



Nano Packaging Technology for Interconnect and Heat Dissipation

NANOPACK

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WORK PACKAGE 1 : Systems and applications specifications

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WORK PACKAGE 1: Systems and applications specifications

**TASK 1.1
TECHNICAL SPECIFICATION REPORT**

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WORK PACKAGE 1 : SYSTEMS AND APPLICATIONS SPECIFICATIONS

TASK 1.1 TECHNICAL SPECIFICATION REPORT

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1 ABBREVIATION / DEFINITION

TIM	Thermal Interface Material
SOI	Silicon On Insulator
CNT	Carbon Nano Tube
BLT	Bond Line Thickness
MCM	Multi-Chip Module
LCC	Life Cycle Cost
SCM	Single-Chip Module
R _{th}	Thermal Resistance
HP	Heat Pipe
DBC	Direct Bonded Copper

2 INTRODUCTION

The NANOPACK project aims to develop new technologies and materials for thermal interfaces and electrical interconnects by exploring systems such as carbon nanotubes and nanoparticles.

This report is expected to give NANOPACK project the list and description of general specification for the thermal interface material and electrical interconnects. This document is part of WP1 (Systems and Applications Demonstration) ; its constitutes the final report of T1.1 (Systems and Applications Specification). WP1 aims at the establishment of common specifications for end users domains (avionics, cars, consumer,..) in term of material thermal and electric performance, environment conditions, heat densities, installation constraints, mechanical performance, environmental impact, technologies foreseen, expected cost range of the material.

The specification elaborated integrates the needs of each end user : Bosch, Foab, IBM and Thales Aerospace. Sometime, the end user do not specify his need because the environmental specifications is not defined or not applicable. Thus the specifications of the other end user can be applied as a guide line.

The TIM developed should take into account the overall specifications defined in the following sections as an objective, however, in the future and depending of the application it will be possible to reduce some constraints and especially the environmental extrema.

The following specifications are to be used as design drivers, they will not necessarily require a dedicated test to be satisfied as many choice will be based on standard practices. Then a justification by analogy will be sufficient.

3 APPLICABLES DOCUMENTS

The material shall be designed, manufactured, tested and delivered with consideration of the documents listed below as a guideline.

3.1 AERONAUTICAL APPLICABLES DOCUMENTS

AIRLINES ELECTRONIC ENGINEERING COMMITTEE (AEEC):	05-267/CSS-328 Idh
AIRBUS: TECHNICAL SPECIFICATION	4421 M1F 0000 00
BOEING	D6-36440 Volume 1
ARINC SPECIFICATION 600	AIR TRANSPORT AVIONICS EQUIPMENT INTERFACES
FEDERAL AVIATION REGULATION (FAR) 25.601	<i>General</i>
MIL-STD 883, METHOD 3025.2	MICROELECTRONICS TEST METHODS AND PROCEDURES
RTCA DO-160/EUROCAE ED 14	<i>Environmental Conditions and Test PROCEDURES FOR AIRBORNE EQUIPMENT</i>
ARINC SPECIFICATION 413A	<i>Guidance for Aircraft Electrical Power Utilization & TRANSIENT PROTECTION</i>
ARINC REPORT 604	<i>Guidance for Design and Built-in Test Equipment (BITE)</i>
ARINC REPORT 607	DESIGN GUIDANCE FOR AVIONICS EQUIPMENT
ARINC SPECIFICATION 608A	DESIGN GUIDANCE FOR AVIONICS TEST EQUIPMENT
RTCA/DO-160E	ENVIRONMENTAL CONDITIONS AND TEST PROCEDURES FOR AIRBORNE ELECTRIC/ELECTRICAL EQUIPMENT AND INSTRUMENTS (RADIO TECHNICAL COMMISSION FOR AERONAUTICS)
ABD 100	EQUIPMENT - DESIGN - GENERAL REQUIREMENTS FOR SUPPLIERS
DIRECTIVE 2002/95/CE AND 2005/618/CE	RESTRICTION OF USE OF CERTAIN HAZARDOUS SUBSTANCES IN ELECTRICAL AND ELECTRONIC EQUIPMENT (ROHS)

