Title: **HERSCHEL EQM Thermal Model and Analysis**

CI-No:

Prepared by:	J. Hinger	Date:	17 May 2002
Checked by:	J. Kroeker		11. 06. 02
Product Assurance:	R. Stritter		11. 06. 02
Configuration Control:	A. v. Ivády		11. 06. 02
Project Management:	W. Rühe/ K. Moritz		11. 06. 02
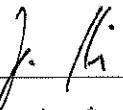
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Issue	Date	Sheet	Description of Change	Release
1	26/02/02	all	First formal issue	
2	17/05/02	7	Analysis of helium-cooled cover shield added. Transient analysis for cool-down added.	
		10	Alternative design with helium-cooled vacuum-tight plate / shield design added.	
		23	§ 4.2.5: Auxiliary tank mounting straps linked to Ti-heads of upper spatial framework interface (node 8) instead of to Main Tank.	
		30	HeII changed to HeI in Fig. 4-12	
		39	"Preliminary" inserted.	
		47	coupling between node 1128 and node 1121 erased in Fig 4-34	
		49 ff	Chapter 4.6 "Submodel "CPLATE", CTA Cold Plate for EQM" inserted.	
		101ff	Chapter 5.5 "CTA Cold Plate Design 1" inserted	
		113 ff	Chapter 5.6 "CTA Cold Plate Design 2" inserted	
		124ff	Chapter 5.7 "Transient Thermal Analysis" inserted	
		135ff	Conclusions modified	

Table of Content

Table of Figures

List of Tables

1   SCOPE

This technical note reports on the thermal analyses and thermal design developed for the Engineering Qualification Model (EQM). A comprehensive description of the thermal-mathematical models as well as a brief description of relevant design details are included. Two different thermal design concepts of the cryogenic test adapter for the EQM (CTCE) are investigated, one with and another without the application of multilayer-insulation (MLI) blankets. Also thermal design concepts for the attachment and cooling-system of the reflector within the CTCE are proposed and analysed. As an alternative to the CTA-cryostats a helium-cooled cover shield is analysed.

Temperatures heater powers and helium mass flow rates are predicted for different design concepts and operating parameters. Analysis are performed for steady-state test conditions as well as for transient cool-down at ambient air.

2   Applicable and Reference Documents

2.1   Applicable Documents

AD 01   HERSCHEL/PLANCK Instrument Interface Document IID Part A, Doc.No.: SCI-PT-IIDA-04624, Issue 2/0, 31.07.2001

AD 02   HERSCHEL/PLANCK Instrument Interface Document IID Part B for PACS, Doc.No.: SCI-PT-IIDB/HIFI-02126, Issue 2/0, 31.07.2001

AD 03   HERSCHEL/PLANCK Instrument Interface Document IID Part B for SPIRE, Doc.No.: SCI-PT-IIDB/HIFI-02124, Issue 3/0 (TBD), to be issued
issue 2/0 shall be updated according to change requests HR-SP-RAL-ECR-009-v2 and ECR-011

AD 04   HERSCHEL/PLANCK Instrument Interface Document IID Part B for HIFI, Doc.No.: SCI-PT-IIDB/HIFI-02125, Issue 2/0, 31.07.2001

AD 05   H-EPLM Environment & Test Requirements Specification, Doc.No.: HP-2-ASED-SP-0004, 21.11.01

AD 06   HERSCHEL/PLANCK System Requirements Specification, Doc.No.: SCI-PT-RS-05991, Issue 2, 13.07.2001

AD 07   HERSCHEL PLM Interface Specification, Doc.No.: HP-2-ASPI-IS-0039, Issue 1/1, 27.07.2001

AD 08   HERSCHEL PLM / EQM AIT Plan, Doc.No.: HP-2-ASED-PL-0022, Draft, dated 16.01.2002

AD 09   EQM Test Program Definition, Doc. No. HP-2-ASED-TN-0004, iss. 1, dated 03.08.2001

2.2   Reference Documents

RD 01   H-EPLM Design Description; Doc.No.: HP-2-ASED-RP-0003_1_H-EPLM, 24.07.01

RD 02   Herschel Ventline Heat Exchanger Layout, Doc.No. HP-2-ASED-TN-0027, 14.12.2001

RD 03   HPLM Thermal Model and Analysis, Doc.No. HP-2-ASED-RP-0011, 30.11.2001

RD 04   Analysis of Change Requests:SPIRE ECR #9 and #11, Doc.No. HP-2-ASED-TN-0038, 11.02.2002

RD 05   Herschel PLM Drawings: CVV PFM Upper bulkhead,   HP-2-ASED-0004
                                CVV PFM cylinder,   HP-2-ASED-0005
                                CVV PFM lower bulkhead,   HP-2-ASED-0006

RD 06   Herschel EQM Drawings: CVV EQM Upper bulkhead,   HP-2-ASED-0007
                                CVV EQM Intermediate ring, HP-2-ASED-0008

RD 07   Procurement Specification for FIRST MLI, Doc.No.: FIRST-PS-BCB00.001, 11.08.2000

RD 08   FIRST PLM MLI, Technical Proposal from AAE, Doc.No.: MS-PRO-0250-AAE, 04.10.2000

RD 09 Evaluation of LINDE/ESTEC-MLI Measurements and Transformation to the ISO Cryostat MLI Design, Doc.No.: ISO.TN-B1430.007, 12.07.1988

RD 10 M. Sander: ISO-PLM Test Evaluation with Thermopt, Doc.No.: ESA SP-324, December 1991

RD 11 PACS FPU Drawing No. PACS-KT-ICD-0000W1.22, 04.09.2001

RD 12 SPIRE Interface Drawing No. 5264 300, 30.07.2001

RD 13 HIFI-FPU External Configuration Drawing No. 455-3-001-0, 29.05.2001

RD 14 Reduced instrument TMMs provided by ESA, Doc.No.: SCI-PT/09948, 04.10.2001

RD 15 ISO-TMM "MD0600.esat", version 6.00, M. Sander DASA / RIT71, 24.02.1994

RD 16 ISO-TMM "PL0600.esat", version 6.00, M. Sander DASA / RIT71, 24.02.1994

RD 17 ISO-TMM "V0300.esat", version 3.00, M. Sander DASA / RIT71, 24.02.1994

RD 18 ISO-FM Thermal Test Prediction Analysis, Doc.No. ISO-AN-B1430.022, iss. 1, 08.12.1994

RD 19 Functional, Design and Interface Requirements for EQM Cryo Test Adapter (CTA), Draft, to be issued

2.3   Abbreviations

ASED Astrium GmbH
ASPI   Alcatel Space
BOL   Begin of Life
CTA   cryogenic test adapter
CTCE cryogenic test cavity for EQM
CVV   Cryostat Vacuum Vessel
EOL   End of Life
EQM   Engineering Qualification Model
FM   flight model
HPLM HERSCHEL payload module
I/F   interface
IR   InfraRed
MLI   multi layer insulation
NA   not applicable
OB   optical bench
PFM   proto flight model
PLM   payload module
SVM   service moule
TBC   to be confirmed
TBD   to be defined
TMM   Thermal Mathematical Model
QM   qualification model
w.r.t. with regard to

3   EQM Test Description

3.1   EQM Test Configuration

The EQM test configuration is described in detail in AD 08 and AD 09. The configuration as illustrated in Figure 3-1 emphasizes all thermal aspects. The whole EQM test configuration comprises of:

▪ The modified ISO-cryostat with the main tank torus and an auxiliary tank

▪ The HERSCHEL payload with the optical bench and the instrument QMs

▪ The cryogenic test cavity for the EQM (CTCE) with the reflector, black body and the antenna

▪ External HeI – dewar for vapor-cooling of the CTA-shrouds and the black body

▪ EGSE (not depicted in Figure 3-1) with the power supplies for the heater circuits

The lower part of the ISO-QM-cryostat is used for the HERSCHEL-EQM without any major changes. The ISO-telescope with baffle of course has to be dismounted. The upper part of the ISO-cryostat (cone with cover), however, can not be used for the HERSCHEL-EQM and has to be replaced by a special bulkhead. This bulkhead is identical to the FM-bulkhead with the exception that its height is shortened by 180 mm. Between bulkhead and CVV of the ISO-cryostat a special connector-interface ring of 180 mm height is inserted.

