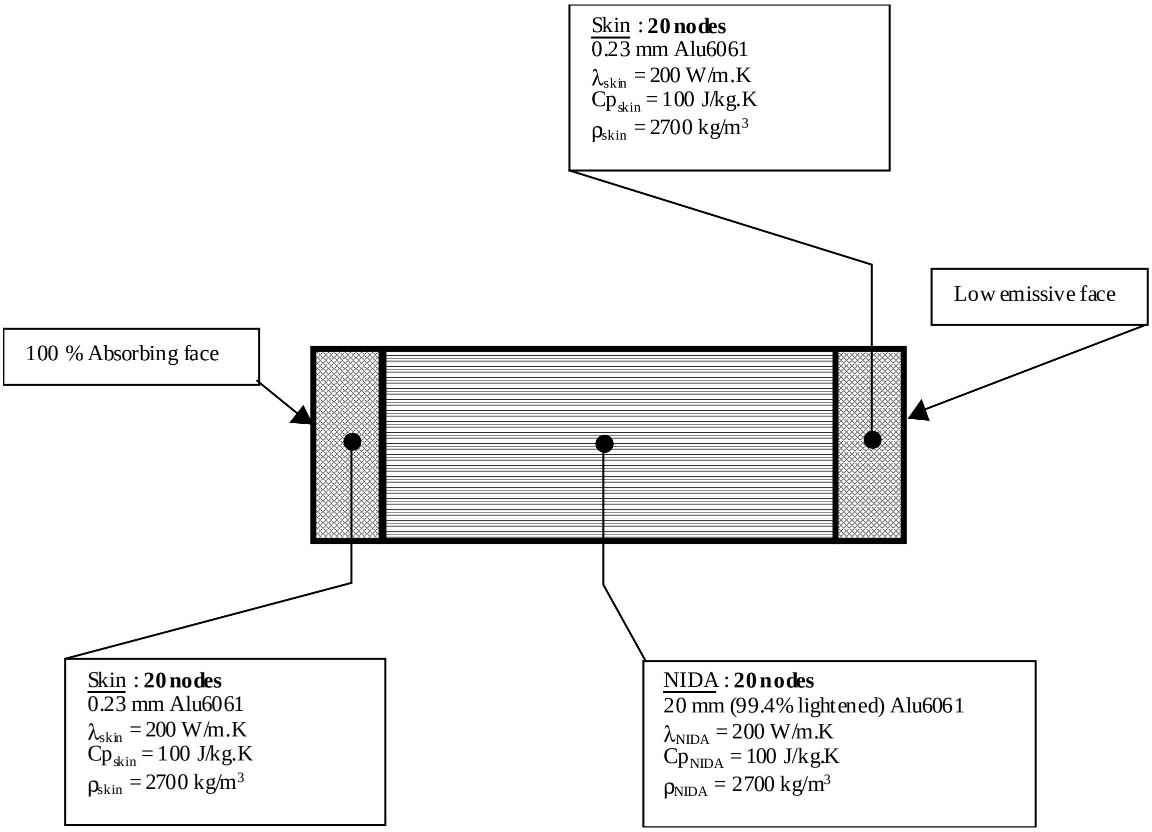


**Figure 6-36 : Baffle modelling**

### *6.3.2.2.2.1 Physical parameters assumptions*

All assumptions are made in order to :

- Minimise the thermal inertia of different parts.
  - → Inertia of open NIDA or paint are neglected.
  - → Glue mass is neglected for the skins inertia estimation.
  - → All Cp are considered at 50 K.
- Maximise the thermal coupling in the baffle thickness.
  - → All conductivity assumptions are optimistic ones :
  - → $\lambda_{Al}$ is taken equal to 200 W/m.K
  - → No interfaces taken into account between skins and NIDA core.
  - → The two skins are directly coupled to each other by a radiative coupling ($\varepsilon = 1$ on each face).

Note :

The model is built per surface unit.

### *6.3.2.2.2.2 Moon illumination evaluation*

The incident flux on baffle due to moon direct illumination is the same as for the PR :

| ***Baffle Moon illumination*** | Planck osa = 10° | Planck osa = 15° | Source |
|---|---|---|---|
| | maa$_{max}$ = 26° | maa$_{max}$ = 31° | |
| **Incident flux density on baffle** | **0.13 mW/m²** | **0.18 mW/m²** | [RD**16**] |
| Baffle absorptance (wrt Moon radiation) | 100% | 100% | |
| ***Baffle absorbed flux density*** | ***0.13 mW/m²*** | ***0.18 mW/m²*** | |

his amplitude is injected to the Baffle as a 60s-period sinusoidal signal. This assumption is clearly pessimistic. Indeed, contrarily to the PR, the Baffle moon illumination should remain quite continuous, the only residual input flux fluctuation resulting from the Baffle being non-symmetrical around X axis.

## 6.3.2.3 Baffle internal face temperature fluctuation results

### *6.3.2.3.1 Typical assumptions*

Modelling assumptions, as presented in §6.3.2.2.2, lead to the following results :

| ***Typical case Period 60s*** | Planck osa = 10° | Planck osa = 15° |
|---|---|---|
| | maa$_{max}$ = 26° | maa$_{max}$ = 31° |
| **Internal face fluctuation** | **8 µK** | **11.2 µK** |

**This amplitude is the max one potentially seen by the Baffle internal surface**.

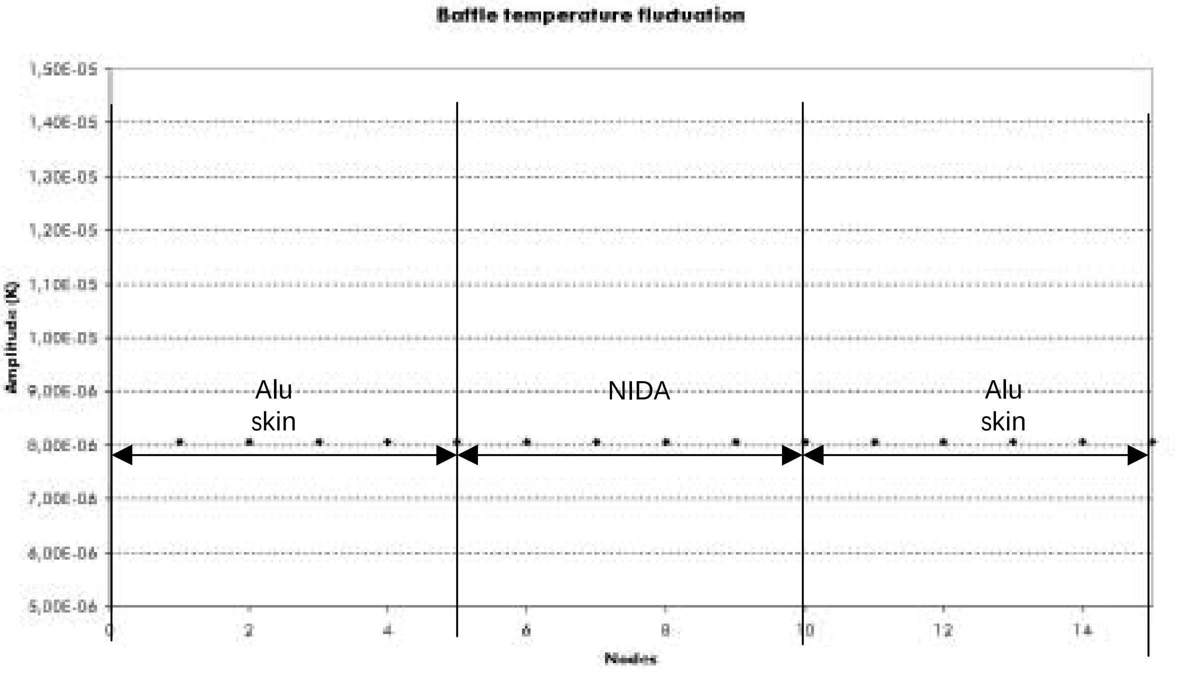


**Figure 6-37 : Baffle fluctuation / 1D model results / osa 10° (maa 26°)**

#### *6.3.2.3.2 Sensitivity analysis*

A sensitivity analysis is performed through the study of degraded case defined as follows :

- The parameters ($\lambda_{skin}$, $\lambda_{NIDA}$) are multiplied by a factor 1.5 (coupling of perturbation absorbing face and internal face).
- The parameters ($Cp_{skin}$, $Cp_{NIDA}$) are divided by a factor 2.
- Moon illumination amplitude multiplied by a factor 2.

These assumptions lead to the following results :

| ***Degraded case Period 60s*** | Planck osa = 10° | Planck osa = 15° |
|---|---|---|
| | $maa_{max}$ = 26° | $maa_{max}$ = 31° |
| **Internal face fluctuation** | **21 µK** | **29 µK** |

**This amplitude is the max one potentially seen by the Baffle internal surface**.

### 6.3.2.4 Conclusion

Though performed through a rather simple modelling approach, the analyses allow to assess a max baffle internal face temperature fluctuation (due to Moon illumination).

Indeed, considering :
- the realistic but nevertheless sizing typical assumptions,
- the results of the sensitivity analyses and the so-defined degraded case,

the max baffle internal face temperature fluctuation, due to direct Moon illumination, is :

# **20 µK** for “osa 10° (maa 26°)” case
# **30 µK** for “osa 15° (maa 31°)” case

## 6.4 Overall synthesis on thermal fluctuation study

### *6.4.1 Temporal expression of thermal fluctuations*

The results are synthetically presented in the Table 6.4-1.

| ***PPLM thermal stability study results*** | Perturbation source | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | SVM | | Sorption Cooler JPL 1999 data | | Sorption Cooler JPL 2002 data | | Moon illumination | |
| | Amplitude | Period | Amplitude | Period | Amplitude | Period | Amplitude | Period |
| Shield 3 internal | negligible | - | 2130 µK | 667 s | 7880 µK<br>4088 µK | # 4000 s<br># 667 s | - | - |
| Shield 3 external | negligible | - | 110 µK | 667 s | 1200 µK<br># 100 µK | # 4000 s<br># 667 s | - | - |
| Sec. Reflector | negligible | - | 0.01 µK [3] | 667 s | # 0.4 µK<br>negligible | # 4000 s<br># 667 s | - | - |
| Prim. Reflector | negligible | - | 0.01 µK [3] | 667 s | # 0.2 µK<br>negligible | # 4000 s<br># 667 s | 0.1 µK [1] | 60 s |
| Baffle internal | negligible | - | 30 µK | 667 s | 400 µK<br># 30 µK | # 4000 s<br># 667 s | 30 µK [2] | 60 s |

**Table 6.4-1 : PPLM thermal fluctuations overall synthesis**

Notes :

[1] ⇒ Value for PR central areas and corresponding to a " osa 15° (maa 26°) w ext. baffle ". See §6.3.1.4 for details. This value takes into account margin as explained in §6.3.1.4.2.

[2] ⇒ Value corresponding to a "osa 15° (maa 26°)" case. This value takes into account margin as explained in §6.3.2.3.2.

[3] ⇒ Values extrapolated from case with amplified perturbation (see §6.2.2.1.2).

### *6.4.2 Spectral expression of temporal fluctuations*

The temporal fluctuations are processed through a Fourier transform operation.

The comparison of temporal results obtained with JPL 2002 or 1999 data points out the JPL 2002 fluctuation profile as a worst case. As far as Sorption Cooler perturbation is concerned, only results in line with JPL 2002 data are therefore presented hereafter.

The Table 6.4-2 presents for each straylight sensitive element, the computed amplitude corresponding to 1/60 Hz, as well as the max specified value at this frequency.

| ***PPLM thermal stability*** | | Computed max amplitude at 1/60 Hz (µK) | Requirements (µK) |
|---|---|---|---|
| Primary Reflector | Circular central part | 0.2 [1] | 1 |
| | Moon illuminated part | 1.3 [1] | 15 |
| | Circular outer part | 1.1 [1] | 3 |
| Secondary Reflector | | << 0.1 | 1 |
| Baffle | | 30 [1] | 100 |
| Shield 3 (internal) | | 4.7 | 100 |
| Shield 3 (external) | | 1.3 | 13 |

**Table 6.4-2 : Temperature fluctuation / Comparison with specification**

[1] includes fluctuations due to Moon illumination, SVM and Sorption Cooler perturbations

All stability requirements are met.

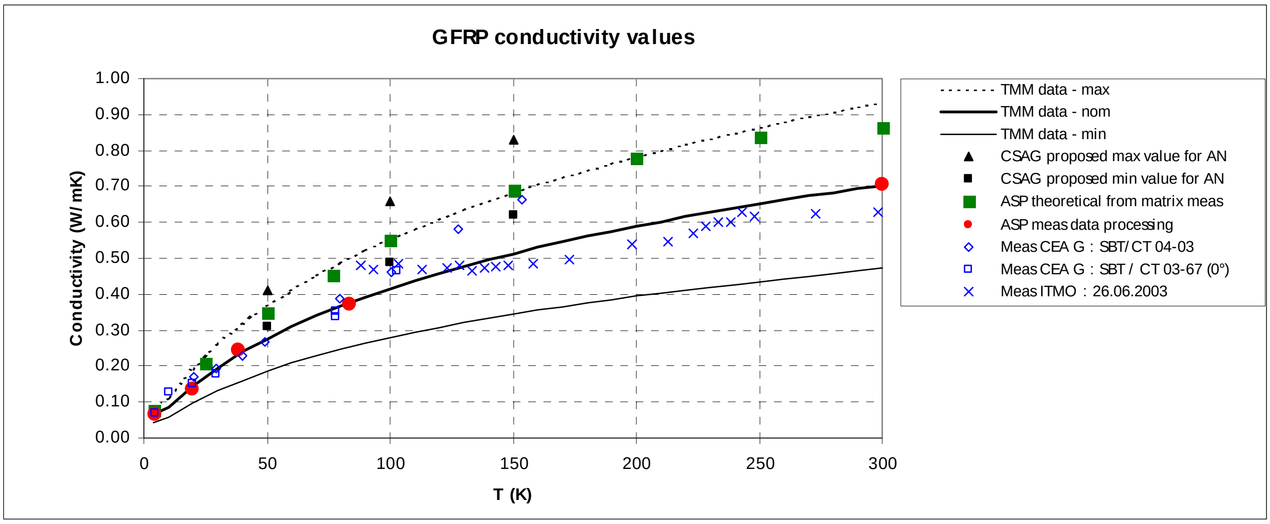
# APPENDIX

# APPENDIX 1

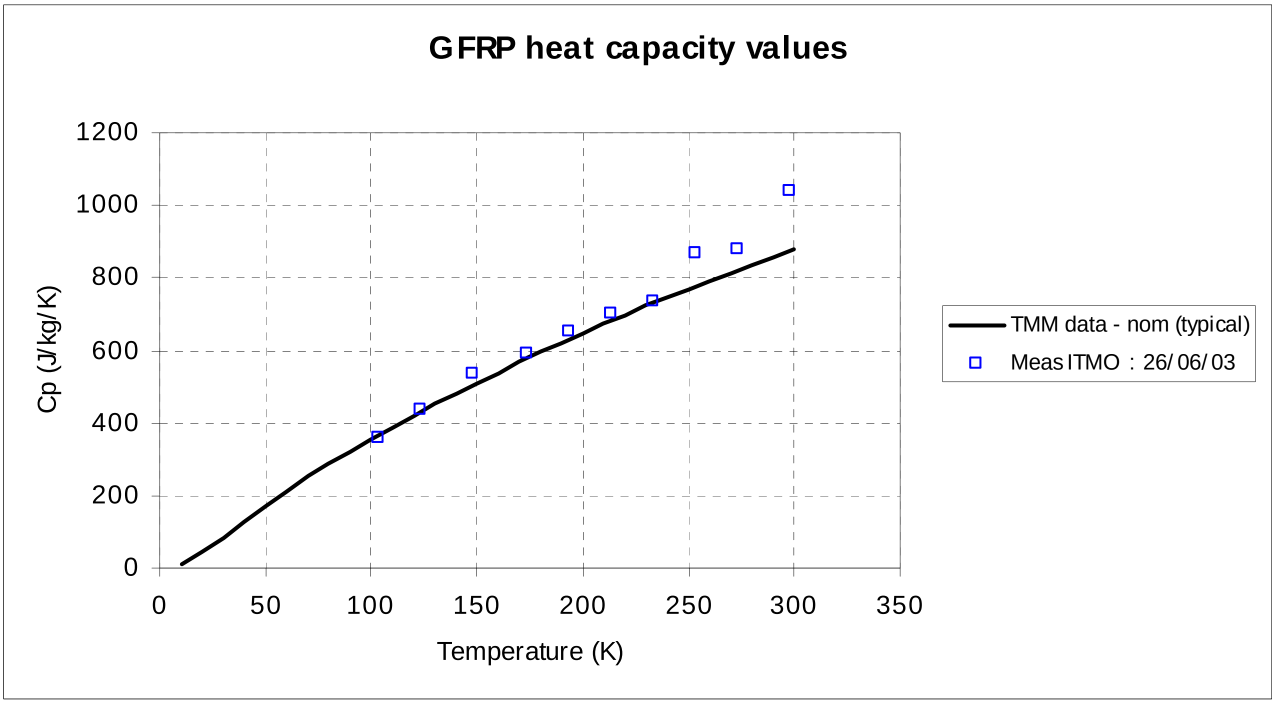
## MATERIALS PROPERTIES : CONDUCTIVITY AND HEAT CAPACITY VALUES

## GFRP

⇒ Cryo-Struts, bracing …

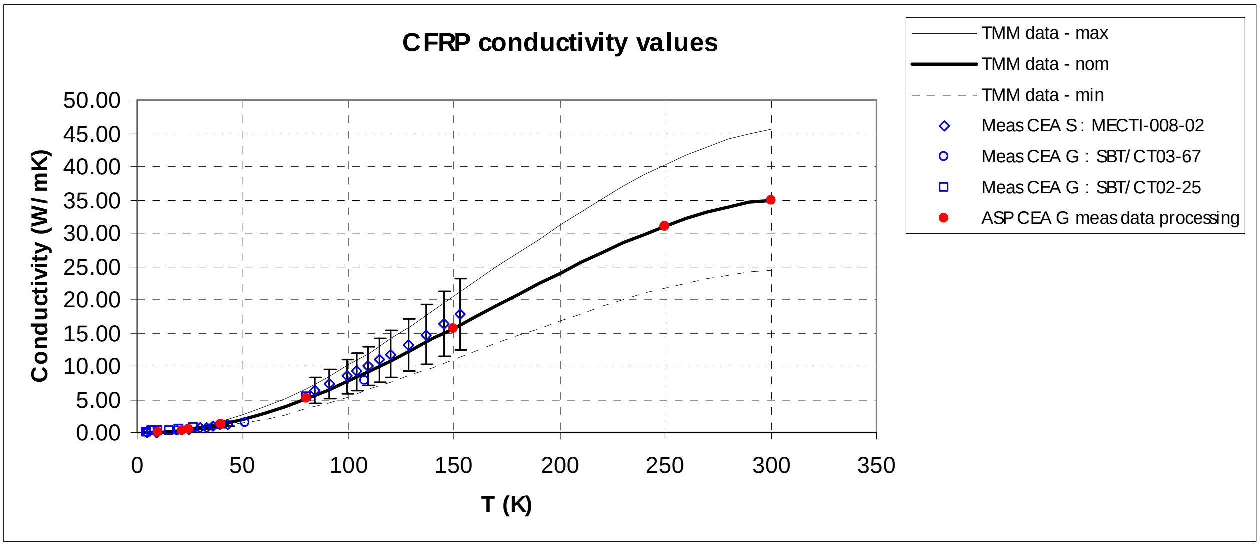


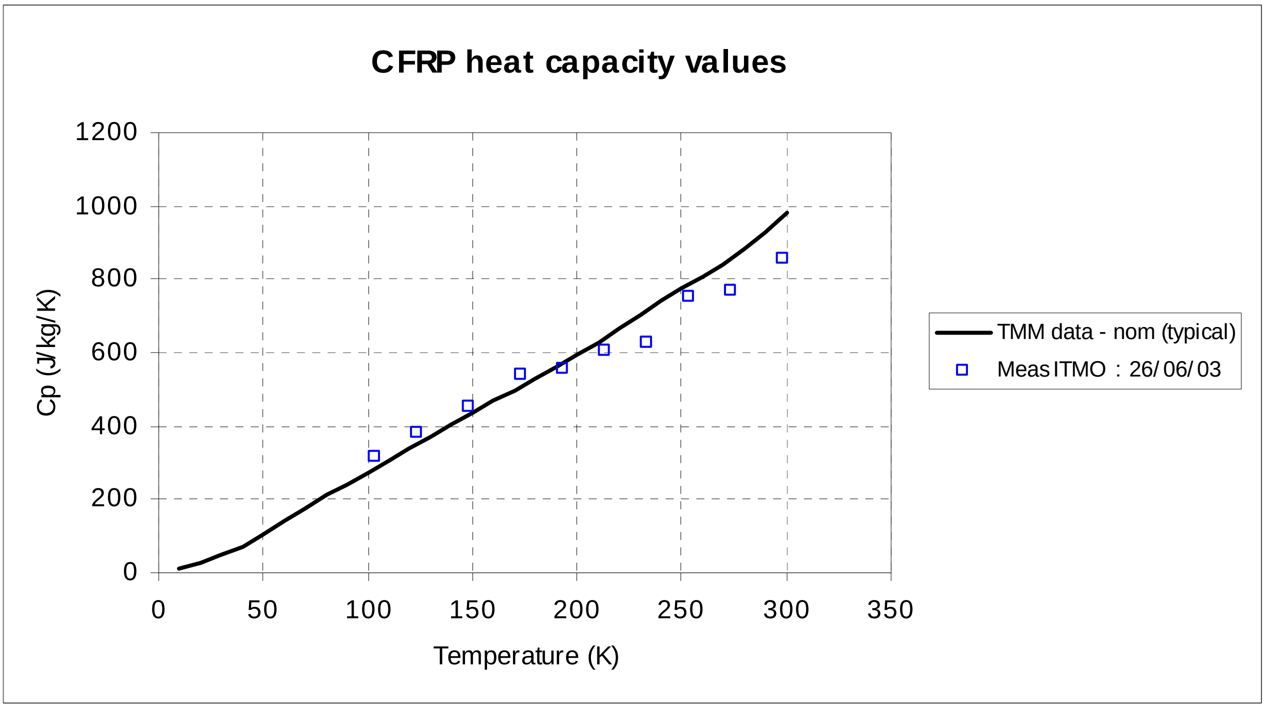
CSAG proposed data out of date.



## CFRP

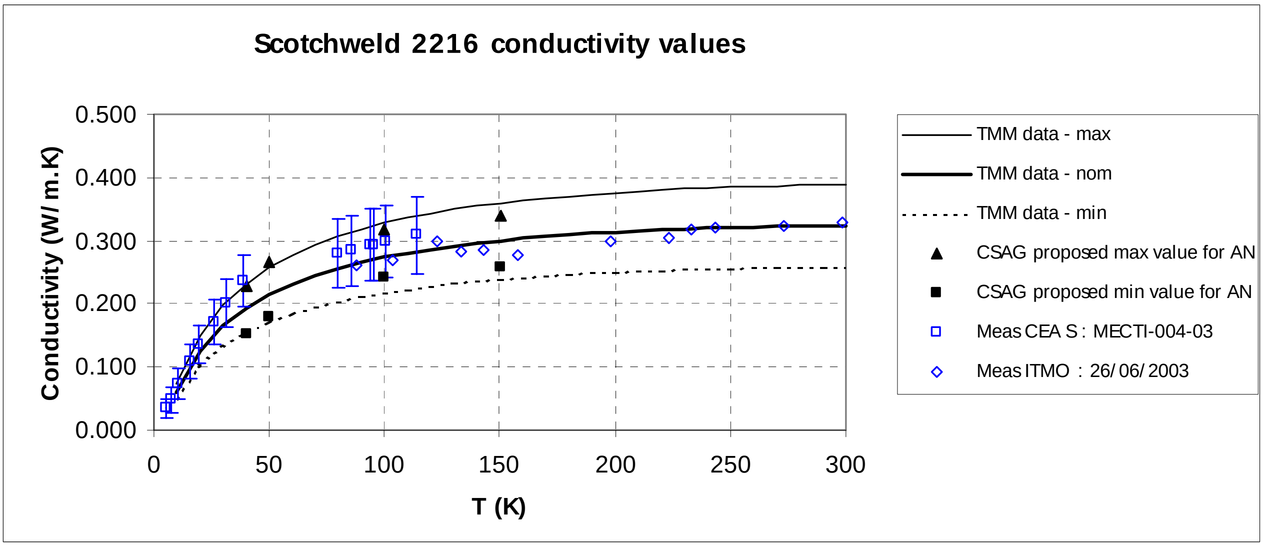
⇒ Telescope sandwich facesheets

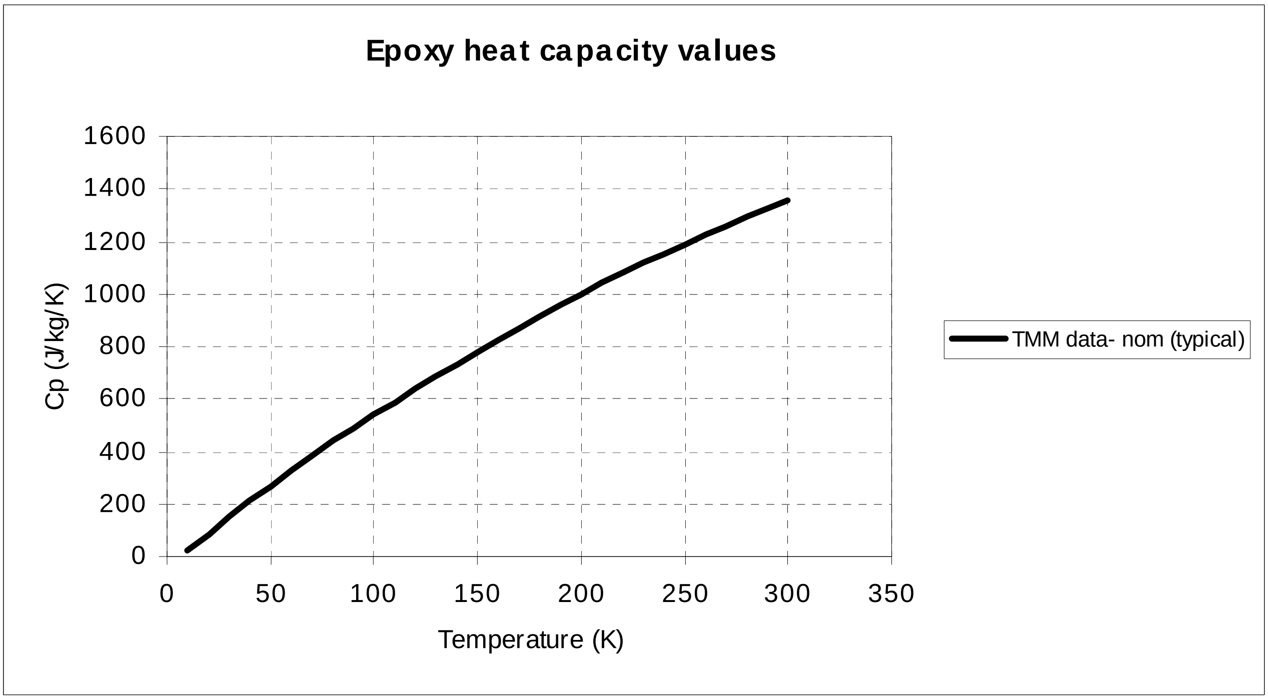




## Scotchweld 2216

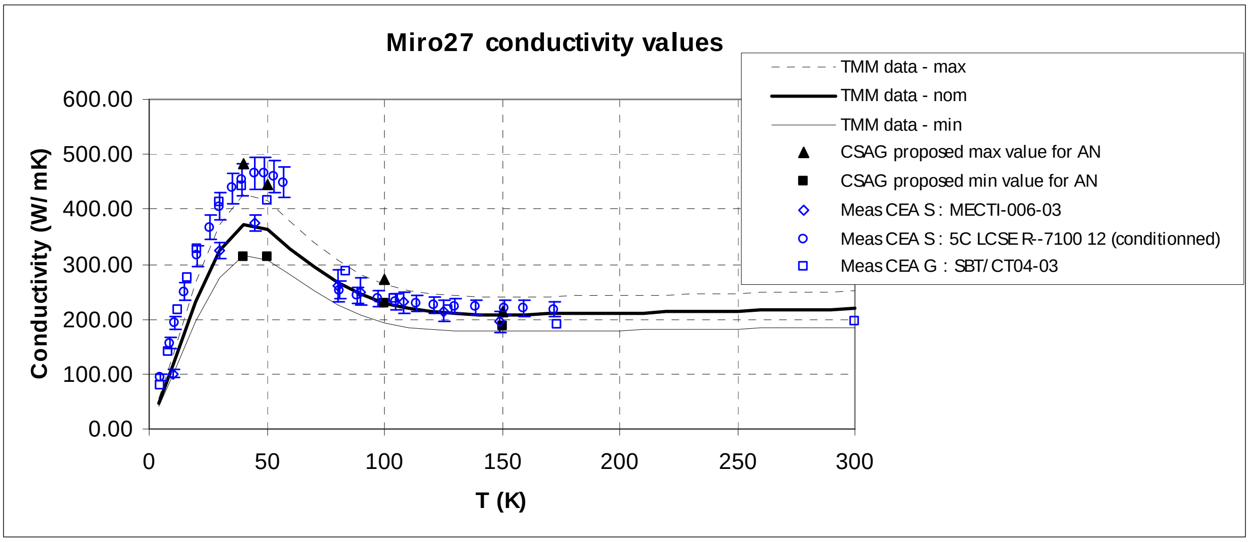
⇒ Elements interfacing (struts blades, braids …)

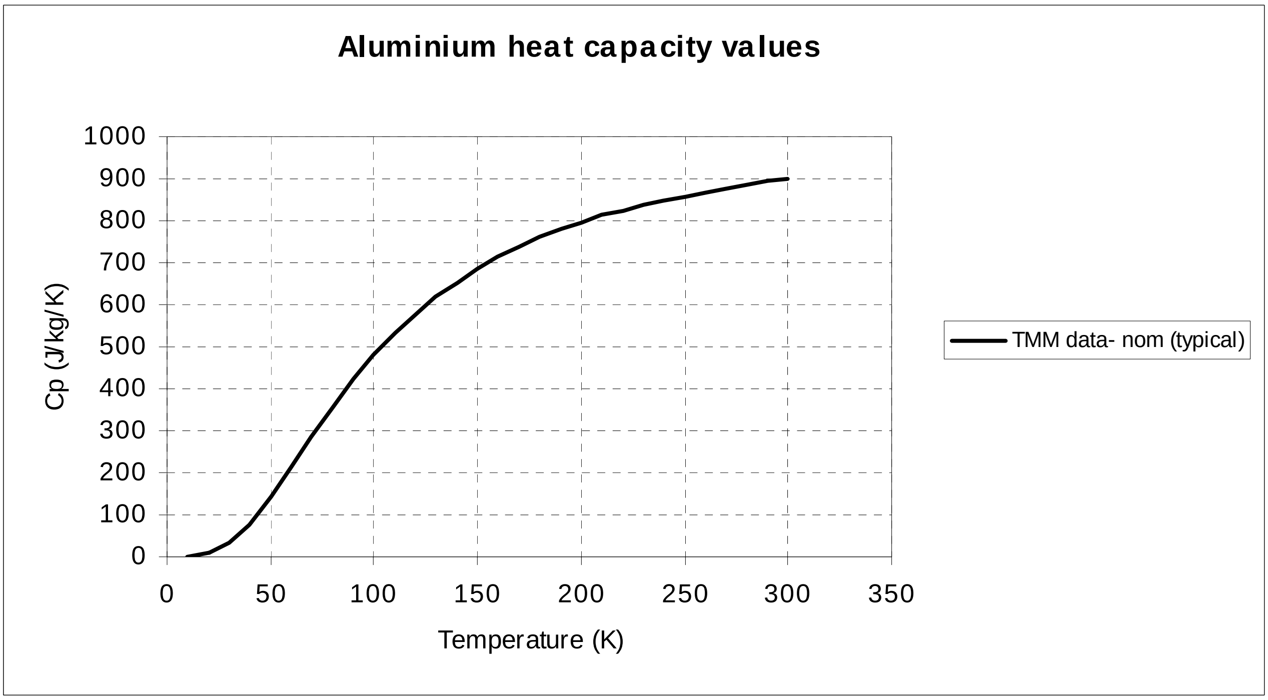




## Miro27

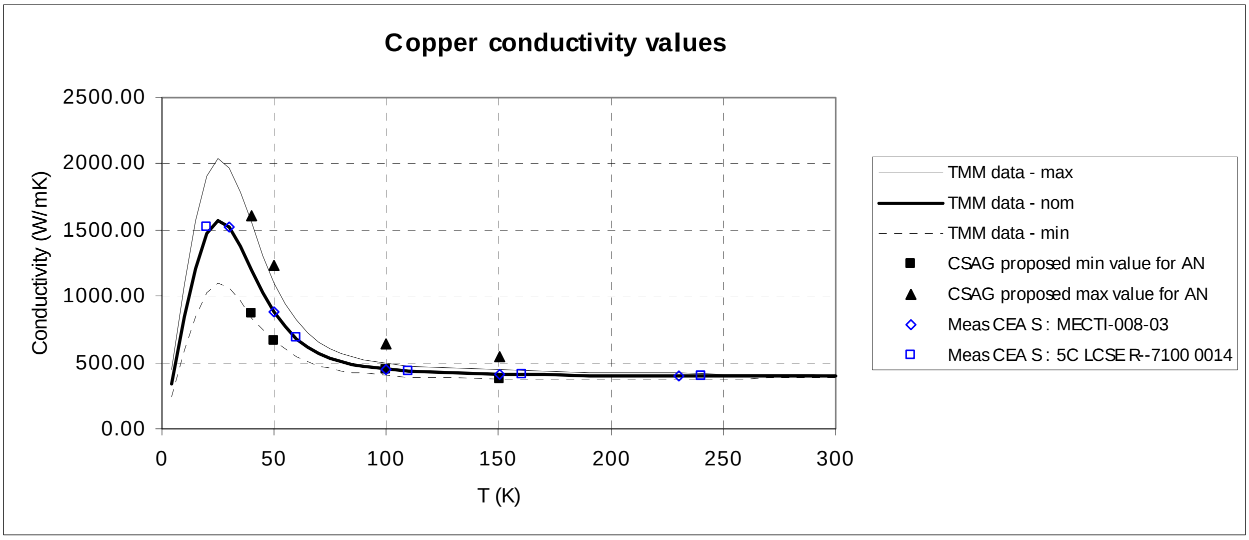
⇒ Shields1&2&3 and Baffle sandwich facesheets

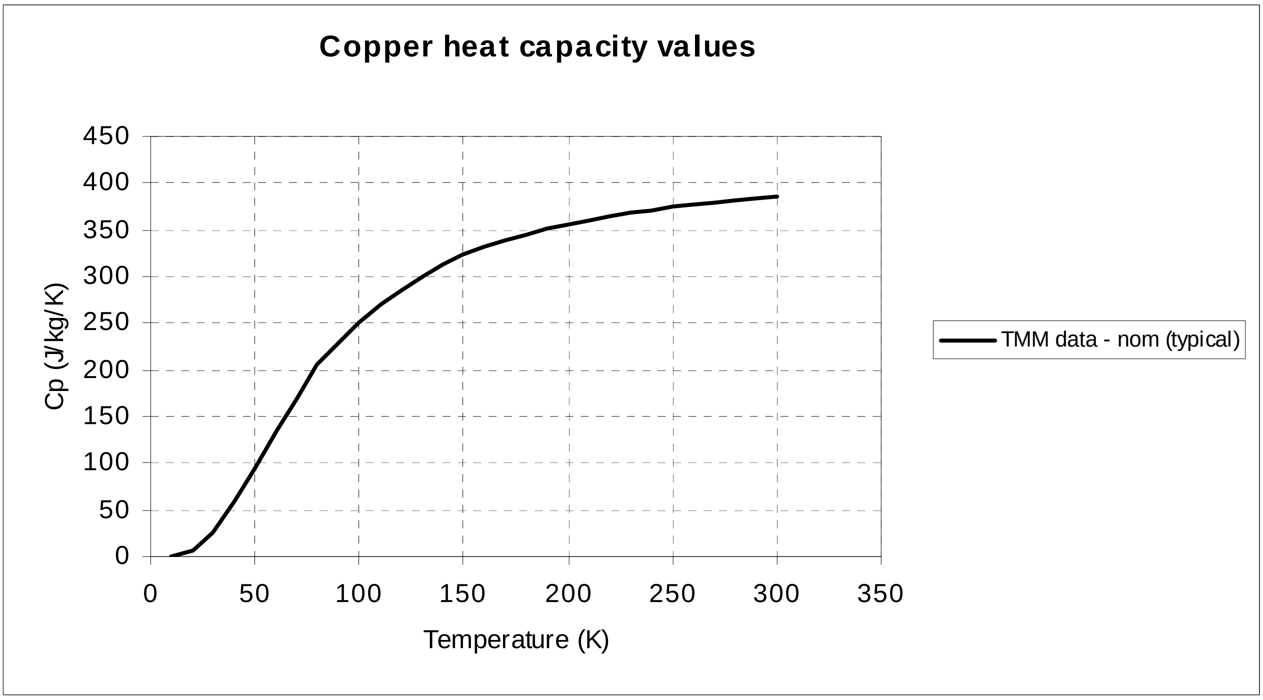




## Copper

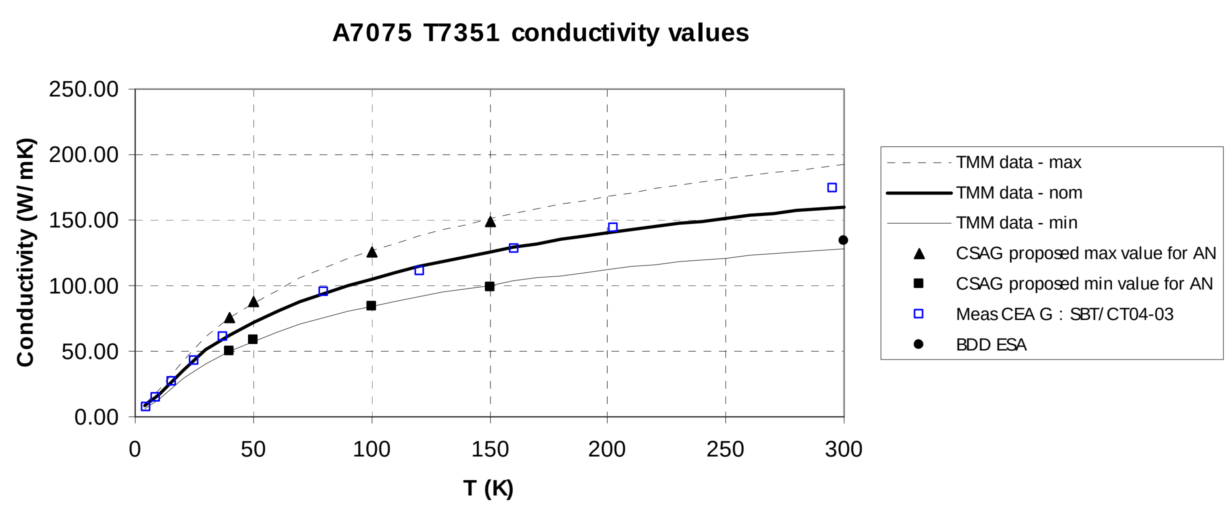
⇒ Thermal braids





## AA7075

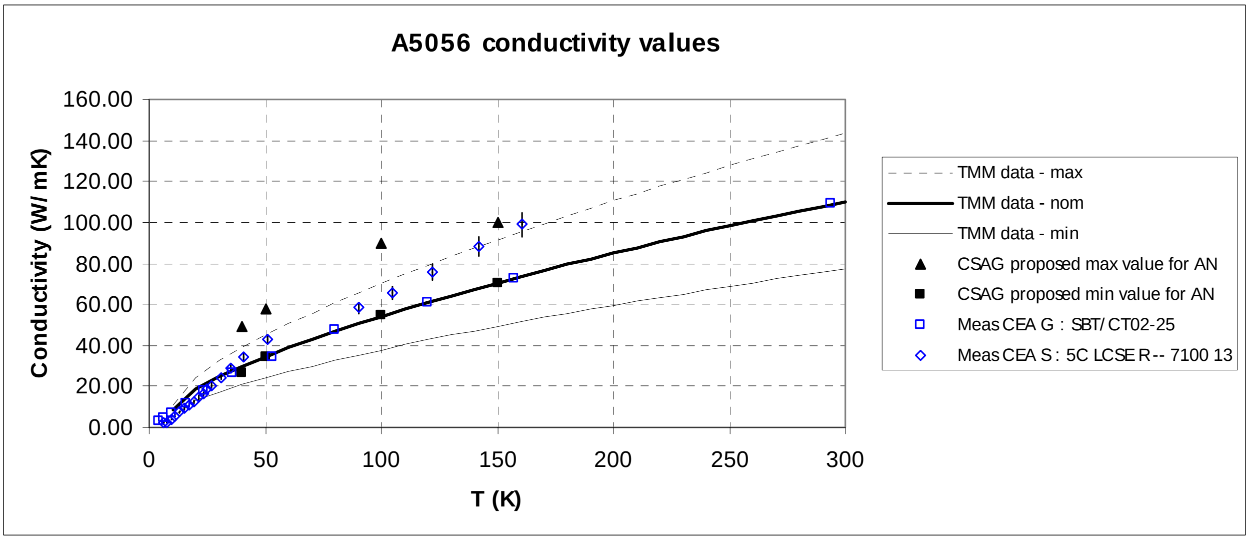
⇒ Struts collars and blades



➥ Same heat capacity values as for Miro27.