Table 1: Applicable documents

3.2 AUTOMOTIVE APPLICABLES DOCUMENTS

BOSCH INTERNATIONAL STANDARD N2580-1.1	PROHIBITION AND DECLARATION OF SUBSTANCES IN PRODUCTS, COMPONENTS, MATERIALS AND PREPARATIONS.
DIN EN 80068-1 (IEC 68-1)	ENVIRONMENTAL TESTING – PART 1: GENERAL AND GUIDANCE
DIN EN 80068-2-2 (IEC 68-2-2)	ENVIRONMENTAL TESTING – PART 2: TESTS – TESTS B: DRY HEAT
DIN EN 80068-2-6 (IEC 68-2-6)	ENVIRONMENTAL TESTING – PART 2: TESTS – TESTS FC: VIBRATION (SINUSOIDAL)
DIN EN 80068-2-14 (IEC 68-2-14)	ENVIRONMENTAL TESTING – PART 2: TESTS – TESTS N: CHANGE OF TEMPERATURE
DIN EN 80068-2-67 (IEC 68-2-67)	ENVIRONMENTAL TESTING – PART 2: TESTS – TESTS CY: DAMP HEAT, STEADY STATE, ACCELERATED TEST PRIMARILY INTENDED FOR COMPONENTS

4 MATERIAL SPECIFICATION

4.1 BOSCH SPECIFICATION

Electronic systems are enabler for new functions like safety, engine management, exhaust treatment, and comfort in cars. Share of electronic systems in modern cars is expected to increase up to 35 % of overall costs within the next few years. Driving forces in automotive electronics are:

- Smaller housings of controller units for any aggregates
- System integration (die shrinkage, mechatronic modules, improved functions)
- Position of electronic components closer to mechanic and/or heat dissipating components (harsh environment)
- Higher power consumption of electronic modules like x-by-wire systems, power converters for hybrid cars

This leads to higher power consumption on smaller areas and elevated heat sink temperatures. Thermal conductive adhesives are the basis for high power applications like next generations controller units for engines and braking systems.

4.1.1 Geometrical and thermal specification

All specifications refer to TIM2; TIM1 is not primarily addressed in NanoPack project.

- Area : **60*40 mm**
- Thickness : **maximum 50 μm**
- Warpage : **maximum 100 μm**

- Thermal resistance: **5 Kmm^2/W at BLT > 35 μm**
- Thermal conductivity: **10 W/mK**
- Heat density: **200 W/cm^2 .**

The mechanical performance requested is : **non-collapsing**.

4.1.2 Electrical specification

TIM will be used for attachment of DBC to housing. As top and bottom side of DBC are galvanically separated, electrically insulating TIM is not needed.

4.2 IBM SPECIFICATION

Continued downscaling of transistors and chip wiring has lead to large increases in microprocessor power density. Leakage currents within the transistor are also thermally activated causing power consumption to increase with elevated temperatures. Lower thermal resistance interfaces between the processor chip and heat spreading lid or heat sink will allow more efficient operation of the processor and cooling solutions as well as support continued performance increases for new chip architectures.

4.2.1 Geometrical and thermal specification

- TIM1: **2-3 Kmm²/W**, 20x20 mm area, BLT : 10-35 μm
- TIM2: **3-4 Kmm²/W** , 45x45mm area, BLT : < 20 μm

4.2.2 Electrical specification

- Electrical interface material : Contact resistance **5m Ω for a 12*12 mm area.**

4.3 FOAB SPECIFICATION

Geometrical and thermal specification

- Area : **10x10 mm²** Thickness : **20 μm**
- Area : **25*25 mm²** Thickness : **50-100 μm**

- Thermal conductivity : **10 W/mK at 80 $^{\circ}\text{C}$**

4.3.1 Other specification

The TIM should preferably have adhesive function (i.e. not necessary to hold the heat sink by extra mechanical structures)

4.4 THALES SPECIFICATION

Avionics

With increased hot spots dissipation, there is a need to spread efficiently the heat on the sinks. Most of the avionics equipments, as is the case for Airbus, are forced air cooled and compatible with ARINC 600 standards in the Electronic Bay. Future modules will dissipate up to 60 W with local hot spots of 30 W and should operate in all aircraft conditions including the loss of cooling.

