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1. SCOPE

The objective of this report is the description of the Launch To Activation phases at the end of which AMS-02 is mounted on ISS truss.
For each phase the power profile used in the thermal analysis is reported.
Analysis results are presented as well.
The document corresponds to contract deliverable DEL 032.

2. ACRONYM LIST

AD	Applicable Document
AMS-02	Alpha Magnetic Spectrometer
BCS	Berthing Cues System
BOL	Begin Of Life
CGS	Carlo Gavazzi Space
EOL	End Of Life
GMM	Geometrical Mathematical Model
I/F	Interface
ISS	International Space Station
LTA	Launch to activation
MERAT	Mean Effective Radiation Temperature
MLI	Multi Layer Insulation
MPA	Minimum Propulsion Attitude
PVGF	Power and Video Grapple Fixture
RD	Reference Document
RICH	Ring Image Cherenkov Counter
STS	Space Transportation System
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written
TCS	Thermal Control Subsystem
TMM	Thermal Mathematical Model
TRP	Temperature Reference Point
w.r.t.	With respect to

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3. RELEVANT DOCUMENTS

Documents here below identified are applicable and/or reference for the activities described in the present document and are considered part of it to the extent specified herein.

3.1 APPLICABLE DOCUMENTS

AD	Doc.Number	Issue	Issue/Date	Rev.	Title/Applicability
1	JSC-28792	D	March 2005		AMS-02 Structural Verification Plan for the Space Transportation System and the International Space Station.
	JSC29095	A	06/01/2002		Experiment/Payload Integration Hardware Interfaces - Part I
2	JSC29095	A	Aug 2004		Experiment/Payload Integration Hardware Interfaces - Part II
3	JSC29202	C	March 2005		Experiment/Vacuum Case Payload Integration Hardware Interface
4	AMSTCS-SP-CGS-003	1	25/03/2008		AMS-02 Thermal Requirements specification document

3.2 REFERENCE DOCUMENTS

RD	Doc. Number	Issue	Date	Rev.	Title
RD 1	AMSTCS-RP-CGS-004	1	25/03/2008		Main and Tracker radiators thermal analysis report
RD 2	AMS-OHB-TAR-003	3	24/10/2006	D	Thermal Analysis Report TRD/Upper TOF
RD 3	AMS02-TN-CGS-007	2	16/10/2006		AMS-02 120VDC and 28VDC heater description
RD 4	AMS02-RP-CGS-014_iss1	1	12/02/2007		AMS-02 thermal analysis report: survey and system level model results
RD 4	RICSYS-RP-CGS-015	2	07/03/2005		ECAL thermal analysis report
RD 5	AMS-RP-CGS-008	2	13/06/2005		EHV/RHV bricks thermal analysis report
RD 6	AMS02-TN-CGS-010	1	07/03/2005		CAB LHP freezing assessment
RD 8	AMSTCS-TN-CGS-009	1	31/03/2008		CAB TCS Thermal Analysis Report
RD 9	AMS-OHB-TAR-002	2	27/05/2005	B	Main radiator including CAB thermal analysis report
RD 10	AMSTCS-TN-CGS-012	1	31/03/2008		Cryo TCS thermal analysis report

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4. SYSTEM DESCRIPTION

A complete system description is provided in AD [4].

5. REQUIREMENTS AND INTERFACES

5.1 TEMPERATURE REQUIREMENTS

Temperature requirements are listed in AD [4].

5.2 THERMAL INTERFACES

5.2.1 CONDUCTIVE INTERFACES

All the following results have been obtained assuming the AMS-02 thermal as conductively decoupled from STS, from the ISS and from the robotic arms during the whole transfer phase.

5.2.2 RADIATIVE INTERFACES

The AMS Geometrical Mathematical Model (GMM) has been integrated in the ISS GMM and STS GMM in order to determine all the radiative couplings with the neighboring surfaces and with the environment.

AMS is capable to exchange heat with its neighboring via radiation only. There are radiative coupling factors with the STS and with the ISS (but in the STS free flying case), and the models are subjected to the heat fluxes from Sun, Albedo, Earth I/R, while irradiating towards the deep space.
The AMS-02 GMM has been exposed to a space sink temperature of 3 K. Solar , IR and Albedo parameters are described into par. 6.1 .

The reference version for the NSTS is ORB390 without petals. The NSTS is the only visiting vehicle taken into account when AMS-02 is onboard ISS.

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6. THERMAL ENVIRONMENT

AMS-02 thermal control has been designed to withstand the worst thermal environment the detectors will undergo during their mission lifetime, including the transfer sequence.

The thermal environment AMS-02 experiment experiences is influenced by the following external parameters:

- Impinging solar, albedo and Earth radiative fluxes
- ISS/STS surfaces temperatures
- Radiative heat exchange with other STS and ISS surfaces

In addition to these, AMS-02 internal dissipation, geometry, surface coatings, materials, etc. have their own influence on AMS-02 detector temperatures. Moreover, during transfer phase, the other objects visibility will vary depending on of AMS-02 position:

- in phase 1 will be in view contact with the STS Cargo Bay.
- in phase 2 will be in view contact with the STS Cargo Bay and the ISS from inside the Cargo Bay.
- in phase 3 will be in view contact with the STS external surfaces and the ISS from hand-off position.
- in phase 4 will be in view contact with the ISS, from TRUSS position.

Impinging radiative fluxes and heat exchange are variable during the orbit. They are also deeply influenced by beta angle of the orbit and spaceship attitude or Euler angles as well as by the resulting motion of articulating surfaces (e.g. ISS solar arrays and radiators).
Beta angle is the angle between the solar vector and the orbit plane, and for the ISS/STS orbit varies between –75° and +75°.
Euler angles are yaw, pitch and roll angles, and determine the ISS attitude. Nominal ISS attitude foresees yaw axis pointing toward nadir direction and roll axis aligned with the direction of motion. The ISS attitude is however variable and off-nominal attitudes are combination of the possible rotations, in the ranges reported in the following table:

Angle	Variation Range
Beta angle	–75° to +75°
Yaw (Z) attitude angle	–15° to +15°
Roll (X) attitude angle	–15° to +15°
Pitch(Y) attitude angle	0° to +25° with docked STS -20° to +15° with undocked STS

Tab. 6-1 Beta and attitudes angles ranges for the ISS

AMS-02 thermal control shall cope with the entire range of combinations of the parameters above. The worst cases have been identified and the results of the thermal analysis are presented in section 8.

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6.1 EXTERNAL LOADS

In order to consider the radiative loads impinging over AMS-02 and ISS surfaces due to the presence of Sun and Earth, the data in Tab. 6-2 have been considered as input in the thermal model. These values represent the envelope of worst parameters for the ISS environment.

Parameter	Hot Cases	Cold Cases
Solar constant	1410 W/m^2	1322 W/m^2
Albedo	0.4	0.2
Earth temperature	266.5 K	245.5 K
ISS orbit height	150 nm	270 nm
Thermo-optical database	EOL	BOL

Tab. 6-2 Parameters influencing external loads

Into this external environment, the beta angle of the orbit and the ISS / STS attitude, constitute the last variables to be investigated in order to determine for each phase the worst case for each AMS-02 sub detector.

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6.2 INTERNAL LOADS

6.2.1 PHASE 1: STS UNMATED PHASES

INPUT FEED	APCU	FEED = B		1800W	
	ITEM	Unit dissipation	Quantity	Sum	Remarks
	E-crate	0	2	0	
	EHV	0	6	0	
	EPD	0	2	0	
	ECAL detector	0	1	0	
	J-Crate	28,0	1	**28,0**	
	JT-Crate	3,8	1	**3,8**	
	JPD	18,8	1	**18,8**	
	M-Crate	0	1	0	
	MPD	0	1	0	
	RHV	0	4	0	
	RPD	0	2	0	
	RICH detector	0	1	0	
	SHV	0	4	0	
	S-Crate	0	4	0	
	SPD	0	4	0	
	TOF detector	0	1	0	
	T-Crate	0	8	0	
	TPD	0	8	0	
	TT-Crate	0	1	0	
	TTPD	0	1	0	
	TTCB	0	2	0	
	TRACKER detector	0	1	0	
	U-Crate	0	2	0	
	UPD	0	2	0	
	TRD detector	0	1	0	
	UG-Crate	0	1	0	
	UGPD	0	1	0	
	TRD Gas Boxes S + C	0	1	0	
	ASTC	0	2	0	
	GPS	0	1	0	
	PDS	210,0	1	**210,0**	
	CAB	35,5	1	**35,5**	
	CCEB	59,8	1	**59,8**	
	Cryo-cooler	100 + 5 (heat lift)	4	**400 + 20 (heat lift)**	
	TOTAL			**775,7**[1]	

Tab. 6-3 Phase1 power profile.

[1] It doesn't include heater power request

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6.2.2 PHASE 2: STS DOCKED TO THE ISS, AMS-02 IN THE CARGO BAY

INPUT FEED	APCU	FEED = B		1800W	
	ITEM	Unit dissipation	Quantity	Sum	Remarks
	E-crate	0	2	0	
	EHV	0	6	0	
	EPD	0	2	0	
	ECAL detector	0	1	0	
	J-Crate	28,0	1	**28,0**	
	JT-Crate	3,8	1	**3,8**	
	JPD	18,8	1	**18,8**	
	M-Crate	0	1	0	
	MPD	0	1	0	
	RHV	0	4	0	
	RPD	0	2	0	
	RICH detector	0	1	0	
	SHV	0	4	0	
	S-Crate	0	4	0	
	SPD	0	4	0	
	TOF detector	0	1	0	
	T-Crate	0	8	0	
	TPD	0	8	0	
	TT-Crate	0	1	0	
	TTPD	0	1	0	
	TTCB	0	2	0	
	TRACKER detector	0	1	0	
	U-Crate	0	2	0	
	UPD	0	2	0	
	TRD detector	0	1	0	
	UG-Crate	0	1	0	
	UGPD	0	1	0	
	TRD Gas Boxes S + C	0	1	0	
	ASTC	0	2	0	
	GPS	0	1	0	
	PDS	210,0	1	**210,0**	
	CAB	35,5	1	**35,5**	
	CCEB	59,8	1	**59,8**	
	Cryo-cooler	100 + 5 (heat lift)	4	**400 + 20 (heat lift)**	
	TOTAL			**775,7**[2]	

Tab. 6-4 Phase2 power profile.

[2] It doesn't include heater power request

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6.2.3 PHASE 3: STS DOCKED TO THE ISS, AMS-02 IN HAND-OFF POSITION

During the first 4 hours in Hand-off position AMS-02 experiment will be completely un-powered. As soon as it is powered-up again the following profile has been applied :

INPUT FEED	PVGF	FEED = A/B		1800W x 2	
	ITEM	Unit dissipation	Quantity	Sum	Remarks
	E-crate	0	2	0	
	EHV	0	6	0	
	EPD	0	2	0	
	ECAL detector	0	1	0	
	J-Crate	77,5	1	**77,5**	4 JMDC operating
	JT-Crate	9,6	1	**9,6**	
	JPD	43,8	1	**43,8**	
	M-Crate	0	1	0	
	MPD	0	1	0	
	RHV	0	4	0	
	RPD	0	2	0	
	RICH detector	0	1	0	
	SHV	0	4	0	
	S-Crate	0	4	0	
	SPD	0	4	0	
	TOF detector	0	1	0	
	T-Crate	0	8	0	
	TPD	0	8	0	
	TT-Crate	0	1	0	
	TTPD	0	1	0	
	TTCB	0	2	0	
	TRACKER detector	0	1	0	
	U-Crate	0	2	0	
	UPD	0	2	0	
	TRD detector	0	1	0	
	UG-Crate	0	1	0	
	UGPD	0	1	0	
	TRD Gas Boxes S + C	0	1	0	
	ASTC	0	2	0	
	GPS	0	1	0	
	PDS	178,0	1	**178,0**	
	CAB	0	1	0	
	CCEB	0	1	0	
	Cryo-cooler	0	4	0	
	TOTAL			**308,9**[3]	

Tab. 6-5 Phase3 power profile

[3] It doesn't include heater power request

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6.2.4 PHASE 4: AMS-02 ON ISS

INPUT FEED	ISS	FEED = A/B		2400W	
	ITEM	Unit dissipation	Quantity	Sum	Remarks
	E-crate	10,9	2	21,8	
	EHV	(2,8)	6	16,8	
	EPD	5,5	2	11,0	
	ECAL detector	(68,4)	1	68,4	
	J-Crate	28,0	1	28,0	
	JT-Crate	3,8	1	3,8	
	JPD	18,8	1	18,8	
	M-Crate	16,5	1	16,5	
	MPD	15,4	1	15,4	
	RHV	(2,8)	4	11,2	
	RPD	8,5	2	17,0	
	RICH detector	(49,8)	1	**49,8**	
	SHV	3,7	4	14,8	
	S-Crate	25,8	4	103,2	
	SPD	9,4	4	37,6	
	TOF detector	(8,25)	1	8,25	
	T-Crate	37,7	8	301,6	
	TPD	25,1	8	200,8	
	TT-Crate	17,3	1	17,3	
	TTPD	15,0	1	15,0	
	TTCB	50,0	2	100,0	
	TRACKER detector	144,0	1	144,0	
	U-Crate	19,1	2	38,2	
	UPD	16,6	2	33,2	
	TRD detector	(18,5)	1	**18,5**	
	UG-Crate	13,2	1	13,2	
	UGPD	5,2	1	5,2	
	TRD Gas Boxes S + C	(0,9 + 3,6)	1	4,5	
	ASTC	3,8	2	7,6	
	GPS	6,1	1	6,1	
	PDS	352	1	352,0	
	CAB	(88,8)	1	88,8	
	CCEB	59,8	1	59,8	
	Cryo-cooler	100 + 5 (heat lift)	4	400 + 20 (heat lift)	
	TOTAL			**2237,0**	

Tab. 6-6 Phase 4 power profile

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6.2.5 HEATER POWER

For a complete list of the heaters location, thermostat level and sizing, see RD [3] .

7. THERMAL ANALYSIS CASES DESCRIPTION

7.1 LAUNCH TO ACTIVATION SEQUENCE

The AMS-02 Launch To Activation sequence has been subdivided into 4 phases, significant from the thermal point of view.
In the following sections, for each phase, the configuration of the AMS-02 model from power profile point of view and the relevant design cases will be described.

7.1.1 PHASE 0: LAUNCH

JS is in charge of this thermal analysis scenario.

7.1.2 PHASE 1: STS UNMATED ATTITUDES

The thermal environment attitudes described throughout this section are based on the Orbiter structural coordinate reference system (with the Orbiter +Z-axis pointing out of the payload bay, +Y-axis pointing out the starboard wing, and +X-axis pointing aft).
The shuttle will normally be oriented in a bay-to-earth local vertical attitude (+ZLV) with the tail on the velocity vector when orbiting at Beta angles less than |60°|.
For Beta angles greater than |60°|, the shuttle will normally be in a Passive Thermal Control (PTC) attitude. PTC is defined as the shuttle X-axis perpendicular to the solar vector and rolling about the X-axis at a rate of 4 revolutions/hour. AMS experiment has to be designed to survive these attitudes continuously.
The following table contains a list of shuttle attitudes that AMS experiment is required to analyze in the shuttle-alone configuration. For the transient run (i.e. 36 hours) the analysis has to determine how long it would take to recover the critical temperatures of the payload (back to within 3°F of the initial temperature achieved in the previous +ZLV or PTC attitude).

Attitude	Duration	Payload Recovery time at +ZLV to repeat attitude (β≤60 degrees)	Payload Recovery time at PTC to repeat attitude (β>60 degrees)
+ZLV (±XVV, ±YVV)[4] for β≤60 degrees (see Fig. 7-2)	Continuous	N/A	N/A
PTC for β >60 degrees[5] (see Fig. 7-3)	Continuous	N/A	N/A

Tab. 7-1 STS unmated attitudes

[4] BOL thermal optical properties have been used
[5] BOL thermal optical properties have been used
[7] CGS assumption in agreement with Jacobs Sverdrup

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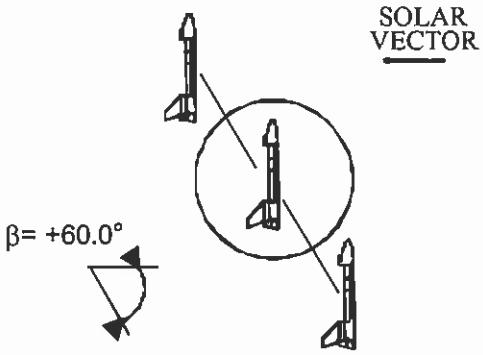

Fig. 7-1 –Z Solar Inertial STS unmated attitude

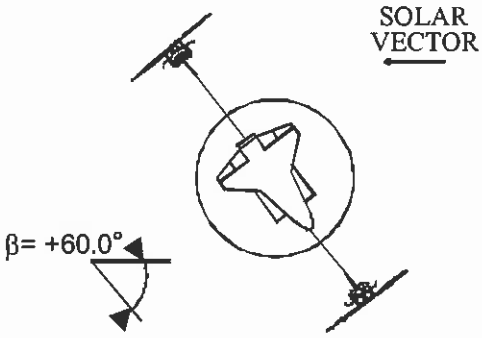

Fig. 7-2 +ZLV (-XVV) STS unmated attitude

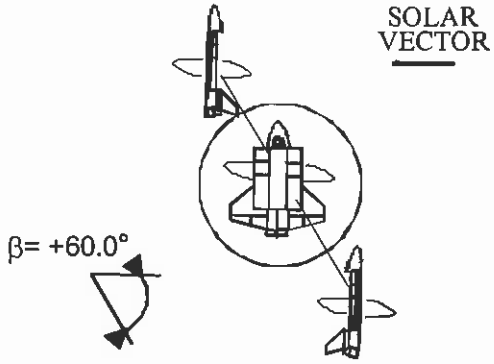

Fig. 7-3 PTC STS unmated attitude

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For this phase, the analysis will verify the ability of the thermal control system to maintain the TRPs in their non-operative temperature ranges for the sub-detectors that are switched OFF. There are only few nominal user that need to maintain their temperatures in the operative range, as can be seen in Tab. 6-3.

The following picture illustrates AMS-02 GMM integrated into the STS GMM, with Cargo Bay opened.

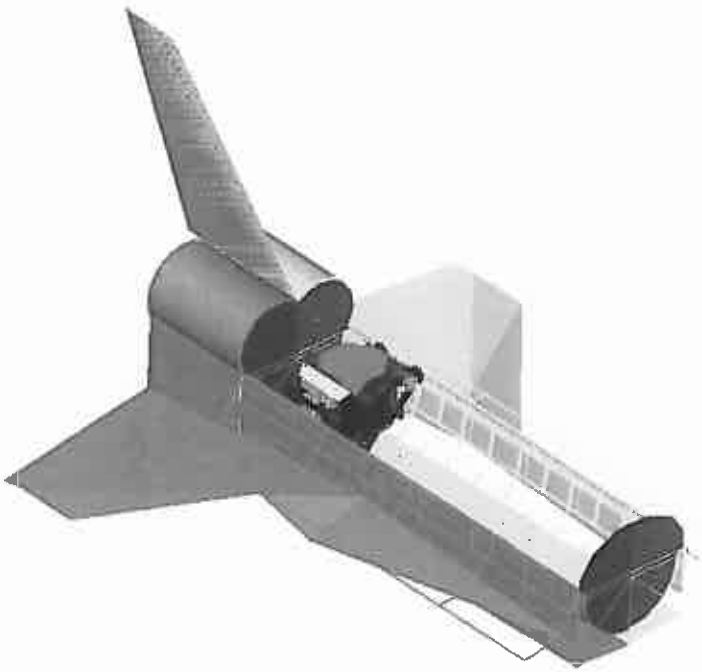

Fig. 7-4 STS ORB390 GMM model, Cargo Bay opened with integrated AMS-02 model

In order to select for each AMS experiment detector the worst hot and cold design cases the following Beta screening has been carried out:

STS ATTITUDE	BETA
Bay to Earth/ nose/tail on V	0° , +30° , +60°
Bay to Earth/ wing on V	0° , +30° , +60°
PTC attitude	+60° , +75°

Tab. 7-2 STS unmated attitudes and beta angles used in the determination of the worst hot/cold design cases

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The following table summarizes the worst cold/hot design cases for different AMS-02 detectors during STS unmated phases:

ITEM	BETA	Attitude	Environment	Remarks/Rationale
RAM radiator	60	-ZSOLAR IN	COLD	
	0	+ZLV+XVV	COLD	
	75	PTC	HOT	
WAKE radiator	60	-ZSOLAR IN	COLD	
	0	+ZLV+XVV	COLD	
	75	PTC	HOT	
TRACKER RAM radiator	75	-ZSOLAR IN	COLD	
	60	+ZLV+XVV	COLD	
	75	PTC	HOT	
TRACKER WAKE radiator	75	-ZSOLAR IN	COLD	
	0	+ZLV+XVV	COLD	
	60	+ZLV+XVV	HOT	
TRACKER HYBRIDS	75	-ZSOLAR IN	COLD	
	0	+ZLV+XVV	COLD	
	75	PTC	HOT	
TRACKER SILICON WAFER	75	-ZSOLAR IN	COLD	
	0	+ZLV+XVV	COLD	
	75	PTC	HOT	
Zenith	60	-ZSOLAR IN	COLD	
	0	+ZLV+XVV	COLD	
	75	PTC	HOT	
Star Tracker	75	-ZSOLAR IN	COLD	
	0	ZLV-YVV	COLD	
	75	PTC	HOT	
Cryo-coolers	See Zenith Radiator	See Zenith Radiator	See Zenith Radiator	
Rich	75	-ZSOLAR IN	COLD	
	0	ZLV-YVV	COLD	
	75	PTC	HOT	
Lower-Tof	60	-ZSOLAR IN	COLD	
	0	+ZLV+XVV	COLD	
	75	PTC	HOT	
Ecal	75	-ZSOLAR IN	COLD	
	0	ZLV-YVV	COLD	
	75	PTC	HOT	
EHV	75	-ZSOLAR IN	COLD	
	0	ZLV-YVV	COLD	
	75	PTC	HOT	
RHV	75	-ZSOLAR IN	COLD	
	60	+ZLV+XVV	COLD	
	75	PTC	HOT	
E-Crate	75	-ZSOLAR IN	COLD	
	0	+ZLV-YVV	COLD	
	75	PTC	HOT	

Tab. 7-3 STS unmated attitudes worst hot/cold design cases AMS must survive continuously (1).

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ITEM	BETA	Attitude	Environment	Remarks/Rationale
TRD/Upper-TOF	60	-ZSOLAR IN	COLD	
	0	+ZLV-YVV	COLD	
	75	PTC	HOT	
TRDGB	75	-ZSOLAR IN	COLD	
	0	+ZLV+XVV	COLD	
	75	PTC	HOT	
UPS	75	-ZSOLAR IN	COLD	
	0	+ZLV+XVV	COLD	
	75	PTC	HOT	
TTCS-P	75	-ZSOLAR IN	COLD	
	0	+ZLV+XVV	COLD	
	75	PTC	HOT	
TTCS-S	75	-ZSOLAR IN	COLD	
	0	+ZLV+XVV	COLD	
	75	PTC	HOT	
ACC PMTS	75	-Z SOLAR IN	COLD	
	0	+ZLV+XVV	COLD	
	75	PTC	HOT	
VACUUM CASE	75	-Z SOLAR IN	COLD	
	0	+ZLV+XVV	COLD	
	75	PTC	HOT	
PAS	75	-Z SOLAR IN	COLD	
	0	+ZLV-YVV	COLD	
	75	PTC	HOT	

Tab. 7-4 STS unmated attitudes worst hot/cold design cases AMS must survive continuously (2).

Additionally, AMS-02 is required to verify the attitudes listed in Tab. 7-5.
These are extreme attitudes (hot and cold) that the shuttle could fly (in a contingency case). AMS-02 is required to determine the length of time it can remain in these extreme attitudes before a non-operating limit is violated; and then, determine how long it would take to recover (back to a +ZLV or PTC attitude).

Attitude	Beta angle less than or equal to 60 degrees		Beta angle greater than 60 degrees	
	Allowable time (to Non-Op Limit)	Recovery time In +ZLV to repeat attitude	Allowable time (to Non-Op Limit)	Recovery time In PTC to repeat attitude
+ZSI = (Bay-to-Sun Solar Inertial)	N/A	N/A	Results are presented in section 8.1	Results are presented in section 8.1
+Z Space Orbrate (tail sun, Beta=0°, OR or Zero Q)	Results are presented in section 8.1	Results are presented in section 8.1	N/A	N/A

Tab. 7-5 STS unmated attitudes (contingency cases)

Beta angle selection has been done screening the beta range running Beta 0° , +30° , +60° and +75°

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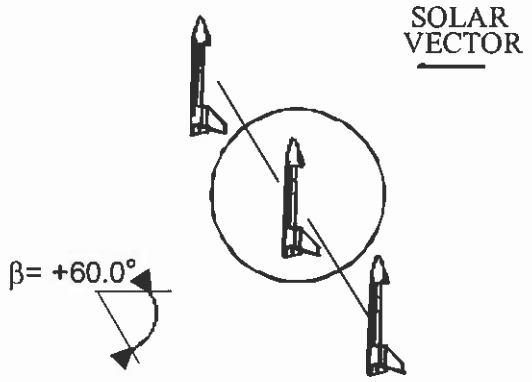

Fig. 7-5 +Z Solar Inertial STS unmated attitude

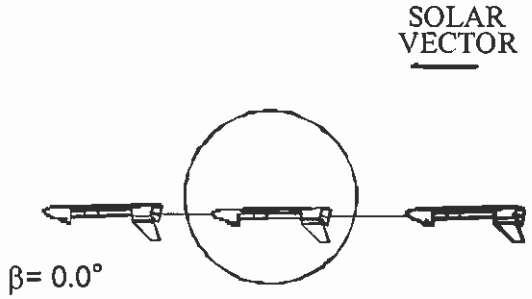

Fig. 7-6 Tto or Zero Q unmated attitude

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7.1.3 PHASE 2: STS DOCKED TO THE ISS, AMS-02 IN THE CARGO BAY

In this phase AMS-02 experiment is still inside STS cargo bay but this time STS has reached ISS and it has already docked.
Below a picture illustrating this condition.

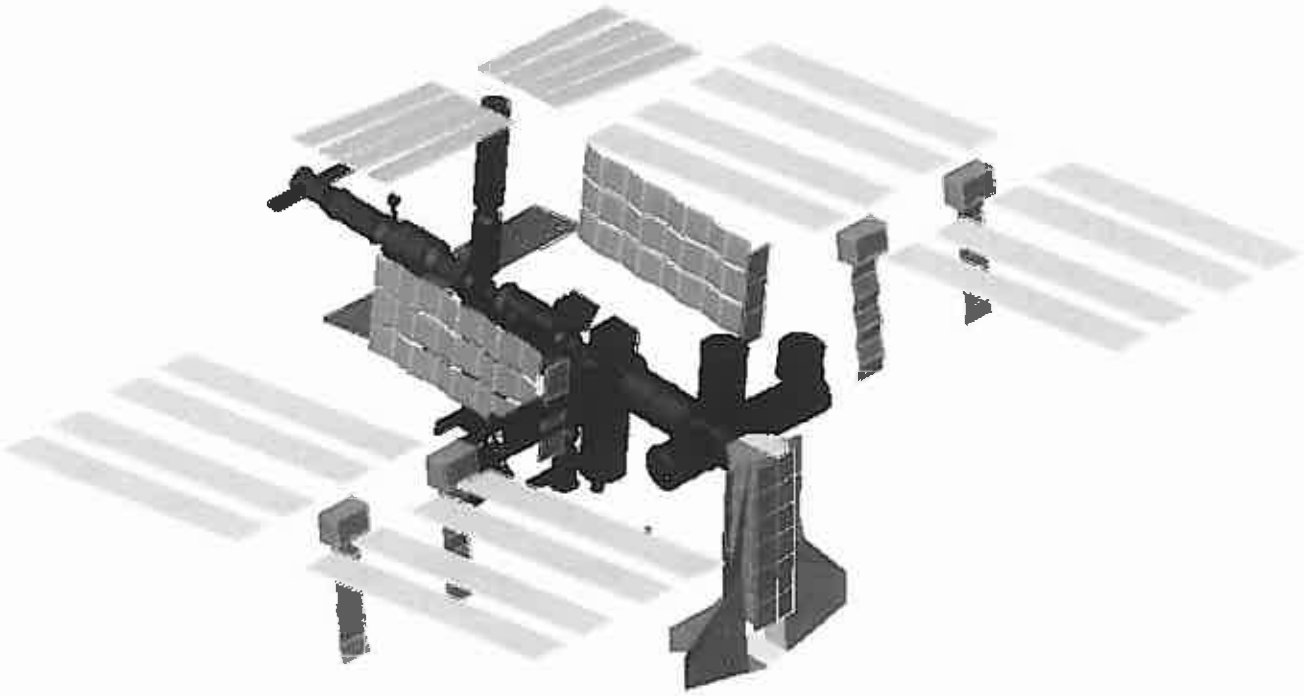

Fig. 7-7 Phase 2 configuration: AMS-02 into opened Cargo Bay, STS docked to the ISS.

For this phase, the analysis will verify the ability of the thermal control system to maintain the TRPs in their non-operative temperature ranges for the subdetectors that are switched OFF. There are only few nominal user that need to maintain their temperatures in the operative range, as can be seen Tab. 6-4.
Heater power is available via APCU bus B.

In order to select for each AMS experiment detector the worst hot and cold design cases the following Beta screening has been carried out:

STS ATTITUDE	ISS ATTITUDE[8]	BETA
STS docked to the ISS, AMS-02 into cargo bay; doors open	YPR= 0°,0°,0°	-60° , -30° , 0° , +30° , +60°

Tab. 7-6 STS docked to the station : beta angles/YPR Euler angles used in the determination of the worst hot/cold design cases

[8] CGS assumption in agreement with Jacobs Sverdrup

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ITEM	BETA	Attitude	Enviroment	Remarks/Rationale
RAM radiator	0	0 / 0 / 0	COLD	
WAKE radiator	0	0 / 0 / 0	COLD	
TRACKER RAM radiator	0	0 / 0 / 0	COLD	
TRACKER WAKE radiator	0	0 / 0 / 0	COLD	
Zenith Radiator	0	0 / 0 / 0	COLD	
Star Tracker	0	0 / 0 / 0	COLD	
Cryo-coolers	See Zenith radiator	See Zenith radiator	COLD	
Rich	60	0 / 0 / 0	COLD	
Lower-Tof	60	0 / 0 / 0	COLD	
Ecal	-60	0 / 0 / 0	COLD	
EHV	0	0 / 0 / 0	COLD	
RHV	0	0 / 0 / 0	COLD	
E-Crate	0	0 / 0 / 0	COLD	
TRD/Upper-TOF	0	0 / 0 / 0	COLD	
TRDGB	0	0 / 0 / 0	COLD	
UPS	0	0/ 0/ 0	COLD	
TTCS-P	60	0 / 0 / 0	COLD	
TTCS-S	0	0/ 0/ 0	COLD	
ACC PMTs	0	0/ 0/ 0	COLD	
VACUUM CASE	0	0 / 0 / 0	COLD	
PAS	0	0/ 0/ 0	COLD	

Tab. 7-7 STS docked worst cold design cases AMS must survive continuously

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7.1.4 PHASE 3: TRANSFER (STS DOCKED TO THE ISS, AMS-02 IN HAND-OFF POSITION)

AMS is removed from the Shuttle cargo bay by the SRMS (Shuttle Remote Manipulator System). No power is supplied to the AMS-02 experiment while attached to the SRMS; that means no electrical connectivity power nor data. The UPS system, which is active in this phase, only supplies power to the Cryomagnet Self Protection (CSP) system.
The precise set of time-dependent positions of AMS during the transfer phase from STS to ISS is not available yet. The only available information is the intermediate position (HAND-OFF position), when both SRMS and SSRMS robotic arms are attached to AMS-02 experiment.

The hand-off position is characterized by the following values in ISS coordinates:

	X[in]	Y[in]	Z[in]
POSITION	180	161	599
	Yaw	**Pitch**	**Roll**
ATTITUDE	59°	173°	140°

Tab. 7-8 Hand-off position in ISS coordinates

It has been assumed to extend this phase to a maximum of 4 hours : that should represent the maximum period during which AMS-02 experiment is grabbed by the SRMS. The initial conditions for this analysis are determined leaving AMS-02 inside the STS-docked cargo-bay indefinitely under the worst cold conditions. Starting from these stabilized temperature distribution, AMS-02 will be moved in Hand-off position where the analysis will verify the ability of the thermal control system to maintain the AMS-02 TRPs above the non-operative temperature ranges during the 4 hours completely unpowered.

In HAND-OFF position AMS-02 experiment will be grabbed by both SRMS and SSRMS (Space Station Remote Manipulator System). After a maximum of 4 hours unpowered, power is supplied again (up to 1800W) to the experiment through the EBCS, via the PVGF, from the ISS. During operations on the SSRMS no connection to a 1553 bus is available; that means no commanding is possible. One bus only will power AMS-02, in order to keep the heaters power density below the maximum allowed value of 0.465W/cm^2.
AMS-02 experiment must survive continuously in the HAND-OFF position when powered.
The analysis will verify the ability of the thermal control system to maintain the TRPs in their non-operative temperature ranges for the subdetectors that are switched OFF. There are only few nominal user that need to maintain their temperatures in the operative range, as can be seen Tab. 6-5.

Fig. 7-8 STS docked to the ISS, AMS-02 in HAND-OFF position - GMM

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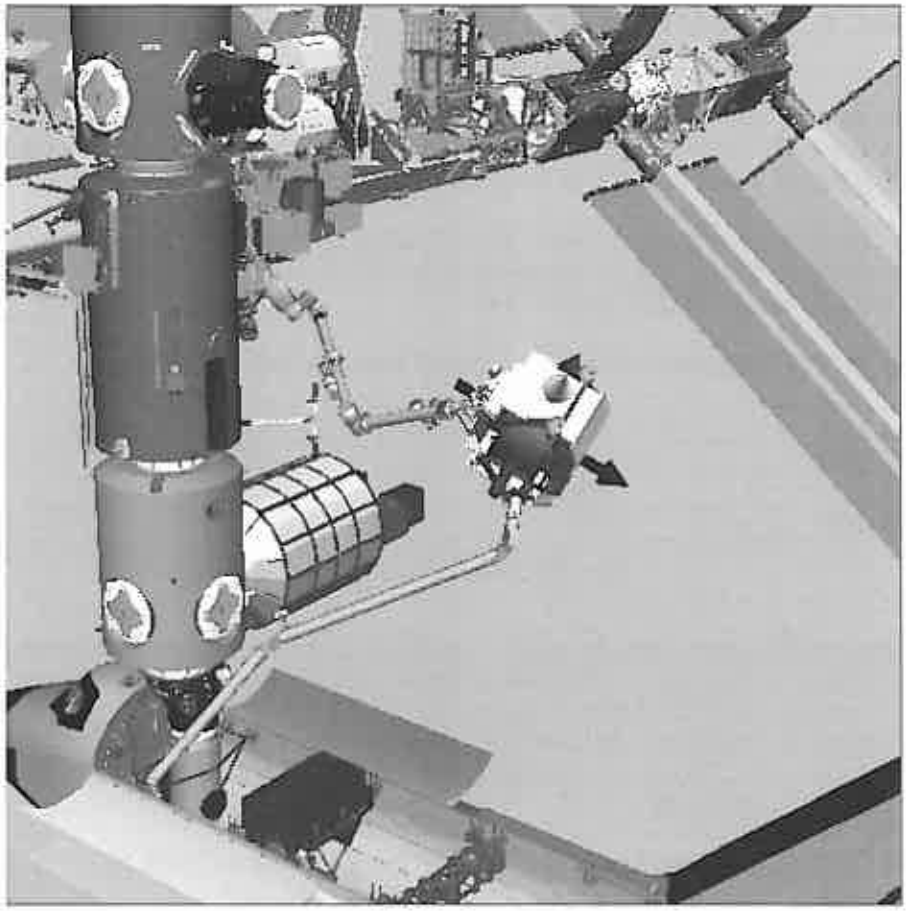

Fig. 7-9 STS docked to the ISS, AMS-02 in HAND-OFF position

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The following picture illustrates the complete transfer sequence :

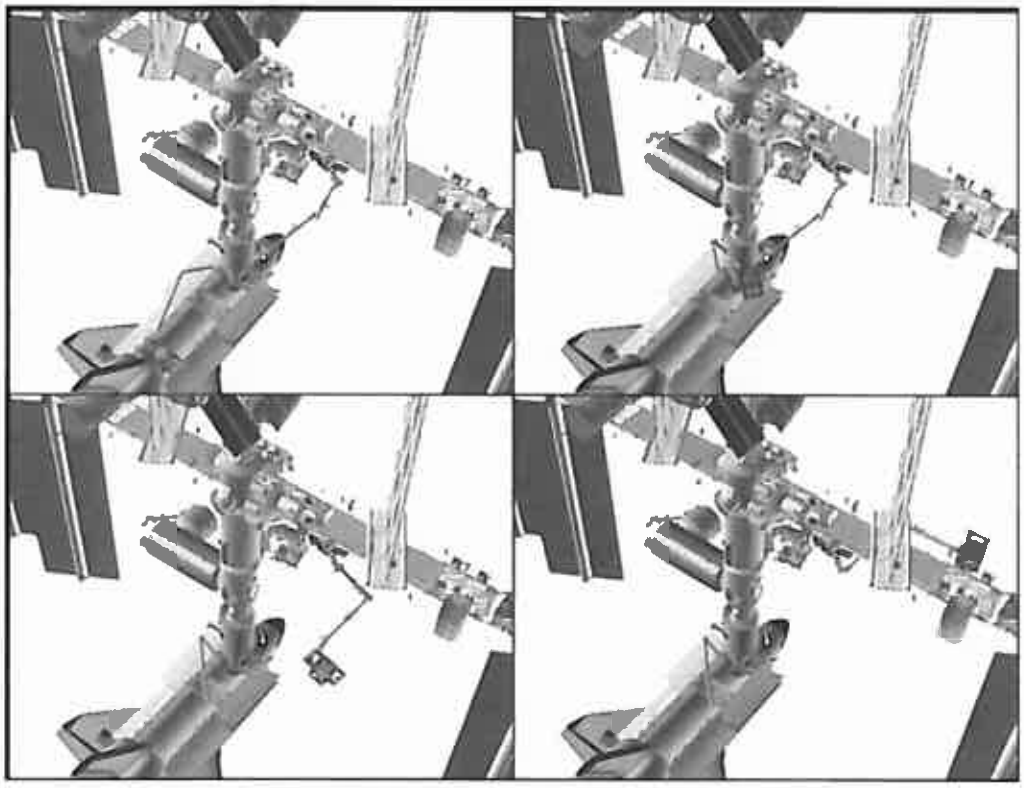

Fig. 7-10 AMS transfer from STS to ISS

In order to select for each AMS experiment detector the coldest design cases in HAND-OFF position the following Beta screening has been carried out:

STS ATTITUDE	ISS ATTITUDE[9]	BETA
STS docked to the ISS, AMS-02 in HAND-OFF position	YPR= 0°,0°,0°	-60° , -30° , 0° , +30° , +60°

Tab. 7-9 STS docked to the station- AMS-02 in HAND-OFF position: beta angles/YPR Euler angles used in the determination of the coldest design cases

[9] CGS assumption in agreement with Jacobs Sverdrup

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ITEM	BETA	Attitude	Enviroment	Remarks/Rationale
RAM radiator	0	0 / 0 / 0	cold	
WAKE radiator	0	0 / 0 / 0	cold	
TRACKER RAM radiator	0	0 / 0 / 0	cold	
TRACKER WAKE radiator	0	0 / 0 / 0	cold	
Zenith Radiator	0	0 / 0 / 0	cold	
Star Tracker	0	0 / 0 / 0	cold	
Cryo-coolers	0	0 / 0 / 0	cold	
Rich	0	0 / 0 / 0	cold	
Lower-Tof	0	0 / 0 / 0	cold	
Ecal	-60	0 / 0 / 0	cold	
EHV	0	0 / 0 / 0	cold	
RHV	0	0 / 0 / 0	cold	
E-Crate	0	0 / 0 / 0	cold	
TRD/Upper-TOF	0	0 / 0 / 0	cold	
TRDGB	0	0 / 0 / 0	cold	
UPS	0	0/ 0/ 0	cold	
TTCS-P	60	0 / 0 / 0	cold	
TTCS-S	0	0/ 0/ 0	cold	
ACC PMTs	0	0/ 0/ 0	cold	
VACUUM CASE	0	0/ 0/ 0	cold	
PAS	0	0/ 0/ 0	cold	

Tab. 7-10 HAND-OFF worst cold design cases AMS must survive for 4 hours unpowered and then heater assisted

In order to have heaters enabled in HAND-OFF position a PDS switch-on sequence has to be implemented (see section 7.1.5), since AMS-02 experiment heaters are PDS supplied.

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7.1.5 PHASE 4: AMS-02 ON ISS TRUSS

In this phase the AMS-02 model is moved on its final location on ISS TRUSS and the STS is still docked. In Fig. 7-11 the ISS/STS/AMS-02 GMM used to simulate this phase is shown :

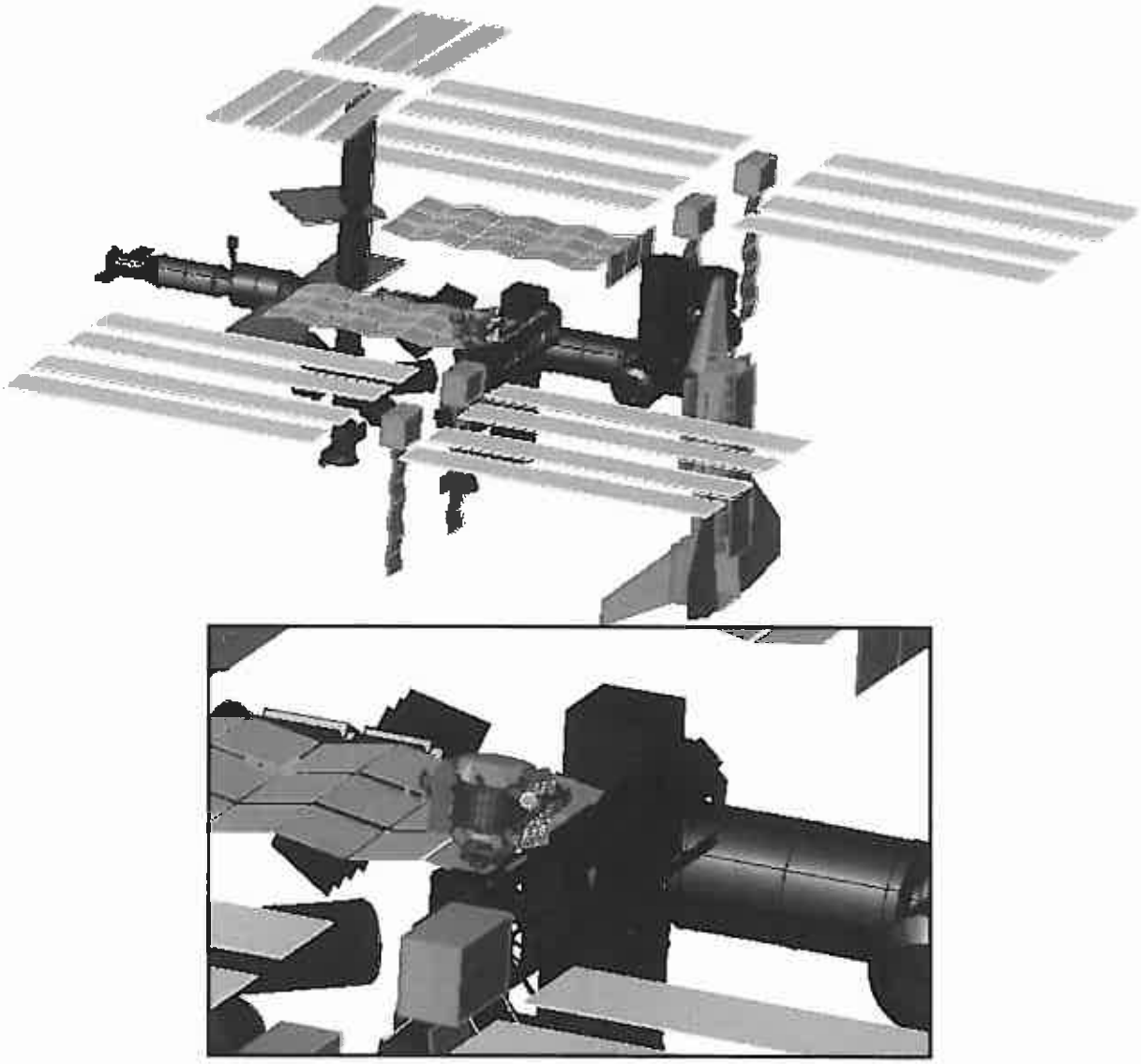

Fig. 7-11 Phase 4: AMS-02 on the ISS Truss, with STS docked.

For this phase, the analysis will verify the ability of the thermal control system to carry each detector up to the minimum switch on temperature and to meet all the operative/non-operative requirements.