## AA5056

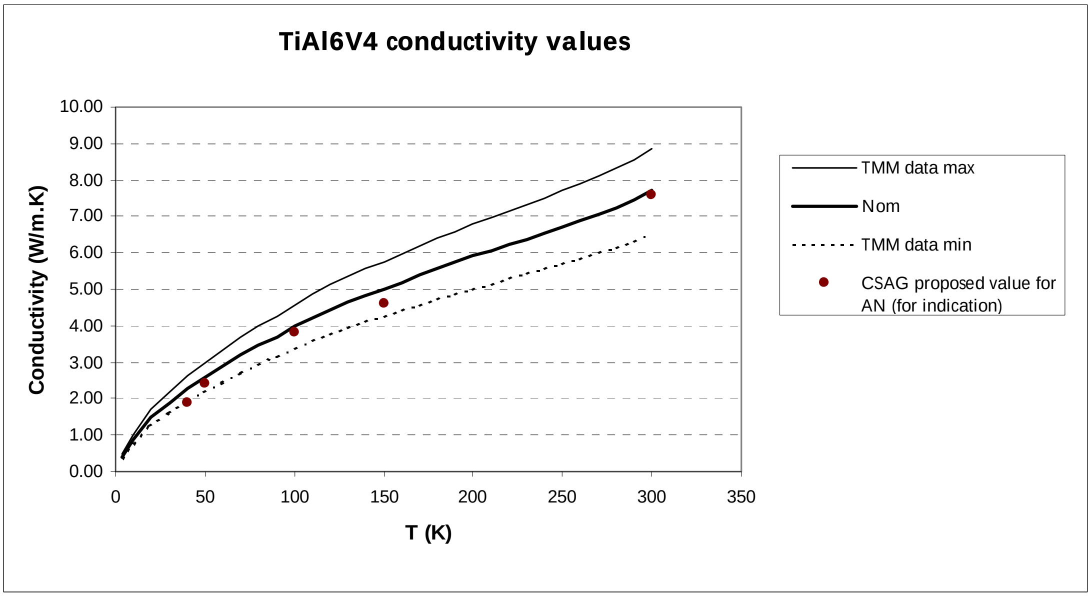
⇒ All sandwich cores

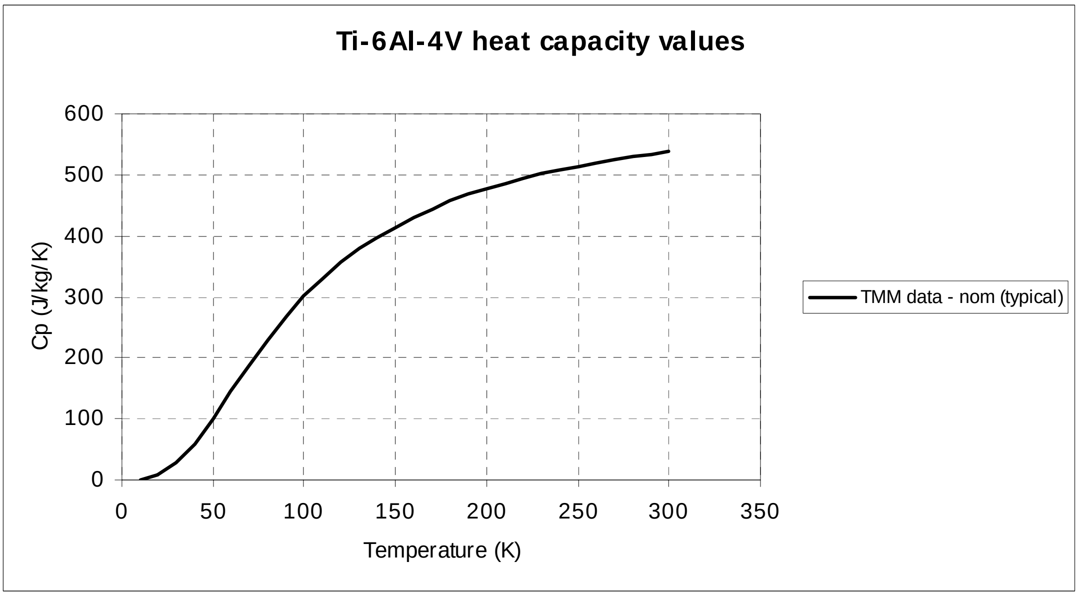


➥ Same heat capacity values as for Miro27.

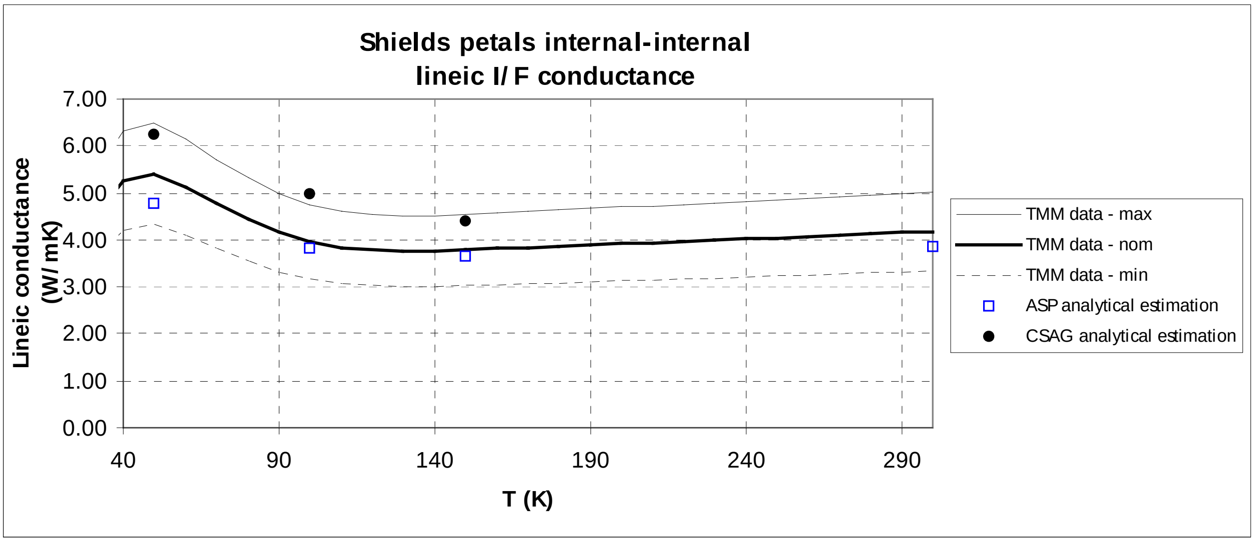
## Titanium

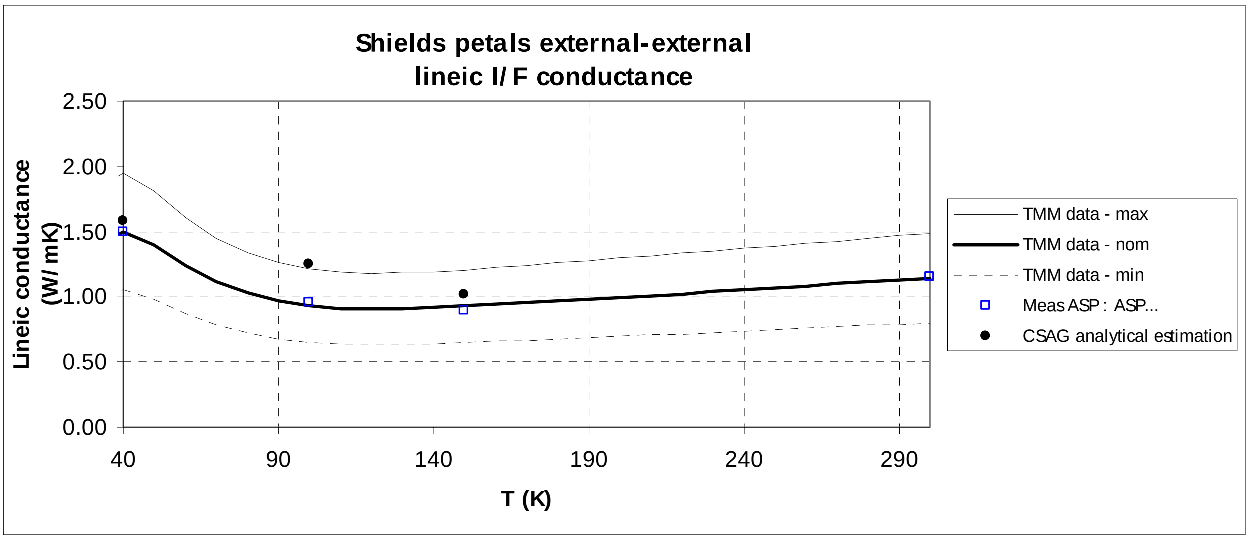
⇒ Telescope and struts brackets

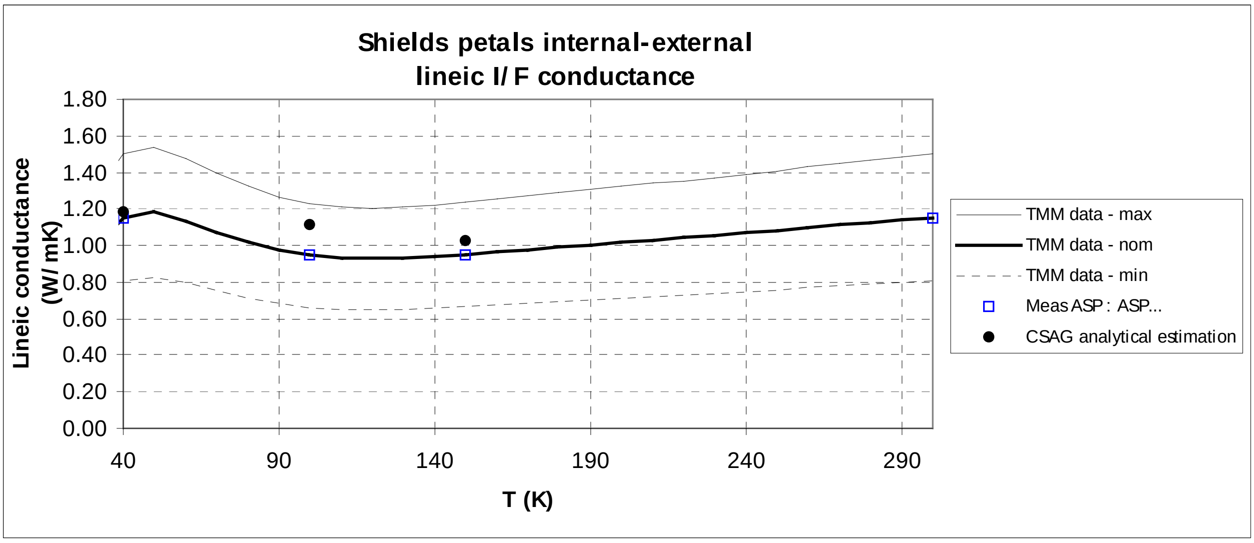


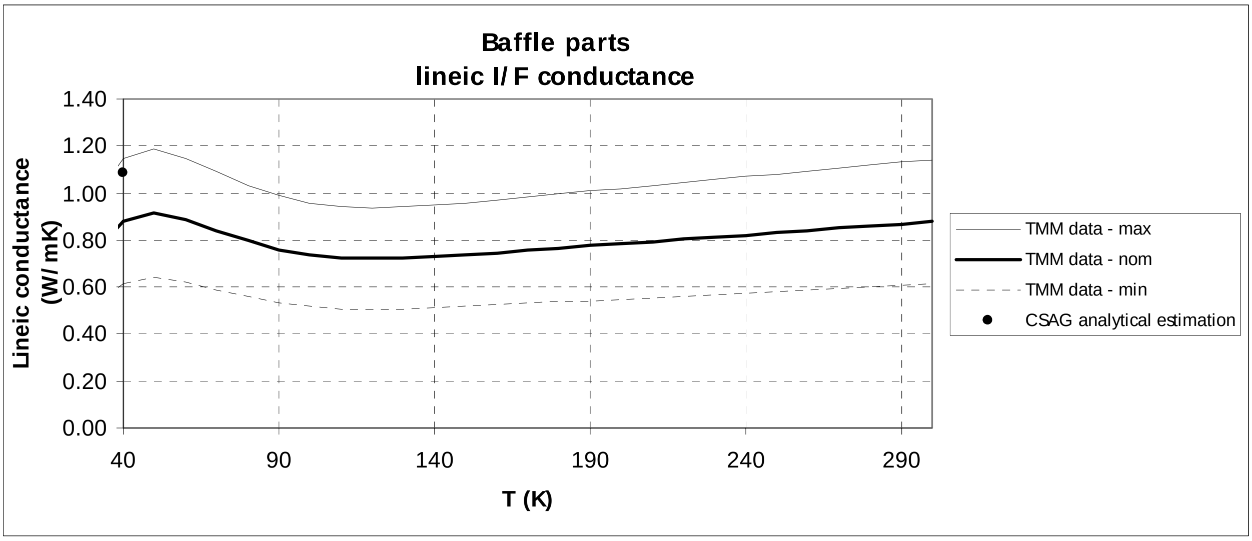


## Shields petals inter-conductance








Baffle parts
lineic I/F conductance
Lineic conductance (W/mK)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
40
90
140
190
240
290
T (K)
TMM data - max
TMM data - nom
TMM data - min
CSAG analytical estimation

# APPENDIX 2

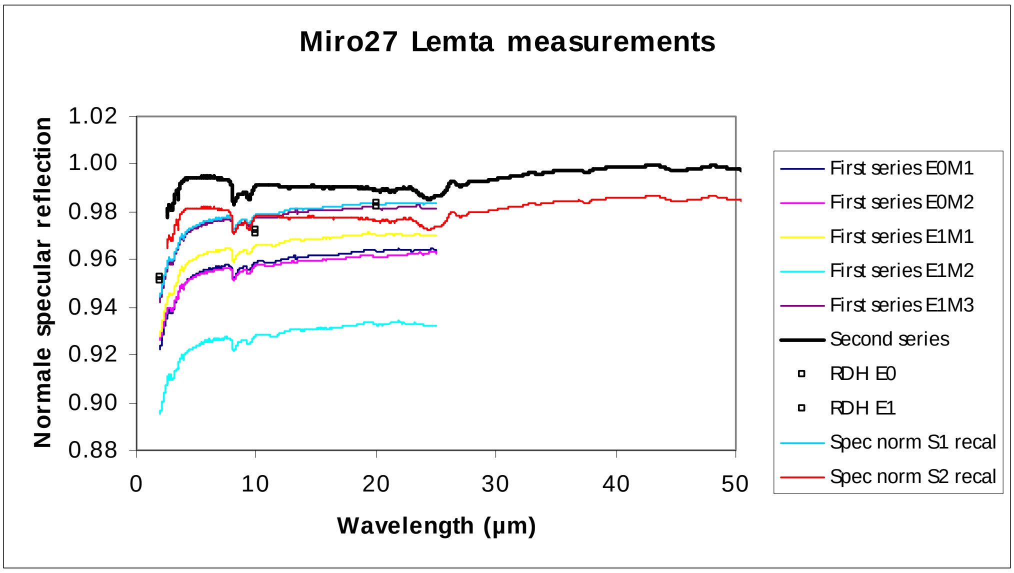
## MATERIALS PROPERTIES : THERMO-OPTICAL PROPERTIES

## LEC

EADS measurement (calorimetric method) :

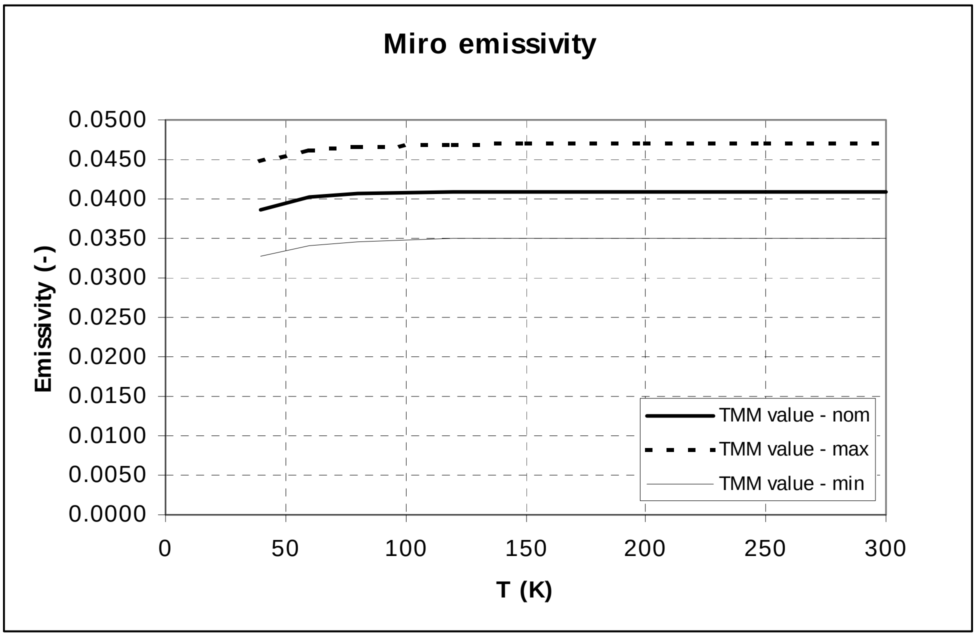
ε = 0.041 ±0.006 @ 20°C

LEMTA measurements : Normal Specular reflectance and RDH (hemispherical diffuse reflectance) :

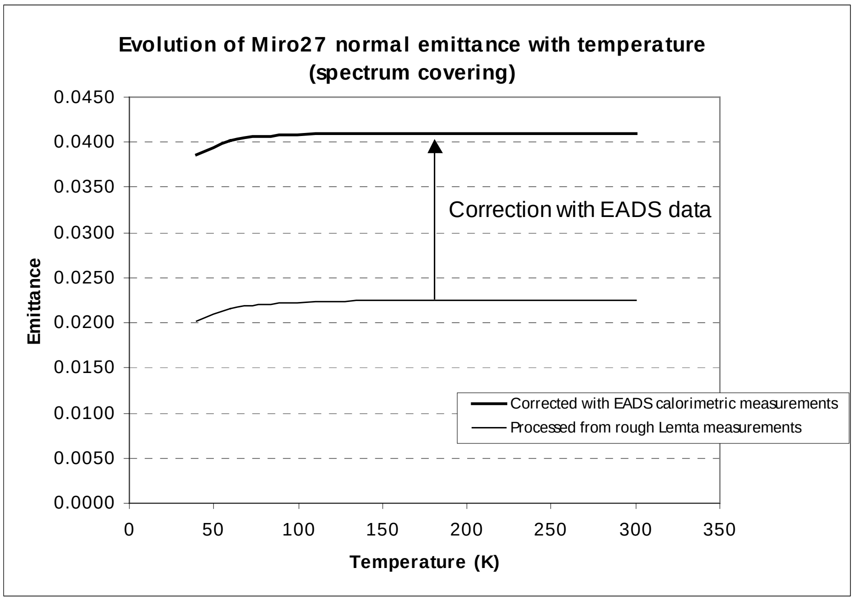


Results of data processing :

✓ Emissivity as a function of temperature



The ε(T) curve is processed from spectral measurements (integration through Planck law at T) adjusted from EADS measurement (see next figure).



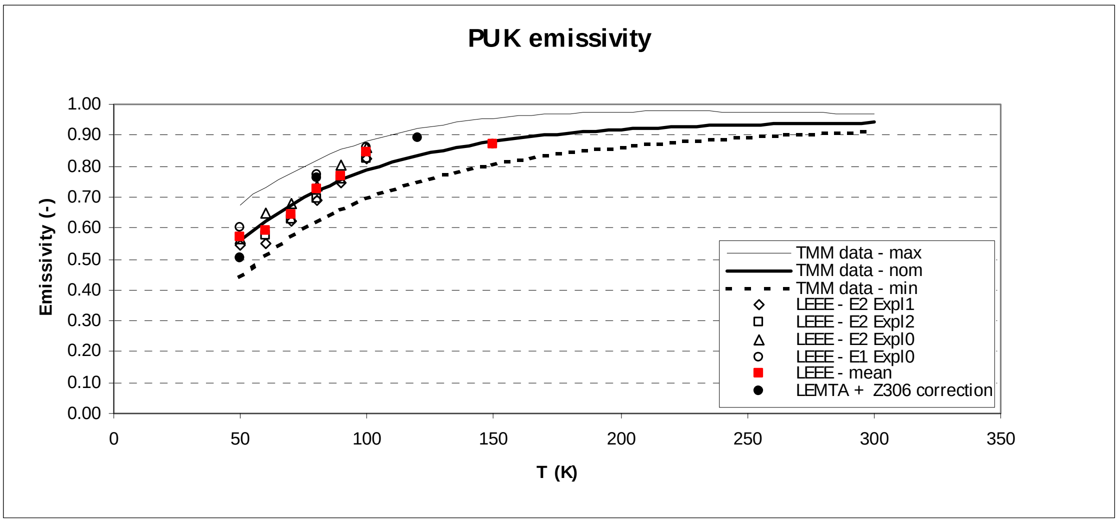
- ✓ Reflectance properties

| ***Miro*** | Nominal | Max (cold) | Min (hot) |
|---|---|---|---|
| Specular ratio | 98.2% | 100% | 94.9% |

Reflectance properties are directly assessed from available LEMTA data. An average specular ratio between 10 and 20µm has been taken into account as conservative value for all IR spectral range (specular ratio increase with wavelength).

## HEC

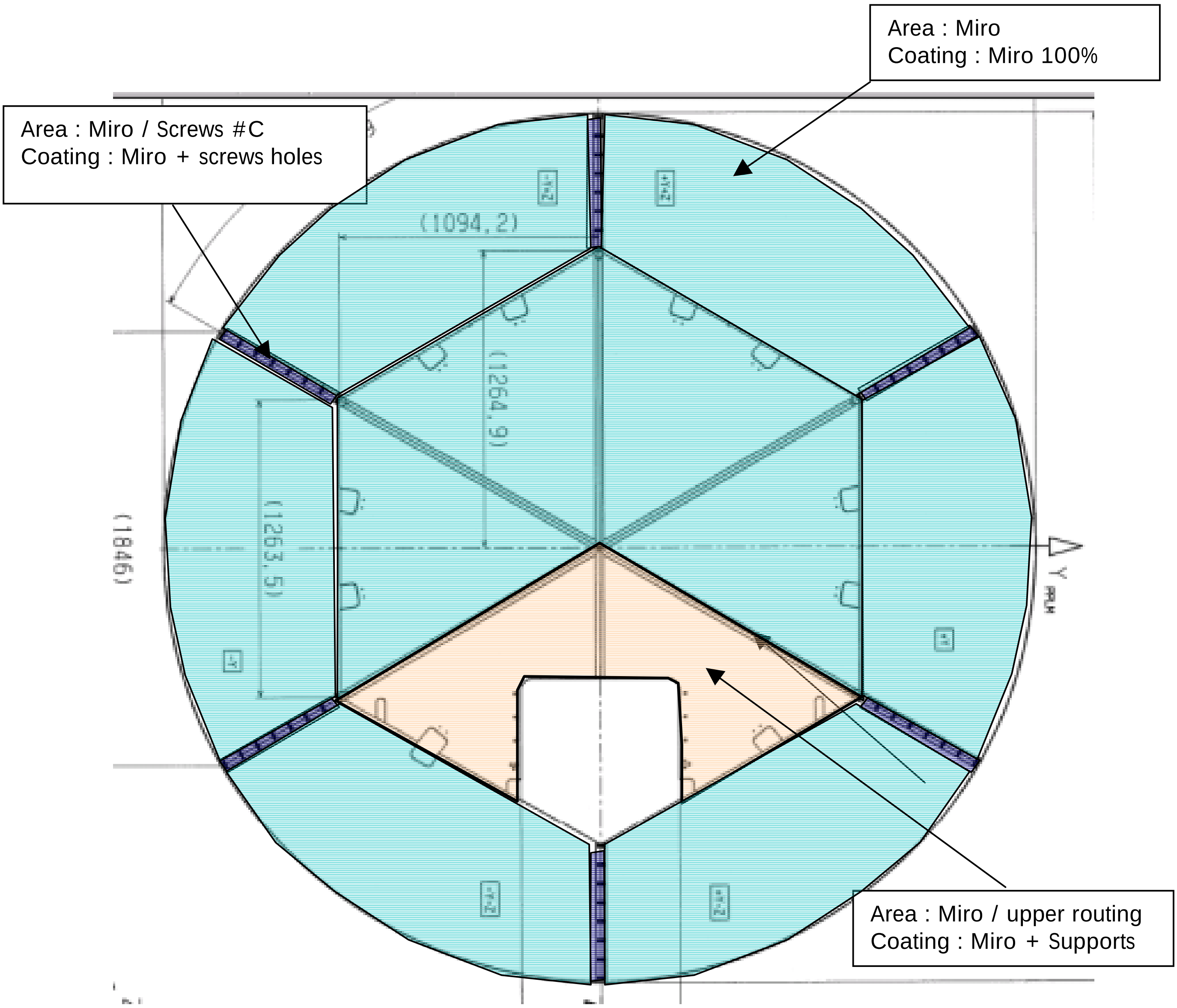
LEEE measurements :



# APPENDIX 3

## MATERIALS PROPERTIES : AREAS AND COATING DEFINITION FOR RADIATIVE MODELLING

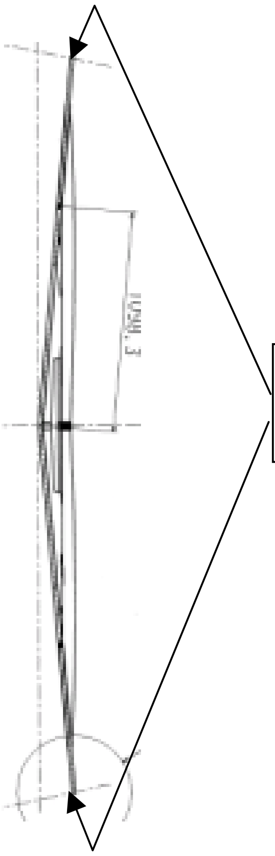
## Shield 1



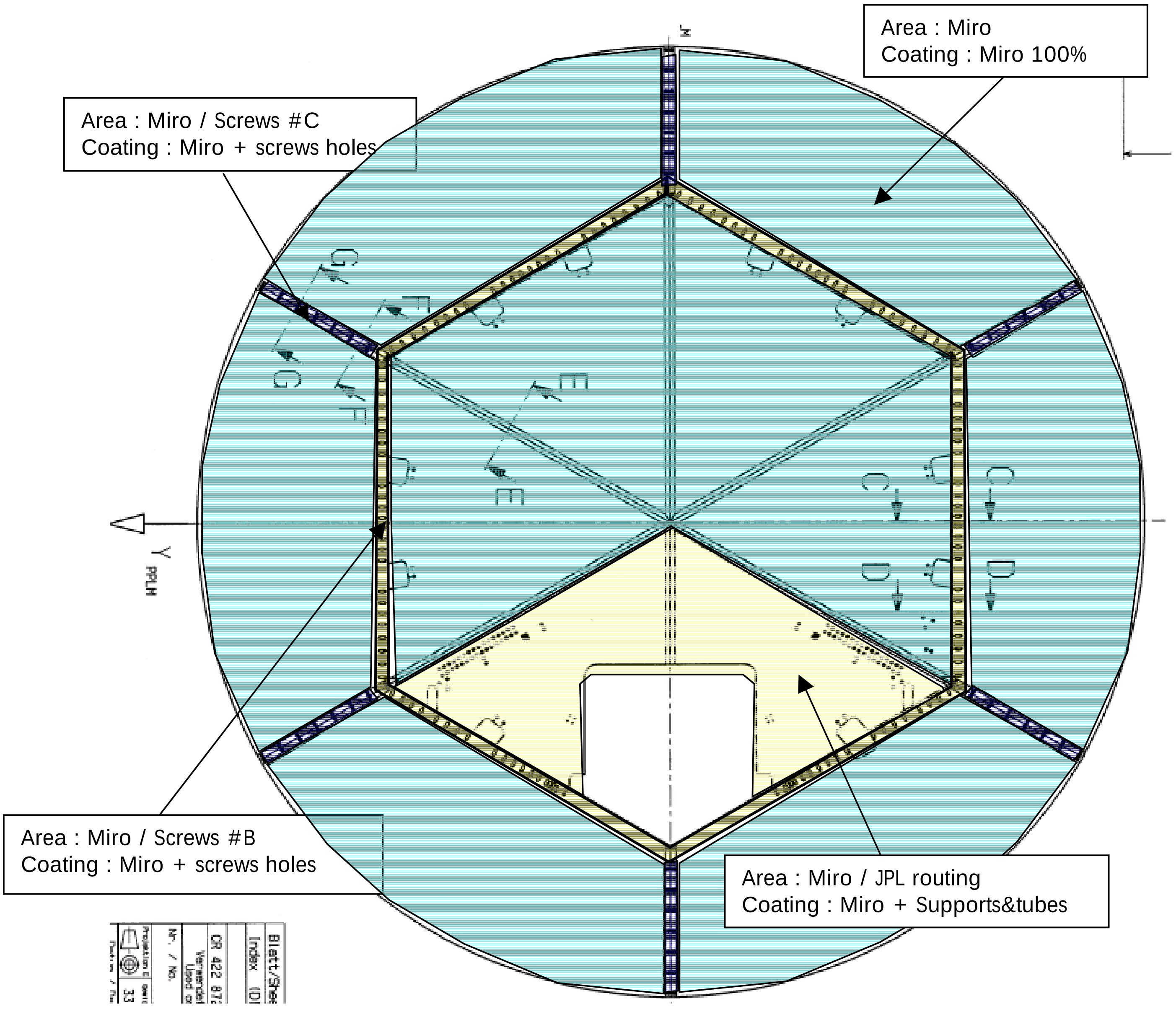
Area : Miro
Coating : Miro 100%

Area : Miro / Screws #C
Coating : Miro + screws holes

Area : Miro / upper routing
Coating : Miro + Supports



Area : VG1 / Edges
Coating : PUK (flat) 100%



Area : Miro
Coating : Miro 100%

Area : Miro / Screws #C
Coating : Miro + screws holes

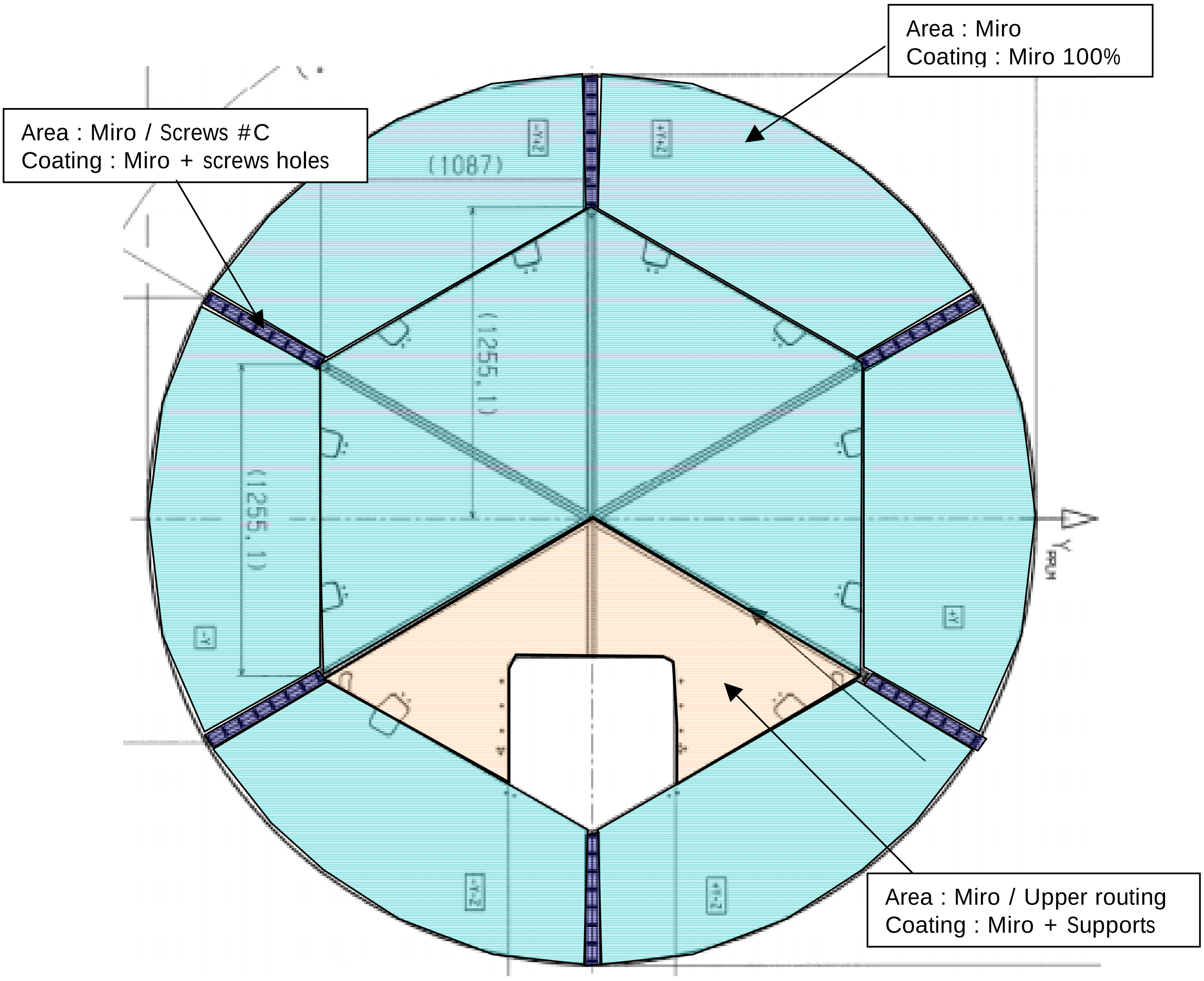
Area : Miro / Screws #B
Coating : Miro + screws holes

Area : Miro / JPL routing
Coating : Miro + Supports&tubes

Parasitic elements on LEC :

| ***Area number*** | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| ***Area designation*** | Miro upper | Miro lower | Miro screws#B | Miro screws#C | Miro upper routing | Miro JPL routing |
| Total surface (m²) | 9.204 | 9.052 | 0.152 | 0.144 | 0.910 | 0.910 |
| Default surface (m²) | 0.020 | 0.020 | 0.106 | 0.001 | 0.021 | 0.066 |

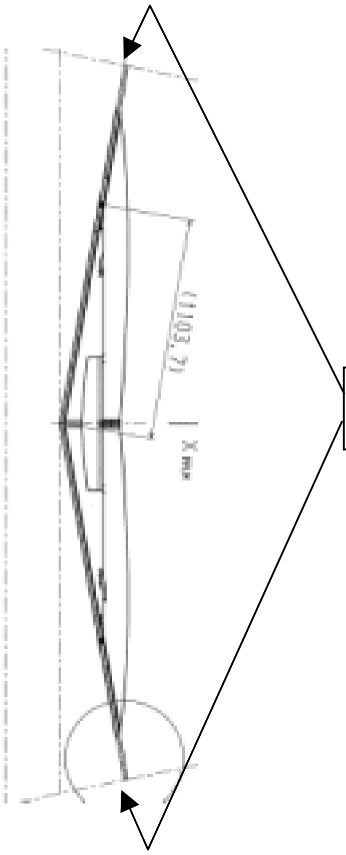
## Shield 2



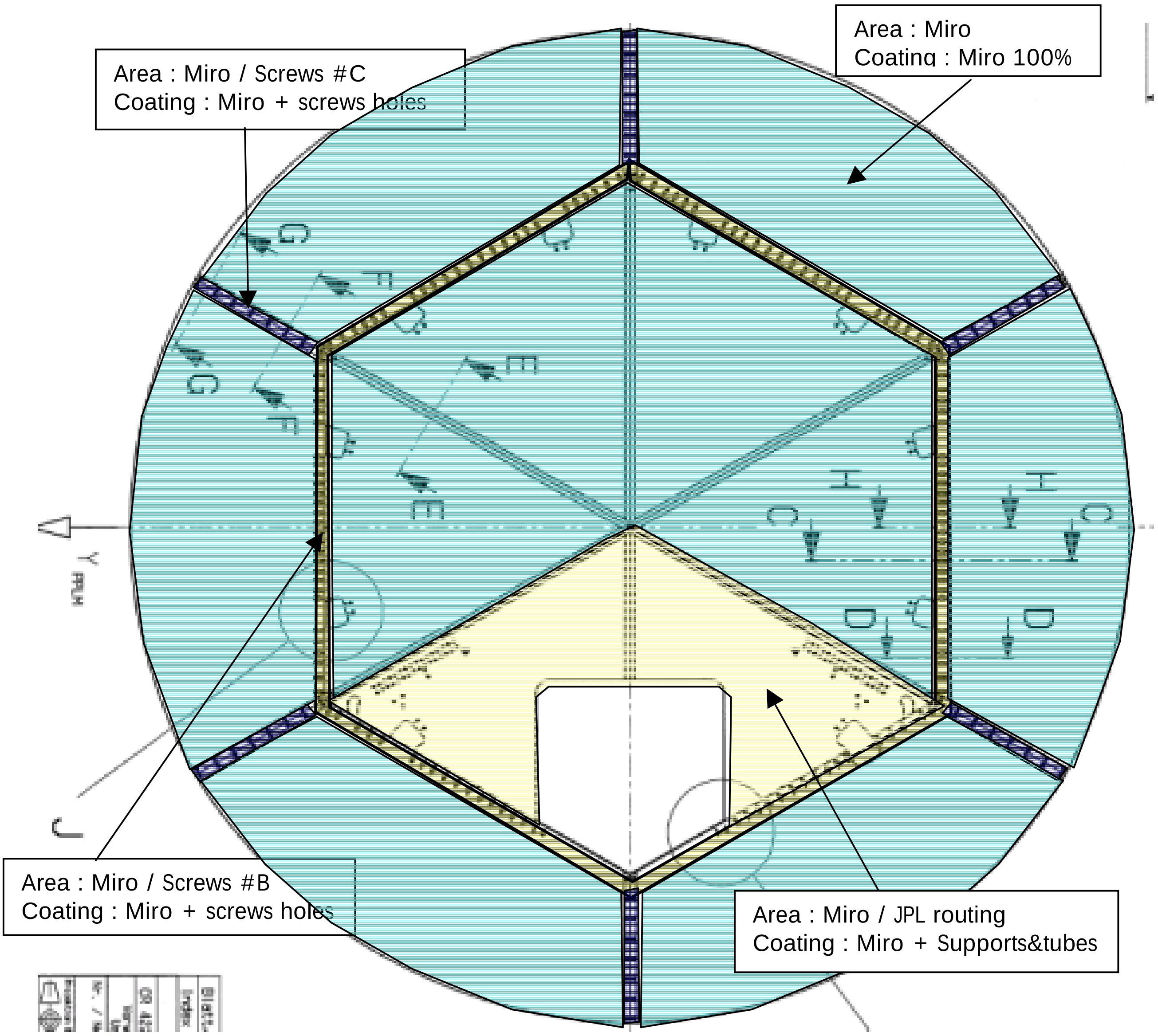
Area : Miro
Coating : Miro 100%

Area : Miro / Screws #C
Coating : Miro + screws holes

Area : Miro / Upper routing
Coating : Miro + Supports



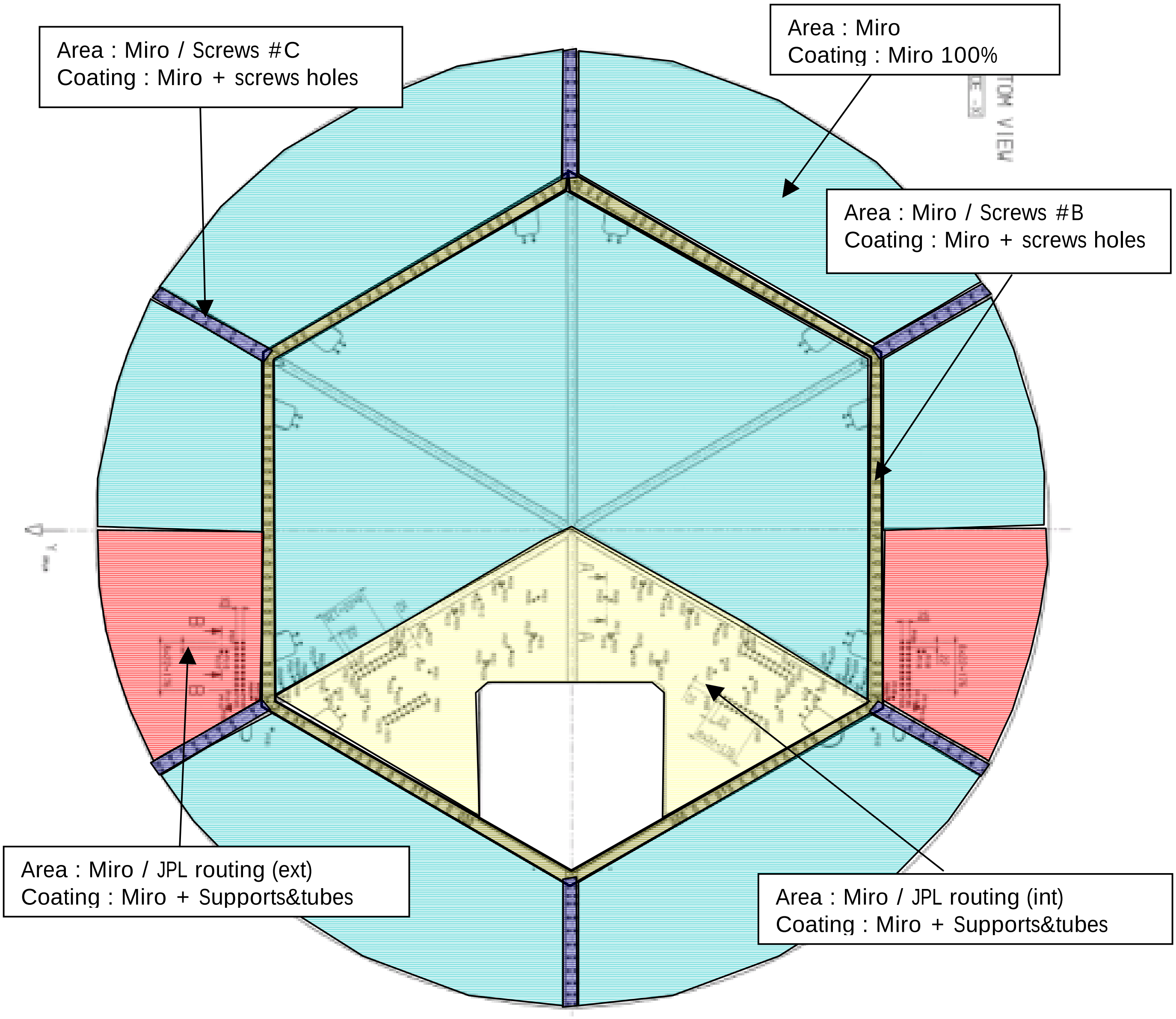
Area : VG2 / Edges
Coating : PUK (flat) 100%

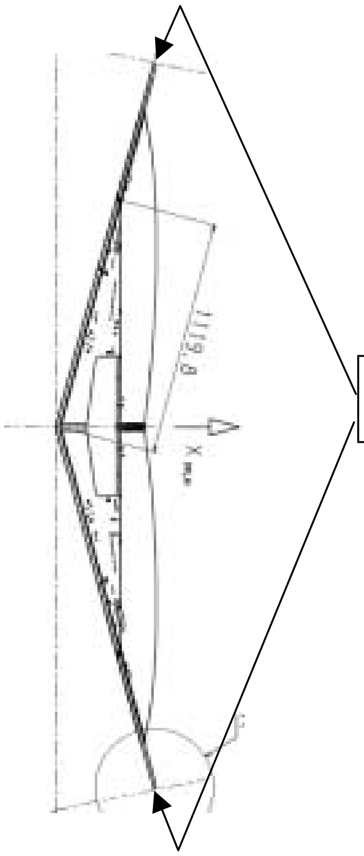


Parasitic elements on LEC :