The whole thermal chain from the component to the rack is to be optimized, and the thermal resistance associated to the TIM materials represent up to 20% of the total thermal resistance from the component to the ambient air. New cooling techniques based on Heat Pipes (HP) phase change system are being introduced in future programs, in order to increase the thermal conductivity from the components to the housing, but in this case two layers of TIM are necessary, one on each side of the heat pipe.

Avionics electronic equipment are characterized by the resistance to hostile environment conditions, a high level of electronic integration, and high reliability. These requirements integrate the data available from the relevant programs and applicable avionics standards.

High Power MEMS

Over the past several years, developments in Micro-Electro-Mechanical Systems (MEMS) have promoted exciting advancements in the field of microwave switching. Micromechanical switches were first demonstrated in 1979 as electrostatically actuated cantilever arms used to switch low-frequency electrical signals. Since then, these switches have demonstrated useful performances at microwave frequencies. MEMS technology holds much promise for space and commercial wireless communication systems. This is due to their vast advantages as compared to their conventional semiconductor counterparts, such as very low insertion loss, very low power consumption and high linearity that result in lower signal distortion. However, most of reported RF MEMS switches are only capable of handling low microwave power, several hundred milliwatts, before device failure. It is a general rule for RF and microwave devices supporting a significant RF power (>20 dBm) that these devices face critical reliability issues, leading to specific solutions for the technology, the design and the packaging. The lifetime of every 'power device' is strongly dependant of the local temperature elevation T and the electrical current I (Arrhenius' rule), and higher are these parameters, shorter is the lifetime (Black's law). As it has been already demonstrated in US laboratories, RF MEMS do not break this universal rule.

4.4.1 Geometrical and thermal specification

According to the heat sink size and to the component size, the required contact area may vary between 5*5 to 50*50 mm. The usual area is generally about 20*20 mm. In the case of large components (greater than 50*50 mm), one of the technical issue is to use more than one TIM in order to cover the entire surface.

Concerning the thickness, we can define two classes of material :

- Class 1 : this class concerns material with low thickness (from 0.05 to 0.25 mm) for thermal contact between two solids having a plane surface
- Class 2 : this class concerns material with high thickness (from 1 to 3 mm). The TIM are generally referred as gap-filler. They are widely used when there are two components with a different height in contact with a same heat sink or when there is a large mechanical tolerance on the component height. Thus the TIM thickness must adapt (conform) to the gap thickness during the mounting operation (see §4.4.3).

The thermal characteristics of the material should be expressed in term of thermal conductivity for the Class 2 material with large thickness and in term of thermal resistance for Class1 material with thin thickness.

The expected thermal characteristics are given in Table 2 :

	Class 1	Class 2
Thickness (BLT)	0.05-0.25 mm	1-3 mm
Thermal Conductivity	-	20 W/m.K
Thermal resistance	20 K.mm ² /W	-
Power density	5 W/mm ²	5 W/cm ²
Contact pressure	< 1 bar	< 1 bar
Hardness	-	< 65 shore 00

Table 2 : TIM thermal specification

4.4.2 Electrical specification

According to the use as a gap-pad filler (Class 2), the thermal interface material can be in contact with several components, then it is important to avoid electrical interconnect and then to have an **insulated** material.

For some application of high-power MEMS, the TIM must ensure an electrical insulation between the MEMS and the heat sink. Assuming a thickness of 50 microns with a voltage around 40 V leads to a dielectric strength of 1 kV/mm.

	Class 1	Class2
Volume resistivity	-	> 10 ² MΩ.m
Dielectric strength	> 1 kV/mm	-
Dielectric constant (at 10 GHz)	To minimize (≤3)	-
Dissipation factor (at 10 GHz)	To minimize	-

Table 3 : TIM electrical specification

4.4.3 Other specification

Mass : as light as possible. The TIM density should be lower than the aluminum density (2.7).

Corrosion resistance : The selected material shall be corrosion resistance and not exhibit galvanics effects. Compared to aluminum, the electrochimic potential must be lower than 300 mV. Surface protection can be considered to limit this effect.

Conformability : In the case of TIM Class 2 use as a gap-filler, the material must conform to the surface. It should support a deflection between 10% and 50% of the original thickness under moderate pressure (up to 2 or 3 bar).
The material can be elastic or not (putty behavior).