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As soon as AMS-02 experiment gets installed on the ISS, the following activation steps are foreseen:

1. PDS heaters are switched on by means of ISS feed (either feed A or B, NEVER both).
2. When PDS electronic switch-on temperature is restored (namely -20°C), PDS itself is switched on (automatically by means of a thermal interlock circuit) together with the supplied 120VDC heaters that are by default enabled (provided the corresponding thermostats are closed)
3. As soon as JPD (close on-rise) thermostat closes the circuit, 28Vdc is provided
4. As soon as J-crate is operating we can start (via JMDC) to monitor temperatures via **GTSN** (Global Temperature Sensor Net) composed only by Dallas temperature sensors
5. We use these sensors to decide if we need to warm up detectors and their electronics
6. LOW TEMPERATURE sensors MONITORING (PT1000 on the LHP assembly and tracker radiators) by CCEB and TT CRATE is not yet available
7. CCEB and TT Crate ON as soon as they reach minimum switch on temperature. Then LOW TEMPERATURE sensors MONITORING can start and read-out of LHP assemby and Tracker radiator temperature comes available.
8. TRACKER TTCS can be started if TRACKER radiator temperature has reached -40°C.
9. CRYO COOLERS can be started if rejection collar reaches the minimum switch-on temperature

In order to select for each AMS experiment detector the coldest and hottest design case on-orbit onboard ISS the following Beta screening has been carried out (see RD [4] for details):

STS ATTITUDE	**ISS ATTITUDE**[10]	**BETA variation range**
AMS-02 on ISS	Yaw (Z) attitude angle : –15° to +15° Roll (X) attitude angle: –15° to +15° Pitch(Y) attitude angle: 0° to +25° with docked STS ; -20° to +15° with undocked STS	-75°, -50° , -25° , 0° , +25° , +50°, +75°

Tab. 7-11 AMS-02 on ISS truss - Beta angles/YPR Euler angles used in the determination of the coldest/hottest design cases

[10] CGS assumption in agreement with Jacobs Sverdrup

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ITEM	BETA	Attitude	Environment	Remarks/Rationale
RAM radiator	-75	15 / -20 /0	HOT	
	0	-15 / +25/ -15	COLD	
WAKE radiator	-75	-15 / +25 / -15	HOT	
	0	15 / -20 / -15	COLD	
TRACKER RAM radiator	+75	-15 / -20 / -15	HOT	
	+60	+15 / +15/ +15	COLD	
TRACKER WAKE radiator	+75	-15 / -20 / -15	HOT	
	+75	+15 / +15/ +15	COLD	
Zenith Radiator	+75	-15 / -20 / -15	HOT	
	+75	-15 / +15 / -15	COLD	
Star Tracker	+75	-15 / -20 / -15	HOT	
	0	0 / 0 / 0	COLD	
Rich	-75	-15 / 0 / 0	HOT	
	+25	-15 / -20/-15	COLD	
Lower-Tof	-75	-15 / 0 / 0	HOT	
	+25	-15 / -20 / -15	COLD	
Ecal	-75	-15 / 0 / 0	HOT	
	+25	-15 / -20 / -15	COLD	
EHV	-75	-15 / 0 / 0	HOT	
	0	0 / 0 / 0	COLD	
RHV	-75	-15 / -20 / -15	HOT	
	0	0 / 0 / 0	COLD	
E-Crate	-75	-15/0/0	HOT	
	0	0 /0 / 0	COLD	
TRD/Upper-TOF	+75	-15 / -20 / -15	HOT	
	0	0 / 0 / -15	cold	
TRDGB	+75	-15 / -20 / -15	HOT	
	0	0 /0 / 0	COLD	
UPS	-75	-15/_0/_0	HOT	
	+25	-15/-20/15	COLD	
TTCS-P	+75	-15 / -20 / -15	HOT	
	+25	-15 / -20 / -15	COLD	
TTCS-S	-75	-15 / +15 / -15	HOT	
	+25	-15 / -20 / -15	COLD	
ACC PMTs	75	-15/-20/+15	HOT	
	0	0/ 0/ 0	COLD	
VACUUM CASE	+75	-15 / -20 / -15	HOT	
	0	0 / 0 / 0	COLD	
PAS	-75	-15/_0/_0	HOT	
	+25	-15/-20/-15	COLD	

Tab. 7-12 AMS-02 on ISS worst cold and hot design cases. AMS must survive continuously.

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8. ANALYSIS RESULTS

The results presented in this chapter are obtained using the AMS-02 system integrated model in the above described different phases.
Where detector reduced models have been used , detailed analysis will be done by each detector using the interface data generated at system level.
The following graphs show the maximum and minimum temperature reached by detector TRPs (defined in AD [4])

8.1 PHASE 1: STS UNMATED ATTITUDES

For each detector the design cases selected and reported in Tab. 7-3 have been analyzed and results reported.

8.1.1 MAIN RADIATORS

8.1.1.1 RAM RADIATOR

The design cases for Main Ram radiator during STS unmated attitudes are as follows:

BETA	Attitude	STS	Enviroment	Remarks/Rationale
75	PTC	free flying	HOT	
0	+ZLV+XVV	free flying	COLD	

Tab. 8-1 Ram radiator design cases during STS unmated phases

Results are presented in RD [9]

Cold contingency case

Starting from the initial temperatures obtained in the coldest case described in Tab. 8-1, RAM radiator electronics temperature results are shown after having moved to +Z Space attitude : RAM radiator electronics detector is requested to survive for at least 90 minutes in this extreme cold phase:

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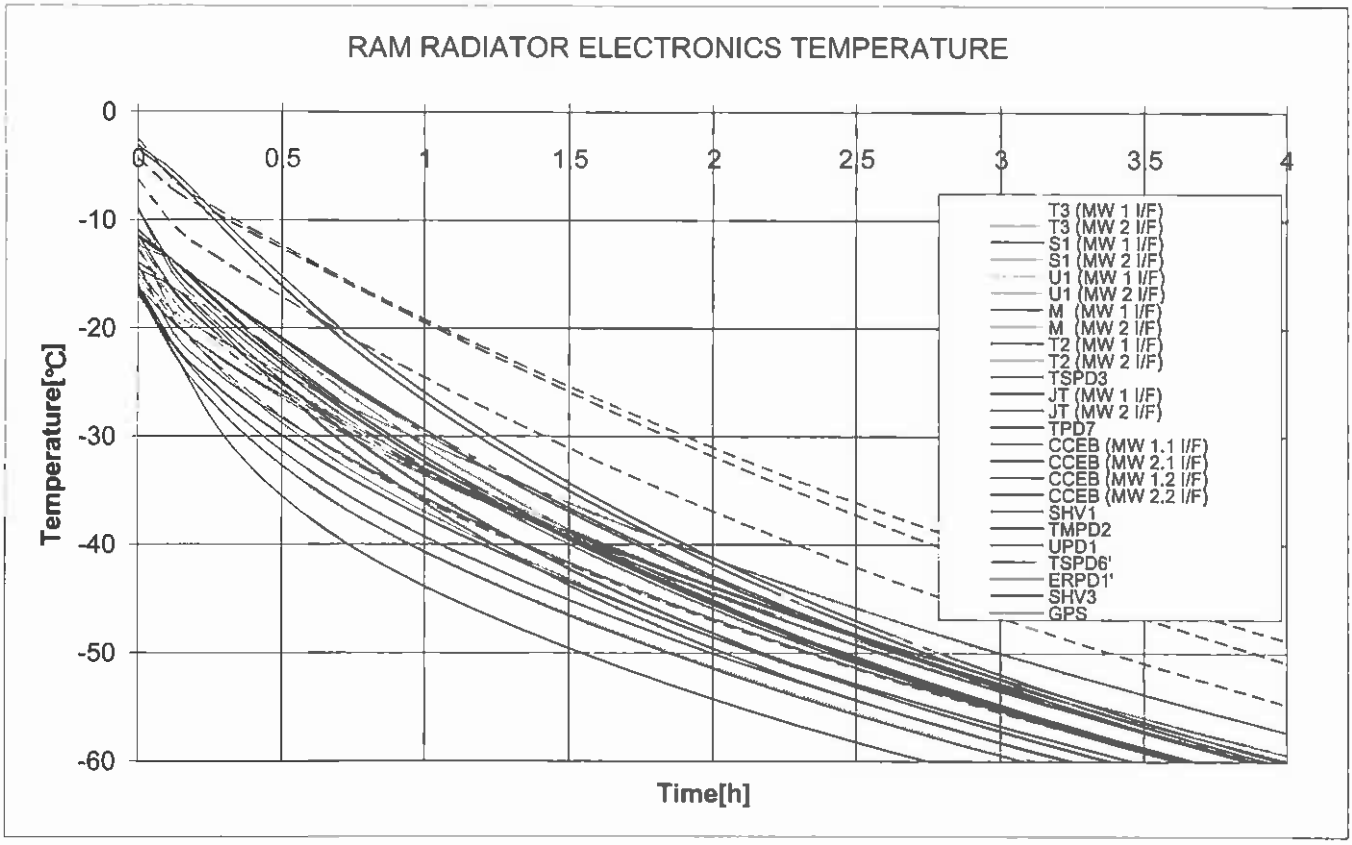

Fig. 8-1 Minimum RAM radiator electronics temperatures for orbit +Z Space (zero Q). GPS and T2 main wall IF can withstand a maximum of 60 minutes before the non operating limit is violated.

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Hot contingency case

Starting from the initial temperatures obtained in the hottest case described in Tab. 8-1, RAM electronics temperature results are shown after having moved to +Z Solar Inertial attitude : RAM electronics is requested to survive for at least 30 minutes in this extreme hot phase:

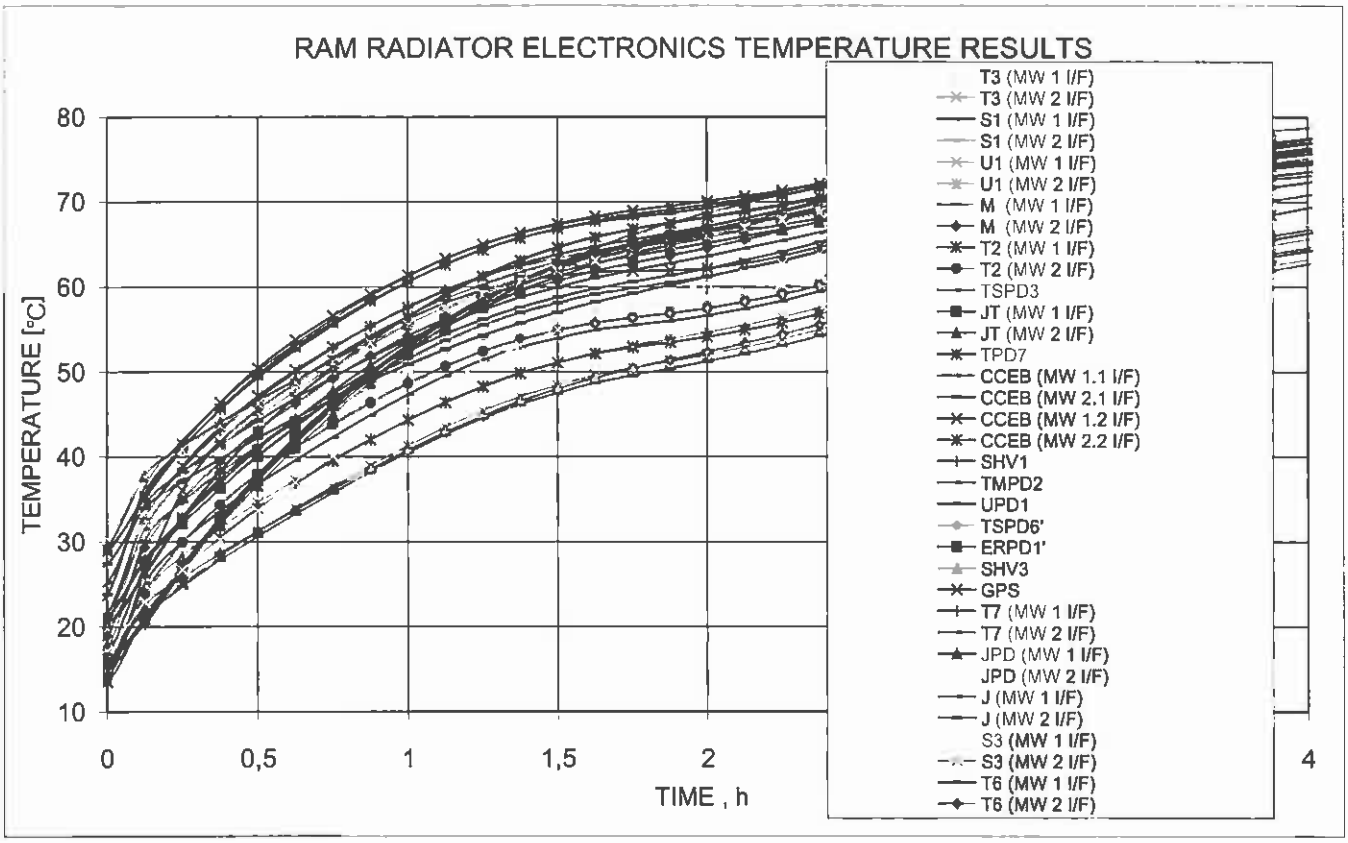

Fig. 8-2 Maximum RAM radiator electronics temperatures for orbit B+75 PTC hot BOL. Crate electronics can withstand even more than 30 minutes

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8.1.1.2 WAKE RADIATOR

The design cases for Main Wake radiator during STS unmated attitudes are as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
75	PTC	Free flying	HOT	
0	+ZLV+XLV	Free flying	COLD	

Tab. 8-2 Wake radiator design cases during STS unmated phases

Results are presented in RD [9]

Cold contingency case

Starting from the initial temperatures obtained in the coldest case described in Tab. 8-2, WAKE electronics temperature results are shown after having moved to +Z Space attitude : WAKE electronics is requested to survive for at least 90 minutes in this extreme cold phase:

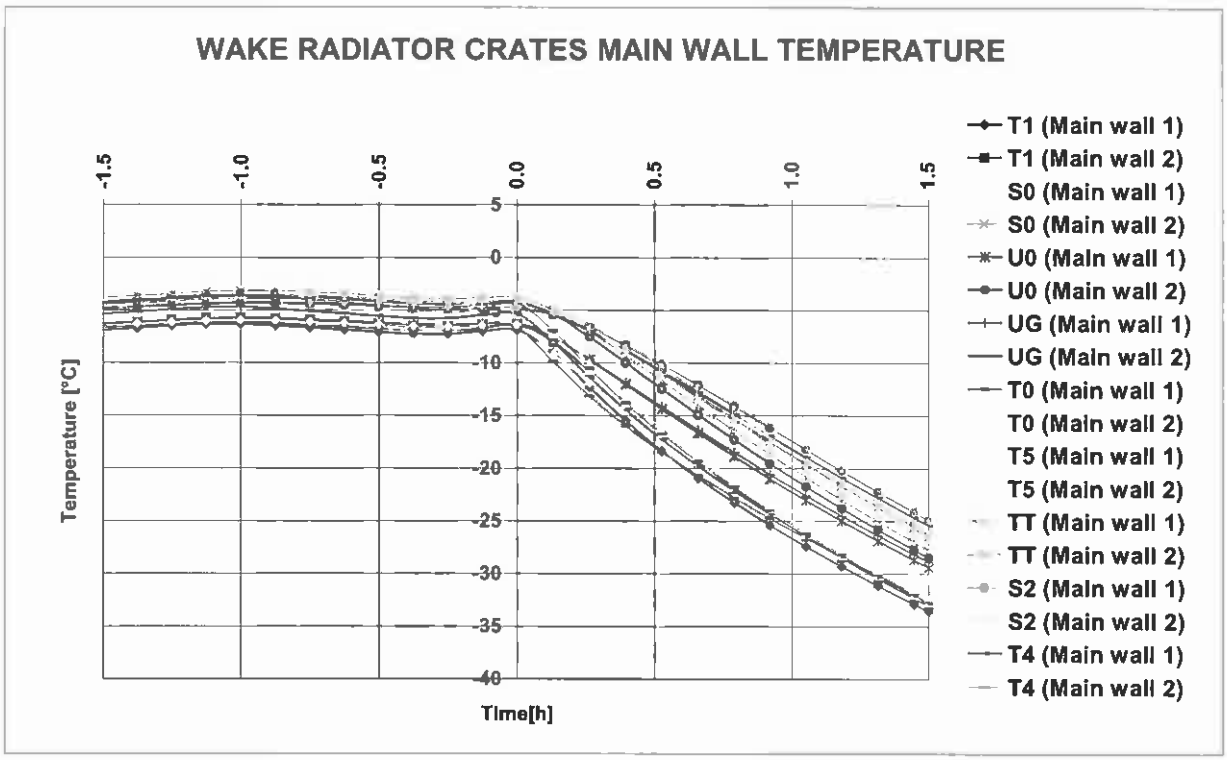

Fig. 8-3 Minimum WAKE radiator CRATE electronics temperatures for orbit +Z Space (zero Q). Crate electronics can withstand even more than 90 minutes.

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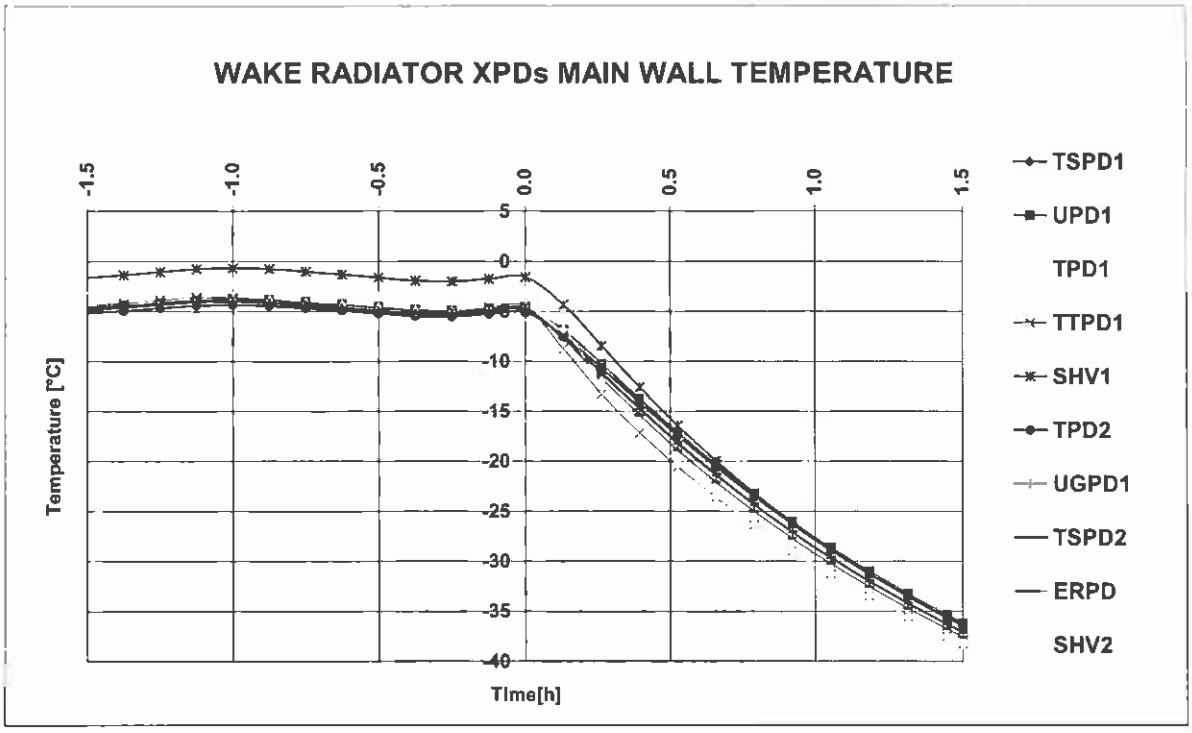

Fig. 8-4 Minimum WAKE radiator xPD electronics temperatures for orbit +Z Space (zero Q). XPD electronics can withstand even more than 90 minutes

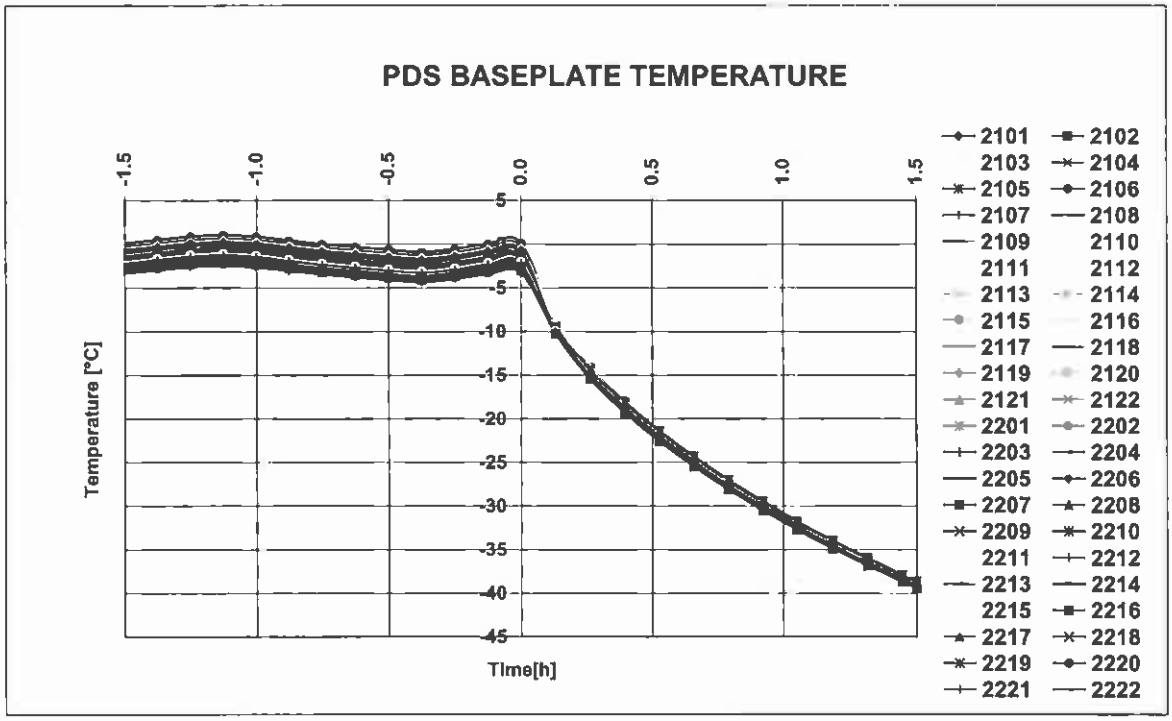

Fig. 8-5 Minimum PDS case temperatures for orbit +Z Space (zero Q). PDS can withstand 90 minutes in the contingency attitude

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Hot contingency case

Starting from the initial temperatures obtained in the hottest case described in Tab. 8-2, WAKE electronics temperature results are shown after having moved to +Z Solar Inertial attitude : WAKE electronics is requested to survive for at least 30 minutes in this extreme hot phase:

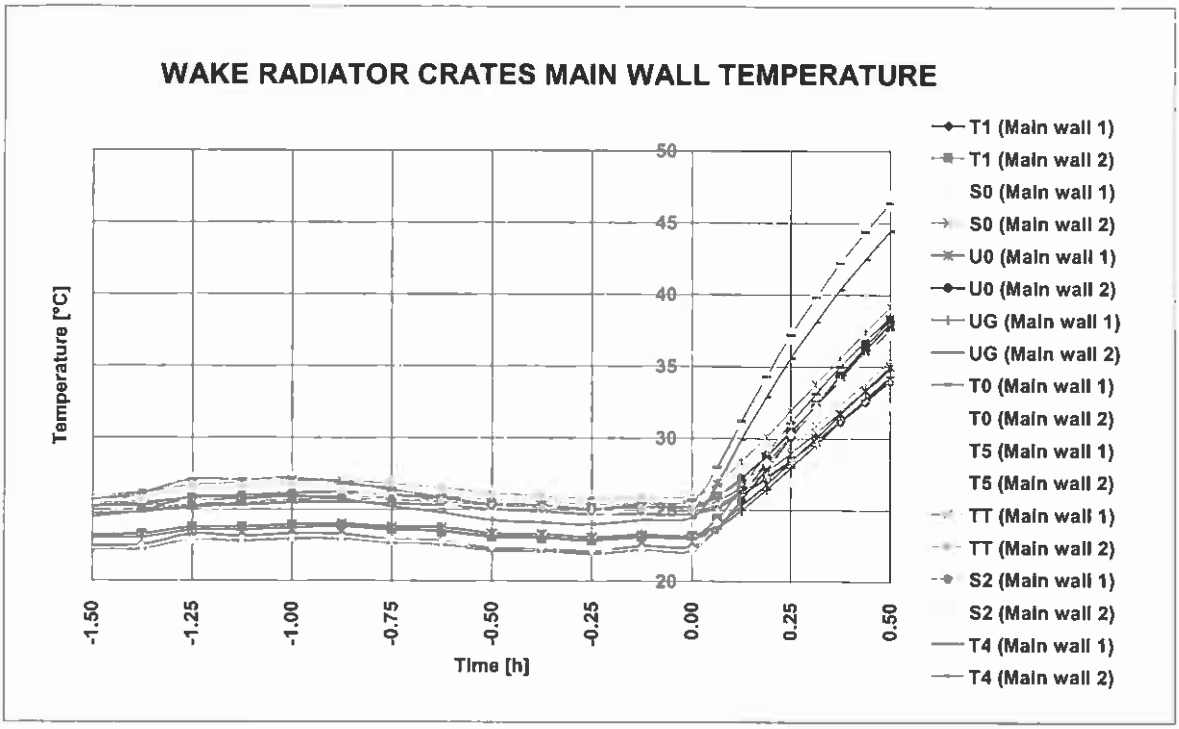

Fig. 8-6 Maximum WAKE radiator CRATE electronics temperatures for orbit B+75 PTC hot BOL. Crate electronics can withstand even more than 30 minutes

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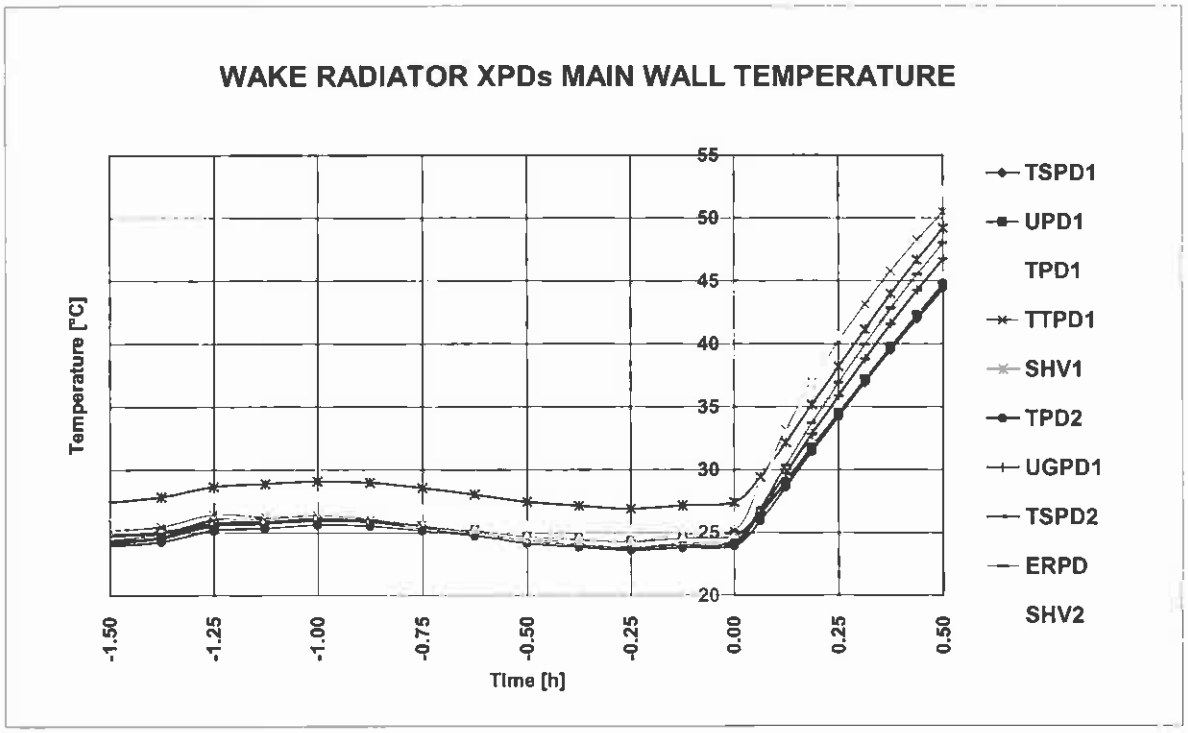

Fig. 8-7 Maximum WAKE radiator xPD electronics temperatures for orbit B+75 PTC hot BOL. XPD electronics can withstand even more than 30 minutes

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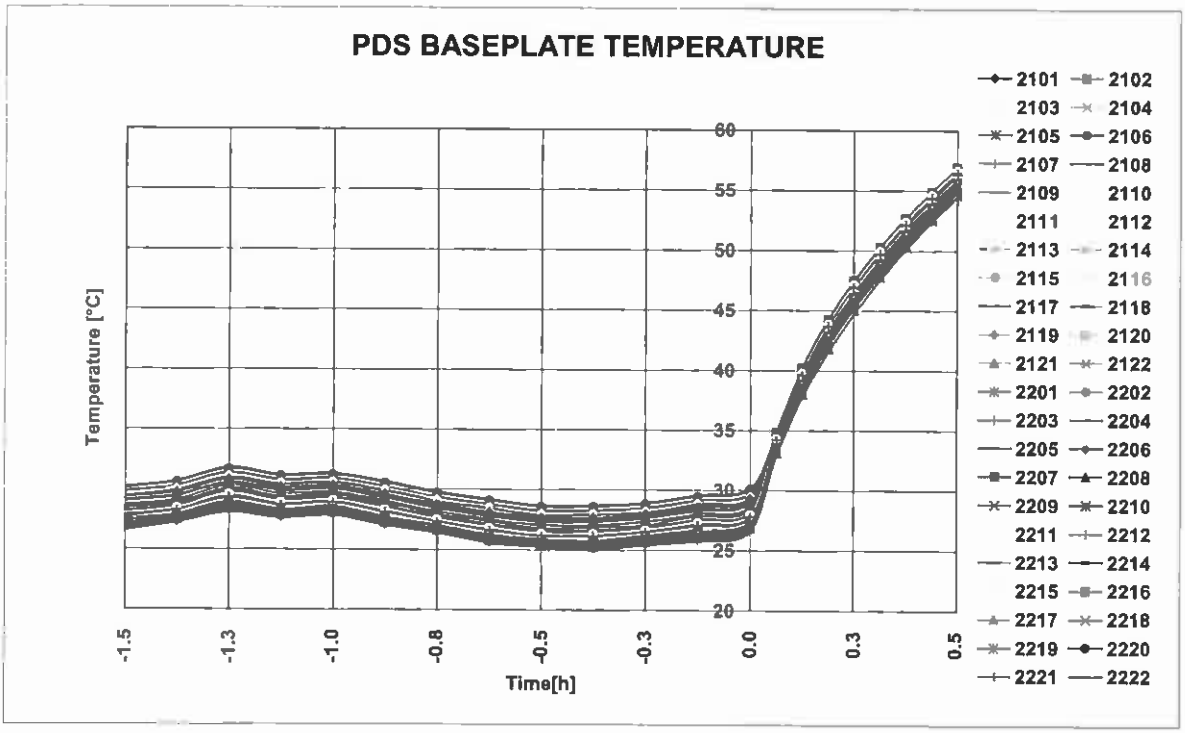

Fig. 8-8 Maximum PDS case temperatures for orbit B+75 PTC hot BOL. PDS can withstand even more than 30 minutes in the contingency attitude

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8.1.2 ZENITH RADIATOR

The design cases for Zenith radiator during STS unmated attitudes are as follows:

BETA	Attitude	STS	Enviroment	Remarks/Rationale
0	+ZLV+XVV	free flying	COLD	

Tab. 8-3 Zenith radiator design cases during STS unmated phases

The following graphs show the temperatures of the Zenith radiator being the Cryo cooler dissipation evenly distributed on the 4 zenith radiators panels.
Detailed analysis has to be done yet.

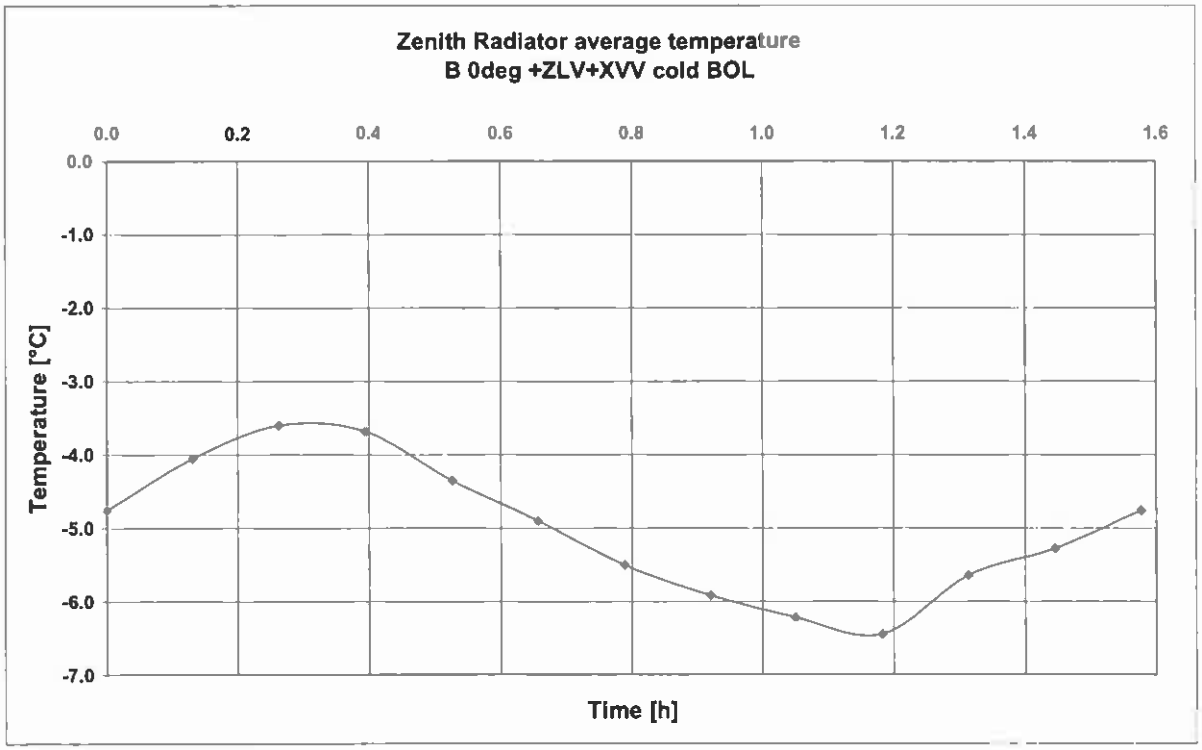

Fig. 8-9 Zenith radiator temperature for orbit B 0 +ZLV+XVV cold – BOL properties

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8.1.3 CRYOCOOLER

The design cases for Cryocoolers during STS unmated attitudes are the one presented in Tab. 8-3. Cryocoolers temperatures are derived from RD [10].

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8.1.4 RICH

The design cases for RICH detector during STS unmated attitudes are as follows:

BETA	Attitude	STS	Enviroment	Remarks/Rationale
75	PTC	free flying	HOT	
0	ZLV-YVV	free flying	COLD	

Tab. 8-4 RICH detector design cases during STS unmated phases

The following graphs show the temperatures of the RICH PMTs (maximum or minimum) on the eight octagon sections. It is worthwhile to notice that as described in Tab. 6-3 RICH is not-operative during this phase.

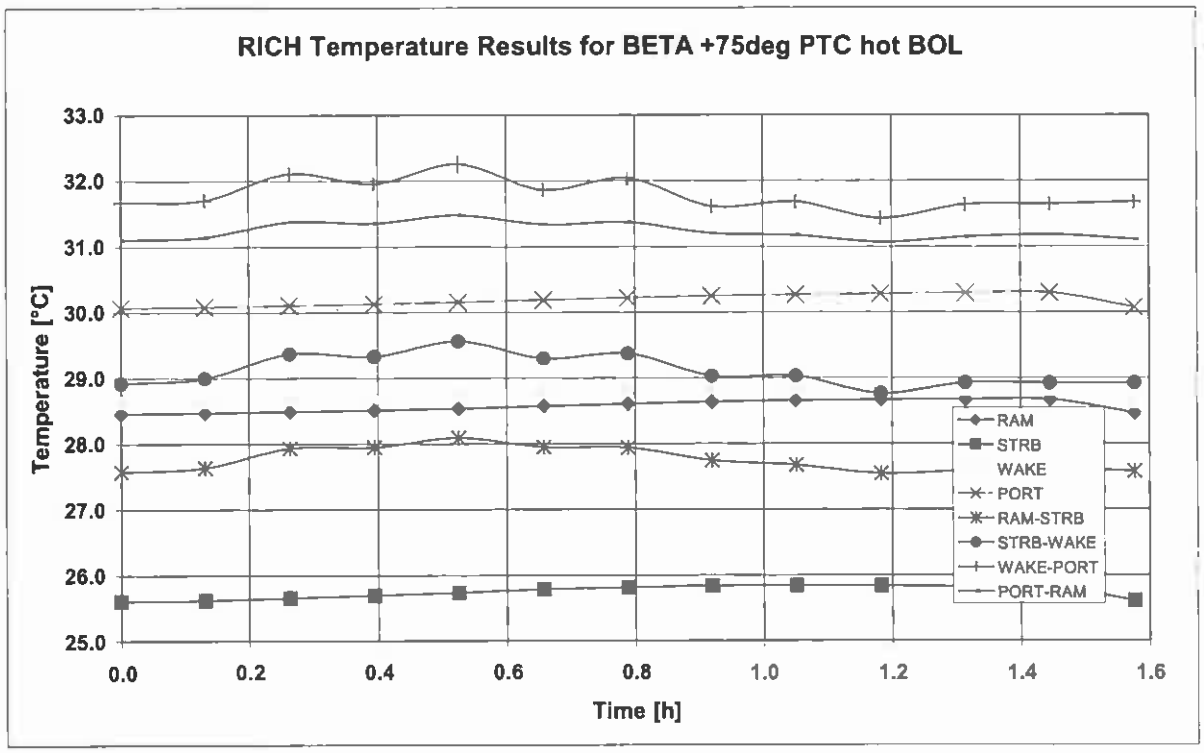

Fig. 8-10 Maximum RICH PMTs temperatures for orbit B+75 PTC hot BOL. Maximum non operative requirements fulfilled.

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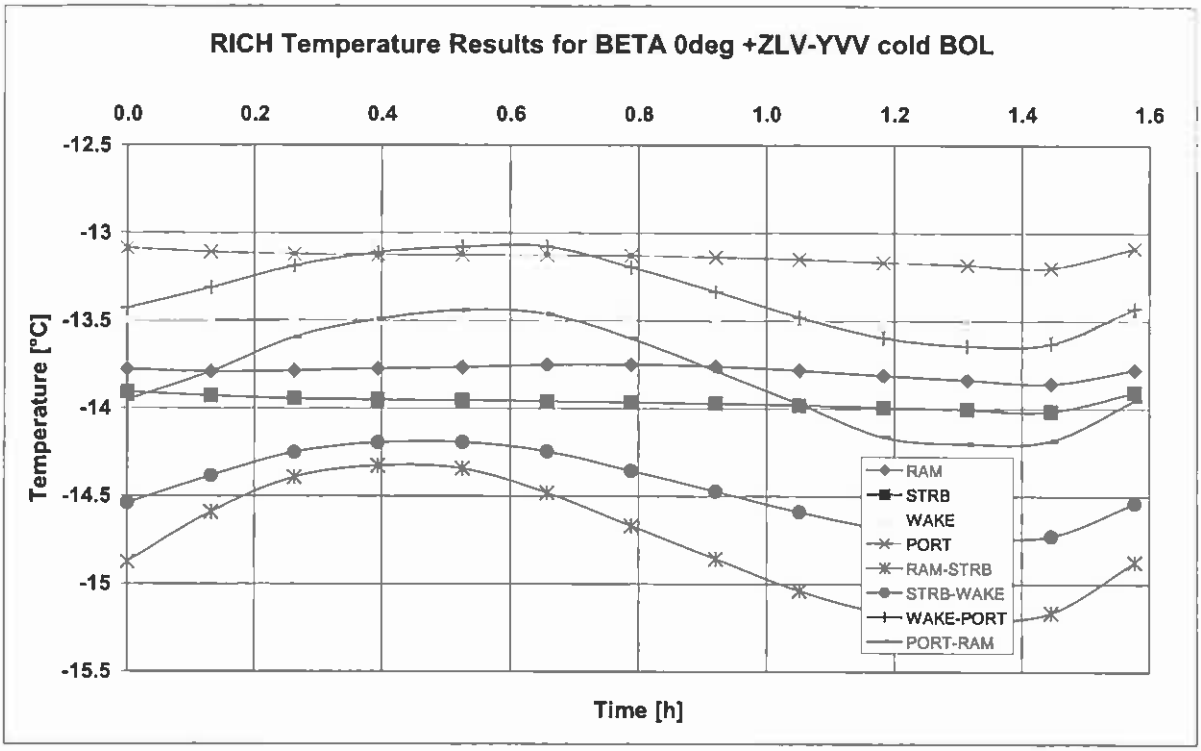

Fig. 8-11 Minimum RICH PMTs temperatures for orbit B 0 +ZLV-YVV cold BOL - Minimum non operative requirements fulfilled without heater power

As described in Tab. 7-5 RICH detector is required to determine the length of time it can remain in extreme attitudes described in Tab. 7-5 before a non-operating limit is violated.

Cold contingency case

Starting from the initial temperatures obtained in the coldest case described in Fig. 8-11, RICH PMTs temperature results are shown after having moved to +Z Space attitude : RICH detector is requested to survive for at least 90 minutes in this extreme cold phase:

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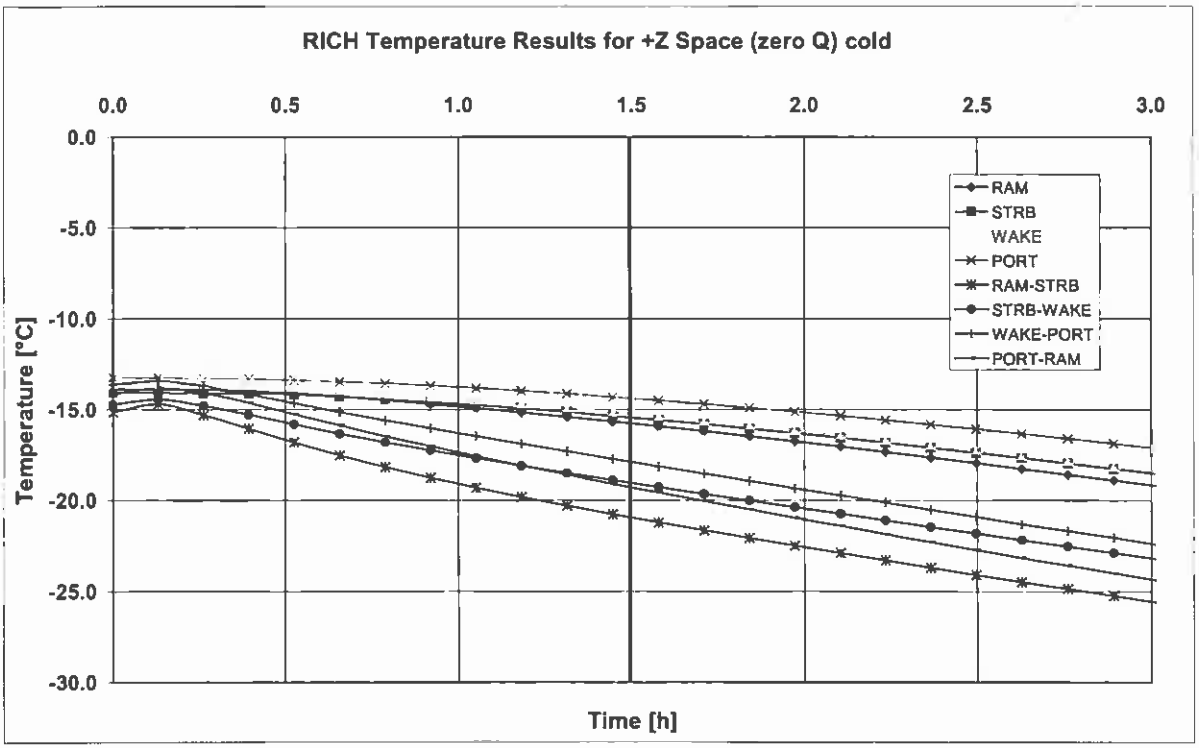

Fig. 8-12 Minimum RICH PMTs temperatures for orbit +Z Space (zero Q). RICH PMTs can withstand even more than 90 minutes

Hot contingency case

Starting from the initial temperatures obtained in the hottest case described in Fig. 8-10, RICH PMTs temperature results are shown after having moved to +Z Solar Inertial attitude : RICH detector is requested to survive for at least 30 minutes in this extreme hot phase:

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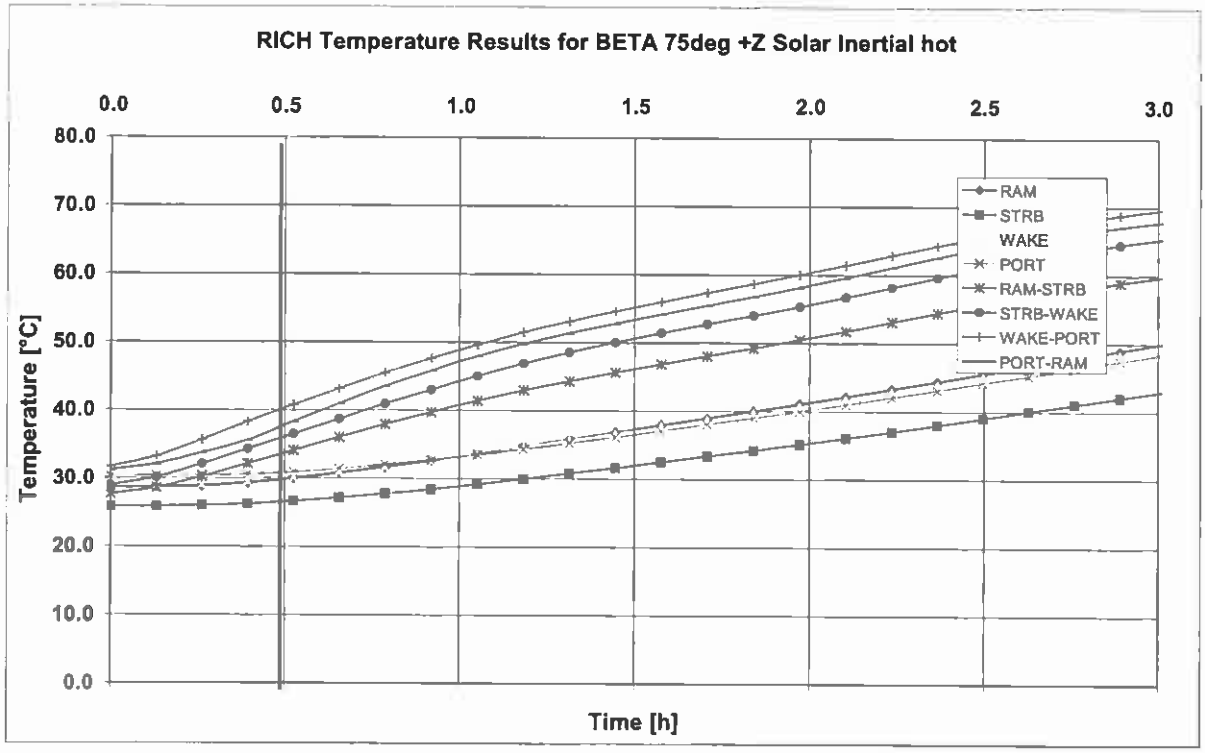

Fig. 8-13 Maximum RICH PMTs temperatures for orbit B+75+Zsolar Inertial. RICH PMTs can withstand even more than 30 minutes

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8.1.5 LOWER TOF

The design cases for LOWER-TOF detector during STS unmated attitudes are as follows:

BETA	Attitude	STS	Enviroment	Remarks/Rationale
75	PTC	free flying	HOT	**Worst hot case for LOWER TOF**
0	ZLV+XVV	free flying	COLD	**Worst cold case BOL for LOWER TOF**

Tab. 8-5 LOW-TOF detector design cases during STS unmated phases

The following graphs show the temperatures of the LOWER TOF PMTs (maximum or minimum) on the two planes. It is worthwhile to notice that as described in Tab. 6-3 LOWER TOF is not-operative during this phase.