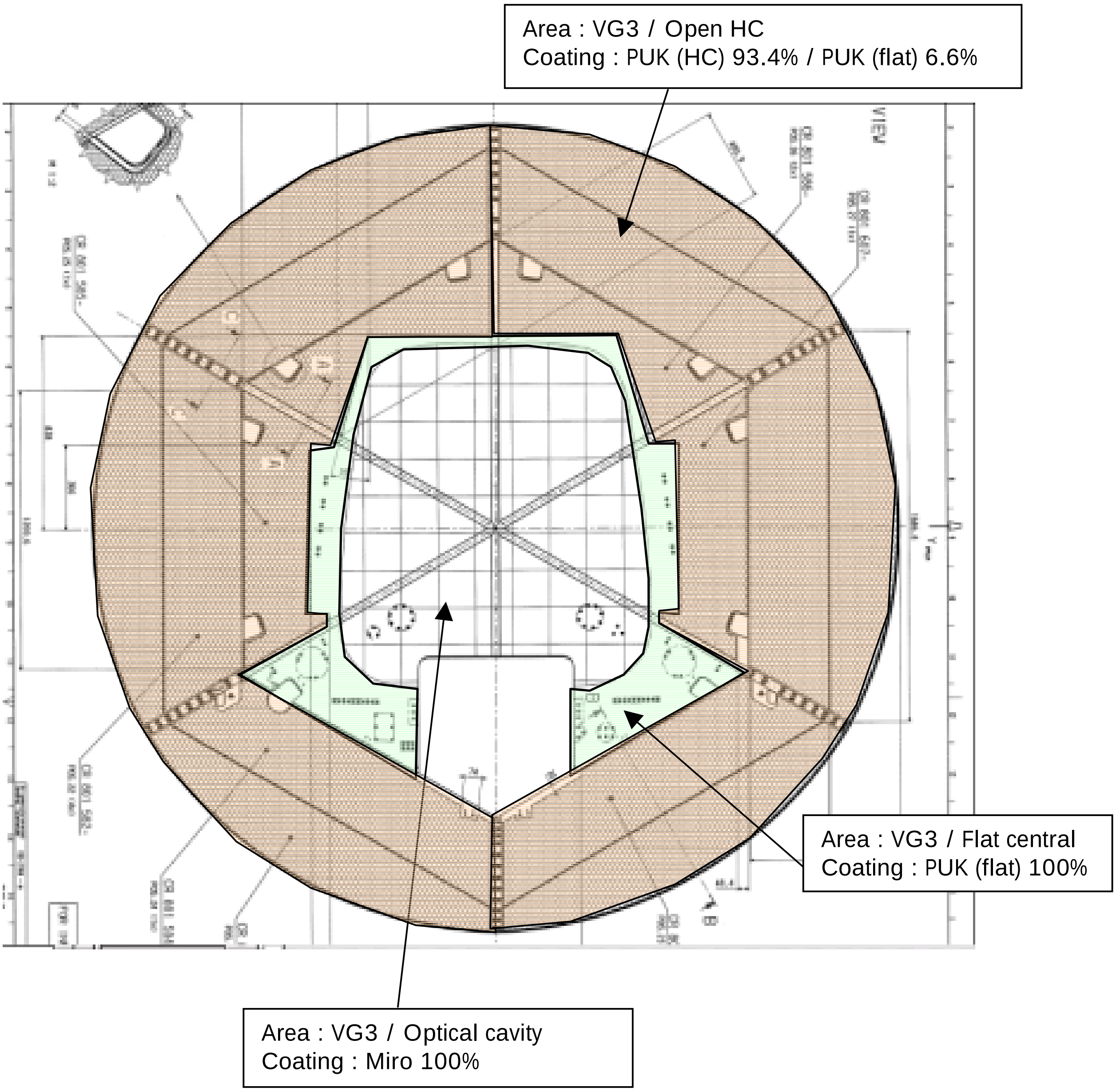
| ***Area number*** | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| ***Area designation*** | Miro upper | Miro lower | Miro screws#B | Miro screws#C | Miro upper routing | Miro JPL routing |
| Total surface (m²) | 8.791 | 8.640 | 0.151 | 0.132 | 0.909 | 0.909 |
| Default surface (m²) | 0.020 | 0.020 | 0.106 | 0.001 | 0.020 | 0.045 |

## Shield 3


Area : Miro / Screws #C
Coating : Miro + screws holes
Area : Miro
Coating : Miro 100%
Area : Miro / Screws #B
Coating : Miro + screws holes
Area : Miro / JPL routing (ext)
Coating : Miro + Supports&tubes
Area : Miro / JPL routing (int)
Coating : Miro + Supports&tubes



Area : VG3 / Edges
Coating : PUK (flat) 100%



Area : VG3 / Open HC
Coating : PUK (HC) 93.4% / PUK (flat) 6.6%

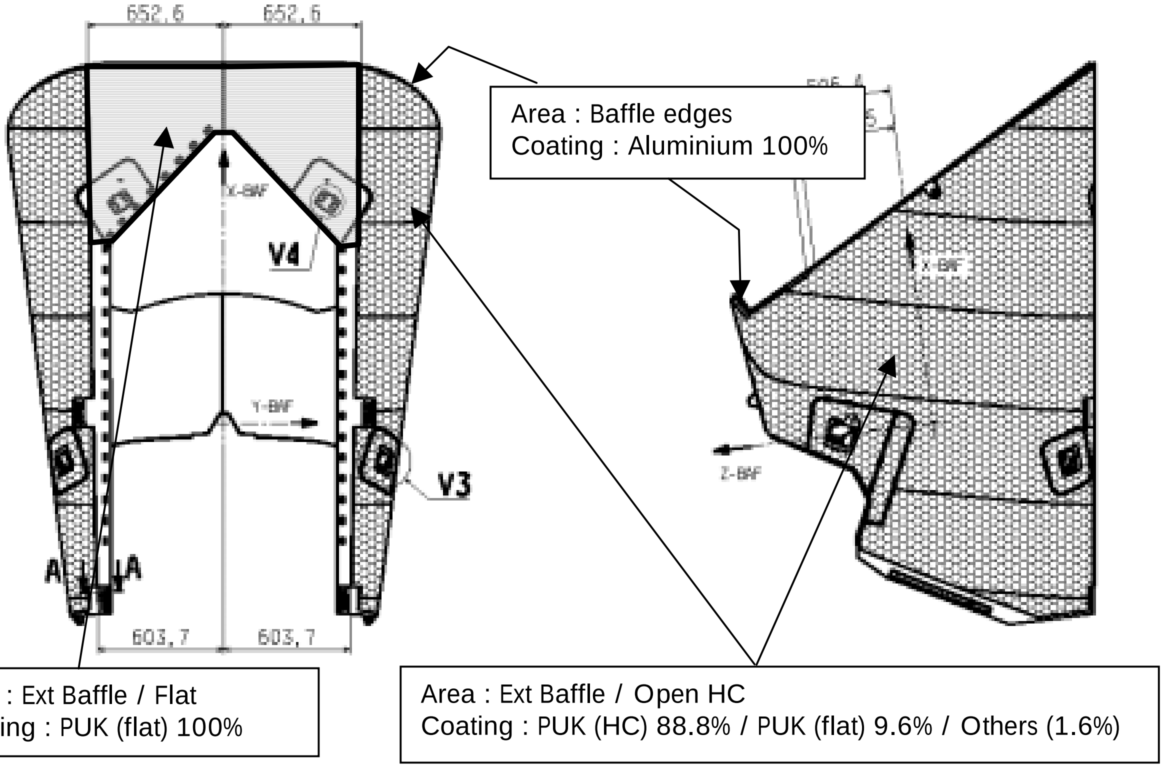
Area : VG3 / Flat central
Coating : PUK (flat) 100%

Area : VG3 / Optical cavity
Coating : Miro 100%

Parasitic elements on LEC :

| ***Area number*** | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| ***Area designation*** | Miro | Miro screws#B | Miro screws#C | Miro JPL routing (int) | Miro JPL routing (ext) |
| Total surface (m²) | 7.429 | 0.150 | 0.125 | 0.918 | 0.490 |
| Default surface (m²) | 0.020 | 0.106 | 0.002 | 0.177 | 0.007 |

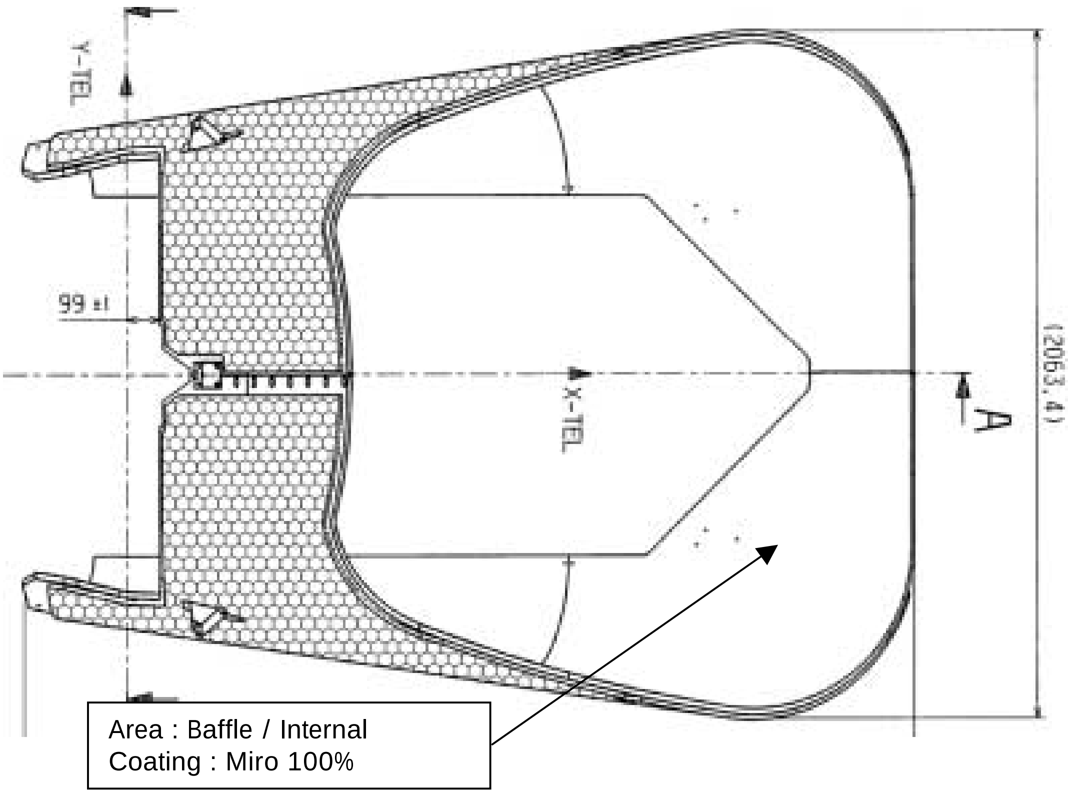
## Baffle



Area : Baffle edges
Coating : Aluminium 100%

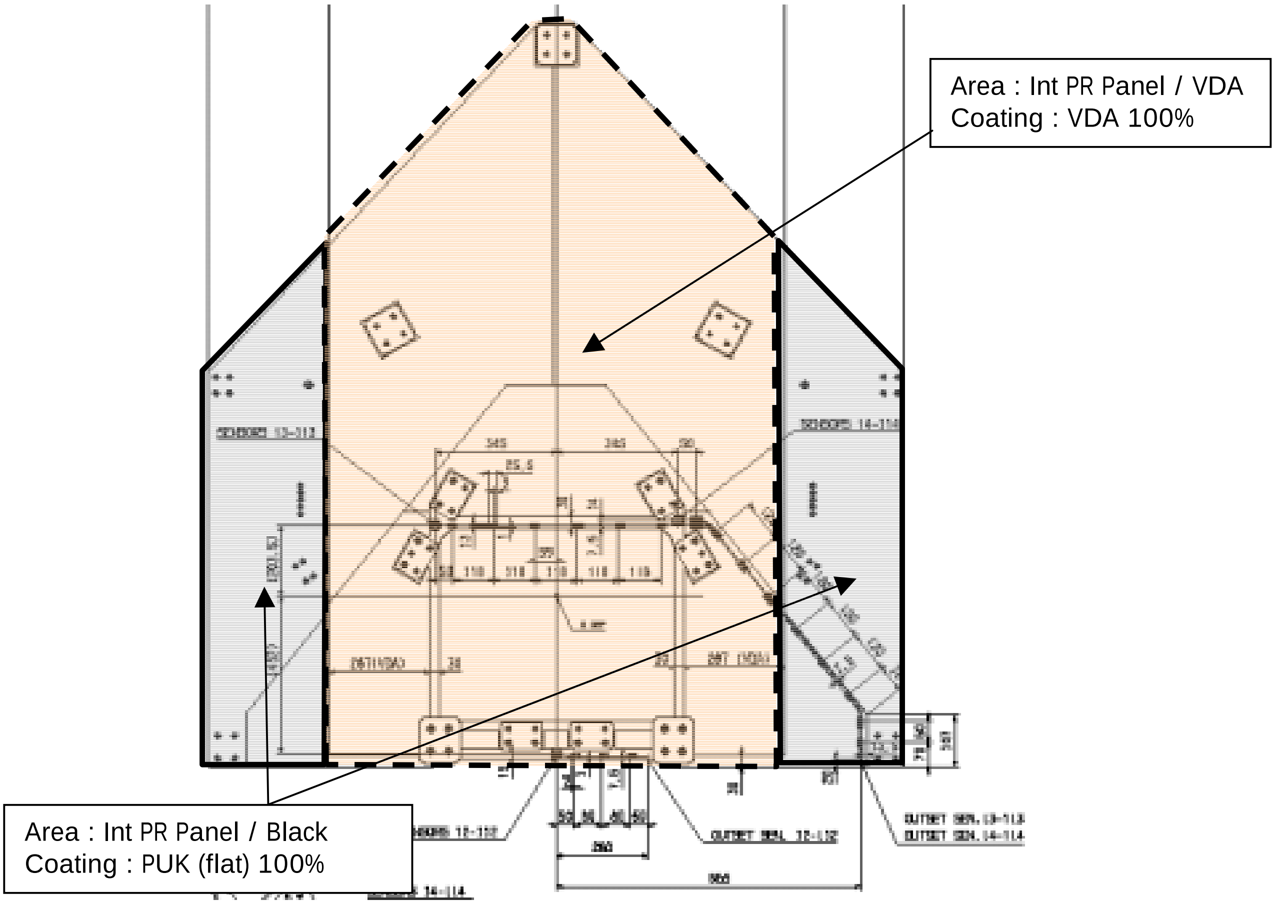
Area : Ext Baffle / Flat
Coating : PUK (flat) 100%

Area : Ext Baffle / Open HC
Coating : PUK (HC) 88.8% / PUK (flat) 9.6% / Others (1.6%)



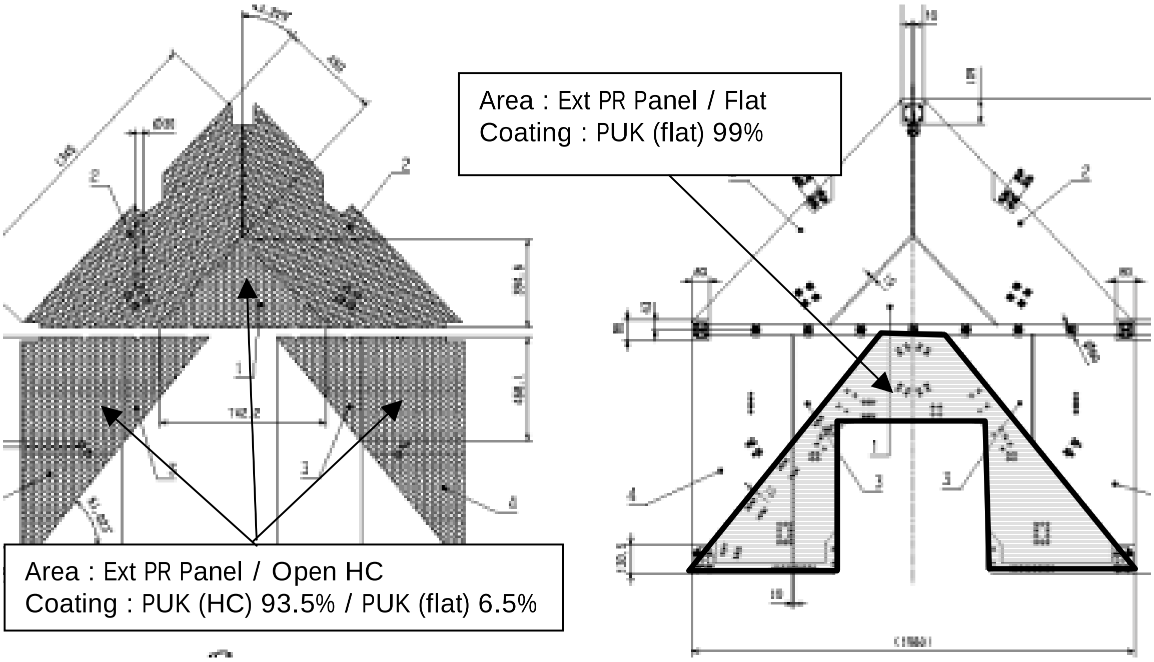
Area : Baffle / Internal
Coating : Miro 100%

## PR Panel



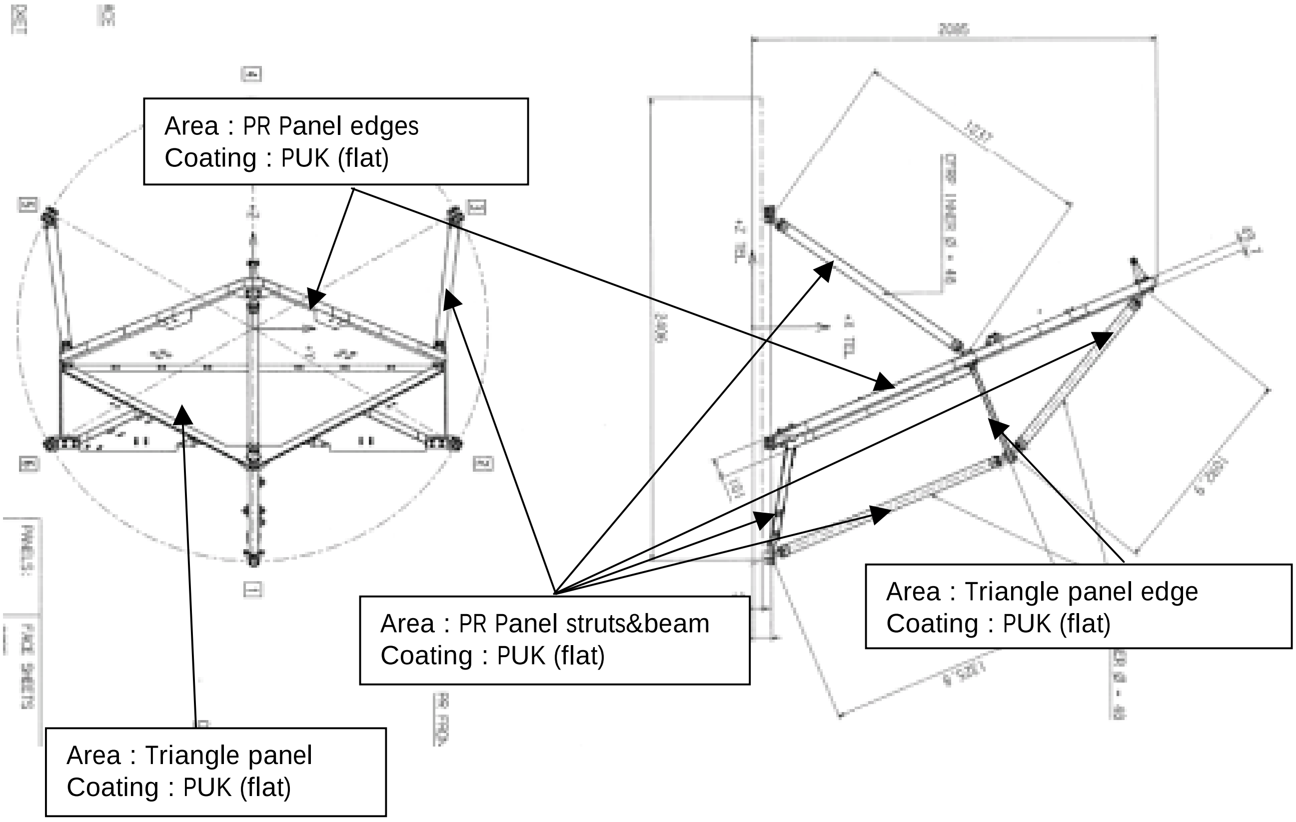
Area : Int PR Panel / VDA
Coating : VDA 100%

Area : Int PR Panel / Black
Coating : PUK (flat) 100%



Area : Ext PR Panel / Flat
Coating : PUK (flat) 99%

Area : Ext PR Panel / Open HC
Coating : PUK (HC) 93.5% / PUK (flat) 6.5%



Area : PR Panel edges
Coating : PUK (flat)

Area : PR Panel struts&beam
Coating : PUK (flat)

Area : Triangle panel edge
Coating : PUK (flat)

Area : Triangle panel
Coating : PUK (flat)

# APPENDIX 4

## PPLM CTA HARNESS DESIGN JUSTIFICATION

## A4 – 0 Introduction

The P-PLM harness to be routed from SVM to cold P-PLM stages is constituted by temperature sensors and heating lines cables.
The choice of cables characteristics will be driven by :

- for T° sensors lines, the measurement uncertainty due to the non perfect knowledge of the wires electrical resistance (the sensors are thermistors),
- for heating lines, the max amperage to be seen by the conducting wires,
- for all lines, a need to minimise the heat leaks, through the harness, from the SVM hot parts to the P-PLM coldest stages.

The final cables definition must also keep hardware characteristics (wires materials and gauge) within reasonable and well tried range.

The detailed description of the temperature acquisition accuracy and power injection, is given in A4 – 1 – 1 and A4 – 1 - 2.

## A4 – 1 P-PLM Harness functional requirements

### A4 – 1-1 Temperature acquisition lines

Extract from [RD**1**] :

| ***Decontamination sensors*** | Quantity | Type | NominalT | Accuracy |
|---|---|---|---|---|
| **Primary Reflectors** | | | | |
| PRTC1 | 1 | A | 40K | ± 2.5K |
| PRTC2 | 1 | B | 40K | ± 2.5K |
| PRTC3 | 1 | C | 40K | ± 2.5K |
| **Sub total 1** | **3** | | | |
| **Secondary Reflectors** | | | | |
| SRTC1 | 1 | A | 40K | ± 2.5K |
| SRTC2 | 1 | B | 40K | ± 2.5K |
| SRTC3 | 1 | C | 40K | ± 2.5K |
| **Sub total 2** | **3** | | | |
| **FPU-HFI** | | | | |
| FPUHFITC1 | 1 | A | 4K | ± 2.5K |
| FPUHFITC2 | 1 | B | 4K | ± 2.5K |
| FPUHFITC3 | 1 | C | 4K | ± 2.5K |
| **Sub total 3** | **3** | | | |
| **FPU-LFI** | | | | |
| FPULFITC1 | 1 | A | 20K | ± 2.5K |
| FPULFITC2 | 1 | B | 20K | ± 2.5K |
| FPULFITC3 | 1 | C | 20K | ± 2.5K |
| **Sub total 4** | **3** | | | |
| **Total** | **12** | | | |

| *Operational sensors* | Quantity | Type | NominalT | Accuracy |
|---|---|---|---|---|
| **Groove 1** | | | | |
| SC heat exchanger 1 | 1 | N | 135K | ± 1K |
| | 1 | R | 135K | ± 2.5K |
| SC heat exchanger 2 | 1 | N | 135K | ± 1K |
| | 1 | R | 135K | ± 2.5K |
| +Z External edge | 1 | N | 113K | ± 1K |
| | 1 | R | 113K | ± 2.5K |
| **Groove 2** | | | | |
| SC heat exchanger 1 | 1 | N | 80K | ± 1K |
| | 1 | R | 80K | ± 2.5K |
| SC heat exchanger 2 | 1 | N | 80K | ± 1K |
| | 1 | R | 80K | ± 2.5K |
| **Groove 3** | | | | |
| SC heat exchanger 1 | 1 | N | 50K | ± 1K |
| | 1 | R | 50K | ± 2.5K |
| SC heat exchanger 2 | 1 | N | 50K | ± 1K |
| | 1 | R | 50K | ± 2.5K |
| Wave Guides Interface1 | 1 | N | 50K | ± 1K |
| | 1 | R | 50K | ± 2.5K |
| Wave Guides Interface2 | 1 | N | 50K | ± 1K |
| | 1 | R | 50K | ± 2.5K |
| Optical cavity | 1 | N | 50K | ± 1K |
| | 1 | R | 50K | ± 2.5K |
| **PR panel** | | | | |
| JFET interfaces | 1 | N | 40K | ± 1K |
| | 1 | R | 40K | ± 2.5K |
| FPU interface 1(lower beam) | 1 | N | 40K | ± 1K |
| | 1 | R | 40K | ± 2.5K |
| FPU interface2 (+Y) | 1 | N | 40K | ± 1K |
| | 1 | R | 40K | ± 2.5K |
| FPU interface3 (-Y) | 1 | N | 40K | ± 1K |
| | 1 | R | 40K | ± 2.5K |
| **Baffle** | | | | |
| Baffle 1 (Front face) | 1 | N | 40K | ± 1K |
| | 1 | R | 40K | ± 2.5K |
| Baffle 2 (Lateral face medium) | 1 | N | 40K | ± 1K |
| | 1 | R | 40K | ± 2.5K |
| Baffle 3 (Lateral face upper position) | 1 | N | 40K | ± 1K |
| | 1 | R | 40K | ± 2.5K |
| Baffle 3 (Rear face) | 1 | N | 40K | ± 1K |
| | 1 | R | 40K | ± 2.5K |
| **Reflectors** | | | | |
| PR1 | 1 | N | 40K | ± 1K |
| | 1 | R | 40K | ± 1K |
| PR2 | 1 | N | 40K | ± 1K |
| | 1 | R | 40K | ± 1K |
| SR1 | 1 | N | 40K | ± 1K |
| | 1 | R | 40K | ± 1K |
| SR2 | 1 | N | 40K | ± 1K |
| | 1 | R | 40K | ± 1K |
| **Total** | **44** | | | |

The indicated accuracies are for electronic only, worst case without calibration. A calibration is requested to improve the situation. The goal for the sensor line (sensor and wires) is to not degrade the above accuracy more than 20% for operational cryo temperatures.

According to CDMU possibilities, only 2 wire sensors can be acquired.

This 2 wire acquisition has a direct impact on the selection of sensors. Indeed, in order to have an acceptable T° measurement uncertainty due to the wires resistance, the total wires resistance (resp the uncertainty wrt its knowledge) has to be kept low when compared to the sensor resistance (resp the sensors sensitivity).

This becomes a serious problem at low temperature where sensors resistance and sensitivity become very low. Next table shows examples with different Rosemount 118MF Pt probes, assuming a 60Ω harness with a 7Ω (approx 10% of total resistance) uncertainty upon its actual resistance knowledge.

| ***118MF Pt probe*** | Ratio $R_{wiring}$ / $R_{probe\ 50K}$ (%) | T° measurement at 50K Uncertainty due to wires (K) |
|---|---|---|
| Pt100 | 673% | 16.9 |
| Pt500 | 134% | 3.4 |
| Pt1000 | 67% | 1.7 |
| Pt2000 | 33% | 0.8 |
| Pt5000 | 13% | 0.4 |

**Measurement accuracy / Influence of Pt probe selection**

Therefore, due to :

- ✓ Planck PLM dimensions and resulting important cable lengths,
- ✓ the 2 wire acquisition,
- ✓ the need to lower the heat leaks induced by the wiring,
- ✓ the required measurement accuracy,
- ✓ unreliability of PT5000 sensors,

it appears compulsory to use PT2000 sensors.

The harness sizing will be based on this **PT2000** use assumption.

One of Pt probes drawbacks is the need of a rather high excitation current (≤1mA) leading to potential significant probe self heating.

Next table presents examples of dissipated power for PT2000 (Joule effect in wires neglected), in case of continuous current supply (conservative approach). These loads are of interest only for operational mode.

| ***118MF PT2000 I = 1mA*** | T (K) | Self dissipated power (mW) | |
|---|---|---|---|
| | | 1 probe | Total |
| Shield1 (2 probes) | 150 | 1.0 | 2.0 |
| Shield 2 (2 probes) | 110 | 0.7 | 1.4 |
| Shield 3 and Telescope (42 probes) | 50 | 0.18 | 7.5 |

**PT2000 self heating estimation**

Though negligible wrt global performance, this self heating may decay the measurement accuracy since the sensor may overheat wrt the substrate. This overheat, linked to the potting quality and to the contact with the substrate, is difficult to predict. For a rough estimation, it is assumed a static gain equal to 50 (independent of T°) which means that a self heating power of 1 W induces a gradient “probe – substrate” equal to 50 K. It is moreover assumed that the 1mA current is applied permanently, which is a conservative assumption. Next table presents estimations of overheat values (K) taking into account these assumptions :

| ***118MF PT2000*** | T<br>(K) | Self Heating<br>(mW) | Overheat [G=50 K/W]<br>(K) |
|---|---|---|---|
| | 300 (FPU+Tel Decont) | 2.3 | 0.12 |
| | 150 (Sh1 Operational) | 1.0 | 0.05 |
| | 110 (Sh2 Operational) | 0.7 | 0.04 |
| | 50 (Sh3+Tel Operational) | 0.18 | 0.01 |

**PT2000 overheat estimation**

### A4 – 1-2 Heating lines

| Classification | Heated element / area | Number of lines | | Mode | Max power (W) | | Required power (W) | |
|---|---|---|---|---|---|---|---|---|
| | | N | R | | ΣN | ΣR | ΣN | ΣR |
| PR dec | Primary Reflector | 2 | 1 | dec | 120 | 60 | 49.5 | 49.5 |
| SR dec | Secondary Reflector | 1 | 1 | dec | 60 | 60 | 26.4 | 26.4 |
| FPU dec | FPU -HFI | 1 | 1 | dec | 60 | 60 | TBD | TBD |
| FPU dec | FPU - LFI | 1 | 1 | dec | 60 | 60 | TBD | TBD |

**Power injection needs**

Note :

- The required power values are drawn from ASED analyses (see [RD**13**]).

Next table present, for information, heating lines resistance values used for further computations :

| Classification | Heated element / area | Total resistance (Ω) | Required power (theoretical power under 28V) (W) |
|---|---|---|---|
| PR dec N1 | Primary Reflector | 32.8 | 23.9 |
| PR dec N2 | Primary Reflector | 30.7 | 25.6 |
| PR dec R | Primary Reflector | 15.9 | 49.5 |
| SR dec | Secondary Reflector | 29.7 | 26.4 |
| FPU dec | FPU | TBD | TBD |

## Heating lines characteristics

### A4 – 2 Wires materials classification

Absolute indicators, in term of thermo-electrical best behaviour, have to be expressed in order to classify a priori the different candidate materials.

### A4 – 2 – 1 Temperature acquisition lines

The T° measurement uncertainty due to the wires resistance can be considered, at first order, proportional to the wire material **electrical resistivity [$R_e$ (Ω.m)]** at the corresponding temperature.

The **measurement uncertainty δ [K]** (induced by wires resistance) can be written as follows :

$$\delta = A \times R_e \times l / (S \times \eta) \qquad [1]$$

where :

- ✓ l is the wire length (forth and back) [m]
- ✓ S is the wire section [m²]
- ✓ η is the sensor sensitivity [Ω/K]
- ✓ A is an non-dimensional constant depending of the acquisition electronics.

The heat leaks can be considered as proportional to the **conductivity integral [IK (W/m)]** between the hot and cold harness boundaries.

Notes :

- No dedicated device is foreseen to heat sink the P-PLM harness to the intermediate shields. Though the harness, routing along the struts, will obviously be linearly heat sinked, the conservative assumption is made according to which the 50K parts are linked, through the harness, directly to the 300K SVM parts.
- As a conservative approach, the presented computations involve only conductive couplings.. Besides, the harness routing has been defined so that the induced radiative perturbations may be as low as possible (routing on the struts). Moreover, the current optimisation already takes into account limitations in certain parameters, such as the max wire size, in order to keep the “pure conductive” assumption as reasonable as possible.

The **heat leak ϕ [W] on shield 3** (induced by one wire) can be written as follows

$$\phi = IK(300,50) \times S / l \qquad [2]$$

where :

- ✓ IK(300,50) is the conductivity integral between 300K and 50K.

Using [1] and [2], the heat leak can be written as follows :

$$\phi = A \times IK(300,50) \times Re \ / \ (\delta \times \eta) \qquad [3]$$

Then, with given δ and η values, the best material will be the one minimising IK(300,50)×Re.

Note :

- Equation [3] shows that a probe with high sensitivity η will yield a lower impact, on T° measurement uncertainty, of wires resistance.

The next table presents an overview of different common materials and associated IK(300,50)×Re values.

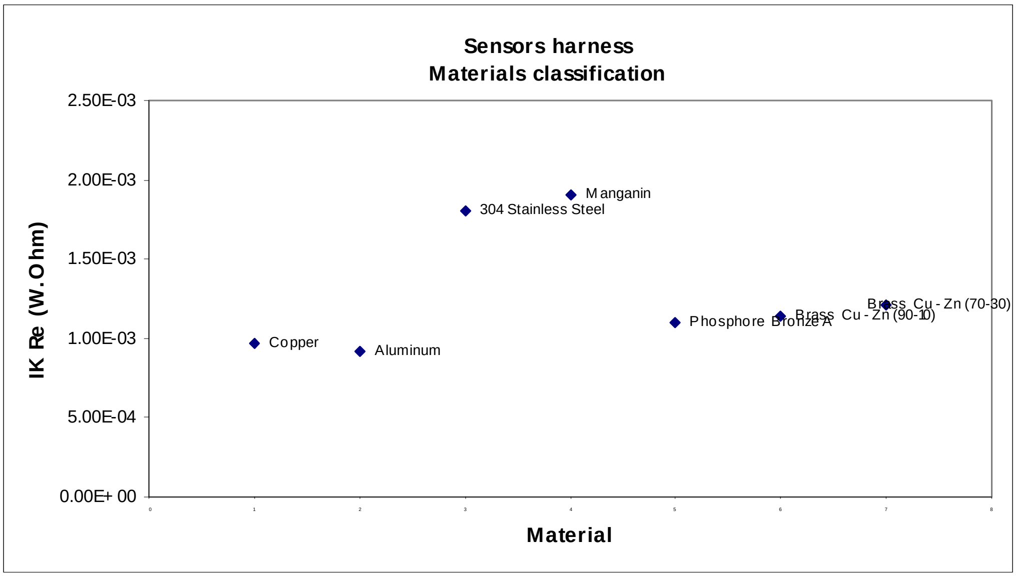
| Material description | Int. Cond. IK(W/m) | | Resist. elec Re (Ohm.m) | IK.Re (W.Ohm) |
|---|---|---|---|---|
| | 300 K --- | ---> 50 K | Moy | Probes |
| Copper | 88024 | 88024 | 1.10E-08 | 9.68E-04 |
| Aluminum | 53791 | 53791 | 1.71E-08 | 9.20E-04 |
| 304 Stainless Steel | 2939 | 2939 | 6.15E-07 | **1.81E-03** |
| Manganin | 4137 | 4137 | 4.61E-07 | **1.91E-03** |
| Phosphore Bronze A | 11327 | 11327 | 9.68E-08 | 1.10E-03 |
| Brass Cu - Zn (90-10) | 36114 | 36114 | 3.15E-08 | 1.14E-03 |
| Brass Cu - Zn (70-30) | 21331 | 21331 | 5.66E-08 | 1.21E-03 |

**Material classification / Sensors lines**

Note :

- The Re value is the average value between 300K and 50K, assuming a linear temperature distribution along the wire, even for Decontamination mode (weak influence on results and T° distribution roughly known during Decontamination ).

The figure below displays the classification of these materials for the sensors harness definition. The best materials correspond to the lower Y values.



**Material classification / Sensors lines**

### A4- 2 – 2 Heating lines

The performance indicator related to heating lines is expressed through the equation [4].

$$\phi = B \times IK[300,50] \times Re^{2/3} \qquad [4]$$

where :

- ✓ B is constant independent of conductivity and resistivity values

Next table presents an overview of different common materials and associated IK(300,50)× $Re^{2/3}$ values.

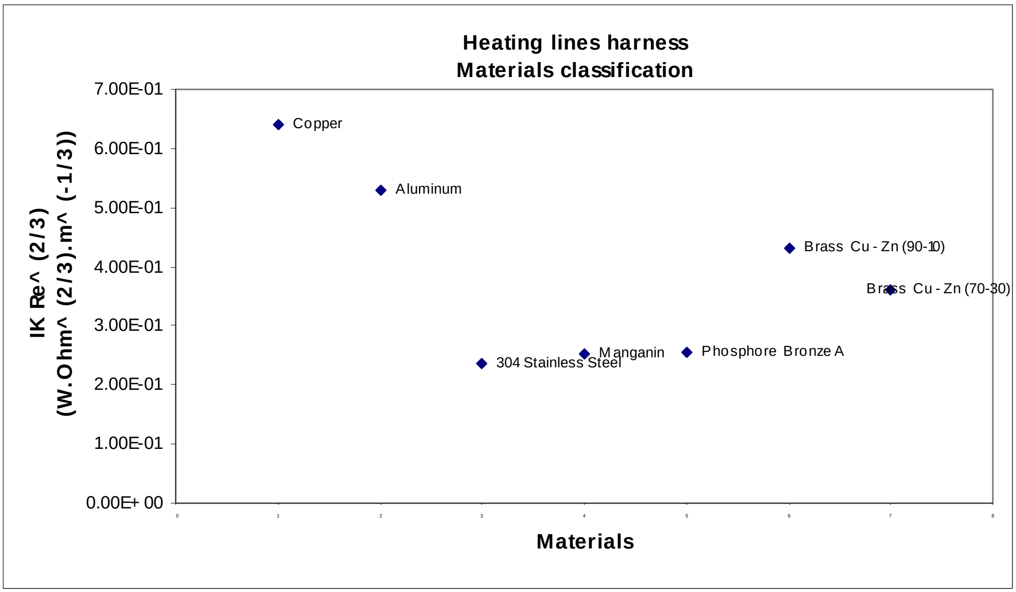
| Material description | Int. Cond. IK (W/m) | | Resist. elec Re (Ohm.m) | IK.Re^(2/3) |
|---|---|---|---|---|
| | 300 K --- | ---> 50 K | 300 K | Heaters |
| Copper | 88024 | 88024 | 1.96E-08 | **6.39E-01** |
| Aluminum | 53791 | 53791 | 3.09E-08 | 5.30E-01 |
| 304 Stainless Steel | 2939 | 2939 | 7.20E-07 | 2.36E-01 |
| Manganin | 4137 | 4137 | 4.76E-07 | 2.52E-01 |
| Phosphore Bronze A | 11327 | 11327 | 1.07E-07 | **2.55E-01** |
| Brass Cu - Zn (90-10) | 36114 | 36114 | 4.11E-08 | 4.30E-01 |
| Brass Cu - Zn (70-30) | 21331 | 21331 | 6.92E-08 | 3.60E-01 |

**Material classification / Heating lines**

Note :

- The Re value is the value at 300K, since the significant value of this parameter corresponds to a heating mode.

Next figure displays the classification of these materials for the heaters harness definition. The best materials correspond to the lower Y values.



**Material classification / Heating lines**

### A4 – 3 Design constraints

Acceptance criteria have to be defined in order to guide the wire selection according to specific Planck constraints.

### A4 – 3 – 1 Maximum heat leaks

The overall harness will be defined so as to induce, at 50K level, heat leaks (**$HL_{50K}$**) inferior to 8% of global loads on Shield 3 (#2W). The contribution of both heating and sensors lines are as defined by criteria [C1] and [C2] :

$$HL_{50K}^{heaters} \leq 30mW \qquad [C1]$$

$HL_{50K}^{sensors} \leq 140mW$ [C2]

### A4 – 3 – 2 Wires size

The smaller size, considering fragility and classical handling, has been taken equal to AWG28.
Hence the [C3] criteria on the min wire gauge to be considered :

Min wires size : AWG28 [C3]

Though difficult to quantify, it is felt that the wires overall dimension has to be kept as reduced as possible (influence of radiative effect, required holes in shields for pass through, handling …). The [C4] criteria upon max wires size has been quantified as follows :

Max wires size : AWG22 [C4]

Note :

- 20 AWG22 wires (approximately the number of wires for the heating lines) would roughly lead to a 5mm diameter cylindrical harness or to a 20mm wide flat harness.

### A4 – 3 – 3 Voltage loss in heater wires

Harnesses, in cryo application, often experience large voltage losses. Planck PLM heaters harness will be designed so that its resistance induce a total power loss, when compared to the theoretical heaters dissipation under 28V nominal voltage, inferior to 15%. Hence the [C5] criteria :

Power loss due to wires < 15% theoretical power [C5]

## A4 – 4 Wires optimisation

The materials selection and the design constraints must be confronted in order to lead to the final optimisation.

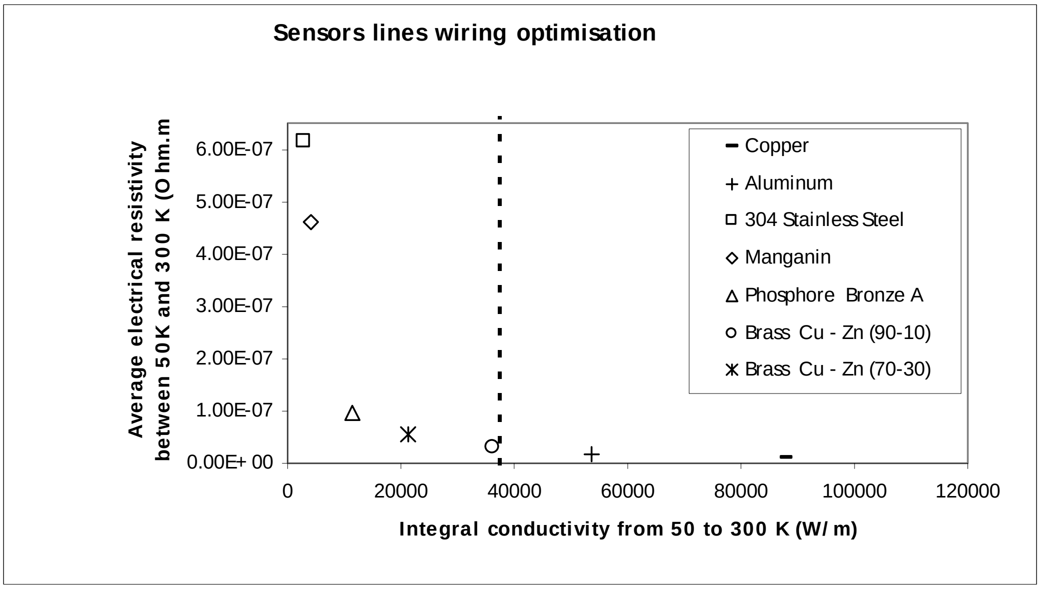
### A4 – 4 – 1 Temperature acquisition lines

### A4 - 4 – 1 – 1 Selection of material

The needs of temperature acquisitions are presented in term of wires reaching each stage :

- Shield 1 : 112
- Shield 2 : 100
- Shield 3 + Telescope : 92

It can be seen that most of the sensors will be placed on the 50K level. As a conservative approach the all 112 wires are preliminarily considered as reaching the 50K shield.
The combination of [C2] and [C3] criteria, associated to the number of wires, lead to a maximum IK. This maximum IK eliminates the use of the most conductive materials as shown below (the accepted materials are those on the left side of the borderline).



