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Verification identification, classification, selection of criteria and verification matrices

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Contents

(20 pages in total)

1 Introduction

This document serves as a first iteration towards a verification approach of the AMS Overall thermal system. The main topic of this document is the verification matrices of the AMS subsystem with respect to thermal design.

2 Verification methods

Verification will be accomplished by one or more of the following verification methods:

- Test (T)
- Analysis (A)
- Review-of-design (R)
- Inspection (I)

2.1 Test

When the requirements have to be verified by measuring system/product performance and functioning under various simulated conditions, the method is referred to as “Test”.

2.1.1 Test principles and procedures

The measurements may need the use of special equipment, instrumentation and simulation techniques. Established principles and procedures shall be used to determine conformance to requirements

2.1.2 Test evaluation

The analysis of data obtained and derived from the test is an integral part of the test.

2.1.3 Demonstration

When relevant, tests also include the demonstration of qualitative operational performance and of requirements. The performance, as demonstrated, shall be observed and recorded.

2.2 Analysis

When verification is achieved by performing theoretical or empirical evaluation by accepted techniques, the method is referred to as "Analysis".

2.2.1 Analytical techniques

The analytical techniques are systematic, statistical and qualitative design analysis, modelling and computational simulation.

2.2.2 Similarity

Verification by similarity is considered part of analysis. It is applied only if it can be shown that the article under verification is similar to another article that has already been verified to equivalent or more stringent requirements.
The verification activity consists of the assessment and review of prior test data, hardware configuration and applications.

2.3 Review-of-design

When verification is achieved by validation of records or by evidence of validated design documents or when approved design reports, technical descriptions, engineering drawings unambiguously show the requirement is met, the method shall be referred as "Review-of-design".

2.4 Inspection

When verification is achieved by visual determination of physical characteristics (such as construction features, hardware conformance to document drawing or workmanship requirements) the method shall be referred to as "Inspection".

3 Verification levels

The requirement verification shall be performed incrementally at different verification levels. The number and type of verification levels depend on the complexity of the project and on its characteristics.

The typical verification levels identified for AMS-02 are:

EQ:	Equipment (Example: TTCS valves, a PMT, radiator, individual electronic boxes);
SS:	Subsystem (Example: Power distribution system, ECAL, structure, TTCS,);
SY:	System

Below the equipment level there is the parts and materials level. Requirements for parts and materials defined in the customer's specification of a product will be subjected to formal verification (TBC, by whom?).

4 Verification stages

The verification process shall be implemented in subsequent verification stages in AMS. The verification stages identified preliminarily for AMS are:

- Verification on the engineering model (EM)
- Verification on the final, flight model (FM)

TBW

5 Verification strategy

5.1 Selection of methods, levels and stages of verification

Verification by test
Verification by analysis
Verification by review of design
Verification by inspection

6 Verification implementation

7 Verification matrices

In this paragraph the first iteration of the verification matrices of the subsystems are given. The complete filled-in set of verification matrices yields the overall system verification matrix by eliminating all entries only with equipment (EQ) or subsystem (SS) verification, without a system (SY) verification activity. In general all EM tests and the FM equipment and FM subsystem tests take place at the subsystem groups, FM system tests take place at JSC. The verification matrices should reflect this approach.

7.1 TRD

Req. nr.	Requirement	Verif. stage	Verification methods		
			EQ	SS	SY
	TRD operating temperature shall be in the range of +10 °C to +25 °C	EM	A	A,T	
	TRD non-operating temperature shall be in the range of –20 °C to +40 °C	EM	A	A,T	
	Temperature stability over one orbit shall be better than 1°C	FM	A	A	A,T
	The temperature difference top to bottom shall be less than 1°C	FM	A	A	A,T
	The temperature difference over circumference shall be less than 1°C	FM	A	A	A,T
	TRD power dissipation shall not exceed 17 W	FM	A	A	A,T
	Interface conductance between TRD M structure and USS is 1.13 W/K (TBC) for each of the 4 support brackets	FM	A	A	A,T
	Conductance through the 4m gas tubes shall not exceed 0.0053 W/K (TBC)	FM	A	A	A,T
	Conductance through the TRD signal cable shall not exceed 0.06W/K (TBC)	FM	A	A	A,T
	Conductance through the TRD senscable shall not exceed 0.009W/K	FM	A	A	A,T
	Conductance through the TRD HV cable shall not exceed 0.006W/K	FM	A	A	A,T