5 ENVIRONMENTAL SPECIFICATION

5.1 BOSCH ENVIRONMENTAL SPECIFICATION

5.1.1 Thermal specification

The TIM shall provide a void-free layer between electrical circuits and heat sink without delamination. In case of grease-like (viscous) TIM : No pump-out, oil bleed ore flow-out is allowed. In case of solid TIM: no delaminations or cracks are allowed. The assembly (consisting of power module attached to heat sink by TIM2) should function correctly after stored and manipulated under low and high temperature conditions.

The TIM should withstand the following operating temperature:

- **continuous 150 °C**
- **minimum -40 °C**
- **maximum +180 °C**

5.1.1.1 High temperature storage (DIN EN 80068-2-2)

The assembly is subjected to high temperature storage: **150 °C for 3000 h**
200 °C for 200 h

5.1.1.2 Cycling temperature (DIN EN 80068-2-14)

The assembly is subjected to thermal shock between: **1500 cycles -40 / +150 °C, dwell time 30 min, transfer time < 10 s**

or

The assembly should withstand thermal cycling: **2500 cycles -40 / +150 °C, dwell time 30 min, temperature gradient max. 5 K/min**

5.1.2 Mechanical

There are no particular requirements concerning the mechanical specification. The TIM shall provide a void-free layer between electrical circuits and heat sink without delamination. In case of grease-like (viscous) TIM: No pump-out, oil bleed ore flow-out is allowed. In case of solid TIM: no delaminations or cracks are allowed. The assembly should function correctly after stored and manipulated under low and high temperature conditions:

The assembly will be used under **normal pressure** (atmospheric pressure).

5.1.2.1 Humidity storage (DIN EN 80068-2-67)

The assembly is subjected to humidity storage condition: **1000 h 85% / 85 °C**

5.1.3 Fungus, Contamination, Toxicity

The TIM should be submit to the following Hazard Identification : **none or Xi**
The TIM shall fulfill the internal standard N2580-1.1 “Prohibition and Declaration of Substances” (see annex 1)

5.2 IBM ENVIRONMENTAL SPECIFICATION

5.2.1 Thermal specification

5.2.1.1 Storage / Operating temperature

Non operating

All materials should survive conditions of **-40°C – +150°C** after application to product (shipping conditions, non-operational).

Operating

The material should operate between **+20 °C and +85 °C** .

5.2.1.2 Cycling temperature

The TIM should withstand thermal cycling : **2000 cycles 20°C/+105 °C, 12 minutes cycle**

The 12 minutes include 2*5 min stabilization at +20 °C and +105 °C.

5.3 FOAB ENVIRONMENTAL SPECIFICATION

5.3.1 Cycling / Operating temperature

The material should survive : **1000 hours operation time, 85 °C, 85% RH**

5.4 THALES ENVIRONMENTAL SPECIFICATION

5.4.1 Thermal specifications

The following sub-chapters identify the various temperature conditions the equipment is likely to encounter during its service life. Each TIM must be designed and verified to withstand the range of temperature extremes experienced in its intended locations.

5.4.1.1 Storage / Operating temperature

The *RTCA DO160E, Section 4 category D2* shall be used for the test procedures.

The equipment should function correctly after stored and manipulated under low and high temperature conditions (ambient temperature). The values given in

Table 4 are used to compute the equipment reliability. These values give the test chamber air temperature during the test, after the equipment temperature has become stabilized. Its means that the TIM temperature is greater and can vary according to the application. According to the usual component junction temperature limitation, the maximum TIM operating temperature will be **150 °C**.

Temperature Variations					
Operating Temperature		Short Time Operating Temperature		Ground Survival Temperature	
Min	Max	Min	Max	Min	Max
- 55 °C	+ 70°C	- 55°C	+ 70°C	- 55°C	+ 85°C

Table 4: Temperature criteria

5.4.1.2 Thermal shocks

Each equipment must be tested to verify its ability to withstand the variations of temperature between the high and low operating temperatures experienced in the airplane environment.

The equipment shall comply with the temperature variation requirements of *RTCA DO160E, Section 5 for Category B*.