**Sensors lines wiring optimisation**

When referring to the figure above, it can be noted that the accepted materials are not the optimum ones. This is due to the fact that, because of the min AWG value (criteria [C3]), the only significant parameter is the IK.

***The baseline material for sensors wires is therefore Brass.***

***A back-up material may be Phosphore Bronze***

### A4 - 4 – 1 – 2 Final definition and verification

For availability and technological reasons, Brass is preferred to Phosphore Bronze. The chosen definition is AWG28 Brass. The design verification, in term of induced uncertainties and heat loads, is given in tables below.

| T° (K) | Mode | PT2000 resistance (Ω) | PT2000 sensitivity (Ω/K) | Total wire length (m) | Total wires resistance (Ω) | Uncertainty on wires resistance (%) | Resulting uncertainty on T° measurement (K) | *Uncertainty including overheat (K)* |
|---|---|---|---|---|---|---|---|---|
| 40 | Ope | 115 | 7 | 8 | 5 | ±20 | ±0.15 | *±0.16* |
| 110 | Ope | 692 | 9 | 6 | 4 | ±20 | ±0.10 | *±0.14* |
| 150 | Ope | 1030 | 8 | 4 | 3 | ±20 | ±0.07 | *±0.12* |
| 300 | Dec | 2314 | 8 | 8 | 7 | ±20 | ±0.15 | *±0.27* |

**Sensors lines wiring verification / T° measurement accuracy**

Notes :

- The 2×4m wires length takes into account potential routing on shields and/or sensors locating on Baffle.
- The ±20% uncertainty on wires resistance corresponds, for example, to an uncertainty of ±50K on the wires distribution temperature between the shields.
- It is of course assumed that the wires resistance can be subtracted from each probe R=f(T) curve.
- The 300K case corresponds to a Decontamination mode i.e. to probes on Reflectors at ambient temperature.

As shown below, the induced heat loads are below the 150mW defined as goal.

| Material description | AWG - | nb wires - | Length (m) | S per cond (m²) | Tmax (K) | Tmin (K) | I cond (W/m) | Load (mW) |
|---|---|---|---|---|---|---|---|---|
| Brass 65/35 | 28 | 112 | 2 | 8.8E-08 | 300 | 50 | 2.10E+04 | **100** |

**Sensors lines wiring verification / Heat loads**

Note :

- The 2m length is assumed as the minimum length between SVM and shield 3 (conservative assumption).
- The exact wires definition (type of Brass and cross section) is drawn from supplier data (see [RD**1**])

### A4 – 4 – 2 Heating lines

### A4 – 4 – 2-1 Selection of material

The needs of heating lines are expressed in next table in term of wires number.

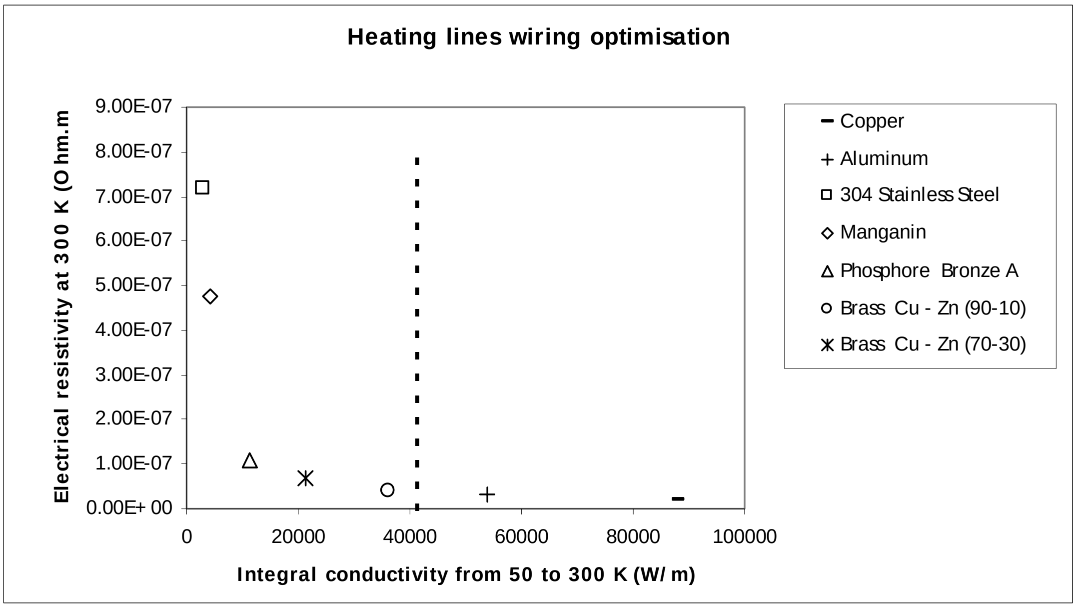
| Classification | Heated element / area | Number of lines | | Number of wires | Required power (W) | |
|---|---|---|---|---|---|---|
| | | N | R | | ΣN | ΣR |
| PR dec | Primary Reflector | 2 | 1 | 8 | 49.5 | 49.5 |
| SR dec | Secondary Reflector | 1 | 1 | 4 | 26.4 | 26.4 |
| FPU dec | FPU | 2 | 2 | 8 | TBD | TBD |

**Heating lines / Number of wires**

Notes :

- The same type of wires shall be used for all circuits.
- The number of wires is chosen so that approximately 25W shall be supported by a 2-wire circuit (hence a 4-wire circuit for PR dec R)

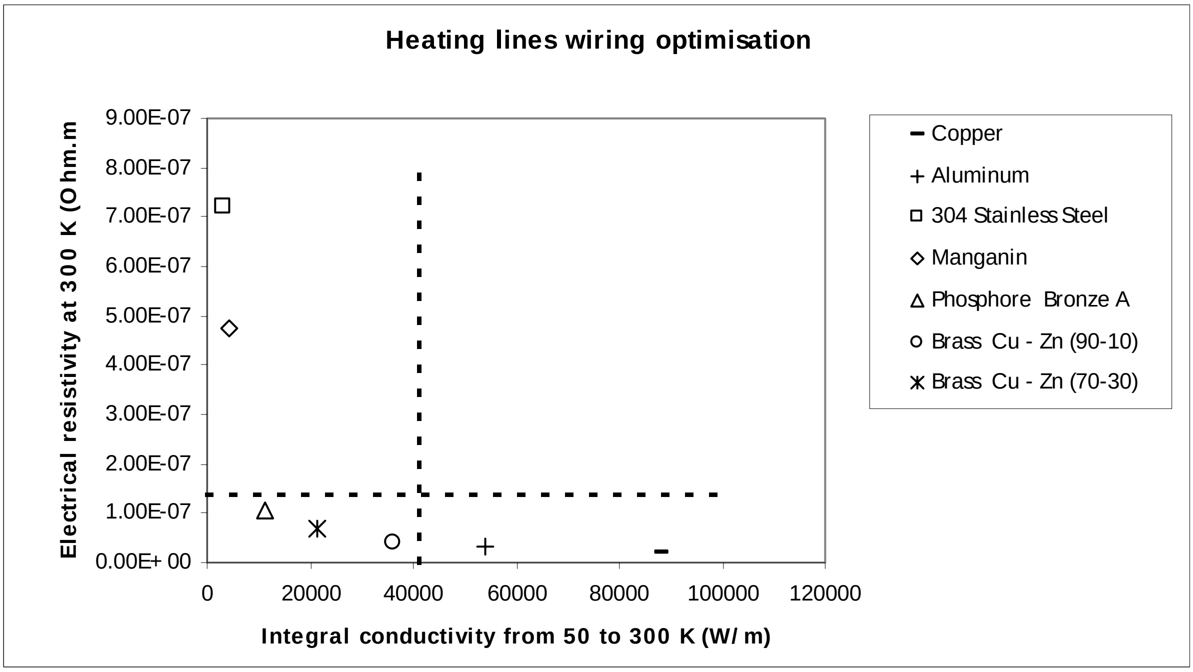
The combination of [C1] and [C3] criteria, associated to the number of wires, lead to a maximum IK. This maximum IK eliminates the use of the most conductive materials as shown in figure below (the accepted materials are those on the left side of the borderline).



### Heating lines wiring optimisation 1/2

The combination of [C4] and [C5] criteria, associated to the min 2-wire heaters circuits resistance (=29.7 Ω), lead to a maximum $R_e$. This maximum $R_e$ eliminates the use of the most resistive materials.

Both borderlines define an acceptance area (lower left side) as shown in next figure.



### Heating lines wiring optimisation 2/2

The best material is Brass.

***The selected material for sensors wires is therefore Brass.***

***A back-up material may be Phosphore Bronze.***

### A4 – 4 – 2-2 Final definition and verification

As for the sensors wires, the chosen material is brass. The final definition is AWG24 Brass . The wires design is verified wrt heat loads, power loss at heaters level and max amperage.

### A4 – 4 – 2-2-1 Heat loads

The design verification, in term of heat loads, is given here below :

| Harness description - | Material description | AWG - | nb wires - | length (m) | S per cond (m²) | Tmax (K) | Tmin (K) | I cond (W/m) | Load (mW) |
|---|---|---|---|---|---|---|---|---|---|
| Heaters PR | Brass | 24 | 8 | 2 | 3.24E-07 | 300 | 50 | 2.1E+04 | **20** |
| Heaters SR | Brass | 24 | 4 | 2 | 3.24E-07 | 300 | 50 | 2.1E+04 | **10** |
| Heaters FPU | Brass | 24 | 8 | 2 | 3.24E-07 | 300 | 50 | 2.1E+04 | **20** |
| Total heaters harness | | | | | | | | | **50** |

**Heating lines wiring verification / Heat loads**

The resulting heat loads appear acceptable, though slightly exceeding the initial upper limit.

Note :

- The 2m length assumption is the same as for the sensors lines.

### A4 – 4 – 2-2-2 Power loss due to wires resistance

The next table shows the final power available at heaters level:

| Line | Re (Ohm.m) | AWG - | Section (m²) | Length (m) | Voltage (V) | Wires resistance (Ohm) | Heaters resistance (Ohm) | Power in heater (W) | Theoretical power in heater (W) | Loss of power (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| PR N1 | 7.21E-08 | 24 | 2.4E-07 | 6 | 28 | 1.8E+00 | 32.8 | 21.5 | 23.9 | 10 |
| PR N2 | 7.21E-08 | 24 | 2.4E-07 | 6 | 28 | 1.8E+00 | 30.7 | 22.8 | 25.6 | 11 |
| PR R | 7.21E-08 | 24 | 2.4E-07 | 6 | 28 | 9.0E-01 | 15.9 | 44.3 | 49.5 | 10 |
| SR N&R | 7.21E-08 | 24 | 2.4E-07 | 6 | 28 | 1.8E+00 | 29.7 | 23.5 | 26.4 | 11 |

**Heating lines wiring verification / Power loss due to wires resistance**

The power loss is below the 15% goal.

Notes :

- $R_e$ value at ambient (heaters operating mode).
- Wires are assumed to be doubled for PR redundant line (hence a twice as low wires resistance).
- The wiring length is assumed equal to 3m (6m forth and back).
- The exact wires definition (type of Brass and cross section) is drawn from supplier data (see [RD**1**])

### A4 – 4 – 2-2-3 Max amperage

The wires definition is compatible with max amperage.

Indeed :

- Maximum current admissible for 24AWG brass is 1.95 A which, taking into account 50% derating, becomes 0.97A
- With a 28V PCDU output voltage, and according to heating needs, the max amperage seen by the SR wires (worst case) will be ≤ 0.95A

## A4 – 5 Conclusion

The chosen wire for **sensors lines** wiring is **AWG28 Brass**. This choice leads to the following performance :

- Temperature measurement uncertainty due to wires resistance @50K ≈ ± 0.2K
- Heat leaks on cold stage (50K) ≈ 100mW

The chosen wire for **heating lines** is **AWG24 Brass**. This choice leads to the following performance :

- Power loss in wires ≈ 10%
- Heat leaks on cold stage (50K) ≈ 50mW

This definition is included in global TMM modelling.

# APPENDIX 5

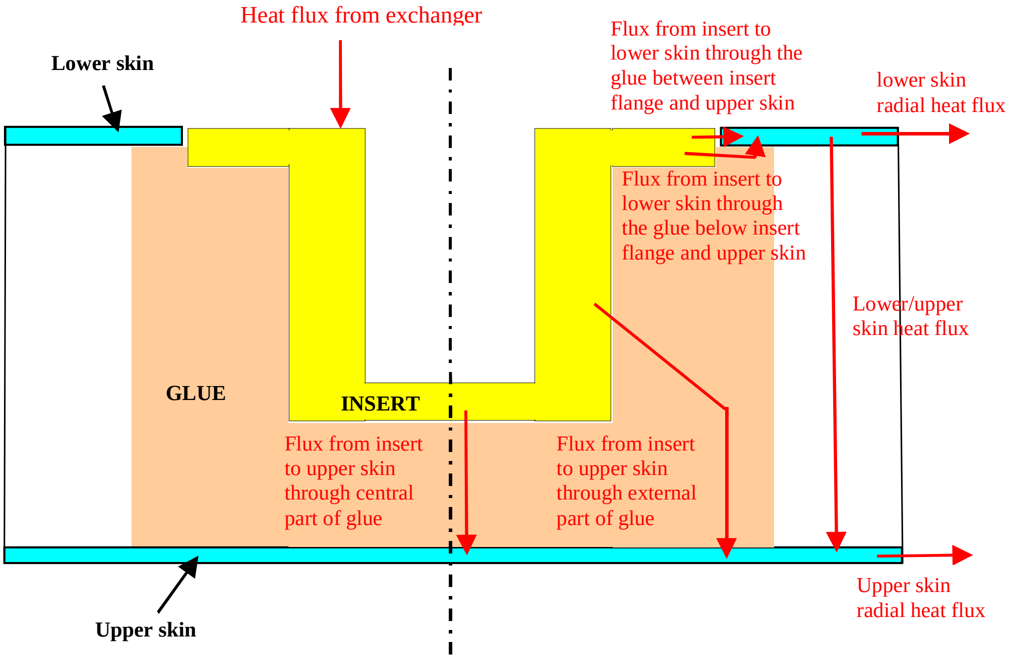
## PPLM INTERFACES : SVM STRUCTURE TEMPERATURE

| LABEL | T EOL + uncertainties (K) | **SVM hot&nom (K) in TMM** | T BOL survival - uncertainties (K) | **SVM safe (K) in TMM** |
|---|---|---|---|---|
| Solar Array (+Y.+Z) | 398.8 | **398.8** | 373.8 | **373.8** |
| Solar Array (+Y.-Z) | 399.4 | **399.4** | 374.1 | **374.1** |
| Solar Array (-Y.-Z) | 399.4 | **399.4** | 372.7 | **372.7** |
| Solar Array (-Y.+Z) | 399.1 | **399.1** | 373.9 | **373.9** |
| SVM Top (+Y.+Z) | 301.3 | **301.3** | 252.5 | **252.5** |
| SVM Top (+Y.-Z) | 300.9 | **300.9** | 259.1 | **259.1** |
| SVM Top (-Y.-Z) | 301.2 | **301.2** | 265.6 | **265.6** |
| SVM Top (-Y.+Z) | 300.4 | **300.4** | 266.0 | **266.0** |
| Sub-platform (+Y.+Z) | 306.5 | **306.5** | 262.2 | **262.2** |
| Sub-platform (+Y.-Z) | 306.0 | **306.0** | 258.5 | **258.5** |
| Sub-platform (-Y.-Z) | 304.1 | **304.1** | 254.4 | **254.4** |
| Sub-platform (-Y.+Z) | 306.3 | **306.3** | 265.9 | **265.9** |
| SVM radiator (-Y.+Z) | 284.5 | **284.5** | 256.3 | **256.3** |
| SVM radiator (+Z) | 281.9 | **281.9** | 239.9 | **239.9** |
| SVM radiator (+Y.+Z) | 287.7 | **287.7** | 235.9 | **235.9** |
| SVM radiator (+Y) | 286.6 | **286.6** | 242.1 | **242.1** |
| SVM radiator (+Y.-Z) | 261.9 | **261.9** | 236.3 | **236.3** |
| SVM radiator (-Z) | 263.3 | **263.3** | 238.1 | **238.1** |
| SVM radiator (-Y.-Z) | 259.1 | **259.1** | 237.8 | **237.8** |
| SVM radiator (-Y) | 284.5 | **284.5** | 257.7 | **257.7** |
| BEU (radiative area) | 281.3 | **310.0** | 232.1 | **253.9** |
| BEU lateral -Y | 309.8 | **-** | 254.1 | **-** |
| BEU central | 304.1 | **-** | 247.9 | **-** |
| BEU lateral +Y | 310.4 | **-** | 253.9 | **-** |
| PAU (radiative area) | 266.6 | **269.3** | 229.9 | **232.2** |
| I/F struts (+Y.+Z) | 301.6 | **301.6** | 257.8 | **257.8** |
| I/F struts (+Y) | 301.5 | **301.5** | 257.8 | **257.8** |
| I/F struts (+Y.-Z) | 304.4 | **304.4** | 250.9 | **250.9** |
| I/F struts (-Y.-Z) | 304.2 | **304.2** | 251.0 | **251.0** |
| I/F struts (-Y) | 302.0 | **302.0** | 264.2 | **264.2** |
| I/F struts (-Y.+Z) | 301.4 | **301.4** | 260.3 | **260.3** |

# APPENDIX 6

## INSERT DETAILED MODELLING

Next picture shows how main thermal paths, around the insert, are identified :



Next table shows the heat fluxes distribution along different thermal paths, with several assumptions on the glue filling :

| ***Heat balance on 20 mm around insert*** | Assumption on glue thickness between insert flange and lower skin | | | |
|---|---|---|---|---|
| | **100%** | 50% | **10%** | 1% |
| Insert flange to lower skin (through the glue) | **57,4%** | 40,7% | **12,2%** | 1,4% |
| Glue under lower skin | **27,8%** | 39,0% | **58,0%** | 65,3% |
| ***Lower skin total flux*** | ***85,2%*** | ***79,6%*** | ***70,2%*** | ***66,7%*** |
| Lower skin radial heat flux | **83,9%** | 78,6% | **69,5%** | 66,1% |
| Lower skin - Upper skin (through nida) | **1,3%** | 1,1% | **0,7%** | 0,6% |
| Glue (central part) to upper skin | **8,3%** | 11,4% | **16,7%** | 18,7% |
| Glue (external part) to upper skin | **6,5%** | 9,0% | **13,1%** | 14,7% |
| ***Upper skin total flux*** | ***16,1%*** | ***21,4%*** | ***30,5%*** | ***33,9%*** |
| Upper skin radial heat flux | **16,0%** | 21,3% | **30,3%** | 33,8% |
| Upper skin radiative flux to space | **0,2%** | 0,2% | **0,2%** | 0,2% |

# APPENDIX 7

## TEMPERATURES LISTING

## HOT CASE

| | | |
|---|---|---|
| 1001 | Solar Array vs. satellit | 285.19492 |
| 1002 | Solar Array vs. satellit | 281.13587 |
| 1003 | Solar Array vs. satellit | 280.58879 |
| 1004 | Solar Array vs. satellit | 283.42355 |
| 1010 | Solar Array | 399.39999 |
| 1061 | I/F struts -Y | 302.00000 |
| 1062 | I/F struts -Y-Z | 304.20001 |
| 1063 | I/F struts +Y-Z | 304.39999 |
| 1064 | I/F struts +Y | 301.50000 |
| 1065 | I/F struts +Y+Z | 301.60001 |
| 1066 | I/F struts -Y+Z | 301.39999 |
| 1501 | FIRING CONE | 247.60001 |
| 1503 | THRUSTER | 225.80000 |
| 1504 | HEAD PLATE DISC | 252.00000 |
| 1505 | HEAT BARRIER | 253.70000 |
| 1507 | HEAT FLANGE | 269.00000 |
| 1509 | HEAT FLANGE | 287.00000 |
| 1510 | HEAT FLANGE | 287.10001 |
| 1521 | FIRING CONE | 247.20000 |
| 1523 | THRUSTER | 229.60001 |
| 1524 | HEAD PLATE DISC | 251.30000 |
| 1525 | HEAT BARRIER | 252.89999 |
| 1527 | HEAT FLANGE | 268.00000 |
| 1529 | HEAT FLANGE | 287.00000 |
| 1530 | HEAT FLANGE | 286.89999 |
| 1532 | THR_COM | 292.70001 |
| 1533 | FCV MAIN | 287.00000 |
| 1534 | FCV MAIN | 287.00000 |
| 1543 | HEAT FLANGE | 287.00000 |
| 1544 | HEAT FLANGE | 287.00000 |
| 1546 | HEAT FLANGE | 193.10001 |
| 1701 | FIRING CONE | 249.89999 |
| 1703 | THRUSTER | 231.70000 |
| 1704 | HEAD PLATE DISC | 254.10001 |
| 1705 | HEAT BARRIER | 255.70000 |
| 1707 | HEAT FLANGE | 270.00000 |
| 1709 | HEAT FLANGE | 287.29999 |
| 1710 | HEAT FLANGE | 287.29999 |
| 1721 | FIRING CONE | 245.30000 |
| 1723 | THRUSTER | 224.80000 |
| 1724 | HEAD PLATE DISC | 249.60001 |
| 1725 | HEAT BARRIER | 251.20000 |
| 1727 | HEAT FLANGE | 267.10001 |
| 1729 | HEAT FLANGE | 286.89999 |
| 1730 | HEAT FLANGE | 286.79999 |
| 1732 | THR_COM | 293.20001 |
| 1733 | FCV MAIN | 287.29999 |
| 1734 | FCV MAIN | 286.89999 |
| 1743 | HEAT FLANGE | 287.39999 |
| 1744 | HEAT FLANGE | 287.00000 |
| 1746 | HEAT FLANGE | 193.39999 |
| 2001 | SVM Rad -Y+Z | 284.50000 |
| 2002 | SVM Rad +Z | 281.89999 |
| 2003 | SVM Rad +Y+Z | 287.70001 |
| 2004 | SVM Rad +Y | 286.60001 |
| 2005 | SVM Rad +Y-Z | 261.89999 |
| 2006 | SVM Rad -Z | 263.29999 |
| 2007 | SVM Rad -Y-Z | 259.10001 |
| 2008 | SVM Rad -Y | 284.50000 |
| 3000 | SVM I/F | 300.00000 |
| 3001 | MLI SVM Top +Z | 186.04116 |
| 3002 | MLI SVM Top +Y | 190.73742 |
| 3003 | MLI SVM Top -Z | 196.91539 |
| 3004 | MLI SVM Top +Z-Y | 185.97056 |
| 3011 | SVM Top +Y+Z | 301.29999 |
| 3012 | SVM Top +Y-Z | 300.89999 |
| 3013 | SVM Top -Y-Z | 301.20001 |
| 3014 | SVM Top -Y+Z | 300.39999 |
| 3501 | MLI on Subplatform +Y+Z | 193.52504 |
| 3502 | MLI on Subplatform +Y-Z | 201.18697 |
| 3503 | MLI on Subplatform -Y-Z | 204.02824 |
| 3504 | MLI on Subplatform -Y+Z | 193.76194 |
| 3511 | Subplatform +Y+Z | 306.50000 |
| 3512 | Subplatform +Y-Z | 306.00000 |
| 3513 | Subplatform -Y-Z | 304.10001 |
| 3514 | Subplatform -Y+Z | 306.29999 |
| 3550 | MLI on Subplatform hole | 196.90080 |
| 3560 | Subplatform hole | 306.29999 |
| 3600 | MLI BEU | 221.36022 |
| 3901 | BAFFLE STR1 | 165.30000 |
| 3902 | BAFFLE STR1 | 167.89999 |
| 3922 | LGA2 | 268.50000 |
| 3962 | LGA3 | 287.29999 |
| 4901 | BAFFLE STR1 | 191.39999 |
| 4902 | BAFFLE STR1 | 207.00000 |
| 4921 | SAS1 | 227.89999 |
| 4922 | LGA2 | 242.89999 |
| 4961 | SREM | 156.30000 |
| 4962 | LGA3 | 238.80000 |
| 4963 | VMC | 220.20000 |
| 7522 | MLI PAU | 209.52696 |
| 8501 | NOZZLE | 218.80000 |
| 8503 | DECOMP. COVER | 216.39999 |
| 8512 | HEAT BARRIER | 291.60001 |
| 8513 | HEAT BARRIER | 281.79999 |
| 8514 | HEAT BARRIER | 276.70001 |
| 8533 | DECOMP. COVER | 218.60001 |
| 8601 | NOZZLE | 212.10001 |
| 8603 | DECOMP. COVER | 210.39999 |
| 8612 | HEAT BARRIER | 291.00000 |
| 8613 | HEAT BARRIER | 279.39999 |
| 8614 | HEAT BARRIER | 275.29999 |
| 8633 | DECOMP. COVER | 211.80000 |
| 8701 | NOZZLE | 218.99001 |
| 8703 | DECOMP. COVER | 216.39999 |
| 8712 | HEAT BARRIER | 294.50000 |
| 8713 | HEAT BARRIER | 284.00000 |
| 8714 | HEAT BARRIER | 278.70001 |
| 8733 | DECOMP. COVER | 218.80000 |
| 8801 | NOZZLE | 220.10001 |
| 8803 | DECOMP. COVER | 217.60001 |
| 8812 | HEAT BARRIER | 294.50000 |
| 8813 | HEAT BARRIER | 284.10001 |
| 8814 | HEAT BARRIER | 278.79999 |
| 8833 | DECOMP. COVER | 219.89999 |
| 13001 | WG_BEU_VG1_Ti | 260.44480 |
| 13002 | WG_BEU_VG1 | 195.46192 |
| 13003 | WG_VG1_VG2 | 152.42279 |
| 13004 | WG_VG1_VG2 | 137.42840 |
| 13005 | WG_VG1_VG2 | 124.15324 |
| 13006 | WG_VG1_VG2 | 111.37404 |
| 13007 | WG_VG2_VG3 | 98.97409 |
| 13008 | WG_VG2_VG3 | 88.20025 |
| 13009 | WG_VG2_VG3 | 77.54541 |
| 13010 | WG_VG2_VG3 | 66.41745 |
| 13011 | WG_SS | 56.74878 |
| 13012 | WG_SS | 49.22564 |
| 13013 | WG_SS | 40.77525 |
| 13014 | WG_SS | 30.05494 |
| 13015 | WG_Cu | 22.27520 |

| | | |
|---|---|---|
| 13016 | WG_Cu | 22.15476 |
| 13017 | WG_Cu | 22.03310 |
| 13018 | WG_Cu | 21.91022 |
| 13100 | I/F_WG_VG1 | 161.68363 |
| 13200 | I/F_WG_VG2 | 104.75716 |
| 13300 | I/F_WG_VG3 | 60.45320 |
| 13500 | I/F_WG_ss_cu | 22.33514 |
| 15001 | Harnes_BEUVG1 | 245.40861 |
| 15002 | Harnes_BEUVG1 | 198.20745 |
| 15003 | Harnes_VG1_VG2 | 164.17324 |
| 15004 | Harnes_VG1_VG2 | 149.01522 |
| 15005 | Harnes_VG1_VG2 | 136.67843 |
| 15006 | Harnes_VG1_VG2 | 126.04835 |
| 15007 | Harnes_VG2_VG3 | 114.24018 |
| 15008 | Harnes_VG2_VG3 | 103.27858 |
| 15009 | Harnes_VG2_VG3 | 94.34888 |
| 15010 | Harnes_VG2_VG3 | 86.83798 |
| 15011 | Harnes_VG3_TOP | 78.61411 |
| 15012 | Harnes_VG3_TOP | 70.94354 |
| 15013 | Harnes_VG3_TOP | 64.89569 |
| 15014 | Harnes_VG3_TOP | 59.94884 |
| 15015 | Harnes_TOP_bend | 55.98358 |
| 15016 | Harnes_TOP_bend | 52.75135 |
| 15017 | Harnes_TOP_bend | 49.80237 |
| 15018 | harness_bend | 47.07878 |
| 15019 | harness_bend | 44.54103 |
| 15020 | harness_bend | 42.15671 |
| 15021 | harness_bend | 39.89968 |
| 15022 | harness_bend | 37.74893 |
| 15023 | harness_bend | 35.68763 |
| 15024 | harness_bend | 33.70085 |
| 15025 | harness_bend | 31.77687 |
| 15026 | harness_bend | 29.90408 |
| 15027 | harness_bend | 28.04924 |
| 15028 | harness_bend_FPU | 26.22360 |
| 15029 | harness_bend_FPU | 24.42041 |
| 15030 | harness_bend_FPU | 22.63750 |
| 15101 | I/F_Hr_VG1 | 174.11052 |
| 15201 | I/F_Hr_VG2 | 121.16714 |
| 15301 | I/F_Hr_VG3 | 83.52184 |
| 15450 | I/F_Hr_VG3-ss_cu | 67.78416 |
| 15501 | I/F_Hr_ss_cu | 57.75578 |
| 16301 | Block 4 | 4.68416 |
| 16441 | Block 4 | 4.69296 |
| 16701 | Block 4 | 4.70416 |
| 16702 | Block 4 | 4.70415 |
| 16707 | Block 4 | 4.70415 |
| 16708 | Block 4 | 4.70413 |
| 16709 | Block 4 | 4.70414 |
| 18001 | Tube_BEU_VG1 | 270.60579 |
| 18002 | Tube_BEU_VG1 | 206.24270 |
| 18003 | Tube_VG1_VG2 | 160.38756 |
| 18004 | Tube_VG1_VG2 | 137.80712 |
| 18005 | Tube_VG1_VG2 | 123.23153 |
| 18006 | Tube_VG1_VG2 | 110.24770 |
| 18007 | Tube_VG2_VG3 | 96.24887 |
| 18008 | Tube_VG2_VG3 | 84.04949 |
| 18009 | Tube_VG2_VG3 | 73.99986 |
| 18010 | Tube_VG2_VG3 | 65.15553 |
| 18011 | Tube_VG3_TOP | 55.88980 |
| 18012 | Tube_VG3_TOP | 48.76126 |
| 18013 | Tube_VG3_TOP | 41.49479 |
| 18014 | Tube_VG3_TOP | 32.41274 |
| 18015 | Tube_TOP_END | 23.14270 |
| 18090 | I/F_Ti_GFRP | 269.25394 |
| 18100 | FLANGE_Thermal_Braid_VG1 | 178.95442 |
| 18101 | I/F_Column_FLANGE_Therma | 179.70469 |
| 18110 | Panels_VG1 | 169.62276 |
| 18200 | FLANGE_Thermal_Braid_VG2 | 104.75688 |
| 18201 | I/F_Column_FLANGE_Therma | 104.70058 |
| 18210 | Panels_VG2 | 103.47234 |
| 18300 | FLANGE_Thermal_Braid_VG3 | 60.45469 |
| 18301 | I/F_Column_FLANGE_Therma | 60.63516 |
| 18310 | Panels_VG3 | 62.83571 |
| 18410 | Panels_Plane_VG3 | 54.37068 |
| 18450 | I/F_Column_VG3-ss_cu | 45.50122 |
| 18500 | FLANGE_SS_CU | 22.34075 |
| 18501 | I/F_Column_FLANGE_Therma | 23.10252 |
| 18510 | Panel_plaine_TOP | 29.45996 |
| 29010 | Harness_SVM | 300.00000 |
| 29020 | Harness2 | 278.49159 |
| 29030 | Harness3 | 254.96289 |
| 29040 | Harness4 | 229.25929 |
| 29050 | Harness5 | 201.37714 |
| 29060 | Harness6 | 171.62116 |
| 29070 | Harness7 | 140.75864 |
| 29080 | Harness8 | 109.95248 |
| 29090 | Harness9 | 80.21367 |
| 29100 | Harness_3rd_Gr | 51.31669 |
| 29110 | Harness_SVM | 300.00000 |
| 29120 | Harness2 | 278.68088 |
| 29130 | Harness3 | 255.37686 |
| 29140 | Harness4 | 229.93593 |
| 29150 | Harness5 | 202.34967 |
| 29160 | Harness6 | 172.90344 |
| 29170 | Harness7 | 142.32715 |
| 29180 | Harness8 | 111.74547 |
| 29190 | Harness9 | 82.17652 |
| 29200 | Harness_3rd_Gr | 53.52909 |
| 30000 | Baffle +Y ext | 47.55771 |
| 30001 | Baffle -Z ext | 49.57717 |
| 30002 | Baffle -Z ext | 48.33775 |
| 30003 | Baffle +Z ext | 49.28793 |
| 30004 | Baffle +Z ext | 48.22022 |
| 30005 | Baffle -Y ext | 49.40555 |
| 30500 | Baffle +Y int | 47.56709 |
| 30501 | Baffle -Z int49.60692 | |
| 30502 | Baffle -Z int48.34852 | |
| 30503 | Baffle +Z int | 49.31188 |
| 30504 | Baffle +Z int | 48.23092 |
| 30505 | Baffle -Y int49.39300 | |
| 31000 | Main panel -Z low +Y | 52.22398 |
| 31001 | Main panel -Z low +Y | 47.88049 |
| 31002 | Main panel -Z low +Y | 45.53559 |
| 31003 | Main panel -Z low +Y | 47.65024 |
| 31005 | Main panel -Z +Y | 47.39563 |
| 31006 | Main panel -Z +Y | 47.37601 |
| 31007 | Main panel -Z +Y | 47.66203 |
| 31008 | Main panel -Z +Y | 47.97297 |
| 31009 | Main panel -Z +Y | 48.57914 |
| 31010 | Main panel -Z low -Y | 47.19105 |
| 31011 | Main panel -Z low -Y | 46.40612 |
| 31012 | Main panel -Z low -Y | 45.53211 |
| 31013 | Main panel -Z low -Y | 46.48150 |
| 31015 | Main panel -Z -Y | 46.54426 |
| 31016 | Main panel -Z -Y | 46.63076 |
| 31017 | Main panel -Z -Y | 47.33193 |

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|---|---|---|
| 31018 | Main panel -Z -Y | 47.64901 |
| 31019 | Main panel -Z -Y | 48.54846 |
| 31020 | Main panel -Z | 50.08668 |
| 31021 | Main panel -Z | 52.41220 |
| 31022 | Main panel -Z | 50.13692 |
| 31023 | Main panel -Z | 53.72392 |
| 31024 | Main panel -Z Top +Y | 45.34490 |
| 31025 | Main panel -Z Top | 45.35192 |
| 31026 | Main panel -Z Top -Y | 45.34485 |
| 31027 | Main panel -Z Top +Y | 43.48248 |
| 31028 | Main panel -Z Top | 43.32065 |
| 31029 | Main panel -Z Top -Y | 43.47794 |
| 31030 | Main panel -Z Top +Y | 42.71029 |
| 31031 | Main panel -Z low +Y | 42.41195 |
| 31032 | Main panel -Z Top -Y | 42.70745 |
| 31033 | Main panel -Z Top | 41.99185 |
| 31100 | Main panel +Z low +Y | 51.88091 |
| 31101 | Main panel +Z low +Y | 47.83572 |
| 31102 | Main panel +Z low +Y | 45.69418 |
| 31103 | Main panel +Z low +Y | 47.66563 |
| 31105 | Main panel +Z +Y | 47.38997 |
| 31106 | Main Panel +Z medium +Y | 47.37933 |
| 31107 | Main panel +Z medium +Y | 47.68178 |
| 31108 | Main panel +Z medium +Y | 47.95893 |
| 31109 | Main panel +Z +Y | 48.61936 |
| 31110 | Main panel +Z low -Y | 47.13391 |
| 31111 | Main panel +Z low -Y | 46.41983 |
| 31112 | Main panel +Z low -Y | 45.60406 |
| 31113 | Main panel +Z low -Y | 46.47931 |
| 31115 | Main panel +Z -Y | 46.55649 |
| 31116 | Main panel +Z medium -Y | 46.63208 |
| 31117 | Main panel +Z medium -Y | 47.35150 |
| 31118 | Main panel +Z medium -Y | 47.63231 |
| 31119 | Main panel +Z -Y | 48.58972 |
| 31120 | Main panel top +Z +Y | 50.04986 |
| 31121 | Main panel top +Z | 52.40839 |
| 31122 | Main panel top +Z -Y | 50.08712 |
| 31123 | Main panel top +Z | 53.62397 |
| 31124 | Main panel +Z Top +Y | 45.36763 |
| 31125 | Main panel +Z Top | 45.39440 |
| 31126 | Main panel +Z Top -Y | 45.36734 |
| 31127 | Main panel +Z Top +Y | 43.49394 |
| 31128 | Main panel +Z Top | 43.33001 |
| 31129 | Main panel +Z Top -Y | 43.48948 |
| 31130 | Main panel +Z Top +Y | 42.72278 |
| 31131 | Main panel +Z low +Y | 42.42030 |
| 31132 | Main panel +Z Top -Y | 42.71998 |
| 31133 | Main panel +Z Top | 42.01128 |
| 31203 | Doubler panel -Z low +Y | 47.62555 |
| 31206 | Doubler panel -Z medium | 47.36652 |
| 31208 | Doubler panel -Z medium | 47.96993 |
| 31213 | Doubler panel -Z low -Y | 46.48697 |
| 31216 | Doubler panel -Z medium | 46.62800 |
| 31218 | Doubler panel -Z medium | 47.65353 |
| 31220 | Doubler panel top -Z +Y | 50.09537 |
| 31221 | Doubler panel top -Z | 52.42208 |
| 31222 | Doubler panel top -Z +Y | 50.15975 |
| 31223 | Doubler panel top -Z | 53.96100 |
| 31303 | Doubler panel +Z low +Y | 47.64999 |
| 31306 | Doubler panel +Z medium | 47.37598 |
| 31308 | Doubler panel +Z medium | 47.97301 |
| 31313 | Doubler panel +Z low -Y | 46.48154 |
| 31316 | Doubler panel +Z medium | 46.63075 |
| 31318 | Doubler panel +Z medium | 47.64908 |
| 31320 | Doubler panel top +Z +Y | 50.08683 |
| 31321 | Doubler panel top +Z | 52.41230 |
| 31322 | Doubler panel top +Z -Y | 50.13726 |
| 31323 | Doubler panel top +Z | 53.72534 |
| 31400 | Dismountable panel face | 45.40903 |
| 31401 | Dismountable panel face | 45.52927 |
| 31500 | Triangle Panel down . . | 45.32496 |
| 31501 | Triangle Panel up . . | 45.34355 |
| 31600 | strut - Y panel . | 45.42714 |
| 31601 | strut - Y panel . | 45.18489 |
| 31602 | strut - Y panel . | 45.07485 |
| 31603 | strut - Y panel . | 45.09688 |
| 31604 | strut - Y panel . | 45.25593 |
| 31605 | strut - Y panel . | 45.56006 |
| 31606 | strut - Y panel . | 46.01422 |
| 31607 | strut - Y panel . | 46.62712 |
| 31608 | strut - Y panel . | 47.40495 |
| 31609 | strut - Y panel . | 48.35667 |
| 31610 | strut + Y panel . | 45.49001 |
| 31611 | strut + Y panel . | 45.26332 |
| 31612 | strut + Y panel . | 45.16364 |
| 31613 | strut + Y panel . | 45.19091 |
| 31614 | strut + Y panel . | 45.35110 |
| 31615 | strut + Y panel . | 45.65075 |
| 31616 | strut + Y panel . | 46.09540 |
| 31617 | strut + Y panel . | 46.69602 |
| 31618 | strut + Y panel . | 47.45713 |
| 31619 | strut + Y panel . | 48.38991 |
| 31620 | Bottom strut panel . . | 44.29661 |
| 31621 | Bottom strut panel . . | 44.31590 |
| 31622 | Bottom strut panel . . | 44.35547 |
| 31623 | Bottom strut panel . . | 44.41811 |
| 31624 | Bottom strut panel . . | 44.50534 |
| 31625 | Bottom strut panel . . | 44.61678 |
| 31626 | Bottom strut panel . . | 44.75138 |
| 31627 | Bottom strut panel . . | 44.90879 |
| 31628 | Bottom strut panel . . | 45.08814 |
| 31629 | Bottom strut panel . . | 45.28947 |
| 31630 | Back strut panel . . | 43.98328 |
| 31631 | Back strut panel . . | 43.24309 |
| 31632 | Back strut panel . . | 42.71454 |
| 31633 | Back strut panel . . | 42.40850 |
| 31634 | Back strut panel . . | 42.32456 |
| 31635 | Back strut panel . . | 42.46411 |
| 31636 | Back strut panel . . | 42.82267 |
| 31637 | Back strut panel . . | 43.39237 |
| 31638 | Back strut panel . . | 44.15920 |
| 31639 | Back strut panel . . | 45.11878 |
| 31640 | top strut panel . . | 45.11167 |

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|---|---|---|
| 31641 | top strut panel . . | 44.18040 |
| 31642 | top strut panel . . | 43.39509 |
| 31643 | top strut panel . . | 42.75202 |
| 31644 | top strut panel . . | 42.25283 |
| 31645 | top strut panel . . | 41.89766 |
| 31646 | top strut panel . . | 41.68741 |
| 31647 | top strut panel . . | 41.62135 |
| 31648 | top strut panel . . | 41.69978 |
| 31649 | top strut panel . . | 41.92336 |
| 31700 | SR panel +Z low | 46.11589 |
| 31701 | SR panel +Z low | 46.69933 |
| 31702 | SR panel +Z low | 46.11275 |
| 31703 | SR panel +Z low | 46.31693 |
| 31704 | SR panel +Z medium | 46.19866 |
| 31705 | SR panel +Z medium2 | 46.21117 |
| 31706 | SR panel +Z Top | 46.28377 |
| 31710 | SR panel -Z low | 46.11283 |
| 31711 | SR panel -Z low | 46.71126 |
| 31712 | SR panel -Z low | 46.11442 |
| 31713 | SR panel -Z low | 46.31867 |
| 31714 | SR panel -Z medium | 46.19736 |
| 31715 | SR panel -Z medium2 | 46.20904 |
| 31716 | SR panel -Z top | 46.26868 |
| 31800 | strut + Y panel . | 45.90744 |
| 31801 | strut + Y panel . | 45.85547 |
| 31802 | strut + Y panel . | 45.80406 |
| 31803 | strut + Y panel . | 45.75367 |
| 31804 | strut + Y panel . | 45.71683 |
| 31805 | strut + Y panel . | 45.71362 |
| 31806 | strut + Y panel . | 45.74596 |
| 31807 | strut + Y panel . | 45.81048 |
| 31808 | strut + Y panel . | 45.90337 |
| 31809 | strut + Y panel . | 46.02298 |
| 31810 | strut - Y panel . | 45.88483 |
| 31811 | strut - Y panel . | 45.88366 |
| 31812 | strut - Y panel . | 45.88502 |
| 31813 | strut - Y panel . | 45.89164 |
| 31814 | strut - Y panel . | 45.91397 |
| 31815 | strut - Y panel . | 45.97281 |
| 31816 | strut - Y panel . | 46.07195 |
| 31817 | strut - Y panel . | 46.20582 |
| 31818 | strut - Y panel . | 46.37090 |
| 31819 | strut - Y panel . | 46.56758 |