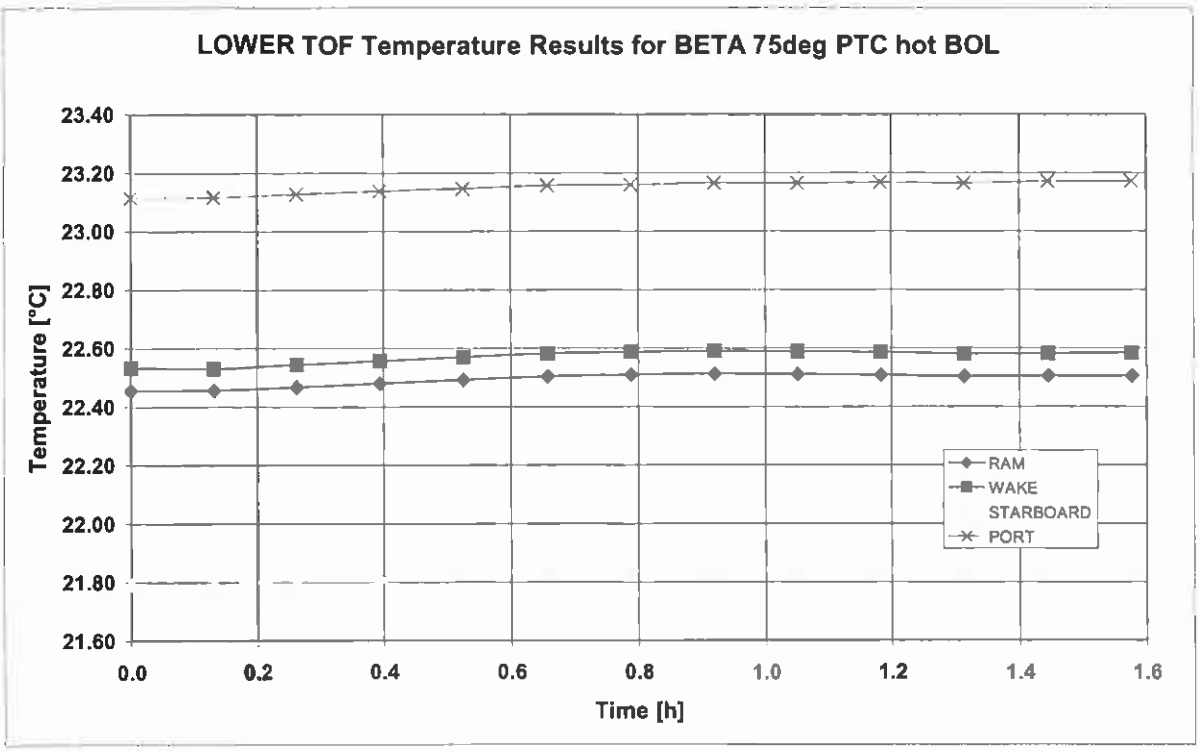

Fig. 8-14 Maximum LOWER TOF PMTs temperatures for orbit B+75 PTC hot BOL

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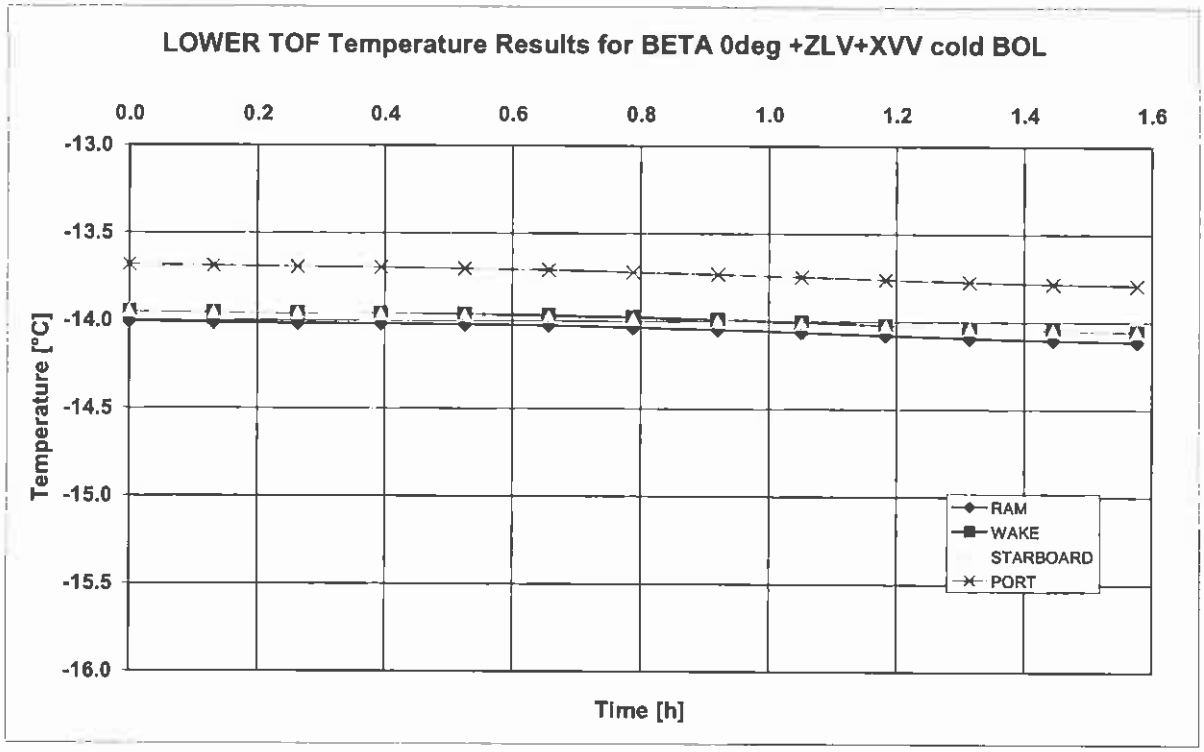

Fig. 8-15 Minimum LOWER TOF PMTs temperatures for orbit B 0 +ZLV+XVV cold BOL. Minimum non operative requirements fulfilled without heater power.

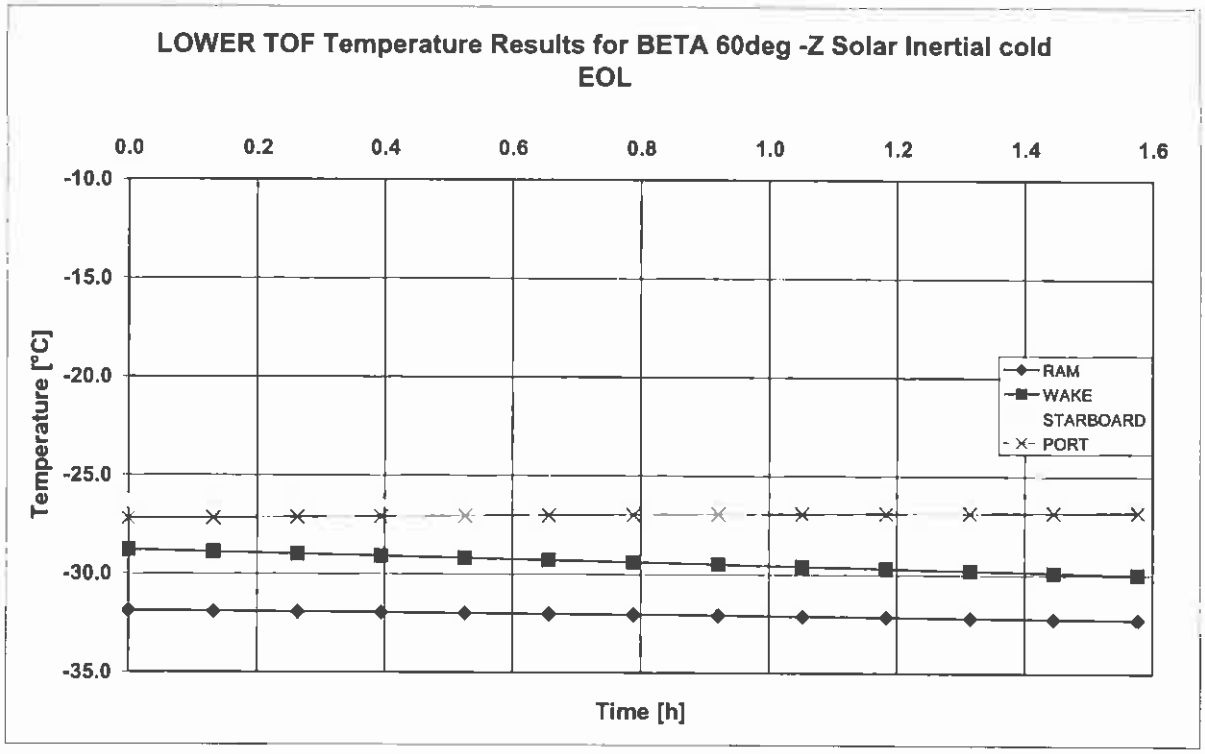

Fig. 8-16 Minimum LOWER TOF PMTs temperatures for orbit B+60 –Z Solar Inertial cold EOL. Minimum non operative requirements fulfilled with 30W heater power

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As described in Tab. 7-5 LOWER TOF detector is required to determine the length of time it can remain in extreme attitudes described in Tab. 8-4 before a non-operating limit is violated.

Cold contingency case

Starting from the initial temperatures obtained in the coldest case described in Fig. 8-15, LOWER TOF PMTs temperature results are shown after having moved to +Z Space attitude : LOWER_TOF detector is requested to survive for at least 90 minutes in this extreme cold phase:

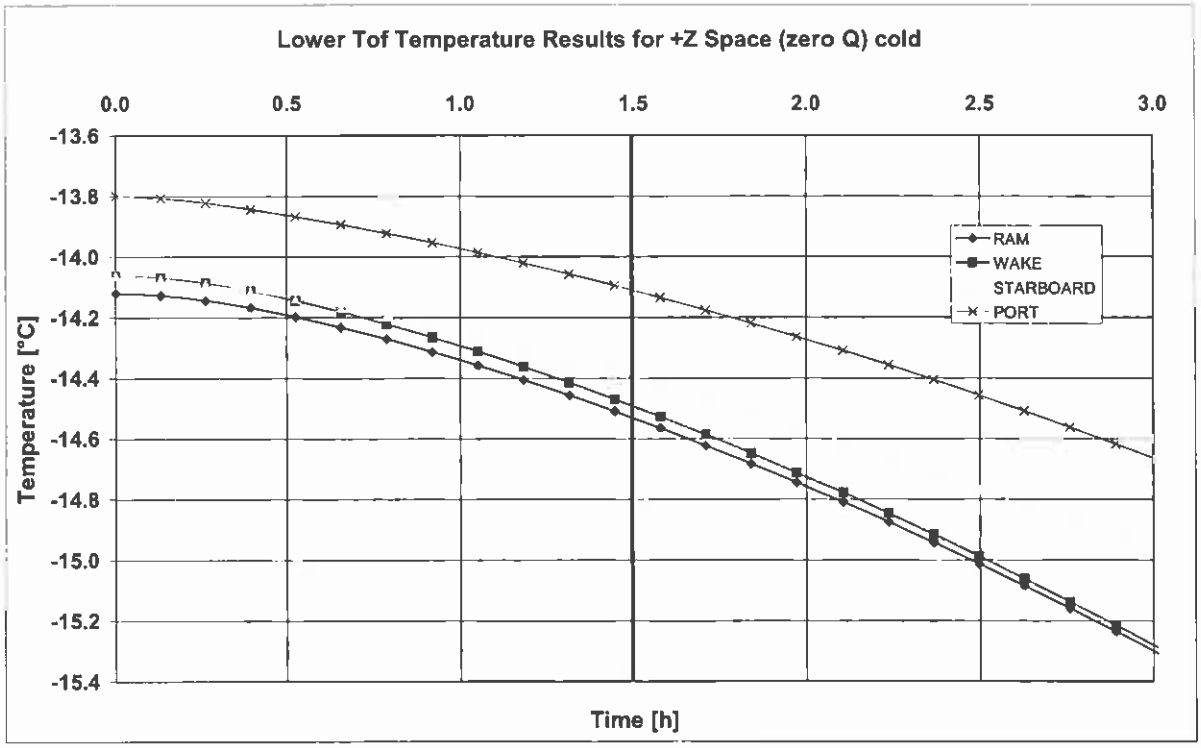

Fig. 8-17 Minimum lower Tof PMTs temperatures for orbit +Z Space (zero Q). LOWER TOF PMTs can withstand even more than 90 minutes

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Hot contingency case

Starting from the initial temperatures obtained in the hottest case described in Fig. 8-14, LOWER TOF PMTs temperature results are shown after having moved to +Z Solar Inertial attitude : LOWER TOF detector is requested to survive for at least 30 minutes in this extreme hot phase:

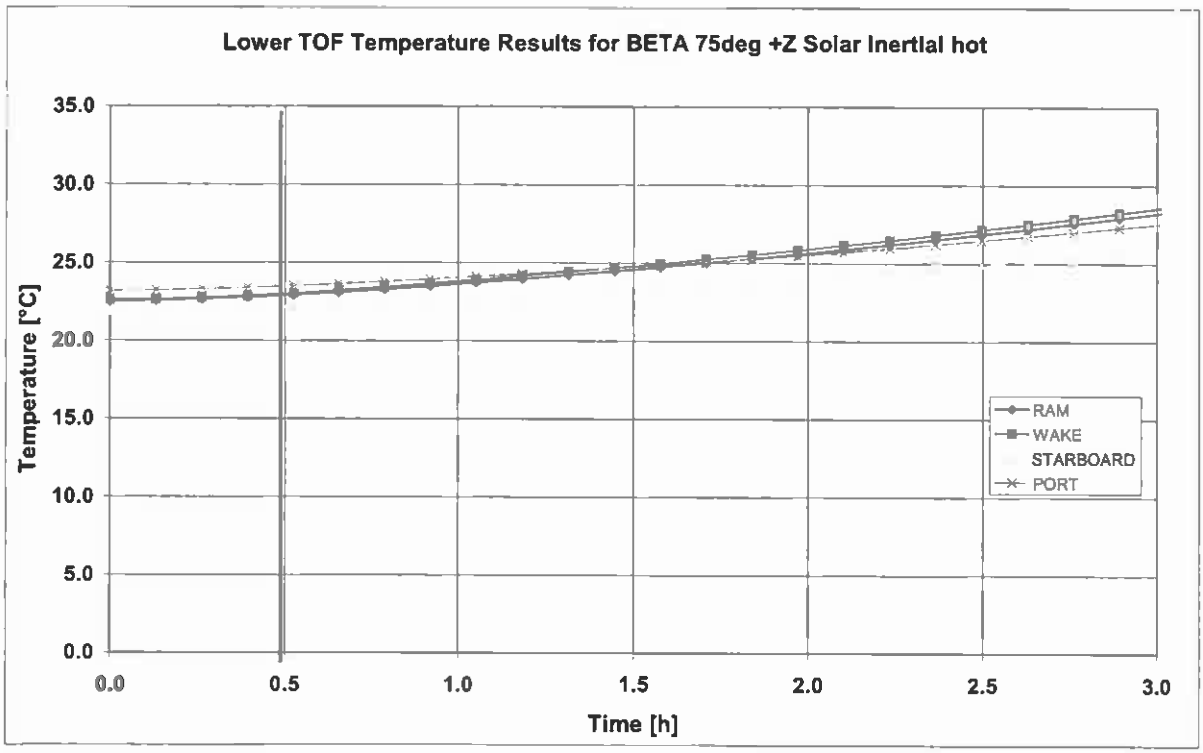

Fig. 8-18 Maximum Lower Tof PMTs temperatures for orbit B+75+Zsolar Inertial. LOWER TOF PMTs can withstand even more than 30 minutes

8.1.6 ECAL

The design cases for the ECAL detector during STS unmated attitudes are as follows:

BETA	Attitude	STS	Enviroment	Remarks/Rationale
75	PTC	free flying	HOT	
0	ZLV-YVV	free flying	COLD	

Tab. 8-6 ECAL detector design cases during STS unmated phases

Detailed results are presented in RD [5]

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8.1.7 RHV/EHV BRICKS

The design cases for the ECAL/RICH HV bricks during STS unmated attitudes are as follows:

BETA	Attitude	STS	Enviroment	Remarks/Rationale
75	PTC	free flying	HOT	**Worst hot case for EHV and RHV**
0	ZLV-YVV	free flying	COLD	**Worst cold case BOL for EHV and RHV**

Tab. 8-7 ECAL/RICH HV bricks design cases during STS unmated phases

Detailed results are presented in RD [6]

8.1.8 E CRATES

The design cases for the E crates during STS unmated attitudes are as follows:

BETA	Attitude	STS	Enviroment	Remarks/Rationale
75	PTC	free flying	HOT	**Worst hot case for E crates**
0	ZLV-YVV	free flying	COLD	**Worst cold case BOL for E crates**

Tab. 8-8 E crates design cases during STS unmated phases

The following graphs show the temperatures of the E crates main walls I/F (maximum or minimum). It is worthwhile to notice that as described in Tab. 6-3. E crates are not-operative during this phase.

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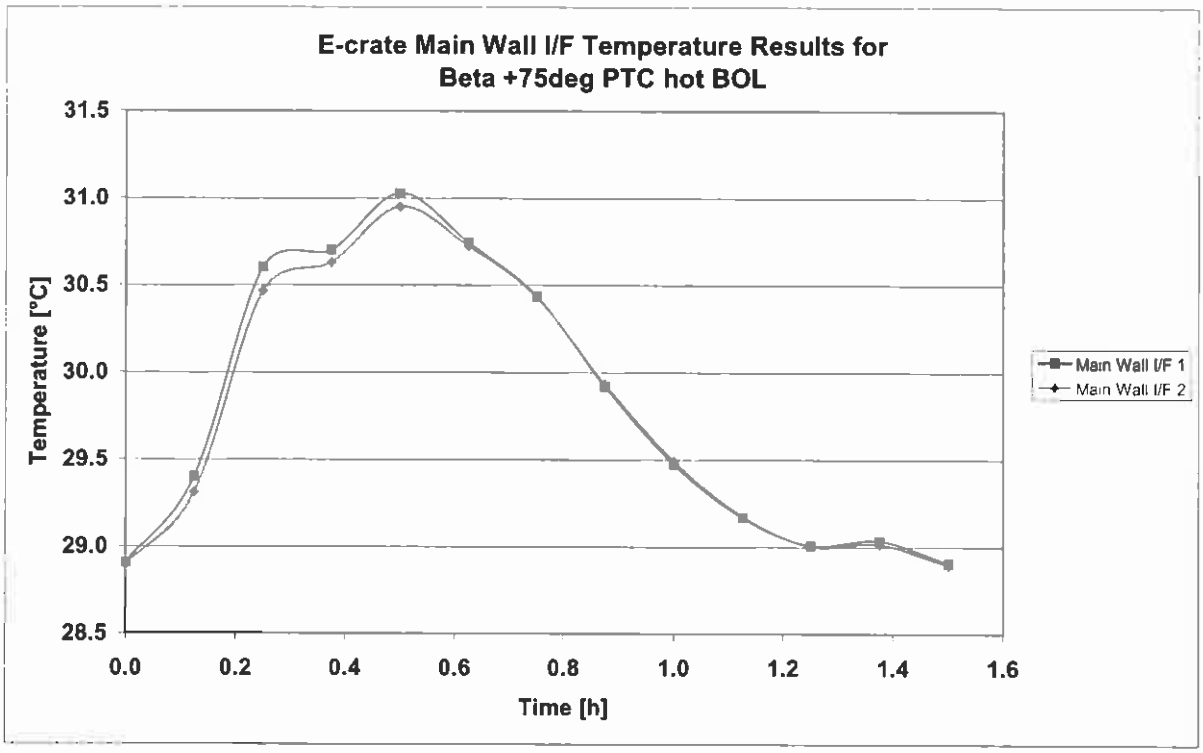

Fig. 8-19 Maximum E crates main wall I/F temperatures for orbit B+75 PTC hot BOL

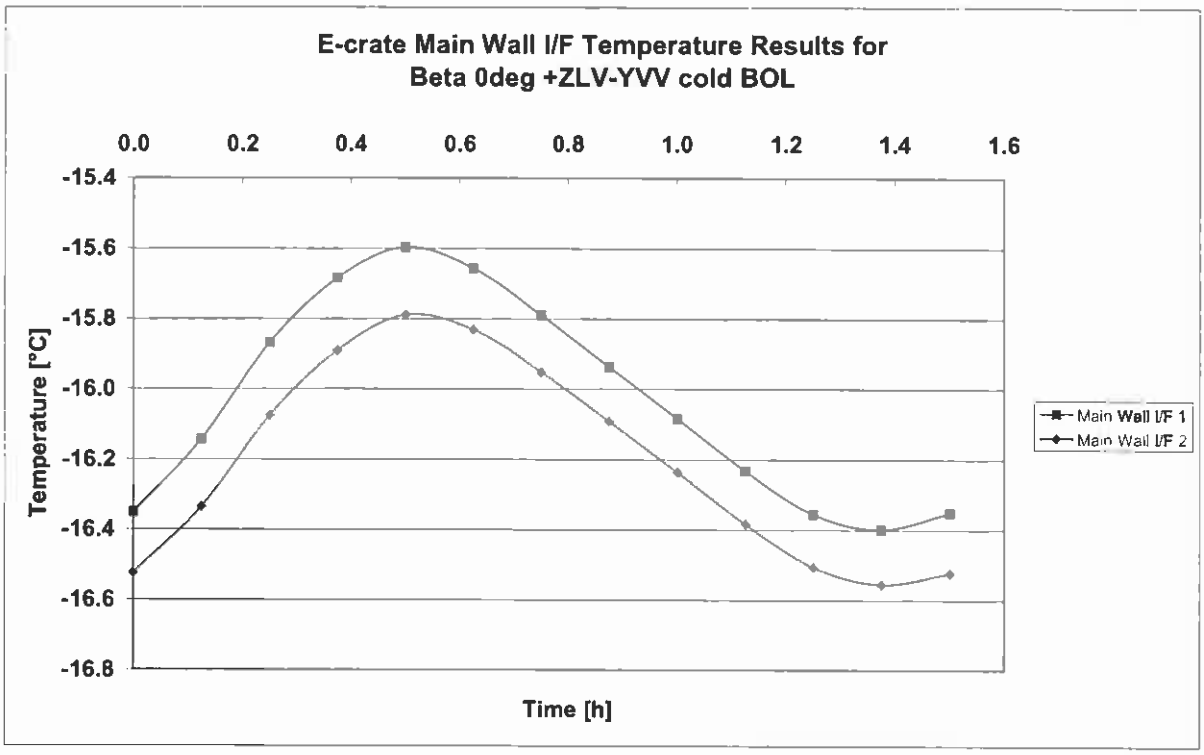

Fig. 8-20 Minimum E crates main wall I/F temperatures for orbit B 0 +ZLV-YVV cold BOL. Minimum non operative requirements fulfilled with 30W heater power.

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Cold contingency case

Starting from the initial temperatures obtained in the coldest case described in Tab. 8-8, E crates main walls I/F temperature results are shown after having moved to +Z Space attitude : E crates are requested to survive for at least 90 minutes in this extreme cold phase:

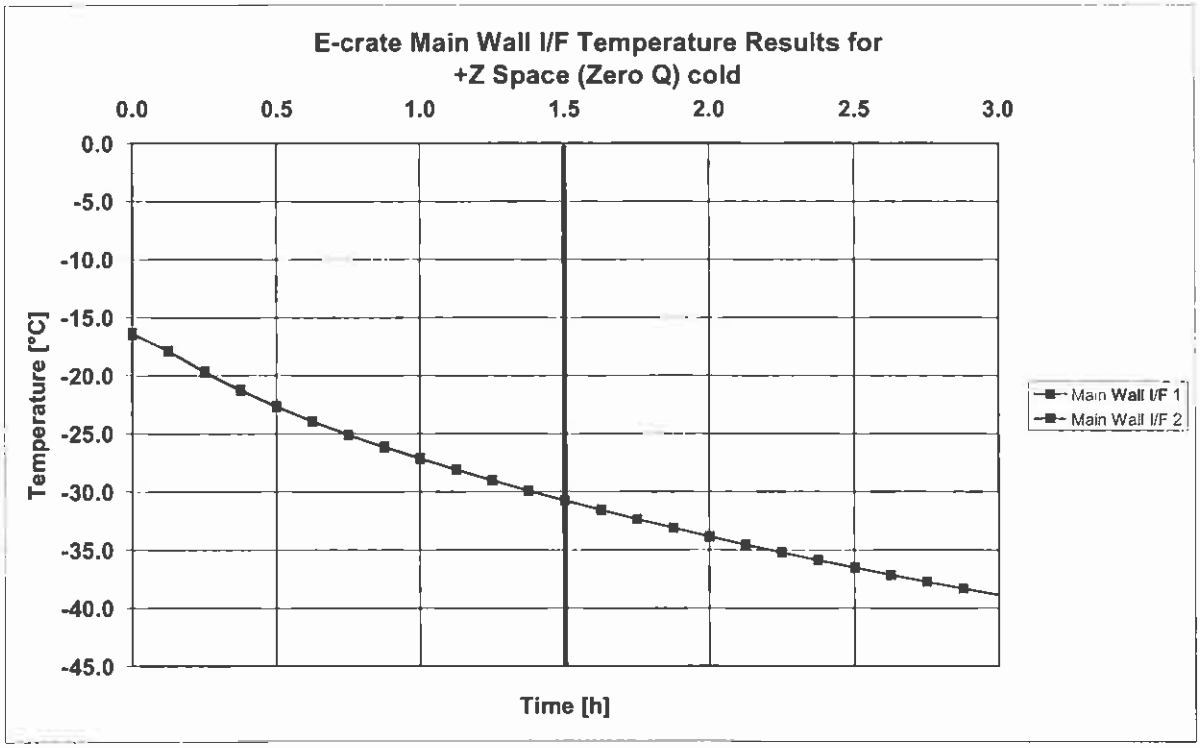

Fig. 8-21 Minimum E crates main wall I/F temperatures for orbit +Z Space (zero Q). E crates can withstand even more than 90 minutes

Hot contingency case

Starting from the initial temperatures obtained in the hottest case described in Tab. 8-8, E crates main walls I/F temperature results are shown after having moved to +Z Solar Inertial attitude : E crates are requested to survive for at least 30 minutes in this extreme hot phase:

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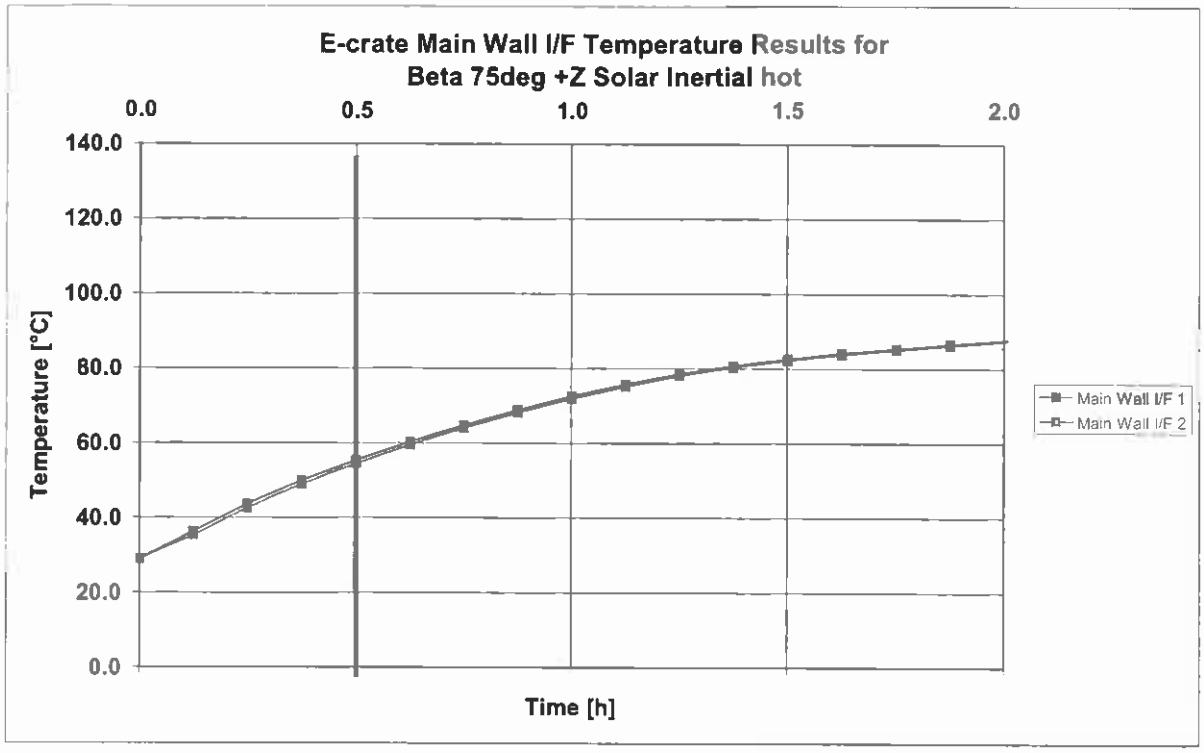

Fig. 8-22 Maximum E crates main walls I/F temperatures for orbit B+75+Zsolar Inertial. E crates can withstand even more than 30 minutes

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8.1.9 TRACKER SYSTEM (TRACKER ELECTRONICS/TTCB)

The design cases for the TRACKER detector during STS unmated attitudes are as follows:

BETA	Attitude	STS	Enviroment	Remarks/Rationale
60	+ZLV+XVV	Free Flying	COLD	**Worst cold case BOL during unmated phases**
75	PTC	Free Flying	HOT	**Worst hot case BOL during unmated phases**

Tab. 8-9 TRACKER RAM radiator design cases during STS unmated phases

BETA	Attitude	STS	Enviroment	Remarks/Rationale
0	+ZLV+XVV	Free Flying	COLD	**Worst cold case BOL during unmated phases**
60	+ZLV+XVV	Free Flying	HOT	**Worst hot case BOL during unmated phases**

Tab. 8-10 TRACKER WAKE radiator design cases during STS unmated phases

Tracker is unpowered, so its temperature (hybrids and silicon wafers) is equal to ACC temperature shown in paragraph 8.1.15 .

8.1.10 STAR TRACKER

The design cases for the STAR TRACKER detector during STS unmated attitudes are as follows:

BETA	Attitude	STS	Enviroment	Remarks/Rationale
75	PTC	free flying	HOT	**Worst hot case for Star Tracker**
0	+ZLV-YVV	free flying	COLD	**Worst cold case BOL for Star Tracker**

Tab. 8-11 STAR TRACKER design cases during STS unmated phases

The following graphs show the temperatures of the STAR TRACKER CCDs. It is worthwhile to notice that as described in Tab. 6-3, STAR TRACKER is not-operative during this phase.

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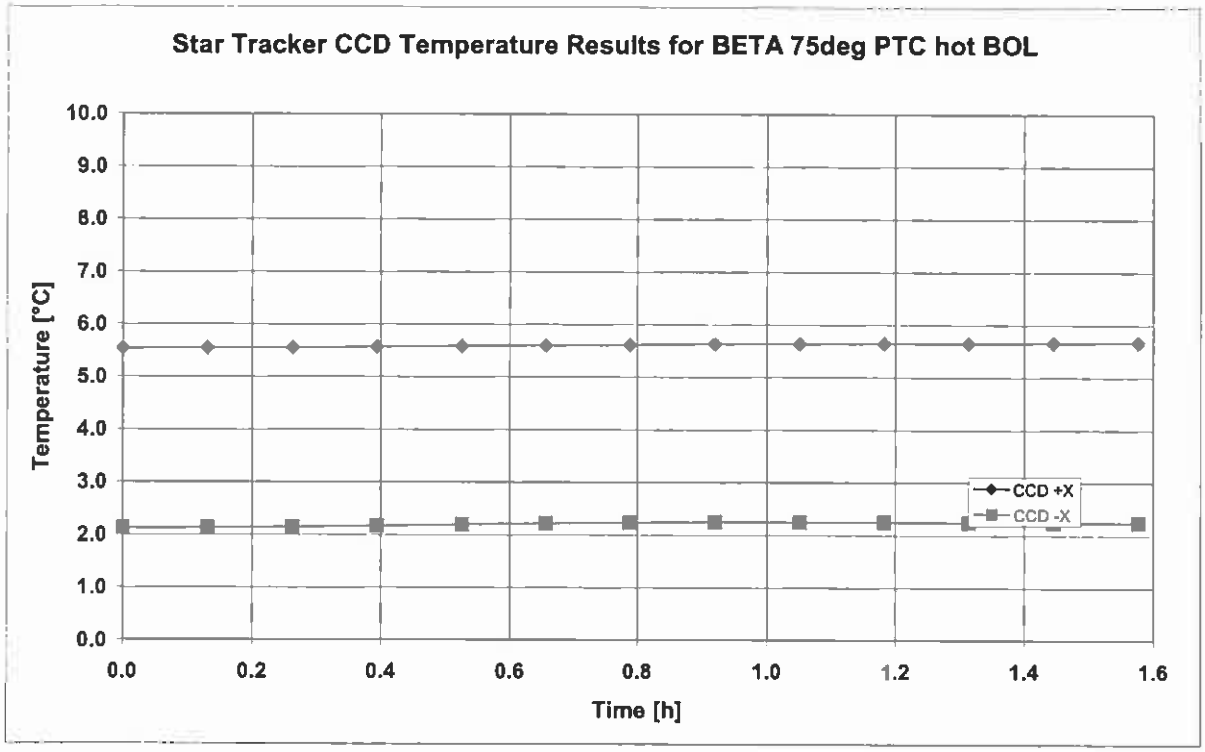

Fig. 8-23 Star Tracker CCDs temperatures for orbit B+75 PTC hot BOL

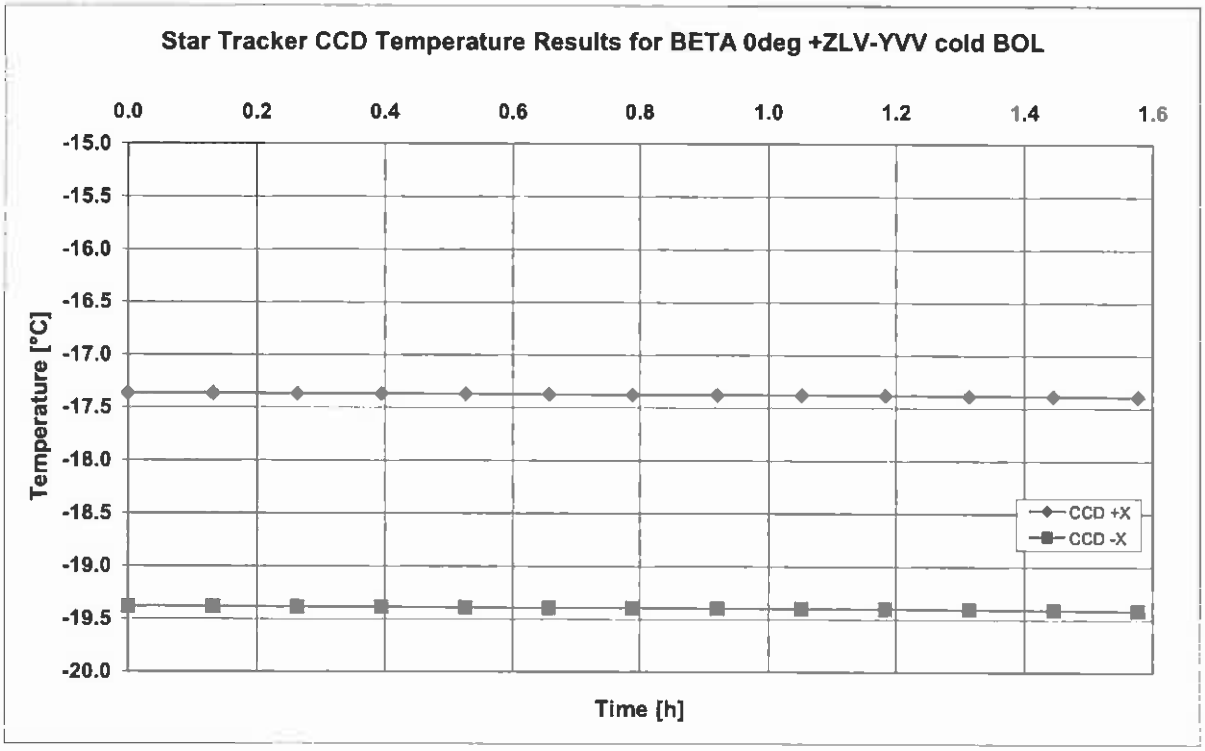

Fig. 8-24 Star Tracker CCDs temperatures for orbit B 0 +ZLV-YVV cold BOL. Minimum non operative requirements fulfilled without heater power.

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As described in Tab. 7-5 STAR-TRACKER is required to determine the length of time it can remain in extreme attitudes before a non-operating limit is violated.

Cold contingency case

Starting from the initial temperatures obtained in the coldest case described in Fig. 8-24, STAR TRACKER CCDs temperature results are shown after having moved to +Z Space attitude : STAR TRACKER detector is requested to survive for at least 90 minutes in this extreme cold phase:

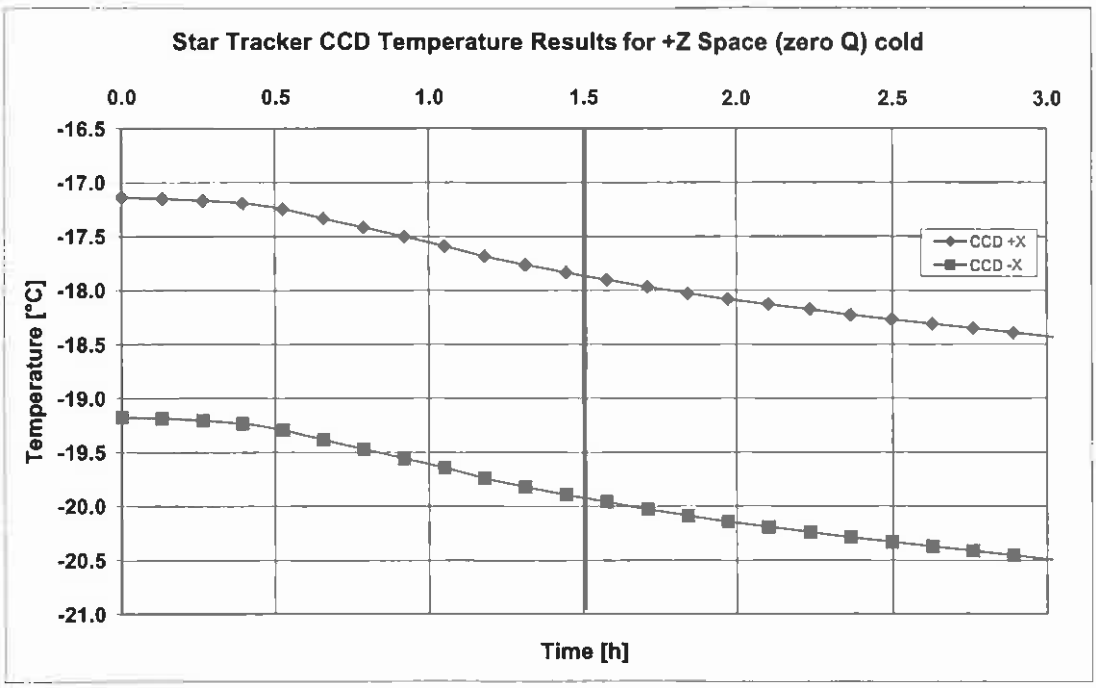

Fig. 8-25 Star Tracker CCDs temperatures for orbit +Z Space (zero Q). Star Tracker CCDs can withstand even more than 90 minutes

Hot contingency case

Starting from the initial temperatures obtained in the hottest case described in Fig. 8-23, STAR TRACKER CCDs temperature results are shown after having moved to +Z Solar Inertial attitude : STAR TRACKER CCDs are requested to survive for at least 30 minutes in this extreme hot phase:

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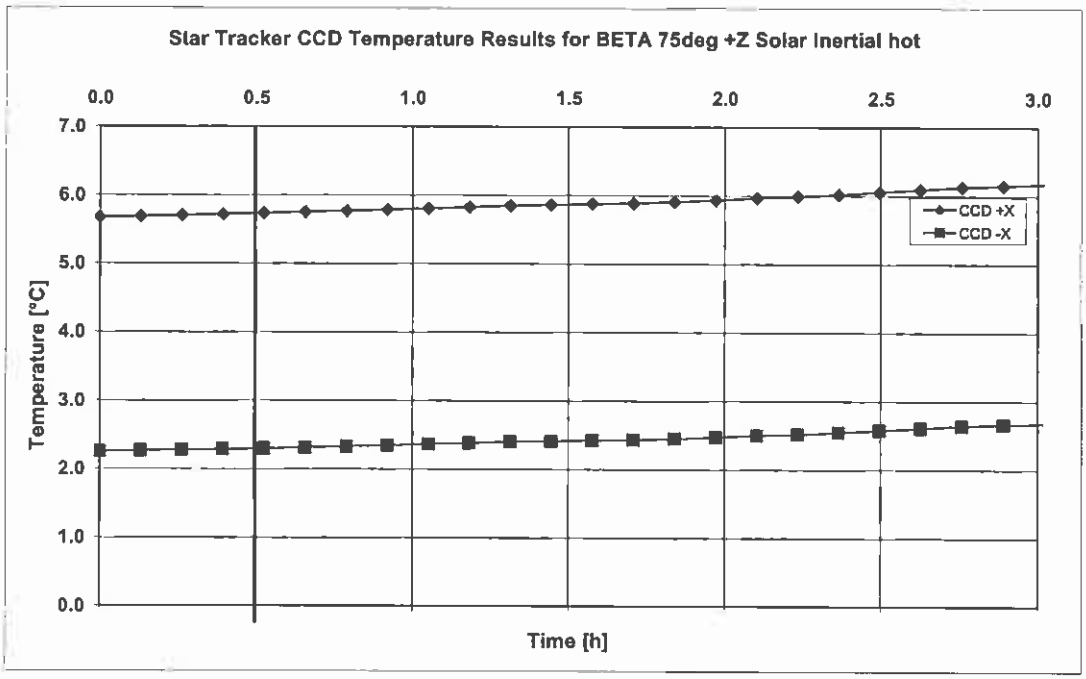

Fig. 8-26 Star Tracker CCDs temperatures for orbit B+75+Zsolar Inertial. Star Tracker CCDs can withstand even more than 30 minutes

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8.1.11 VACUUM CASE

The hottest and coldest cases for the Vacuum Case during STS unmated attitudes are as follows:

BETA	Attitude	STS	Enviroment	Remarks/Rationale
75	PTC	free flying	HOT	**Worst hot case for Vacuum Case**
0	+ZLV+XVV	free flying	COLD	**Worst cold case BOL for Vacuum Case**

Tab. 8-12 Vacuum Case coldest and hottest cases during STS unmated phases

The following graphs show the Vacuum Case surface-weighted average temperature for the above mentioned cases.

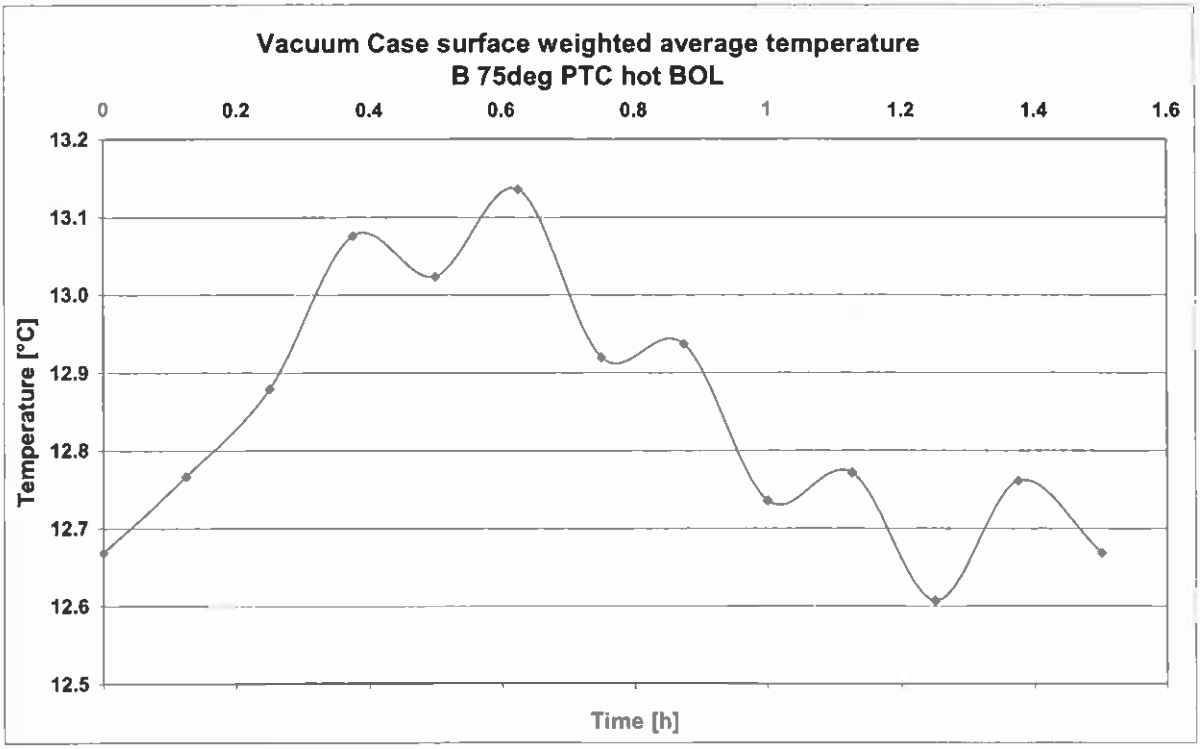

Fig. 8-27 Vacuum Case surface-weighted average temperature for orbit B+75 PTC hot BOL

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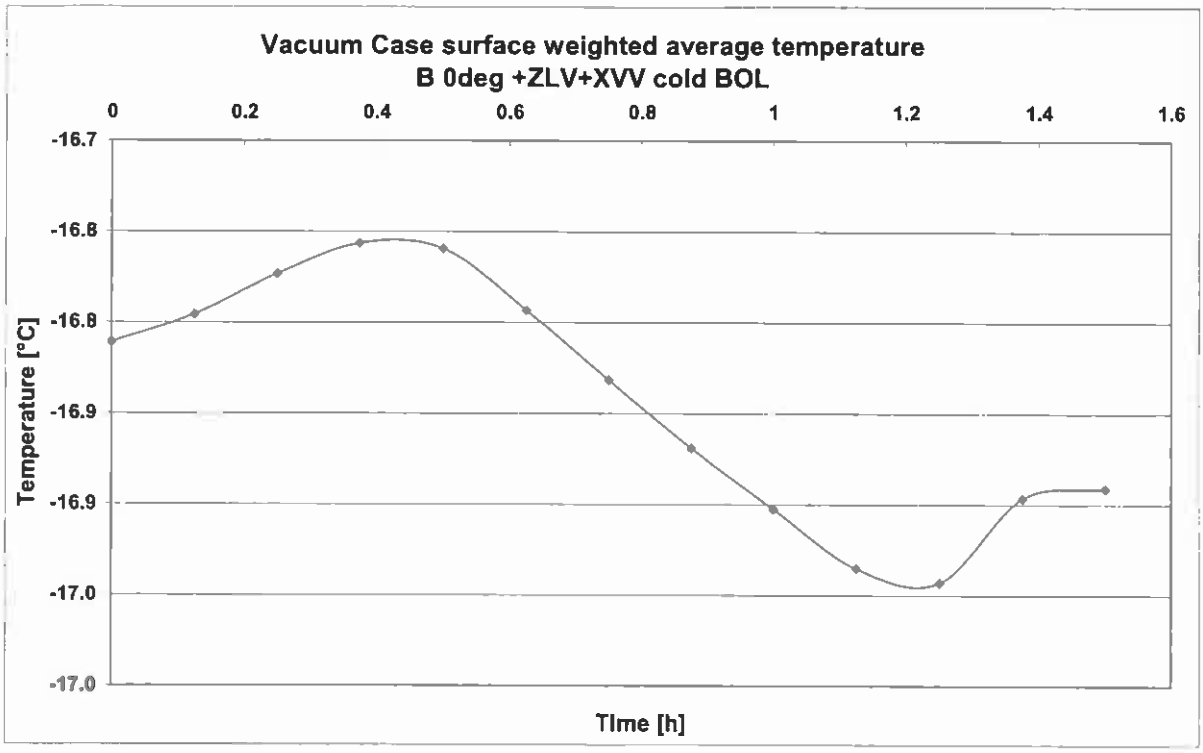

Fig. 8-28 Vacuum Case surface-weighted average temperature for orbit B 0 +ZLV+XVV cold BOL

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8.1.12 CAB

The design cases for the CAB unit during STS unmated attitudes are as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
75	PTC	Free flying	HOT	
0	+ZLV+XLV	Free flying	COLD	

Tab. 8-13 CAB design cases during STS unmated phases

Detailed results are presented in RD [9]

The following graph shows temperatures of CAB baseplate during STS free flying cold contingency case.