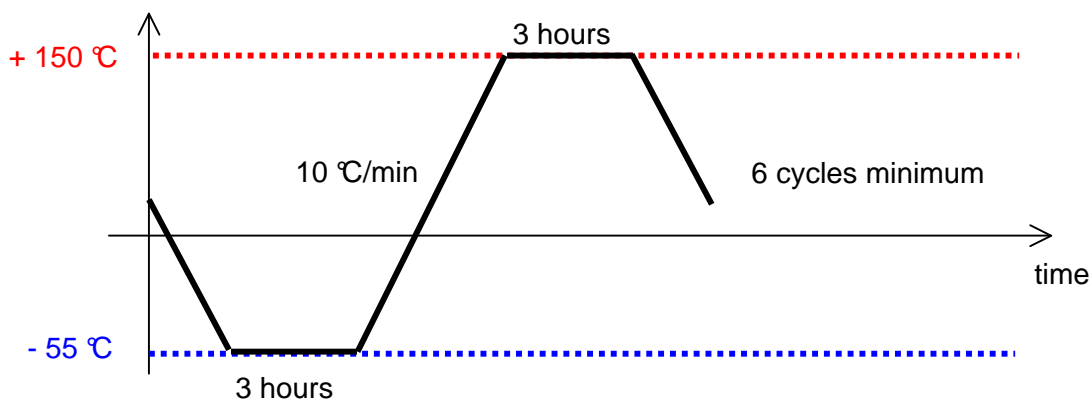


Figure 1 : Thermal shocks

Figure 1 gives the temperature variation test. The equipment must stay at least 3 hours at the extreme temperature in order to ensure a good stabilization.

5.4.1.3 Thermal cycling

The equipemnt shall be able to withstand **2000 thermal cycles between -40 °C and + 95 °C** .
 The stabilisation time at hot and cold temperature shall be at least 1 hour.
 The velocity of the temperature variation between one extreme temperature to the other shall be **10 °C/min** .

5.4.2 Mechanical

5.4.2.1 Atmospheric pressure, altitude requirements

The equipment is installed within the pressure vessel where pressure is normally controlled. However, in the event of decompression at high altitude, the system may be subjected to significantly lower pressure. The following sub-chapters identify the different pressure conditions the equipment can be exposed to.

5.4.2.1.1 Steady State – Altitude

The equipment of the IFE system shall comply with the Altitude requirements of *RTCA DO160E, Section 4 Paragraph 4.6.1 for Category D2*.
 The Steady State Altitude is *50,000 feet*. The corresponding absolute pressure is **116 mbar** (Table 5).

5.4.2.1.2 Decompression Altitude

The decompression test requirements associated with the *RTCA DO160E, Section 4 Paragraph 4.6.2 for Category D2*.

Altitude	Absolute Pressure	
	kPa	mbars
-15,000 ft (-4,572 m)	169,73	1697.3
0 ft (0 m)	101.32	1013.2
+8,000 ft (+2,438 m)	75.26	752.6
+15,000 ft (+4,572 m)	57.18	571.8
+25,000 ft (+7,260 m)	37.60	376.0
+35,000 ft (+10,668 m)	23.84	238.4
+50,000 ft (+15,240 m)	11.60	116.0
+70,000 (+21,336 m)	4.44	44.4

Table 5: Pressure values for various altitude level

5.4.2.1.3 Overpressure Altitude

The overpressure test requirements associated with the *RTCA DO160E, Section 4 Paragraph 4.6.3 for Category D2*.

The Overpressure Altitude is -15,000 feet. (the absolute pressure is 1700 mbar).

5.4.2.2 Humidity

Each equipment must be tested to verify its ability to withstand the extremes of humidity experienced in the airplane environment. The equipment must maintain safe conditions throughout the test even if it fails to function throughout the test.

The equipment of the IFE System shall comply with the Humidity requirements of *RTCA DO160E, Section 6 for Category B*.

Temperature range : between +38 °C and +65 °C

Relative humidity : +95 %

Duration : 240 hours

5.4.2.3 Vibrations

The size of an airplane, and the power necessary to lift the airplane and its contents to 50,000 feet, and the high duty cycle of each airplane in service combine to generate considerable vibration for an equipment throughout its service life. The equipment must maintain safe conditions throughout the test even if it fails to function throughout the test. How well the equipment withstands the test vibration levels and continues to perform intended function, as defined in the qualification test procedure, is a measure of product quality.