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|---|---|---|
| 31901 | brac_strut+Y | 240.07132 |
| 31902 | brac_strut+Y | 196.60414 |
| 31903 | brac_strut+Y | 175.17793 |
| 31904 | brac_strut+Y | 164.27625 |
| 31905 | brac_strut+Y | 158.75577 |
| 31906 | brac_strut+Y | 156.07408 |
| 31907 | brac_strut+Y | 155.30557 |
| 31908 | brac_strut+Y | 155.29787 |
| 31909 | brac_strut+Y | 155.67064 |
| 31910 | brac_strut+Y | 156.17707 |
| 31911 | brac_strut-Y | 243.54085 |
| 31912 | brac_strut-Y | 204.75302 |
| 31913 | brac_strut-Y | 186.74392 |
| 31914 | brac_strut-Y | 177.95476 |
| 31915 | brac_strut-Y | 173.45589 |
| 31916 | brac_strut-Y | 171.38294 |
| 31917 | brac_strut-Y | 170.04843 |
| 31918 | brac_strut-Y | 168.63047 |
| 31919 | brac_strut-Y | 166.04995 |
| 31920 | brac_strut-Y | 161.12843 |
| 31951 | brac_CFRP+Y | 50.10121 |
| 31952 | brac_CFRP+Y | 49.61524 |
| 31953 | brac_CFRP+Y | 49.13599 |
| 31954 | brac_CFRP+Y | 48.66253 |
| 31955 | brac_CFRP+Y | 48.19470 |
| 31956 | brac_CFRP+Y | 47.73177 |
| 31957 | brac_CFRP+Y | 47.27280 |
| 31958 | brac_CFRP+Y | 46.81707 |
| 31959 | brac_CFRP+Y | 46.36343 |
| 31960 | brac_CFRP+Y | 45.91027 |
| 31961 | brac_CFRP-Y | 49.79476 |
| 31962 | brac_CFRP-Y | 49.50647 |
| 31963 | brac_CFRP-Y | 49.23101 |
| 31964 | brac_CFRP-Y | 48.96819 |
| 31965 | brac_CFRP-Y | 48.71793 |
| 31966 | brac_CFRP-Y | 48.47964 |
| 31967 | brac_CFRP-Y | 48.25332 |
| 31968 | brac_CFRP-Y | 48.03862 |
| 31969 | brac_CFRP-Y | 47.83458 |
| 31970 | brac_CFRP-Y | 47.64064 |
| 32001 | strut 1 - Y (+Z) | 224.62429 |
| 32002 | strut 1 - Y (+Z) | 182.83249 |
| 32003 | strut 1 - Y (+Z) | 161.65245 |
| 32004 | strut 1 - Y (+Z) | 149.67908 |

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|---|---|---|
| 32005 | strut 1 - Y (+Z) | 142.58526 |
| 32006 | strut 1 - Y (+Z) | 137.61117 |
| 32007 | strut 1 - Y (+Z) | 132.94978 |
| 32008 | strut 1 - Y (+Z) | 127.40965 |
| 32009 | strut 1 - Y (+Z) | 131.21025 |
| 32010 | strut 1 - Y (+Z) | 127.31145 |
| 32011 | strut 1 - Y (+Z) | 114.84197 |
| 32012 | strut 1 - Y (+Z) | 105.67216 |
| 32013 | strut 1 - Y (+Z) | 98.67709 |
| 32014 | strut 1 - Y (+Z) | 93.01093 |
| 32015 | strut 1 - Y (+Z) | 88.08959 |
| 32016 | strut 1 - Y (+Z) | 83.46353 |
| 32017 | strut 1 - Y (+Z) | 84.73438 |
| 32018 | strut 1 - Y (+Z) | 83.41431 |
| 32019 | strut 1 - Y (+Z) | 75.98017 |
| 32020 | strut 1 - Y (+Z) | 69.72970 |
| 32021 | strut 1 - Y (+Z) | 63.94169 |
| 32022 | strut 1 - Y (+Z) | 58.24344 |
| 32023 | strut 1 - Y (+Z) | 52.36092 |
| 32024 | strut 1 - Y (+Z) | 50.03182 |
| 32025 | strut 1 - Y (+Z) | 52.33480 |
| 32026 | strut 1 - Y (+Z) | 50.94047 |
| 32027 | strut 1 - Y (+Z) | 49.62486 |
| 32028 | strut 1 - Y (+Z) | 48.36277 |
| 32029 | strut 1 - Y (+Z) | 47.13930 |
| 32030 | strut 1 - Y (+Z) | 45.95064 |
| 32031 | eccofoam strut 1 - Y (+Z | 221.46658 |
| 32032 | eccofoam strut 1 - Y (+Z | 184.15312 |
| 32033 | eccofoam strut 1 - Y (+Z | 162.44507 |
| 32034 | eccofoam strut 1 - Y (+Z | 150.10312 |
| 32035 | eccofoam strut 1 - Y (+Z | 142.77191 |
| 32036 | eccofoam strut 1 - Y (+Z | 137.64622 |
| 32037 | eccofoam strut 1 - Y (+Z | 132.93464 |
| 32038 | eccofoam strut 1 - Y (+Z | 128.04421 |
| 32039 | eccofoam strut 1 - Y (+Z | 130.65218 |
| 32040 | eccofoam strut 1 - Y (+Z | 126.66559 |
| 32041 | eccofoam strut 1 - Y (+Z | 115.04711 |
| 32042 | eccofoam strut 1 - Y (+Z | 105.85266 |

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|---|---|---|
| 32043 | eccofoam strut 1 - Y (+Z | 98.79113 |
| 32044 | eccofoam strut 1 - Y (+Z | 93.07719 |
| 32045 | eccofoam strut 1 - Y (+Z | 88.14615 |
| 32046 | eccofoam strut 1 - Y (+Z | 83.88352 |
| 32047 | eccofoam strut 1 - Y (+Z | 84.58386 |
| 32048 | eccofoam strut 1 - Y (+Z | 83.50556 |
| 32051 | strut 2 - Y (-Z) | 224.90535 |
| 32052 | strut 2 - Y (-Z) | 183.31007 |
| 32053 | strut 2 - Y (-Z) | 162.50809 |
| 32054 | strut 2 - Y (-Z) | 151.14506 |
| 32055 | strut 2 - Y (-Z) | 144.66776 |
| 32056 | strut 2 - Y (-Z) | 140.38606 |
| 32057 | strut 2 - Y (-Z) | 136.85901 |
| 32058 | strut 2 - Y (-Z) | 132.79328 |
| 32059 | strut 2 - Y (-Z) | 138.34497 |
| 32060 | strut 2 - Y (-Z) | 132.69577 |
| 32061 | strut 2 - Y (-Z) | 119.12045 |
| 32062 | strut 2 - Y (-Z) | 109.31610 |
| 32063 | strut 2 - Y (-Z) | 101.92703 |
| 32064 | strut 2 - Y (-Z) | 95.94339 |
| 32065 | strut 2 - Y (-Z) | 90.62056 |
| 32066 | strut 2 - Y (-Z) | 85.32769 |
| 32067 | strut 2 - Y (-Z) | 86.25972 |
| 32068 | strut 2 - Y (-Z) | 85.27335 |
| 32069 | strut 2 - Y (-Z) | 77.59286 |
| 32070 | strut 2 - Y (-Z) | 71.20621 |
| 32071 | strut 2 - Y (-Z) | 65.27572 |
| 32072 | strut 2 - Y (-Z) | 59.39019 |
| 32073 | strut 2 - Y (-Z) | 53.21237 |
| 32074 | strut 2 - Y (-Z) | 50.66754 |
| 32075 | strut 2 - Y (-Z) | 53.18510 |
| 32076 | strut 2 - Y (-Z) | 51.84856 |
| 32077 | strut 2 - Y (-Z) | 50.61336 |
| 32078 | strut 2 - Y (-Z) | 49.45812 |
| 32079 | strut 2 - Y (-Z) | 48.36808 |
| 32080 | strut 2 - Y (-Z) | 47.34340 |
| 32081 | eccofoam strut 2 - Y (-Z | 221.76420 |
| 32082 | eccofoam strut 2 - Y (-Z | 184.64635 |
| 32083 | eccofoam strut 2 - Y (-Z | 163.31883 |
| 32084 | eccofoam strut 2 - Y (-Z | 151.57145 |
| 32085 | eccofoam strut 2 - Y (-Z | 144.86257 |
| 32086 | eccofoam strut 2 - Y (-Z | 140.45566 |
| 32087 | eccofoam strut 2 - Y (-Z | 136.87127 |
| 32088 | eccofoam strut 2 - Y (-Z | 133.43169 |
| 32089 | eccofoam strut 2 - Y (-Z | 137.53601 |
| 32090 | eccofoam strut 2 - Y (-Z | 132.08114 |
| 32091 | eccofoam strut 2 - Y (-Z | 119.36346 |
| 32092 | eccofoam strut 2 - Y (-Z | 109.51723 |
| 32093 | eccofoam strut 2 - Y (-Z | 102.04761 |
| 32094 | eccofoam strut 2 - Y (-Z | 96.00275 |
| 32095 | eccofoam strut 2 - Y (-Z | 90.65931 |
| 32096 | eccofoam strut 2 - Y (-Z | 85.77368 |
| 32097 | eccofoam strut 2 - Y (-Z | 86.15815 |
| 32098 | eccofoam strut 2 - Y (-Z | 85.34239 |
| 32101 | strut 3 - Z -Y | 236.26763 |
| 32102 | strut 3 - Z -Y | 210.34540 |
| 32103 | strut 3 - Z -Y | 211.97093 |
| 32104 | strut 3 - Z -Y | 222.61849 |
| 32105 | strut 3 - Z -Y | 228.39423 |
| 32106 | strut 3 - Z -Y | 224.94141 |
| 32107 | strut 3 - Z -Y | 207.22818 |
| 32108 | strut 3 - Z -Y | 172.50856 |
| 32109 | strut 3 - Z -Y | 156.79752 |
| 32110 | strut 3 - Z -Y | 172.09664 |
| 32111 | strut 3 - Z -Y | 145.01072 |
| 32112 | strut 3 - Z -Y | 136.79925 |
| 32113 | strut 3 - Z -Y | 130.06615 |
| 32114 | strut 3 - Z -Y | 116.01986 |
| 32115 | strut 3 - Z -Y | 103.75893 |
| 32116 | strut 3 - Z -Y | 91.33537 |
| 32117 | strut 3 - Z -Y | 88.21996 |
| 32118 | strut 3 - Z -Y | 91.24885 |
| 32119 | strut 3 - Z -Y | 89.73917 |
| 32120 | strut 3 - Z -Y | 84.95639 |
| 32121 | strut 3 - Z -Y | 75.52042 |
| 32122 | strut 3 - Z -Y | 66.00809 |
| 32123 | strut 3 - Z -Y | 55.72022 |
| 32124 | strut 3 - Z -Y | 51.06926 |
| 32125 | strut 3 - Z -Y | 55.67594 |
| 32126 | strut 3 - Z -Y | 53.90392 |
| 32127 | strut 3 - Z -Y | 52.24575 |
| 32128 | strut 3 - Z -Y | 50.67322 |
| 32129 | strut 3 - Z -Y | 49.16532 |
| 32130 | strut 3 - Z -Y | 47.70353 |
| 32131 | eccofoam inside strut 3234.39440 | |
| 32132 | eccofoam inside strut 3212.25907 | |
| 32133 | eccofoam inside strut 3212.73683 | |
| 32134 | eccofoam inside strut 3222.26497 | |
| 32135 | eccofoam inside strut 3227.61559 | |
| 32136 | eccofoam inside strut 3223.76525 | |
| 32137 | eccofoam inside strut 3206.01665 | |
| 32138 | eccofoam inside strut 3173.95184 | |
| 32139 | eccofoam inside strut 3158.94173 | |
| 32140 | eccofoam inside strut 3169.26902 | |
| 32141 | eccofoam inside strut 3146.18334 | |
| 32142 | eccofoam inside strut 3136.95412 | |
| 32143 | eccofoam inside strut 3129.55498 | |
| 32144 | eccofoam inside strut 3116.11546 | |
| 32145 | eccofoam inside strut 3103.80560 | |
| 32146 | eccofoam inside strut 392.04732 | |
| 32147 | eccofoam inside strut 388.70181 | |
| 32148 | eccofoam inside strut 391.05012 | |
| 32151 | strut 4 - Z (-Y) | 231.62659 |
| 32152 | strut 4 - Z (-Y) | 195.08683 |
| 32153 | strut 4 - Z (-Y) | 178.33980 |
| 32154 | strut 4 - Z (-Y) | 170.22850 |
| 32155 | strut 4 - Z (-Y) | 166.05706 |
| 32156 | strut 4 - Z (-Y) | 163.10839 |
| 32157 | strut 4 - Z (-Y) | 159.63851 |
| 32158 | strut 4 - Z (-Y) | 152.86223 |
| 32159 | strut 4 - Z (-Y) | 155.21014 |
| 32160 | strut 4 - Z (-Y) | 152.71009 |
| 32161 | strut 4 - Z (-Y) | 135.01086 |
| 32162 | strut 4 - Z (-Y) | 122.76284 |
| 32163 | strut 4 - Z (-Y) | 113.60510 |
| 32164 | strut 4 - Z (-Y) | 105.91539 |
| 32165 | strut 4 - Z (-Y) | 98.49498 |
| 32166 | strut 4 - Z (-Y) | 90.05567 |

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|---|---|---|
| 32167 | strut 4 - Z (-Y) | 89.13309 |
| 32168 | strut 4 - Z (-Y) | 89.98020 |
| 32169 | strut 4 - Z (-Y) | 81.60904 |
| 32170 | strut 4 - Z (-Y) | 74.73219 |
| 32171 | strut 4 - Z (-Y) | 68.24816 |
| 32172 | strut 4 - Z (-Y) | 61.63653 |
| 32173 | strut 4 - Z (-Y) | 54.47635 |
| 32174 | strut 4 - Z (-Y) | 51.49302 |
| 32175 | strut 4 - Z (-Y) | 54.44399 |
| 32176 | strut 4 - Z (-Y) | 52.83006 |
| 32177 | strut 4 - Z (-Y) | 51.34097 |
| 32178 | strut 4 - Z (-Y) | 49.95291 |
| 32179 | strut 4 - Z (-Y) | 48.64273 |
| 32180 | strut 4 - Z (-Y) | 47.40528 |
| 32181 | eccofoam strut 4 - Z (-Y | 228.87606 |
| 32182 | eccofoam strut 4 - Z (-Y | 196.37408 |
| 32183 | eccofoam strut 4 - Z (-Y | 179.08310 |
| 32184 | eccofoam strut 4 - Z (-Y | 170.57544 |
| 32185 | eccofoam strut 4 - Z (-Y | 166.16748 |
| 32186 | eccofoam strut 4 - Z (-Y | 163.06434 |
| 32187 | eccofoam strut 4 - Z (-Y | 159.44075 |
| 32188 | eccofoam strut 4 - Z (-Y | 153.48035 |
| 32189 | eccofoam strut 4 - Z (-Y | 154.82410 |
| 32190 | eccofoam strut 4 - Z (-Y | 151.60621 |
| 32191 | eccofoam strut 4 - Z (-Y | 135.34410 |
| 32192 | eccofoam strut 4 - Z (-Y | 123.01980 |
| 32193 | eccofoam strut 4 - Z (-Y | 113.73186 |
| 32194 | eccofoam strut 4 - Z (-Y | 105.94176 |
| 32195 | eccofoam strut 4 - Z (-Y | 98.46322 |
| 32196 | eccofoam strut 4 - Z (-Y | 90.60930 |
| 32197 | eccofoam strut 4 - Z (-Y | 89.29738 |
| 32198 | eccofoam strut 4 - Z (-Y | 89.92693 |
| 32201 | strut 5 - Z (+Y) | 227.93544 |
| 32202 | strut 5 - Z (+Y) | 187.89843 |
| 32203 | strut 5 - Z (+Y) | 168.76564 |
| 32204 | strut 5 - Z (+Y) | 159.59944 |
| 32205 | strut 5 - Z (+Y) | 155.50290 |
| 32206 | strut 5 - Z (+Y) | 153.86872 |
| 32207 | strut 5 - Z (+Y) | 152.57070 |
| 32208 | strut 5 - Z (+Y) | 149.79844 |
| 32209 | strut 5 - Z (+Y) | 155.68996 |
| 32210 | strut 5 - Z (+Y) | 149.68517 |
| 32211 | strut 5 - Z (+Y) | 132.98745 |
| 32212 | strut 5 - Z (+Y) | 121.41557 |
| 32213 | strut 5 - Z (+Y) | 112.80454 |
| 32214 | strut 5 - Z (+Y) | 105.68512 |
| 32215 | strut 5 - Z (+Y) | 98.88160 |
| 32216 | strut 5 - Z (+Y) | 91.34590 |
| 32217 | strut 5 - Z (+Y) | 91.10906 |
| 32218 | strut 5 - Z (+Y) | 91.27400 |
| 32219 | strut 5 - Z (+Y) | 82.70196 |
| 32220 | strut 5 - Z (+Y) | 75.74682 |
| 32221 | strut 5 - Z (+Y) | 69.25613 |
| 32222 | strut 5 - Z (+Y) | 62.69955 |
| 32223 | strut 5 - Z (+Y) | 55.66818 |
| 32224 | strut 5 - Z (+Y) | 52.91004 |
| 32225 | strut 5 - Z (+Y) | 55.63569 |
| 32226 | strut 5 - Z (+Y) | 53.80266 |
| 32227 | strut 5 - Z (+Y) | 52.10464 |
| 32228 | strut 5 - Z (+Y) | 50.51382 |
| 32229 | strut 5 - Z (+Y) | 49.00556 |
| 32230 | strut 5 - Z (+Y) | 47.56896 |
| 32231 | eccofoam strut 5 - Z (+Y | 224.91742 |
| 32232 | eccofoam strut 5 - Z (+Y | 189.25461 |
| 32233 | eccofoam strut 5 - Z (+Y | 169.61727 |
| 32234 | eccofoam strut 5 - Z (+Y | 160.04341 |
| 32235 | eccofoam strut 5 - Z (+Y | 155.71579 |
| 32236 | eccofoam strut 5 - Z (+Y | 153.90385 |
| 32237 | eccofoam strut 5 - Z (+Y | 152.50699 |
| 32238 | eccofoam strut 5 - Z (+Y | 150.35723 |
| 32239 | eccofoam strut 5 - Z (+Y | 154.81050 |
| 32240 | eccofoam strut 5 - Z (+Y | 148.87149 |
| 32241 | eccofoam strut 5 - Z (+Y | 133.31746 |
| 32242 | eccofoam strut 5 - Z (+Y | 121.66302 |
| 32243 | eccofoam strut 5 - Z (+Y | 112.93267 |
| 32244 | eccofoam strut 5 - Z (+Y | 105.71637 |
| 32245 | eccofoam strut 5 - Z (+Y | 98.86939 |
| 32246 | eccofoam strut 5 - Z (+Y | 91.87813 |
| 32247 | eccofoam strut 5 - Z (+Y | 91.17611 |
| 32248 | eccofoam strut 5 - Z (+Y | 91.26636 |
| 32251 | strut 6 - Z +Y | 226.99029 |
| 32252 | strut 6 - Z +Y | 186.02330 |
| 32253 | strut 6 - Z +Y | 165.84453 |
| 32254 | strut 6 - Z +Y | 155.10212 |
| 32255 | strut 6 - Z +Y | 149.33387 |
| 32256 | strut 6 - Z +Y | 146.08966 |
| 32257 | strut 6 - Z +Y | 144.55994 |
| 32258 | strut 6 - Z +Y | 143.95000 |
| 32259 | strut 6 - Z +Y | 154.24748 |
| 32260 | strut 6 - Z +Y | 143.86230 |
| 32261 | strut 6 - Z +Y | 127.88251 |
| 32262 | strut 6 - Z +Y | 116.58812 |
| 32263 | strut 6 - Z +Y | 108.17933 |
| 32264 | strut 6 - Z +Y | 101.44565 |
| 32265 | strut 6 - Z +Y | 95.51714 |
| 32266 | strut 6 - Z +Y | 89.59833 |
| 32267 | strut 6 - Z +Y | 90.74888 |
| 32268 | strut 6 - Z +Y | 89.53838 |
| 32269 | strut 6 - Z +Y | 81.03852 |
| 32270 | strut 6 - Z +Y | 74.14598 |
| 32271 | strut 6 - Z +Y | 67.82389 |
| 32272 | strut 6 - Z +Y | 61.61553 |
| 32273 | strut 6 - Z +Y | 55.17040 |
| 32274 | strut 6 - Z +Y | 52.66995 |
| 32275 | strut 6 - Z +Y | 55.14136 |
| 32276 | strut 6 - Z +Y | 53.53643 |
| 32277 | strut 6 - Z +Y | 52.05604 |
| 32278 | strut 6 - Z +Y | 50.67450 |
| 32279 | strut 6 - Z +Y | 49.37061 |
| 32280 | strut 6 - Z +Y | 48.13371 |
| 32281 | eccofoam strut 6 - Z +Y | 223.89841 |
| 32282 | eccofoam strut 6 - Z +Y | 187.36283 |

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|---|---|---|
| 32283 | eccofoam strut 6 - Z +Y | 166.65594 |
| 32284 | eccofoam strut 6 - Z +Y | 155.53714 |
| 32285 | eccofoam strut 6 - Z +Y | 149.55886 |
| 32286 | eccofoam strut 6 - Z +Y | 146.23925 |
| 32287 | eccofoam strut 6 - Z +Y | 144.68737 |
| 32288 | eccofoam strut 6 - Z +Y | 144.64138 |
| 32289 | eccofoam strut 6 - Z +Y | 152.76520 |
| 32290 | eccofoam strut 6 - Z +Y | 143.37335 |
| 32291 | eccofoam strut 6 - Z +Y | 128.20379 |
| 32292 | eccofoam strut 6 - Z +Y | 116.83065 |
| 32293 | eccofoam strut 6 - Z +Y | 108.32332 |
| 32294 | eccofoam strut 6 - Z +Y | 101.51742 |
| 32295 | eccofoam strut 6 - Z +Y | 95.55962 |
| 32296 | eccofoam strut 6 - Z +Y | 90.10378 |
| 32297 | eccofoam strut 6 - Z +Y | 90.62069 |
| 32298 | eccofoam strut 6 - Z +Y | 89.62283 |
| 32301 | strut 7 + Y (-Z) | 224.46224 |
| 32302 | strut 7 + Y (-Z) | 182.28871 |
| 32303 | strut 7 + Y (-Z) | 160.96010 |
| 32304 | strut 7 + Y (-Z) | 149.21416 |
| 32305 | strut 7 + Y (-Z) | 142.33365 |
| 32306 | strut 7 + Y (-Z) | 138.10586 |
| 32307 | strut 7 + Y (-Z) | 134.89391 |
| 32308 | strut 7 + Y (-Z) | 131.64679 |
| 32309 | strut 7 + Y (-Z) | 137.69211 |
| 32310 | strut 7 + Y (-Z) | 131.55845 |
| 32311 | strut 7 + Y (-Z) | 118.45025 |
| 32312 | strut 7 + Y (-Z) | 108.99511 |
| 32313 | strut 7 + Y (-Z) | 101.95389 |
| 32314 | strut 7 + Y (-Z) | 96.40564 |
| 32315 | strut 7 + Y (-Z) | 91.66691 |
| 32316 | strut 7 + Y (-Z) | 87.13110 |
| 32317 | strut 7 + Y (-Z) | 88.72524 |
| 32318 | strut 7 + Y (-Z) | 87.07928 |
| 32319 | strut 7 + Y (-Z) | 79.06152 |
| 32320 | strut 7 + Y (-Z) | 72.46703 |
| 32321 | strut 7 + Y (-Z) | 66.38879 |
| 32322 | strut 7 + Y (-Z) | 60.40145 |
| 32323 | strut 7 + Y (-Z) | 54.17081 |
| 32324 | strut 7 + Y (-Z) | 51.65469 |
| 32325 | strut 7 + Y (-Z) | 54.14317 |
| 32326 | strut 7 + Y (-Z) | 52.73262 |
| 32327 | strut 7 + Y (-Z) | 51.42909 |
| 32328 | strut 7 + Y (-Z) | 50.21396 |
| 32329 | strut 7 + Y (-Z) | 49.07269 |
| 32330 | strut 7 + Y (-Z) | 47.99968 |
| 32331 | eccofoam strut 7 + Y (-Z | 221.27607 |
| 32332 | eccofoam strut 7 + Y (-Z | 183.62624 |
| 32333 | eccofoam strut 7 + Y (-Z | 161.78146 |
| 32334 | eccofoam strut 7 + Y (-Z | 149.64238 |
| 32335 | eccofoam strut 7 + Y (-Z | 142.56341 |
| 32336 | eccofoam strut 7 + Y (-Z | 138.19953 |
| 32337 | eccofoam strut 7 + Y (-Z | 134.94248 |
| 32338 | eccofoam strut 7 + Y (-Z | 132.25938 |
| 32339 | eccofoam strut 7 + Y (-Z | 136.81510 |
| 32340 | eccofoam strut 7 + Y (-Z | 131.00749 |
| 32341 | eccofoam strut 7 + Y (-Z | 118.68934 |
| 32342 | eccofoam strut 7 + Y (-Z | 109.19638 |
| 32343 | eccofoam strut 7 + Y (-Z | 102.08170 |
| 32344 | eccofoam strut 7 + Y (-Z | 96.47719 |
| 32345 | eccofoam strut 7 + Y (-Z | 91.71813 |
| 32346 | eccofoam strut 7 + Y (-Z | 87.56436 |
| 32347 | eccofoam strut 7 + Y (-Z | 88.53028 |
| 32348 | eccofoam strut 7 + Y (-Z | 87.19250 |
| 32351 | strut 8 + Y (+Z) | 224.12950 |
| 32352 | strut 8 + Y (+Z) | 181.95451 |
| 32353 | strut 8 + Y (+Z) | 160.28737 |
| 32354 | strut 8 + Y (+Z) | 148.09884 |
| 32355 | strut 8 + Y (+Z) | 140.93504 |
| 32356 | strut 8 + Y (+Z) | 136.03616 |
| 32357 | strut 8 + Y (+Z) | 131.63528 |
| 32358 | strut 8 + Y (+Z) | 126.58805 |
| 32359 | strut 8 + Y (+Z) | 130.58479 |
| 32360 | strut 8 + Y (+Z) | 126.49508 |
| 32361 | strut 8 + Y (+Z) | 114.28215 |
| 32362 | strut 8 + Y (+Z) | 105.36530 |
| 32363 | strut 8 + Y (+Z) | 98.57363 |
| 32364 | strut 8 + Y (+Z) | 93.13516 |
| 32365 | strut 8 + Y (+Z) | 88.50202 |
| 32366 | strut 8 + Y (+Z) | 84.21359 |
| 32367 | strut 8 + Y (+Z) | 85.75073 |
| 32368 | strut 8 + Y (+Z) | 84.16554 |
| 32369 | strut 8 + Y (+Z) | 76.61076 |
| 32370 | strut 8 + Y (+Z) | 70.29772 |
| 32371 | strut 8 + Y (+Z) | 64.46101 |
| 32372 | strut 8 + Y (+Z) | 58.72578 |
| 32373 | strut 8 + Y (+Z) | 52.80930 |
| 32374 | strut 8 + Y (+Z) | 50.41412 |
| 32375 | strut 8 + Y (+Z) | 52.78344 |
| 32376 | strut 8 + Y (+Z) | 51.49505 |
| 32377 | strut 8 + Y (+Z) | 50.29334 |
| 32378 | strut 8 + Y (+Z) | 49.15973 |
| 32379 | strut 8 + Y (+Z) | 48.07853 |
| 32380 | strut 8 + Y (+Z) | 47.05121 |
| 32381 | eccofoam strut 8 + Y (+Z | 220.94125 |
| 32382 | eccofoam strut 8 + Y (+Z | 183.26686 |
| 32383 | eccofoam strut 8 + Y (+Z | 161.10000 |
| 32384 | eccofoam strut 8 + Y (+Z | 148.53574 |
| 32385 | eccofoam strut 8 + Y (+Z | 141.13424 |
| 32386 | eccofoam strut 8 + Y (+Z | 136.08671 |
| 32387 | eccofoam strut 8 + Y (+Z | 131.63647 |
| 32388 | eccofoam strut 8 + Y (+Z | 127.20033 |
| 32389 | eccofoam strut 8 + Y (+Z | 129.99930 |
| 32390 | eccofoam strut 8 + Y (+Z | 125.87974 |
| 32391 | eccofoam strut 8 + Y (+Z | 114.48900 |
| 32392 | eccofoam strut 8 + Y (+Z | 105.54247 |
| 32393 | eccofoam strut 8 + Y (+Z | 98.68954 |

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|---|---|---|
| 32394 | eccofoam strut 8 + Y (+Z | 93.20618 |
| 32395 | eccofoam strut 8 + Y (+Z | 88.56195 |
| 32396 | eccofoam strut 8 + Y (+Z | 84.62594 |
| 32397 | eccofoam strut 8 + Y (+Z | 85.56248 |
| 32398 | eccofoam strut 8 + Y (+Z | 84.27454 |
| 32401 | strut 9 + Y +Z | 223.69619 |
| 32402 | strut 9 + Y +Z | 180.86676 |
| 32403 | strut 9 + Y +Z | 158.77084 |
| 32404 | strut 9 + Y +Z | 146.22008 |
| 32405 | strut 9 + Y +Z | 138.68368 |
| 32406 | strut 9 + Y +Z | 133.61924 |
| 32407 | strut 9 + Y +Z | 129.37135 |
| 32408 | strut 9 + Y +Z | 124.48673 |
| 32409 | strut 9 + Y +Z | 128.31539 |
| 32410 | strut 9 + Y +Z | 124.39544 |
| 32411 | strut 9 + Y +Z | 112.45979 |
| 32412 | strut 9 + Y +Z | 103.74899 |
| 32413 | strut 9 + Y +Z | 97.14662 |
| 32414 | strut 9 + Y +Z | 91.88939 |
| 32415 | strut 9 + Y +Z | 87.47653 |
| 32416 | strut 9 + Y +Z | 83.48274 |
| 32417 | strut 9 + Y +Z | 85.08041 |
| 32418 | strut 9 + Y +Z | 83.43648 |
| 32419 | strut 9 + Y +Z | 76.01866 |
| 32420 | strut 9 + Y +Z | 69.80399 |
| 32421 | strut 9 + Y +Z | 64.06207 |
| 32422 | strut 9 + Y +Z | 58.42494 |
| 32423 | strut 9 + Y +Z | 52.61555 |
| 32424 | strut 9 + Y +Z | 50.26089 |
| 32425 | strut 9 + Y +Z | 52.59021 |
| 32426 | strut 9 + Y +Z | 51.33573 |
| 32427 | strut 9 + Y +Z | 50.16878 |
| 32428 | strut 9 + Y +Z | 49.06843 |
| 32429 | strut 9 + Y +Z | 48.02145 |
| 32430 | strut 9 + Y +Z | 47.02604 |
| 32431 | eccofoam strut 9 + Y +Z | 220.45790 |
| 32432 | eccofoam strut 9 + Y +Z | 182.19224 |
| 32433 | eccofoam strut 9 + Y +Z | 159.58931 |
| 32434 | eccofoam strut 9 + Y +Z | 146.65788 |
| 32435 | eccofoam strut 9 + Y +Z | 138.89969 |
| 32436 | eccofoam strut 9 + Y +Z | 133.69412 |
| 32437 | eccofoam strut 9 + Y +Z | 129.37340 |
| 32438 | eccofoam strut 9 + Y +Z | 125.07684 |
| 32439 | eccofoam strut 9 + Y +Z | 127.75341 |
| 32440 | eccofoam strut 9 + Y +Z | 123.78926 |
| 32441 | eccofoam strut 9 + Y +Z | 112.66203 |
| 32442 | eccofoam strut 9 + Y +Z | 103.92458 |
| 32443 | eccofoam strut 9 + Y +Z | 97.26205 |
| 32444 | eccofoam strut 9 + Y +Z | 91.96351 |
| 32445 | eccofoam strut 9 + Y +Z | 87.54082 |
| 32446 | eccofoam strut 9 + Y +Z | 83.87776 |
| 32447 | eccofoam strut 9 + Y +Z | 84.88255 |
| 32448 | eccofoam strut 9 + Y +Z | 83.54931 |
| 32451 | strut 10 + Z (+Y) | 223.57175 |
| 32452 | strut 10 + Z (+Y) | 180.86001 |
| 32453 | strut 10 + Z (+Y) | 158.79721 |
| 32454 | strut 10 + Z (+Y) | 146.15454 |
| 32455 | strut 10 + Z (+Y) | 138.53418 |
| 32456 | strut 10 + Z (+Y) | 133.30238 |
| 32457 | strut 10 + Z (+Y) | 128.79320 |
| 32458 | strut 10 + Z (+Y) | 123.51417 |
| 32459 | strut 10 + Z (+Y) | 126.91163 |
| 32460 | strut 10 + Z (+Y) | 123.42047 |
| 32461 | strut 10 + Z (+Y) | 111.57878 |
| 32462 | strut 10 + Z (+Y) | 102.88730 |
| 32463 | strut 10 + Z (+Y) | 96.27582 |
| 32464 | strut 10 + Z (+Y) | 91.00395 |
| 32465 | strut 10 + Z (+Y) | 86.60747 |
| 32466 | strut 10 + Z (+Y) | 82.65927 |
| 32467 | strut 10 + Z (+Y) | 84.22096 |
| 32468 | strut 10 + Z (+Y) | 82.61384 |
| 32469 | strut 10 + Z (+Y) | 75.31822 |
| 32470 | strut 10 + Z (+Y) | 69.21284 |
| 32471 | strut 10 + Z (+Y) | 63.57958 |
| 32472 | strut 10 + Z (+Y) | 58.06006 |
| 32473 | strut 10 + Z (+Y) | 52.38887 |
| 32474 | strut 10 + Z (+Y) | 49.99255 |
| 32475 | strut 10 + Z (+Y) | 52.36486 |
| 32476 | strut 10 + Z (+Y) | 51.34533 |
| 32477 | strut 10 + Z (+Y) | 50.42264 |
| 32478 | strut 10 + Z (+Y) | 49.58156 |
| 32479 | strut 10 + Z (+Y) | 48.81180 |
| 32480 | strut 10 + Z (+Y) | 48.12070 |
| 32481 | eccofoam strut 10 + Z (+ | 220.34216 |
| 32482 | eccofoam strut 10 + Z (+ | 182.17931 |
| 32483 | eccofoam strut 10 + Z (+ | 159.60613 |
| 32484 | eccofoam strut 10 + Z (+ | 146.59173 |
| 32485 | eccofoam strut 10 + Z (+ | 138.74353 |
| 32486 | eccofoam strut 10 + Z (+ | 133.36924 |
| 32487 | eccofoam strut 10 + Z (+ | 128.78510 |
| 32488 | eccofoam strut 10 + Z (+ | 124.10529 |
| 32489 | eccofoam strut 10 + Z (+ | 126.41050 |
| 32490 | eccofoam strut 10 + Z (+ | 122.79395 |
| 32491 | eccofoam strut 10 + Z (+ | 111.77396 |
| 32492 | eccofoam strut 10 + Z (+ | 103.06030 |
| 32493 | eccofoam strut 10 + Z (+ | 96.39083 |
| 32494 | eccofoam strut 10 + Z (+ | 91.08042 |
| 32495 | eccofoam strut 10 + Z (+ | 86.67365 |
| 32496 | eccofoam strut 10 + Z (+ | 83.04886 |
| 32497 | eccofoam strut 10 + Z (+ | 84.02780 |
| 32498 | eccofoam strut 10 + Z (+ | 82.72416 |
| 32501 | strut 11 + Z (-Y) | 223.63094 |
| 32502 | strut 11 + Z (-Y) | 181.03720 |
| 32503 | strut 11 + Z (-Y) | 159.03430 |
| 32504 | strut 11 + Z (-Y) | 146.33188 |
| 32505 | strut 11 + Z (-Y) | 138.69579 |
| 32506 | strut 11 + Z (-Y) | 133.57065 |

| | | |
|---|---|---|
| 32507 | strut 11 + Z (-Y) | 129.03241 |
| 32508 | strut 11 + Z (-Y) | 123.69282 |
| 32509 | strut 11 + Z (-Y) | 127.01724 |
| 32510 | strut 11 + Z (-Y) | 123.59808 |
| 32511 | strut 11 + Z (-Y) | 111.72766 |
| 32512 | strut 11 + Z (-Y) | 103.02382 |
| 32513 | strut 11 + Z (-Y) | 96.39207 |
| 32514 | strut 11 + Z (-Y) | 91.08278 |
| 32515 | strut 11 + Z (-Y) | 86.62597 |
| 32516 | strut 11 + Z (-Y) | 82.59431 |
| 32517 | strut 11 + Z (-Y) | 84.11029 |
| 32518 | strut 11 + Z (-Y) | 82.54857 |
| 32519 | strut 11 + Z (-Y) | 75.26314 |
| 32520 | strut 11 + Z (-Y) | 69.15085 |
| 32521 | strut 11 + Z (-Y) | 63.51798 |
| 32522 | strut 11 + Z (-Y) | 58.00329 |
| 32523 | strut 11 + Z (-Y) | 52.33874 |
| 32524 | strut 11 + Z (-Y) | 49.93852 |
| 32525 | strut 11 + Z (-Y) | 52.31478 |
| 32526 | strut 11 + Z (-Y) | 51.30595 |
| 32527 | strut 11 + Z (-Y) | 50.39267 |
| 32528 | strut 11 + Z (-Y) | 49.56059 |
| 32529 | strut 11 + Z (-Y) | 48.79928 |
| 32530 | strut 11 + Z (-Y) | 48.11655 |
| 32531 | eccofoam strut 11 + Z (- | 220.41023 |
| 32532 | eccofoam strut 11 + Z (- | 182.35231 |
| 32533 | eccofoam strut 11 + Z (- | 159.83449 |
| 32534 | eccofoam strut 11 + Z (- | 146.77224 |
| 32535 | eccofoam strut 11 + Z (- | 138.91356 |
| 32536 | eccofoam strut 11 + Z (- | 133.62809 |
| 32537 | eccofoam strut 11 + Z (- | 129.02133 |
| 32538 | eccofoam strut 11 + Z (- | 124.28354 |
| 32539 | eccofoam strut 11 + Z (- | 126.52610 |
| 32540 | eccofoam strut 11 + Z (- | 122.96504 |
| 32541 | eccofoam strut 11 + Z (- | 111.92350 |
| 32542 | eccofoam strut 11 + Z (- | 103.19619 |
| 32543 | eccofoam strut 11 + Z (- | 96.50566 |
| 32544 | eccofoam strut 11 + Z (- | 91.15737 |
| 32545 | eccofoam strut 11 + Z (- | 86.69056 |
| 32546 | eccofoam strut 11 + Z (- | 82.98700 |
| 32547 | eccofoam strut 11 + Z (- | 83.92373 |
| 32548 | eccofoam strut 11 + Z (- | 82.65587 |
| 32551 | strut 12 + Z -Y | 223.78293 |
| 32552 | strut 12 + Z -Y | 181.05578 |
| 32553 | strut 12 + Z -Y | 159.10214 |
| 32554 | strut 12 + Z -Y | 146.60889 |
| 32555 | strut 12 + Z -Y | 139.06099 |
| 32556 | strut 12 + Z -Y | 134.05283 |
| 32557 | strut 12 + Z -Y | 129.66002 |
| 32558 | strut 12 + Z -Y | 124.76710 |
| 32559 | strut 12 + Z -Y | 128.73002 |
| 32560 | strut 12 + Z -Y | 124.67519 |
| 32561 | strut 12 + Z -Y | 112.61666 |
| 32562 | strut 12 + Z -Y | 103.78847 |
| 32563 | strut 12 + Z -Y | 97.08493 |
| 32564 | strut 12 + Z -Y | 91.68611 |
| 32565 | strut 12 + Z -Y | 87.12294 |
| 32566 | strut 12 + Z -Y | 82.93246 |
| 32567 | strut 12 + Z -Y | 84.38207 |
| 32568 | strut 12 + Z -Y | 82.88547 |
| 32569 | strut 12 + Z -Y | 75.51181 |
| 32570 | strut 12 + Z -Y | 69.32513 |
| 32571 | strut 12 + Z -Y | 63.60431 |
| 32572 | strut 12 + Z -Y | 57.98332 |
| 32573 | strut 12 + Z -Y | 52.19552 |
| 32574 | strut 12 + Z -Y | 49.90619 |
| 32575 | strut 12 + Z -Y | 52.16987 |
| 32576 | strut 12 + Z -Y | 50.80441 |
| 32577 | strut 12 + Z -Y | 49.51767 |
| 32578 | strut 12 + Z -Y | 48.28468 |
| 32579 | strut 12 + Z -Y | 47.09055 |
| 32580 | strut 12 + Z -Y | 45.92986 |
| 32581 | eccofoam strut 12 + Z -Y | 220.55286 |
| 32582 | eccofoam strut 12 + Z -Y | 182.38430 |
| 32583 | eccofoam strut 12 + Z -Y | 159.91432 |
| 32584 | eccofoam strut 12 + Z -Y | 147.04149 |
| 32585 | eccofoam strut 12 + Z -Y | 139.28055 |
| 32586 | eccofoam strut 12 + Z -Y | 134.11410 |
| 32587 | eccofoam strut 12 + Z -Y | 129.67167 |
| 32588 | eccofoam strut 12 + Z -Y | 125.36686 |
| 32589 | eccofoam strut 12 + Z -Y | 128.14922 |
| 32590 | eccofoam strut 12 + Z -Y | 124.06855 |
| 32591 | eccofoam strut 12 + Z -Y | 112.81933 |
| 32592 | eccofoam strut 12 + Z -Y | 103.96506 |
| 32593 | eccofoam strut 12 + Z -Y | 97.19743 |
| 32594 | eccofoam strut 12 + Z -Y | 91.75916 |
| 32595 | eccofoam strut 12 + Z -Y | 87.18414 |
| 32596 | eccofoam strut 12 + Z -Y | 83.33230 |
| 32597 | eccofoam strut 12 + Z -Y | 84.20522 |
| 32598 | eccofoam strut 12 + Z -Y | 82.98844 |
| 33000 | PR front centre . | 45.54066 |
| 33011 | PR front ring1 0. | 45.58236 |
| 33012 | PR front ring1 60. | 45.31884 |
| 33013 | PR front ring1 120. | 45.89464 |
| 33014 | PR front ring1 180. | 45.57467 |
| 33015 | PR front ring1 240. | 45.89551 |
| 33016 | PR front ring1 300. | 45.31942 |
| 33041 | PR front ring2 0. | 46.03678 |
| 33042 | PR front ring2 60. | 45.17642 |
| 33043 | PR front ring2 120. | 46.28743 |
| 33044 | PR front ring2 180. | 45.61706 |
| 33045 | PR front ring2 240. | 46.28808 |
| 33046 | PR front ring2 300. | 45.17791 |
| 33071 | PR front ring3 0. | 45.44000 |
| 33072 | PR front ring3 60. | 45.11570 |
| 33073 | PR front ring3 120. | 46.28515 |
| 33074 | PR front ring3 180. | 45.64175 |
| 33075 | PR front ring3 240. | 46.28583 |
| 33076 | PR front ring3 300. | 45.11769 |
| 33100 | PR rear centre . . | 45.53992 |
| 33111 | PR rear ring1 0. | 45.60337 |
| 33112 | PR rear ring1 60. | 45.33344 |