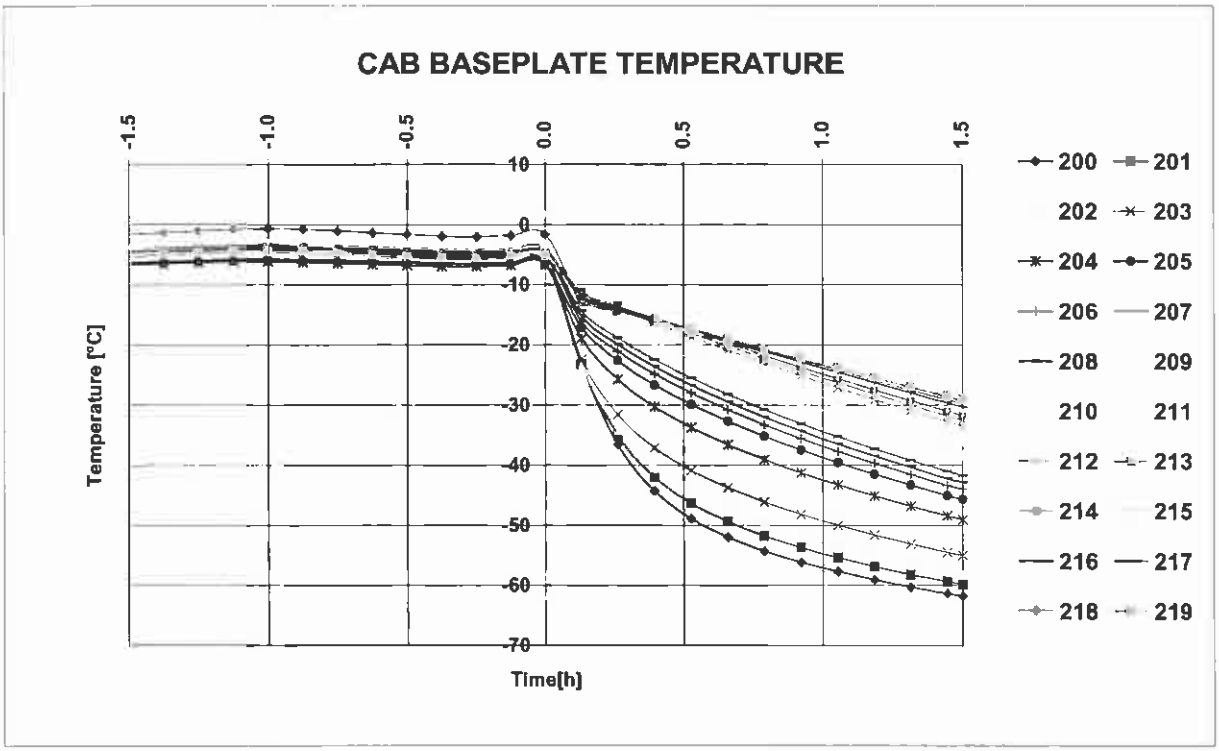

Fig. 8-29 CAB case temperatures for orbit +Z Space (zero Q) in cold contingency. CAB can not withstand the foreseen 90 minutes

The following graph shows temperatures of CAB baseplate during STS free flying hot contingency. CAB can withstand even a larger period of time than 30 minutes.

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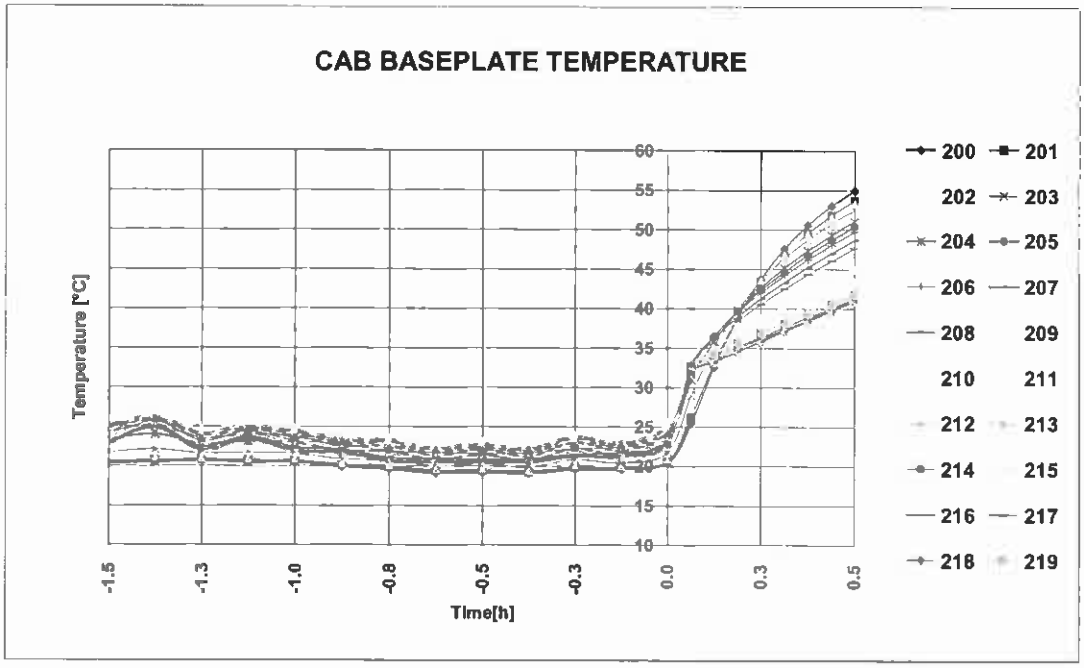

Fig. 8-30 Maximum CAB case temperatures for orbit B+75 PTC hot BOL in hot contingency.

8.1.13 TRD GAS BOX

The design cases for the TRD GAS BOX unit during STS unmated attitudes are as follows:

BETA	Attitude	STS	Environment	Remarks/Rationale
75	PTC	free flying	HOT	**Worst hot case for TRD GAS BOX**
0	+ZLV-YVV	free flying	COLD	**Worst cold case BOL for TRD GAS BOX**

Tab. 8-14 TRD Gas Box design cases during STS unmated phases

The following graphs show the temperatures of the TRD Gas Box. It is worthwhile to notice that as described in Tab. 6-3, TRD Gas Box is not-operative during this phase, but it is heater assisted.

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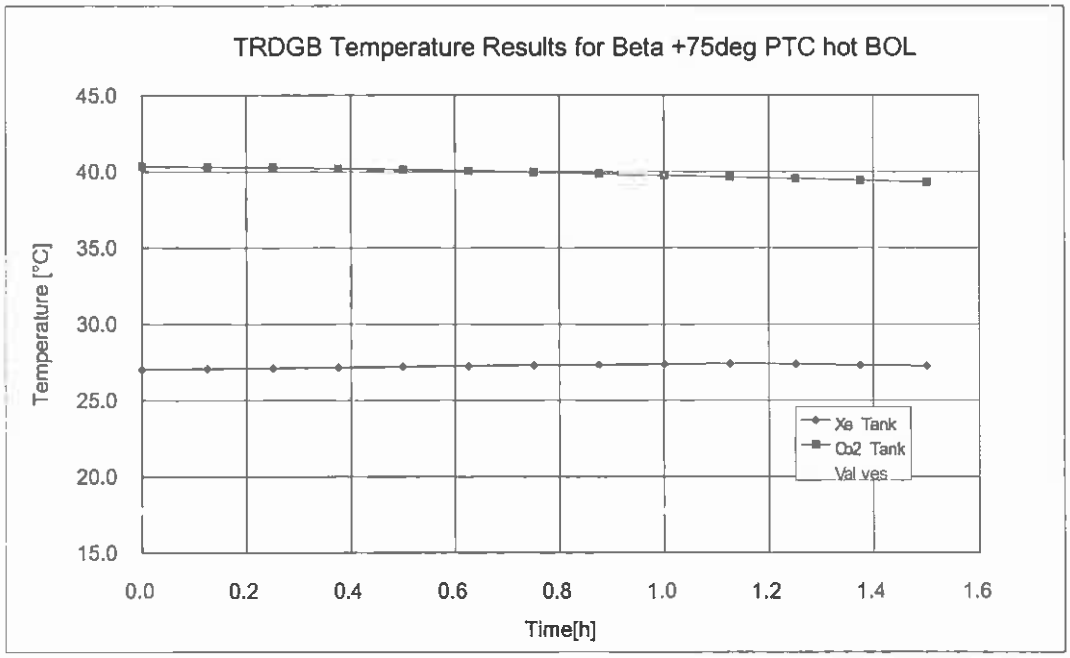

Fig. 8-31 TRD GAS BOX temperatures for orbit B+75 PTC hot BOL

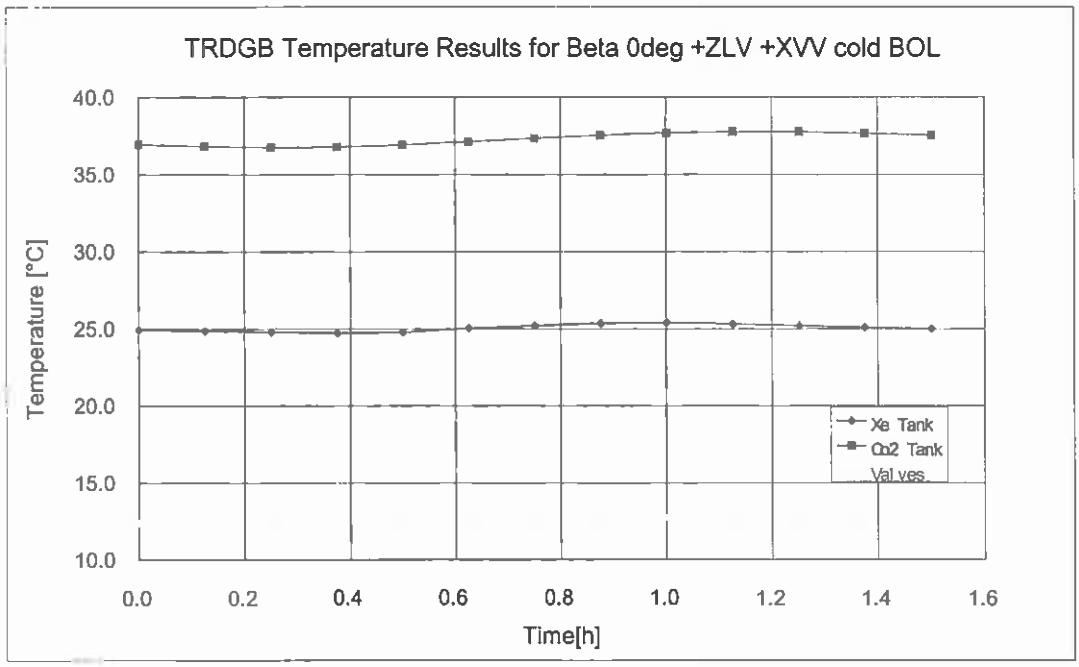

Fig. 8-32 TRD GAS BOX temperatures for orbit B 0 deg +ZLV + XVV COLD BOL. Heater assisted

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8.1.14 TRD/UPPER TOF

The design cases for the TRD detector during STS unmated attitudes are as follows:

BETA	Attitude	STS	Environment	Remarks/Rationale
0	+ZLV-YVV	Free flying	COLD	**Worst cold case BOL for TRD**
75	PTC	Free flying	HOT	**Worst hot case BOL for TRD**

Tab. 8-15 TRD detector design cases during STS unmated phases

8.1.15 ACC

The design cases for the ACC detector during STS unmated attitudes are as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
75	PTC	STS free flying	HOT	**Worst hot case BOL for ACC**
0	+ZLV+XVV	STS free flying	COLD	**Worst cold case BOL for ACC**

Tab. 8-16 ACC detector design cases during STS unmated phases

The following graphs show the temperatures of the ACC PMTs. It is worthwhile to notice that as described in Tab. 6-3, ACC detector is not-operative during this phase.

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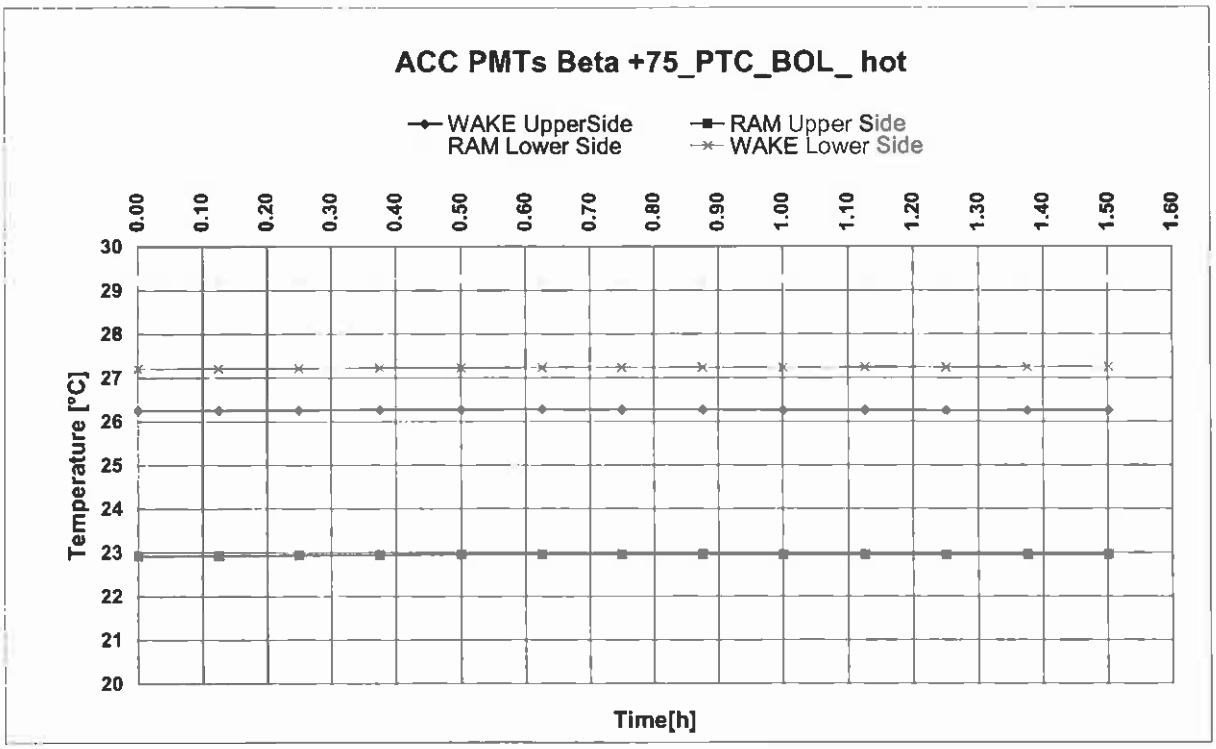

Fig. 8-33 ACC PMTs temperature for orbit Beta +75_PTC_BOL_hot

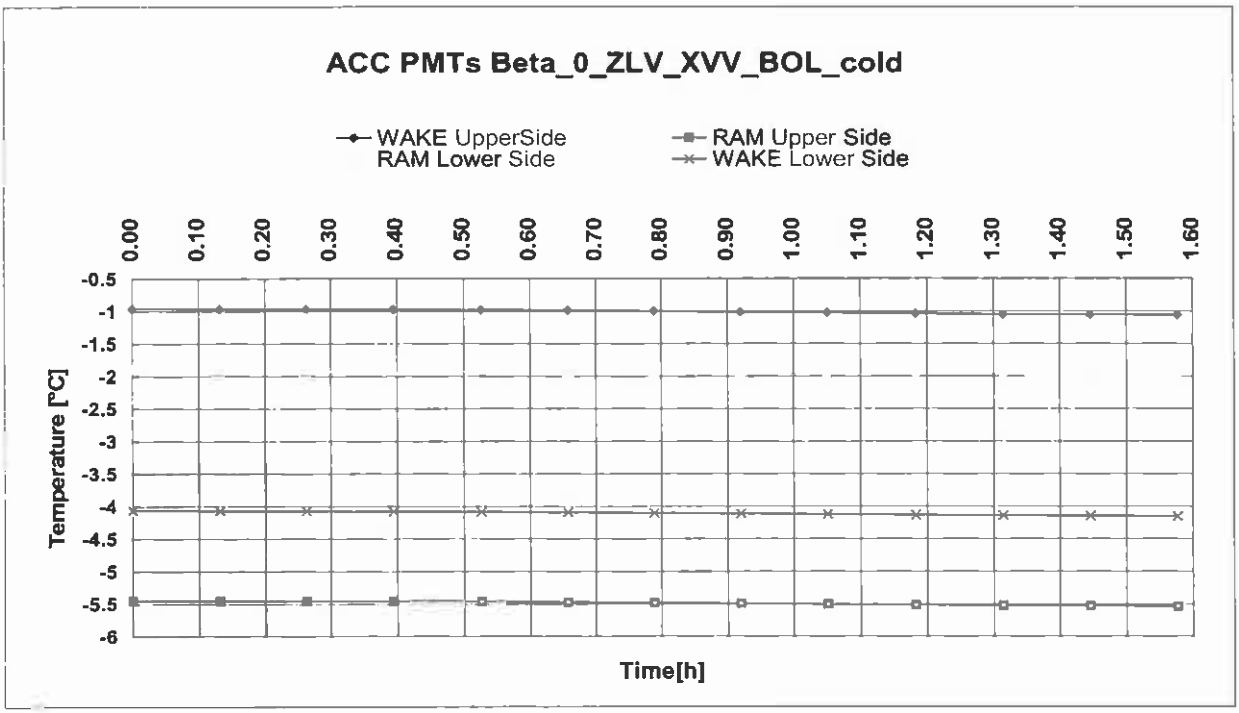

Fig. 8-34 ACC PMTs temperature for orbit Beta +0_ZLV_XVV_BOL_cold

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8.1.16 PAS

The design cases for the PAS during STS unmated attitudes are as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
75	PTC	STS free flying	HOT	Worst hot case for PAS
0	+ZLV-YVV	STS free flying	COLD	Worst cold case BOL for PAS

Tab. 8-17 PAS design cases during STS unmated phases

The following graphs show the temperatures of the PAS parts.

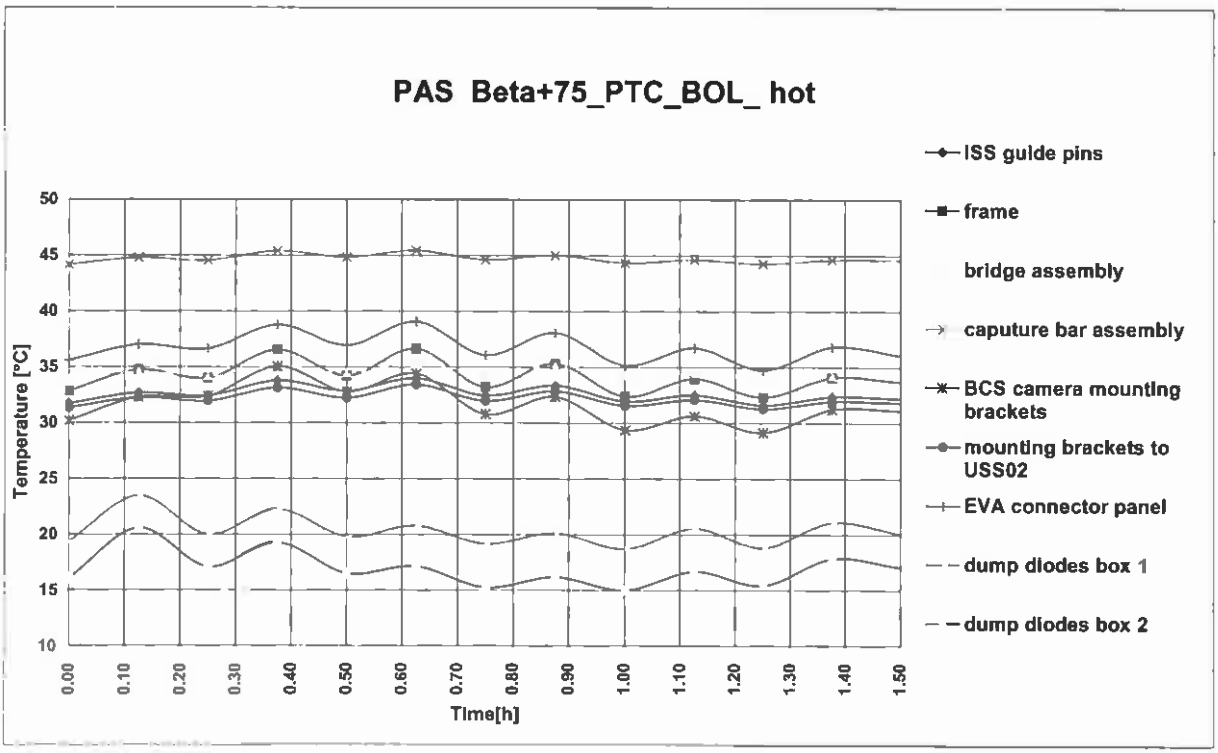

Fig. 8-35 PAS temperature for orbit Beta+75_PTC_BOL_hot

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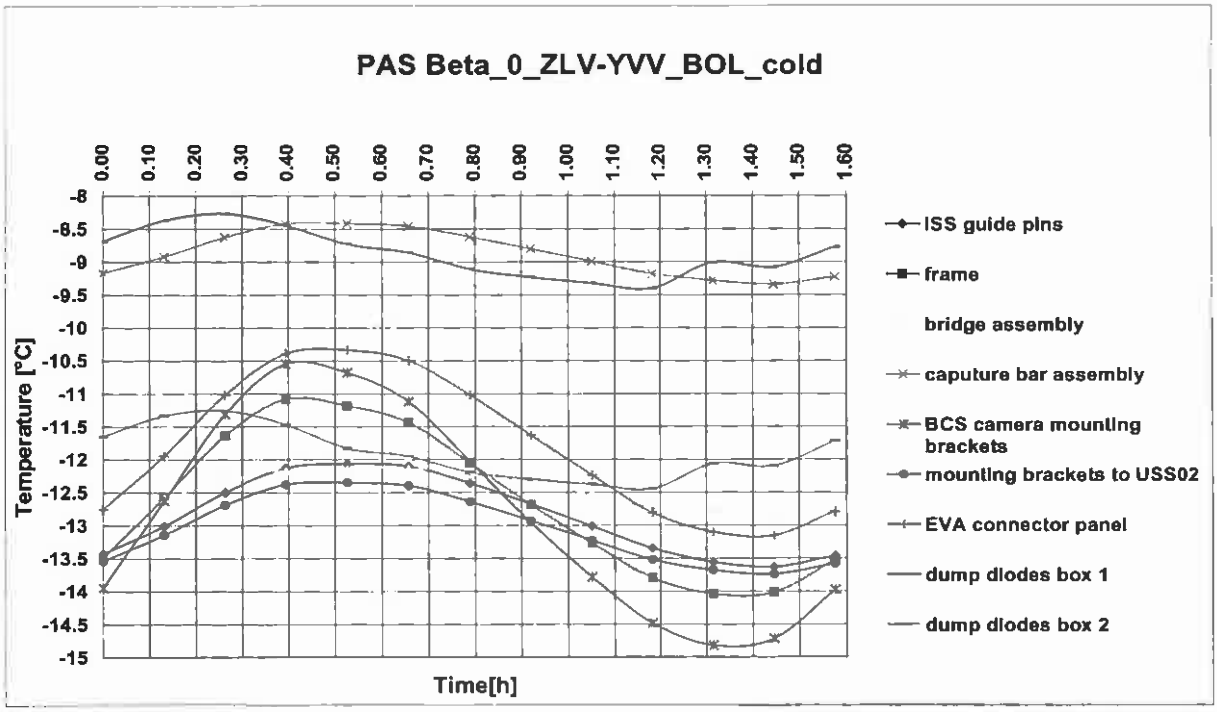

Fig. 8-36 PAS temperature for orbit Beta_0_ZLV-YVV_BOL_ cold

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8.1.17 UPS

The design cases for the UPS during STS unmated attitudes are as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
75	PTC	STS free flying	HOT	Worst hot case for UPS
0	+ZLV+XVV	STS free flying	COLD	Worst cold case BOL for UPS

Tab. 8-18 UPS design cases during STS unmated phases

The following graphs show the temperatures of the UPS parts:

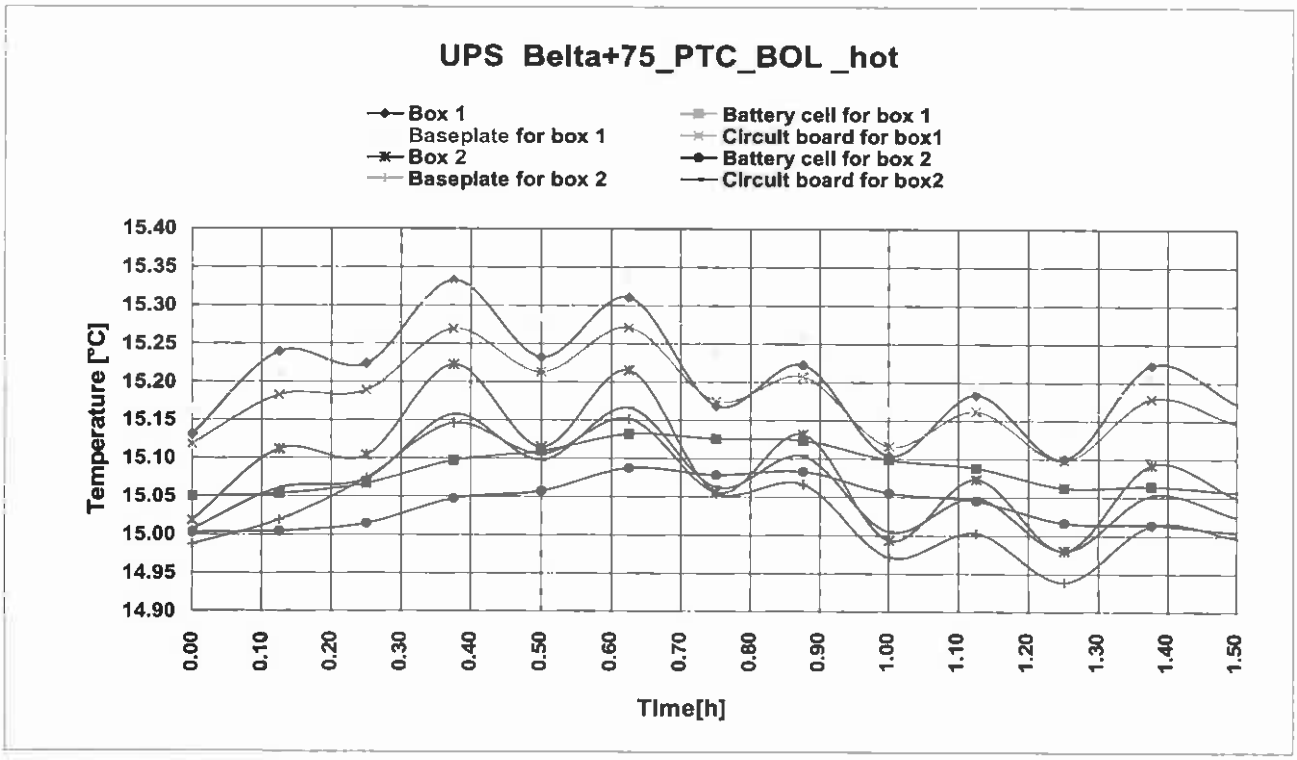

Fig. 8-37 UPS temperature for orbit Beta +75-Z_PTC_BOL_hot

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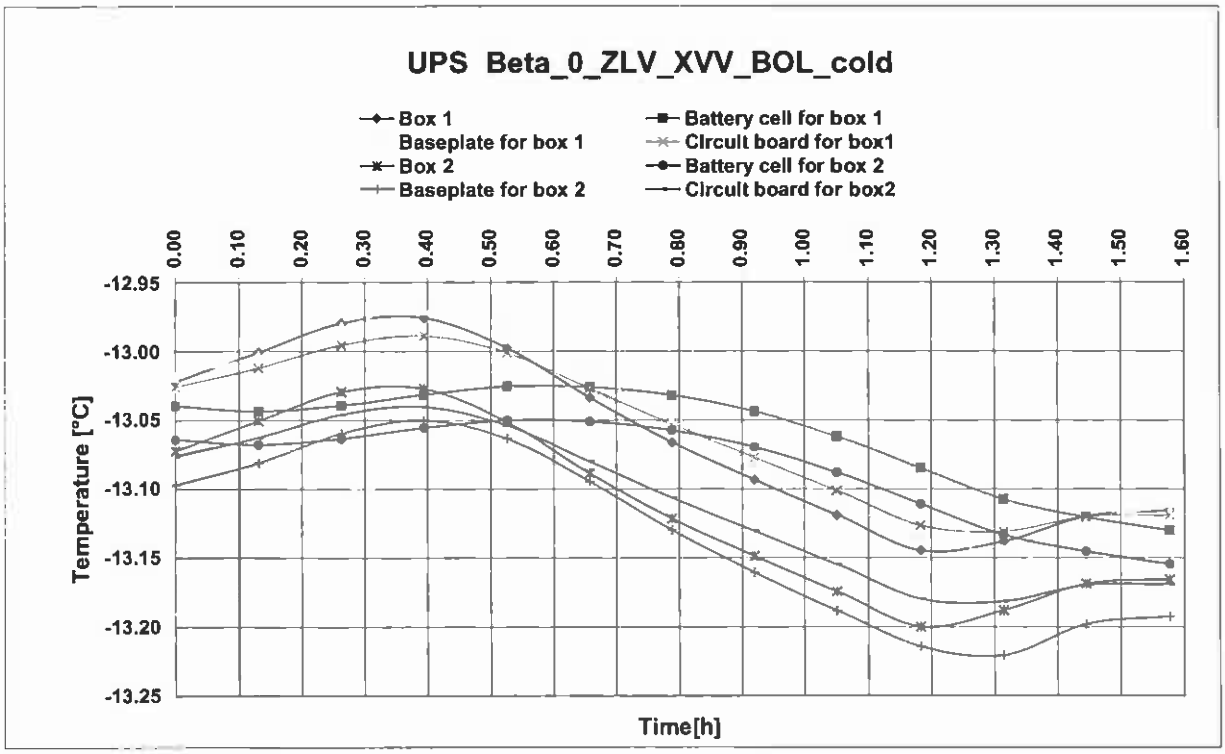

Fig. 8-38 UPS temperature for orbit Beta _0_ZLV_XVV_BOL_cold

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8.2 PHASE 2: STS DOCKED TO THE ISS, AMS-02 IN THE CARGO BAY

For each detector the design cases selected and reported in Tab. 7-7 have been analyzed and results reported.

8.2.1 MAIN RADIATORS

8.2.1.1 RAM RADIATOR

The design case for Main Ram radiator when STS is docked are as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	docked	Cold	**Worst cold case for Ram Radiator**

Tab. 8-19 RAM radiator design case with STS docked to the ISS

Results are presented in RD [9]

8.2.1.2 WAKE RADIATOR

The design case for Main WAKE radiator with STS docked are as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0/0/0	docked	COLD	**Worst cold case for wake radiator**

Tab. 8-20 WAKE radiator design case with STS docked to the ISS

Results are presented in RD [9]

8.2.2 ZENITH RADIATOR

The design cases for Zenith radiator when STS is docked are as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0 / 0 / 0	docked	cold	**Worst cold case for Zenith radiator**

Tab. 8-21 Zenith radiator design case with STS docked to the ISS

The following graphs show the temperatures of the Zenith radiator being the cryo cooler dissipation evenly distributed on the 4 zenith radiators panels.

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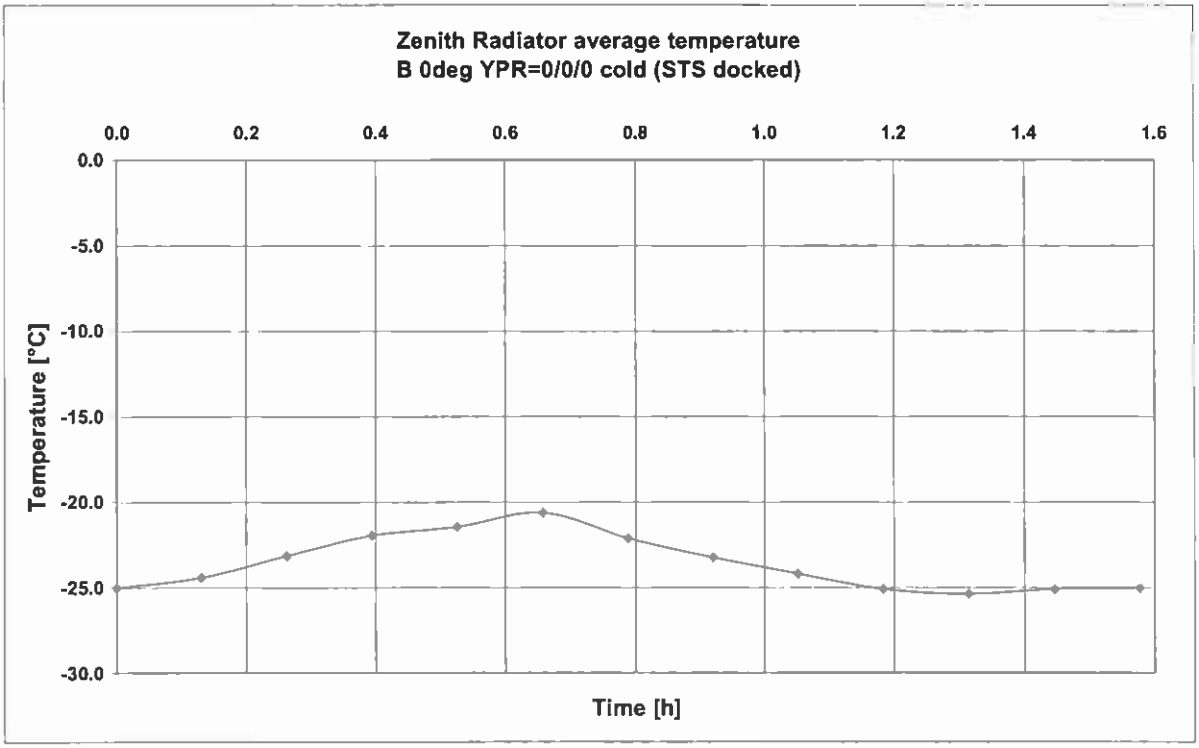

Fig. 8-39 Zenith radiator average temperature for orbit B_0_0_0_0 cold BOL

8.2.3 CRYOCOOLER

The design cases for Cryocoolers when STS is docked are the one presented in Tab. 8-1.
Cryocoolers temperature are derived from RD [10], considering the delta T between Zenith radiator and Cryo.

8.2.4 RICH

The design cases for RICH detector when STS is docked are as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
60	0 / 0 / 0	docked	cold	**Worst cold case for RICH**

Tab. 8-22 RICH detector design case with STS docked to the ISS

The following graphs show the temperatures of the RICH PMTs (minimum) on the eight octagon sections. It is worthwhile to notice that as described in Tab. 6-4 , RICH is not-operative during this phase.

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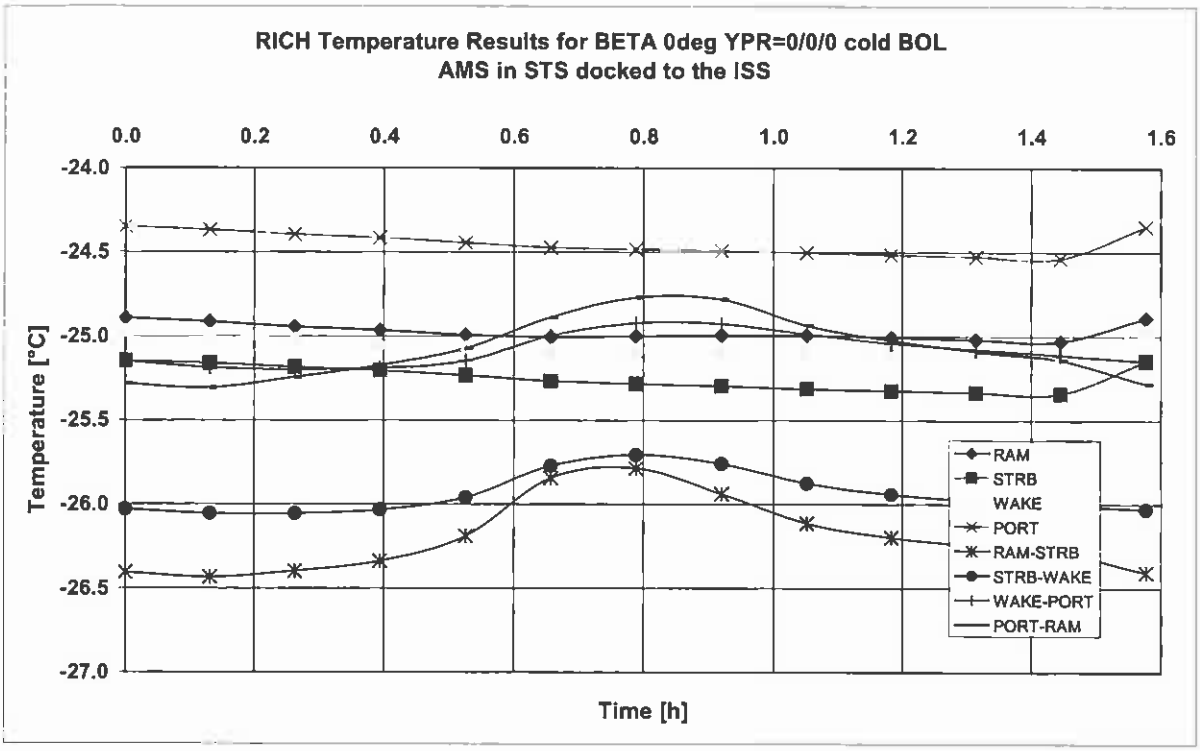

Fig. 8-40 Minimum RICH PMTs temperatures for orbit B_60_0_0_0 cold BOL . Minimum non-operative requirements are fulfilled

8.2.5 LOWER TOF

The design case for LOWER TOF detector when STS is docked are as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
60	0 / 0 / 0	docked	cold	**Worst cold case for LOWER TOF**

Tab. 8-23 LOWER TOF design case with STS docked to the ISS

The following graphs show the temperatures of the LOWER TOF PMTs (minimum). It is worthwhile to notice that as described in Tab. 6-4 LOWER TOF is not-operative during this phase.

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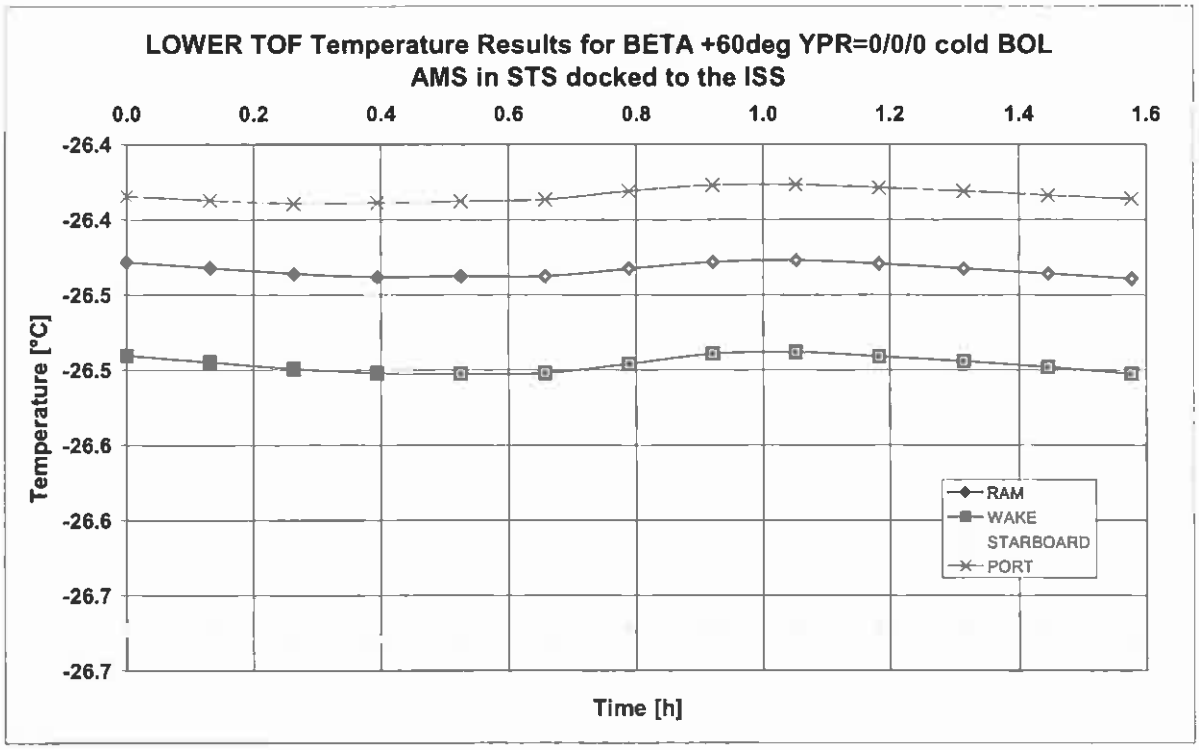

Fig. 8-41 Minimum lower TOF PMTs temperatures for orbit B_60_0_0_0 cold BOL. Non-operative requirements are fulfilled without heater power.

8.2.6 ECAL

The design case for ECAL detector when STS is docked are as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
-60	0 / 0 / 0	docked	cold	**Worst cold case for ECAL**

Tab. 8-24 ECAL detector design case with STS docked to the ISS

Detailed results will be presented in RD [5]

8.2.7 RHV/EHV BRICKS

The design case for RHV/EHV (Lower USS-02) bricks when STS is docked are as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	docked	cold	**Worst cold case for EHV and RHV**

Tab. 8-25 EHV/RHV bricks design case with STS docked to the ISS

Detailed results will be presented in RD [6]

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8.2.8 E-CRATE

The design case for E crates when STS is docked are as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	docked	cold	**Worst cold case for E crates**

Tab. 8-26 E crates design case with STS docked to the ISS

The following graphs show the temperatures of the E crates main wall I/F (minimum). It is worthwhile to notice that as described in Tab. 6-4 E crates are not-operative during this phase.

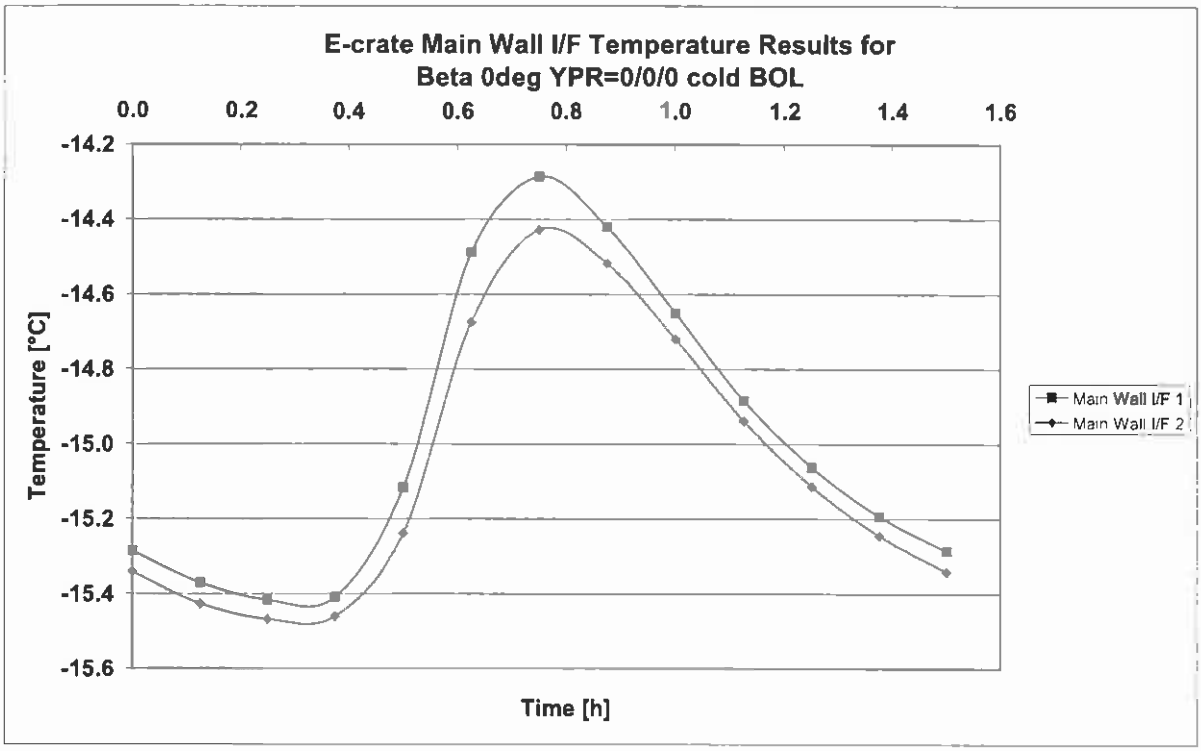

Fig. 8-42 Minimum E crates main walls I/F temperatures for orbit B_0_0_0_0 cold BOL. Non-operative requirements are fulfilled with 30W heater power.