The equipment shall meet the requirements of *RTCA DO160E, Section 8* using the Robust test category for Fixed Wing Turbojet or Turbofan Engine Aircraft.

5.4.2.4 Mechanical shocks

Each equipment must be tested to verify its ability to withstand operational shocks during normal airplane operations. These shocks occur during taxi, landing, and when the airplane encounters turbulence in flight.

The equipment shall conform to the operational shocks and crash safety requirements of *RTCA DO160E, Section 7 for Category B* : with the equipment operating and with its temperature stabilized, apply to the test item 3 shocks in each orientation having a terminal saw-tooth wave shape with an acceleration peak value of 6 g. The nominal pulse duration shall be 11 ms (Table 6).

Peak value	6 g
Duration	11 ms
Number of shocks per axis	3

Table 6 : Mechanical shocks

5.4.2.5 Acceleration

Even if acceleration is not a fundamental parameter which governs the TIM efficiency, it is important to remember that the material will be subject to acceleration. For example, in the case of the unit of an IFE, the system shall fulfil the requirements of ABD11.1.2 chapter 1.20 *Category C* for functional and structural integrity (Table 7).

- The ABD100 specifies taking the higher level. The description of each axis is given on Figure 2.

	Emergency		Flight	
	Boeing	Airbus	Boeing	Airbus
Forward	9	9	1.5	1.63
Rearward	1.5	1.5	1.5	1.09
Down	6	6	6.5	7.30
Up	3	3	3.5	4.20
Side	3	4	3.0	2.38

Table 7 : IFE Acceleration value

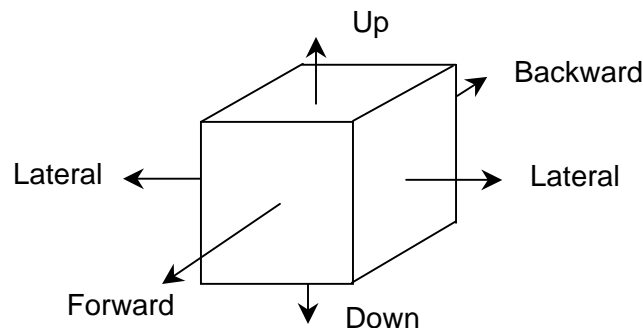


Figure 2 : Equipment orientation in air plane

5.4.3 Fungus, Salt spray, Contamination, Toxicity

5.4.3.1 Salt spray

The TIM material must withstand the effects of an aqueous salt atmosphere. It should not be attack, degrade or loose its thermal and electrical properties when use in a salt atmosphere.

The test conditions are :

- temperature : 35 °C
- salt concentration : 5%
- duration : 48 hours

5.4.3.2 Fungus resistance

The object is to determine whether equipment material is adversely affected by fungi under conditions favorable for their development, namely, high humidity, warm atmosphere and presence of inorganic salts. Typical problems caused by fungi growing on equipment are :

- microorganisms digest organic materials as a normal metabolic process, thus degrading the substrate and increasing moisture penetration,
- organics acid, produced during the metabolism, diffuse out of the cells and onto the substrate and cause metal corrosion,
- the physical presence of microorganism produces living bridges across components that may result in electrical failures,
- the physical presence of fungi can also cause health problems and produce unpleasant situations in which users will reject using the equipment.

Each equipment shall be constructed of materials that are not nutrient for fungi, that do not deteriorate over time to become nutrient for fungi. When not practicable, a suitable fungicide agent or other means should be used to protect the materials.

Each equipment shall be verified to be resistant to fungi in accordance with *RTCA DO160E, Section 13.0, Category F*.

5.4.3.3 Contamination resistance

Most of the liquid or gaseous fluids used in the various aircraft systems shall be considered as possible pollution agents for the generally non metallic components of the equipment with which they might accidentally come into contact. The case of cleaning agents is considered too.

This contact shall be made by spraying or exceptionally by immersion.

These potential polluting products are the following ones (non exhaustive list) :

- Hydraulic fluids,
- Fuels and additives (antifreeze, anti static, anti corrosive, fungicide),
- Lubricants for engines,
- Various greases,
- Extinguisher liquids,
- Cleaning fluids, solvents, etc.