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|---|---|---|
| 33113 | PR rear ring1 120. | 45.97581 |
| 33114 | PR rear ring1 180. | 45.59501 |
| 33115 | PR rear ring1 240. | 45.97684 |
| 33116 | PR rear ring1 300. | 45.33409 |
| 33141 | PR rear ring2 0. | 46.14562 |
| 33142 | PR rear ring2 60. | 45.18557 |
| 33143 | PR rear ring2 120. | 46.68565 |
| 33144 | PR rear ring2 180. | 45.63588 |
| 33145 | PR rear ring2 240. | 46.68613 |
| 33146 | PR rear ring2 300. | 45.18698 |
| 33171 | PR rear ring3 0. | 45.44790 |
| 33172 | PR rear ring3 60. | 45.12271 |
| 33173 | PR rear ring3 120. | 46.36655 |
| 33174 | PR rear ring3 180. | 45.65570 |
| 33175 | PR rear ring3 240. | 46.36706 |
| 33176 | PR rear ring3 300. | 45.12450 |
| 33200 | PR thermal foil . | 45.05407 |
| 33311 | PR MLI fwd ring | 45.41101 |
| 33312 | PR MLI fwd ring | 45.15951 |
| 33313 | PR MLI fwd ring | 45.82266 |
| 33314 | PR MLI fwd ring | 45.46079 |
| 33315 | PR MLI fwd ring | 45.82773 |
| 33316 | PR MLI fwd ring | 45.16024 |
| 33341 | PR MLI fwd ring | 45.92373 |
| 33342 | PR MLI fwd ring | 44.99901 |
| 33343 | PR MLI fwd ring | 46.53740 |
| 33344 | PR MLI fwd ring | 45.52562 |
| 33345 | PR MLI fwd ring | 46.53995 |
| 33346 | PR MLI fwd ring | 45.00021 |
| 33371 | PR MLI fwd ring | 45.21150 |
| 33372 | PR MLI fwd ring | 44.92725 |
| 33373 | PR MLI fwd ring | 46.20899 |
| 33374 | PR MLI fwd ring | 45.53307 |
| 33375 | PR MLI fwd ring | 46.20815 |
| 33376 | PR MLI fwd ring | 44.92830 |
| 33411 | PR MLI rear ring | 37.42919 |
| 33412 | PR MLI rear ring | 38.17592 |
| 33413 | PR MLI rear ring | 39.91400 |
| 33414 | PR MLI rear ring | 40.42749 |
| 33415 | PR MLI rear ring | 40.11307 |
| 33416 | PR MLI rear ring | 38.18087 |
| 33441 | PR MLI rear ring | 36.18043 |
| 33442 | PR MLI rear ring | 37.31902 |
| 33443 | PR MLI rear ring | 40.88407 |
| 33444 | PR MLI rear ring | 41.53689 |
| 33445 | PR MLI rear ring | 40.98420 |
| 33446 | PR MLI rear ring | 37.30844 |
| 33471 | PR MLI rear ring | 34.37838 |
| 33472 | PR MLI rear ring | 36.73269 |
| 33473 | PR MLI rear ring | 40.09948 |
| 33474 | PR MLI rear ring | 41.01627 |
| 33475 | PR MLI rear ring | 40.03235 |
| 33476 | PR MLI rear ring | 36.69019 |
| 34000 | SR front centre . | 45.74409 |
| 34011 | SR front ring1 0. | 45.75027 |
| 34012 | SR front ring1 60. | 45.71109 |
| 34013 | SR front ring1 120. | 45.75917 |
| 34014 | SR front ring1 180. | 45.73204 |
| 34015 | SR front ring1 240. | 45.79964 |
| 34016 | SR front ring1 300. | 45.72694 |
| 34071 | SR front ring2 0. | 45.73201 |
| 34072 | SR front ring2 60. | 45.69260 |
| 34073 | SR front ring2 120. | 45.74455 |
| 34074 | SR front ring2 180. | 45.71519 |
| 34075 | SR front ring2 240. | 45.78736 |
| 34076 | SR front ring2 300. | 45.70984 |
| 34100 | SR rear centre . . | 45.77067 |
| 34111 | SR rear ring1 0. | 45.81142 |
| 34112 | SR rear ring1 60. | 45.72853 |
| 34113 | SR rear ring1 120. | 45.82606 |
| 34114 | SR rear ring1 180. | 45.75572 |
| 34115 | SR rear ring1 240. | 45.89131 |
| 34116 | SR rear ring1 300. | 45.74612 |
| 34171 | SR rear ring2 0. | 45.74942 |
| 34172 | SR rear ring2 60. | 45.70199 |
| 34173 | SR rear ring2 120. | 45.77247 |
| 34174 | SR rear ring2 180. | 45.73056 |
| 34175 | SR rear ring2 240. | 45.82176 |
| 34176 | SR rear ring2 300. | 45.71995 |
| 34200 | SR thermal foil . | 45.59686 |
| 34311 | SR MLI fwd ring | 45.63958 |
| 34312 | SR MLI fwd ring | 45.62060 |
| 34313 | SR MLI fwd ring | 45.79373 |
| 34314 | SR MLI fwd ring | 45.71220 |
| 34315 | SR MLI fwd ring | 45.85653 |
| 34316 | SR MLI fwd ring | 45.63702 |
| 34371 | SR MLI fwd ring | 45.52831 |
| 34372 | SR MLI fwd ring | 45.53703 |
| 34373 | SR MLI fwd ring | 45.72087 |
| 34374 | SR MLI fwd ring | 45.61844 |
| 34375 | SR MLI fwd ring | 45.76535 |
| 34376 | SR MLI fwd ring | 45.55592 |
| 34411 | SR MLI rear ring | 38.78808 |
| 34412 | SR MLI rear ring | 41.73035 |
| 34413 | SR MLI rear ring | 44.73537 |
| 34414 | SR MLI rear ring | 44.26905 |
| 34415 | SR MLI rear ring | 44.71506 |
| 34416 | SR MLI rear ring | 41.69836 |
| 34471 | SR MLI rear ring | 35.79446 |
| 34472 | SR MLI rear ring | 39.03421 |
| 34473 | SR MLI rear ring | 43.99316 |
| 34474 | SR MLI rear ring | 41.55264 |
| 34475 | SR MLI rear ring | 43.86568 |
| 34476 | SR MLI rear ring | 39.10109 |
| 35000 | rim1_in | 46.85243 |
| 35001 | rim1_lo | 47.22688 |
| 35002 | rim1_out | 46.71949 |
| 35003 | rim1_up | 46.69036 |
| 35010 | rim1_in | 46.04587 |
| 35011 | rim1_lo | 46.17408 |
| 35012 | rim1_out | 45.97382 |
| 35013 | rim1_up | 45.99122 |
| 35020 | rim1_in | 45.88749 |
| 35021 | rim1_lo | 46.29980 |
| 35022 | rim1_out | 45.76437 |
| 35023 | rim1_up | 45.49941 |
| 35030 | rim2_in | 45.88711 |
| 35031 | rim2_lo | 46.29936 |
| 35032 | rim2_out | 45.76397 |
| 35033 | rim2_up | 45.49900 |
| 35040 | rim2_in | 45.44757 |
| 35041 | rim2_lo | 45.46177 |
| 35042 | rim2_out | 45.31884 |
| 35043 | rim2_up | 45.31875 |
| 35050 | rim2_in | 47.59224 |
| 35051 | rim2_lo | 47.66300 |
| 35052 | rim2_out | 47.50428 |
| 35053 | rim2_up | 47.95245 |
| 35060 | rim3_in | 47.59287 |
| 35061 | rim3_lo | 47.66374 |
| 35062 | rim3_out | 47.50522 |
| 35063 | rim3_up | 47.95311 |
| 35070 | rim3_in | 46.44322 |
| 35071 | rim3_lo | 46.65342 |

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|---|---|---|
| 35072 | rim3_out | 46.86316 |
| 35073 | rim3_up | 46.38410 |
| 35080 | rim3_in | 44.14836 |
| 35081 | rim3_lo | 45.05632 |
| 35082 | rim3_out | 44.61178 |
| 35083 | rim3_up | 44.29746 |
| 35090 | rim4_in | 44.14646 |
| 35091 | rim4_lo | 45.05439 |
| 35092 | rim4_out | 44.60966 |
| 35093 | rim4_up | 44.29552 |
| 35100 | rim4_in | 43.29265 |
| 35101 | rim4_lo | 43.41644 |
| 35102 | rim4_out | 43.23434 |
| 35103 | rim4_up | 43.09753 |
| 35110 | rim4_in | 46.26156 |
| 35111 | rim4_lo | 46.60143 |
| 35112 | rim4_out | 46.15021 |
| 35113 | rim4_up | 46.38887 |
| 35120 | rim5_in | 46.26267 |
| 35121 | rim5_lo | 46.60246 |
| 35122 | rim5_out | 46.15123 |
| 35123 | rim5_up | 46.38998 |
| 35130 | rim5_in | 45.18738 |
| 35131 | rim5_lo | 45.20751 |
| 35132 | rim5_out | 45.05614 |
| 35133 | rim5_up | 45.05261 |
| 35140 | rim5_in | 45.93995 |
| 35141 | rim5_lo | 46.50231 |
| 35142 | rim5_out | 45.86483 |
| 35143 | rim5_up | 45.55882 |
| 35150 | rim6_in | 45.94040 |
| 35151 | rim6_lo | 46.50281 |
| 35152 | rim6_out | 45.86530 |
| 35153 | rim6_up | 45.55932 |
| 35160 | rim6_in | 45.91602 |
| 35161 | rim6_lo | 46.01524 |
| 35162 | rim6_out | 45.84381 |
| 35163 | rim6_up | 45.87660 |
| 35170 | rim6_in | 46.85235 |
| 35171 | rim6_lo | 47.22678 |
| 35172 | rim6_out | 46.71941 |
| 35173 | rim6_up | 46.69029 |
| 35210 | I/F 1 rim1_in | 46.85237 |

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|---|---|---|
| 35211 | I/F 1 rim1_lo | 47.22996 |
| 35212 | I/F 1 rim1_out | 46.71864 |
| 35213 | I/F 1 rim1_up | 46.69029 |
| 35220 | I/F 2 rim1_in | 45.88731 |
| 35221 | I/F 2 rim1_lo | 46.30237 |
| 35222 | I/F 2 rim1_out | 45.76352 |
| 35223 | I/F 2 rim1_up | 45.49743 |
| 35230 | I/F 3 rim2_in | 47.59242 |
| 35231 | I/F 3 rim2_lo | 47.66505 |
| 35232 | I/F 3 rim2_out | 47.50394 |
| 35233 | I/F 3 rim2_up | 47.95642 |
| 35240 | I/F 4 rim3_in | 44.14436 |
| 35241 | I/F 4 rim3_lo | 45.05867 |
| 35242 | I/F 4 rim3_out | 44.61009 |
| 35243 | I/F 4 rim3_up | 44.29579 |
| 35250 | I/F 5 rim4_in | 46.26210 |
| 35251 | I/F 5 rim4_lo | 46.60544 |
| 35252 | I/F 5 rim4_out | 46.15006 |
| 35253 | I/F 5 rim4_up | 46.39178 |
| 35260 | I/F 6 rim5_in | 45.93992 |
| 35261 | I/F 6 rim5_lo | 46.50629 |
| 35262 | I/F 6 rim5_out | 45.86443 |
| 35263 | I/F 6 rim5_up | 45.55734 |
| 41000 | FEMs | 21.84815 |
| 41100 | LR2 | 18.57276 |
| 41500 | FPU_MF | 21.75018 |
| 42000 | LR2 fluid | 18.39800 |
| 45000 | BEU-DAE | 316.48463 |
| 45100 | BEU-DAE_box | 312.93952 |
| 45200 | DAE_Black_Side | 286.25414 |
| 46000 | BEM | 312.86194 |
| 46100 | BEM_box | 312.67149 |
| 46200 | BEM_dx_Black_Side | 231.94973 |
| 47000 | FEM | 291.93051 |
| 47100 | FEM_box | 312.34549 |
| 47200 | FEM_dx_Black_Side | 275.58682 |
| 49000 | BEU_I/F_SVM | 313.14999 |
| 50110 | SHield 1 inf facet 1 | 140.53374 |
| 50111 | SHield 1 inf facet 1 | 143.09655 |
| 50112 | SHield 1 inf facet 1 | 168.28356 |
| 50115 | SHield 1 inf ext fac | 141.42076 |
| 50116 | SHield 1 inf ext fac | 137.77372 |
| 50120 | SHield 1 inf facet 1 | 139.73974 |
| 50121 | SHield 1 inf facet 1 | 143.71052 |

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|---|---|---|
| 50122 | SHield 1 inf facet 1 | 156.09905 |
| 50125 | SHield 1 inf ext fac | 142.73122 |
| 50126 | SHield 1 inf ext fac | 137.17493 |
| 50130 | SHield 1 inf facet 1 | 139.23504 |
| 50131 | SHield 1 inf facet 1 | 142.20244 |
| 50135 | SHield 1 inf ext fac | 138.67878 |
| 50136 | SHield 1 inf ext fac | 134.31191 |
| 50170 | SHield 1 inf facet 1 | 151.31069 |
| 50171 | SHield 1 inf facet 1 | 150.70557 |
| 50172 | SHield 1 inf facet 1 | 150.12830 |
| 50173 | SHield 1 inf facet 1 | 149.58128 |
| 50174 | SHield 1 inf facet 1 | 149.06571 |
| 50175 | SHield 1 inf facet 1 | 148.58121 |
| 50176 | SHield 1 inf facet 1 | 148.12731 |
| 50177 | SHield 1 inf facet 1 | 147.70398 |
| 50178 | SHield 1 inf facet 1 | 147.31163 |
| 50179 | SHield 1 inf facet 1 | 146.95142 |
| 50180 | SHield 1 inf facet 1 | 146.62602 |
| 50181 | SHield 1 inf facet 1 | 146.34073 |
| 50182 | SHield 1 inf facet 1 | 146.10544 |
| 50183 | SHield 1 inf facet 1 | 145.93947 |
| 50184 | SHield 1 inf facet 1 | 145.34819 |
| 50210 | SHield 1 inf facet 2 | 137.87257 |
| 50211 | SHield 1 inf facet 2 | 138.68144 |
| 50212 | SHield 1 inf facet 2 | 138.65883 |
| 50215 | SHield 1 inf ext fac | 133.00629 |
| 50216 | SHield 1 inf ext fac | 129.56813 |
| 50220 | SHield 1 inf facet 2 | 136.59805 |
| 50221 | SHield 1 inf facet 2 | 136.16384 |
| 50222 | SHield 1 inf facet 2 | 134.18745 |
| 50225 | SHield 1 inf ext fac | 129.43533 |
| 50226 | SHield 1 inf ext fac | 126.26851 |
| 50230 | SHield 1 inf facet 2 | 135.69712 |
| 50231 | SHield 1 inf facet 2 | 133.93194 |
| 50232 | SHield 1 inf facet 2 | 131.20569 |
| 50235 | SHield 1 inf ext fac | 127.17678 |
| 50236 | SHield 1 inf ext fac | 124.48665 |
| 50310 | SHield 1 inf facet 3 | 134.36607 |
| 50311 | SHield 1 inf facet 3 | 131.89256 |
| 50312 | SHield 1 inf facet 3 | 128.88837 |
| 50315 | SHield 1 inf ext fac | 125.39667 |
| 50316 | SHield 1 inf ext fac | 123.31999 |
| 50320 | SHield 1 inf facet 3 | 133.73066 |
| 50321 | SHield 1 inf facet 3 | 131.05388 |

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|---|---|---|
| 50322 | SHield 1 inf facet 3 | 127.96706 |
| 50325 | SHield 1 inf ext fac | 124.31479 |
| 50326 | SHield 1 inf ext fac | 121.97644 |
| 50330 | SHield 1 inf facet 3 | 133.44938 |
| 50331 | SHield 1 inf facet 3 | 130.55836 |
| 50332 | SHield 1 inf facet 3 | 127.40301 |
| 50335 | SHield 1 inf ext fac | 123.82815 |
| 50336 | SHield 1 inf ext fac | 121.38079 |
| 50410 | SHield 1 inf facet 4 | 133.51738 |
| 50411 | SHield 1 inf facet 4 | 130.61187 |
| 50412 | SHield 1 inf facet 4 | 127.49290 |
| 50415 | SHield 1 inf ext fac | 124.01514 |
| 50416 | SHield 1 inf ext fac | 121.57019 |
| 50420 | SHield 1 inf facet 4 | 133.94755 |
| 50421 | SHield 1 inf facet 4 | 131.21039 |
| 50422 | SHield 1 inf facet 4 | 128.26450 |
| 50425 | SHield 1 inf ext fac | 124.63369 |
| 50426 | SHield 1 inf ext fac | 122.25287 |
| 50430 | SHield 1 inf facet 4 | 134.45199 |
| 50431 | SHield 1 inf facet 4 | 132.22788 |
| 50432 | SHield 1 inf facet 4 | 129.30639 |
| 50435 | SHield 1 inf ext fac | 125.86435 |
| 50436 | SHield 1 inf ext fac | 123.79941 |
| 50510 | SHield 1 inf facet 5 | 135.86135 |
| 50511 | SHield 1 inf facet 5 | 134.33395 |
| 50512 | SHield 1 inf facet 5 | 131.79377 |
| 50515 | SHield 1 inf ext fac | 128.15245 |
| 50516 | SHield 1 inf ext fac | 125.51329 |
| 50520 | SHield 1 inf facet 5 | 137.08166 |
| 50521 | SHield 1 inf facet 5 | 136.46166 |
| 50522 | SHield 1 inf facet 5 | 135.08781 |
| 50525 | SHield 1 inf ext fac | 131.05396 |
| 50526 | SHield 1 inf ext fac | 127.98635 |
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| 60315 | shield 2 inf ext fac | 84.50236 |
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| 60325 | shield 2 inf ext fac | 83.99490 |
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| 60332 | shield 2 inf facet 3 | 84.44709 |

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| 60336 | shield 2 inf ext fac | 83.21039 |
| 60410 | shield 2 inf facet 4 | 85.85083 |
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| 60415 | shield 2 inf ext fac | 83.53113 |
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| 60535 | shield 2 inf ext fac | 85.58370 |
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| 60620 | shield 2 inf facet 6 | 87.17524 |
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| 60670 | shield 2 inf facet 6 | 87.04204 |
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| 70181 | SHield 3 inf facet 1 | 54.15090 |
| 70182 | SHield 3 inf facet 1 | 53.90737 |
| 70183 | SHield 3 inf facet 1 | 53.72399 |
| 70184 | SHield 3 inf facet 1 | 53.59865 |
| 70185 | SHield 3 inf facet 1 | 53.52575 |
| 70186 | SHield 3 inf facet 1 | 53.45617 |
| 70187 | SHield 3 inf facet 1 | 53.43277 |
| 70188 | SHield 3 inf facet 1 | 53.45463 |
| 70189 | SHield 3 inf facet 1 | 53.21044 |
| 70210 | SHield3_inf_facet2 | 51.04821 |
| 70211 | SHield3_inf_facet2 | 51.50797 |
| 70212 | SHield3_inf_facet2 | 51.37645 |
| 70213 | SHield3_inf_facet2 | 51.47597 |
| 70214 | SHield3_inf_facet2 | 50.99794 |
| 70215 | SHield3_inf_facet2 | 50.96073 |
| 70216 | SHield3_inf_facet2 | 50.70059 |
| 70217 | SHield3_inf_facet2 | 50.79493 |
| 70220 | SHield3_inf_facet2 | 50.92310 |
| 70221 | SHield3_inf_facet2 | 50.74157 |
| 70222 | SHield3_inf_facet2 | 50.40334 |
| 70223 | SHield3_inf_facet2 | 50.53620 |
| 70225 | SHield3_inf_ext_facet2 | 50.55651 |
| 70226 | SHield3_inf_ext_facet2 | 50.43426 |
| 70227 | SHield3_inf_ext_facet2 | 50.39192 |
| 70230 | SHield3_inf_facet2 | 50.84776 |
| 70231 | SHield3_inf_facet2 | 50.54571 |
| 70232 | SHield3_inf_facet2 | 50.22354 |
| 70233 | SHield3_inf_facet2 | 50.24807 |
| 70235 | SHield3_inf_ext_facet2 | 50.15941 |
| 70236 | SHield3_inf_ext_facet2 | 50.09735 |
| 70237 | SHield3_inf_ext_facet2 | 50.04676 |
| 70270 | SHield3_inf_ext_facet2 | 51.22245 |
| 70271 | SHield3_inf_ext_facet2 | 51.07178 |
| 70272 | SHield3_inf_ext_facet2 | 50.96111 |
| 70273 | SHield3_inf_ext_facet2 | 51.24790 |
| 70274 | SHield3_inf_ext_facet2 | 51.04605 |
| 70275 | SHield3_inf_ext_facet2 | 50.94812 |

| | | |
|---|---|---|
| 70276 | SHield3_inf_ext_facet2 | 50.98614 |
| 70277 | SHield3_inf_ext_facet2 | 50.85091 |
| 70278 | SHield3_inf_ext_facet2 | 50.84168 |
| 70310 | SHield 3 inf facet 3 | 50.74075 |
| 70311 | SHield 3 inf facet 3 | 50.40870 |
| 70312 | SHield 3 inf facet 3 | 50.16578 |
| 70313 | SHield 3 inf facet 3 | 50.09830 |
| 70315 | SHield 3 inf ext fac | 49.90598 |
| 70316 | SHield 3 inf ext fac | 49.83807 |
| 70317 | SHield 3 inf ext fac | 49.79838 |
| 70320 | SHield 3 inf facet 3 | 50.68570 |
| 70321 | SHield 3 inf facet 3 | 50.27928 |
| 70322 | SHield 3 inf facet 3 | 50.03687 |
| 70323 | SHield 3 inf facet 3 | 49.90923 |
| 70325 | SHield 3 inf ext fac | 49.69269 |
| 70326 | SHield 3 inf ext fac | 49.63004 |
| 70327 | SHield 3 inf ext fac | 49.59523 |
| 70330 | SHield 3 inf facet 3 | 50.65652 |
| 70331 | SHield 3 inf facet 3 | 50.20698 |
| 70332 | SHield 3 inf facet 3 | 49.95552 |
| 70333 | SHield 3 inf facet 3 | 49.82782 |
| 70335 | SHield 3 inf ext fac | 49.59848 |
| 70336 | SHield 3 inf ext fac | 49.52972 |
| 70337 | SHield 3 inf ext fac | 49.49698 |
| 70410 | SHield 3 inf facet 4 | 50.62433 |
| 70411 | SHield 3 inf facet 4 | 50.16832 |
| 70412 | SHield 3 inf facet 4 | 49.91132 |
| 70413 | SHield 3 inf facet 4 | 49.77372 |
| 70415 | SHield 3 inf ext fac | 49.48460 |
| 70416 | SHield 3 inf ext fac | 49.38546 |
| 70417 | SHield 3 inf ext fac | 49.33609 |
| 70420 | SHield 3 inf facet 4 | 50.61412 |
| 70421 | SHield 3 inf facet 4 | 50.12888 |
| 70422 | SHield 3 inf facet 4 | 49.85435 |
| 70423 | SHield 3 inf facet 4 | 49.70259 |
| 70425 | SHield 3 inf ext fac | 49.42597 |
| 70426 | SHield 3 inf ext fac | 49.34672 |
| 70427 | SHield 3 inf ext fac | 49.30255 |
| 70430 | SHield 3 inf facet 4 | 50.63331 |
| 70431 | SHield 3 inf facet 4 | 50.14199 |
| 70432 | SHield 3 inf facet 4 | 49.86392 |
| 70433 | SHield 3 inf facet 4 | 49.74947 |
| 70435 | SHield 3 inf ext fac | 49.43462 |
| 70436 | SHield 3 inf ext fac | 49.34663 |

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|---|---|---|
| 70437 | SHield 3 inf ext fac | 49.30359 |
| 70510 | SHield3_inf_facet5 | 50.68449 |
| 70511 | SHield3_inf_facet5 | 50.17016 |
| 70512 | SHield3_inf_facet5 | 49.86851 |
| 70513 | SHield3_inf_facet5 | 49.87167 |
| 70514 | SHield3_inf_facet5 | 50.73395 |
| 70515 | SHield3_inf_facet5 | 50.22690 |
| 70516 | SHield3_inf_facet5 | 49.98320 |
| 70517 | SHield3_inf_facet5 | 50.01272 |
| 70520 | SHield3_inf_facet5 | 50.79585 |
| 70521 | SHield3_inf_facet5 | 50.45558 |
| 70522 | SHield3_inf_facet5 | 50.10408 |
| 70523 | SHield3_inf_facet5 | 50.20874 |
| 70525 | SHield3_inf_ext_facet5 | 49.99748 |
| 70526 | SHield3_inf_ext_facet5 | 49.89071 |
| 70527 | SHield3_inf_ext_facet5 | 49.84984 |
| 70530 | SHield3_inf_facet5 | 50.84215 |
| 70531 | SHield3_inf_facet5 | 50.70249 |
| 70532 | SHield3_inf_facet5 | 50.37638 |
| 70533 | SHield3_inf_facet5 | 50.49021 |
| 70535 | SHield3_inf_ext_facet5 | 49.84516 |
| 70536 | SHield3_inf_ext_facet5 | 49.80937 |
| 70537 | SHield3_inf_ext_facet5 | 49.78157 |
| 70570 | SHield3_inf_ext_facet5 | 50.69496 |
| 70571 | SHield3_inf_ext_facet5 | 50.73789 |
| 70572 | SHield3_inf_ext_facet5 | 50.68546 |
| 70573 | SHield3_inf_ext_facet5 | 50.54123 |
| 70574 | SHield3_inf_ext_facet5 | 50.46684 |
| 70575 | SHield3_inf_ext_facet5 | 50.42505 |
| 70576 | SHield3_inf_ext_facet5 | 50.28987 |
| 70577 | SHield3_inf_ext_facet5 | 50.17647 |
| 70578 | SHield3_inf_ext_facet5 | 50.17957 |
| 70610 | SHield 3 inf facet 6 | 50.95912 |
| 70611 | SHield 3 inf facet 6 | 51.04344 |
| 70613 | SHield 3 inf facet 6 | 50.73636 |
| 70615 | SHield 3 inf ext fac | 50.48364 |
| 70616 | SHield 3 inf ext fac | 50.39406 |
| 70617 | SHield 3 inf ext fac | 50.33762 |
| 70618 | SHield 3 inf facet 6 | 51.00174 |
| 70619 | SHield 3 inf facet 6 | 51.31553 |
| 70620 | SHield 3 inf facet 6 | 51.03677 |
| 70621 | SHield 3 inf facet 6 | 51.52484 |
| 70625 | SHield 3 inf ext fac | 50.68017 |
| 70626 | SHield 3 inf ext fac | 50.52013 |
| 70627 | SHield 3 inf ext fac | 50.38155 |

| | | |
|---|---|---|
| 70628 | SHield 3 inf facet 6 | 50.75622 |
| 70629 | SHield 3 inf facet 6 | 51.32946 |
| 70630 | SHield 3 inf facet 6 | 51.09686 |
| 70631 | SHield 3 inf facet 6 | 51.67346 |
| 70632 | SHield 3 inf facet 6 | 59.71012 |
| 70635 | SHield 3 inf ext fac | 50.27463 |
| 70636 | SHield 3 inf ext fac | 50.26859 |
| 70637 | SHield 3 inf ext fac | 50.25006 |
| 70670 | SHield 3 inf facet 6 | 50.77753 |
| 70671 | SHield 3 inf facet 6 | 50.86128 |
| 70672 | SHield 3 inf facet 6 | 50.94224 |
| 70673 | SHield 3 inf facet 6 | 51.02576 |
| 70674 | SHield 3 inf facet 6 | 51.11392 |
| 70675 | SHield 3 inf facet 6 | 51.20903 |
| 70676 | SHield 3 inf facet 6 | 51.31365 |
| 70677 | SHield 3 inf facet 6 | 51.37345 |
| 70678 | SHield 3 inf facet 6 | 51.43675 |
| 70679 | SHield 3 inf facet 6 | 51.51153 |
| 70680 | SHield 3 inf facet 6 | 51.59760 |
| 70681 | SHield 3 inf facet 6 | 51.69253 |
| 70682 | SHield 3 inf facet 6 | 51.79872 |
| 70683 | SHield 3 inf facet 6 | 51.91592 |
| 70684 | SHield 3 inf facet 6 | 52.05405 |
| 70685 | SHield 3 inf facet 6 | 52.20609 |
| 70686 | SHield 3 inf facet 6 | 52.35758 |
| 70687 | SHield 3 inf facet 6 | 52.50115 |
| 70688 | SHield 3 inf facet 6 | 52.62372 |
| 70689 | SHield 3 inf facet 6 | 52.70317 |
| 71110 | SHield 3 sup facet 1 | 51.19949 |
| 71111 | SHield 3 sup facet 1 | 51.94081 |
| 71112 | SHield 3 sup facet 1 | 59.79359 |
| 71115 | SHield 3 sup ext fac | 50.80608 |
| 71116 | SHield 3 sup ext fac | 50.75884 |
| 71117 | SHield 3 sup ext fac | 50.67548 |
| 71118 | SHield 3 sup facet 1 | 51.19814 |
| 71119 | SHield 3 sup facet 1 | 52.62395 |
| 71120 | SHield 3 sup facet 1 | 51.18250 |
| 71121 | SHield 3 sup facet 1 | 52.48508 |
| 71122 | SHield 3 sup facet 1 | 51.15319 |
| 71123 | SHield 3 sup facet 1 | 52.14556 |
| 71124 | SHield 3 sup facet 1 | 52.59382 |
| 71125 | SHield 3 sup ext fac | 51.51963 |
| 71126 | SHield 3 sup ext fac | 51.32487 |
| 71127 | SHield 3 sup ext fac | 51.22796 |

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|---|---|---|
| 71134 | SHield 3 sup facet 1 | 52.37223 |
| 71135 | SHield 3 sup ext fac | 51.21479 |
| 71136 | SHield 3 sup ext fac | 51.00451 |
| 71137 | SHield 3 sup ext fac | 50.91772 |
| 71170 | SHield 3 sup facet 1 | 55.02408 |
| 71171 | SHield 3 sup facet 1 | 54.54505 |
| 71172 | SHield 3 sup facet 1 | 54.20758 |
| 71173 | SHield 3 sup facet 1 | 53.97248 |
| 71174 | SHield 3 sup facet 1 | 53.81236 |
| 71175 | SHield 3 sup facet 1 | 53.70671 |
| 71176 | SHield 3 sup facet 1 | 53.63818 |
| 71177 | SHield 3 sup facet 1 | 53.58918 |
| 71178 | SHield 3 sup facet 1 | 53.53808 |
| 71179 | SHield 3 sup facet 1 | 53.45652 |
| 71180 | SHield 3 sup facet 1 | 53.29817 |
| 71181 | SHield 3 sup facet 1 | 53.08851 |
| 71182 | SHield 3 sup facet 1 | 52.90917 |
| 71183 | SHield 3 sup facet 1 | 52.75228 |
| 71184 | SHield 3 sup facet 1 | 52.61720 |
| 71185 | SHield 3 sup facet 1 | 52.49800 |
| 71186 | SHield 3 sup facet 1 | 52.38947 |
| 71187 | SHield 3 sup facet 1 | 52.28685 |
| 71188 | SHield 3 sup facet 1 | 52.18565 |
| 71189 | SHield 3 sup facet 1 | 52.08147 |
| 71210 | SHield3_sup_facet2 | 51.04489 |
| 71211 | SHield3_sup_facet2 | 51.48162 |
| 71212 | SHield3_sup_facet2 | 51.09394 |
| 71213 | SHield3_sup_facet2 | 51.43854 |
| 71214 | SHield3_sup_facet2 | 50.99510 |
| 71215 | SHield3_sup_facet2 | 50.95660 |
| 71216 | SHield3_sup_facet2 | 50.66638 |
| 71217 | SHield3_sup_facet2 | 50.78997 |
| 71220 | SHield3_sup_facet2 | 50.92070 |
| 71221 | SHield3_sup_facet2 | 50.73653 |
| 71222 | SHield3_sup_facet2 | 50.32076 |
| 71223 | SHield3_sup_facet2 | 50.52500 |
| 71225 | SHield3_sup_ext_facet2 | 50.55098 |
| 71226 | SHield3_sup_ext_facet2 | 50.42684 |
| 71227 | SHield3_sup_ext_facet2 | 50.38553 |
| 71230 | SHield3_sup_facet2 | 50.84568 |
| 71231 | SHield3_sup_facet2 | 50.54189 |
| 71232 | SHield3_sup_facet2 | 50.16813 |
| 71233 | SHield3_sup_facet2 | 50.23084 |
| 71235 | SHield3_sup_ext_facet2 | 50.15378 |
| 71236 | SHield3_sup_ext_facet2 | 50.09089 |
| 71237 | SHield3_sup_ext_facet2 | 50.03835 |
| 71270 | SHield3_sup_ext_facet2 | 51.20117 |
| 71271 | SHield3_sup_ext_facet2 | 51.06292 |
| 71272 | SHield3_sup_ext_facet2 | 50.95485 |
| 71273 | SHield3_sup_ext_facet2 | 51.22139 |
| 71274 | SHield3_sup_ext_facet2 | 51.03651 |
| 71275 | SHield3_sup_ext_facet2 | 50.94103 |
| 71276 | SHield3_sup_ext_facet2 | 50.97628 |
| 71277 | SHield3_sup_ext_facet2 | 50.84123 |
| 71278 | SHield3_sup_ext_facet2 | 50.83472 |
| 71310 | SHield 3 sup facet 3 | 50.73898 |
| 71311 | SHield 3 sup facet 3 | 50.40666 |
| 71312 | SHield 3 sup facet 3 | 50.15725 |
| 71313 | SHield 3 sup facet 3 | 50.07992 |
| 71315 | SHield 3 sup ext fac | 49.89202 |
| 71316 | SHield 3 sup ext fac | 49.82437 |
| 71317 | SHield 3 sup ext fac | 49.78841 |
| 71320 | SHield 3 sup facet 3 | 50.68408 |
| 71321 | SHield 3 sup facet 3 | 50.27771 |
| 71322 | SHield 3 sup facet 3 | 50.03184 |
| 71323 | SHield 3 sup facet 3 | 49.90180 |
| 71325 | SHield 3 sup ext fac | 49.67902 |
| 71326 | SHield 3 sup ext fac | 49.61535 |
| 71327 | SHield 3 sup ext fac | 49.58023 |
| 71330 | SHield 3 sup facet 3 | 50.65494 |
| 71331 | SHield 3 sup facet 3 | 50.20556 |
| 71332 | SHield 3 sup facet 3 | 49.95074 |
| 71333 | SHield 3 sup facet 3 | 49.80957 |
| 71335 | SHield 3 sup ext fac | 49.58050 |
| 71336 | SHield 3 sup ext fac | 49.51177 |
| 71337 | SHield 3 sup ext fac | 49.47772 |
| 71410 | SHield 3 sup facet 4 | 50.62278 |
| 71411 | SHield 3 sup facet 4 | 50.16692 |
| 71412 | SHield 3 sup facet 4 | 49.90654 |
| 71413 | SHield 3 sup facet 4 | 49.75611 |
| 71415 | SHield 3 sup ext fac | 49.47894 |
| 71416 | SHield 3 sup ext fac | 49.37964 |
| 71417 | SHield 3 sup ext fac | 49.33031 |
| 71420 | SHield 3 sup facet 4 | 50.61254 |
| 71421 | SHield 3 sup facet 4 | 50.12734 |
| 71422 | SHield 3 sup facet 4 | 49.84950 |
| 71423 | SHield 3 sup facet 4 | 49.69559 |
| 71425 | SHield 3 sup ext fac | 49.41783 |
| 71426 | SHield 3 sup ext fac | 49.33809 |
| 71427 | SHield 3 sup ext fac | 49.29383 |
| 71430 | SHield 3 sup facet 4 | 50.63167 |
| 71431 | SHield 3 sup facet 4 | 50.14007 |
| 71432 | SHield 3 sup facet 4 | 49.85554 |
| 71433 | SHield 3 sup facet 4 | 49.73186 |
| 71435 | SHield 3 sup ext fac | 49.42558 |
| 71436 | SHield 3 sup ext fac | 49.33779 |
| 71437 | SHield 3 sup ext fac | 49.29461 |
| 71510 | SHield3_sup_facet5 | 50.68270 |
| 71511 | SHield3_sup_facet5 | 50.16686 |
| 71512 | SHield3_sup_facet5 | 49.82055 |
| 71513 | SHield3_sup_facet5 | 49.85540 |
| 71514 | SHield3_sup_facet5 | 50.73207 |
| 71515 | SHield3_sup_facet5 | 50.22431 |
| 71516 | SHield3_sup_facet5 | 49.96277 |
| 71517 | SHield3_sup_facet5 | 50.00876 |
| 71520 | SHield3_sup_facet5 | 50.79384 |
| 71521 | SHield3_sup_facet5 | 50.44993 |
| 71522 | SHield3_sup_facet5 | 50.01463 |
| 71523 | SHield3_sup_facet5 | 50.19668 |
| 71525 | SHield3_sup_ext_facet5 | 49.99245 |
| 71526 | SHield3_sup_ext_facet5 | 49.88394 |
| 71527 | SHield3_sup_ext_facet5 | 49.84380 |
| 71530 | SHield3_sup_facet5 | 50.84007 |
| 71531 | SHield3_sup_facet5 | 50.69526 |
| 71532 | SHield3_sup_facet5 | 50.23870 |
| 71533 | SHield3_sup_facet5 | 50.47094 |
| 71535 | SHield3_sup_ext_facet5 | 49.83977 |
| 71536 | SHield3_sup_ext_facet5 | 49.80322 |
| 71537 | SHield3_sup_ext_facet5 | 49.77584 |
| 71570 | SHield3_sup_ext_facet5 | 50.68892 |
| 71571 | SHield3_sup_ext_facet5 | 50.73147 |

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|---|---|---|
| 71572 | SHield3_sup_ext_facet5 | 50.67951 |
| 71573 | SHield3_sup_ext_facet5 | 50.53464 |
| 71574 | SHield3_sup_ext_facet5 | 50.45965 |
| 71575 | SHield3_sup_ext_facet5 | 50.41839 |
| 71576 | SHield3_sup_ext_facet5 | 50.28314 |
| 71577 | SHield3_sup_ext_facet5 | 50.16846 |
| 71578 | SHield3_sup_ext_facet5 | 50.17309 |
| 71610 | SHield 3 sup facet 6 | 50.95694 |
| 71611 | SHield 3 sup facet 6 | 51.03755 |
| 71613 | SHield 3 sup facet 6 | 50.69158 |
| 71615 | SHield 3 sup ext fac | 50.47141 |
| 71616 | SHield 3 sup ext fac | 50.38312 |
| 71617 | SHield 3 sup ext fac | 50.32651 |
| 71618 | SHield 3 sup facet 6 | 50.99958 |
| 71619 | SHield 3 sup facet 6 | 51.31622 |
| 71620 | SHield 3 sup facet 6 | 51.03460 |
| 71621 | SHield 3 sup facet 6 | 51.53726 |
| 71625 | SHield 3 sup ext fac | 50.66467 |
| 71626 | SHield 3 sup ext fac | 50.50846 |
| 71627 | SHield 3 sup ext fac | 50.37014 |
| 71628 | SHield 3 sup facet 6 | 50.58384 |
| 71629 | SHield 3 sup facet 6 | 51.34392 |
| 71630 | SHield 3 sup facet 6 | 51.09450 |
| 71631 | SHield 3 sup facet 6 | 51.67266 |
| 71632 | SHield 3 sup facet 6 | 59.70993 |
| 71635 | SHield 3 sup ext fac | 50.27045 |
| 71636 | SHield 3 sup ext fac | 50.26292 |
| 71637 | SHield 3 sup ext fac | 50.24274 |
| 71670 | SHield 3 sup facet 6 | 50.65387 |
| 71671 | SHield 3 sup facet 6 | 50.73915 |
| 71672 | SHield 3 sup facet 6 | 50.82335 |
| 71673 | SHield 3 sup facet 6 | 50.90876 |
| 71674 | SHield 3 sup facet 6 | 50.99771 |
| 71675 | SHield 3 sup facet 6 | 51.09260 |
| 71676 | SHield 3 sup facet 6 | 51.19603 |
| 71677 | SHield 3 sup facet 6 | 51.29633 |
| 71678 | SHield 3 sup facet 6 | 51.38592 |
| 71679 | SHield 3 sup facet 6 | 51.48244 |
| 71680 | SHield 3 sup facet 6 | 51.58889 |
| 71681 | SHield 3 sup facet 6 | 51.70840 |
| 71682 | SHield 3 sup facet 6 | 51.84456 |
| 71683 | SHield 3 sup facet 6 | 52.00165 |
| 71684 | SHield 3 sup facet 6 | 52.20026 |
| 71685 | SHield 3 sup facet 6 | 52.44462 |
| 71686 | SHield 3 sup facet 6 | 52.73237 |
| 71687 | SHield 3 sup facet 6 | 53.08101 |
| 71688 | SHield 3 sup facet 6 | 53.51520 |
| 71689 | SHield 3 sup facet 6 | 54.07070 |