For the tests underlying the thermal analysis in this report the cryostat cover is not existent but the cryostat opening is covered by a cryogenic test cavity (CTCE). This part is a separate cryostat consisting of a vacuum vessel and vapor-cooled shields. The vessel is mounted onto the CTA-flange of the upper CVV-bulkhead and hermetically sealed by an O-ring.

The CTCE contains a reflector and a blackbody for the "dark-background test". In this test the thermal influence of the non-existent telescope is simulated by the reflector that is temperature controlled at 40 K to 80 K. The observation target for the instruments is simulated by the black body controlled at < 5 K. In order to avoid thermal disturbances and straylight the internal CTCE walls are coated by a vapor-cooled shroud at a temperature of < 5 K.

The helium gas for the cooling of the CTCE-shroud and black body is provided by an external HeI – dewar.

As an alternative to the CTCE a vacuum-tight plate similar to the PFM cryostat cover with a helium-cooled cover shield is thermally analysed. In this case neither a reflector nor a blackbody target is needed.

Reflector
T = 40 – 80 K

CTCE
(Vacuum vessel with
vapor-cooled shields)
T $_{shroud}$ < 5 K

elec. HTR power
Q $_{Reflector}$

Antenna

mass flow rate °m $_3$

Antenna dissip.
Q $_{Antenna}$

Black body
T < 5 K

CTA
Shroud
Dewar
T = 4.2 K

HERSCHEL
payload

mass flow rate
°m $_4$

Instrument dissip.
Q $_{Instruments}$

Optical Bench
T $_{OB}$ < 15 K

mass flow rate °m $_2$

elec. HTR power
Q $_{Aux. Tank}$

Auxiliary tank
T = 1.7 K

Harness dissip. Q $_{harness}$

mass flow rate °m $_1$

harness

elec. HTR power
Q $_{Main Tank}$

Main tank
T = 4.2 K

Modified ISO
cryostat

Free convection

Ambient air   T = 293 K

Figure 3-1:   EQM Testconfiguration

3.2 EQM Thermal Test Objectives

As stated in AD 08 the following test objectives are identified:

- Functional test of the scientific instruments

- EMC test

- Dark background test

- Verification of the alignment procedure

- Pre-validation of the Payload thermal design

- Verification of the Payload integration procedure

- First functional check of the EGSE (H/W and S/W) and EGSE Test Procedure preparation/evaluation

3.3 Thermal Requirements

During the EQM test the HERSCHEL payload consisting of the instrument flight-representative QMs and the OB shall be operated in a flight-representative thermal environment and shall meet the thermal requirements specified in AD2, AD3 and AD4 for the operational conditions in flight.

As specified in AD2, AD3 and AD4 the temperature reference points of the instruments shall be kept within the temperature ranges depending on the respective temperature levels compiled in Table 3-1 thru Table 3-5.

Instrument Level-0 - I/F	Tmin (K)	Tmax (K)	Level 0 max. heat flow on strap (mW)	Level 0 heat dissipation on respective thermal node (mW)	Stability	Reference
# 811 SPIRE SM Detector enclosure	TBD	1.80	5	NA	NA	*) AD 03
# 819 SPIRE Cooler Pump HS	TBD	1.80	2	NA	NA	*) AD 03
# 820 SPIRE Cooler Evaporator HS	TBD	1.80	1	NA	NA	*) AD 03
# 765 PACS Blue Detector	1.6	3.50	NA	0.8	NA	AD 02
# 760 PACS Red Detector	1.6	1.75	NA	0	NA	AD 02
# 781 PACS He-Pump	1.6	2.20	NA	7.61	NA	AD 02
# 912 HIFI I0-Boundary	0	2.00	"see TMM"	"see TMM"	6 mK/100s	AD 04

*) stated in change request HR-SP-RAL-ECR-009-v2, not yet agreed by ASED

Table 3-1: Level 0 temperature requirements of instruments

Instrument Level-1 - I/F	Tmin (K)	Tmax (K)	Level 1 heat load on strap (mW)	Stability	Reference
SPIRE L1-interface	TBD	*) 4.5	*) 13	NA	*) AD 03
PACS Photometer Optics	3	5	"from TMM"	NA	AD 02
PACS Collimator	3	5	"from TMM"	NA	AD 02
PACS Spectrom. Housing	3	5	"from TMM"	NA	AD 02
HIFI L1-interface	TBD	6	"from TMM"	6 mK/100s	AD 01

*)   stated in change request HR-SP-RAL-ECR-009-v2, not yet agreed by ASED

Table 3-3:   Level 1 temperature requirements of instruments

Instrument Level-2 - I/F	Tmin (K)	Tmax (K)	Level 2 heat load on FPU (mW)	Stability	Reference
#801, 802 SPIRE JFETs	TBD	15	"from TMM"	NA	AD 03
PACS	NA	NA	NA	NA	AD 02
#910 HIFI FPU Structure	TBD	20	"from TMM"	15 mK/100s	AD 01

Table 3-5:   Level 2 temperature requirements of instruments

In order to meet the a.m. requirements it is mandatory to expose the HERSCHEL payload consisting of the OB with instruments, instrument shield and instrument shield MLI to an thermal environment identical or at least similar to the flight-environment. This is achieved by the following measures:

- Cooling the innermost heatshield (HS1) of the EQM-cryostat to a temperature at or below the flight-level of 30 K. This shall be done by adequate heating of the main tank resulting in an adequate helium mass flow rate.

- Controlling the auxiliary tank temperature at flight-representative value (currently 1.7 K)

- Using similar thermal links between instrument L0-interfaces and auxiliary tank as for the FM. Since the auxiliary EQM-tank is smaller in diameter than the optical bench additional "tank-interface-brackets" shall be provided which allow the same L0-strap routing as for the FM. If this is not possible the EQM-cooling straps shall be tailored in order to achieve flight-relevant instrument L0-temperatures. Anyhow the same tank/strap interface design shall be provided for the EQM as for the PFM.

- Adjustment of a flight-representative mass flow rate of approximately 2.1 mg/s (see RD 03) for the payload-ventline. This shall be achieved by an adequate thermal decoupling of the auxiliary tank (1.7K) from the main tank (4.2 K) and by adjusting the electrical heater power of the auxiliary tank.

- Avoid an excessive infrared heat flow onto the instruments and OB by an adequate baffling of the cryostat opening. This is intended to be obtained by a baffle penetrating the cryostat opening. The baffle shall be coupled to the vapor-cooled shroud of the CTCE that is cooled beyond 5 K. Note: Analysis demonstrated that an infrared heat flow of 3.5 Watts ! would be absorbed by the payload if the cryostat opening was not baffled and exposed to ambient temperature (293 K). In this case the a.m. requirements would by far not be met!

4   Thermal Design and Thermal-Mathematical Model Description

4.1   TMM Submodel Structure

The ESATAN TMMs are defined as independent submodels (submodel-technique) assembled to an overall EQM model. The model hierarchy is illustrated in Figure 4-1.

The ventline model $VENT is based on the one developed for ISO (see RD 17). It computes the heat exchanges by forced convection between gaseous helium and the ventline walls as well as the heat transfer by advection within the main tank ventline. Pressure drop computation, however, has been deleted in order to avoid numerical instabilities. A brief pressure drop analysis is performed in § 6.