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8.2.9 TRACKER SYSTEM (TRACKER ELECTRONICS/TTCB)

The design case for TRACKER detector when STS is docked are as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	Docked	COLD	**Worst cold case for Tracker**

Tab. 8-27 Tracker detector design case with STS docked to the ISS

Tracker is unpowered, therefore its temperature is equal to ACC temperature shown in paragraph 8.2.15 .

8.2.10 STAR TRACKER

The design case for STAR TRACKER detector when STS is docked are as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	docked	cold	**Worst cold case for Star Tracker**

Tab. 8-28 Star Tracker detector design case with STS docked to the ISS

The following graphs show the CCDs temperatures (minimum). It is worthwhile to notice that as described in Tab. 6-4 Star Tracker is not-operative during this phase.

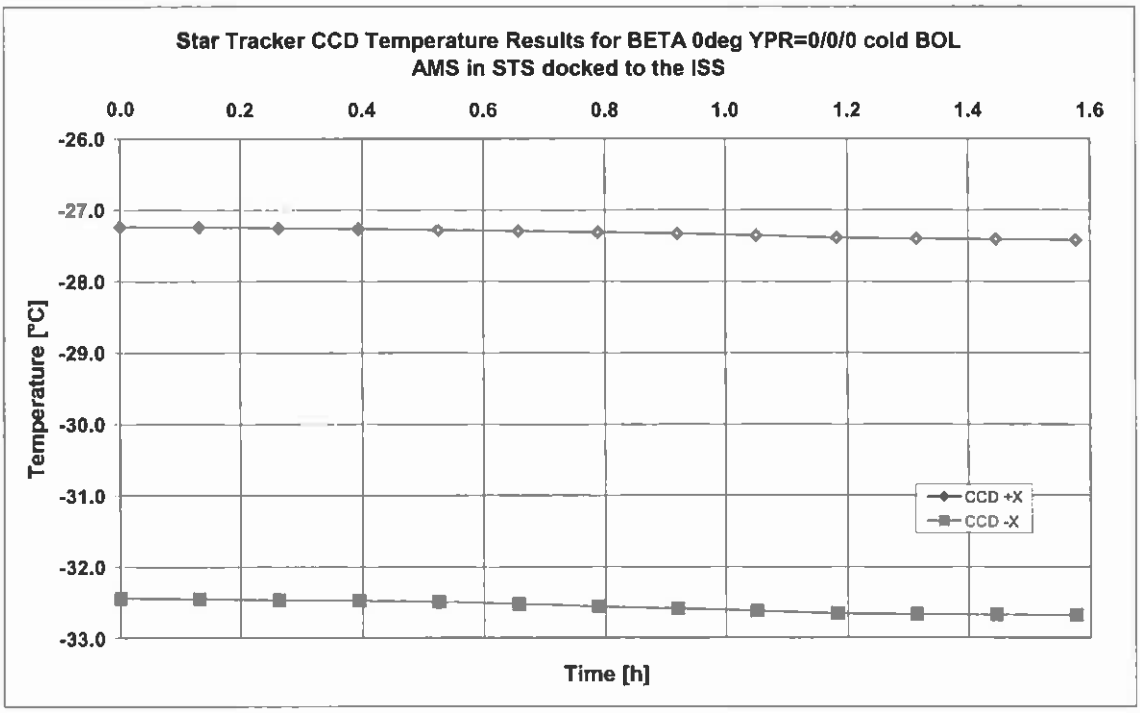

Fig. 8-43 Star Tracker CCDs temperatures for orbit B_0_0_0_0 cold BOL. Non-operative requirements fulfilled.

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8.2.11 VACUUM CASE

The design case for Vacuum Case when STS is docked are as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0 / 0 / 0	docked	cold	**Worst cold case for Vacuum Case**

Tab. 8-29 Vacuum Case design case with STS docked to the ISS

The following graphs show the Vacuum Case surface-weighted average temperature for the above mentioned case:

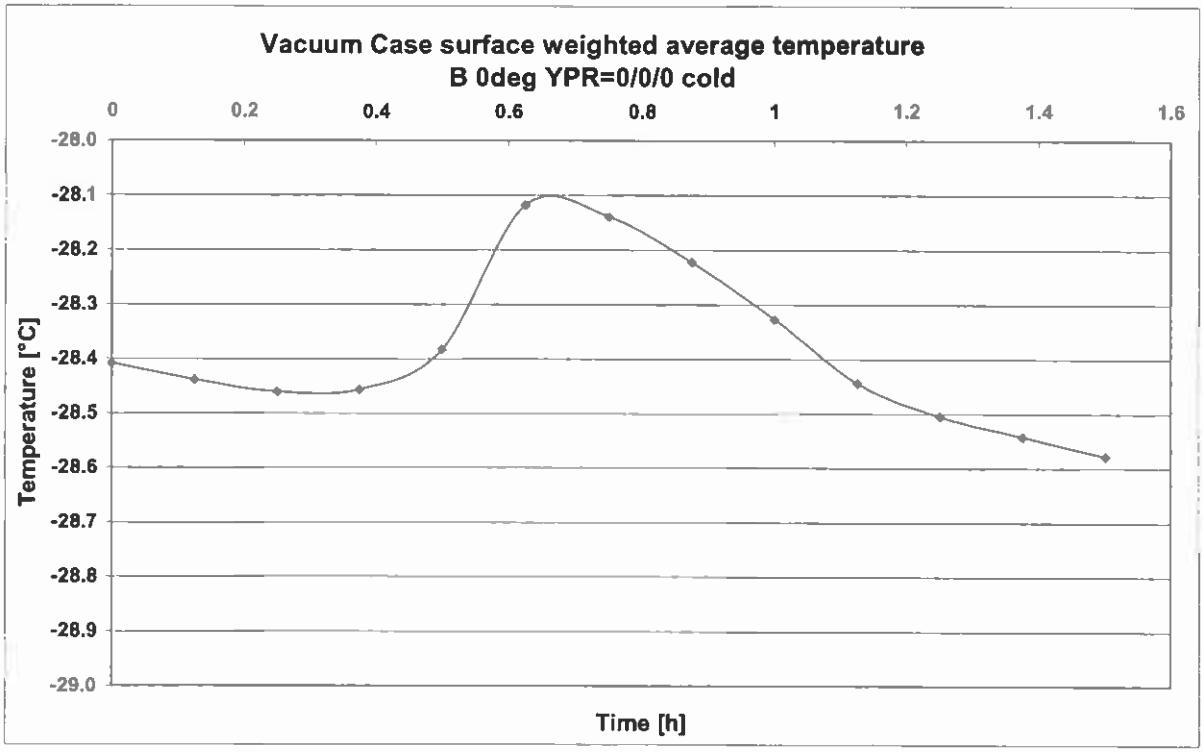

Fig. 8-44 Vacuum Case surface-weighted average temperature for orbit B_0_0_0_0 cold BOL

8.2.12 CAB

The design case for CAB unit when STS is docked are as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0/0/0	docked	COLD	**Worst cold case for CAB**

Tab. 8-30 CAB design case with STS docked to the ISS

Results are presented in RD [9]

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8.2.13 TRD GAS BOX

The design case for TRD Gas Box when STS is docked are as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0 / 0 / 0	docked	cold	**Worst COLD case for TRDGB**

Tab. 8-31 TRD Gas Box design case with STS docked to the ISS

The following graphs show the TRD Gas Box temperatures (minimum). It is worthwhile to notice that as described in Tab. 6-4 TRD Gas Box is not-operative during this phase, but heater assisted.

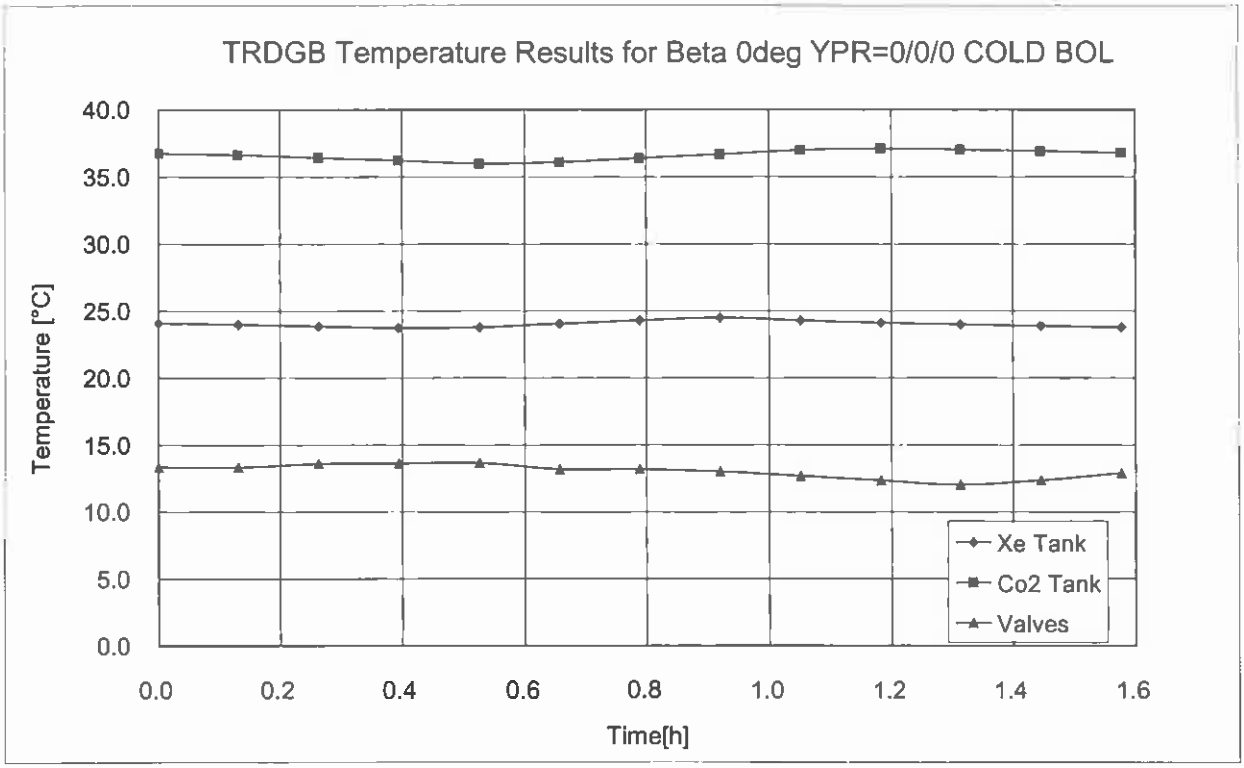

Fig. 8-45 TRD GAS BOX temperatures results for orbit B_0_0_0_0 cold BOL . Non-operative requirements fulfilled.

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8.2.14 TRD/UPPER TOF

The design case for TRD/Upper Tof Detector when STS is docked are as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0 / 0 / 0	docked	cold	**Worst COLD case for TRD**

Tab. 8-32 TRD Detector design case with STS docked to the ISS

8.2.15 ACC

The design case for ACC Detector when STS is docked are as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0/ 0/ 0	STS docked	COLD	Worst cold case for ACC PMTs

Tab. 8-33 ACC Detector design case with STS docked to the ISS

The following graphs show the ACC PMTs temperatures (minimum). It is worthwhile to notice that as described in Tab. 6-4 ACC is not-operative during this phase.

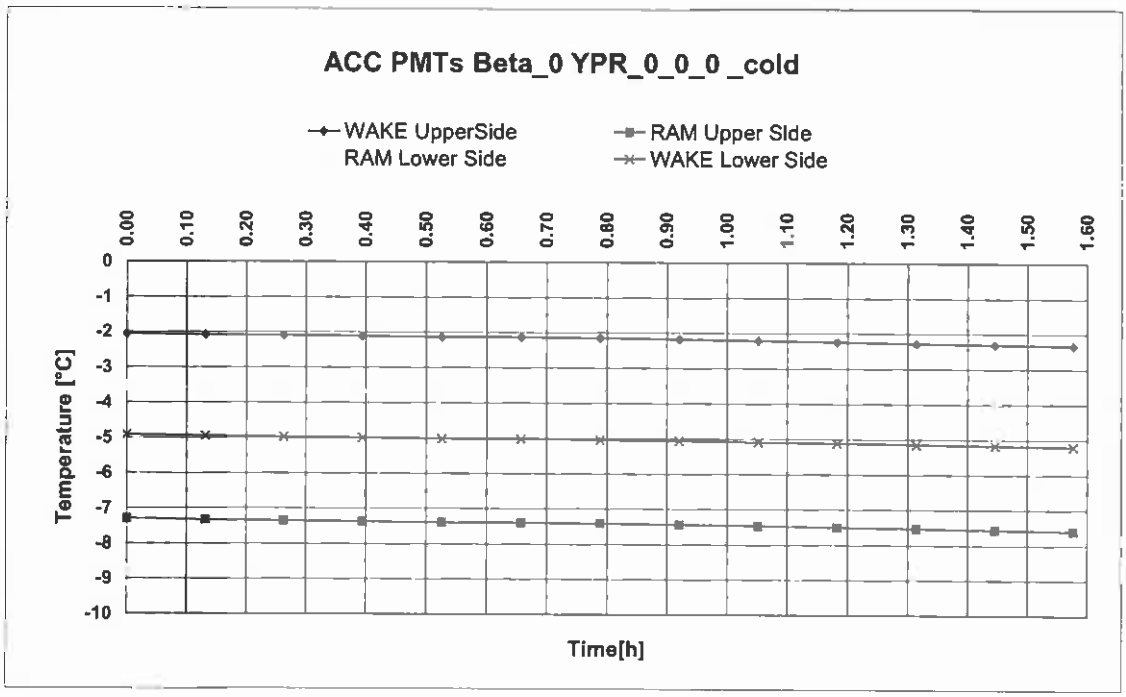

Fig. 8-46 ACC PMTs temperature for orbit B_0_0_0_0_cold. Non-operative requirements fulfilled

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8.2.16 PAS

The design case for PAS when STS is docked are as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0/ 0/ 0	STS docked	COLD	Worst cold case for PAS

Tab. 8-34 PAS design case with STS docked to the ISS

The following graphs show the PAS temperatures (minimum).

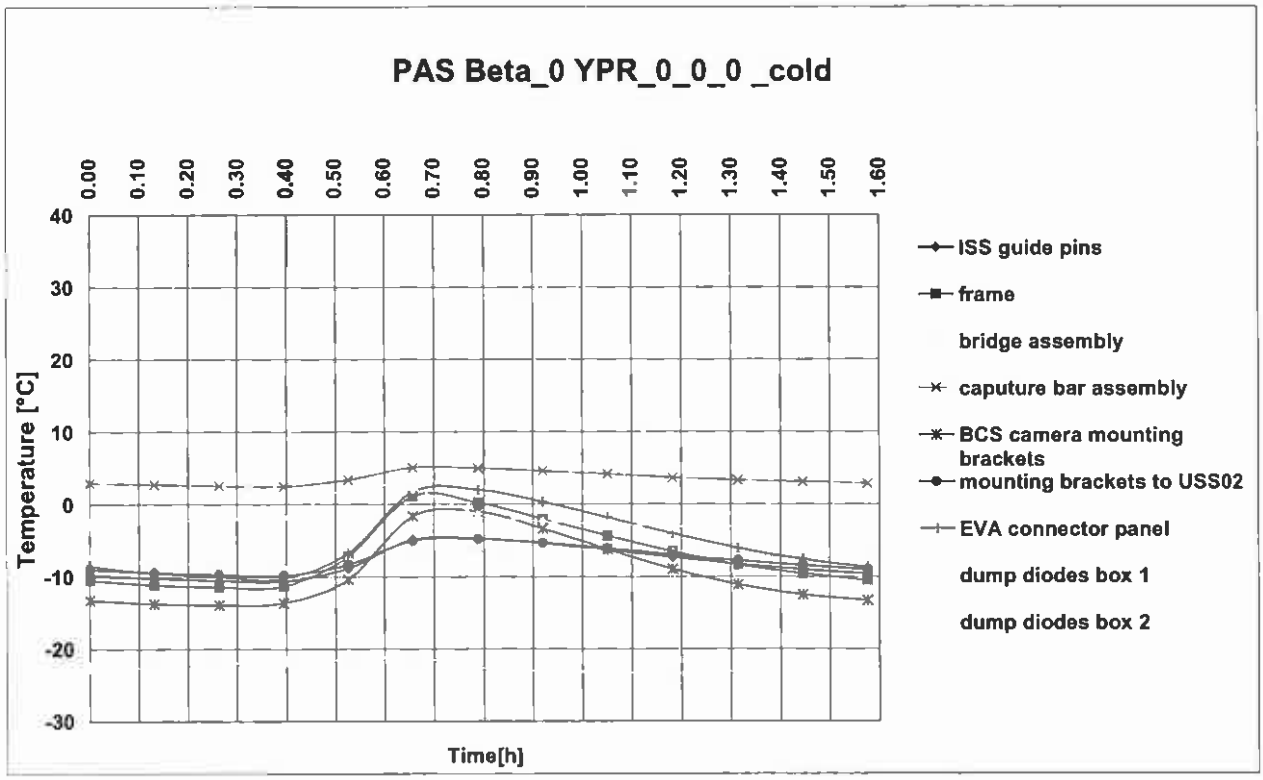

Fig. 8-47 PAS temperature for orbit B_0_0_0_0_cold

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8.2.17 UPS

The design case for UPS when STS is docked are as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0/ 0/ 0	STS docked	COLD	Worst cold case for UPS

Tab. 8-35 UPS design case with STS docked to the ISS

The following graphs show the UPS temperatures (minimum).

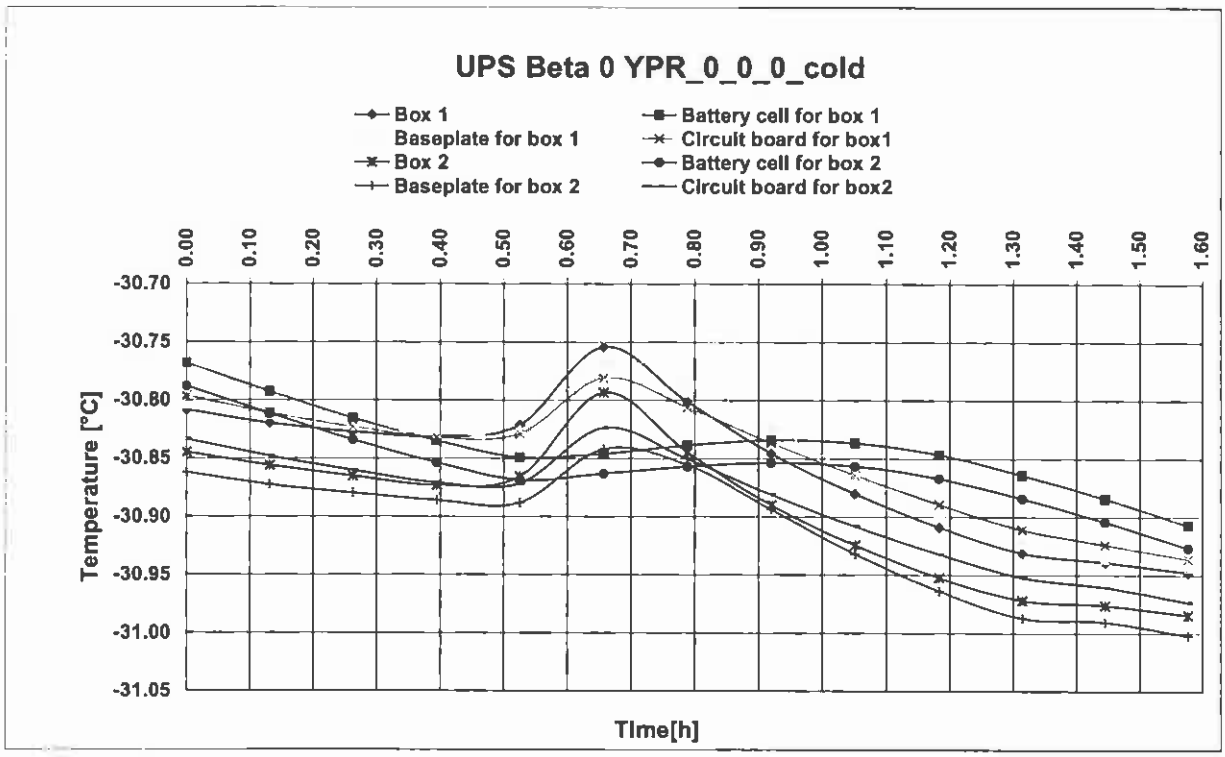

Fig. 8-48 UPS temperature for orbitB_0_0_0_0_cold

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8.3 PHASE3: STS DOCKED TO THE ISS, AMS-02 IN HAND-OFF POSITION

For each detector the design cases selected and reported in Tab. 7-10 have been analyzed and results reported. Initial conditions for this analysis are the stabilized conditions when AMS-02 experiment is inside the STS cargo-bay.

8.3.1 MAIN RADIATORS

8.3.1.1 RAM RADIATOR

The design case for Main Ram radiator during when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0 / 0 / 0	Hand-off	cold	**Worst cold case for Ram Radiator**

Tab. 8-36 Ram radiator design case during in Hand-Off position

Results are presented in RD [9]

8.3.1.2 WAKE RADIATOR

The design case for Wake radiator during when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0/0/0	Hand-off	COLD	**Worst cold case for wake radiator**

Tab. 8-37 Wake radiator design case in Hand-Off position

Results are presented in RD [9]

8.3.2 ZENITH RADIATOR

The design cases for Zenith radiator when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0 / 0 / 0	Hand-off	cold	**Worst cold case for Zenith Radiator**

Tab. 8-38 Zenith radiator design case in Hand-Off position

Zenith radiator has been designed to survive to a minimum temperature of -133°C corresponding to 8 hours without power applied. This low temperature will be never reached in the four hours transfer.

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8.3.3 CRYOCOOLER

The design cases for Cryocoolers when AMS is in hand-off position and STS docked to the ISS are described in Tab. 8-38.
The Loop Heat Pipe bypass valve (described in RD [10]) will prevent the Cryocoolers temperature dropping below -20°C.

8.3.4 RICH

The design cases for RICH detector when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	Hand-off	cold	**Worst cold case for RICH**

Tab. 8-39 RICH detector design case in Hand-Off position

The following graphs show the RICH PMTstemperatures (minimum) after the 4 unpowered hours (red line) and then the results when the detector is heater assisted. This phase the RICH detector is not working.

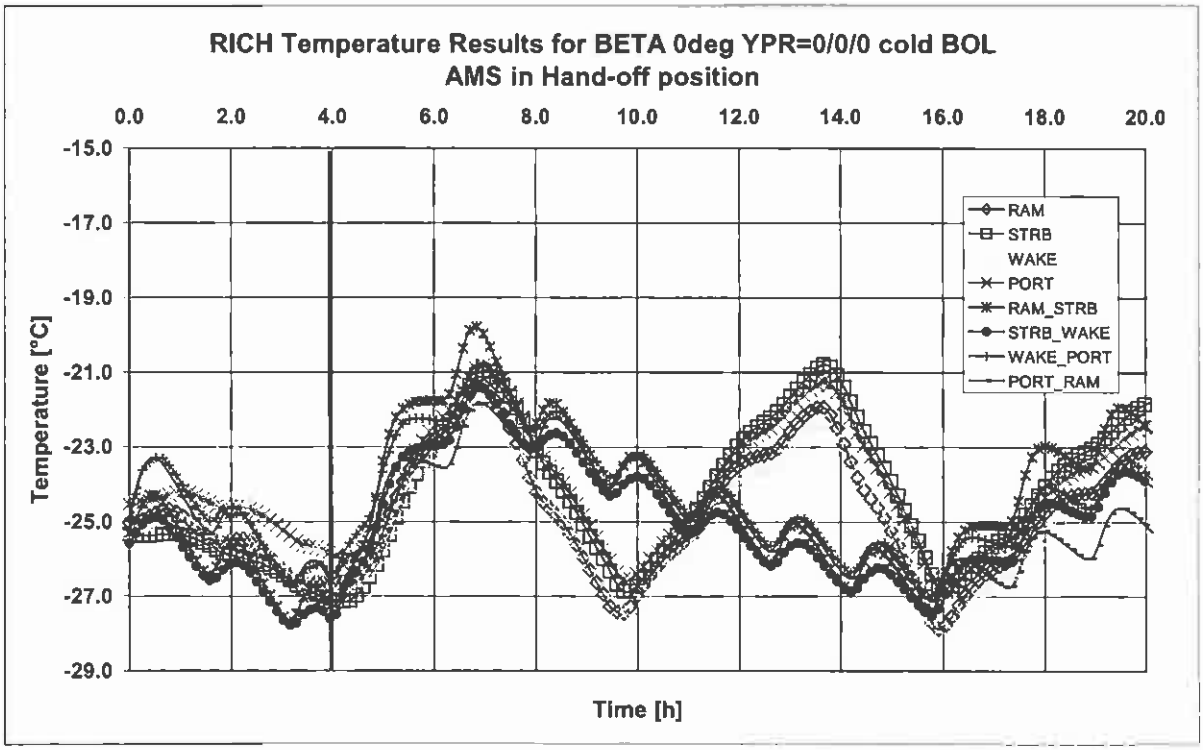

Fig. 8-49 Minimum RICH PMTs temperatures for orbit B_0_0_0_0 cold BOL (AMS in hand-off position)- Minimum non-operative requirements fulfilled with the detector supported by heaters when power is restored.

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8.3.5 LOWER TOF

The design cases for Lower TOF detector when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	Hand-off	cold	**Worst cold case for Lower ToF**

Tab. 8-40 LOWER TOF detector design case in Hand-Off position

The following graphs show the LOWER TOF PMTs temperatures (minimum) after the 4 unpowered hours (red line) and then the results when the detector is heater assisted. This phase the LOWER TOF detector is not working.

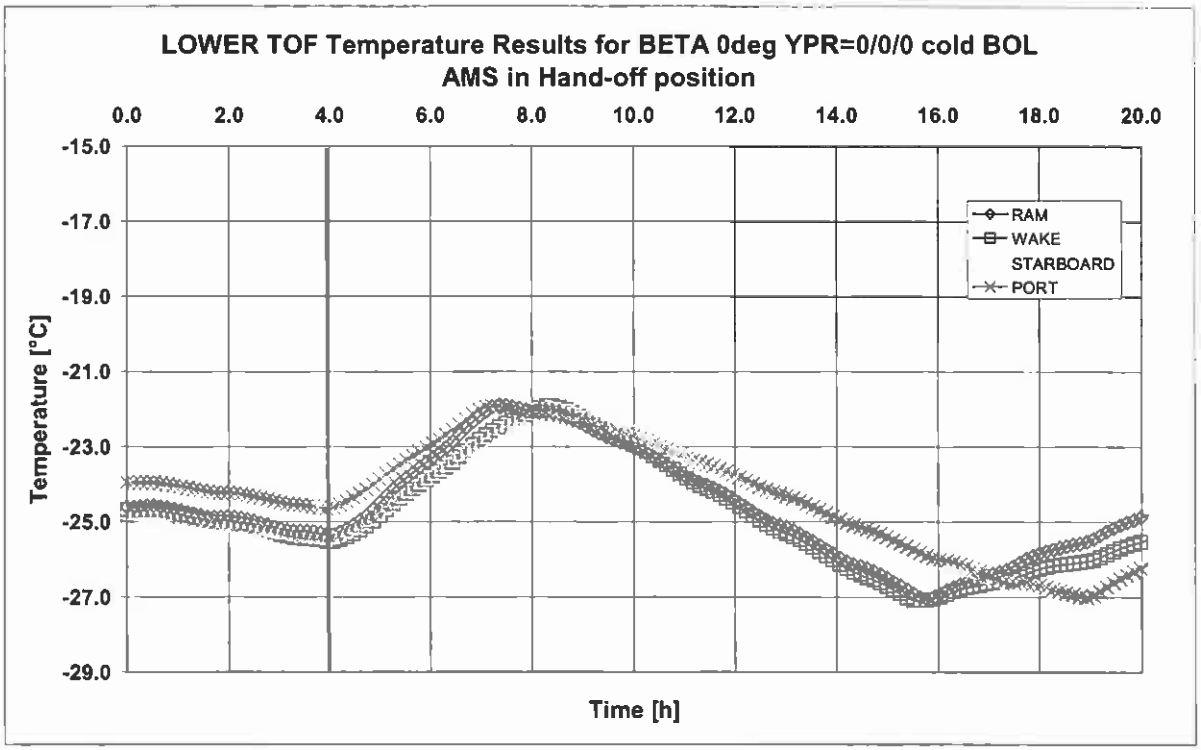

Fig. 8-50 Minimum Lower ToF PMTs temperatures for orbit B_0_0_0_0 cold BOL- Minimum non-operative requirements fulfilled with the detector supported by heaters

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8.3.6 ECAL

The design cases for ECAL detector when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
-60	0 / 0 / 0	Hand-off	cold	**Worst cold case for ECAL**

Tab. 8-41 ECAL detector design case in Hand-Off position

Detailed results are presented in RD [5]

8.3.7 RHV/EHV BRICKS

The design cases for RHV/EHV bricks when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	Hand OFF	cold	**Worst cold case for EHV and RHV**

Tab. 8-42 EHV/RHV design case in Hand-Off position

Detailed results are presented in RD [6]

8.3.8 E CRATE

The design cases for E crates when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	docked	cold	**Worst cold case for E crates**

Tab. 8-43 E crates design case in Hand-Off position

The following graphs show the E crates main walls I/F temperatures (minimum) after the 4 unpowered hours (red line) and then the results when the detector is heater assisted. This phase the E crates are not working.

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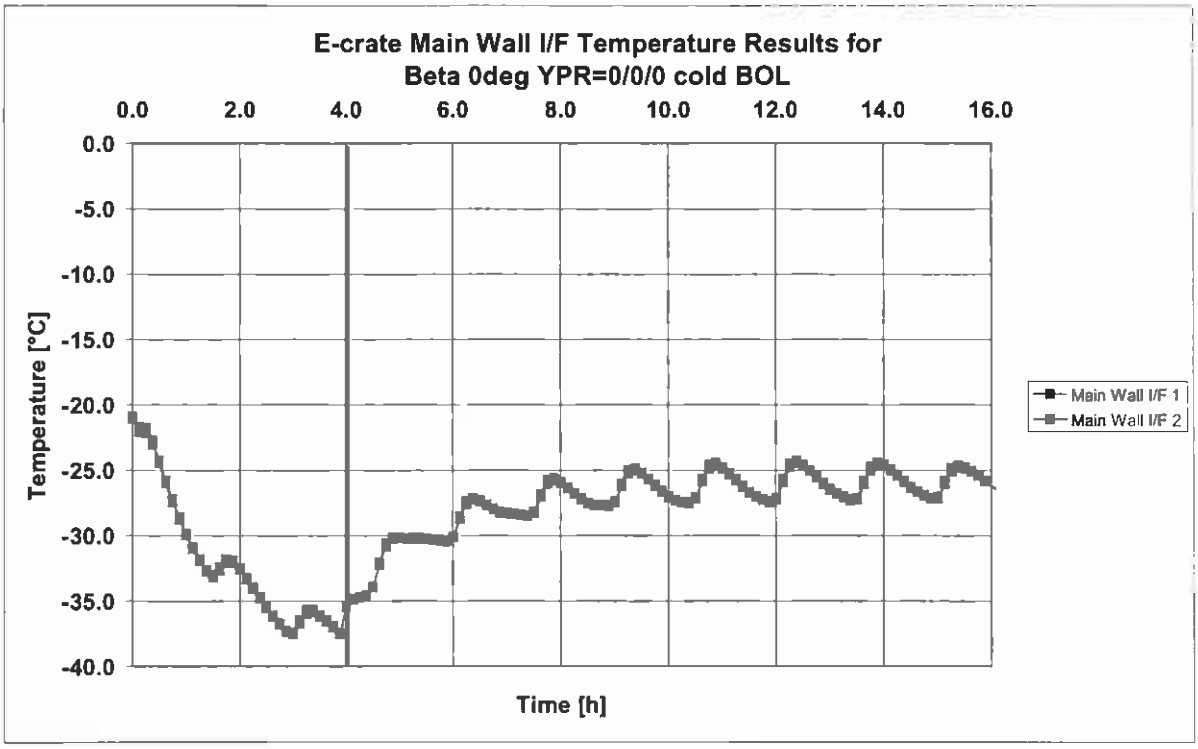

Fig. 8-51 Minimum E crates main walls I/F temperatures for orbit B_0_0_0_0 cold BOL- Minimum non-operative requirements fulfilled with the detector supported by heaters

8.3.9 TRACKER SYSTEM (TRACKER ELECTRONICS/TTCB)

The design cases for TRACKER system when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	Hand OFF	cold	**Worst cold case for Tracker system**

Tab. 8-44 TRACKER system design case in Hand-Off position

Tracker temperature is always equal to ACC temperature shown in paragraph 8.3.14 .

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8.3.10 STAR TRACKER

The design cases for Star Tracker detector when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	docked	cold	**Worst cold case for Star Tracker**

Tab. 8-45 Star Tracker detector design case in Hand-Off position

The following graphs show the Star Tracker CCDs temperatures (minimum) after the 4 unpowered hours (red line) and then the results when power is restored (not to Star Tracker since according to Tab. 6-5 it is not operative).

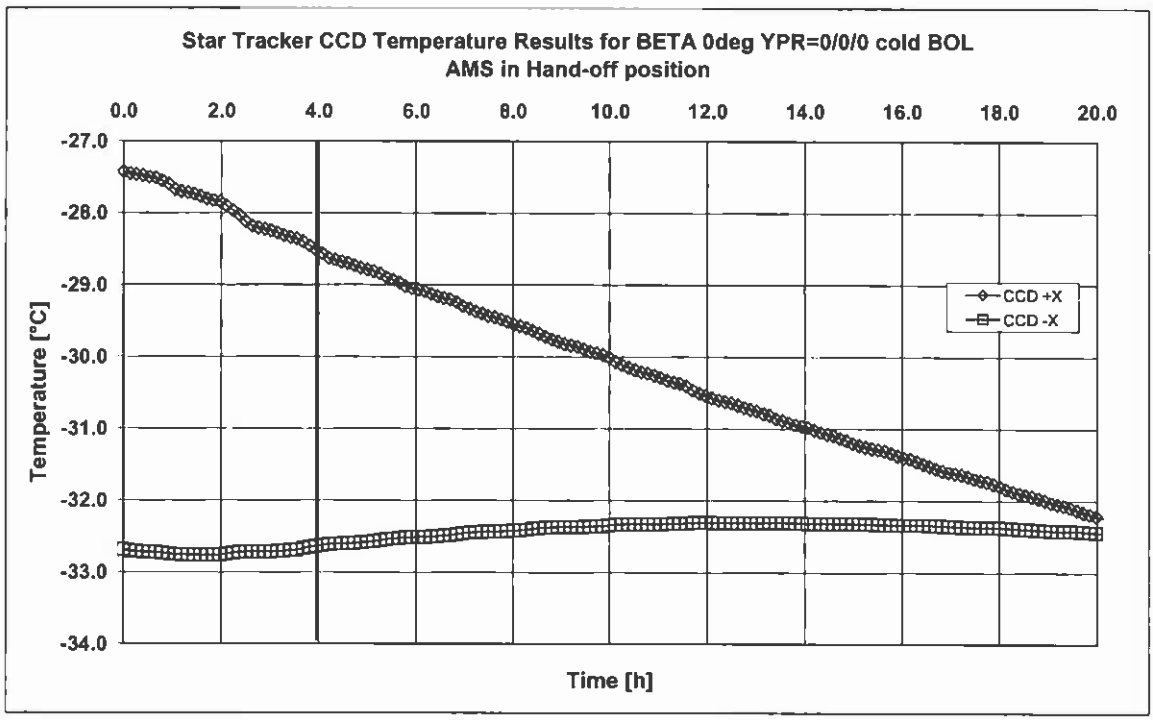

Fig. 8-52 Minimum Star Tracker CCDs temperatures for orbit B_0_0_0_0 cold BOL – Minimum non operative temperatures fulfilled.

8.3.11 CAB

The design cases for CAB unit when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0/0/0	Hand-off	COLD	**Worst cold case for wake radiator**

Tab. 8-46 CAB unit design case in Hand-Off position

Detailed results are presented in RD [9]

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8.3.12 TRD GAS BOX

The design cases for TRD Gas Box when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0 / 0 / 0	Hand off	cold	**Worst cold case for TRDGB**

Tab. 8-47 TRD Gas Box design case in Hand-Off position

The following graphs show the TRD Gas Box temperatures (minimum) after the 4 unpowered hours (red line) and then the results when power is restored (Heaters available).

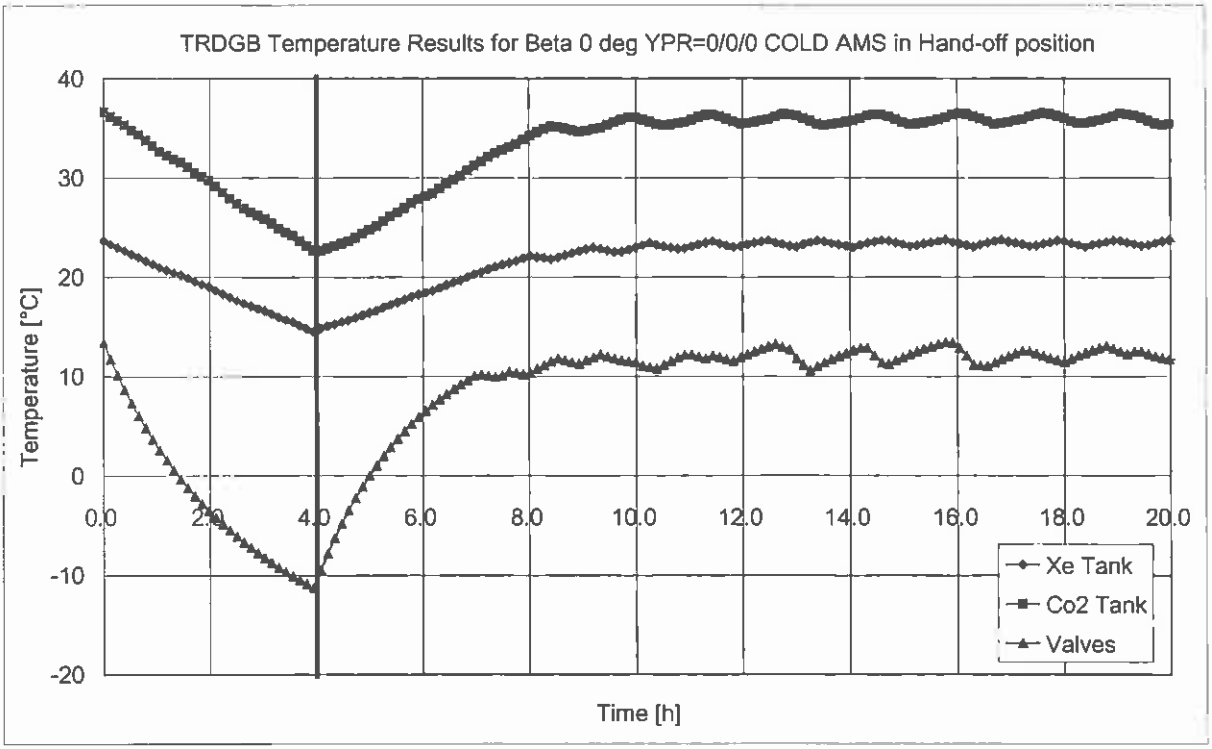

Fig. 8-53 TRD GAS BOX temperatures for orbit B_0_0_0_0 cold – Valves temperature is slightly before the non operative limit (namely -10°C) after 4 hours unpowered.

8.3.13 TRD/UPPER TOF

The design cases for TRD/ Upper TOF detector when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	Hand OFF	cold	**Worst cold case for TRD detector**

Tab. 8-48 TRD detector design case in Hand-Off position

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8.3.14 ACC

The design cases for ACC detector when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0 / 0 / 0	Hand off	cold	**Worst cold case for ACC PMTs**

Tab. 8-49 ACC PMTs design case in Hand-Off position

The following graphs show the ACC PMTs temperatures (minimum) after the 4 unpowered hours (red line) and then the results when power is restored

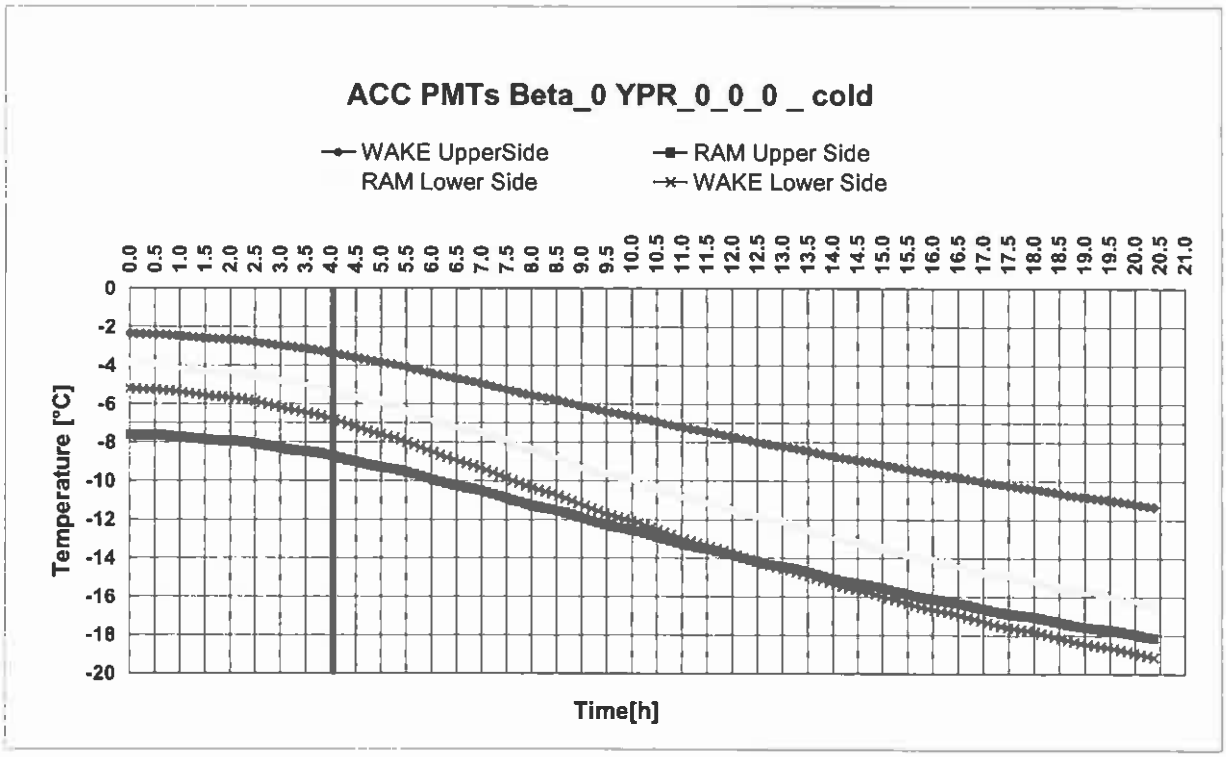

Fig. 8-54 ACC PMTs temperature for orbit B_0_0_0_0_cold - Minimum PMTs non operative temperatures fulfilled.

8.3.15 PAS

The design cases for PAS parts when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0 / 0 / 0	Hand off	cold	**Worst cold case for PAS**

Tab. 8-50 PAS design case in Hand-Off position

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The following graphs show the PAS parts temperatures (minimum) after the 4 unpowered hours (blue line) and then the results when power is restored

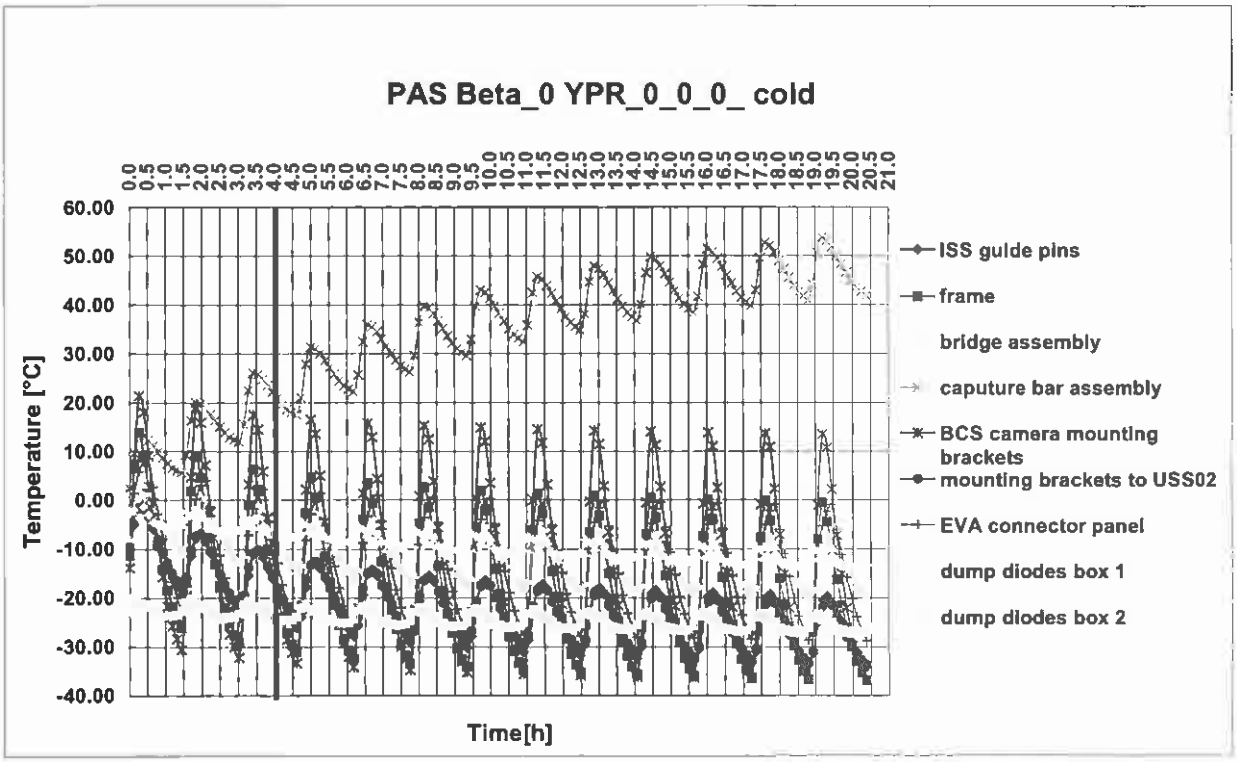

Fig. 8-55 PAS temperature for orbit B_0_0_0_0_cold

8.3.16 UPS

The design cases for UPS when AMS is in hand-off position and STS docked to the ISS is as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
0	0 / 0 / 0	Hand off	cold	**Worst cold case for UPS**

Tab. 8-51 UPS design case in Hand-Off position

The following graphs show the UPS parts temperatures (minimum) after the 4 unpowered hours (blue line) and then the results when power is restored

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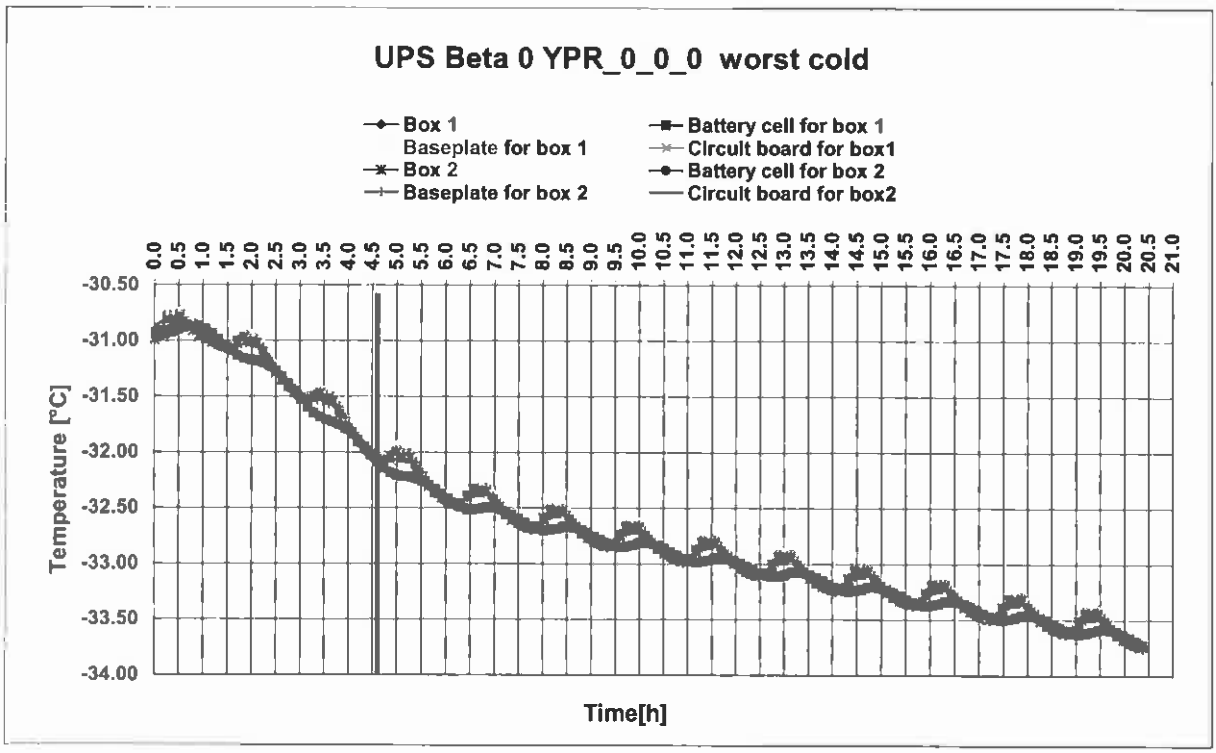

Fig. 8-56 UPS temperature for orbit B_0_0_0_0_cold- Minimum non-operative temperature requirements fulfilled

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8.4 PHASE 4: AMS-02 ON ISS TRUSS

For each detector the design cases selected and reported in Tab. 7-12 have been analyzed and results reported. The analysis has been performed considering the power profile described in Tab. 6-6.