# APPENDIX 8

## TEMPERATURES LISTING

## NOMINAL CASE

| | | |
|---|---|---|
| 1001 | Solar Array vs. satellit | 313.80787 |
| 1002 | Solar Array vs. satellit | 311.50380 |
| 1003 | Solar Array vs. satellit | 311.35980 |
| 1004 | Solar Array vs. satellit | 314.14508 |
| 1010 | Solar Array | 399.39999 |
| 1061 | I/F struts -Y | 302.00000 |
| 1062 | I/F struts -Y-Z | 304.20001 |
| 1063 | I/F struts +Y-Z | 304.39999 |
| 1064 | I/F struts +Y | 301.50000 |
| 1065 | I/F struts +Y+Z | 301.60001 |
| 1066 | I/F struts -Y+Z | 301.39999 |
| 1501 | FIRING CONE | 247.60001 |
| 1503 | THRUSTER | 225.80000 |
| 1504 | HEAD PLATE DISC | 252.00000 |
| 1505 | HEAT BARRIER | 253.70000 |
| 1507 | HEAT FLANGE | 269.00000 |
| 1509 | HEAT FLANGE | 287.00000 |
| 1510 | HEAT FLANGE | 287.10001 |
| 1521 | FIRING CONE | 247.20000 |
| 1523 | THRUSTER | 229.60001 |
| 1524 | HEAD PLATE DISC | 251.30000 |
| 1525 | HEAT BARRIER | 252.89999 |
| 1527 | HEAT FLANGE | 268.00000 |
| 1529 | HEAT FLANGE | 287.00000 |
| 1530 | HEAT FLANGE | 286.89999 |
| 1532 | THR_COM | 292.70001 |
| 1533 | FCV MAIN | 287.00000 |
| 1534 | FCV MAIN | 287.00000 |
| 1543 | HEAT FLANGE | 287.00000 |
| 1544 | HEAT FLANGE | 287.00000 |
| 1546 | HEAT FLANGE | 193.10001 |
| 1701 | FIRING CONE | 249.89999 |
| 1703 | THRUSTER | 231.70000 |
| 1704 | HEAD PLATE DISC | 254.10001 |
| 1705 | HEAT BARRIER | 255.70000 |
| 1707 | HEAT FLANGE | 270.00000 |
| 1709 | HEAT FLANGE | 287.29999 |
| 1710 | HEAT FLANGE | 287.29999 |
| 1721 | FIRING CONE | 245.30000 |
| 1723 | THRUSTER | 224.80000 |
| 1724 | HEAD PLATE DISC | 249.60001 |
| 1725 | HEAT BARRIER | 251.20000 |
| 1727 | HEAT FLANGE | 267.10001 |
| 1729 | HEAT FLANGE | 286.89999 |
| 1730 | HEAT FLANGE | 286.79999 |
| 1732 | THR_COM | 293.20001 |
| 1733 | FCV MAIN | 287.29999 |
| 1734 | FCV MAIN | 286.89999 |
| 1743 | HEAT FLANGE | 287.39999 |
| 1744 | HEAT FLANGE | 287.00000 |
| 1746 | HEAT FLANGE | 193.39999 |
| 2001 | SVM Rad -Y+Z | 284.50000 |
| 2002 | SVM Rad +Z | 281.89999 |
| 2003 | SVM Rad +Y+Z | 287.70001 |
| 2004 | SVM Rad +Y | 286.60001 |
| 2005 | SVM Rad +Y-Z | 261.89999 |
| 2006 | SVM Rad -Z | 263.29999 |
| 2007 | SVM Rad -Y-Z | 259.10001 |
| 2008 | SVM Rad -Y | 284.50000 |
| 3000 | SVM I/F | 300.00000 |
| 3001 | MLI SVM Top +Z | 209.40753 |
| 3002 | MLI SVM Top +Y | 211.78060 |
| 3003 | MLI SVM Top -Z | 215.43486 |
| 3004 | MLI SVM Top +Z-Y | 208.96363 |
| 3011 | SVM Top +Y+Z | 301.29999 |
| 3012 | SVM Top +Y-Z | 300.89999 |
| 3013 | SVM Top -Y-Z | 301.20001 |
| 3014 | SVM Top -Y+Z | 300.39999 |
| 3501 | MLI on Subplatform +Y+Z | 215.07516 |
| 3502 | MLI on Subplatform +Y-Z | 218.88600 |
| 3503 | MLI on Subplatform -Y-Z | 220.28154 |
| 3504 | MLI on Subplatform -Y+Z | 215.22536 |
| 3511 | Subplatform +Y+Z | 306.50000 |
| 3512 | Subplatform +Y-Z | 306.00000 |
| 3513 | Subplatform -Y-Z | 304.10001 |
| 3514 | Subplatform -Y+Z | 306.29999 |
| 3550 | MLI on Subplatform hole | 216.21595 |
| 3560 | Subplatform hole | 306.29999 |
| 3600 | MLI BEU | 239.58767 |
| 3901 | BAFFLE STR1 | 165.30000 |
| 3902 | BAFFLE STR1 | 167.89999 |
| 3922 | LGA2 | 268.50000 |
| 3962 | LGA3 | 287.29999 |
| 4901 | BAFFLE STR1 | 191.39999 |
| 4902 | BAFFLE STR1 | 207.00000 |
| 4921 | SAS1 | 227.89999 |
| 4922 | LGA2 | 242.89999 |
| 4961 | SREM | 156.30000 |
| 4962 | LGA3 | 238.80000 |
| 4963 | VMC | 220.20000 |
| 7522 | MLI PAU | 228.11198 |
| 8501 | NOZZLE | 218.80000 |
| 8503 | DECOMP. COVER | 216.39999 |
| 8512 | HEAT BARRIER | 291.60001 |
| 8513 | HEAT BARRIER | 281.79999 |
| 8514 | HEAT BARRIER | 276.70001 |
| 8533 | DECOMP. COVER | 218.60001 |
| 8601 | NOZZLE | 212.10001 |
| 8603 | DECOMP. COVER | 210.39999 |
| 8612 | HEAT BARRIER | 291.00000 |
| 8613 | HEAT BARRIER | 279.39999 |
| 8614 | HEAT BARRIER | 275.29999 |
| 8633 | DECOMP. COVER | 211.80000 |
| 8701 | NOZZLE | 218.99001 |
| 8703 | DECOMP. COVER | 216.39999 |
| 8712 | HEAT BARRIER | 294.50000 |
| 8713 | HEAT BARRIER | 284.00000 |
| 8714 | HEAT BARRIER | 278.70001 |
| 8733 | DECOMP. COVER | 218.80000 |
| 8801 | NOZZLE | 220.10001 |
| 8803 | DECOMP. COVER | 217.60001 |
| 8812 | HEAT BARRIER | 294.50000 |
| 8813 | HEAT BARRIER | 284.10001 |
| 8814 | HEAT BARRIER | 278.79999 |
| 8833 | DECOMP. COVER | 219.89999 |
| 13001 | WG_BEU_VG1_Ti | 257.13663 |
| 13002 | WG_BEU_VG1 | 185.52235 |
| 13003 | WG_VG1_VG2 | 139.46149 |
| 13004 | WG_VG1_VG2 | 126.18232 |
| 13005 | WG_VG1_VG2 | 113.98742 |
| 13006 | WG_VG1_VG2 | 101.97075 |
| 13007 | WG_VG2_VG3 | 90.29894 |
| 13008 | WG_VG2_VG3 | 79.93890 |
| 13009 | WG_VG2_VG3 | 69.42461 |
| 13010 | WG_VG2_VG3 | 58.21319 |
| 13011 | WG_SS | 49.21882 |
| 13012 | WG_SS | 43.21561 |
| 13013 | WG_SS | 36.41415 |
| 13014 | WG_SS | 27.84468 |
| 13015 | WG_Cu | 21.85621 |
| 13016 | WG_Cu | 21.76610 |
| 13017 | WG_Cu | 21.67504 |

| | | |
|---|---|---|
| 13018 | WG_Cu | 21.58304 |
| 13100 | I/F_WG_VG1 | 147.27646 |
| 13200 | I/F_WG_VG2 | 95.69607 |
| 13300 | I/F_WG_VG3 | 52.11586 |
| 13500 | I/F_WG_ss_cu | 21.90106 |
| 15001 | Harnes_BEUVG1 | 242.75181 |
| 15002 | Harnes_BEUVG1 | 194.06353 |
| 15003 | Harnes_VG1_VG2 | 160.09924 |
| 15004 | Harnes_VG1_VG2 | 144.91798 |
| 15005 | Harnes_VG1_VG2 | 132.56170 |
| 15006 | Harnes_VG1_VG2 | 122.00845 |
| 15007 | Harnes_VG2_VG3 | 110.56609 |
| 15008 | Harnes_VG2_VG3 | 99.95570 |
| 15009 | Harnes_VG2_VG3 | 91.33335 |
| 15010 | Harnes_VG2_VG3 | 84.12196 |
| 15011 | Harnes_VG3_TOP | 76.34156 |
| 15012 | Harnes_VG3_TOP | 69.03899 |
| 15013 | Harnes_VG3_TOP | 63.25641 |
| 15014 | Harnes_VG3_TOP | 58.51658 |
| 15015 | Harnes_TOP_bend | 54.70202 |
| 15016 | Harnes_TOP_bend | 51.57859 |
| 15017 | Harnes_TOP_bend | 48.71979 |
| 15018 | harness_bend | 46.07332 |
| 15019 | harness_bend | 43.60325 |
| 15020 | harness_bend | 41.27919 |
| 15021 | harness_bend | 39.07710 |
| 15022 | harness_bend | 36.97773 |
| 15023 | harness_bend | 34.96552 |
| 15024 | harness_bend | 33.02745 |
| 15025 | harness_bend | 31.15285 |
| 15026 | harness_bend | 29.33166 |
| 15027 | harness_bend | 27.53075 |
| 15028 | harness_bend_FPU | 25.76197 |
| 15029 | harness_bend_FPU | 24.01924 |
| 15030 | harness_bend_FPU | 22.30042 |
| 15101 | I/F_Hr_VG1 | 170.02336 |
| 15201 | I/F_Hr_VG2 | 117.25751 |
| 15301 | I/F_Hr_VG3 | 80.96472 |
| 15450 | I/F_Hr_VG3-ss_cu | 66.00972 |
| 15501 | I/F_Hr_ss_cu | 56.40808 |
| 16301 | Block 4 | 4.67832 |
| 16441 | Block 4 | 4.68680 |
| 16701 | Block 4 | 4.69741 |
| 16702 | Block 4 | 4.69740 |
| 16707 | Block 4 | 4.69739 |
| 16708 | Block 4 | 4.69738 |
| 16709 | Block 4 | 4.69738 |
| 18001 | Tube_BEU_VG1 | 269.20793 |
| 18002 | Tube_BEU_VG1 | 201.96503 |
| 18003 | Tube_VG1_VG2 | 155.29642 |
| 18004 | Tube_VG1_VG2 | 132.17626 |
| 18005 | Tube_VG1_VG2 | 116.68045 |
| 18006 | Tube_VG1_VG2 | 102.57248 |
| 18007 | Tube_VG2_VG3 | 88.70756 |
| 18008 | Tube_VG2_VG3 | 77.29078 |
| 18009 | Tube_VG2_VG3 | 67.27619 |
| 18010 | Tube_VG2_VG3 | 57.74698 |
| 18011 | Tube_VG3_TOP | 49.21701 |
| 18012 | Tube_VG3_TOP | 43.79767 |
| 18013 | Tube_VG3_TOP | 37.86885 |
| 18014 | Tube_VG3_TOP | 30.26031 |
| 18015 | Tube_TOP_END | 22.55313 |
| 18090 | I/F_Ti_GFRP | 267.80598 |
| 18100 | FLANGE_Thermal_Braid_VG1 173.57264 | |
| 18101 | I/F_Column_FLANGE_Therma 174.55877 | |
| 18110 | Panels_VG1 | 161.93249 |
| 18200 | FLANGE_Thermal_Braid_VG2 95.70043 | |
| 18201 | I/F_Column_FLANGE_Therma 96.14518 | |
| 18210 | Panels_VG2 | 95.81235 |
| 18300 | FLANGE_Thermal_Braid_VG3 52.11928 | |
| 18301 | I/F_Column_FLANGE_Therma 52.56603 | |
| 18310 | Panels_VG3 | 55.39066 |
| 18410 | Panels_Plane_VG3 | 48.51464 |
| 18450 | I/F_Column_VG3-ss_cu 41.23351 | |
| 18500 | FLANGE_SS_CU | 21.90551 |
| 18501 | I/F_Column_FLANGE_Therma 22.52337 | |
| 18510 | Panel_plaine_TOP | 27.20431 |
| 29010 | Harness_SVM | 300.00000 |
| 29020 | Harness2 | 278.18779 |
| 29030 | Harness3 | 254.29781 |
| 29040 | Harness4 | 228.17140 |
| 29050 | Harness5 | 199.81322 |
| 29060 | Harness6 | 169.56089 |
| 29070 | Harness7 | 138.24402 |
| 29080 | Harness8 | 107.08598 |
| 29090 | Harness9 | 77.07663 |
| 29100 | Harness_3rd_Gr | 47.73541 |
| 29110 | Harness_SVM | 300.00000 |
| 29120 | Harness2 | 277.98401 |
| 29130 | Harness3 | 253.85124 |
| 29140 | Harness4 | 227.44040 |
| 29150 | Harness5 | 198.76216 |
| 29160 | Harness6 | 168.17755 |
| 29170 | Harness7 | 136.55957 |
| 29180 | Harness8 | 105.17124 |
| 29190 | Harness9 | 74.98095 |
| 29200 | Harness_3rd_Gr | 45.30432 |
| 30000 | Baffle +Y ext | 43.29910 |
| 30001 | Baffle -Z ext | 44.34084 |
| 30002 | Baffle -Z ext | 43.68327 |
| 30003 | Baffle +Z ext | 44.78250 |
| 30004 | Baffle +Z ext | 43.86448 |
| 30005 | Baffle -Y ext | 44.46153 |
| 30500 | Baffle +Y int | 43.30477 |
| 30501 | Baffle -Z int44.35314 | |
| 30502 | Baffle -Z int43.68964 | |
| 30503 | Baffle +Z int | 44.80292 |
| 30504 | Baffle +Z int | 43.87094 |
| 30505 | Baffle -Y int44.45635 | |
| 31000 | Main panel -Z low +Y | 46.65625 |
| 31001 | Main panel -Z low +Y | 43.51220 |
| 31002 | Main panel -Z low +Y | 41.96834 |
| 31003 | Main panel -Z low +Y | 43.39544 |
| 31005 | Main panel -Z +Y | 43.31681 |
| 31006 | Main panel -Z +Y | 43.22381 |
| 31007 | Main panel -Z +Y | 43.33286 |
| 31008 | Main panel -Z +Y | 43.56799 |
| 31009 | Main panel -Z +Y | 43.88754 |
| 31010 | Main panel -Z low -Y | 43.11689 |
| 31011 | Main panel -Z low -Y | 42.53382 |
| 31012 | Main panel -Z low -Y | 41.96538 |
| 31013 | Main panel -Z low -Y | 42.62935 |
| 31015 | Main panel -Z -Y | 42.67791 |
| 31016 | Main panel -Z -Y | 42.74598 |
| 31017 | Main panel -Z -Y | 43.15052 |
| 31018 | Main panel -Z -Y | 43.38347 |
| 31019 | Main panel -Z -Y | 43.87290 |
| 31020 | Main panel -Z | 44.86996 |
| 31021 | Main panel -Z | 46.34368 |
| 31022 | Main panel -Z | 44.91894 |
| 31023 | Main panel -Z | 47.14531 |
| 31024 | Main panel -Z Top +Y | 41.62594 |
| 31025 | Main panel -Z Top | 41.63182 |
| 31026 | Main panel -Z Top -Y | 41.62593 |

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|---|---|---|
| 31027 | Main panel -Z Top +Y | 40.37957 |
| 31028 | Main panel -Z Top | 40.27677 |
| 31029 | Main panel -Z Top -Y | 40.38203 |
| 31030 | Main panel -Z Top +Y | 39.85786 |
| 31031 | Main panel -Z low +Y | 39.65449 |
| 31032 | Main panel -Z Top -Y | 39.85978 |
| 31033 | Main panel -Z Top | 39.34425 |
| 31100 | Main panel +Z low +Y | 46.43752 |
| 31101 | Main panel +Z low +Y | 43.49206 |
| 31102 | Main panel +Z low +Y | 42.07178 |
| 31103 | Main panel +Z low +Y | 43.40472 |
| 31105 | Main panel +Z +Y | 43.31421 |
| 31106 | Main Panel +Z medium +Y | 43.22584 |
| 31107 | Main panel +Z medium +Y | 43.34310 |
| 31108 | Main panel +Z medium +Y | 43.55917 |
| 31109 | Main panel +Z +Y | 43.91213 |
| 31110 | Main panel +Z low -Y | 43.08134 |
| 31111 | Main panel +Z low -Y | 42.55269 |
| 31112 | Main panel +Z low -Y | 42.01427 |
| 31113 | Main panel +Z low -Y | 42.62614 |
| 31115 | Main panel +Z -Y | 42.68530 |
| 31116 | Main panel +Z medium -Y | 42.74626 |
| 31117 | Main panel +Z medium -Y | 43.16219 |
| 31118 | Main panel +Z medium -Y | 43.37264 |
| 31119 | Main panel +Z -Y | 43.89806 |
| 31120 | Main panel top +Z +Y | 44.84842 |
| 31121 | Main panel top +Z | 46.34110 |
| 31122 | Main panel top +Z -Y | 44.88879 |
| 31123 | Main panel top +Z | 47.08389 |
| 31124 | Main panel +Z Top +Y | 41.63928 |
| 31125 | Main panel +Z Top | 41.65813 |
| 31126 | Main panel +Z Top -Y | 41.63924 |
| 31127 | Main panel +Z Top +Y | 40.38689 |
| 31128 | Main panel +Z Top | 40.28267 |
| 31129 | Main panel +Z Top -Y | 40.38931 |
| 31130 | Main panel +Z Top +Y | 39.86595 |
| 31131 | Main panel +Z low +Y | 39.65987 |
| 31132 | Main panel +Z Top -Y | 39.86785 |
| 31133 | Main panel +Z Top | 39.35810 |
| 31203 | Doubler panel -Z low +Y | 43.37997 |
| 31206 | Doubler panel -Z medium | 43.21723 |
| 31208 | Doubler panel -Z medium | 43.56576 |
| 31213 | Doubler panel -Z low -Y | 42.63549 |
| 31216 | Doubler panel -Z medium | 42.74465 |
| 31218 | Doubler panel -Z medium | 43.38728 |
| 31220 | Doubler panel top -Z +Y | 44.87479 |
| 31221 | Doubler panel top -Z | 46.34966 |
| 31222 | Doubler panel top -Z +Y | 44.93448 |
| 31223 | Doubler panel top -Z | 47.29005 |
| 31303 | Doubler panel +Z low +Y | 43.39523 |
| 31306 | Doubler panel +Z medium | 43.22378 |
| 31308 | Doubler panel +Z medium | 43.56802 |
| 31313 | Doubler panel +Z low -Y | 42.62942 |
| 31316 | Doubler panel +Z medium | 42.74597 |
| 31318 | Doubler panel +Z medium | 43.38354 |
| 31320 | Doubler panel top +Z +Y | 44.87007 |
| 31321 | Doubler panel top +Z | 46.34376 |
| 31322 | Doubler panel top +Z -Y | 44.91922 |
| 31323 | Doubler panel top +Z | 47.14645 |
| 31400 | Dismountable panel face | 41.87592 |
| 31401 | Dismountable panel face | 41.96274 |
| 31500 | Triangle Panel down . . | .41.61098 |
| 31501 | Triangle Panel up . . | 41.62474 |
| 31600 | strut - Y panel . | 41.49269 |
| 31601 | strut - Y panel . | 41.35418 |
| 31602 | strut - Y panel . | 41.30555 |
| 31603 | strut - Y panel . | 41.34752 |
| 31604 | strut - Y panel . | 41.48093 |
| 31605 | strut - Y panel . | 41.70798 |
| 31606 | strut - Y panel . | 42.03907 |
| 31607 | strut - Y panel . | 42.47780 |
| 31608 | strut - Y panel . | 43.02887 |
| 31609 | strut - Y panel . | 43.69889 |
| 31610 | strut + Y panel . | 41.33084 |
| 31611 | strut + Y panel . | 41.20519 |
| 31612 | strut + Y panel . | 41.16951 |
| 31613 | strut + Y panel . | 41.22479 |
| 31614 | strut + Y panel . | 41.37697 |
| 31615 | strut + Y panel . | 41.62780 |
| 31616 | strut + Y panel . | 41.97973 |
| 31617 | strut + Y panel . | 42.43957 |
| 31618 | strut + Y panel . | 43.01405 |
| 31619 | strut + Y panel . | 43.70628 |
| 31620 | Bottom strut panel . . | 40.83087 |
| 31621 | Bottom strut panel . . | 40.86577 |
| 31622 | Bottom strut panel . . | 40.91559 |
| 31623 | Bottom strut panel . . | 40.98292 |
| 31624 | Bottom strut panel . . | 41.06841 |
| 31625 | Bottom strut panel . . | 41.17146 |
| 31626 | Bottom strut panel . . | 41.29168 |
| 31627 | Bottom strut panel . . | 41.42865 |
| 31628 | Bottom strut panel . . | 41.58188 |
| 31629 | Bottom strut panel . . | 41.75161 |
| 31630 | Back strut panel . . | 40.48747 |
| 31631 | Back strut panel . . | 39.92618 |
| 31632 | Back strut panel . . | 39.52600 |
| 31633 | Back strut panel . . | 39.29520 |
| 31634 | Back strut panel . . | 39.23516 |
| 31635 | Back strut panel . . | 39.34823 |
| 31636 | Back strut panel . . | 39.62923 |
| 31637 | Back strut panel . . | 40.07116 |
| 31638 | Back strut panel . . | 40.66922 |
| 31639 | Back strut panel . . | 41.41393 |
| 31640 | top strut panel . . | 41.41616 |
| 31641 | top strut panel . . | 40.74182 |
| 31642 | top strut panel . . | 40.17680 |
| 31643 | top strut panel . . | 39.72109 |
| 31644 | top strut panel . . | 39.37641 |
| 31645 | top strut panel . . | 39.14084 |
| 31646 | top strut panel . . | 39.01454 |
| 31647 | top strut panel . . | 38.99468 |
| 31648 | top strut panel . . | 39.08090 |
| 31649 | top strut panel . . | 39.27276 |
| 31700 | SR panel +Z low | 42.02559 |
| 31701 | SR panel +Z low | 42.40996 |
| 31702 | SR panel +Z low | 42.01458 |
| 31703 | SR panel +Z low | 42.15839 |

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|---|---|---|
| 31704 | SR panel +Z medium | 42.07551 |
| 31705 | SR panel +Z medium2 | 42.07750 |
| 31706 | SR panel +Z Top | 42.10486 |
| 31710 | SR panel -Z low | 42.02379 |
| 31711 | SR panel -Z low | 42.41757 |
| 31712 | SR panel -Z low | 42.01614 |
| 31713 | SR panel -Z low | 42.15987 |
| 31714 | SR panel -Z medium | 42.07480 |
| 31715 | SR panel -Z medium2 | 42.07636 |
| 31716 | SR panel -Z top | 42.09732 |
| 31800 | strut + Y panel . | 41.62386 |
| 31801 | strut + Y panel . | 41.61681 |
| 31802 | strut + Y panel . | 41.60737 |
| 31803 | strut + Y panel . | 41.59740 |
| 31804 | strut + Y panel . | 41.59597 |
| 31805 | strut + Y panel . | 41.61889 |
| 31806 | strut + Y panel . | 41.66664 |
| 31807 | strut + Y panel . | 41.73627 |
| 31808 | strut + Y panel . | 41.82481 |
| 31809 | strut + Y panel . | 41.93021 |
| 31810 | strut - Y panel . | 41.80384 |
| 31811 | strut - Y panel . | 41.81517 |
| 31812 | strut - Y panel . | 41.82405 |
| 31813 | strut - Y panel . | 41.83291 |
| 31814 | strut - Y panel . | 41.85092 |
| 31815 | strut - Y panel . | 41.89356 |
| 31816 | strut - Y panel . | 41.96253 |
| 31817 | strut - Y panel . | 42.05473 |
| 31818 | strut - Y panel . | 42.16746 |
| 31819 | strut - Y panel . | 42.30011 |
| 31901 | brac_strut+Y | 230.24430 |
| 31902 | brac_strut+Y | 182.76948 |
| 31903 | brac_strut+Y | 159.83541 |
| 31904 | brac_strut+Y | 148.29023 |
| 31905 | brac_strut+Y | 142.71762 |
| 31906 | brac_strut+Y | 140.56739 |
| 31907 | brac_strut+Y | 139.88833 |
| 31908 | brac_strut+Y | 140.15208 |
| 31909 | brac_strut+Y | 140.48155 |
| 31910 | brac_strut+Y | 139.67585 |
| 31911 | brac_strut-Y | 233.34267 |
| 31912 | brac_strut-Y | 190.25328 |
| 31913 | brac_strut-Y | 170.87428 |
| 31914 | brac_strut-Y | 162.13089 |
| 31915 | brac_strut-Y | 157.67444 |
| 31916 | brac_strut-Y | 155.65811 |
| 31917 | brac_strut-Y | 155.03125 |
| 31918 | brac_strut-Y | 154.44293 |
| 31919 | brac_strut-Y | 152.84884 |
| 31920 | brac_strut-Y | 148.61159 |
| 31951 | brac_CFRP+Y | 43.88219 |
| 31952 | brac_CFRP+Y | 43.58641 |
| 31953 | brac_CFRP+Y | 43.29537 |
| 31954 | brac_CFRP+Y | 43.00900 |
| 31955 | brac_CFRP+Y | 42.72735 |
| 31956 | brac_CFRP+Y | 42.45007 |
| 31957 | brac_CFRP+Y | 42.17659 |
| 31958 | brac_CFRP+Y | 41.90650 |
| 31959 | brac_CFRP+Y | 41.63927 |
| 31960 | brac_CFRP+Y | 41.37416 |
| 31961 | brac_CFRP-Y | 45.16910 |
| 31962 | brac_CFRP-Y | 44.97851 |
| 31963 | brac_CFRP-Y | 44.79666 |
| 31964 | brac_CFRP-Y | 44.62355 |
| 31965 | brac_CFRP-Y | 44.45915 |
| 31966 | brac_CFRP-Y | 44.30312 |
| 31967 | brac_CFRP-Y | 44.15548 |
| 31968 | brac_CFRP-Y | 44.01597 |
| 31969 | brac_CFRP-Y | 43.88431 |
| 31970 | brac_CFRP-Y | 43.76018 |
| 32001 | strut 1 - Y (+Z) | 217.28643 |
| 32002 | strut 1 - Y (+Z) | 172.00512 |
| 32003 | strut 1 - Y (+Z) | 150.04415 |
| 32004 | strut 1 - Y (+Z) | 138.18535 |
| 32005 | strut 1 - Y (+Z) | 131.34711 |
| 32006 | strut 1 - Y (+Z) | 126.75643 |
| 32007 | strut 1 - Y (+Z) | 123.11734 |
| 32008 | strut 1 - Y (+Z) | 118.93135 |
| 32009 | strut 1 - Y (+Z) | 123.92840 |
| 32010 | strut 1 - Y (+Z) | 118.87292 |
| 32011 | strut 1 - Y (+Z) | 106.42530 |
| 32012 | strut 1 - Y (+Z) | 97.65403 |
| 32013 | strut 1 - Y (+Z) | 91.08389 |
| 32014 | strut 1 - Y (+Z) | 85.94794 |
| 32015 | strut 1 - Y (+Z) | 81.67343 |
| 32016 | strut 1 - Y (+Z) | 77.76949 |
| 32017 | strut 1 - Y (+Z) | 79.32456 |
| 32018 | strut 1 - Y (+Z) | 77.74042 |
| 32019 | strut 1 - Y (+Z) | 70.17640 |
| 32020 | strut 1 - Y (+Z) | 63.99333 |
| 32021 | strut 1 - Y (+Z) | 58.38675 |
| 32022 | strut 1 - Y (+Z) | 52.91580 |
| 32023 | strut 1 - Y (+Z) | 47.28090 |
| 32024 | strut 1 - Y (+Z) | 44.96108 |
| 32025 | strut 1 - Y (+Z) | 47.26593 |
| 32026 | strut 1 - Y (+Z) | 46.05154 |
| 32027 | strut 1 - Y (+Z) | 44.92255 |
| 32028 | strut 1 - Y (+Z) | 43.85589 |
| 32029 | strut 1 - Y (+Z) | 42.83491 |
| 32030 | strut 1 - Y (+Z) | 41.85514 |
| 32031 | eccofoam strut 1 - Y (+Z | 213.87074 |
| 32032 | eccofoam strut 1 - Y (+Z | 173.50886 |
| 32033 | eccofoam strut 1 - Y (+Z | 150.91607 |
| 32034 | eccofoam strut 1 - Y (+Z | 138.62635 |
| 32035 | eccofoam strut 1 - Y (+Z | 131.54779 |
| 32036 | eccofoam strut 1 - Y (+Z | 126.84062 |
| 32037 | eccofoam strut 1 - Y (+Z | 123.12821 |
| 32038 | eccofoam strut 1 - Y (+Z | 119.54434 |
| 32039 | eccofoam strut 1 - Y (+Z | 123.20393 |
| 32040 | eccofoam strut 1 - Y (+Z | 118.30271 |
| 32041 | eccofoam strut 1 - Y (+Z | 106.66353 |
| 32042 | eccofoam strut 1 - Y (+Z | 97.83947 |
| 32043 | eccofoam strut 1 - Y (+Z | 91.20658 |
| 32044 | eccofoam strut 1 - Y (+Z | 86.02352 |
| 32045 | eccofoam strut 1 - Y (+Z | 81.73363 |
| 32046 | eccofoam strut 1 - Y (+Z | 78.15510 |
| 32047 | eccofoam strut 1 - Y (+Z | 79.13313 |
| 32048 | eccofoam strut 1 - Y (+Z | 77.84908 |
| 32051 | strut 2 - Y (-Z) | 217.30166 |
| 32052 | strut 2 - Y (-Z) | 172.19593 |
| 32053 | strut 2 - Y (-Z) | 150.10944 |
| 32054 | strut 2 - Y (-Z) | 138.61861 |
| 32055 | strut 2 - Y (-Z) | 132.07650 |
| 32056 | strut 2 - Y (-Z) | 128.12190 |
| 32057 | strut 2 - Y (-Z) | 125.47077 |
| 32058 | strut 2 - Y (-Z) | 123.19204 |
| 32059 | strut 2 - Y (-Z) | 130.31540 |
| 32060 | strut 2 - Y (-Z) | 123.13770 |

| | | |
|---|---|---|
| 32061 | strut 2 - Y (-Z) | 109.97299 |
| 32062 | strut 2 - Y (-Z) | 100.80218 |
| 32063 | strut 2 - Y (-Z) | 94.08980 |
| 32064 | strut 2 - Y (-Z) | 88.80867 |
| 32065 | strut 2 - Y (-Z) | 84.33850 |
| 32066 | strut 2 - Y (-Z) | 80.09129 |
| 32067 | strut 2 - Y (-Z) | 81.52186 |
| 32068 | strut 2 - Y (-Z) | 80.05969 |
| 32069 | strut 2 - Y (-Z) | 72.21513 |
| 32070 | strut 2 - Y (-Z) | 65.86627 |
| 32071 | strut 2 - Y (-Z) | 60.09748 |
| 32072 | strut 2 - Y (-Z) | 54.41745 |
| 32073 | strut 2 - Y (-Z) | 48.45167 |
| 32074 | strut 2 - Y (-Z) | 45.95105 |
| 32075 | strut 2 - Y (-Z) | 48.43562 |
| 32076 | strut 2 - Y (-Z) | 47.16429 |
| 32077 | strut 2 - Y (-Z) | 46.00227 |
| 32078 | strut 2 - Y (-Z) | 44.92663 |
| 32079 | strut 2 - Y (-Z) | 43.92218 |
| 32080 | strut 2 - Y (-Z) | 42.98179 |
| 32081 | eccofoam strut 2 - Y (-Z | 213.89824 |
| 32082 | eccofoam strut 2 - Y (-Z | 173.68124 |
| 32083 | eccofoam strut 2 - Y (-Z | 151.01568 |
| 32084 | eccofoam strut 2 - Y (-Z | 139.05884 |
| 32085 | eccofoam strut 2 - Y (-Z | 132.30407 |
| 32086 | eccofoam strut 2 - Y (-Z | 128.23848 |
| 32087 | eccofoam strut 2 - Y (-Z | 125.55045 |
| 32088 | eccofoam strut 2 - Y (-Z | 123.80403 |
| 32089 | eccofoam strut 2 - Y (-Z | 129.28930 |
| 32090 | eccofoam strut 2 - Y (-Z | 122.64956 |
| 32091 | eccofoam strut 2 - Y (-Z | 110.24166 |
| 32092 | eccofoam strut 2 - Y (-Z | 101.00851 |
| 32093 | eccofoam strut 2 - Y (-Z | 94.21348 |
| 32094 | eccofoam strut 2 - Y (-Z | 88.87997 |
| 32095 | eccofoam strut 2 - Y (-Z | 84.38890 |
| 32096 | eccofoam strut 2 - Y (-Z | 80.49336 |
| 32097 | eccofoam strut 2 - Y (-Z | 81.34887 |
| 32098 | eccofoam strut 2 - Y (-Z | 80.16028 |
| 32101 | strut 3 - Z -Y | 227.25294 |
| 32102 | strut 3 - Z -Y | 199.13452 |
| 32103 | strut 3 - Z -Y | 204.36629 |
| 32104 | strut 3 - Z -Y | 218.60270 |
| 32105 | strut 3 - Z -Y | 225.34883 |
| 32106 | strut 3 - Z -Y | 220.96766 |
| 32107 | strut 3 - Z -Y | 202.81861 |
| 32108 | strut 3 - Z -Y | 164.78378 |
| 32109 | strut 3 - Z -Y | 144.54115 |
| 32110 | strut 3 - Z -Y | 164.49242 |
| 32111 | strut 3 - Z -Y | 137.24671 |
| 32112 | strut 3 - Z -Y | 129.68117 |
| 32113 | strut 3 - Z -Y | 122.22297 |
| 32114 | strut 3 - Z -Y | 108.75737 |
| 32115 | strut 3 - Z -Y | 97.47187 |
| 32116 | strut 3 - Z -Y | 86.12611 |
| 32117 | strut 3 - Z -Y | 82.98129 |
| 32118 | strut 3 - Z -Y | 86.07781 |
| 32119 | strut 3 - Z -Y | 85.74328 |
| 32120 | strut 3 - Z -Y | 80.28873 |
| 32121 | strut 3 - Z -Y | 70.84535 |
| 32122 | strut 3 - Z -Y | 61.43401 |
| 32123 | strut 3 - Z -Y | 51.22930 |
| 32124 | strut 3 - Z -Y | 46.58493 |
| 32125 | strut 3 - Z -Y | 51.20252 |
| 32126 | strut 3 - Z -Y | 49.44454 |
| 32127 | strut 3 - Z -Y | 47.81389 |
| 32128 | strut 3 - Z -Y | 46.27137 |
| 32129 | strut 3 - Z -Y | 44.78977 |
| 32130 | strut 3 - Z -Y | 43.35348 |
| 32131 | eccofoam inside strut 3 | 225.24041 |
| 32132 | eccofoam inside strut 3 | 201.45908 |
| 32133 | eccofoam inside strut 3 | 205.14624 |
| 32134 | eccofoam inside strut 3 | 218.04973 |
| 32135 | eccofoam inside strut 3 | 224.41901 |
| 32136 | eccofoam inside strut 3 | 219.80087 |
| 32137 | eccofoam inside strut 3 | 201.39522 |
| 32138 | eccofoam inside strut 3 | 166.16993 |
| 32139 | eccofoam inside strut 3 | 147.32421 |
| 32140 | eccofoam inside strut 3 | 161.36494 |
| 32141 | eccofoam inside strut 3 | 138.44940 |
| 32142 | eccofoam inside strut 3 | 129.74554 |
| 32143 | eccofoam inside strut 3 | 121.80232 |
| 32144 | eccofoam inside strut 3 | 108.88840 |
| 32145 | eccofoam inside strut 3 | 97.52275 |
| 32146 | eccofoam inside strut 3 | 86.75828 |
| 32147 | eccofoam inside strut 3 | 83.46401 |
| 32148 | eccofoam inside strut 3 | 85.87387 |
| 32151 | strut 4 - Z (-Y) | 222.95846 |
| 32152 | strut 4 - Z (-Y) | 182.88463 |
| 32153 | strut 4 - Z (-Y) | 165.41283 |
| 32154 | strut 4 - Z (-Y) | 156.92123 |
| 32155 | strut 4 - Z (-Y) | 153.01936 |
| 32156 | strut 4 - Z (-Y) | 150.78016 |
| 32157 | strut 4 - Z (-Y) | 148.00650 |
| 32158 | strut 4 - Z (-Y) | 141.33341 |
| 32159 | strut 4 - Z (-Y) | 142.74346 |
| 32160 | strut 4 - Z (-Y) | 141.23828 |
| 32161 | strut 4 - Z (-Y) | 124.21877 |
| 32162 | strut 4 - Z (-Y) | 112.82180 |
| 32163 | strut 4 - Z (-Y) | 104.56879 |
| 32164 | strut 4 - Z (-Y) | 97.74316 |
| 32165 | strut 4 - Z (-Y) | 91.13898 |
| 32166 | strut 4 - Z (-Y) | 83.62411 |
| 32167 | strut 4 - Z (-Y) | 83.04405 |
| 32168 | strut 4 - Z (-Y) | 83.57888 |
| 32169 | strut 4 - Z (-Y) | 75.29490 |
| 32170 | strut 4 - Z (-Y) | 68.57510 |
| 32171 | strut 4 - Z (-Y) | 62.35120 |
| 32172 | strut 4 - Z (-Y) | 56.04536 |
| 32173 | strut 4 - Z (-Y) | 49.19905 |
| 32174 | strut 4 - Z (-Y) | 46.30623 |
| 32175 | strut 4 - Z (-Y) | 49.18019 |
| 32176 | strut 4 - Z (-Y) | 47.65170 |
| 32177 | strut 4 - Z (-Y) | 46.25650 |
| 32178 | strut 4 - Z (-Y) | 44.96771 |
| 32179 | strut 4 - Z (-Y) | 43.76006 |
| 32180 | strut 4 - Z (-Y) | 42.62966 |
| 32181 | eccofoam strut 4 - Z (-Y | 219.94682 |
| 32182 | eccofoam strut 4 - Z (-Y | 184.35937 |
| 32183 | eccofoam strut 4 - Z (-Y | 166.19844 |
| 32184 | eccofoam strut 4 - Z (-Y | 157.32084 |
| 32185 | eccofoam strut 4 - Z (-Y | 153.16530 |
| 32186 | eccofoam strut 4 - Z (-Y | 150.73425 |
| 32187 | eccofoam strut 4 - Z (-Y | 147.76068 |

| | | |
|---|---|---|
| 32188 | eccofoam strut 4 - Z (-Y | 141.88240 |
| 32189 | eccofoam strut 4 - Z (-Y | 142.49142 |
| 32190 | eccofoam strut 4 - Z (-Y | 140.12214 |
| 32191 | eccofoam strut 4 - Z (-Y | 124.56385 |
| 32192 | eccofoam strut 4 - Z (-Y | 113.08329 |
| 32193 | eccofoam strut 4 - Z (-Y | 104.69269 |
| 32194 | eccofoam strut 4 - Z (-Y | 97.76617 |
| 32195 | eccofoam strut 4 - Z (-Y | 91.11152 |
| 32196 | eccofoam strut 4 - Z (-Y | 84.13237 |
| 32197 | eccofoam strut 4 - Z (-Y | 83.15916 |
| 32198 | eccofoam strut 4 - Z (-Y | 83.54613 |
| 32201 | strut 5 - Z (+Y) | 219.60884 |
| 32202 | strut 5 - Z (+Y) | 175.71062 |
| 32203 | strut 5 - Z (+Y) | 155.54473 |
| 32204 | strut 5 - Z (+Y) | 146.07465 |
| 32205 | strut 5 - Z (+Y) | 142.13199 |
| 32206 | strut 5 - Z (+Y) | 140.25976 |
| 32207 | strut 5 - Z (+Y) | 138.62990 |
| 32208 | strut 5 - Z (+Y) | 134.91793 |
| 32209 | strut 5 - Z (+Y) | 137.95500 |
| 32210 | strut 5 - Z (+Y) | 134.84866 |
| 32211 | strut 5 - Z (+Y) | 119.74569 |
| 32212 | strut 5 - Z (+Y) | 109.37694 |
| 32213 | strut 5 - Z (+Y) | 101.66034 |
| 32214 | strut 5 - Z (+Y) | 95.15316 |
| 32215 | strut 5 - Z (+Y) | 88.61146 |
| 32216 | strut 5 - Z (+Y) | 81.00415 |
| 32217 | strut 5 - Z (+Y) | 79.92776 |
| 32218 | strut 5 - Z (+Y) | 80.95959 |
| 32219 | strut 5 - Z (+Y) | 73.23271 |
| 32220 | strut 5 - Z (+Y) | 66.89466 |
| 32221 | strut 5 - Z (+Y) | 60.97917 |
| 32222 | strut 5 - Z (+Y) | 54.94601 |
| 32223 | strut 5 - Z (+Y) | 48.36516 |
| 32224 | strut 5 - Z (+Y) | 45.51327 |
| 32225 | strut 5 - Z (+Y) | 48.34717 |
| 32226 | strut 5 - Z (+Y) | 46.97141 |
| 32227 | strut 5 - Z (+Y) | 45.72156 |
| 32228 | strut 5 - Z (+Y) | 44.57252 |
| 32229 | strut 5 - Z (+Y) | 43.50802 |
| 32230 | strut 5 - Z (+Y) | 42.52175 |
| 32231 | eccofoam strut 5 - Z (+Y | 216.30430 |
| 32232 | eccofoam strut 5 - Z (+Y | 177.25575 |
| 32233 | eccofoam strut 5 - Z (+Y | 156.46544 |
| 32234 | eccofoam strut 5 - Z (+Y | 146.55482 |
| 32235 | eccofoam strut 5 - Z (+Y | 142.31823 |
| 32236 | eccofoam strut 5 - Z (+Y | 140.28233 |
| 32237 | eccofoam strut 5 - Z (+Y | 138.51308 |
| 32238 | eccofoam strut 5 - Z (+Y | 135.36349 |
| 32239 | eccofoam strut 5 - Z (+Y | 137.47882 |
| 32240 | eccofoam strut 5 - Z (+Y | 133.96726 |
| 32241 | eccofoam strut 5 - Z (+Y | 120.04052 |
| 32242 | eccofoam strut 5 - Z (+Y | 109.59773 |
| 32243 | eccofoam strut 5 - Z (+Y | 101.76400 |
| 32244 | eccofoam strut 5 - Z (+Y | 95.15512 |
| 32245 | eccofoam strut 5 - Z (+Y | 88.56942 |
| 32246 | eccofoam strut 5 - Z (+Y | 81.48702 |
| 32247 | eccofoam strut 5 - Z (+Y | 80.11050 |
| 32248 | eccofoam strut 5 - Z (+Y | 80.89334 |
| 32251 | strut 6 - Z +Y | 218.80210 |
| 32252 | strut 6 - Z +Y | 174.03541 |
| 32253 | strut 6 - Z +Y | 152.33041 |
| 32254 | strut 6 - Z +Y | 140.96478 |
| 32255 | strut 6 - Z +Y | 134.88762 |
| 32256 | strut 6 - Z +Y | 131.43997 |
| 32257 | strut 6 - Z +Y | 129.33426 |
| 32258 | strut 6 - Z +Y | 128.15048 |
| 32259 | strut 6 - Z +Y | 136.94006 |
| 32260 | strut 6 - Z +Y | 128.09689 |
| 32261 | strut 6 - Z +Y | 113.69231 |
| 32262 | strut 6 - Z +Y | 103.57938 |
| 32263 | strut 6 - Z +Y | 96.04879 |
| 32264 | strut 6 - Z +Y | 89.89998 |
| 32265 | strut 6 - Z +Y | 84.36447 |
| 32266 | strut 6 - Z +Y | 78.79220 |
| 32267 | strut 6 - Z +Y | 79.48024 |
| 32268 | strut 6 - Z +Y | 78.75742 |
| 32269 | strut 6 - Z +Y | 71.04517 |
| 32270 | strut 6 - Z +Y | 64.76317 |
| 32271 | strut 6 - Z +Y | 59.05331 |
| 32272 | strut 6 - Z +Y | 53.47775 |
| 32273 | strut 6 - Z +Y | 47.70603 |
| 32274 | strut 6 - Z +Y | 45.29199 |
| 32275 | strut 6 - Z +Y | 47.69085 |
| 32276 | strut 6 - Z +Y | 46.54691 |
| 32277 | strut 6 - Z +Y | 45.52187 |
| 32278 | strut 6 - Z +Y | 44.59251 |
| 32279 | strut 6 - Z +Y | 43.74294 |
| 32280 | strut 6 - Z +Y | 42.97065 |
| 32281 | eccofoam strut 6 - Z +Y | 215.42543 |
| 32282 | eccofoam strut 6 - Z +Y | 175.52454 |
| 32283 | eccofoam strut 6 - Z +Y | 153.22010 |
| 32284 | eccofoam strut 6 - Z +Y | 141.42878 |
| 32285 | eccofoam strut 6 - Z +Y | 135.12040 |
| 32286 | eccofoam strut 6 - Z +Y | 131.56277 |
| 32287 | eccofoam strut 6 - Z +Y | 129.45614 |
| 32288 | eccofoam strut 6 - Z +Y | 128.78965 |
| 32289 | eccofoam strut 6 - Z +Y | 135.67590 |
| 32290 | eccofoam strut 6 - Z +Y | 127.62402 |
| 32291 | eccofoam strut 6 - Z +Y | 113.98439 |
| 32292 | eccofoam strut 6 - Z +Y | 103.79609 |
| 32293 | eccofoam strut 6 - Z +Y | 96.16850 |
| 32294 | eccofoam strut 6 - Z +Y | 89.95549 |
| 32295 | eccofoam strut 6 - Z +Y | 84.39845 |
| 32296 | eccofoam strut 6 - Z +Y | 79.24300 |
| 32297 | eccofoam strut 6 - Z +Y | 79.41447 |
| 32298 | eccofoam strut 6 - Z +Y | 78.80868 |