The submodel $PAYLOAD exactly corresponds to the payload-TMM used in the HPLM TMM (see RD 03). It includes the instrument TMMs delivered by ESA (see RD 14). The L0-cooling strap cross-sections between the instrument L0-interfaces and the EQM-auxiliary tank, however, are adapted to the latest instrument requirements w.r.t. AD 02, AD 03, AD04.

The submodel $CRYO comprises the EQM-cryostat with CVV, heatshields, main tank and auxiliary tank and includes the submodels $PAYLOAD and $VENT.

The submodel $CTCE comprises the cryogenic test cavity for EQM.

Concerning thermal node and network identifications and definitions the submodels are explained in detail in the following sections. Conductors and node data as well as subroutine definitions and material data are included in the appropriate ESATAN-files. Due to the excessive extent the complete listings are not contained in this report. The models will be delivered to ESA in electronic form.
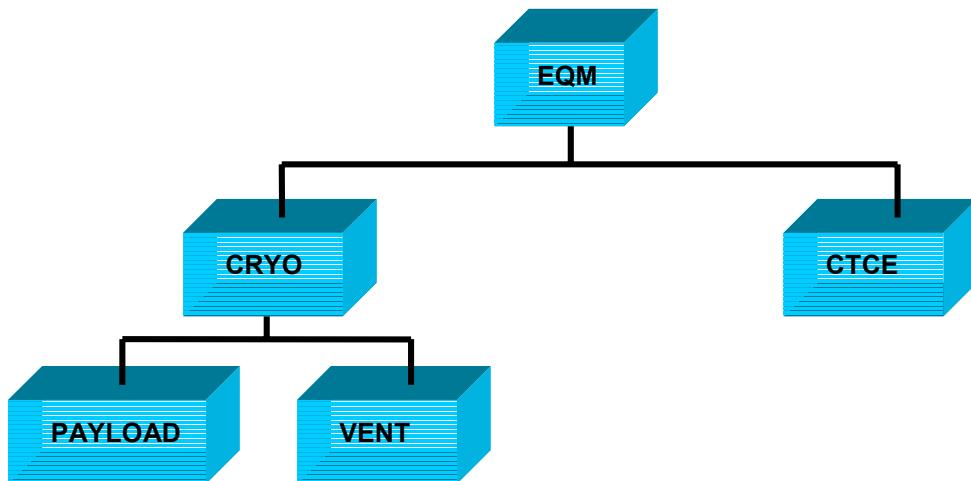
Figure 4-1:   ESATAN Thermal-Mathematical Model hierarchy of EQM

4.2 Submodel "CRYO"

4.2.1 General CRYO-TMM Description

The submodel $CRYO comprises the EQM thermostat including CVV, heatshields, MLI-blankets, main and auxiliary tank, spatial frameworks etc. and includes the submodels $PAYLOAD and $VENT. The thermal node indentifiers and thermal node defintions are shown in Figure 4-3. The included submodels are not depicted in Figure 4-3.
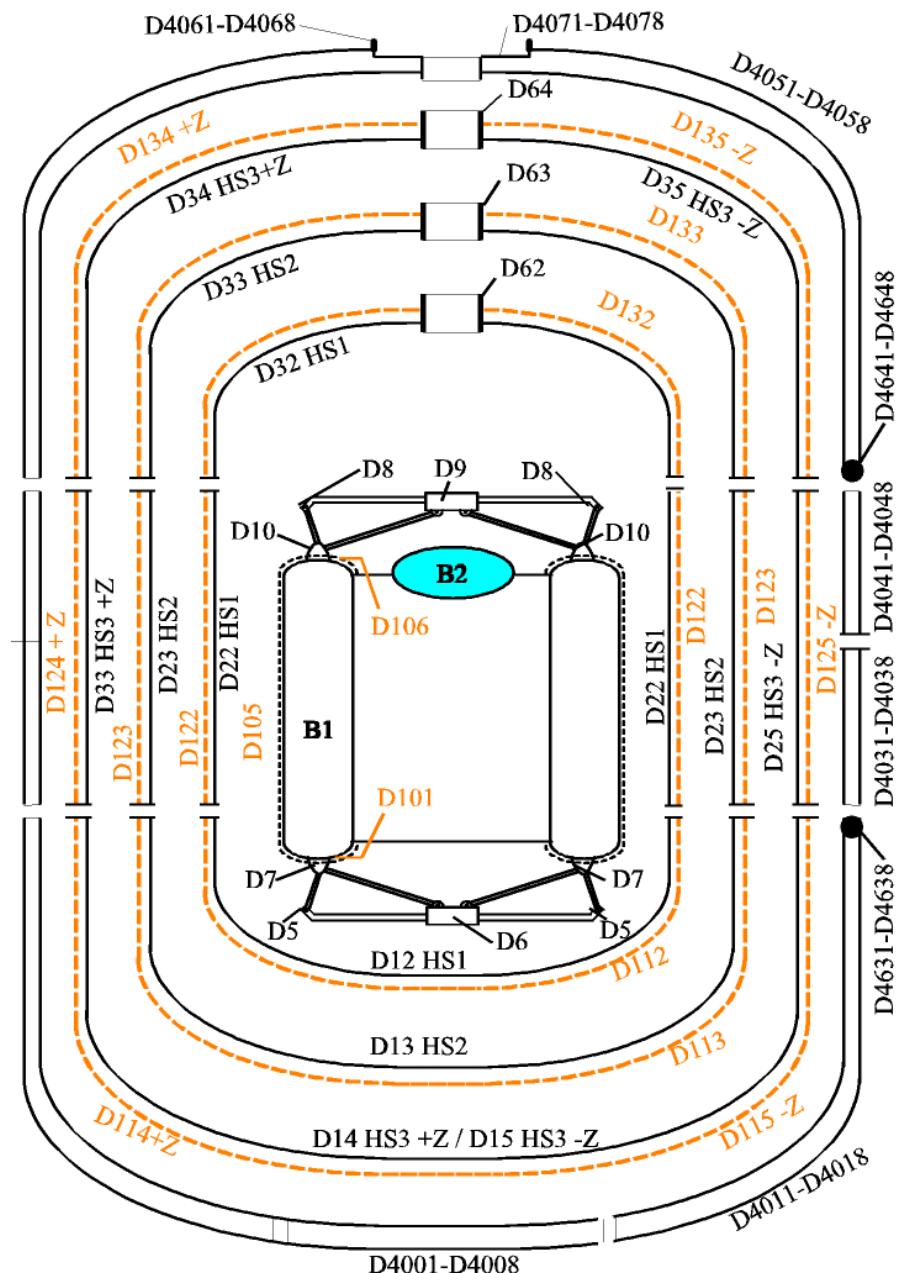
Figure 4-3:   Thermal nodes distribution of EQM-cryostat TMM