	TRD is covered by MLI on all surfaces	FM	R	I	I
	The t/o properties of the MLI are those of beta cloth	FM	R	I	
	TRD is completely wrapped together with the upper TOF	FM	R	R	I
	TRD radiator is Zenith pointing, with an area of 0.786 m^2 maximum	FM	A,R	I,T	
	The TRD radiator mass is 6.45 kg max.	FM	A	A,T	
	The TRD radiators t/o properties are white paint	FM	R	I	
	TRD heat rejection to space through TRD radiator shall exceed 90% ≈ 15W	FM	A	A	A,T
	Heat rejection toward VC shall be less than 3 W	FM	A	A	A,T

7.2 TOF, upper

Req. nr.	Requirement	Verif. stage	Verification methods		
			EQ	SS	SY
	UTOF operating temperature shall be in the range of –20 °C to +40 °C	EM	A	A,T	
	UTOF non-operating temperature shall be in the range of –50 °C to +50 °C	EM	A	A,T	
	Temperature stability over one orbit shall be less than 5°C	FM	A	A	A,T
	The temperature difference between structure and PMTs shall be less than 10°C	FM	A	A	A,T
	UTOF power dissipation shall not exceed 3.2 W	FM	A	A	A,T
	Interface conductance between UTOF and USS is less than TBD W/K for each of the 4 feet	FM	A	A	A,T
	UTOF shall be insulated from the Tracker by	FM	R	R	I

	MLI				
	The t/o properties of the MLI are those of beta cloth	FM	R	I	
	The aluminium side of the boxes is painted black for heat rejection	FM	R	I	
	Heat rejection toward neighbouring systems shall be shall be less than 1 W	FM	A	A	A,T

7.3 Tracker

Req. nr.	Requirement	Verif. stage	Verification methods		
			EQ	SS	SY
	TR operating temperature shall be in the range of –10 °C to +25 °C (Silicons)	EM	A	A,T	
	TR operating temperature shall be in the range of –10 °C to +40 °C (Hybrids)	EM	A	A,T	
	TR non-operating temperature shall be in the range of –20 °C to +40 °C(Silicons)	EM	A	A,T	
	TR non-operating temperature shall be in the range of –20 °C to +60 °C(Hybrids)	EM	A	A,T	
	Temperature stability over one orbit shall be less than 3°C	FM	A	A	A,T
	The temperature difference between any two silicons shall be less than 10°C	FM	A	A	A,T
	TR power dissipation shall not exceed 184.2W	FM	A	A	A,T
	TTCS power dissipation shall be less than 80W (TBC)	FM	A	A	A,T
	Interface conductance between TR and USS is 0.2 W/K for the 8 feet in total	FM	A	A	A,T
	Conductance from TR hybrids (FE) to the 8 crates is because of cables. Conductance is less than 16mW/K for each of the 8 cables	FM	A	A	A,T
	XXX				

7.4 ACC

Req. nr.	Requirement	Verif. stage	Verification methods		
			EQ	SS	SY
	ACC operating temperature shall be in the range of –20 °C to +40 °C	EM	A	A,T	
	ACC non-operating temperature shall be in the range of –20 °C to +40 °C	EM	A	A,T	
	ACC power dissipation shall not exceed 2 W	FM	A	A	A,T
	Interface conductance between ACC PMT boxes and VC is lower than 0.1 W/K (TBC)	FM	A	A	A,T

7.5 Crates

Req. nr.	Requirement	Verif. stage	Verification methods		
			EQ	SS	SY

	Standard crates operating I/F temperature shall be in the range of –20 °C to +50 °C	FM	A	A	A,T
	Standard crates non-operating I/F temperature shall be in the range of –40 °C to +80 °C	FM	A	A	A,T
	CAB operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	CAB non-operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	CCS operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	CCS non-operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	CQDB operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	CQDB non-operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	Cryocooler driver control box operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	Cryocooler driver control box non-operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	Laser align crate operating I/F temperature shall be in the range of 5 °C to 25 °C	FM	A	A	A,T
	Laser align crate non-operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	PDB operating I/F temperature shall be in the range of –25°C to +45 °C	FM	A	A	A,T
	PDB non-operating I/F temperature shall be in the range of –40°C to +80 °C	FM	A	A	A,T
	Warm helium supply operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	Warm helium supply non-operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	TRD gas box S and C operating I/F temperature shall be in the range of 0 °C to +30°C	FM	A	A	A,T
	TRD gas box S and C non-operating I/F	FM	A	A	A,T