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|---|---|---|
| 32301 | strut 7 + Y (-Z) | 217.32032 |
| 32302 | strut 7 + Y (-Z) | 172.17021 |
| 32303 | strut 7 + Y (-Z) | 150.03465 |
| 32304 | strut 7 + Y (-Z) | 138.19950 |
| 32305 | strut 7 + Y (-Z) | 131.37367 |
| 32306 | strut 7 + Y (-Z) | 127.14485 |
| 32307 | strut 7 + Y (-Z) | 123.88908 |
| 32308 | strut 7 + Y (-Z) | 120.25219 |
| 32309 | strut 7 + Y (-Z) | 126.01263 |
| 32310 | strut 7 + Y (-Z) | 120.19518 |
| 32311 | strut 7 + Y (-Z) | 107.43457 |
| 32312 | strut 7 + Y (-Z) | 98.44434 |
| 32313 | strut 7 + Y (-Z) | 91.71862 |
| 32314 | strut 7 + Y (-Z) | 86.41225 |
| 32315 | strut 7 + Y (-Z) | 81.90020 |
| 32316 | strut 7 + Y (-Z) | 77.54334 |
| 32317 | strut 7 + Y (-Z) | 78.70955 |
| 32318 | strut 7 + Y (-Z) | 77.51271 |
| 32319 | strut 7 + Y (-Z) | 70.06922 |
| 32320 | strut 7 + Y (-Z) | 63.99254 |
| 32321 | strut 7 + Y (-Z) | 58.45492 |
| 32322 | strut 7 + Y (-Z) | 53.03678 |
| 32323 | strut 7 + Y (-Z) | 47.42351 |
| 32324 | strut 7 + Y (-Z) | 45.03122 |
| 32325 | strut 7 + Y (-Z) | 47.40875 |
| 32326 | strut 7 + Y (-Z) | 46.32888 |
| 32327 | strut 7 + Y (-Z) | 45.35485 |
| 32328 | strut 7 + Y (-Z) | 44.46978 |
| 32329 | strut 7 + Y (-Z) | 43.66328 |
| 32330 | strut 7 + Y (-Z) | 42.93605 |
| 32331 | eccofoam strut 7 + Y (-Z | 213.91327 |
| 32332 | eccofoam strut 7 + Y (-Z | 173.65338 |
| 32333 | eccofoam strut 7 + Y (-Z | 150.91957 |
| 32334 | eccofoam strut 7 + Y (-Z | 138.64249 |
| 32335 | eccofoam strut 7 + Y (-Z | 131.60010 |
| 32336 | eccofoam strut 7 + Y (-Z | 127.23338 |
| 32337 | eccofoam strut 7 + Y (-Z | 123.91289 |
| 32338 | eccofoam strut 7 + Y (-Z | 120.87381 |
| 32339 | eccofoam strut 7 + Y (-Z | 125.18022 |
| 32340 | eccofoam strut 7 + Y (-Z | 119.65031 |
| 32341 | eccofoam strut 7 + Y (-Z | 107.68182 |
| 32342 | eccofoam strut 7 + Y (-Z | 98.63493 |
| 32343 | eccofoam strut 7 + Y (-Z | 91.84017 |
| 32344 | eccofoam strut 7 + Y (-Z | 86.48177 |
| 32345 | eccofoam strut 7 + Y (-Z | 81.94491 |
| 32346 | eccofoam strut 7 + Y (-Z | 77.93643 |
| 32347 | eccofoam strut 7 + Y (-Z | 78.57295 |
| 32348 | eccofoam strut 7 + Y (-Z | 77.59543 |
| 32351 | strut 8 + Y (+Z) | 217.16833 |
| 32352 | strut 8 + Y (+Z) | 171.97109 |
| 32353 | strut 8 + Y (+Z) | 149.70816 |
| 32354 | strut 8 + Y (+Z) | 137.47310 |
| 32355 | strut 8 + Y (+Z) | 130.41691 |
| 32356 | strut 8 + Y (+Z) | 125.49939 |
| 32357 | strut 8 + Y (+Z) | 121.50795 |
| 32358 | strut 8 + Y (+Z) | 117.22578 |
| 32359 | strut 8 + Y (+Z) | 121.79365 |
| 32360 | strut 8 + Y (+Z) | 117.16766 |
| 32361 | strut 8 + Y (+Z) | 105.03596 |
| 32362 | strut 8 + Y (+Z) | 96.39836 |
| 32363 | strut 8 + Y (+Z) | 89.87190 |
| 32364 | strut 8 + Y (+Z) | 84.76124 |
| 32365 | strut 8 + Y (+Z) | 80.51715 |
| 32366 | strut 8 + Y (+Z) | 76.62333 |
| 32367 | strut 8 + Y (+Z) | 78.06448 |
| 32368 | strut 8 + Y (+Z) | 76.59482 |
| 32369 | strut 8 + Y (+Z) | 69.24885 |
| 32370 | strut 8 + Y (+Z) | 63.23824 |
| 32371 | strut 8 + Y (+Z) | 57.77464 |
| 32372 | strut 8 + Y (+Z) | 52.46734 |
| 32373 | strut 8 + Y (+Z) | 47.01494 |
| 32374 | strut 8 + Y (+Z) | 44.71801 |
| 32375 | strut 8 + Y (+Z) | 47.00071 |
| 32376 | strut 8 + Y (+Z) | 45.94313 |
| 32377 | strut 8 + Y (+Z) | 44.97669 |
| 32378 | strut 8 + Y (+Z) | 44.08173 |
| 32379 | strut 8 + Y (+Z) | 43.24793 |
| 32380 | strut 8 + Y (+Z) | 42.47158 |
| 32381 | eccofoam strut 8 + Y (+Z | 213.75702 |
| 32382 | eccofoam strut 8 + Y (+Z | 173.44672 |
| 32383 | eccofoam strut 8 + Y (+Z | 150.57342 |
| 32384 | eccofoam strut 8 + Y (+Z | 137.92455 |
| 32385 | eccofoam strut 8 + Y (+Z | 130.61038 |
| 32386 | eccofoam strut 8 + Y (+Z | 125.58244 |
| 32387 | eccofoam strut 8 + Y (+Z | 121.53595 |
| 32388 | eccofoam strut 8 + Y (+Z | 117.82028 |
| 32389 | eccofoam strut 8 + Y (+Z | 121.12964 |
| 32390 | eccofoam strut 8 + Y (+Z | 116.59259 |
| 32391 | eccofoam strut 8 + Y (+Z | 105.26010 |
| 32392 | eccofoam strut 8 + Y (+Z | 96.57612 |
| 32393 | eccofoam strut 8 + Y (+Z | 89.99271 |
| 32394 | eccofoam strut 8 + Y (+Z | 84.83692 |
| 32395 | eccofoam strut 8 + Y (+Z | 80.57530 |
| 32396 | eccofoam strut 8 + Y (+Z | 77.00092 |
| 32397 | eccofoam strut 8 + Y (+Z | 77.88844 |
| 32398 | eccofoam strut 8 + Y (+Z | 76.69575 |
| 32401 | strut 9 + Y +Z | 216.52403 |
| 32402 | strut 9 + Y +Z | 170.59819 |
| 32403 | strut 9 + Y +Z | 147.87874 |
| 32404 | strut 9 + Y +Z | 135.49868 |
| 32405 | strut 9 + Y +Z | 128.10071 |
| 32406 | strut 9 + Y +Z | 123.39569 |
| 32407 | strut 9 + Y +Z | 119.62055 |
| 32408 | strut 9 + Y +Z | 115.55065 |
| 32409 | strut 9 + Y +Z | 120.37017 |
| 32410 | strut 9 + Y +Z | 115.49535 |
| 32411 | strut 9 + Y +Z | 103.61737 |
| 32412 | strut 9 + Y +Z | 95.16233 |
| 32413 | strut 9 + Y +Z | 88.83144 |
| 32414 | strut 9 + Y +Z | 83.92203 |
| 32415 | strut 9 + Y +Z | 79.91804 |
| 32416 | strut 9 + Y +Z | 76.35114 |
| 32417 | strut 9 + Y +Z | 77.93232 |
| 32418 | strut 9 + Y +Z | 76.32372 |

| | | |
|---|---|---|
| 32419 | strut 9 + Y +Z | 69.03753 |
| 32420 | strut 9 + Y +Z | 63.07196 |
| 32421 | strut 9 + Y +Z | 57.65435 |
| 32422 | strut 9 + Y +Z | 52.39381 |
| 32423 | strut 9 + Y +Z | 46.99449 |
| 32424 | strut 9 + Y +Z | 44.72448 |
| 32425 | strut 9 + Y +Z | 46.98038 |
| 32426 | strut 9 + Y +Z | 45.92660 |
| 32427 | strut 9 + Y +Z | 44.96347 |
| 32428 | strut 9 + Y +Z | 44.07259 |
| 32429 | strut 9 + Y +Z | 43.24181 |
| 32430 | strut 9 + Y +Z | 42.46903 |
| 32431 | eccofoam strut 9 + Y +Z | 213.05722 |
| 32432 | eccofoam strut 9 + Y +Z | 172.09117 |
| 32433 | eccofoam strut 9 + Y +Z | 148.76710 |
| 32434 | eccofoam strut 9 + Y +Z | 135.94044 |
| 32435 | eccofoam strut 9 + Y +Z | 128.33382 |
| 32436 | eccofoam strut 9 + Y +Z | 123.48189 |
| 32437 | eccofoam strut 9 + Y +Z | 119.64851 |
| 32438 | eccofoam strut 9 + Y +Z | 116.14555 |
| 32439 | eccofoam strut 9 + Y +Z | 119.67240 |
| 32440 | eccofoam strut 9 + Y +Z | 114.95401 |
| 32441 | eccofoam strut 9 + Y +Z | 103.83885 |
| 32442 | eccofoam strut 9 + Y +Z | 95.34089 |
| 32443 | eccofoam strut 9 + Y +Z | 88.95296 |
| 32444 | eccofoam strut 9 + Y +Z | 84.00096 |
| 32445 | eccofoam strut 9 + Y +Z | 79.98166 |
| 32446 | eccofoam strut 9 + Y +Z | 76.71411 |
| 32447 | eccofoam strut 9 + Y +Z | 77.73570 |
| 32448 | eccofoam strut 9 + Y +Z | 76.43389 |
| 32451 | strut 10 + Z (+Y) | 216.67469 |
| 32452 | strut 10 + Z (+Y) | 170.69741 |
| 32453 | strut 10 + Z (+Y) | 147.97856 |
| 32454 | strut 10 + Z (+Y) | 135.52378 |
| 32455 | strut 10 + Z (+Y) | 128.25502 |
| 32456 | strut 10 + Z (+Y) | 123.31531 |
| 32457 | strut 10 + Z (+Y) | 119.31895 |
| 32458 | strut 10 + Z (+Y) | 115.02537 |
| 32459 | strut 10 + Z (+Y) | 119.60608 |
| 32460 | strut 10 + Z (+Y) | 114.96897 |
| 32461 | strut 10 + Z (+Y) | 103.16390 |
| 32462 | strut 10 + Z (+Y) | 94.75320 |
| 32463 | strut 10 + Z (+Y) | 88.47589 |
| 32464 | strut 10 + Z (+Y) | 83.62493 |
| 32465 | strut 10 + Z (+Y) | 79.72514 |
| 32466 | strut 10 + Z (+Y) | 76.29247 |
| 32467 | strut 10 + Z (+Y) | 77.95191 |
| 32468 | strut 10 + Z (+Y) | 76.26543 |
| 32469 | strut 10 + Z (+Y) | 68.95825 |
| 32470 | strut 10 + Z (+Y) | 62.98354 |
| 32471 | strut 10 + Z (+Y) | 57.57955 |
| 32472 | strut 10 + Z (+Y) | 52.35484 |
| 32473 | strut 10 + Z (+Y) | 47.01593 |
| 32474 | strut 10 + Z (+Y) | 44.68522 |
| 32475 | strut 10 + Z (+Y) | 47.00235 |
| 32476 | strut 10 + Z (+Y) | 46.13420 |
| 32477 | strut 10 + Z (+Y) | 45.36973 |
| 32478 | strut 10 + Z (+Y) | 44.69148 |
| 32479 | strut 10 + Z (+Y) | 44.09282 |
| 32480 | strut 10 + Z (+Y) | 43.57928 |
| 32481 | eccofoam strut 10 + Z (+ | 213.20411 |
| 32482 | eccofoam strut 10 + Z (+ | 172.19357 |
| 32483 | eccofoam strut 10 + Z (+ | 148.86261 |
| 32484 | eccofoam strut 10 + Z (+ | 135.97814 |
| 32485 | eccofoam strut 10 + Z (+ | 128.46265 |
| 32486 | eccofoam strut 10 + Z (+ | 123.40063 |
| 32487 | eccofoam strut 10 + Z (+ | 119.34677 |
| 32488 | eccofoam strut 10 + Z (+ | 115.62163 |
| 32489 | eccofoam strut 10 + Z (+ | 118.94220 |
| 32490 | eccofoam strut 10 + Z (+ | 114.41796 |
| 32491 | eccofoam strut 10 + Z (+ | 103.38265 |
| 32492 | eccofoam strut 10 + Z (+ | 94.93229 |
| 32493 | eccofoam strut 10 + Z (+ | 88.59805 |
| 32494 | eccofoam strut 10 + Z (+ | 83.70737 |
| 32495 | eccofoam strut 10 + Z (+ | 79.79084 |
| 32496 | eccofoam strut 10 + Z (+ | 76.65072 |
| 32497 | eccofoam strut 10 + Z (+ | 77.74402 |
| 32498 | eccofoam strut 10 + Z (+ | 76.38079 |
| 32501 | strut 11 + Z (-Y) | 216.39463 |
| 32502 | strut 11 + Z (-Y) | 170.85042 |
| 32503 | strut 11 + Z (-Y) | 148.37530 |
| 32504 | strut 11 + Z (-Y) | 136.01810 |
| 32505 | strut 11 + Z (-Y) | 128.64177 |
| 32506 | strut 11 + Z (-Y) | 123.80040 |
| 32507 | strut 11 + Z (-Y) | 119.86619 |
| 32508 | strut 11 + Z (-Y) | 115.44510 |
| 32509 | strut 11 + Z (-Y) | 119.93861 |
| 32510 | strut 11 + Z (-Y) | 115.38783 |
| 32511 | strut 11 + Z (-Y) | 103.50299 |
| 32512 | strut 11 + Z (-Y) | 95.02451 |
| 32513 | strut 11 + Z (-Y) | 88.67659 |
| 32514 | strut 11 + Z (-Y) | 83.78751 |
| 32515 | strut 11 + Z (-Y) | 79.85219 |
| 32516 | strut 11 + Z (-Y) | 76.40969 |
| 32517 | strut 11 + Z (-Y) | 78.09139 |
| 32518 | strut 11 + Z (-Y) | 76.38268 |
| 32519 | strut 11 + Z (-Y) | 69.06223 |
| 32520 | strut 11 + Z (-Y) | 63.07308 |
| 32521 | strut 11 + Z (-Y) | 57.64763 |
| 32522 | strut 11 + Z (-Y) | 52.40315 |
| 32523 | strut 11 + Z (-Y) | 47.03661 |
| 32524 | strut 11 + Z (-Y) | 44.69564 |
| 32525 | strut 11 + Z (-Y) | 47.02295 |
| 32526 | strut 11 + Z (-Y) | 46.14811 |
| 32527 | strut 11 + Z (-Y) | 45.37815 |
| 32528 | strut 11 + Z (-Y) | 44.69708 |
| 32529 | strut 11 + Z (-Y) | 44.09699 |
| 32530 | strut 11 + Z (-Y) | 43.58259 |
| 32531 | eccofoam strut 11 + Z (- | 212.95689 |
| 32532 | eccofoam strut 11 + Z (- | 172.33435 |
| 32533 | eccofoam strut 11 + Z (- | 149.24682 |
| 32534 | eccofoam strut 11 + Z (- | 136.45769 |

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|---|---|---|
| 32535 | eccofoam strut 11 + Z (- | 128.86304 |
| 32536 | eccofoam strut 11 + Z (- | 123.88309 |
| 32537 | eccofoam strut 11 + Z (- | 119.88029 |
| 32538 | eccofoam strut 11 + Z (- | 116.04415 |
| 32539 | eccofoam strut 11 + Z (- | 119.28669 |
| 32540 | eccofoam strut 11 + Z (- | 114.82567 |
| 32541 | eccofoam strut 11 + Z (- | 103.72180 |
| 32542 | eccofoam strut 11 + Z (- | 95.20357 |
| 32543 | eccofoam strut 11 + Z (- | 88.80114 |
| 32544 | eccofoam strut 11 + Z (- | 83.87046 |
| 32545 | eccofoam strut 11 + Z (- | 79.91996 |
| 32546 | eccofoam strut 11 + Z (- | 76.77021 |
| 32547 | eccofoam strut 11 + Z (- | 77.88055 |
| 32548 | eccofoam strut 11 + Z (- | 76.49955 |
| 32551 | strut 12 + Z -Y | 216.76124 |
| 32552 | strut 12 + Z -Y | 171.04819 |
| 32553 | strut 12 + Z -Y | 148.62169 |
| 32554 | strut 12 + Z -Y | 136.36916 |
| 32555 | strut 12 + Z -Y | 129.40046 |
| 32556 | strut 12 + Z -Y | 124.81894 |
| 32557 | strut 12 + Z -Y | 121.02554 |
| 32558 | strut 12 + Z -Y | 116.82837 |
| 32559 | strut 12 + Z -Y | 121.72566 |
| 32560 | strut 12 + Z -Y | 116.77134 |
| 32561 | strut 12 + Z -Y | 104.61788 |
| 32562 | strut 12 + Z -Y | 96.01808 |
| 32563 | strut 12 + Z -Y | 89.60669 |
| 32564 | strut 12 + Z -Y | 84.68384 |
| 32565 | strut 12 + Z -Y | 80.68267 |
| 32566 | strut 12 + Z -Y | 77.13279 |
| 32567 | strut 12 + Z -Y | 78.81836 |
| 32568 | strut 12 + Z -Y | 77.10496 |
| 32569 | strut 12 + Z -Y | 69.63114 |
| 32570 | strut 12 + Z -Y | 63.52247 |
| 32571 | strut 12 + Z -Y | 57.99070 |
| 32572 | strut 12 + Z -Y | 52.61613 |
| 32573 | strut 12 + Z -Y | 47.09763 |
| 32574 | strut 12 + Z -Y | 44.81896 |
| 32575 | strut 12 + Z -Y | 47.08298 |
| 32576 | strut 12 + Z -Y | 45.90207 |
| 32577 | strut 12 + Z -Y | 44.80574 |
| 32578 | strut 12 + Z -Y | 43.77147 |
| 32579 | strut 12 + Z -Y | 42.78438 |
| 32580 | strut 12 + Z -Y | 41.83567 |
| 32581 | eccofoam strut 12 + Z -Y | 213.31152 |
| 32582 | eccofoam strut 12 + Z -Y | 172.54747 |
| 32583 | eccofoam strut 12 + Z -Y | 149.49995 |
| 32584 | eccofoam strut 12 + Z -Y | 136.83046 |
| 32585 | eccofoam strut 12 + Z -Y | 129.61196 |
| 32586 | eccofoam strut 12 + Z -Y | 124.89275 |
| 32587 | eccofoam strut 12 + Z -Y | 121.04569 |
| 32588 | eccofoam strut 12 + Z -Y | 117.43672 |
| 32589 | eccofoam strut 12 + Z -Y | 121.01645 |
| 32590 | eccofoam strut 12 + Z -Y | 116.21563 |
| 32591 | eccofoam strut 12 + Z -Y | 104.84820 |
| 32592 | eccofoam strut 12 + Z -Y | 96.20233 |
| 32593 | eccofoam strut 12 + Z -Y | 89.73359 |
| 32594 | eccofoam strut 12 + Z -Y | 84.76445 |
| 32595 | eccofoam strut 12 + Z -Y | 80.74783 |
| 32596 | eccofoam strut 12 + Z -Y | 77.50116 |
| 32597 | eccofoam strut 12 + Z -Y | 78.60750 |
| 32598 | eccofoam strut 12 + Z -Y | 77.22220 |
| 33000 | PR front centre . | 41.84047 |
| 33011 | PR front ring1 0. | 41.89564 |
| 33012 | PR front ring1 60. | 41.65169 |
| 33013 | PR front ring1 120. | 42.14761 |
| 33014 | PR front ring1 180. | 41.86674 |
| 33015 | PR front ring1 240. | 42.14751 |
| 33016 | PR front ring1 300. | 41.65227 |
| 33041 | PR front ring2 0. | 42.31355 |
| 33042 | PR front ring2 60. | 41.52972 |
| 33043 | PR front ring2 120. | 42.49371 |
| 33044 | PR front ring2 180. | 41.90171 |
| 33045 | PR front ring2 240. | 42.49369 |
| 33046 | PR front ring2 300. | 41.53016 |
| 33071 | PR front ring3 0. | 41.79033 |
| 33072 | PR front ring3 60. | 41.47777 |
| 33073 | PR front ring3 120. | 42.48334 |
| 33074 | PR front ring3 180. | 41.92218 |
| 33075 | PR front ring3 240. | 42.48360 |
| 33076 | PR front ring3 300. | 41.47840 |
| 33100 | PR rear centre . . | 41.83828 |
| 33111 | PR rear ring1 0. | 41.91106 |
| 33112 | PR rear ring1 60. | 41.66235 |
| 33113 | PR rear ring1 120. | 42.20747 |
| 33114 | PR rear ring1 180. | 41.88145 |
| 33115 | PR rear ring1 240. | 42.20763 |
| 33116 | PR rear ring1 300. | 41.66301 |
| 33141 | PR rear ring2 0. | 42.39950 |
| 33142 | PR rear ring2 60. | 41.53629 |
| 33143 | PR rear ring2 120. | 42.81060 |
| 33144 | PR rear ring2 180. | 41.91541 |
| 33145 | PR rear ring2 240. | 42.81071 |
| 33146 | PR rear ring2 300. | 41.53672 |
| 33171 | PR rear ring3 0. | 41.79605 |
| 33172 | PR rear ring3 60. | 41.48282 |
| 33173 | PR rear ring3 120. | 42.54247 |
| 33174 | PR rear ring3 180. | 41.93234 |
| 33175 | PR rear ring3 240. | 42.54260 |
| 33176 | PR rear ring3 300. | 41.48335 |
| 33200 | PR thermal foil . | 41.37484 |
| 33311 | PR MLI fwd ring | 41.72978 |
| 33312 | PR MLI fwd ring | 41.49551 |
| 33313 | PR MLI fwd ring | 42.06193 |
| 33314 | PR MLI fwd ring | 41.75036 |
| 33315 | PR MLI fwd ring | 42.06376 |
| 33316 | PR MLI fwd ring | 41.49799 |
| 33341 | PR MLI fwd ring | 42.19179 |
| 33342 | PR MLI fwd ring | 41.35783 |
| 33343 | PR MLI fwd ring | 42.66757 |
| 33344 | PR MLI fwd ring | 41.80447 |
| 33345 | PR MLI fwd ring | 42.67035 |
| 33346 | PR MLI fwd ring | 41.35776 |
| 33371 | PR MLI fwd ring | 41.57631 |
| 33372 | PR MLI fwd ring | 41.29713 |
| 33373 | PR MLI fwd ring | 42.39156 |
| 33374 | PR MLI fwd ring | 41.81427 |

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|---|---|---|---|
| 33375 | PR | MLI fwd ring | 42.39045 |
| 33376 | PR | MLI fwd ring | 41.29687 |
| 33411 | PR | MLI rear ring | 34.13422 |
| 33412 | PR | MLI rear ring | 34.70106 |
| 33413 | PR | MLI rear ring | 36.39695 |
| 33414 | PR | MLI rear ring | 36.76806 |
| 33415 | PR | MLI rear ring | 36.48061 |
| 33416 | PR | MLI rear ring | 34.80298 |
| 33441 | PR | MLI rear ring | 32.98469 |
| 33442 | PR | MLI rear ring | 33.89955 |
| 33443 | PR | MLI rear ring | 37.14538 |
| 33444 | PR | MLI rear ring | 37.72869 |
| 33445 | PR | MLI rear ring | 37.27682 |
| 33446 | PR | MLI rear ring | 33.87102 |
| 33471 | PR | MLI rear ring | 31.44168 |
| 33472 | PR | MLI rear ring | 33.40606 |
| 33473 | PR | MLI rear ring | 36.47217 |
| 33474 | PR | MLI rear ring | 37.42634 |
| 33475 | PR | MLI rear ring | 36.40856 |
| 33476 | PR | MLI rear ring | 33.35797 |
| 34000 | SR | front centre . | 41.75841 |
| 34011 | SR | front ring1 0. | 41.76540 |
| 34012 | SR | front ring1 60. | 41.73100 |
| 34013 | SR | front ring1 120. | 41.77290 |
| 34014 | SR | front ring1 180. | 41.74732 |
| 34015 | SR | front ring1 240. | 41.80468 |
| 34016 | SR | front ring1 300. | 41.74357 |
| 34071 | SR | front ring2 0. | 41.74879 |
| 34072 | SR | front ring2 60. | 41.71494 |
| 34073 | SR | front ring2 120. | 41.75979 |
| 34074 | SR | front ring2 180. | 41.73271 |
| 34075 | SR | front ring2 240. | 41.79313 |
| 34076 | SR | front ring2 300. | 41.72872 |
| 34100 | SR | rear centre . . | 41.77748 |
| 34111 | SR | rear ring1 0. | 41.81277 |
| 34112 | SR | rear ring1 60. | 41.74374 |
| 34113 | SR | rear ring1 120. | 41.82435 |
| 34114 | SR | rear ring1 180. | 41.76456 |
| 34115 | SR | rear ring1 240. | 41.87341 |
| 34116 | SR | rear ring1 300. | 41.75744 |
| 34171 | SR | rear ring2 0. | 41.76103 |
| 34172 | SR | rear ring2 60. | 41.72178 |
| 34173 | SR | rear ring2 120. | 41.78002 |
| 34174 | SR | rear ring2 180. | 41.74383 |
| 34175 | SR | rear ring2 240. | 41.81763 |
| 34176 | SR | rear ring2 300. | 41.73585 |

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|---|---|---|---|
| 34200 | SR | thermal foil . | 41.62183 |
| 34311 | SR | MLI fwd ring | 41.65874 |
| 34312 | SR | MLI fwd ring | 41.65103 |
| 34313 | SR | MLI fwd ring | 41.79925 |
| 34314 | SR | MLI fwd ring | 41.72788 |
| 34315 | SR | MLI fwd ring | 41.84828 |
| 34316 | SR | MLI fwd ring | 41.66621 |
| 34371 | SR | MLI fwd ring | 41.55693 |
| 34372 | SR | MLI fwd ring | 41.57489 |
| 34373 | SR | MLI fwd ring | 41.73491 |
| 34374 | SR | MLI fwd ring | 41.64429 |
| 34375 | SR | MLI fwd ring | 41.77294 |
| 34376 | SR | MLI fwd ring | 41.58883 |
| 34411 | SR | MLI rear ring | 35.55103 |
| 34412 | SR | MLI rear ring | 38.33904 |
| 34413 | SR | MLI rear ring | 40.98228 |
| 34414 | SR | MLI rear ring | 40.51623 |
| 34415 | SR | MLI rear ring | 41.03038 |
| 34416 | SR | MLI rear ring | 38.41429 |
| 34471 | SR | MLI rear ring | 32.52022 |
| 34472 | SR | MLI rear ring | 35.82491 |
| 34473 | SR | MLI rear ring | 40.22823 |
| 34474 | SR | MLI rear ring | 38.05072 |
| 34475 | SR | MLI rear ring | 40.28160 |
| 34476 | SR | MLI rear ring | 35.83257 |
| 35000 | | rim1_in | 42.37765 |
| 35001 | | rim1_lo | 42.49336 |
| 35002 | | rim1_out | 42.28259 |
| 35003 | | rim1_up | 42.37248 |
| 35010 | | rim1_in | 41.97416 |
| 35011 | | rim1_lo | 42.07305 |
| 35012 | | rim1_out | 41.91982 |
| 35013 | | rim1_up | 41.92905 |
| 35020 | | rim1_in | 41.79348 |
| 35021 | | rim1_lo | 41.97725 |
| 35022 | | rim1_out | 41.68305 |
| 35023 | | rim1_up | 41.54665 |
| 35030 | | rim2_in | 41.79328 |
| 35031 | | rim2_lo | 41.97699 |
| 35032 | | rim2_out | 41.68283 |
| 35033 | | rim2_up | 41.54642 |
| 35040 | | rim2_in | 41.70815 |
| 35041 | | rim2_lo | 41.71448 |
| 35042 | | rim2_out | 41.60827 |
| 35043 | | rim2_up | 41.61119 |

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|---|---|---|
| 35050 | rim2_in | 43.29686 |
| 35051 | rim2_lo | 43.29902 |
| 35052 | rim2_out | 43.23294 |
| 35053 | rim2_up | 43.53835 |
| 35060 | rim3_in | 43.29781 |
| 35061 | rim3_lo | 43.30008 |
| 35062 | rim3_out | 43.23420 |
| 35063 | rim3_up | 43.53933 |
| 35070 | rim3_in | 42.95865 |
| 35071 | rim3_lo | 43.12701 |
| 35072 | rim3_out | 43.31742 |
| 35073 | rim3_up | 42.92713 |
| 35080 | rim3_in | 40.64275 |
| 35081 | rim3_lo | 41.20158 |
| 35082 | rim3_out | 40.99430 |
| 35083 | rim3_up | 40.81868 |
| 35090 | rim4_in | 40.64051 |
| 35091 | rim4_lo | 41.19930 |
| 35092 | rim4_out | 40.99183 |
| 35093 | rim4_up | 40.81641 |
| 35100 | rim4_in | 39.85519 |
| 35101 | rim4_lo | 39.93068 |
| 35102 | rim4_out | 39.80474 |
| 35103 | rim4_up | 39.71538 |
| 35110 | rim4_in | 42.24189 |
| 35111 | rim4_lo | 42.37137 |
| 35112 | rim4_out | 42.15855 |
| 35113 | rim4_up | 42.50966 |
| 35120 | rim5_in | 42.24281 |
| 35121 | rim5_lo | 42.37223 |
| 35122 | rim5_out | 42.15940 |
| 35123 | rim5_up | 42.51058 |
| 35130 | rim5_in | 41.19247 |
| 35131 | rim5_lo | 41.19980 |
| 35132 | rim5_out | 41.09240 |
| 35133 | rim5_up | 41.09570 |
| 35140 | rim5_in | 41.62736 |
| 35141 | rim5_lo | 41.88786 |
| 35142 | rim5_out | 41.53880 |
| 35143 | rim5_up | 41.38175 |
| 35150 | rim6_in | 41.62784 |
| 35151 | rim6_lo | 41.88839 |
| 35152 | rim6_out | 41.53930 |
| 35153 | rim6_up | 41.38227 |

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|---|---|---|
| 35160 | rim6_in | 41.85829 |
| 35161 | rim6_lo | 41.94429 |
| 35162 | rim6_out | 41.80549 |
| 35163 | rim6_up | 41.82396 |
| 35170 | rim6_in | 42.37757 |
| 35171 | rim6_lo | 42.49327 |
| 35172 | rim6_out | 42.28251 |
| 35173 | rim6_up | 42.37240 |
| 35210 | I/F 1 rim1_in | 42.37761 |
| 35211 | I/F 1 rim1_lo | 42.49470 |
| 35212 | I/F 1 rim1_out | 42.28191 |
| 35213 | I/F 1 rim1_up | 42.37307 |
| 35220 | I/F 2 rim1_in | 41.79353 |
| 35221 | I/F 2 rim1_lo | 41.97864 |
| 35222 | I/F 2 rim1_out | 41.68240 |
| 35223 | I/F 2 rim1_up | 41.54521 |
| 35230 | I/F 3 rim2_in | 43.29727 |
| 35231 | I/F 3 rim2_lo | 43.30043 |
| 35232 | I/F 3 rim2_out | 43.23291 |
| 35233 | I/F 3 rim2_up | 43.54162 |
| 35240 | I/F 4 rim3_in | 40.63891 |
| 35241 | I/F 4 rim3_lo | 41.20239 |
| 35242 | I/F 4 rim3_out | 40.99251 |
| 35243 | I/F 4 rim3_up | 40.81714 |
| 35250 | I/F 5 rim4_in | 42.24233 |
| 35251 | I/F 5 rim4_lo | 42.37415 |
| 35252 | I/F 5 rim4_out | 42.15838 |
| 35253 | I/F 5 rim4_up | 42.51355 |
| 35260 | I/F 6 rim5_in | 41.62762 |
| 35261 | I/F 6 rim5_lo | 41.89021 |
| 35262 | I/F 6 rim5_out | 41.53852 |
| 35263 | I/F 6 rim5_up | 41.38074 |
| 41000 | FEMs | 21.53655 |
| 41100 | LR2 | 18.55694 |
| 41500 | FPU_MF | 21.44669 |
| 42000 | LR2 fluid | 18.39800 |
| 45000 | BEU-DAE | 315.55651 |
| 45100 | BEU-DAE_box | 312.81844 |
| 45200 | DAE_Black_Side | 284.17195 |
| 46000 | BEM | 312.70855 |
| 46100 | BEM_box | 312.56244 |
| 46200 | BEM_dx_Black_Side | 227.73506 |
| 47000 | FEM | 290.62041 |
| 47100 | FEM_box | 312.27085 |
| 47200 | FEM_dx_Black_Side | 273.78790 |
| 49000 | BEU_I/F_SVM | 313.14999 |
| 50110 | SHield 1 inf facet 1 | 129.69940 |
| 50111 | SHield 1 inf facet 1 | 131.23321 |
| 50112 | SHield 1 inf facet 1 | 161.15076 |
| 50115 | SHield 1 inf ext fac | 131.88408 |
| 50116 | SHield 1 inf ext fac | 129.45305 |
| 50120 | SHield 1 inf facet 1 | 128.79387 |
| 50121 | SHield 1 inf facet 1 | 130.97139 |
| 50122 | SHield 1 inf facet 1 | 137.88336 |
| 50125 | SHield 1 inf ext fac | 130.89606 |
| 50126 | SHield 1 inf ext fac | 127.71224 |
| 50130 | SHield 1 inf facet 1 | 128.33425 |
| 50131 | SHield 1 inf facet 1 | 129.69146 |
| 50135 | SHield 1 inf ext fac | 127.43562 |
| 50136 | SHield 1 inf ext fac | 124.92317 |
| 50170 | SHield 1 inf facet 1 | 134.57679 |
| 50171 | SHield 1 inf facet 1 | 134.15604 |
| 50172 | SHield 1 inf facet 1 | 133.75028 |
| 50173 | SHield 1 inf facet 1 | 133.36031 |
| 50174 | SHield 1 inf facet 1 | 132.98615 |
| 50175 | SHield 1 inf facet 1 | 132.62718 |
| 50176 | SHield 1 inf facet 1 | 132.28274 |
| 50177 | SHield 1 inf facet 1 | 131.95186 |
| 50178 | SHield 1 inf facet 1 | 131.63349 |
| 50179 | SHield 1 inf facet 1 | 131.32684 |
| 50180 | SHield 1 inf facet 1 | 131.03104 |
| 50181 | SHield 1 inf facet 1 | 130.74500 |
| 50182 | SHield 1 inf facet 1 | 130.46809 |
| 50183 | SHield 1 inf facet 1 | 130.20124 |
| 50184 | SHield 1 inf facet 1 | 129.93306 |
| 50210 | SHield 1 inf facet 2 | 127.28985 |
| 50211 | SHield 1 inf facet 2 | 127.28408 |
| 50212 | SHield 1 inf facet 2 | 126.57244 |
| 50215 | SHield 1 inf ext fac | 123.48373 |
| 50216 | SHield 1 inf ext fac | 121.35274 |
| 50220 | SHield 1 inf facet 2 | 126.38164 |
| 50221 | SHield 1 inf facet 2 | 125.66250 |
| 50222 | SHield 1 inf facet 2 | 124.01766 |
| 50225 | SHield 1 inf ext fac | 121.09716 |
| 50226 | SHield 1 inf ext fac | 119.03157 |
| 50230 | SHield 1 inf facet 2 | 125.76783 |
| 50231 | SHield 1 inf facet 2 | 124.24968 |
| 50232 | SHield 1 inf facet 2 | 122.22364 |
| 50235 | SHield 1 inf ext fac | 119.63465 |
| 50236 | SHield 1 inf ext fac | 117.81322 |
| 50310 | SHield 1 inf facet 3 | 124.93727 |
| 50311 | SHield 1 inf facet 3 | 123.00187 |
| 50312 | SHield 1 inf facet 3 | 120.80951 |
| 50315 | SHield 1 inf ext fac | 118.46191 |
| 50316 | SHield 1 inf ext fac | 116.94491 |
| 50320 | SHield 1 inf facet 3 | 124.59116 |
| 50321 | SHield 1 inf facet 3 | 122.54801 |
| 50322 | SHield 1 inf facet 3 | 120.30523 |
| 50325 | SHield 1 inf ext fac | 117.78018 |
| 50326 | SHield 1 inf ext fac | 116.13678 |
| 50330 | SHield 1 inf facet 3 | 124.48097 |
| 50331 | SHield 1 inf facet 3 | 122.35166 |
| 50332 | SHield 1 inf facet 3 | 120.03866 |
| 50335 | SHield 1 inf ext fac | 117.60531 |
| 50336 | SHield 1 inf ext fac | 115.92024 |
| 50410 | SHield 1 inf facet 4 | 124.71558 |
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| 50526 | SHield 1 inf ext fac | 122.26538 |

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| 51535 | SHield 1 sup ext fac | 128.28356 |
| 51536 | SHield 1 sup ext fac | 126.03493 |
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| 51636 | SHield 1 sup ext fac | 131.35392 |
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| 51678 | SHield 1 sup facet 6 | 138.55024 |
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| 52302 | SHield 1 b facet 3 | 114.74410 |
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| 52401 | SHield 1 b facet 4 | 115.64716 |
| 52402 | SHield 1 b facet 4 | 116.97126 |
| 52500 | SHield 1 b facet 5 | 118.68612 |
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| 52600 | SHield 1 b facet 6 | 129.51089 |
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| 60120 | shield 2 inf facet 1 | 79.64506 |
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| 60125 | shield 2 inf ext fac | 79.30182 |
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| 60315 | shield 2 inf ext fac | 77.61255 |
| 60316 | shield 2 inf ext fac | 77.34475 |
| 60320 | shield 2 inf facet 3 | 78.96844 |
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| 60330 | shield 2 inf facet 3 | 79.02610 |
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| 60332 | shield 2 inf facet 3 | 78.09636 |
| 60335 | shield 2 inf ext fac | 77.62803 |
| 60336 | shield 2 inf ext fac | 77.36168 |
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| 60422 | shield 2 inf facet 4 | 78.56576 |
| 60425 | shield 2 inf ext fac | 78.10545 |
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| 61679 | shield 2 sup facet 6 | 82.68960 |
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| 62500 | SHield 2 b facet 5 | 78.55069 |
| 62501 | SHield 2 b facet 5 | 79.27879 |
| 62502 | SHield 2 b facet 5 | 80.04232 |
| 62600 | SHield 2 b facet 6 | 80.60492 |
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| 69010 | scn_VG2 | 83.33285 |
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| 71212 | SHield3_sup_facet2 | 44.76940 |
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| 71222 | SHield3_sup_facet2 | 44.60249 |
| 71223 | SHield3_sup_facet2 | 44.68669 |
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| 72013 | insert nominal | 45.66425 |
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