4.2.2 Harness Thermal Modelling

The harness node definitions and interfaces are shown in Figure 4-5. Each harness node is subjected to a heat dissipation. The dissipations are copied from the HPLM model (see RD 03) and can be found in the original program code, listed below. The connector interface ring used for the EQM is represented by the nodes 4731 to 4738 (plug sections) evenly distributed along the perimeter. Due to absence of approved data it is assumed that the two harness bundles (copied from the HPLM model) are routed to the plug sections 4731 and 4738 only. The knowledge about the exact plug position, however, is not important for thermal aspects. The original ESATAN-program code to compute the harness conductances are listed below:

```
# ---------------------------------------------------------------------------------------
# Harness within CVV, copied from model herschel_delivered.d from 30.11.01
# -------------------------------------------------------------------------
#
#                         HARNESS
# copied from herschel_delivered.d from 30.11.01
# -------------------------------------------------------------------------
#
#   cables are modelled by one conductor as a sum of several terms,
#   one per material:
#       argument 1  =  stainless steel          mm^2
#       argument 2  =  brass                    mm^2
#       argument 3  =  teflon  (insulation)     mm^2
#       argument 4  =  commercial copper        mm^2
#       argument 5  =  Vespel                   mm^2
#       argument 6  =  copper-beryllium         mm^2
#       argument 7  =  copper-nickel            mm^2
#       argument 8  =  length                   m
#       argument 9  =  temperature 1            K
#       argument 10 =  temperature 2            K
#
# modification by J. Hinger: X2-harness routed to CVV-plug 4731
#                            X3-harness routed to CVV-plug 4738
GL(4731,6051) = FCAB(X2SST,X2BRAS,X2PTFE,X2CCU,X2VESP,X2CUBE,X2CUMN, X2L*.20D0, T4731, T6051);
GL(6051,6052) = FCAB(X2SST,X2BRAS,X2PTFE,X2CCU,X2VESP,X2CUBE,X2CUMN, X2L*.20D0, T6051, T6052);
GL(6052,6053) = FCAB(X2SST,X2BRAS,X2PTFE,X2CCU,X2VESP,X2CUBE,X2CUMN, X2L*.20D0, T6052, T6053);
GL(6053,6054) = FCAB(X2SST,X2BRAS,X2PTFE,X2CCU,X2VESP,X2CUBE,X2CUMN, X2L*.20D0, T6053, T6054);
GL(6054,6055) = FCAB(X2SST,X2BRAS,X2PTFE,X2CCU,X2VESP,X2CUBE,X2CUMN, X2L*.20D0, T6054, T6055);
#
GL(6055,6056)= FCAB(X2SST,X2BRAS,X2PTFE,X2CCU,X2VESP,X2CUBE,X2CUMN, X2IL*.25D0, T6055, T6056);
GL(6056,6057)= FCAB(X2SST,X2BRAS,X2PTFE,X2CCU,X2VESP,X2CUBE,X2CUMN, X2IL*.25D0, T6056, T6057);
GL(6057,6058)= FCAB(X2SST,X2BRAS,X2PTFE,X2CCU,X2VESP,X2CUBE,X2CUMN, X2IL*.25D0, T6057, T6058);
#
GL(4738,6061) = FCAB(X3SST,X3BRAS,X3PTFE,X3CCU,X3VESP,X3CUBE,X3CUMN, X3L*.20D0, T4738, T6061);
GL(6061,6062) = FCAB(X3SST,X3BRAS,X3PTFE,X3CCU,X3VESP,X3CUBE,X3CUMN, X3L*.20D0, T6061, T6062);
GL(6062,6063) = FCAB(X3SST,X3BRAS,X3PTFE,X3CCU,X3VESP,X3CUBE,X3CUMN, X3L*.20D0, T6062, T6063);
GL(6063,6064) = FCAB(X3SST,X3BRAS,X3PTFE,X3CCU,X3VESP,X3CUBE,X3CUMN, X3L*.20D0, T6063, T6064);
GL(6064,6065) = FCAB(X3SST,X3BRAS,X3PTFE,X3CCU,X3VESP,X3CUBE,X3CUMN, X3L*.20D0, T6064, T6065);
#
GL(6065,6066)= FCAB(X3SST,X3BRAS,X3PTFE,X3CCU,X3VESP,X3CUBE,X3CUMN, X3IL*.25D0, T6065, T6066);
GL(6066,6067)= FCAB(X3SST,X3BRAS,X3PTFE,X3CCU,X3VESP,X3CUBE,X3CUMN, X3IL*.25D0, T6066, T6067);
GL(6067,6068)= FCAB(X3SST,X3BRAS,X3PTFE,X3CCU,X3VESP,X3CUBE,X3CUMN, X3IL*.25D0, T6067, T6068);
#
#  CVV-plugs to HS1, modification by J. Hinger
#
GL( 4732, 22 ) = 0.25* FCAB(4.99D0,2.75D0,36.0D0,0.0D0,0.0D0,0.0D0,0.0D0, 0.25D0, T4732, T22);
GL( 4733, 22 ) = 0.25* FCAB(4.99D0,2.75D0,36.0D0,0.0D0,0.0D0,0.0D0,0.0D0, 0.25D0, T4733, T22);
GL( 4734, 22 ) = 0.25* FCAB(4.99D0,2.75D0,36.0D0,0.0D0,0.0D0,0.0D0,0.0D0, 0.25D0, T4734, T22);
GL( 4735, 22 ) = 0.25* FCAB(4.99D0,2.75D0,36.0D0,0.0D0,0.0D0,0.0D0,0.0D0, 0.25D0, T4735, T22);
#
#  HS1  to  spatial framework
#
GL( 8, 22 )= FCAB(0.45D0, 1.02D0, 4.00D0, 0.0D0, 0.0D0, 0.0D0, 0.0D0, 1.50D0, T8, T22); # up
```

```
#
GL(8,PLM:376)=FCAB(0.45D0, 1.02D0, 4.00D0, 0.0D0, 0.0D0, 0.0D0, 0.0D0, 0.50D0, T8, T:PLM:376);
# up
#
GL(6058,PLM:6059)=FCAB(X2SST,X2BRAS,X2PTFE,X2CCU,X2VESP,X2CUBE,X2CUMN,X2IL/4.0D0,T6058,T:PLM:6
059)
#
GL(6068,PLM:6069)=FCAB(X3SST,X3BRAS,X3PTFE,X3CCU,X3VESP,X3CUBE,X3CUMN,X3IL/4.0D0,T6068,T:PLM:6
069)

#     Function Subroutine FCAB copied from HERSCHEL-model, delivered 30.11.2001
#
      DOUBLE PRECISION FUNCTION FCAB(HSST,HBRAS,HPTFE,HCCU,HVESP,HCUBE,HCUMN,HL,TEM1,TEM2)
#
#     FCAB CALCULATES THE THERMAL CONDUCTANCE (W/K) FOR THE HARNESS CONDUCTORS
#
#        THE INPUT ARGUMENTS ARE:
#            HSST   CROSS SECTION OF SST-PART                     mm**2
#            HBRAS    "       "   "  BRASS-PART                   mm**2
#            HPTFE    "       "   "  TEFLON-PART (INSULATION)     mm**2
#            HCCU     "       "   "  Commercial Copper            mm**2
#            HVESP    "       "   "  KAPTON-PART (INSULATION)     mm**2
#            HCUBE    "       "   "  Copper-Beryllium             mm**2
#            HCUMN    "       "   "  Copper-Nickel                mm**2
#
#            HL     LENGTH OF THE CABLE                           m
#            TEM1   TEMPERATURE OF 1ST ATTACHED NODE              K
#            TEM2      "       "   2ND    "       "               K
#
#        THE RESULTING VALUE IS MULTIPLIED BY THE USER CONSTANT FMHAR
#
       DOUBLE PRECISION HSST, HBRAS, HPTFE, HCCU, HVESP,
      f                 HCUBE, HCUMN,
      f                 HL, TEM1, TEM2, TM

       IF ( ABS(TEM1-TEM2) .LT. 1.D0 )  THEN
#
       TM   =   .5D0 * (TEM1+TEM2)
#
       FCAB = HSST  * INTRP1( TM, TAB2,   1)   +
      f       HBRAS * INTRP1( TM, TAB10,  1)   +
      f       HPTFE * INTRP1( TM, TAB11,  1)   +
      f       HCCU  * INTRP1( TM, XCCU,   1)   +
      f       HVESP * INTRP1( TM, TLVESP, 1)   +
      f       HCUBE * INTRP1( TM, TLCUBE, 1)   +