	temperature shall be in the range of –25 °C to +45 °C				
	ASTE operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	ASTE non-operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	ASTC operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	ASTC non-operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	Flywheel operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	Flywheel non-operating I/F temperature shall be in the range of TBD °C	FM	A	A	A,T
	Temperature stability over one orbit shall be less than 5°C	FM	A	A	A,T
	The thermal conductance to the radiator shall be better than 7.5 W/Km, depending on the length of the crate	FM	A	A	A,T
	Other sides than the radiator side shall be covered with MLI (t/o properties of beta cloth)	FM	R	I	I
	The radiator area of the RAM radiator is 3.42 m^2 (TBC)	FM	R	I,T	
	The radiator area of the WAKE radiator is 4.34 m^2 (TBC)	FM	R	I,T	
	The t/o properties of the radiators are white paint	FM	R	I	
	The backward radiation of the radiators shall be less than 3% of the total radiator power	FM	A	A	A,T
	Temperature uniformity on the radiators shall be better than 5 °C	FM	A	A	A,T
	Conduction from the radiator to the USS shall be lower than 1 W/K for each fixation point	FM	A	A	A,T
	A layer of cho-therm is put between crates aluminium plates and radiator	FM		R	I

7.6 Magnet/Vacuum case

Req. nr.	Requirement	Verif. stage	Verification methods EQ	SS	SY
	Magnet/VC external temperature shall be less than 10°C on average	FM	A	A	A,T
	Temperature stability over one orbit shall be less than TBD°C	FM	A	A	A,T
	Interface conductance between VC and USS is less than 6.72 W/K for each of the 8 feet	FM	A	A	A,T
	The Outer VC shall be covered by MLI in the ±Y quadrants (beta cloth)	FM	R	I	I
	In the ± Z direction the VC is wrapped in MLI	FM	R	I	I
	The Outer VC shall be covered with silver teflon in the ±X direction	FM	R	I	I
	All other surfaces shall be anodized aluminium	FM	R	I	
	The upper and lower flanges are covered with MLI (beta cloth)	RM	R	R,I	I

7.7 Cryocoolers

Req. nr.	Requirement	Verif. stage	Verification methods EQ	SS	SY
	The cryo-coolers operating temperature shall be in the range of –10 °C to +40 °C	EM	A	A,T	
	The minimum cryocooler turn-on temperature shall be 10 °C or lower.	EM	A	A,T	
	The heat dissipation of the cryocooler shall be in the range of 60 – 150 W	EM	A	A,T	
	The nominal heat dissipation shall be 100 W/ cooler	FM	A	A	A,T
	Interface conductance between cryocooler and	FM	A	A	A,T

	the LHP shall be better than 9.4 W/K (TBC)				
	Interface conductance between cryocooler and VC shall be lower than 0.01 W/K (TBC)	FM	A	A	A,T
	Each cryocooler shall be wrapped in MLI (t/o properties of aluminized polymide)	FM	A	A	A,T
	The cryo radiator (zenith radiator) has an area of 4.1 m^2	FM	R	I,T	
	The cryo radiator (zenith radiator) has an mass of 25.0 kgs max.	FM	A	T	
	T/o properties of the Zenith radiator are white paint	FM	R	I	I
	Backward radiation of the Zenith radiator shall be less than 3% of the radiator power.	FM	A	A	A,T
	The temperature uniformity of the Zenith radiator shall be better than 5 °C	FM	A	A	A,T
	The radiators is attached to the TRD upper honeycomb with a thermal conductance of TBD W/K	FM	A	A	A,T
	Heat leak of the cryocoolers to the VC shall be less than 5 W per cryocooler	FM	A	A	A,T

7.8 TOF, lower

Req. nr.	Requirement	Verif. stage	Verification methods		
			EQ	SS	SY
	LTOF operating temperature shall be in the range of –20 °C to +40 °C	EM	A	A,T	
	LTOF non-operating temperature shall be in the range of –50 °C to +50 °C	EM	A	A,T	
	Temperature stability over one orbit shall be less than 5°C	FM	A	A	A,T
	The temperature difference between structure and PMTs shall be less than 10°C	FM	A	A	A,T
	LTOF power dissipation shall not exceed 3.6	FM	A	A	A,T