8.4.1 HOT CASES

8.4.1.1 MAIN RADIATORS

8.4.1.1.1 RAM RADIATOR

The hottest design case for RAM radiator is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
-75	15 / -20 / 0	Undocked	Hot	**Worst hot case for Ram Radiator**

Tab. 8-52 RAM radiator hottest design case on ISS

Detailed results are presented in RD [1]

8.4.1.1.2 WAKE RADIATOR

The hottest design case for WAKE radiator is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
-75	-15/+25/-15	Undocked	Hot	**Worst hot case for wake radiator**

Tab. 8-53 WAKE radiator hottest design case on ISS

Detailed results are presented in RD [1]

8.4.1.2 ZENITH RADIATOR

The hottest design case for ZENITH radiator is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
+75	-15 / -20 / -15	Undocked	HOT	**Worst hot case for Zenith Radiator**

Tab. 8-54 ZENITH radiator hottest design case on ISS

The following graphs show the temperatures of the Zenith radiator being the cryo cooler dissipation evenly distributed on the 4 zenith radiators panels.

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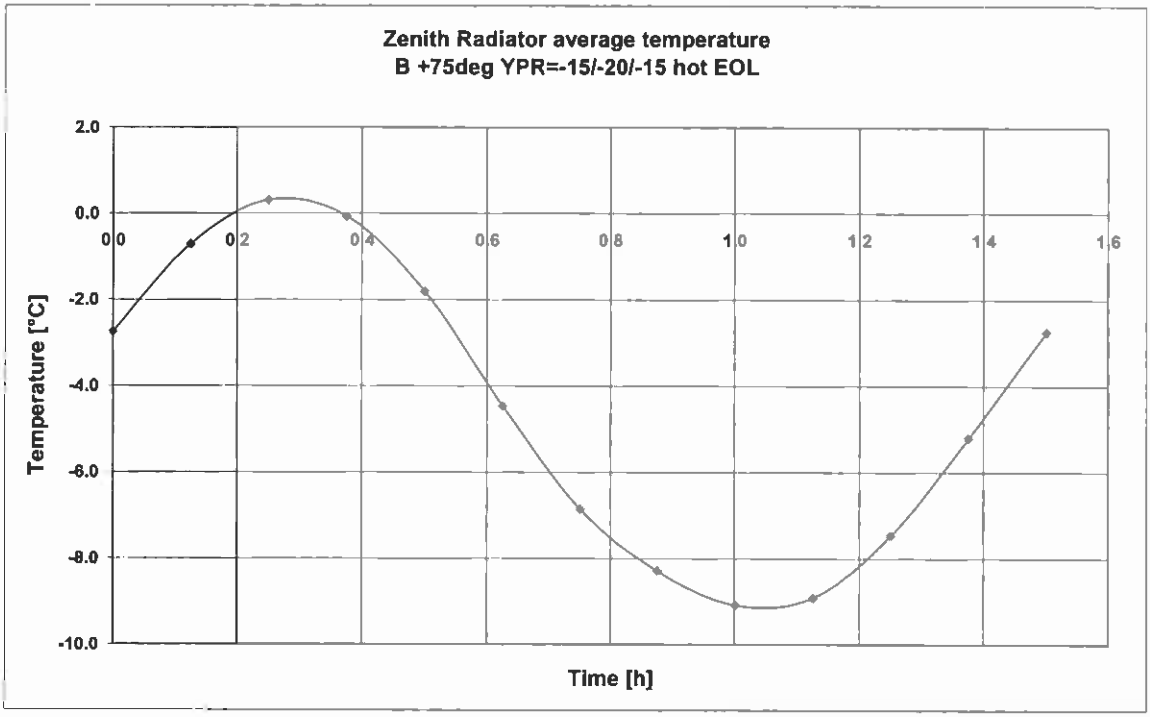

Fig. 8-57 Zenith radiator average temperature for orbit B+75-15-20-15 hot EOL operative. This is just for information.

8.4.1.3 CRYOCOOLER

The hottest design cases for Cryocoolers when AMS-02 experiment is on ISS are the one presented in Tab. 8-54. Detailed results are included in RD [10]

8.4.1.4 RICH

The hottest design case for RICH detector is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
-75	-15 / 0 / 0	Undocked	HOT	**Worst hot case for RICH**

Tab. 8-55 RICH detector hottest design case on ISS

RICH PMTs temperatures for this extreme orbit are presented in the following graph:

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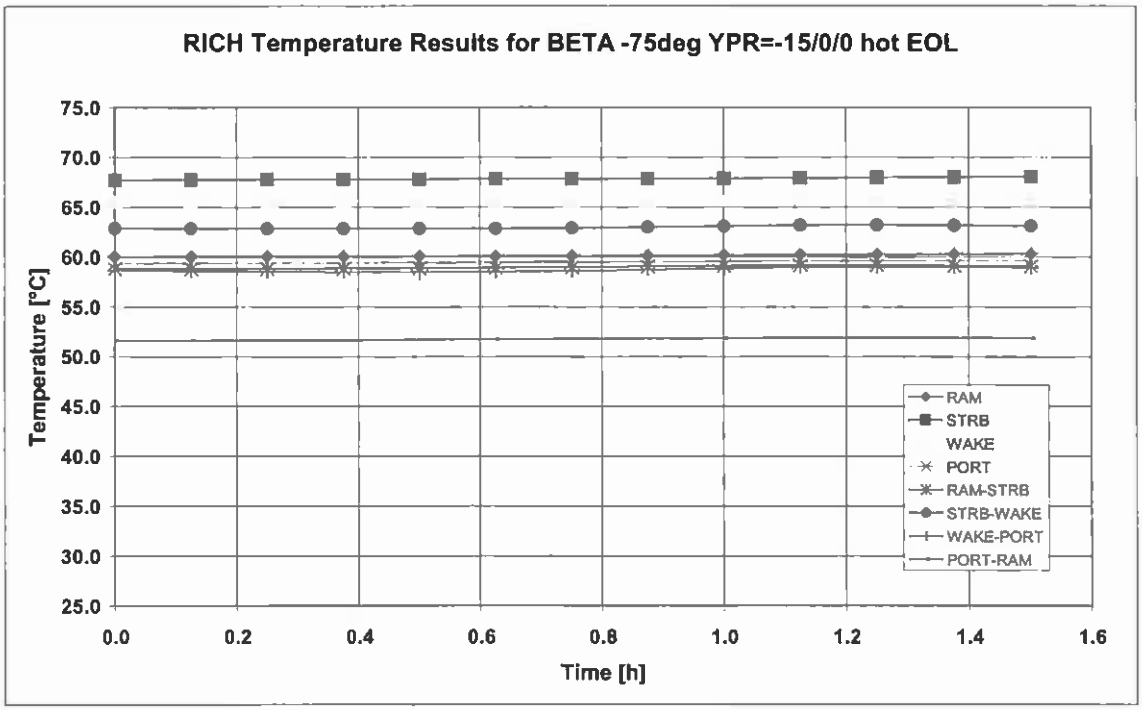

Fig. 8-58 Maximum RICH PMTs temperatures for orbit B-75-15_0_0 hot EOL . RICH is operative.

Since the PMTs temperature is higher than the maximum temperature allowed, in this ISS attitude RICH has to be switched OFF. Below the PMTs results when RICH detector id OFF.

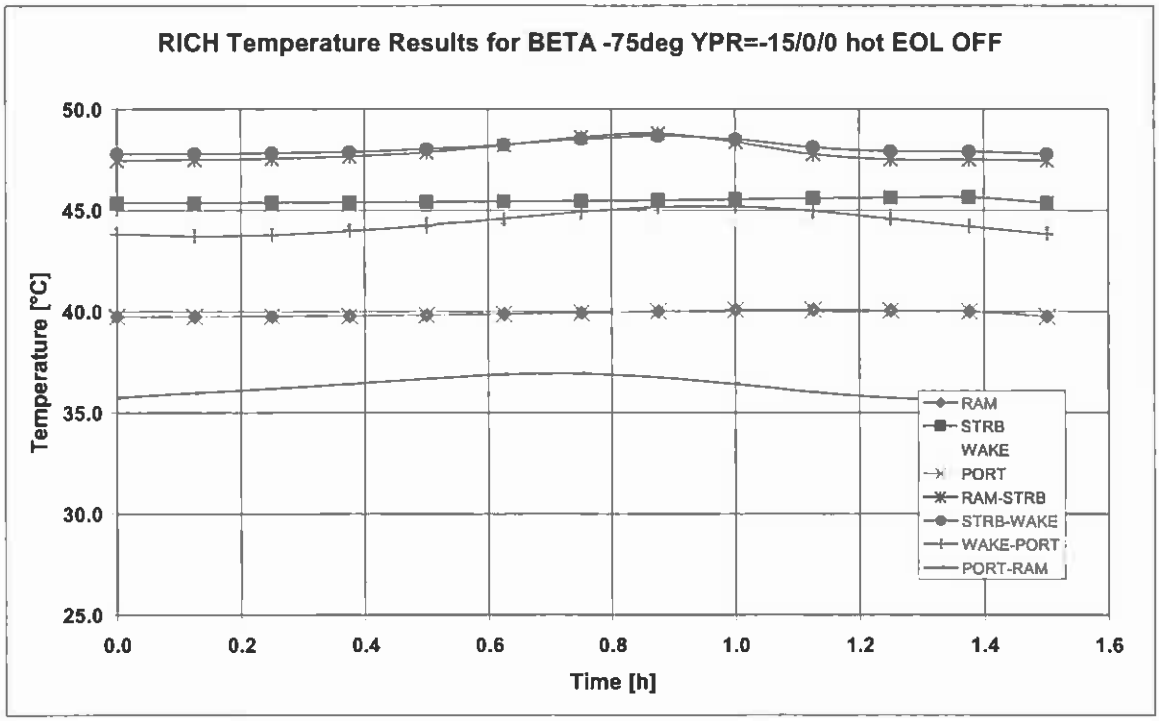

Fig. 8-59 Maximum RICH PMTs temperatures for orbit B-75-15_0_0 hot EOL. RICH is not operative. Non operative temperature requirements are fulfilled.

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The Beta range RICH detector can work continuosly is as follows:

-55 deg to +75 deg

That in terms of time means 92.7% in terms of mission time.

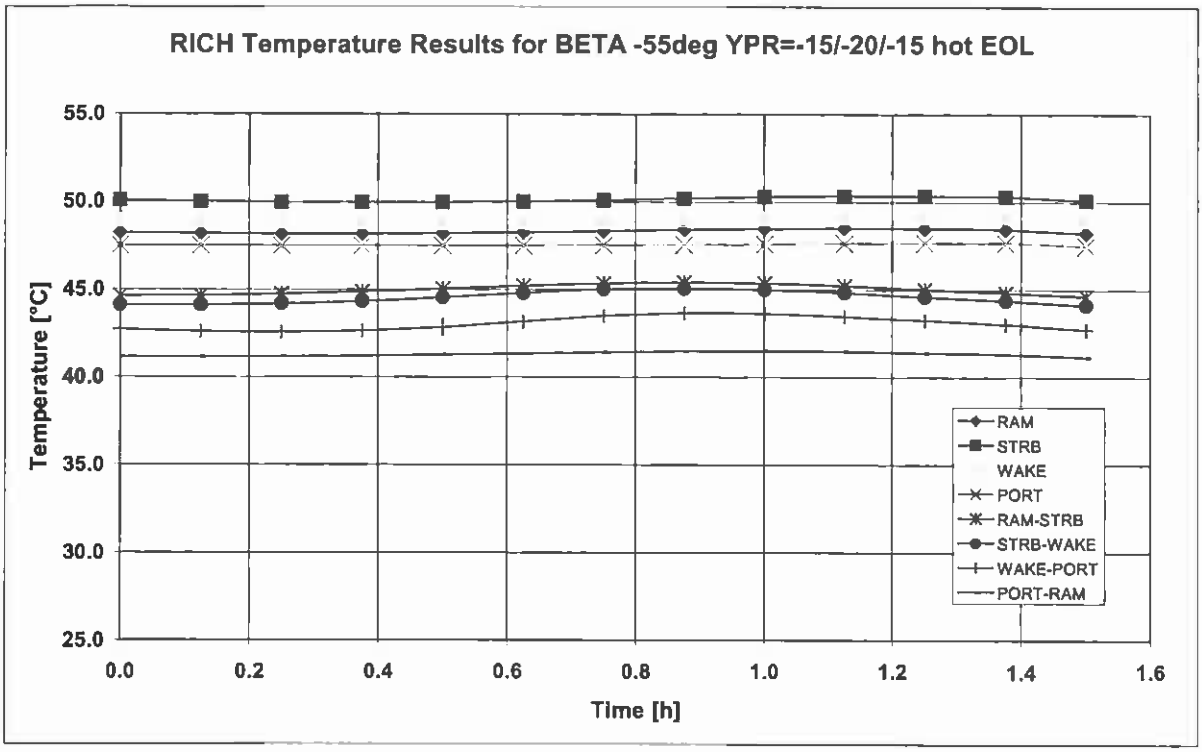

Fig. 8-60 Maximum RICH PMTs temperatures for orbit B-55-15-20-15 hot EOL . RICH is operative. Maximum operative temperature requirements are fulfilled.

Heaters failure on analysis

In case of heaters failure, the system must not exceed the maximum touch temperature, namely 113°C. Considering the worst hot case with RICH operative and the heaters ON at 126.5Vdc (maximum voltage), RICH PMTs temperatures are presented in the following graph

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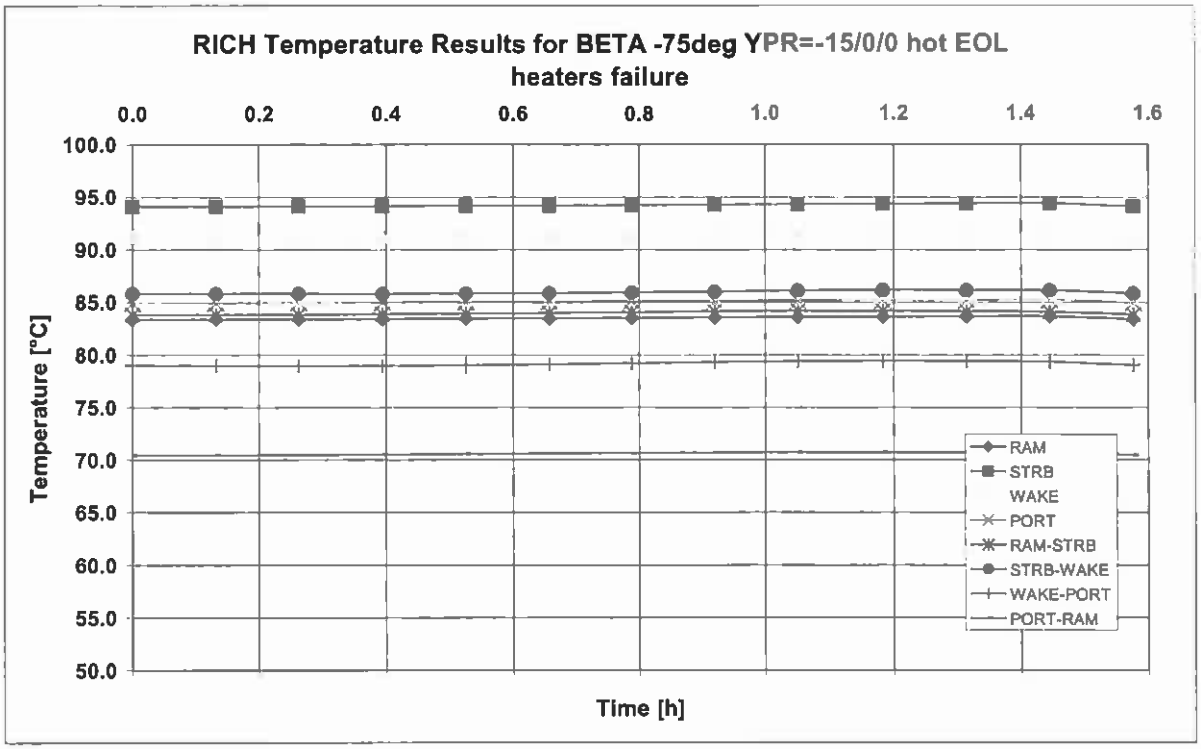

Fig. 8-61 Maximum RICH PMTs temperatures for orbit B-75-15_0_0 hot EOL . RICH is operative. Heaters ON.

8.4.1.5 LOWER TOF

The hottest design case for the LOWER TOF detector is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
-75	-15 / 0 / 0	undocked	HOT	**Worst hot case for LOWER TOF**

Tab. 8-56 Lower TOF detector hottest design case on ISS

LOWER TOF PMTs temperatures for this extreme orbit are presented in the following graph:

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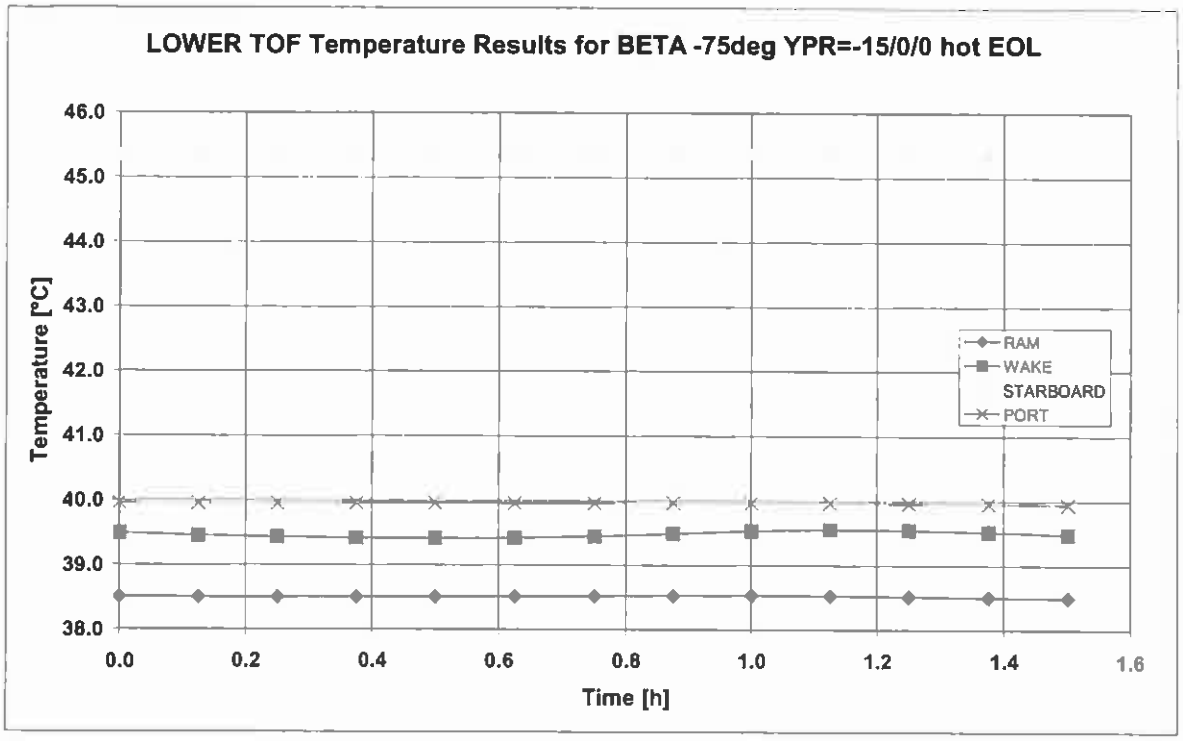

Fig. 8-62 Maximum lower TOF PMTs temperatures for orbit B-75-15_0_0 hot EOL . LOWER TOF is operative and maximum allowed temperatures requirements are fulfilled

Heaters failure on analysis

In case of heaters failure, the system must not exceed the maximum touch temperature, equal to 113°C. Considering the worst hot case with Lower Tof operative and the heaters ON at 126.5Vdc (maximum voltage), ToF PMTs temperatures are presented in the following graph

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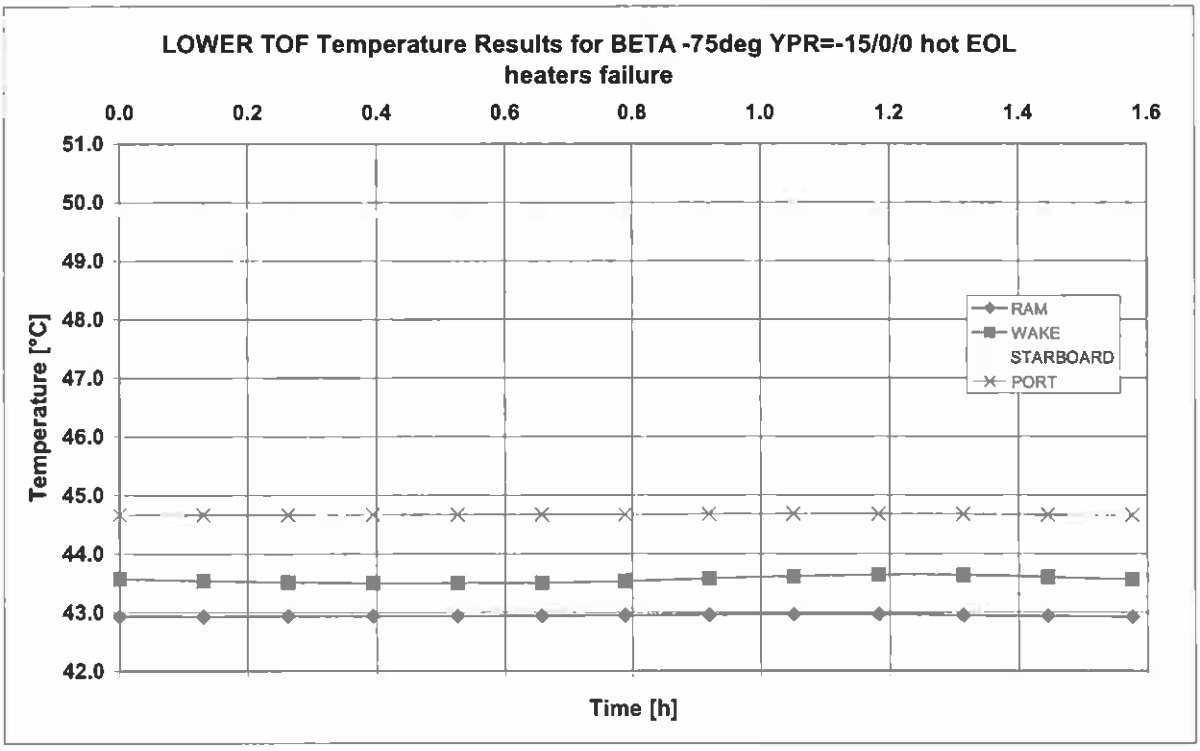

Fig. 8-63 Maximum Lower Tof PMTs temperatures for orbit B-75-15_0_0 hot EOL . Lower Tof is operative. Heaters ON.

8.4.1.6 ECAL

The hottest design case for the ECAL detector is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
-75	-15 / 0 / 0	Undocked	HOT	**Worst hot case for ECAL**

Tab. 8-57 ECAL detector hottest design case on ISS

ECAL PMTs detailed results are presented in RD [5]

8.4.1.7 RHV/EHV BRICKS

The hottest design case for the RHV/EHV bricks is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
-75	-15 / 0 / 0	undocked	HOT	**Worst hot case for EHV and RHV**

Tab. 8-58 EHV/RHV bricks hottest design case on ISS

EHV/RHV bricks detailed results are presented in RD [6]

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8.4.1.8 E-CRATE

The hottest design case for the E crates is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
-75	-15 / 0 / 0	undocked	HOT	**Worst hot case for E crates**

Tab. 8-59 E crates hottest design case on ISS

E crates main walls I/F temperatures for this extreme orbit are presented in the following graph:

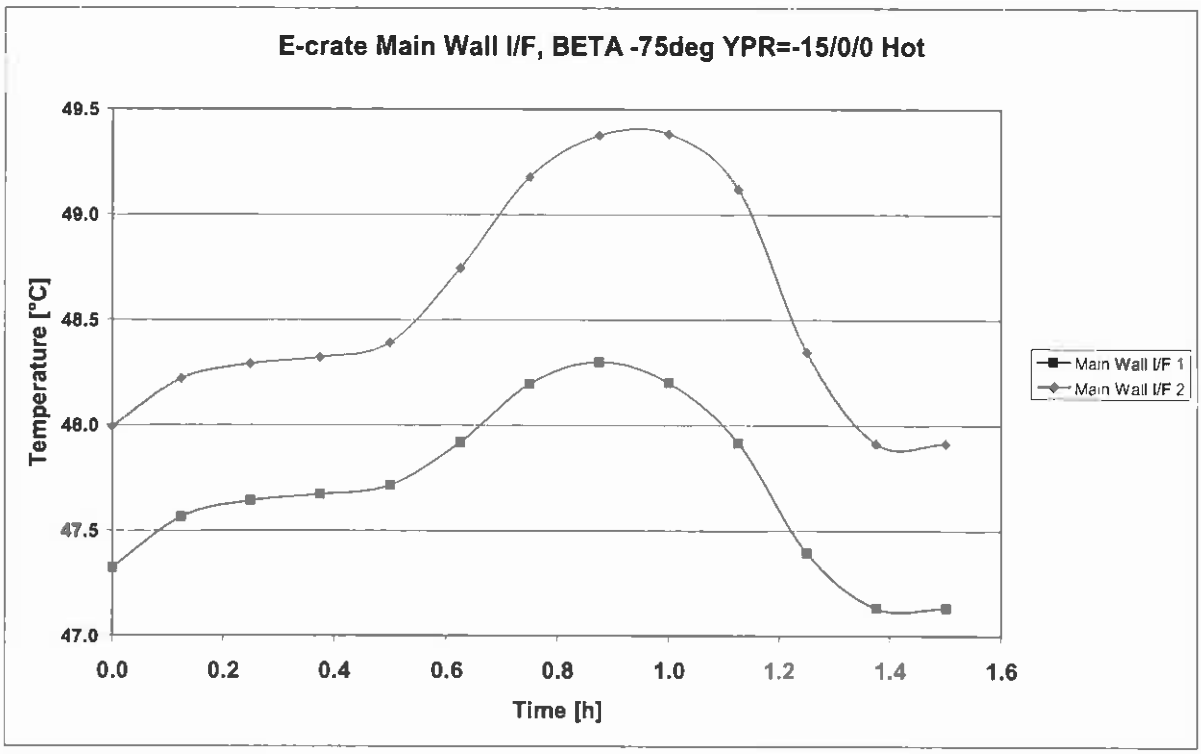

Fig. 8-64 Maximum E crates main walls I/F temperatures for orbit B-75-15_0_0 hot EOL . E crates are operative and maximum allowed temperatures requirements are fulfilled

Heaters failure on analysis

In case of heaters failure, the system must not exceed the maximum touch temperature, equal to 113°C.
Considering the worst hot case with E crates operative and the heaters ON at 126.5Vdc (maximum voltage), E crates main walls I/F temperatures are presented in the following graph

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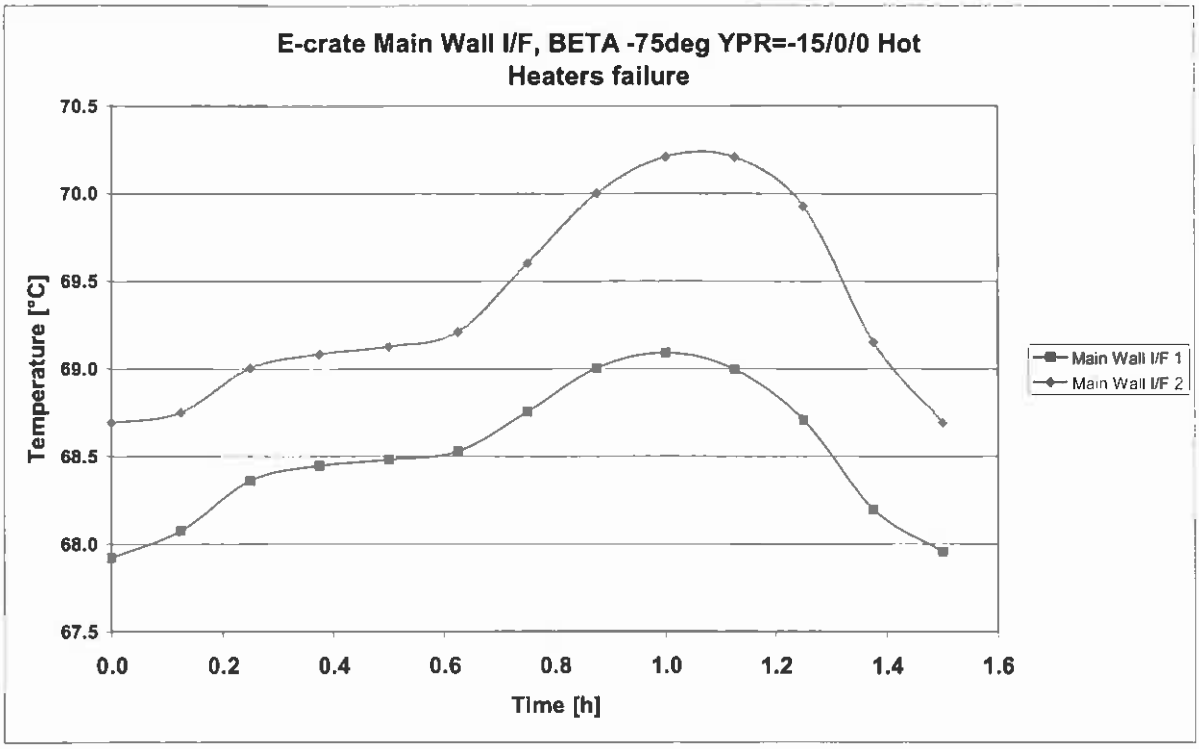

Fig. 8-65 Maximum E crates main walls I/F temperatures for orbit B-75-15_0_0 hot EOL . E crate is operative. Heaters ON.

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8.4.1.9 TRACKER SYSTEM (TRACKER ELECTRONICS/TTCB)

The hottest design case for the TRACKER detector when AMS-02 experiment is on ISS is as follows:

BETA	Attitude	STS	Enviroment	Remarks/Rationale
+75	-15 / -20 / -15	Undocked	HOT	**Worst hot case EOL**

Tab. 8-60 TRACKER RAM radiator hottest design case on ISS

BETA	Attitude	STS	Enviroment	Remarks/Rationale
+75	-15 / -20 / -15	Undocked	HOT	**Worst hot case EOL**

Tab. 8-61 TRACKER WAKE radiator hottest design case on ISS

RD [1] shows that Tracker radiators provide a suitable sink for the TTCS to operate within -15°C to 15°C.

8.4.1.10 STAR TRACKER

The hottest design case for the STAR TRACKER detector when AMS-02 experiment is on ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
+75	-15 / -20 / -15	undocked	HOT	**Worst hot case for Star Tracker CCD**

Tab. 8-62 STAR TRACKER hottest design case on ISS

Considering a loop set point at 288K, Star Tracker CCDs temperatures for this extreme orbit are presented in the following graph:

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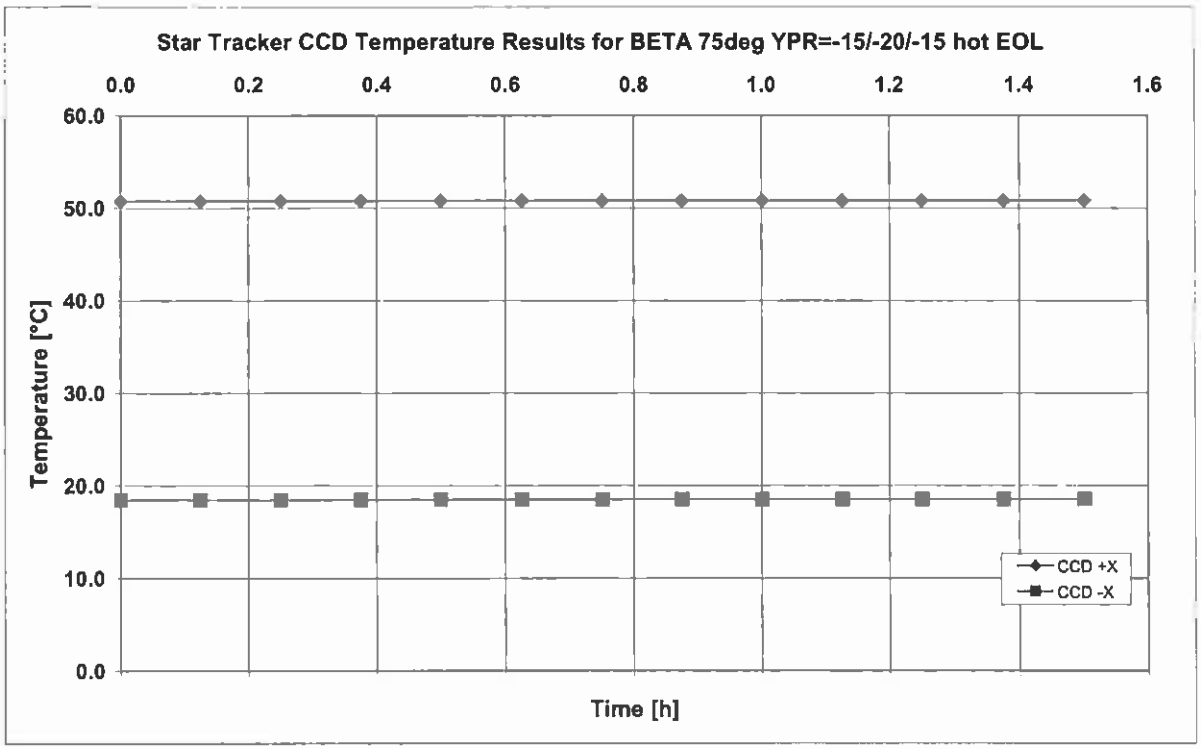

Fig. 8-66 Star Tracker CCDs temperatures for orbit B+75-15-20-15 hot EOL. Star Tracker is operative. Temperature requirementas are fulfilled

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8.4.1.11 VACUUM CASE

The hottest design case for the Vacuum parts when AMS-02 experiment is on ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
+75	-15 / -20 / -15	undocked	HOT	**Worst hot case for Vacuum Case**

Tab. 8-63 Vacuum Case hottest design case on ISS

The Vacuum Case surface-weighted average temperature for this extreme orbit is presented in the following graph.

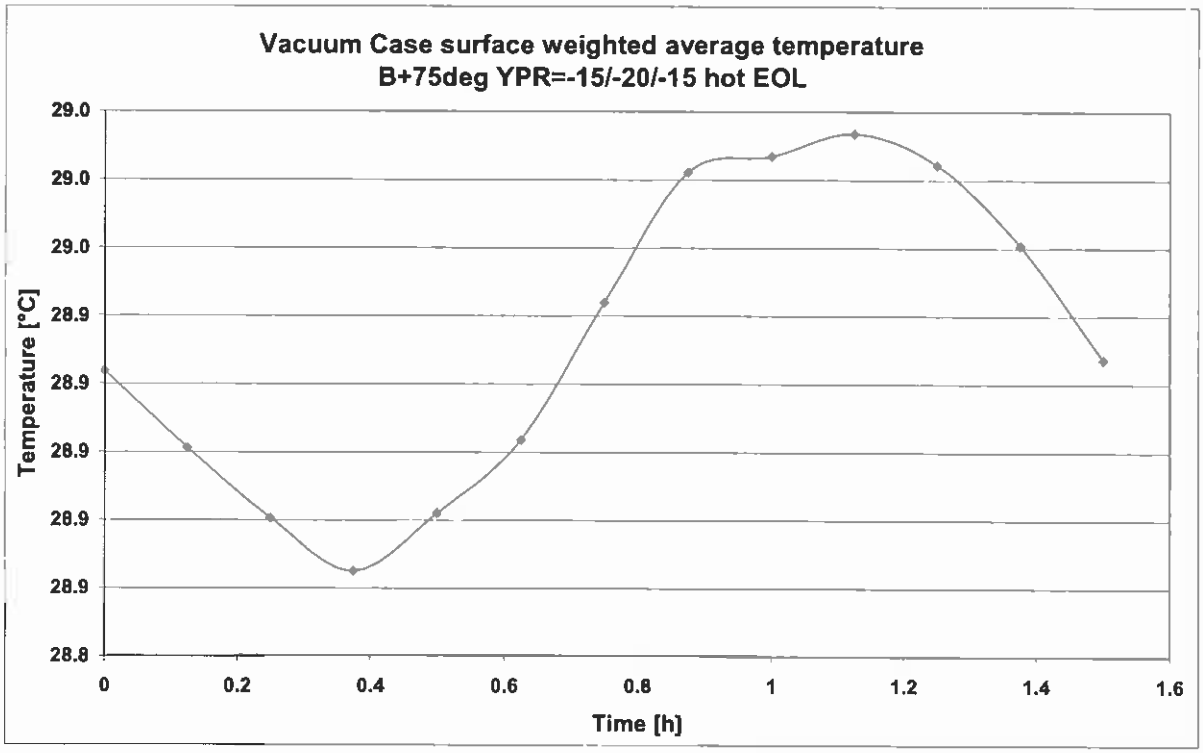

Fig. 8-67 Vacuum Case surface-weighted average temperature for orbit B+75-15-20-15 hot EOL.

8.4.1.12 CAB

The hottest design case for CAB unit is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
-75	-15/+25/ 15	Undocked	HOT	**Worst hot case for CAB**

Tab. 8-64 WAKE radiator hottest design case on ISS

Detailed results are presented in RD [8]

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8.4.1.13 TRD GAS BOX

The hottest design case for TRD Gas box is as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
+75	-15 / -20 / -15	Undocked	HOT	**Worst hot case for TRDGB**

Tab. 8-65 TRD Gas Box hottest design case on ISS

The TRD GAS BOX temperatures for this extreme orbit is presented in the following graph.

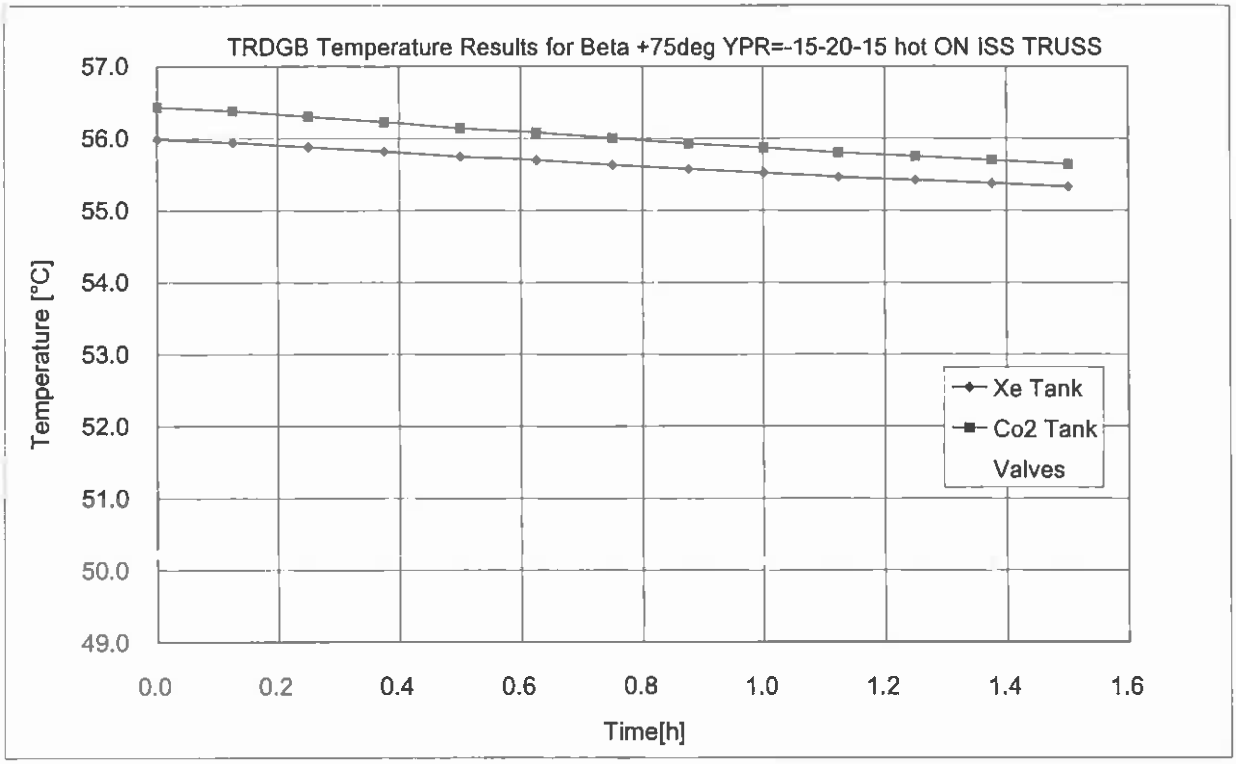

Fig. 8-68 TRD GAS BOX temperature results for orbit B+75-15-20-15 hot . TRD Gas Box is operative

8.4.1.14 TRD/UPPER TOF

The hottest design case for TRD detector is as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
+75	-15 / -20 / -15	Undocked	HOT	**Worst hot case for TRD**

Tab. 8-66 TRD detector hottest design case on ISS

TRD temperatures are presented in RD [2]

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8.4.1.15 ACC PMTS

The hottest design case for ACC detector is as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
75	-15/-20/+15	undocked	HOT	**Worst hot case for ACC PMTs**

Tab. 8-67 ACC detector hottest design case on ISS

The ACC PMTs temperatures for this extreme orbit are presented in the following graph.

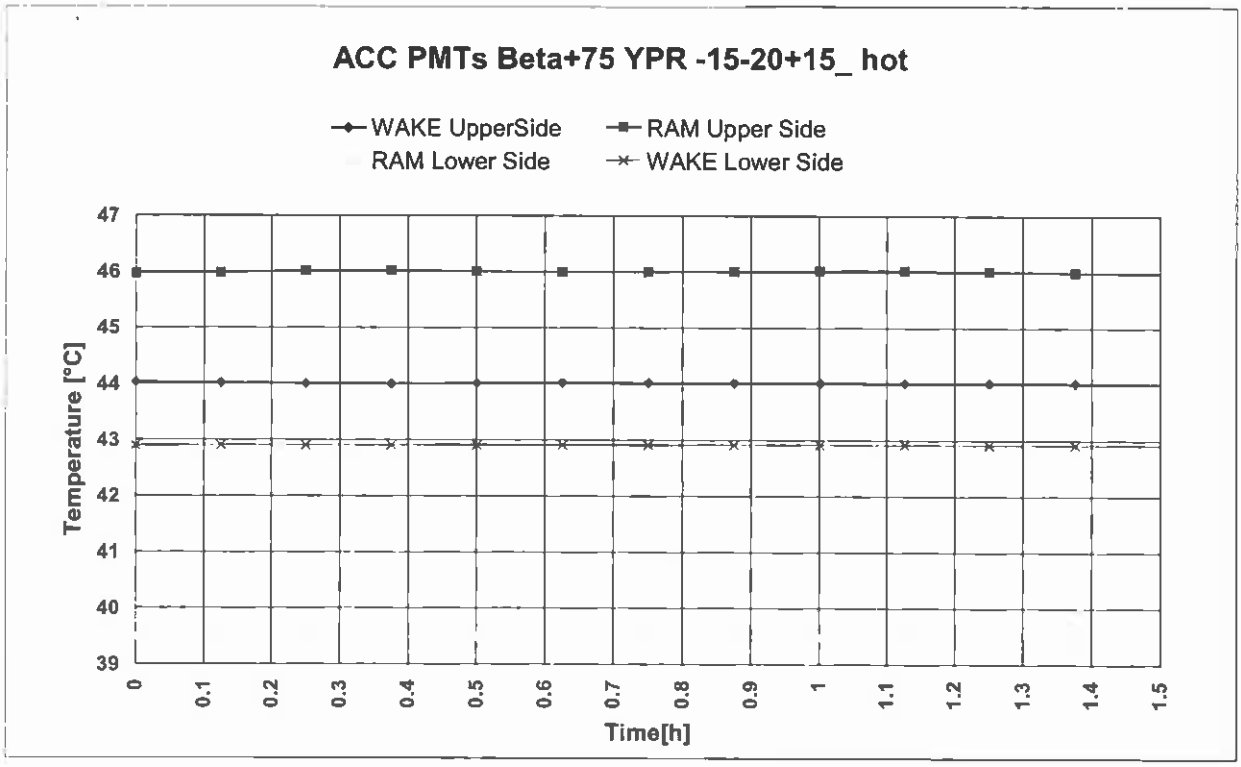

Fig. 8-69 ACC PMTs for orbit B+75-15-20+15_hot . Maximum operative temperature requirements fulfilled

8.4.1.16 PAS

The hottest design case for PAS is as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
-75	-15/-20/-15	undocked	HOT	**Worst hot case for PAS**

Tab. 8-68 PAS hottest design case on ISS

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The PAS temperatures for this extreme orbit are presented in the following graph.