      f       HCUMN * INTRP1( TM, TLCUMN, 1)
#
       ELSE
#
       FCAB = HSST  * INTGL1( TEM1, TEM2, TAB2 ) /(TEM2-TEM1)   +
      f       HBRAS * INTGL1( TEM1, TEM2, TAB10 ) /(TEM2-TEM1)   +
      f       HPTFE * INTGL1( TEM1, TEM2, TAB11 ) /(TEM2-TEM1)   +
      f       HCCU  * INTGL1( TEM1, TEM2, XCCU  ) /(TEM2-TEM1)   +
      f       HVESP * INTGL1( TEM1, TEM2, TLVESP) /(TEM2-TEM1)   +
      f       HCUBE * INTGL1( TEM1, TEM2, TLCUBE) /(TEM2-TEM1)   +
      f       HCUMN * INTGL1( TEM1, TEM2, TLCUMN) /(TEM2-TEM1)
#
       END IF
#
       FCAB = FMHAR * FCAB * 1.D-6 / HL              #  mm**2 --> m**2
#
       RETURN
       END
```

```
#     internal Harness Dissipation
#     --------------------------
#
        QI 4731 = X2OHM*X2L/5.   # CVV plug
        QI 6051 = X2OHM*X2L/5.
        QI 6052 = X2OHM*X2L/5.
        QI 6053 = X2OHM*X2L/5.
        QI 6054 = X2OHM*X2L/5.
        QI 6055 = X2OHM*X2IL/5.
        QI 6056 = X2OHM*X2IL/5.
        QI 6057 = X2OHM*X2IL/5.
        QI 6058 = X2OHM*X2IL/5.
#        QI 6059 = X2OHM*X2IL/5.+ 0.25*(PA3OHM*PA3L+SP3OHM*SP3L+HI3OHM*HI3L)
# this node is part of $PAYLOAD
#
        QI 4738 = X3OHM*X3L/5.   # CVV plug
        QI 6061 = X3OHM*X3L/5.
        QI 6062 = X3OHM*X3L/5.
        QI 6063 = X3OHM*X3L/5.
        QI 6064 = X3OHM*X3L/5.
        QI 6065 = X3OHM*X3IL/5.
        QI 6066 = X3OHM*X3IL/5.
        QI 6067 = X3OHM*X3IL/5.
        QI 6068 = X3OHM*X3IL/5.
#        QI 6069 = X3OHM*X3IL/5.+ 0.25*(SP5OHM*SP5L) # this node is part of $PAYLOAD
#
#                Harness X2  CVV - HS1  (Instruments w/o SPIRE JFETs)
#                copied from model herschel_delivered.d from 30.11.01
#
  X2SST  =  25.00D0;       # [mm^2] X-sect   SST
  X2BRAS =   9.90D0;       # [mm^2] X-sect   BRASS
  X2CUBE =   0.34D0;       # [mm^2] X-sect   CuBe
  X2CUMN =   0.00D0;       # [mm^2] X-sect   Manganin
  X2PTFE = 269.00D0;       # [mm^2] X-sect   Teflon
  X2CCU  =   0.00D0;       # [mm^2] X-sect   commercial Cu
  X2VESP =   0.00D0;       # [mm^2] X-sect   Vespel
  X2L    =   0.35D0;       # [m]    Length
  X2IL   =   1.2D0;        # [m]    Length
  X2OHM  = 10.42D-3;       # [W/m]  Ohmic Heat
#
#                Harness X3  CVV - HS1  (SPIRE JFETs)
#                copied from model herschel_delivered.d from 30.11.01
#
  X3SST  =  18.10D0;       # [mm^2] X-sect   SST
  X3BRAS =  12.70D0;       # [mm^2] X-sect   BRASS
  X3CUBE =   0.00D0;       # [mm^2] X-sect   CuBe
  X3CUMN =   0.00D0;       # [mm^2] X-sect   Manganin
  X3PTFE = 252.00D0;       # [mm^2] X-sect   Teflon
  X3CCU  =   0.00D0;       # [mm^2] X-sect   commercial Cu
  X3VESP =   0.00D0;       # [mm^2] X-sect   Vespel
  X3L    =   0.5D0;        # [m]    Length
  X3IL   =   1.2D0;        # [m]    Length
  X3OHM  =  1.02D-3;       # [W/m]  Ohmic Heat
#
#
#   TABLE  2:  stainless steel for cables  ( Lambda in [W/m * K] )
#              data from Mr. Becker / RR 634  (15. 03. 1983)
#
TAB2  ( 2 ,  10 ) =
   0.100D0, 8.00000D-03,    0.400D0, 3.00000D-02,   1.000D0, 8.00000D-02,
   4.000D0, 3.00000D-01,    10.000D0, 7.00000D-01,  40.000D0, 5.00000D+00,
  80.000D0, 8.00000D+00,   150.000D0, 1.10000D+01, 300.000D0, 1.50000D+01,
 400.000D0, 1.50000D+01;
#
```

```
#   TABLE 10:  brass for cables  ( Lambda in [W/m * K] )
#              data from Mr. Becker / RR 634  (15. 03. 1983)
TAB10  ( 2,  9 ) =
   0.100D0, 6.00000D-02,   0.400D0, 2.00000D-01,   1.000D0, 7.00000D-01,
   4.000D0, 3.00000D+00,  10.000D0, 1.00000D+01,  40.000D0, 3.70000D+01,
  80.000D0, 6.50000D+01, 150.000D0, 8.50000D+01, 300.000D0, 1.20000D+02;
#
#   TABLE 11:  TEFLON for cables  -  insulation   ( Lambda in [W/m * K] )
#              data from Mr. Becker / RR 634  (15. 03. 1983)
TAB11  ( 2,  9 ) =
   0.100D0, 1.02000D-03,   0.400D0, 4.09000D-03,   1.000D0, 1.02000D-02,
   4.000D0, 4.09000D-02,  10.000D0, 9.69000D-02,  40.000D0, 1.96000D-01,
  80.000D0, 2.35000D-01, 150.000D0, 2.55000D-01, 300.000D0, 2.61500D-01;
#*************************************************************************
#    THERMAL CONDUCTIVITY FOR COPPER (COMMERCIAL) (W./M.K.)
#     DATA FROM  DOC AEROSPATIALE CA/CS/T
#*************************************************************************
      XCCU (2,12)=
        1.0D0,  80.0D0,
        2.0D0, 140.0D0,
        3.0D0, 200.0D0,
        4.0D0, 280.0D0,
        6.0D0, 420.0D0,
       10.0D0, 700.0D0,
       15.0D0,1000.0D0,
       30.0D0,1500.0D0,
       50.0D0, 700.0D0,
      100.0D0, 500.0D0,
      200.0D0, 410.0D0,
      300.0D0, 400.0D0;
#*************************************************************************
# Lambda table for CuMn12Ni4 Manganin [W/mK]
#*************************************************************************
TLCUMN (2, 8) =
   1.0D0,      0.06D0,
   4.0D0,      0.5D0,
  10.0D0,      2.0D0,
  40.0D0,      7.0D0,
  80.0D0,     13.0D0,
 150.0D0,     16.000D0,
 200.0D0,     18.000D0,
 300.0D0,     21.000D0;
#*************************************************************************
# Lambda table for CuBe copper-beryllium [W/mK]
#      Data delivered by T. Passvogel ( ESA-fax PT-01750 23.02.1996 )
#*************************************************************************
TLCUBE (2, 7) =
   2.0D0,      0.900D0,
   3.0D0,      1.400D0,
   4.0D0,      1.900D0,
  10.0D0,      4.900D0,
  20.0D0,     11.000D0,
  80.0D0,     37.000D0,
 300.0D0,     95.000D0;
#*************************************************************************
#   TLVESP: Vespel/Kapton for cable insulation and supports [W/m*K]
#   data from Mr. Bruce Swinyard, RAL  (09. 11. 1999)
#*************************************************************************
TLVESP  ( 2,  9 ) =
   0.3D0, 1.6D-04,    1.0D0, 1.1D-03,   2.0D0, 2.2D-03,
   3.0D0, 3.4D-03,    4.0D0, 0.02D0,   10.0D0, 0.025D0,
  15.0D0,  0.035D0,   30.0D0, 0.15D0,  300.0D0, 0.35D0;
#
```
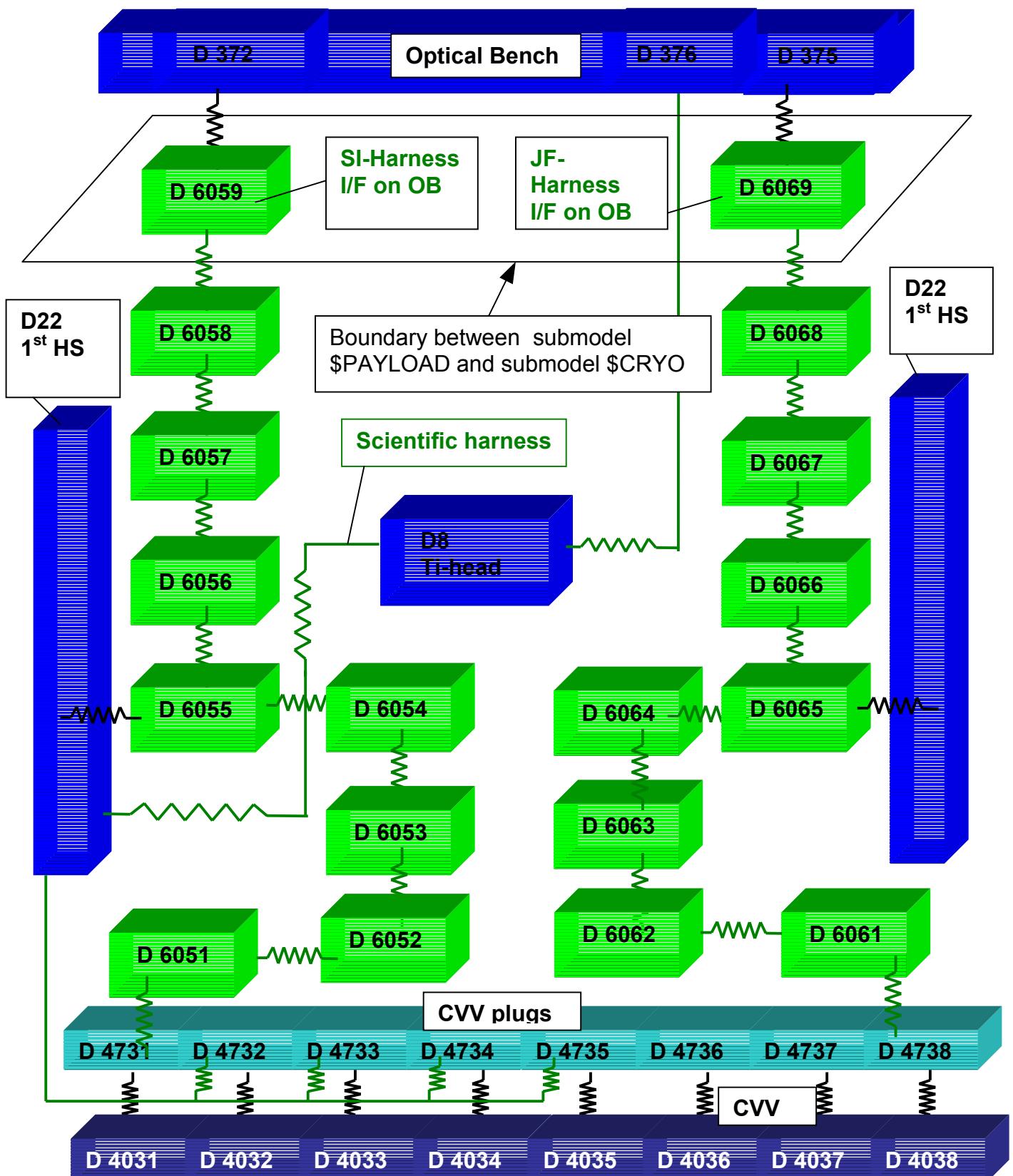
Figure 4-5:   Harness interfaces between $PAYLOAD and $CRYO