	W				
	Interface conductance between LTOF and USS is less than TBD W/K for each of the 4 feet	FM	A	A	A,T
	Radiation shall be less than 20%of dissipated power ≈0.7W (???)	FM	A	A	A,T
	LTOF shall be insulated from the VC/Magnet by MLI	FM	R	I	I
	The t/o properties of the MLI are those of beta cloth	FM	R	I	I
	The aluminium side of the boxes is painted white for heat rejection	FM	R	I	
	Heat rejection toward neighbouring systems shall be shall be less than 1 W	FM	A	A	A,T

7.9 RICH

Req. nr.	Requirement	Verif. stage	Verification methods		
			EQ	SS	SY
	PMT operating temperature shall be inside the range -20°C to 40°C	Q	A	A,T	
	PMT non-operating temperature shall be inside the range –40°C to 40°C	Q	A	A,T	
	PMT temperature stability over one orbit shall be less than 7°C (Max. variation of temperature is ± 3.5 °C)	A	A	A	A,T
	PMT temperature uniformity shall be less than 15°C (1)	A	A	A	A,T
	RICH average power dissipation shall not exceed 19.7 W (2)	A		A	A,T
	Interface conductance between RICH feet and USS shall be less than (0.781 W/K) on each of the 8 fixation points	A	A	A	A,T
	RICH reflector space-facing-side shall be	A		R	I

	covered by a MLI blanket to shield reflector from incident radiation				
	The rear side of the radiator panels shall be covered by MLI to shield them from back radiation	A		R	I
	Between top ECAL and RICH there is an MLI blanket	A		R	I
	Radiator panel coating is OSR	Q	R	I	
		A			I
	The RICH radiator area is 4 × 0.195 m^2 + 4 × 0.248 m^2	Q	R	I	
	RICH shall not reject heat into the ECAL direction more than 2 W (TBC)	A	A	A	A,T

(1) Applied to all the PMT’s distribution into secondary structure
(2) Related to a number of PMTs equal to 740.

7.10 ECAL

Req. nr.	Requirement	Verif. stage	Verification methods		
			EQ	SS	SY
	ECAL operating temperature shall be in the range of –20 °C to +40 °C	EM	A	A,T	
	ECAL non-operating temperature shall be in the range of –40 °C to +40 °C	EM	A	A,T	
	Temperature stability over one orbit shall be less than 5°C	FM	A	A	A,T
	The temperature difference between pancake and aluminium structure shall be less than 10°C	FM	A	A	A,T
	ECAL power dissipation shall not exceed 46.7 W	FM	A	A	A,T

	Interface conductance between ECAL and USS shall be less than 1.5W/K on each of the 8 fixation points	FM	A	A	A,T
	Upper MLI (see RICH req. R XXX)	FM	R	I	I
	ECAL bottom panel is covered by MLI lateral walls (if needed XXX)	FM	R	I	I
	The ECAL radiators consists of 4 winglets of 0.083 m^2 each	FM	R	I	
	The winglets' thermo-optical properties are OSR	FM	R	I	
	ECAL lateral panels are white painted	FM	R	I	
	ECAL power rejection to the USS shall not (??) exceed 60% ≈ 28W	FM	A	A	A,T

Appendix A Contact List

Subsystem	Contact	
TRD	OHB	R. Schlitt, S. Schael, K. Lübelsmeyer
TOF(upper)	CGS	C. Vettore, G. Laurenti
Tracker	NIKHEF	B. Verlaat, M. Pohl, R. Battiston
TTCS	NLR	A. Woering, A. Delil, M. Pohl, R. Battiston
ACC	CGS?	C. Vettore, S. Schael, K. Lübelsmeyer
Electronics Crates	MIT,NSPO,CGS	M. Capell, M. Molina T.R. Tsai
TRD Gas	MIT	U. Becker, R. Becker
Magnet	Oxford,LMSO,ETH	S. Harrison, C. Clark, H. Hofer
VC	LMSO	C. Clark, T. Martin
Cryocoolers	MIT,GSFC	R. Foster?, S. Breon, R. Schlitt?
TOF(lower)	CGS	C. Vettore, G. Laurenti
RICH	CGS	G. Sardo, G. Laurenti
ECAL	CGS	C. Pini, F. Cervelli, F. Cadoux
System Thermal	CGS	M. Molina, H. Hofer, J. Burger, C. Vettore