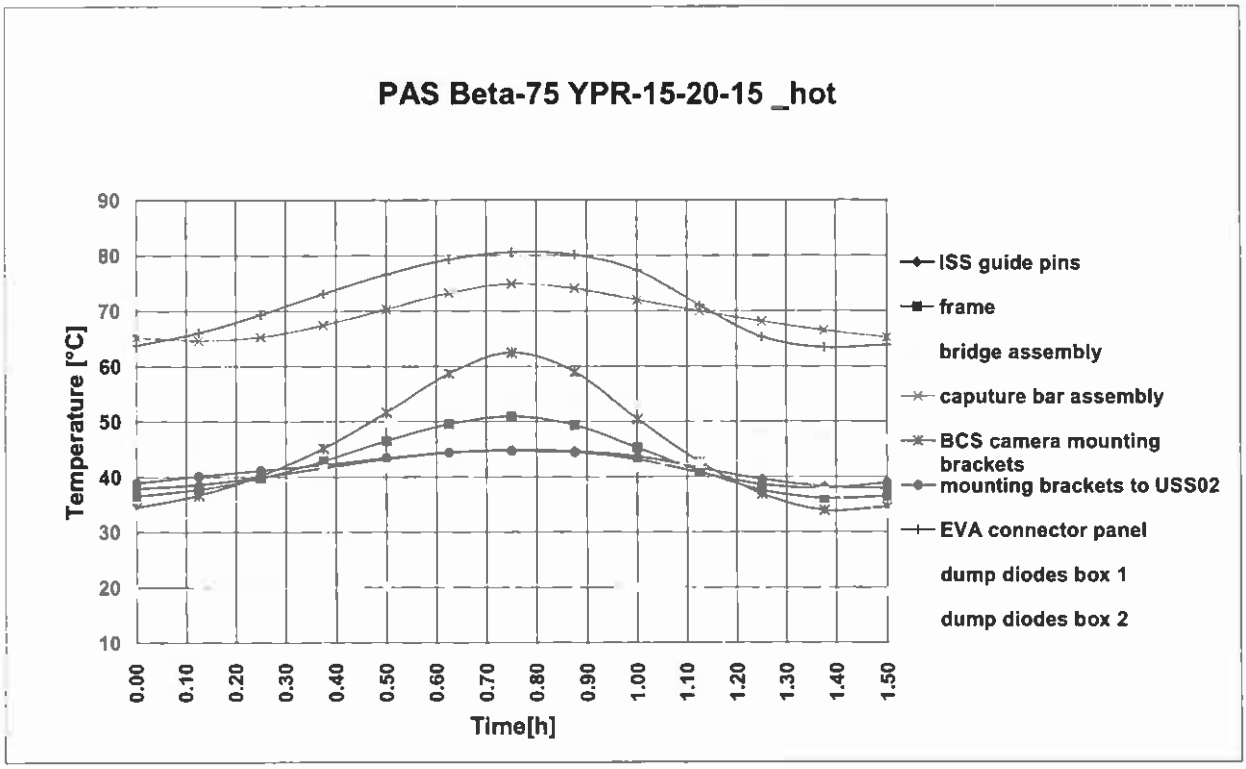

Fig. 8-70 PAS for orbit B-75-15-20-15_hot

8.4.1.17 UPS

The hottest design case for UPS is as follows:

BETA	YPR	STS	Environment	Remarks/Rationale
-75	-15/_0/_0	undocked	HOT	Worst hot case for UPS

Tab. 8-69 UPS hottest design case on ISS

The UPS temperatures for this extreme orbit are presented in the following graph.

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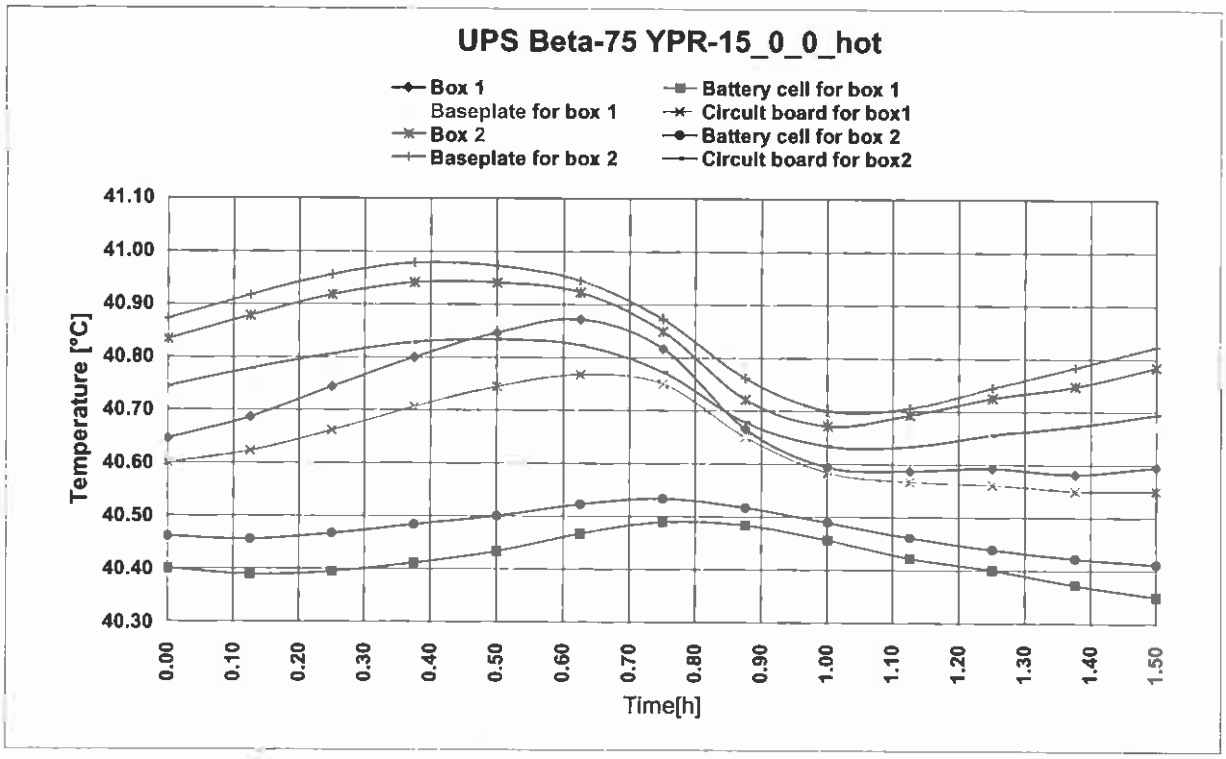

Fig. 8-71 UPS for orbit B-75-15-0_0_hot

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8.4.2 COLD CASES

8.4.2.1 MAIN RADIATORS

8.4.2.1.1 RAM RADIATOR

The coldest design case for Main Ram radiator when AMS is on ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	-15 / +25 / -15	Undocked	cold	**Worst cold case for Ram Radiator**

Tab. 8-70 Ram radiator coldest design case on ISS

Results are presented in RD [1]

8.4.2.1.2 WAKE RADIATOR

The coldest design case for Main Wake radiator when AMS is on ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	15/-20/-15	undocked	COLD	**Worst cold case for wake radiator**

Tab. 8-71 Wake radiator coldest design case on ISS

Results are presented in RD [1]

8.4.2.2 ZENITH RADIATOR

The coldest design case for Zenith radiator when AMS is on ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
+75	-15 / +15 / +15	undocked	COLD	**Worst cold case for Zenith radiator**

Tab. 8-72 Zenith radiator coldest design case on ISS

The following graphs show the temperatures of the Zenith radiator being the cryo cooler dissipation evenly distributed on the 4 zenith radiators panels.
Detailed analysis are included in RD [10].

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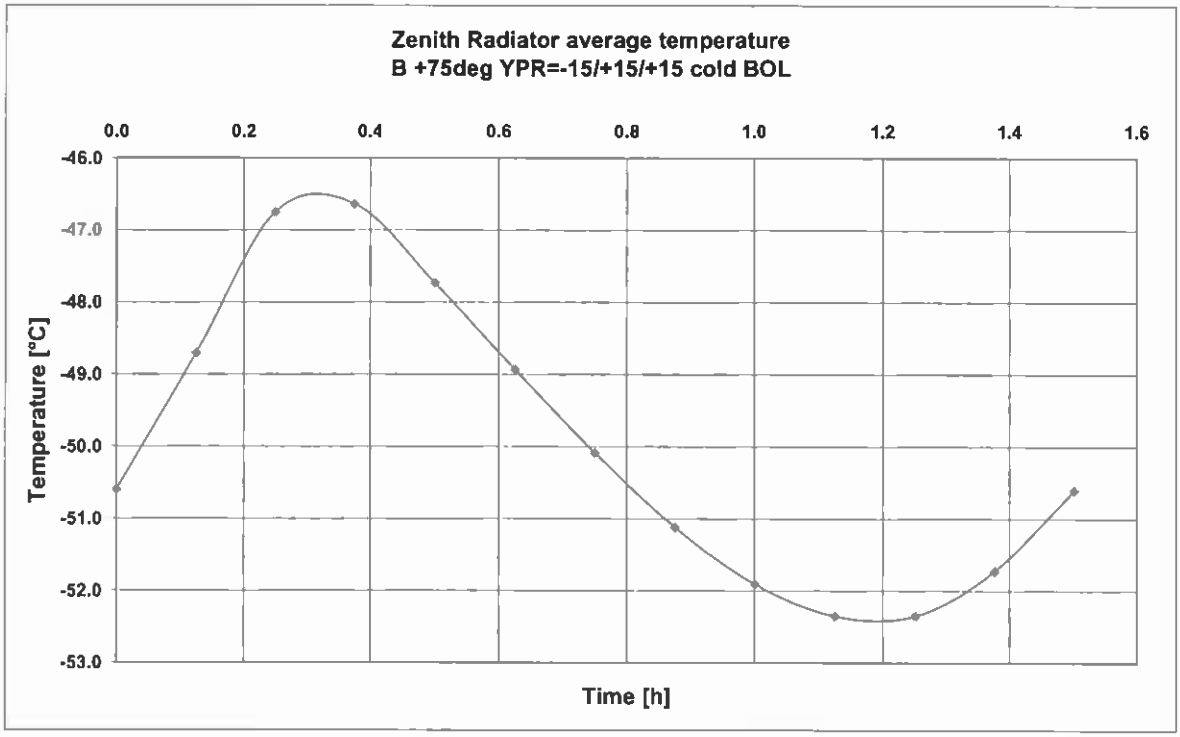

Fig. 8-72 Zenith radiator average temperature for orbit B_0_0_0_0 cold BOL

8.4.2.3 CRYOCOOLER

The coldest design cases for Cryocoolers when AMS is on ISS are described in Tab. 8-72.
Detailed analysis are included in RD [10]

8.4.2.4 RICH

The coldest design case for RICH detector when AMS is on ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
+25	-15 / -20 / -15	Undocked	COLD	**Worst cold case for RICH**

Tab. 8-73 RICH detector coldest design case on ISS

RICH PMTs temperatures for this extreme orbit are presented in the following graph for the operative case.

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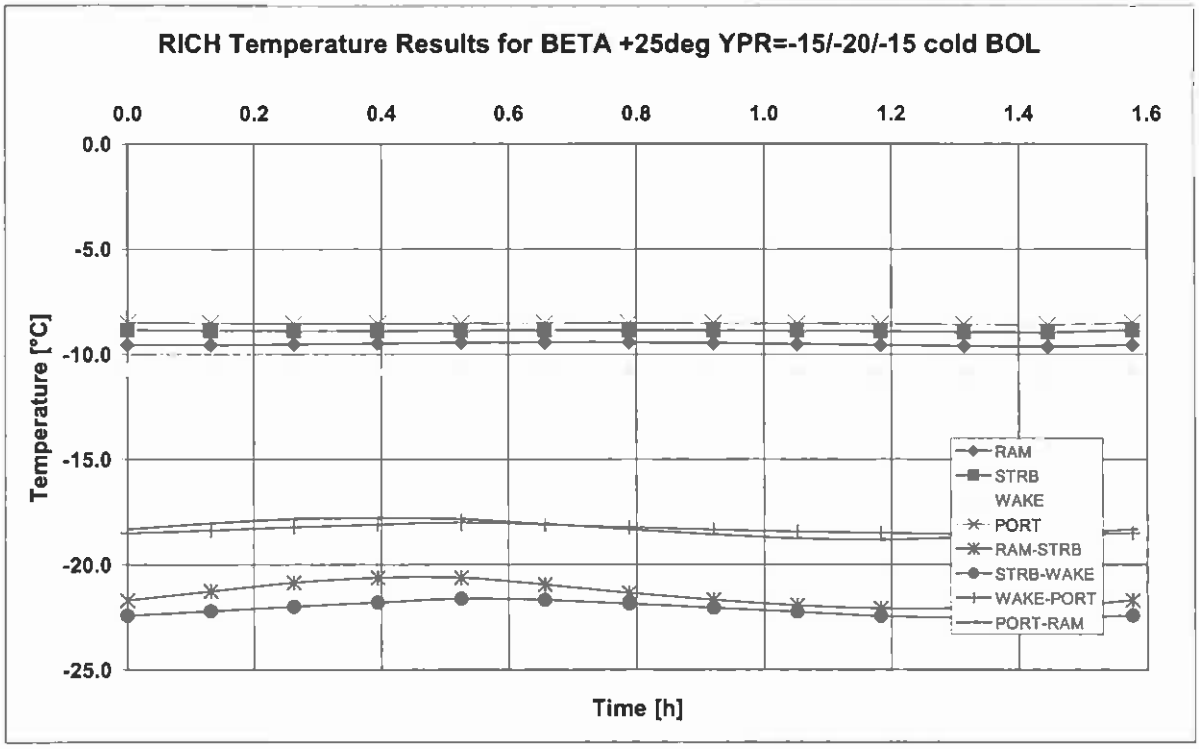

Fig. 8-73 Minimum RICH PMTs temperatures for orbit B+25-15-20-15 cold BOL. RICH is operative.

The temperatures reached for this coldest orbit are within the operational range.

8.4.2.5 LOWER TOF

The coldest design case for Lower Tof detector when AMS is on ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
+25	-15 / -20 / -15	undocked	COLD	**Worst cold case for LOWER TOF**

Tab. 8-74 Lower Tof detector coldest design case on ISS

Lower Tof PMTs temperatures for this extreme orbit are presented in the following graph for the operative case:

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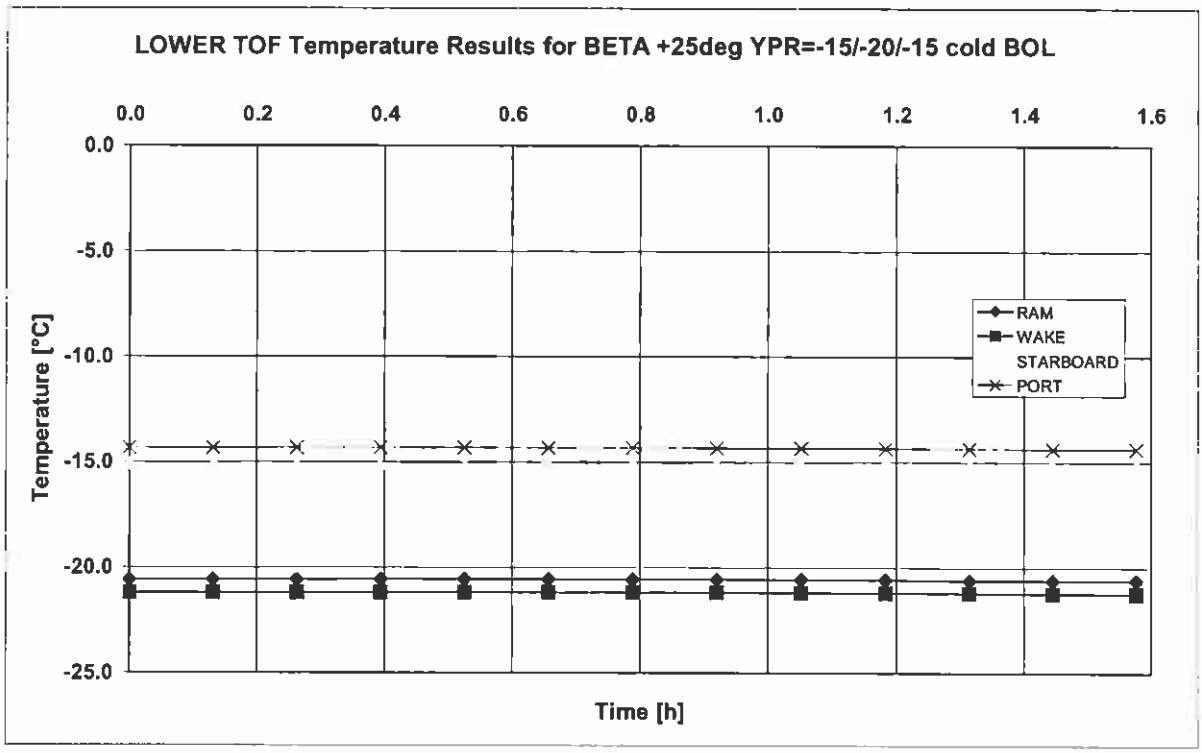

Fig. 8-74 Minimum Lower Tof PMTs temperatures for orbit B+25-15-20-15 cold BOL . Low Tof is operative

The temperatures reached for this worst cold orbit are within the operational range.

8.4.2.6 ECAL

The coldest design case for ECAL when AMS is on the ISS truss is the following one:

BETA	YPR	STS	Enviroment	Remarks/Rationale
+25	-15 / -20 / -15	undocked	COLD	**Worst cold case for ECAL**

Tab. 8-75 ECAL detector coldest design case on ISS

Detailed results are presented in RD [5]

8.4.2.7 EHV/RHV BRICKS

The coldest design case for EHV and RHV bricks when AMS is on the ISS truss is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	undocked	COLD	**Worst cold case for EHV and RHV**

Tab. 8-76 EHV/RHV brick detector coldest design case on ISS

Detailed results are presented in RD [6]

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8.4.2.8 E-CRATE

The coldest design case for E crates when AMS is on ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	undocked	COLD	**Worst cold case for E CRATES**

Tab. 8-77 E crates coldest design case on ISS

E crates main walls I/F temperatures for this extreme orbit are presented in the following graph for the operative case:

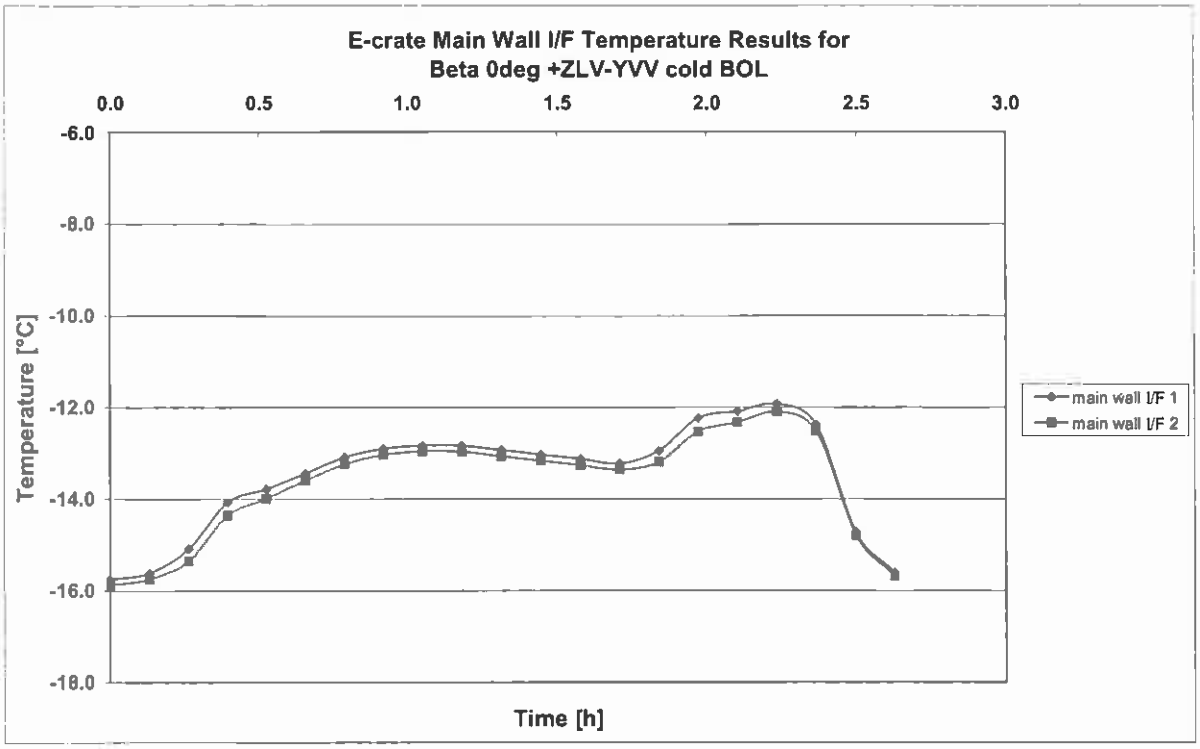

Fig. 8-75 Minimum E crates main walls I/F temperatures for orbit B_0_0_0_0 cold BOL . E crates are operative

The temperatures reached for this worst cold orbit are within the operational range, with 30W heater power.

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8.4.2.9 TRACKER SYSTEM (TRACKER ELECTRONICS/TTCB)

The coldest design case for the TRACKER detector when AMS-02 experiment is on ISS is as follows:

BETA	Attitude	STS	Enviroment	Remarks/Rationale
+60	+15 / +15 / +15	Undocked	COLD	**Worst cold case BOL**

Tab. 8-78 TRACKER RAM radiator hottest design case on ISS

BETA	Attitude	STS	Enviroment	Remarks/Rationale
+75	+15 / +15 / +15	Undocked	COLD	**Worst cold case BOL**

Tab. 8-79 TRACKER WAKE radiator hottest design case on ISS

NLR team is in charge of this analysis.

8.4.2.10 STAR TRACKER

The coldest design case for the STAR TRACKER detector when AMS-02 experiment is on ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	Undocked	COLD	**Worst cold case for Star Tracker**

Tab. 8-80 STAR TRACKER coldest design case on ISS

Considering a loop set point at 263K, Star Tracker CCDs temperatures for this extreme orbit are presented in the following graph for the operative case.

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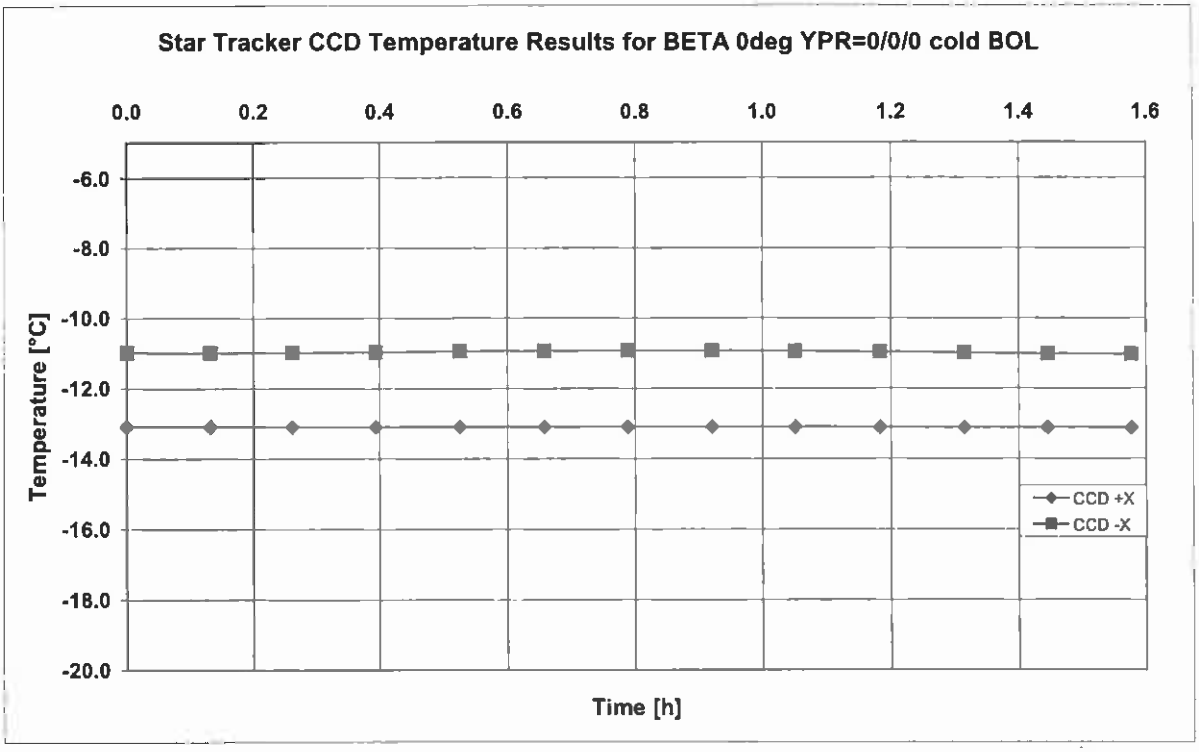

Fig. 8-76 Star Tracker CCDs temperatures for orbit B_0_0_0_0 cold BOL operative

The temperatures reached are within the operational range.

8.4.2.11 VACUUM CASE

The coldest design case for the Vacuum Case when AMS-02 experiment is on ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / 0	undocked	COLD	**Worst cold case for Vacuum Case**

Tab. 8-81 Vacuum Case coldest design case on ISS

The Vacuum Case surface-weighted average temperature for this extreme orbit is presented in the following graph.

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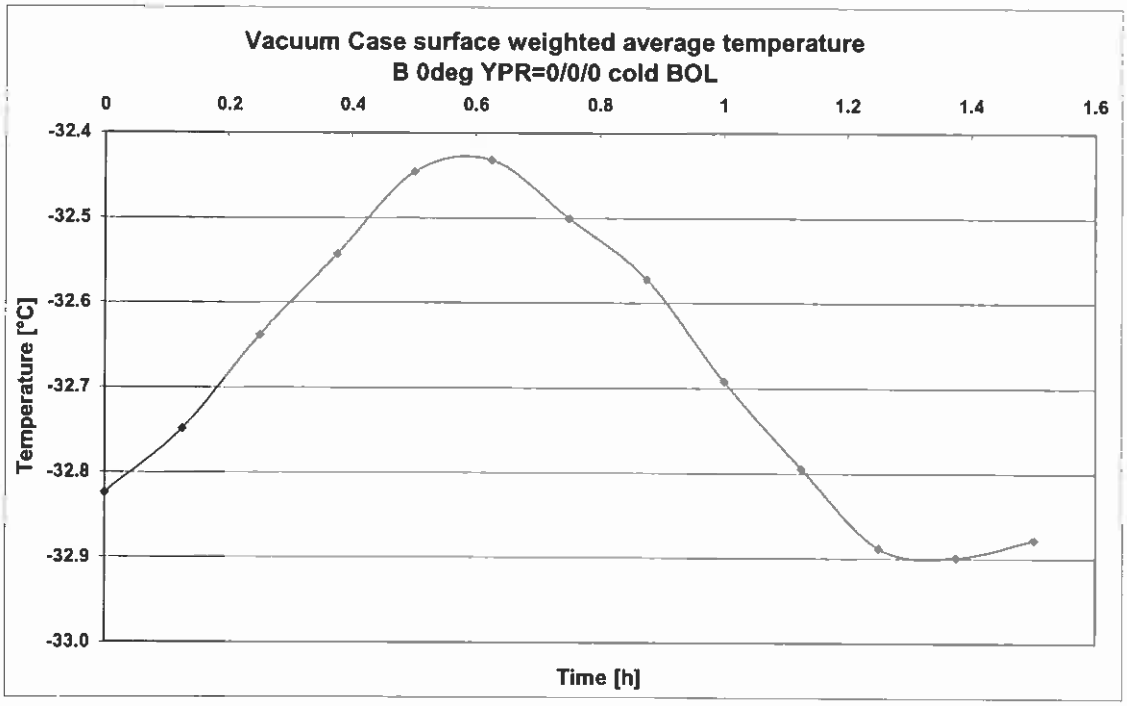

Fig. 8-77 Vacuum Case surface-weighted average temperature for orbit B_0_0_0_0 cold BOL

8.4.2.12 CAB

The coldest design case for the CAB unit when AMS-02 experiment is on ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
75	-15 /-20 / 15	Undocked	COLD	**Worst cold case for Star Tracker**

Tab. 8-82 CAB unit coldest design case on ISS

Results are presented in RD [8]

8.4.2.13 TRD GAS BOX

The coldest design case for the TRD Gas Box when AMS-02 experiment is on ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 /0 / 0	Undocked	COLD	**Worst COLD case for TRDGB**

Tab. 8-83 TRD Gas Box coldest design case on ISS

The TRD GAS BOX temperatures for this extreme orbit is presented in the following graph.

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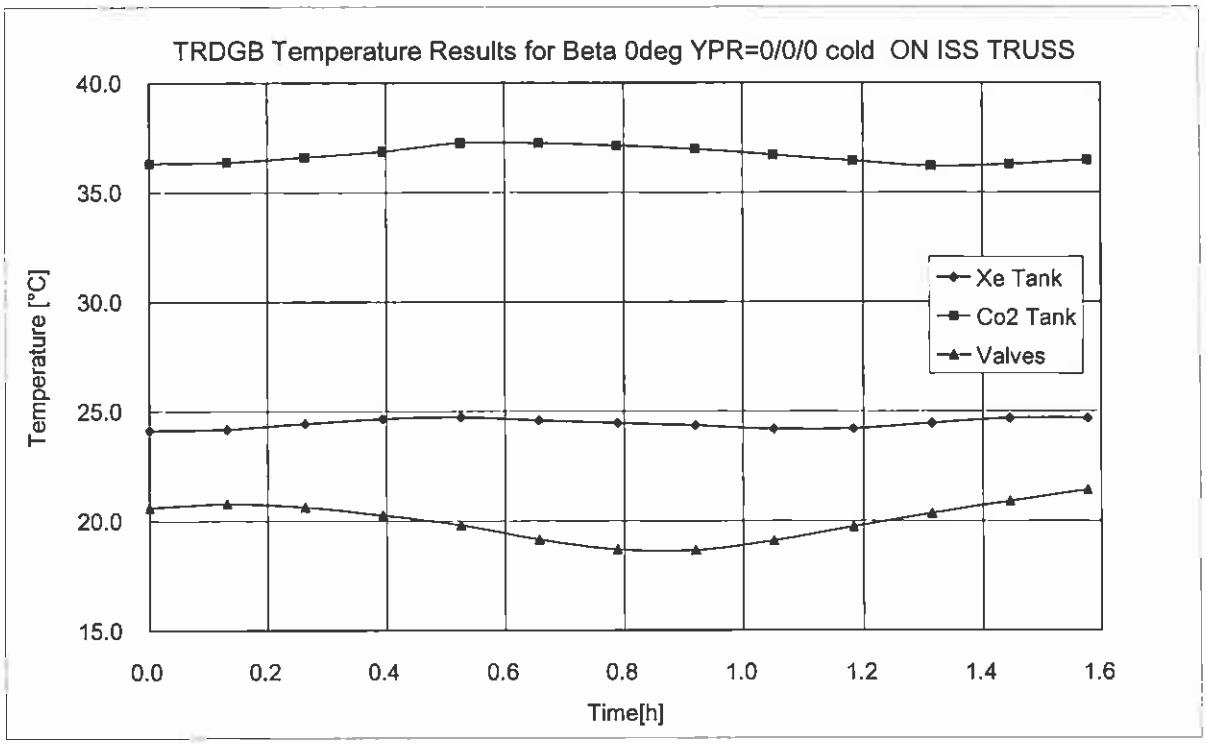

Fig. 8-78 TRD GAS BOX temperature results for orbit B_0_0_0_0 cold operative

TRDGB can stay within its operative temperature ranges heater assisted.

8.4.2.14 TRD/UPPER TOF

The coldest design case for the TRD/Upper Tof detector when AMS-02 experiment is on ISS is as follows:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0 / 0 / -15	Undocked	COLD	**Worst cold case for TRD**

Tab. 8-84 TRD detector coldest design case on ISS

Results are presented in RD [2]

8.4.2.15 ACC

The coldest design case for ACC PMTs when AMS is on ISS Truss configuration is the following one:

BETA	YPR	STS	Enviroment	Remarks/Rationale
0	0/ 0/ 0	undocked	COLD	**Worst cold case for ACC PMTs**

Tab. 8-85 ACC detector coldest design case on ISS

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ACC PMTs temperatures are presented in the next picture:

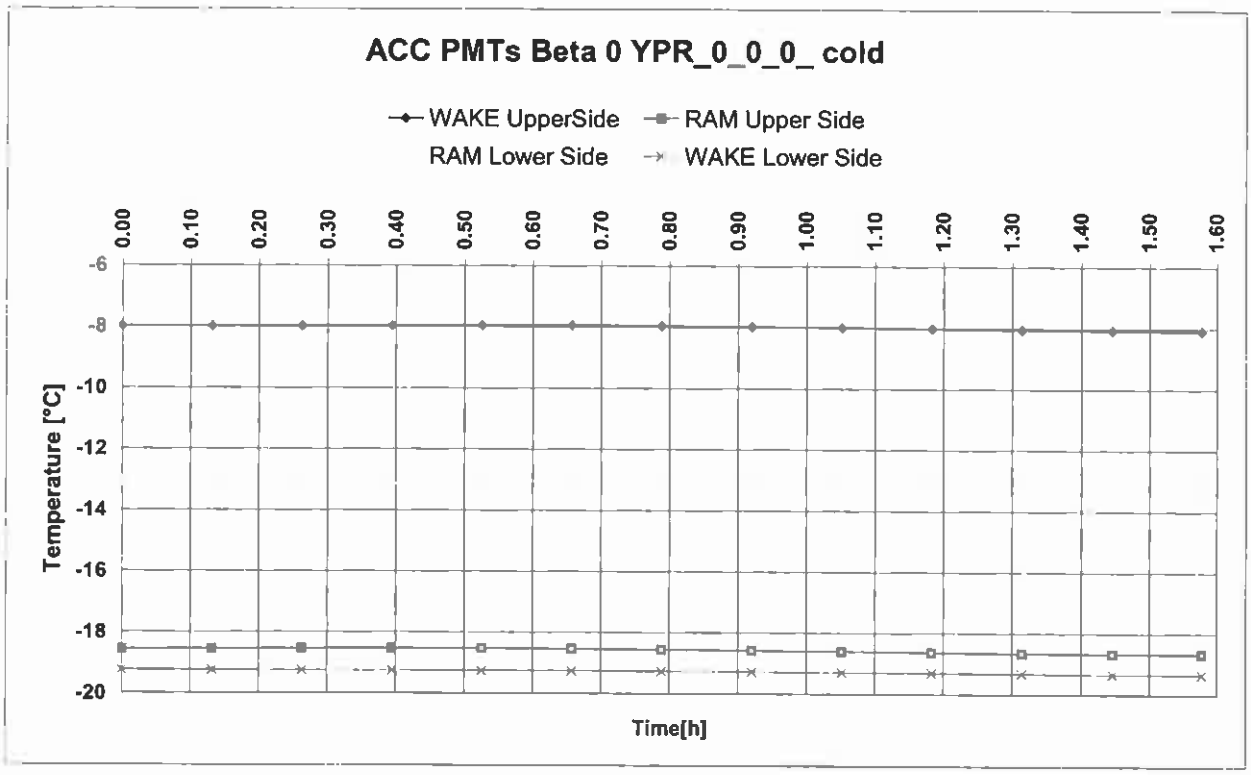

Fig. 8-79 ACC PMTs for orbit B_0_0_0_0_cold . ACC PMTs are operative

8.4.2.16 PAS

The coldest design case for PAS when AMS is on ISS Truss configuration is the following one:

BETA	YPR	STS	Environment	Remarks/Rationale
+25	-15/-20/-15	undocked	COLD	**Worst cold case for PAS**

Tab. 8-86 PAS coldest design case on ISS

PAS temperatures are presented in the next picture:

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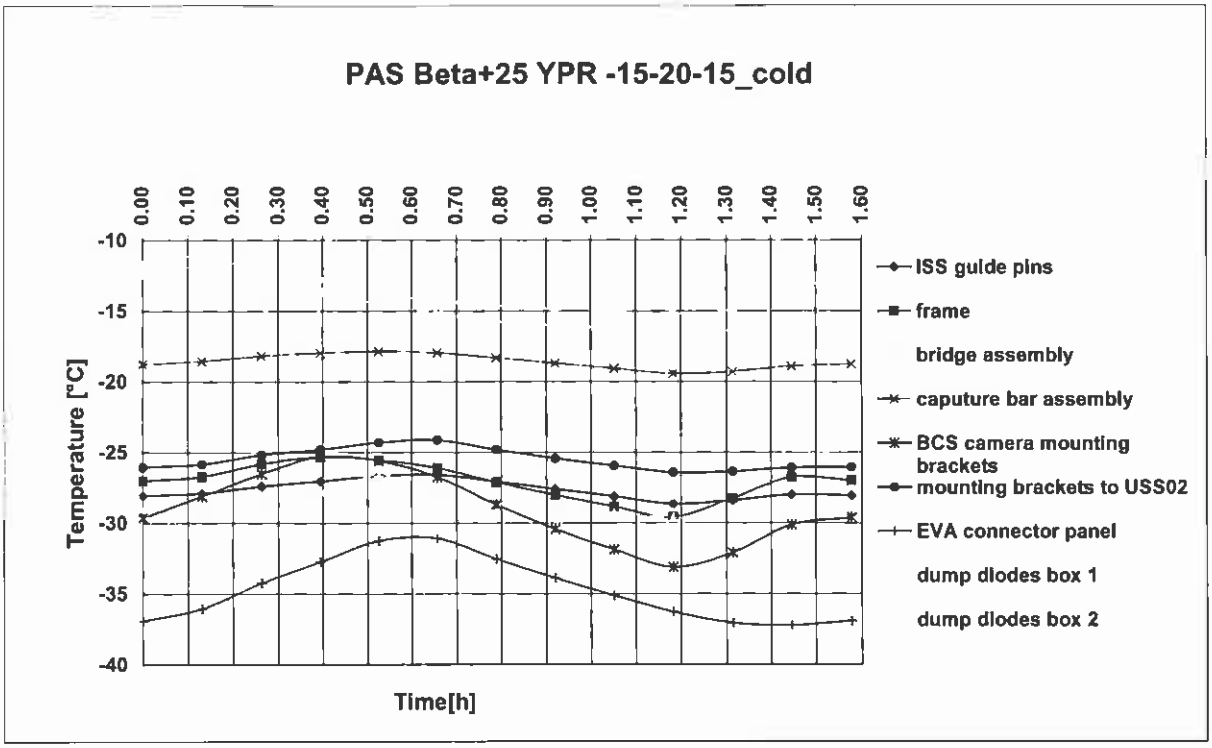

Fig. 8-80 PAS for orbit B+25-15-20-15_cold

8.4.2.17 UPS

The coldest case for UPS when AMS is on ISS Truss is the following one:

BETA	YPR	STS	Environment	Remarks/Rationale
+25	-15/-20/15	undocked	COLD	Worst cold case for UPS

Tab. 8-87 UPS coldest design case on ISS

UPS temperatures are presented in the next picture:

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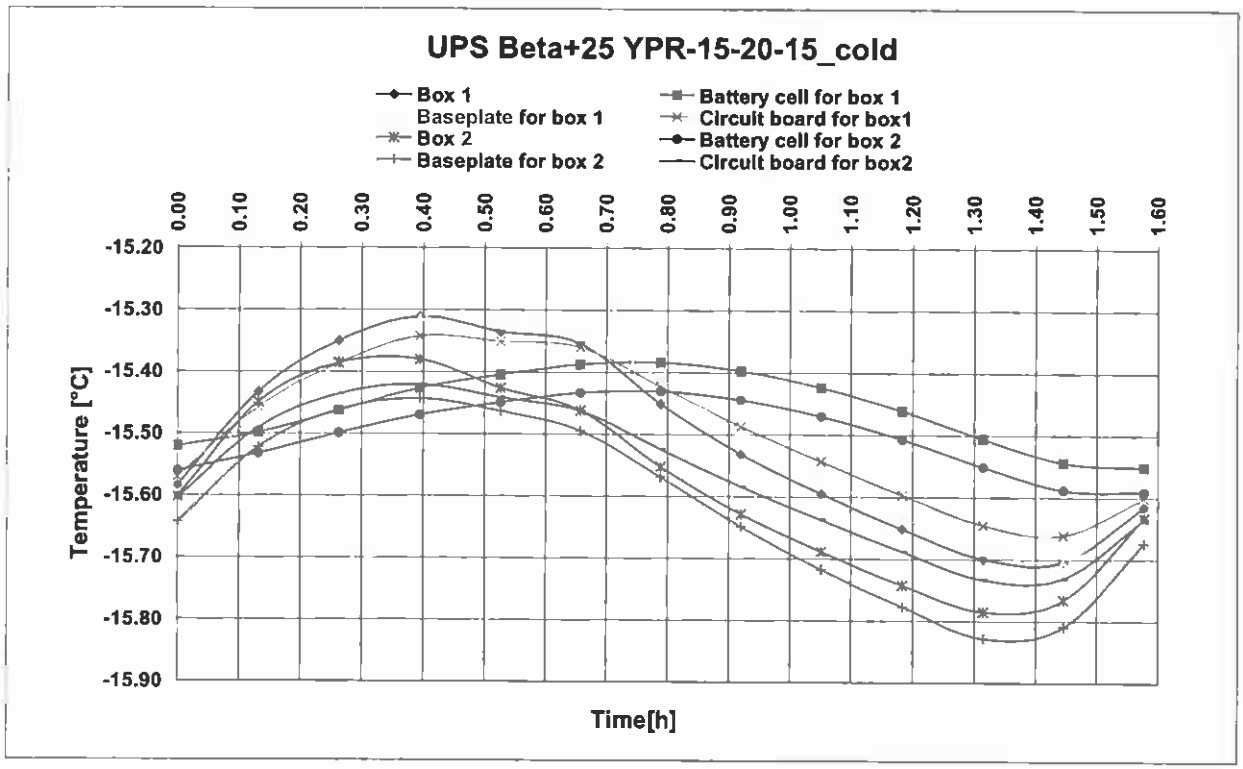

Fig. 8-81 UPS for orbit B+25-15-20-15 cold

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8.4.3 COOLING DOWN (8 HOURS)

Starting from the previously selected coldest cases an outage of power has been simulated.
AMS will experience power interruptions while on ISS up to 3 times per year, 8 hours per event.
Results for each AMS-02 detector are presented hereafter:

8.4.3.1 MAIN RADIATORS

8.4.3.1.1 RAM RADIATOR

Results are presented in RD [1]

8.4.3.1.2 WAKE RADIATOR

Results are presented in RD [1]

8.4.3.2 ZENITH RADIATORS

Detailed analysis has to be done yet.
Hereafter the Zenith radiator panel temperature (obtained at system level) is presented :

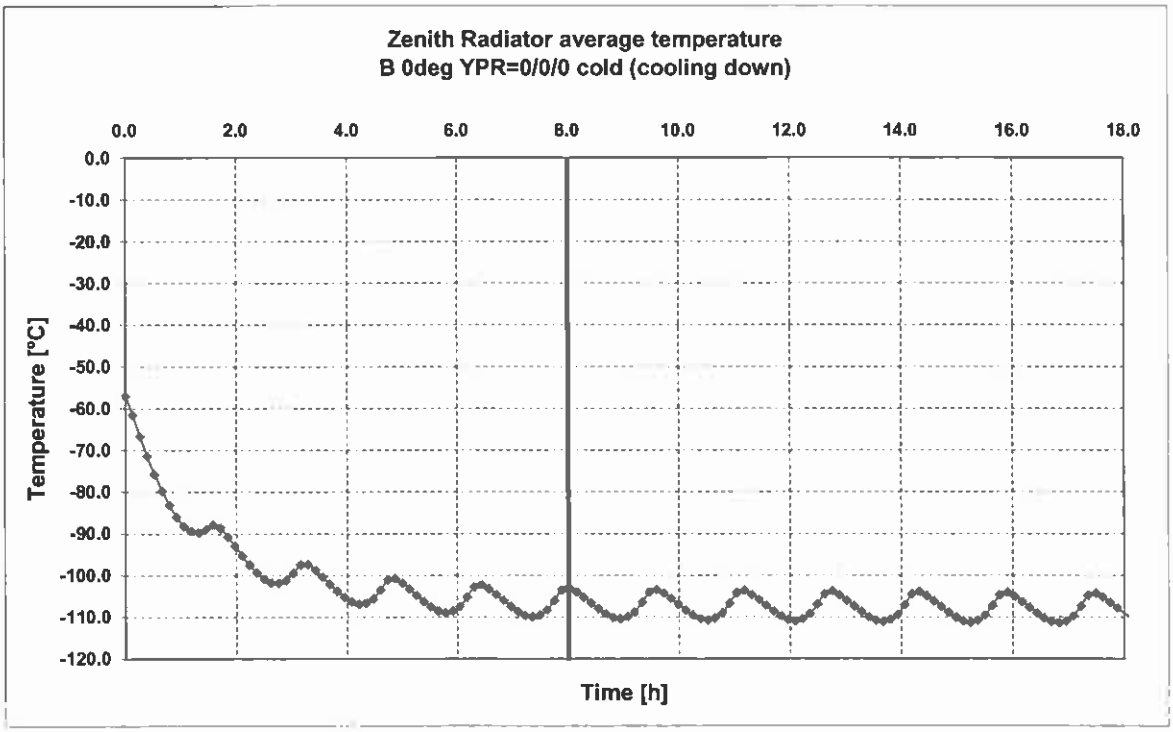

Fig. 8-82 Zenith Radiator average temperature for orbit B+75-15+15-15 cold BOL after power outage

8.4.3.3 CRYOCOOLER

Detailed analysis are included in RD [10]

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8.4.3.4 RICH

If a power outage occurs during coldest orbit for RICH detector, PMTs temperatures evolve as follows:

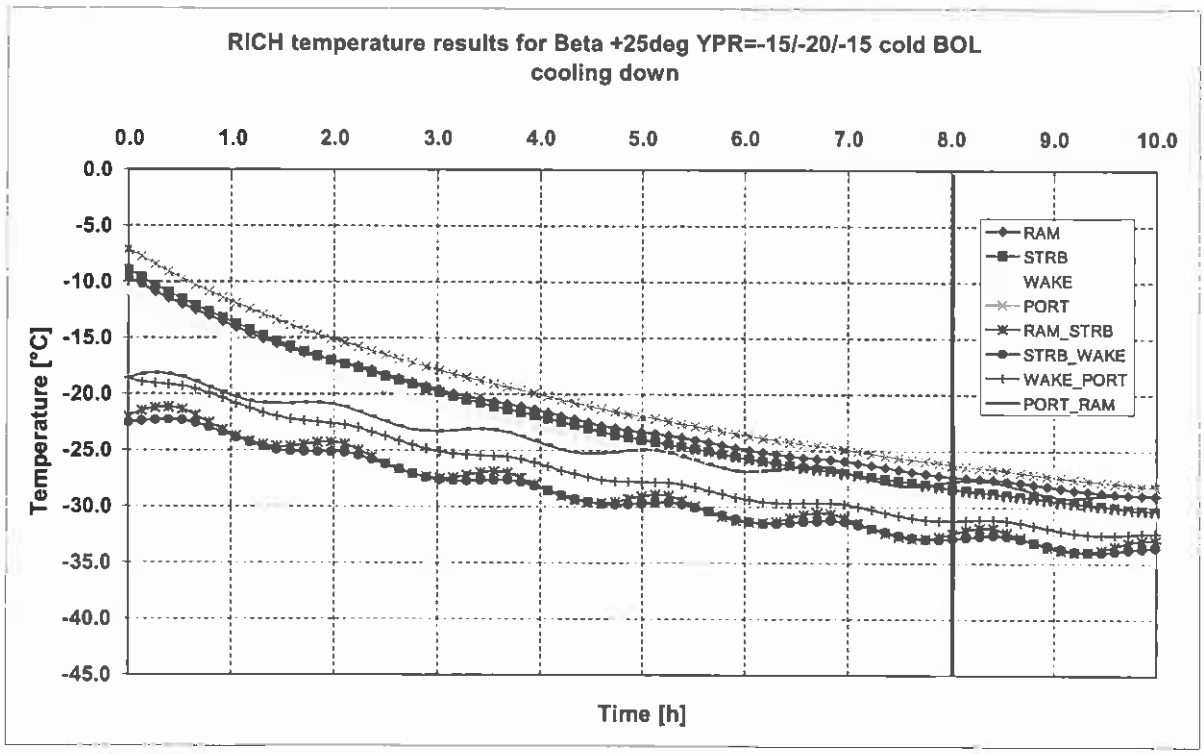

Fig. 8-83 Minimum RICH PMTs temperatures for orbit B+25-15-20-15 cold BOL after power outage

RICH PMTs can withstand even a larger period of time than 8 hours .