4.2.3 Tank Suspension Thermal Modelling

The nodes indentifiers and distributions along the tank suspension straps are shown in Figure 4-7. The strap design is that of ISO as defined in RD 15.
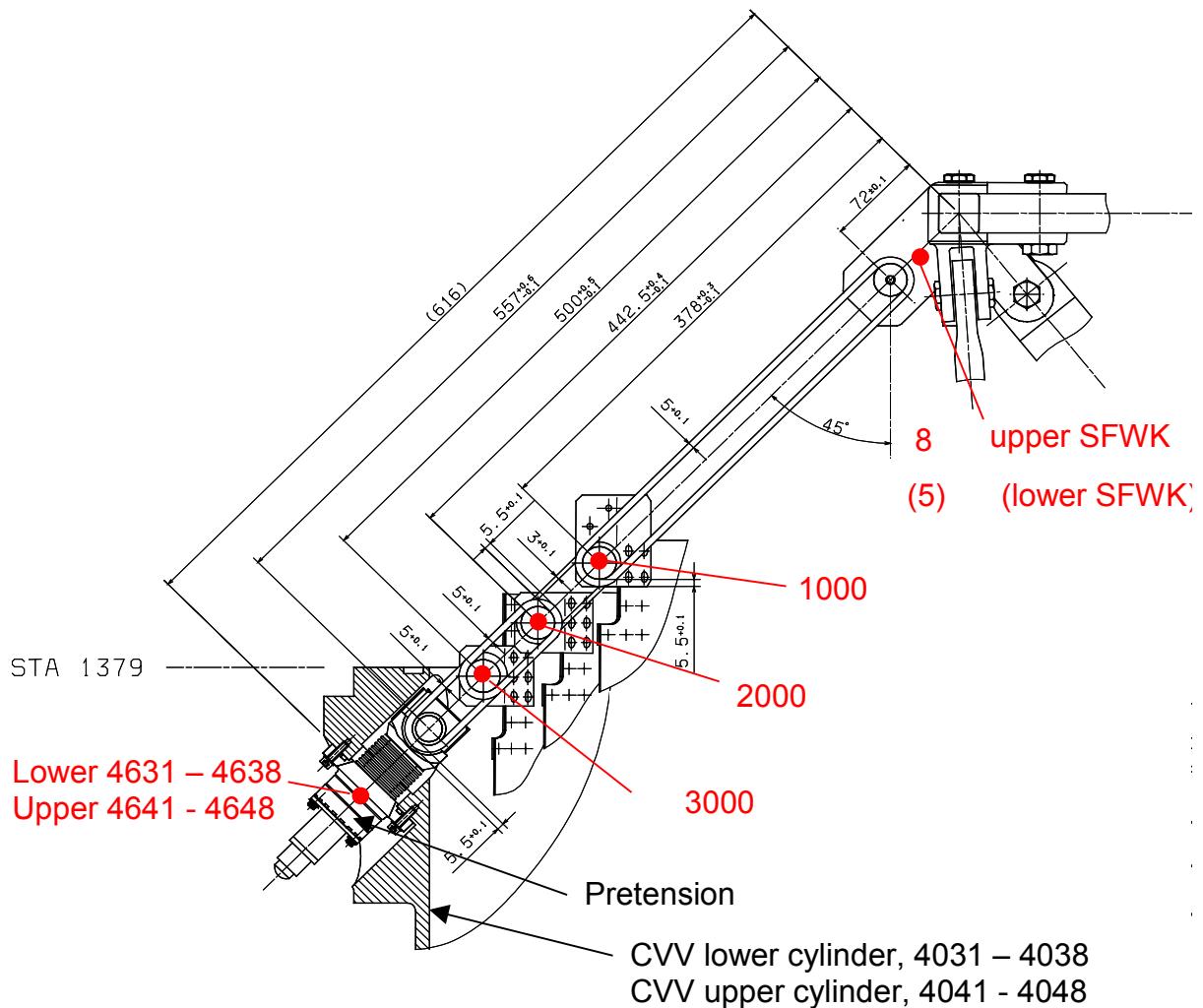
Figure 4-7:   Thermal nodes distribution of tank-suspensions