The TIM material will be chosen to resist the effects of contamination by any of these fluids. No degradation (fluid absorption, dilution,...) is accepted and fluid retention zones should be avoided.

Where contamination is likely to cause corrosion, a suitable treatment shall be applied to the material.

5.4.3.4 Toxicity, inflammability

All equipment shall conform to the requirements of the ABD0031. The reference document defines 4 different tests :

- Flammability test (applicable to equipment located in all pressurised sections of the fuselage)
- Heat Release test (not applicable)
- Smoke Density test (applicable to equipment located in pressurised sections occupied by crew or passengers)
- Toxicity test (applicable to equipment located in pressurised sections occupied by crew or passengers). Toxic fumes due to the combustion of these material should be avoid.

The material should be flame resistant and non propagating (V-0 according to UL94 standard or equivalent).

The material should respect the Directives 2002/95/CE and 2005/618/CE concerning the Restriction Of use of certain Hazardous Substances in electrical and electronic equipment (RoHS).

6 FUNCTIONAL SPECIFICATION

6.1 BOSCH FUNCTIONAL SPECIFICATION

6.1.1 Implementation

All materials will have a shelf life > 6 months, storage below 0 °C must not be necessary.
If curing of TIM is necessary, cure time shall be within 30 min at 140 °C (maximum cure temperature)

6.1.2 Storage and useful life

The useful life should be greater than **15 years** or **6000 operating hours**

6.2 IBM FUNCTIONAL SPECIFICATION

6.2.1 Implementation

All the materials developed in the Nanopack project, will have an application viscosity compatible with syringe dispensing, stencil printing, or roller application.

The curing time should not exceed 1 hour.

All materials will have a shelf life > 6 months

6.3 FOAB FUNCTIONAL SPECIFICATION

6.3.1 Implementation / Application method

The material must be easily apply manually, preferably in the form of pads or films, at room temperature.

Assembly force: for 10*10 mm² < 40 N

The shelf life should be greater than 6 months.

6.4 THALES FUNCTIONAL SPECIFICATION

The principal mission of the Nanopack project defined in the present document is to develop new technologies and materials for thermal interfaces and electrical interconnects.

To fulfill the general specifications, the material must be satisfied :

- technology transparency
 - interchangeability
 - assembly
-

- configurability, growth capability, modularity
- maintainability

6.4.1 Implementation

The TIM implementation should be compatible with standard means (syringe, ...). Thus the viscosity of the product should be lower than 500 Pa.s.

In case of two-part materials, the pot life and working time should be greater than 10 minutes.

The curing times should be lower than 30 minutes for temperature around 150 °C. This time can be extended to 24 hours for temperature lower than 100 °C.

The cleaning agent for the surface preparing must respect the environment. There must be in accordance with the norm ISO14001 (for example isopropyl alcohol).

The preferable storage conditions should not specified temperature lower than -25 °C. Products having ambient temperature (20 °C) or cold temperature (5 °C) storage conditions are preferred.

Each product will have a shelf life clearly identified. This shelf life must be greater than 6 months and products with a shelf life greater than 12 months are preferred.

6.4.2 Storage and useful life

The storage life of the equipment shall be not less than 10 years under the storage conditions without any inspection.

The useful life of the equipment shall be not less than 25 years or 100,000 operating hours.

6.4.3 Reliability

The design of the thermal interface material shall not contradict to any reliability and flight safety requirement stated in this document.

Derating is the limiting of a component's maximum operating stress to a percentage of its rated value, with the object of enhancing reliability. This is a now well established technique for minimizing an equipment failure rate and shall be applied to the equipment in a rational manner.

The equipment including any built in test facilities, after installation in the aircraft shall achieve a total primary defect rate less than 0,1 per 1000 operating hours (TBC). This shall apply to both ground use and flight use.

The equipment, after installation in the aircraft shall achieve a total primary failure rate of less than 0.9 per 1000 operating hours. This shall apply to both ground use and flight use.

6.4.4 Maintainability

The TIM material shall be easily removable and replaceable with a minimum special tools. The surface preparation should be as simple as possible with the use of standard cleaning agent.