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8.4.3.5 LOWER TOF

If a power outage occurs during coldest orbit for Lower Tof detector, PMTs temperatures evolve as follows:

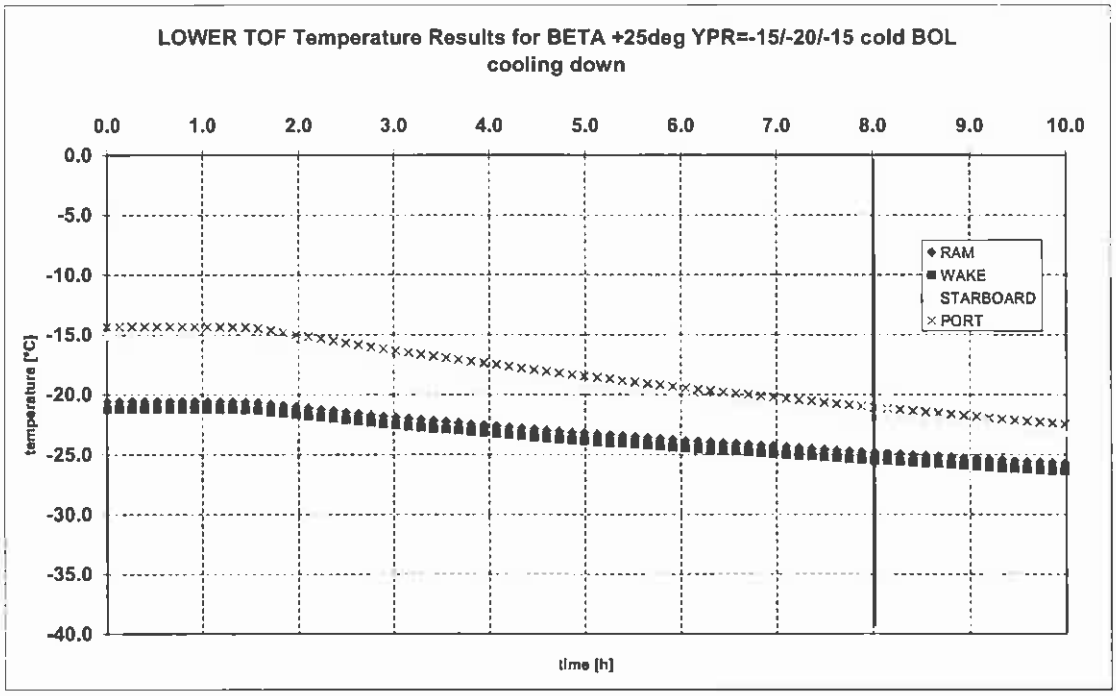

Fig. 8-84 Minimum Lower Tof PMTs temperatures for orbit B+25-15-20-15 cold BOL after power outage. RICH PMTs can withstand even a larger period than 8 hours

8.4.3.6 ECAL

Results are presented in RD [5]

8.4.3.7 RHV/EHV BRICKS

Results are presented in RD [6]

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8.4.3.8 E-CRATE

If a power outage occurs during coldest orbit for E crates, main walls I/F temperatures evolve as follows:

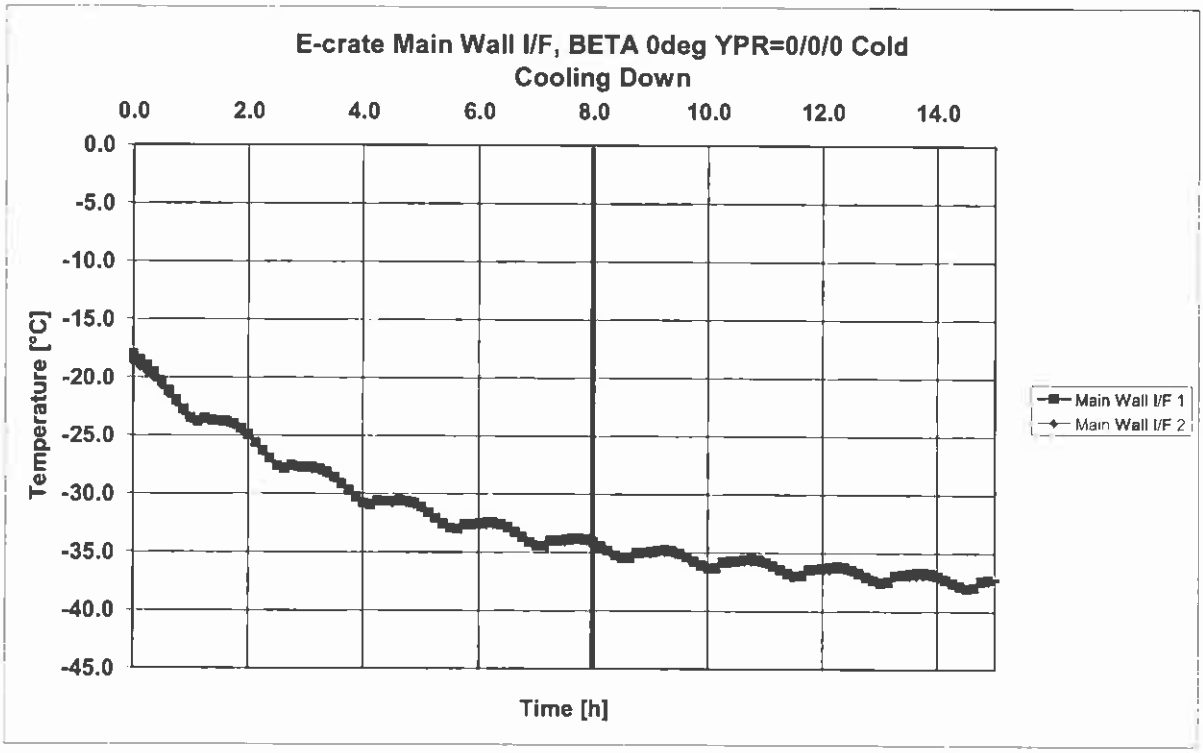

Fig. 8-85 Minimum E crates main walls I/F temperatures for orbit B_0_0_0_0 cold BOL after power outage.E crates can withstand even a larger period than 8 hours

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8.4.3.9 TRACKER SYSTEM (TRACKER ELECTRONICS/TTCB)

NLR team is in charge of this analysis.

8.4.3.10 STAR TRACKER

If a power outage occurs during coldest orbit for Star Tracker, CCDs temperatures evolve as follows:

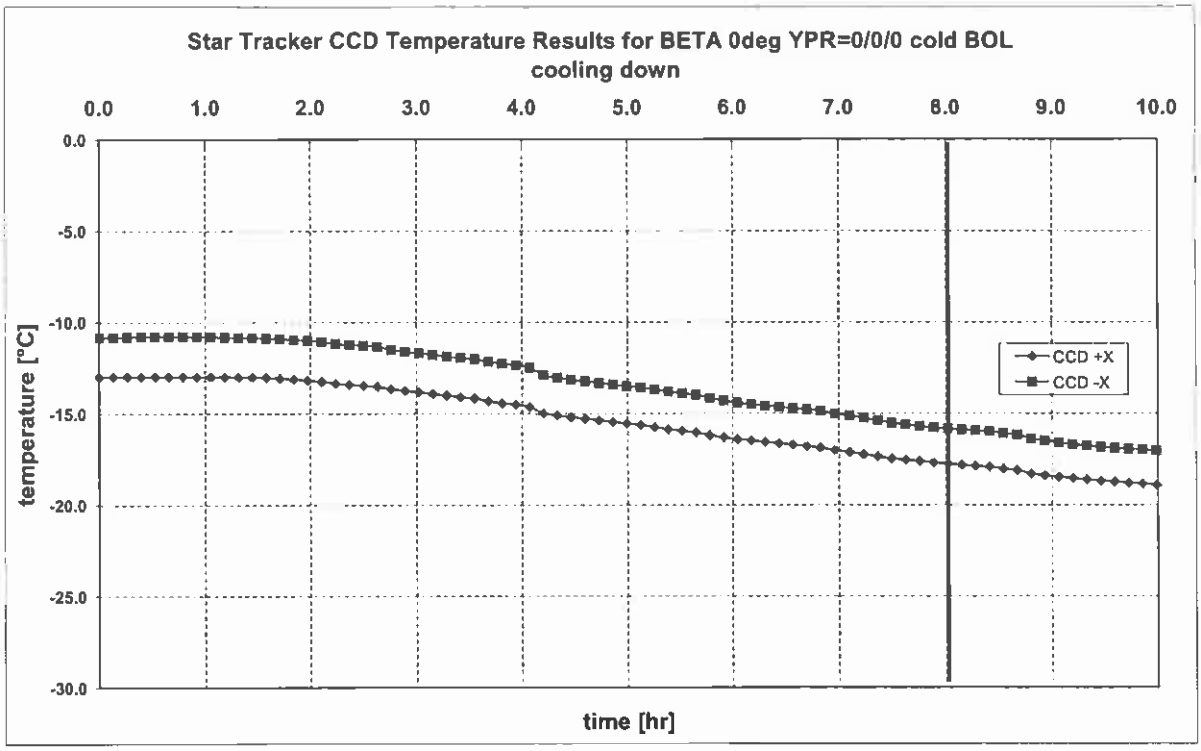

Fig. 8-86 Star Tracker CCDs temperatures for orbit B_0_0_0_0 cold BOL after power outage. Star Tracker CCDs can withstand more than 35 hours before the non operating limit is violated .

8.4.3.11 CAB

Results are presented in RD [8]

8.4.3.12 TRD GAS BOX

If a power outage occurs during coldest orbit for TRD Gas Box, the temperatures evolve as follows:

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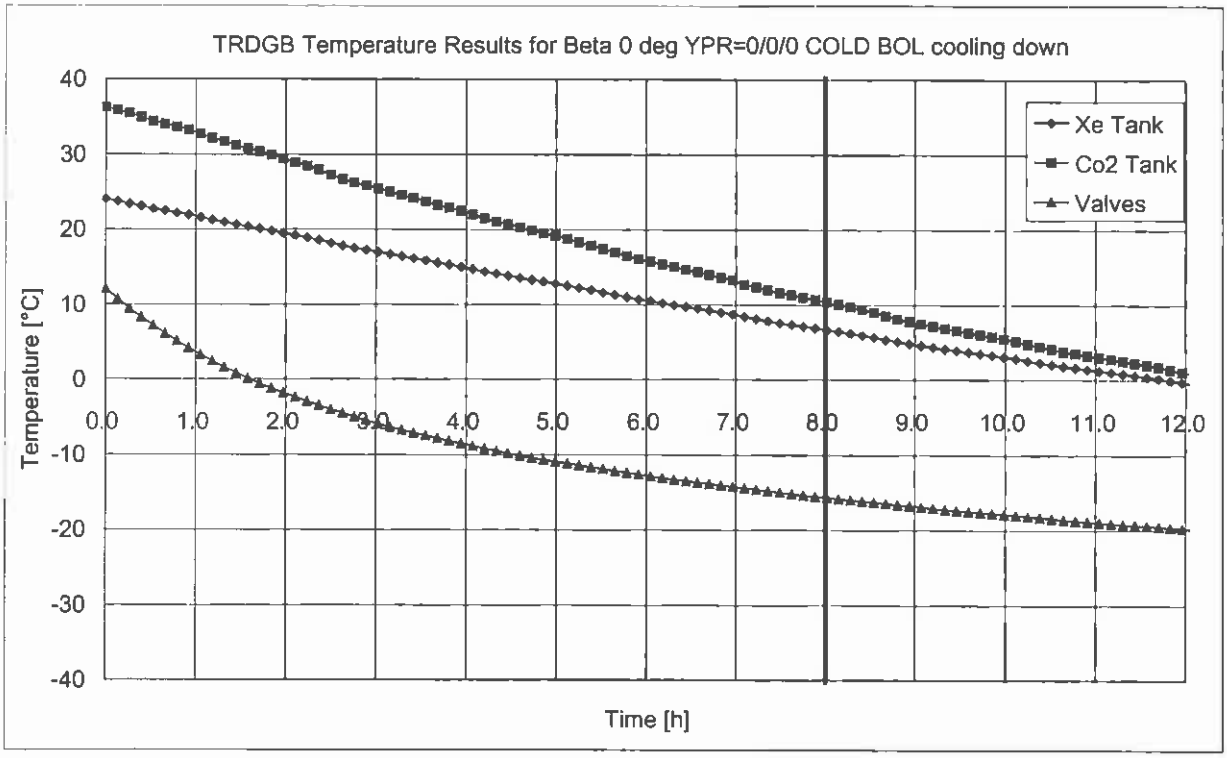

Fig. 8-87 Minimum TRD GAS BOX temperatures for orbit B_0_0_0_0 cold BOL after power outage. TRDGB Xe Tank and Co2 Tank can withstand even larger time than 8 hours before a non operating limit is violated. The TRDGB valves non operating limit is violated 4.5 hours after the power outage starts.

8.4.3.13 TRD/UPPER TOF

Results are presented in RD [2]

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8.4.3.14 ACC

If a power outage occurs during coldest orbit for ACC detector, the temperatures evolve as follows:

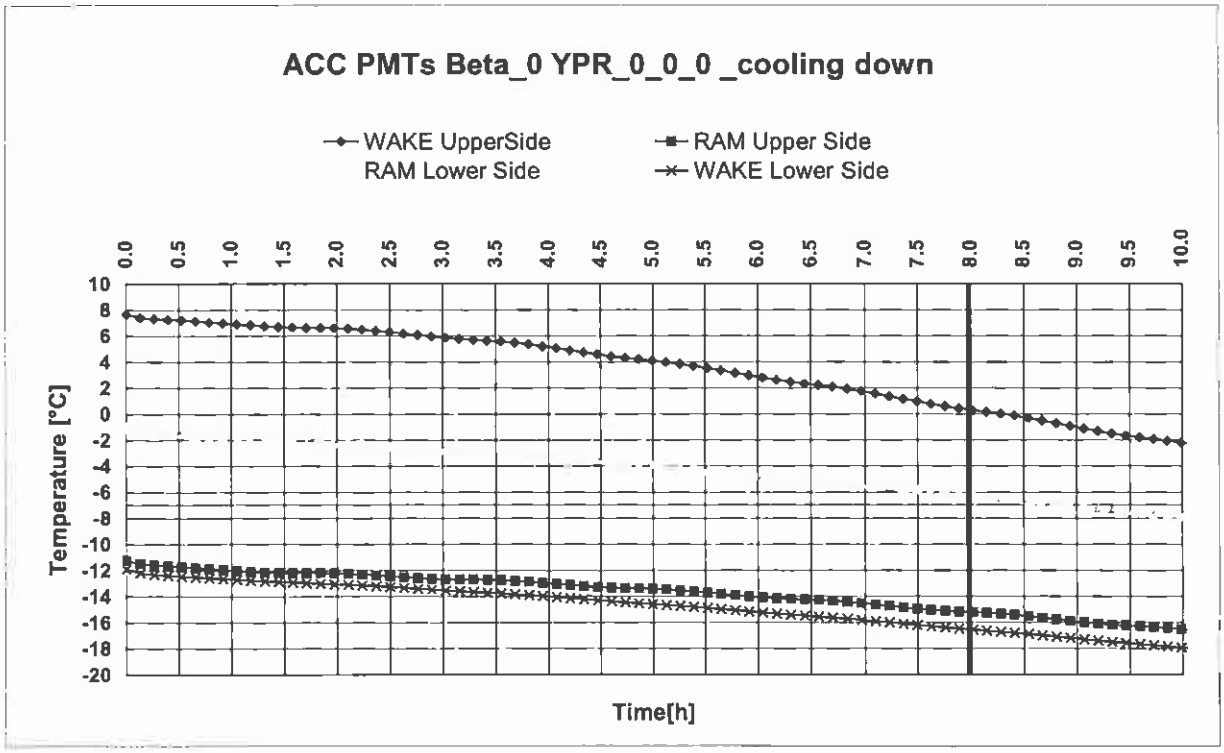

Fig. 8-88 Minimum ACC PMTs temperatures for orbit B_0_0_0_0 cold BOL after power outage.

ACC PMTs can withstand even larger time than 8 hours before a non operating limit is violated.

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8.4.3.15 PAS

If a power outage occurs during coldest orbit for PAS, the temperatures evolve as follows:

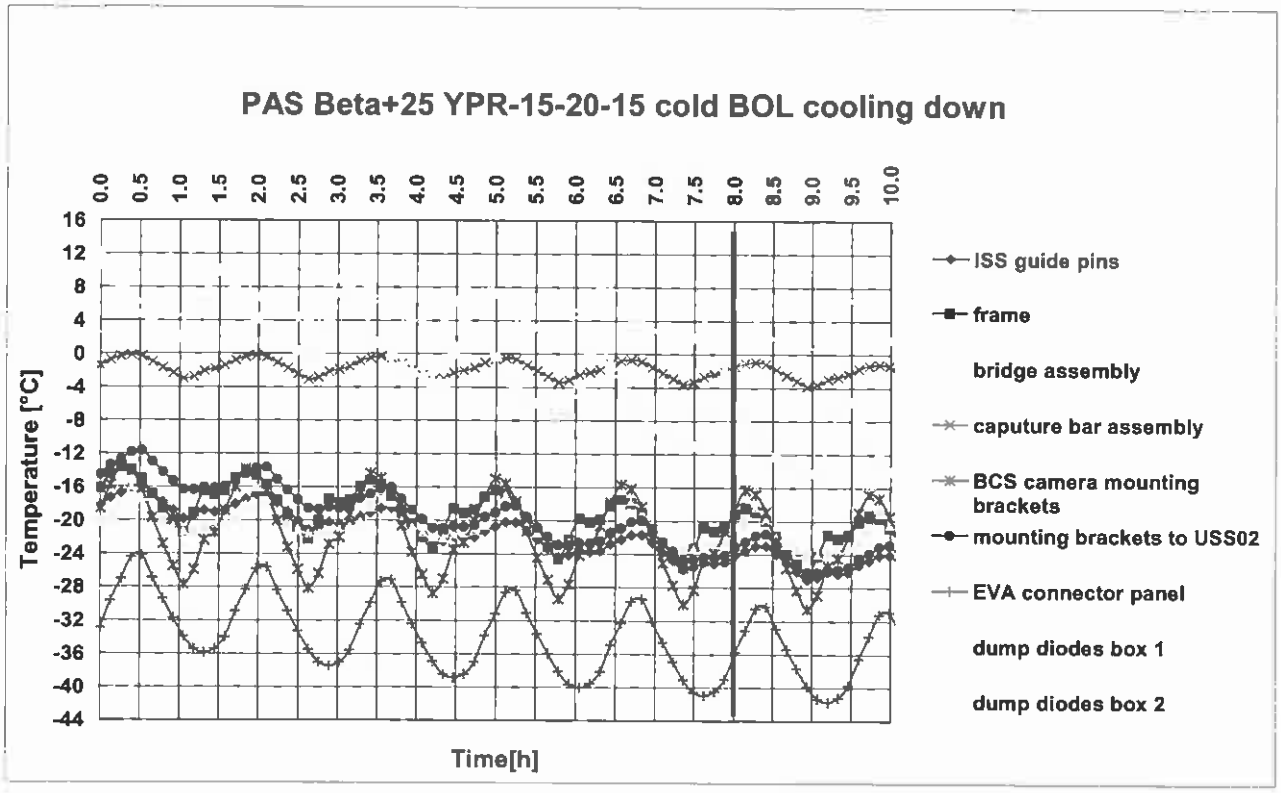

Fig. 8-89 Minimum PAS temperatures for orbit B+25-15-20-15 cold BOL after power outage

PAS parts can withstand even larger time than 8 hours before a non operating limit is violated.

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8.4.3.16 UPS

If a power outage occurs during coldest orbit for UPS, the temperatures evolve as follows:

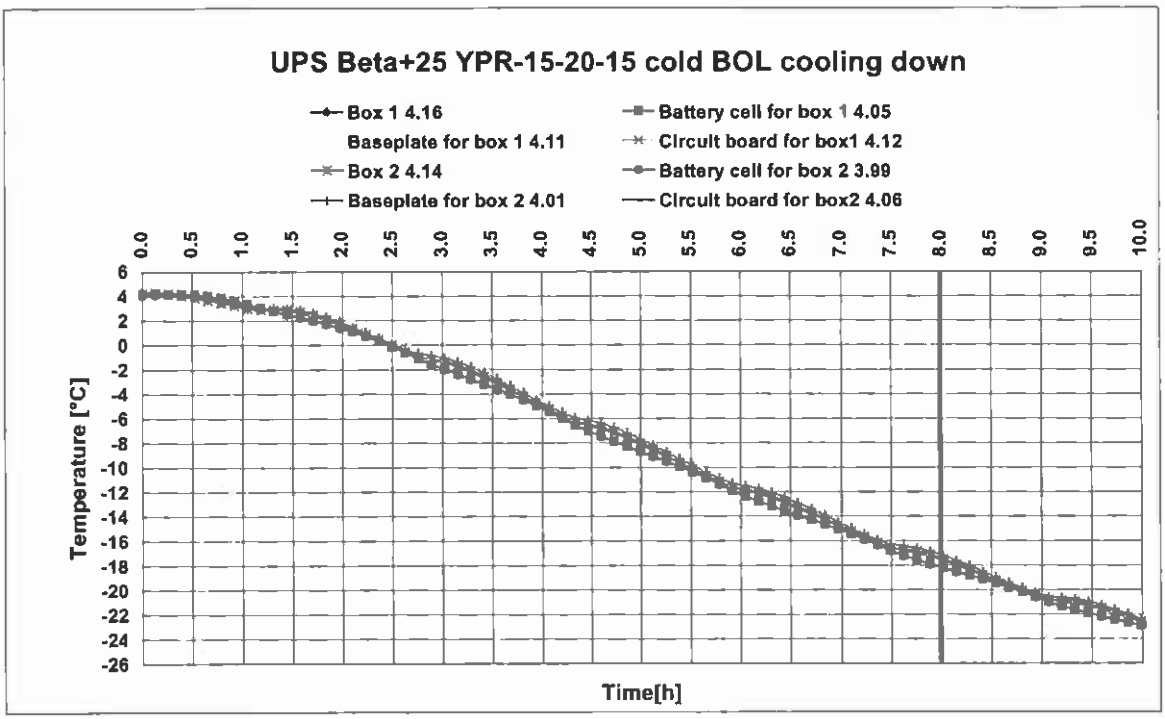

Fig. 8-90 Minimum UPS temperatures for orbit B+25-15-20-15 cold BOL after power outage

UPS parts can withstand even larger time than 8 hours before a non operating limit is violated.

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8.4.4 SWITCH ON SEQUENCE (AFTER COOLING DOWN)

After the 8 hours unpowered a switch-on sequence has been implemented for the main AMS02 experiment detectors. Results are presented in the following sections.

8.4.4.1 MAIN RADIATORS

8.4.4.1.1 RAM RADIATOR

Results are presented in RD [1]

8.4.4.1.2 WAKE RADIATOR

Results are presented in RD [1]

8.4.4.2 ZENITH RADIATOR

Detailed analysis has to be done yet.

8.4.4.3 CRYOCOOLER

Detailed analysis has to be done yet.

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8.4.4.4 RICH

Following picture illustrates the stabilization temperatures of the RICH PMTs with heaters (70W at 113Vdc) enabled. PMTs temperatures are well above the minimum switch-on temperatures.

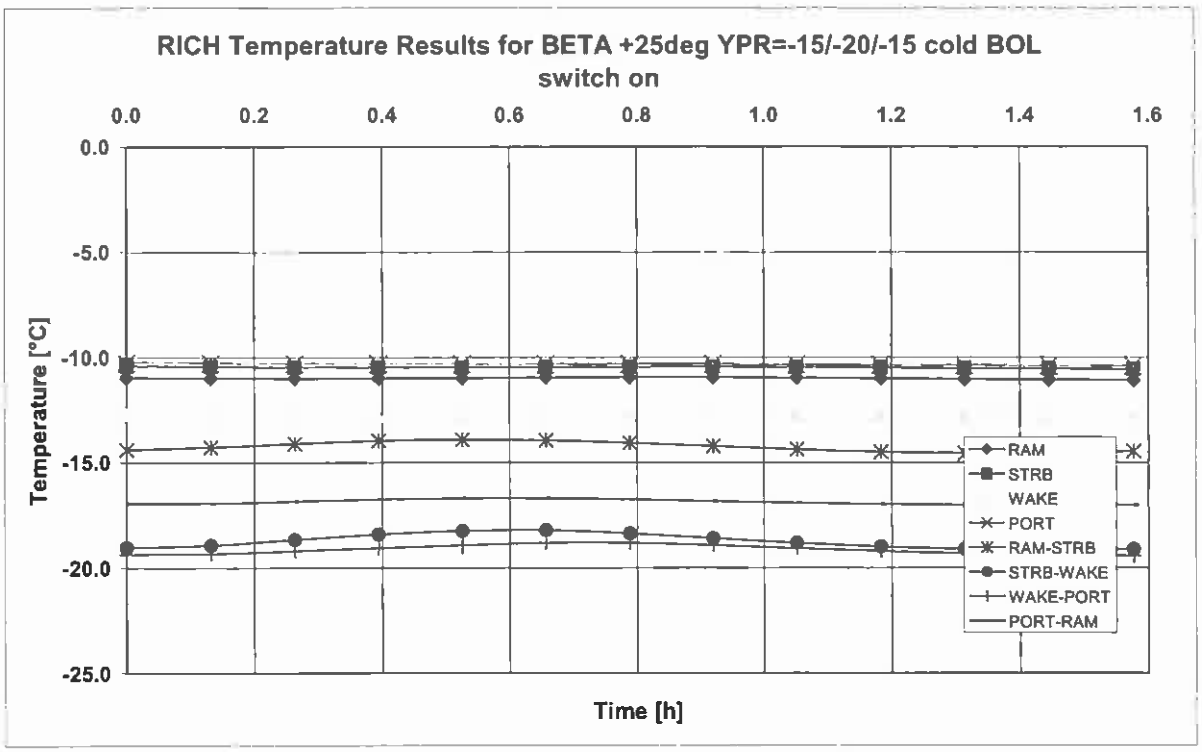

Fig. 8-91 Minimum RICH PMTs temperatures for orbit B+25-15-20-15 cold BOL .

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8.4.4.5 LOWER TOF

Following picture illustrates the stabilization temperatures of the Lower Tof PMTs with heaters (30W at 113Vdc) enabled. PMTs temperatures are at least 5°C above the minimum switch-on temperatures.

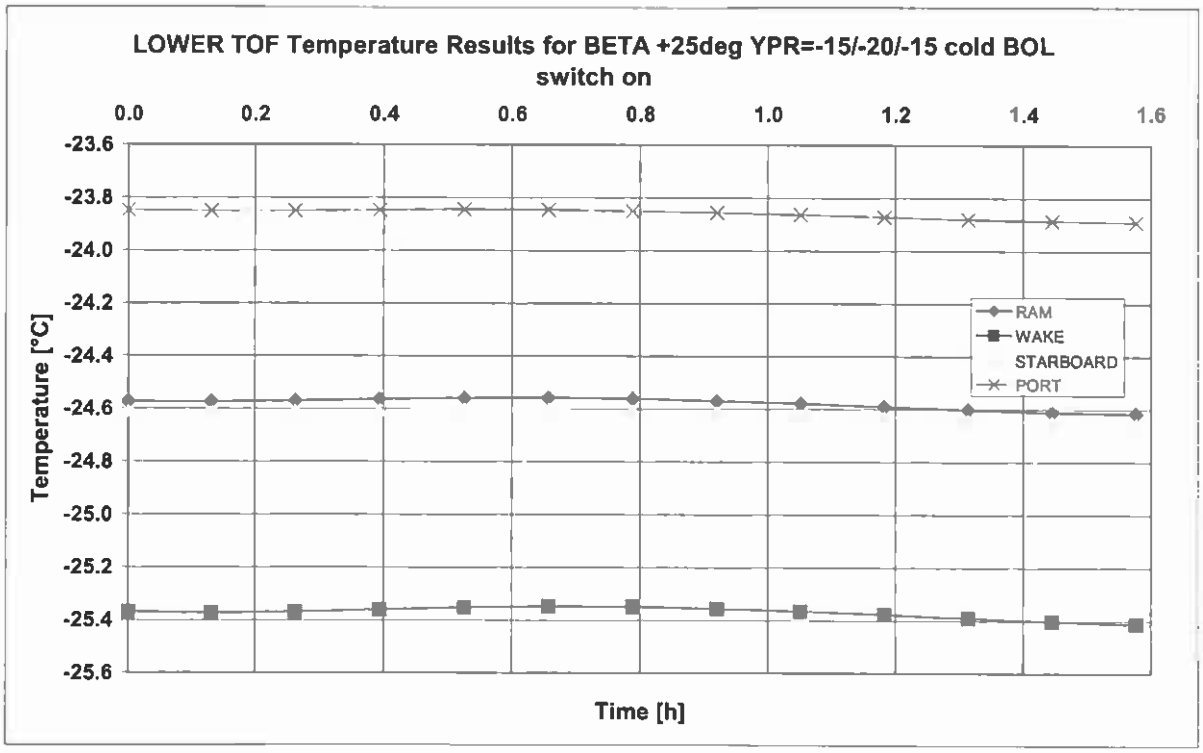

Fig. 8-92 Minimum Lower Tof PMTs temperatures for orbit B+25-15-20-15 cold BOL

8.4.4.6 ECAL

Results are presented in RD [5]

8.4.4.7 EHV/RHV BRICKS

Results are presented in RD [6]

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8.4.4.8 E-CRATE

Following picture illustrates the stabilization temperatures of the E crates with heaters (30W at 113Vdc) enabled. Main walls I/F temperatures are 5°C above the minimum switch-on temperatures.

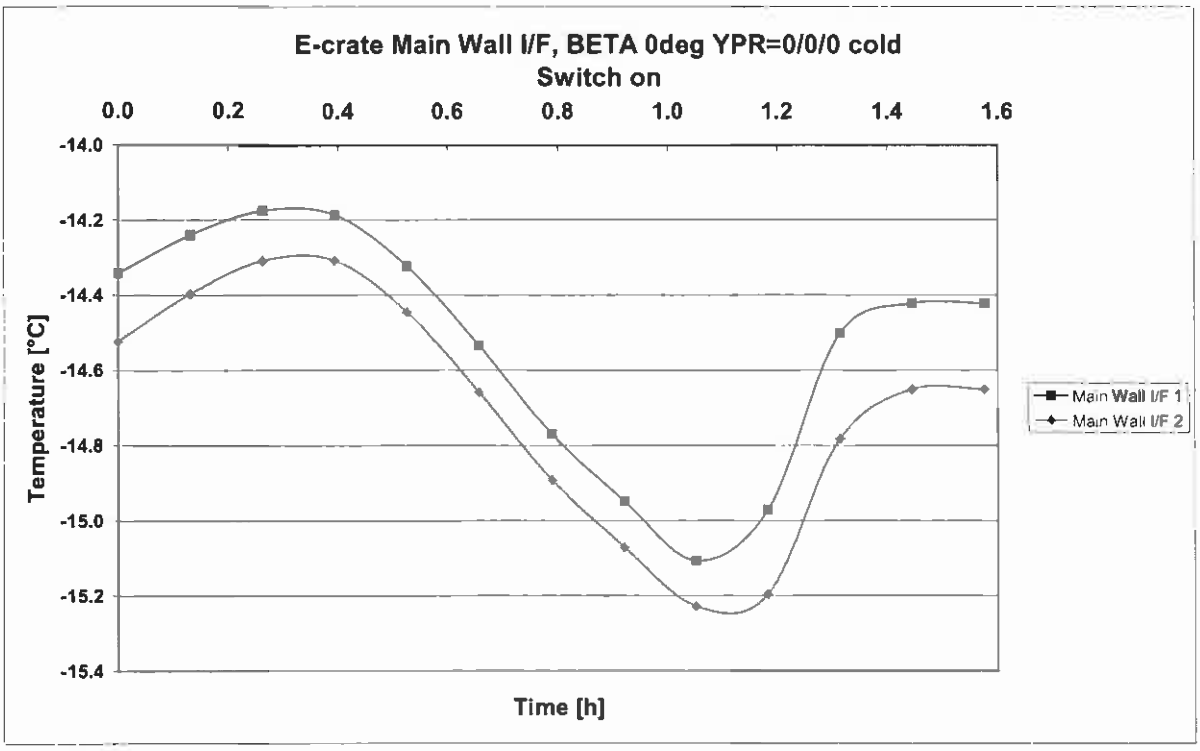

Fig. 8-93 Minimum E crates main walls I/F temperatures for orbit B_0_0_0_0 cold BOL

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8.4.4.9 TRACKER SYSTEM (TRACKER ELECTRONICS/TTCB)

NLR team is in charge of this analysis.

8.4.4.10 STAR TRACKER

Detailed analysis not performed yet.

8.4.4.11 CAB

Results are presented in RD [8]

8.4.4.12 TRD GAS BOX

Following picture illustrates the stabilization temperatures of the TRD GAS BOX with heaters enabled.

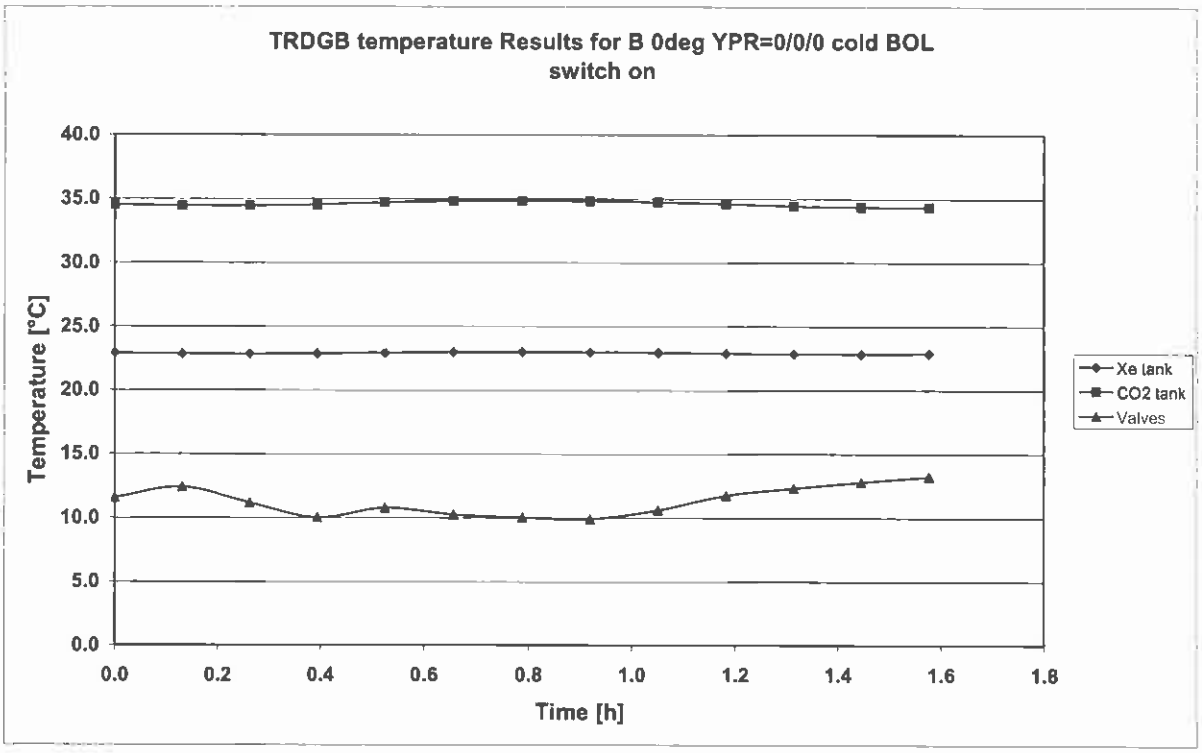

Fig. 8-94 Minimum TRD GAS BOX temperatures for orbit B_0_0_0_0 cold BOL

8.4.4.13 TRD/UPPER TOF

TRD team is in charge of this analysis.

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9. CONCLUSIONS

All the temperature predictions for the 4 phases of the LTA sequence have been presented.
The following tables show the summary results for each AMS-02 experiment detector/unit.

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9.1 PHASE 1: STS UNMATED ATTITUDES

The analysis results for the first phase are summarized in the following table.
For each AMS02 experiment detector the predicted temperature range, according to the analysed configuration (operative/non operative) and the temperature violation warning are provided:

Component	Limit [deg C]	Status	Temperature Violation	Remark
Crates	-40°C to +80°C	Non operative	No temperature violation	See RD [9] for details
J JPD JT	-25°C to +50°C	Operative	No temperature violation	See RD [9] for details
CCEB	-30°C to +50°C	Operative	No temperature violation	See RD [9] for details
RICH PMTs	-35°Cto +60°C.	Non operative	No temperature violation	
LOWER TOF PMTs	-35 °C to +50°C	Non operative	No temperature violation	
ECAL	-30 °C to +50°C	Non operative	No temperature violation	See RD [5] for details
Cryocoolers	-20 °C to +40 °C	Operative	No temperature violation	Ref. RD [10]
HV bricks	-35°c to +65°c	Non operative	No temperature violation	See RD [6] for details
E crates	-40°C to +80°C	Non operative	No temperature violation	
PDS	-25°C to +48°C	Operative	Temperature violation	See RD [9] for details
Tracker Hybrids	-20 °C to +40 °C	Non operative	No temperature violation	
Tracker Silicon Wafer	-20 °C to +40 °C.	Non operative	No temperature violation	
Star Tracker CCD	-40°C to +80°C	Non operative	No temperature violation	
CAB	–25°C to +50°C	Operative	No temperature violation	See RD [9] for details
TRD Gas Box Xe Tank	-51 °C to +65°C	Non operative	No temperature violation	
TRD Gas Box CO2 Tank	-73 °C to +65°C	Non operative	No temperature violation	
TRD Gas Box Valves	-20°C to +65°C	Non operative	No temperature violation	
ACC PMTs	-35°C to +50°C	Non operative	No temperature violation	

Tab. 9-1 AMS-02 experiment temperature violation summary for Phase 1

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9.2 PHASE 2: STS STS DOCKED TO THE ISS, AMS-02 IN THE CARGO BAY

The analysis results for the phase 2 are summarized in the following table.
For each AMS02 experiment detector the predicted temperature range, according to the analysed configuration (operative/non operative) and the temperature violation warning are provided:

Component	Limit [deg C]	Status	Temperature Violation	Remark
Crates	-40°C +80°C	Non operative	No temperature violation	See RD [9] for details
J JPD JT	-25°C to +50°C	Operative	No temperature violation	See RD [9] for details
CCEB	-30°C to +50°C	Operative	No temperature violation	See RD [9] for details
RICH	-35°C to +60°C.	Non operative	No temperature violation	
LOWER TOF	-35 °C to +50°C	Non operative	No temperature violation	
ECAL	-30 °C to +50°C	Non operative	No temperature violation	See RD [5] for details
Cryocoolers	-20 °C to +40 °C	Operative	No temperature violation	Ref. RD [10]
HV bricks	-35°c to +65°c	Non operative	No temperature violation	See RD [6] for details
E crates	-40°C +80°C	Non operative	No temperature violation	
PDS	-25°C to +48°C	Operative	No temperature violation	See RD [9] for details
Tracker Hybrids	-20 °C to +40 °C	Non operative	No temperature violation	
Tracker Silicon Wafer	-20 °C to +40 °C.	Non operative	No temperature violation	
Star Tracker CCD	-40°C to +80°C	Non operative	No temperature violation	
CAB	–25°C to +50°C	Operative	No temperature violation	See RD [9] for details
TRD Gas Box Xe Tank	-51 °C to +65°C	Non operative	No temperature violation	
TRD Gas Box CO2 Tank	-73 °C to +65°C	Non operative	No temperature violation	
TRD Gas Box Valves	-20°C to +65°C (TBC by test)	Non operative	No temperature violation	
ACC PMTs	-35°c to +50°C	Non operative	No temperature violation	

Tab. 9-2 AMS-02 experiment temperature violation summary for Phase 2

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9.3 PHASE 3: STS DOCKED TO THE ISS, AMS-02 IN HAND-OFF POSITION

The analysis results for the phase 3 are summarized in the following table.
For each AMS02 experiment detector the predicted temperature range, according to the analysed configuration (operative/non operative) and the temperature violation warning are provided at the end of the 4 unpowered hours.

Component	Limit [deg C]	Status	Temperature Violation	Remark
Crates	-40°C to +80°C	Non operative	GPS temperature violated (1°C below the minimum non operative limit, covered by qualification margins)	See RD [9] for details
J JPD JT	-40°C to +80°C	Non operative	No temperature violation	See RD [9] for details
CCEB	-40°C +80°C	Non operative	No temperature violation	See RD [9] for details
RICH	-35°C to +60°C.	Non operative	No temperature violation	
LOWER TOF	-35 °C to +50°C	Non operative	No temperature violation	
ECAL	-30 °C to +50°C	Non operative		See RD [5] for details
Cryocoolers	-40 °C to +40 °C -	Non operative	No temperature violation	Ref. RD [10]
HV bricks	-35°c to +65°c	Non operative	No temperature violation	See RD [6] for details
E crates	-40°C +80°C	Non operative	No temperature violation	
PDS	-40°C +80°C	Non operative	No temperature violation	
Tracker Hybrids	-20 °C to +40 °C	Non operative	No temperature violation	
Tracker Silicon Wafer	-20 °C to +40 °C.	Non operative	No temperature violation	
Star Tracker CCD	-40°C to +80°C	Non operative	No temperature violation	
CAB	-40° C[11] to +70°C	Non operative	No temperature violation	See RD [9] for details
TRD Gas Box Xe Tank	-51 °C to +65°C	Non operative	No temperature violation	
TRD Gas Box CO2 Tank	-73 °C to +65°C	Non operative	No temperature violation	
TRD Gas Box Valves	-20°C to +65°C	Non operative	No temperature violation	
ACC PMTs	-35°c to +50°C	Non operative	No temperature violation	

Tab. 9-3 AMS-02 experiment temperature violation summary for Phase 3

[11] Minimum non operational temperature can be, according to CRISA, -40°C instead of -30°C once in the mission.

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9.4 PHASE 4: AMS-02 ON ISS

Component	Limit [deg C]	Status	Temperature Violation	Remark
Crates	-20°C to +50°C	Operative	No temperature violation	See RD [1] for details
J JPD JT	-25°C to +50°C	Operative	No temperature violation	See RD [1] for details
CCEB	-30°C to +50°C	Operative	No temperature violation	See RD [1] for details
RICH	-30 °C to +50°C.	Operative	No temperature violation (in the reduced Beta Range)	See Fig. 8-60
LOWER TOF	-30 °C to +45°C	Operative	No temperature violation	
ECAL	-20 °C to +40°C	Operative	No temperature violation (in the reduced Beta range)	See RD [5] for details
Cryocoolers	-20 °C to +40 °C	Operative	No temperature violation	See RD [10] for details
HV bricks	-20°C to +65°C	Operative	No temperature violation	See RD [6] for details
E crates	-20°C to +50°C	Operative	No temperature violation	
PDS	-25°C to +48°C	Operative	No Temperature violation[12]	See RD [1] for details
Tracker Hybrids	-10 °C to +25 °C	Operative	No temperature violation	Ref. RD [1]
Tracker Silicon Wafer	-10 °C to +25 °C.	Operative	No temperature violation	Ref. RD [1]
Star Tracker CCD	-30°C to +55°C	Operative	No temperature violation	
CAB	–25°C to +50°C	Operative	No temperature violation	See RD [8] for details
TRD Gas Box Xe Tank	+20 °C to +65°C	Operative	No temperature violation	
TRD Gas Box CO2 Tank	+34 °C to +65°C	Operative	No temperature violation	
TRD Gas Box Valves	+5 °C to +55°C	Operative	No temperature violation	
TRD	–20°C to+40 °C.	Operative	No temperature violation	See RD [2] for details
UPPER TOF PMTs	-30° C to +45°C	Operative	No temperature violation	See RD [2] for details
ACC PMTs	-30° C to +45°C	Operative	No temperature violation	

Tab. 9-4 AMS-02 experiment temperature violation summary for Phase 4

[12] The combination of extreme Beta angles and extreme attitude leads to a maximum PDS baseplate temperature of 52°C, which is below the 53°C qualification limit, although higher than the maximum operational of +48°C.

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