4.2.4 LOU Window Thermal Modelling

The LOU-window modelization already considers the two additional alignment windows. In contrast to the HPLM-model (RD 03) 9 LOU windows instead of 7 are considered, i.e. area of node 4090 and all couplings are updated respectively. The LOU window thermal modelization is shown in Figure 4-9.

4052,
4053

4090

M5

Ø34

Ø47

58

Ø68

11.5

10

LOU Windows

R978

9 windows in total

D54   3rd HS HIFI Baffle

D53   2nd HS HIFI Baffle

D52   1st HS HIFI Baffle, ext.

D4052   CVV

D42   1st HS HIFI Baffle, int.

D34   3rd HS +Z

D 390
I. Shield HIFI Baf. ext.

D 391
I. Shield HIFI Baf. int.

D4090
CVV LOU window

D 910
HIFI FPU Structure

D35   3rd HS -Z

D33   2nd HS

D4053   CVV

D32   1st HS

Boundary submodel $CRYO / $PAYLOAD
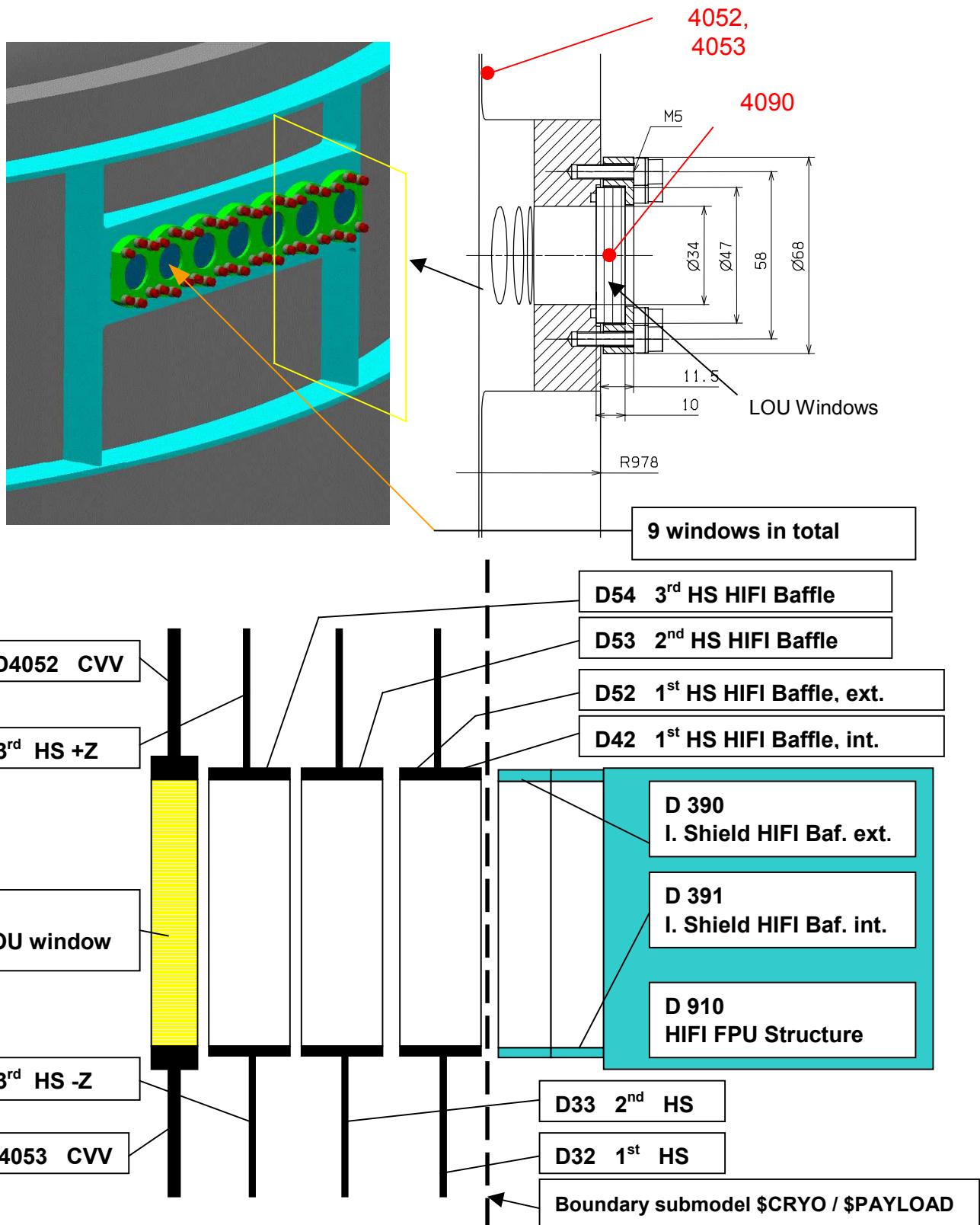
Figure 4-9:   LOU window thermal nodes and interfaces

4.2.5   Particular EQM-relevant Design Details

4.2.5.1 EQM Auxiliary Tank Interfaces to HERSCHEL Spatial Framework

Between EQM-aux. Tank and Ti-heads of upper spatial framework interface (node 8) the following CFRP-straps (EUROCOPTER-design) are considered and included in the TMM:

```
4 CFC-straps between main tank and Ti-heads (node 8) introduced w.r.t.
data provided by E.Wilz, C. Schlosser from H. Bansemir(EUROCOPTER)
e-mails from 4. and 5. Feb. 2002:
4 straps of dimension 200 x 106 x 4mm:
20 layers +-45° a 0.0966 mm, V913/40/G801 with T300 fibres
10 layers   0° a 0.2177 mm, V913/40/G808 with T300 fibres

## ==> volume fraction of +-45° = 47.0%, of 0° fibres = 53.0%
##     Assumption: k90° = 0.197 K0°
##
 GL(  2,  8) =  4.D0*0.106D0*0.004109D0/0.200D0 *
               ( 0.47D0/2.D0*( 1.D0 + 0.197D0) + 0.53D0 )* FLT300( T2, T8) ;
```

4.2.5.2 EQM Auxiliary Tank Interfaces to Instrument Level-0-Interfaces

The routing of the cooling straps between Instrument L0-interfaces and aux. Tank is not yet developed. Due to the absence of data the following PFM-strap design is considered and included in the TMM:

Cooling straps to Level 0 (high conductivity copper, Cu 99.999%)
updated according to cross-sections and lengths emerging from RD 04:

```
GL( PLM:811, 2): SPIRE               20 x 2.0 x 580 mm
GL( PLM:819, 2): SPIRE               20 x 2.0 x 620 mm
GL( PLM:820, 2): SPIRE               20 x 2.0 x 680 mm
GL( PLM:765, 2): PACS Blue detector  20 x 0.5 x 384 mm
GL( PLM:760, 2): PACS Red  detector  20 x 2.0 x 319 mm
GL( PLM:781, 2): PACS Sorption Cooler 20 x 1.0 x 383 mm
GL( PLM:912, 2): HIFI                20 x 1.5 x 400 mm
```