The maintenance concept is one of minimum scheduled maintenance consistent with safe and economic operation. Scheduled maintenance is only permitted when a scheduled action is necessary to prevent a safety hazard, inability to meet safe life design criteria or on the grounds of economy to preclude expensive damage. Each requested scheduled exception shall be based on the Reliability Centred Maintenance Procedures.

Design, assembly and accessibility to the TIM shall be such as to minimize the maintenance workload in order to achieve the objective of increased availability.

6.4.5 Life Cycle Cost, Maintenance Specification

A great emphasis must be placed during the design and development phases on the maintainability and supportability features and particularly on the following objectives :

- No scheduled maintenance,
- No special tools and Ground Support Equipment at Aircraft level maintenance,
- Reduction of maintenance workload
- Reduction of unjustified removals,
- Reduction of special training.

The final product when integrated inside the module must have an affordable LCC while fulfilling its performance requirement.

LCC : Life Cycle Cost are summations of cost estimates from inception to disposal for both equipment and projects as determined by an analytical study and estimate of total costs experienced during their life.

The objective of LCC analysis is to choose the most cost effective approach from a series of alternatives so the least long term cost of ownership is achieved.

LCC analysis helps engineers justify equipment and process selection based on total costs rather than the initial purchase price. Usually the cost of operation, maintenance, and disposal costs exceed all other costs many times over. Life cycle costs are the total costs estimated to be incurred in the design, development, production, operation, maintenance, support, and final disposition of a major system over its anticipated useful life span.

The precise value of LCC is therefore dependant on the cost of the product associated reliability figures ; operational use figures and maintenance options.

Based on previous experience on similar products and on the preliminary definition it is possible to estimate that LCC should not exceed 15% of the acquisition cost.

7 RECAPITULATIVE TABLE

		BOSCH	IBM	FOAB	THALES
Material specifications	Geometrical	60*40 mm, BLT 50µm	TIM1 : 20*20 mm BLT : 10-35 µm TIM2 : 45*45 mm BLT : < 20 µm	10*10 mm², 20µm 25*25 mm², 50-100µm	TIM1 : 5*5 mm² TIM2 : 50 *50 mm² Class1 : BLT 50-250 µm Class2 : BLT 1-3 mm
	Thermal	10 W/m.K 5 K.mm²/W at BLT >35 µm	TIM1 : 2-3 K.mm²/W TIM2 : 3-4 K.mm²/W	10 W/m.K (85 °C)	Class1 : 20 K.mm²/W Class2 : 20 W / m.K
	Electrical	-	< 5mΩ for a 12*12 mm area	-	Class 2 : Insulated
Environmental specifications	Storage temperature	150 °C 3000 h 200 °C 200 h	-40 / +150 °C	-	-55 / +85 °C
	Operating temperature	Cont 150 °C Max 180 °C	+20 °C / + 85 °C	-	Cont -55 / +150 °C
	Thermal shock	1500 cycles -40 / +150 °C	-	-	10 °C/min
	Thermal cycling	2500 cycles -40/+150°C	2000 cycles +20 °C/+105 °C 12 min / cycle		2000 cycles, -40°C/+95 °C 10 °C/min
	Atmospheric Pressure	Normal	-	-	116 / 1797 mbar
	Humidity	1000 h 85°C, 85 %RH	-	1000 h, 85°C, 85%RH	65°C 95% 240h
	Accelerations	-	-	-	9 g
	Salt spray	-	-	-	35°C 5% 48 h
	Fungus	-	-	-	Resistant
	Toxicity	None or Xi	-	-	None, Rohs compliant
Functional specifications	Implementation	6 months shelf life (at ambient or 5°C temperature)	6 months shelf life	6 months shelf life	6 months shelf life (at ambient or 5°C temperature)
	Useful life	6000 op hours	-	1000 op hours, 85°C, 85%RH	25 years or 100 000 operating hours
	Storage life	-	-	-	10 years
	Curing time	< 30min 140°C	< 1 hour	-	< 30min 150°C

These specifications will be used for :

- WP2: Development of materials
- WP3: Process development and optimization
- WP7: Project demonstrators
-

All the material developed in the Nanopack project should meet the requirements specified in WP1.

ANNEXE 1

Bosch N2580-1.1:



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