Considering an "ISO-standard interface" contact conductance of 0.4 W/K at both sides of the strap results in the following definitions of thermal couplings:

```
#
GL( PLM:811, 2) = 1./( 2./0.4 + 1./(40.0D-6/0.580D0 * INTRP1(.5*(T:PLM:811+T2),TLCU,1) ) )
GL( PLM:819, 2) = 1./( 2./0.4 + 1./(40.0D-6/0.620D0 * INTRP1(.5*(T:PLM:819+T2),TLCU,1) ) )
GL( PLM:820, 2) = 1./( 2./0.4 + 1./(40.0D-6/0.680D0 * INTRP1(.5*(T:PLM:820+T2),TLCU,1) ) )
GL( PLM:765, 2) = 1./( 2./0.4 + 1./(10.0D-6/0.384D0 * INTRP1(.5*(T:PLM:765+T2),TLCU,1) ) )
GL( PLM:760, 2) = 1./( 2./0.4 + 1./(40.0D-6/0.319D0 * INTRP1(.5*(T:PLM:760+T2),TLCU,1) ) )
GL( PLM:781, 2) = 1./( 2./0.4 + 1./(20.0D-6/0.383D0 * INTRP1(.5*(T:PLM:781+T2),TLCU,1) ) )
GL( PLM:912, 2) = 1./( 2./0.4 + 1./(30.0D-6/0.400D0 * INTRP1(.5*(T:PLM:912+T2),TLCU,1) ) )
#
```

The current PFM-Design applies rigid high-purity aluminium bars as illustrated in Figure 4-11 with a flexible link to the instrument L0-interfaces. The flexible links can be designed as packages of high-purity aluminium foils connected at their flange-ends by welding. This design has to be adapted to the EQM Auxiliary Tank by modification of the aluminium bar design and by adequate mechanical

interfaces on the EQM Auxiliary Tank. Anyway the thermal performance of the rigid bar/flexible link design including all contact resistances shall show at least the same thermal performance as the copper strap design assumed in the thermal analysis. This can be achieved by adequate dimensioning of the cross sections, flange contact areas and selecting high purity aluminium 99.9995% (A5N) with a residual resistivity ratio of at least 300. This material is commercially available as bars billets or ingots of adequate size, and as foils.
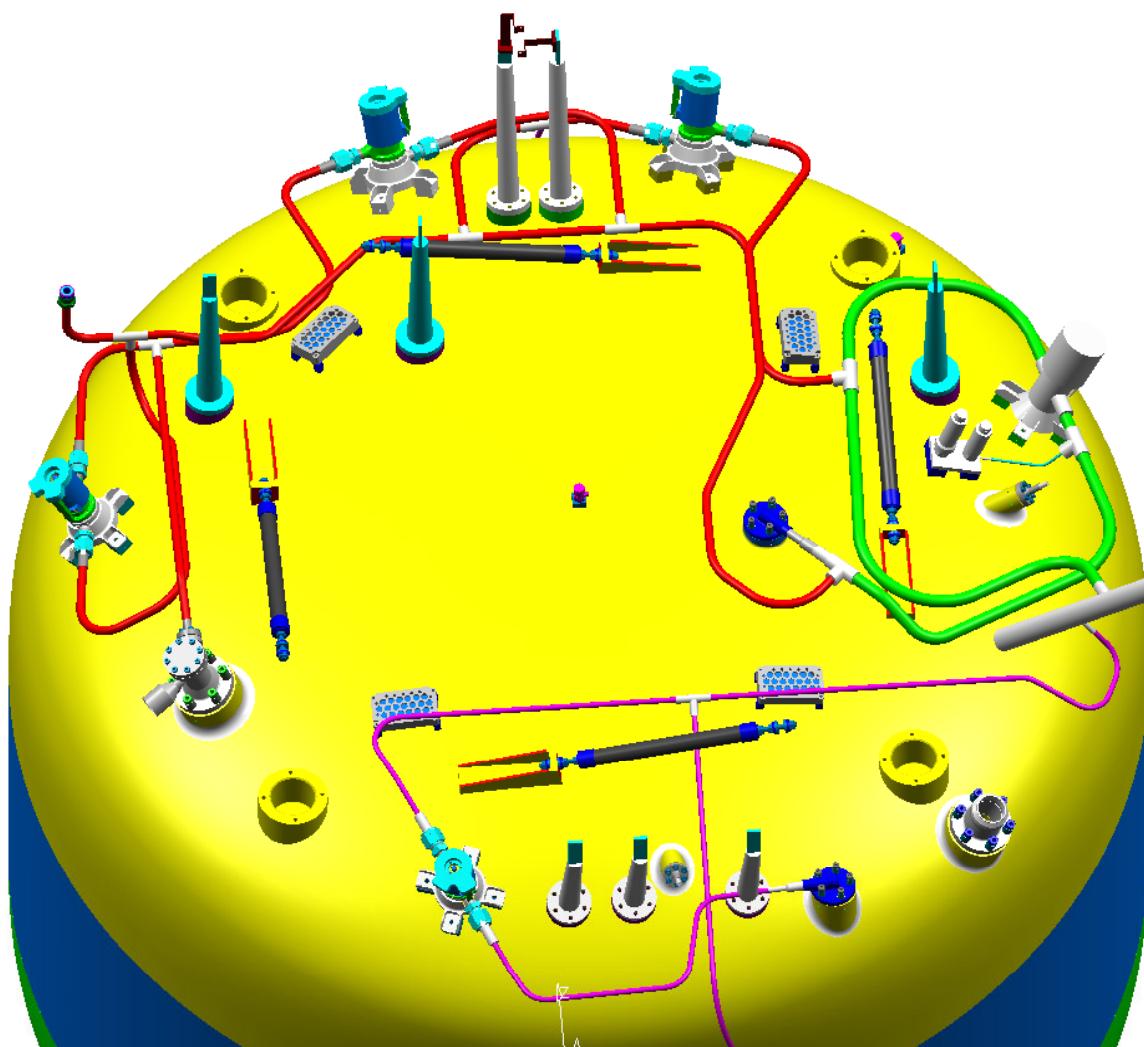
Figure 4-11:   PFM rigid bar L0-link design

4.3   Submodel "VENT"

The submodel "VENT" is based on the ESATAN-submodel "V0300.esat" (see RD 17) developed for the ISO-satellite. Some adaptions had to be performed in order to use it for the heat exchange calculation within the main tank ventline of the modified ISO-cryostat. The thermal modelling technique of the ventline is shown in Figure 4-12. The various fluid couplings are computed according to the original ESATAN-program code listed below:

```
GF( 251, 201) = MFLO1 * CPHEC * (1.D0 - EFOSS );      # inlet to wall

GF( 251, 252) = MFLO1 * CPHEC * EFOSS;               # inlet to outlet

GF( 201, 252) = GF( 251, 201);                       # wall  to outlet


TMOSS  = (T251+T252) / 2.0D0              #  average gas temperature within
                                            pipe section


EFOSS  = EFAC( MFLO1      , 0.012D0, LOSS  , 0.352D0 , TMOSS , T201)
```

```
     #****************************************************************************
           DOUBLE PRECISION FUNCTION EFAC( MASS, D, LENGT, RAD, TM, TWALL )
                                                        #    Version 3.00
     #****************************************************************************
     #   Version 2.00      27. 09. 1989    M. Sander     MBB
     #                        - Subroutines block:
     #                           -- Changes according to KT224-27/89 (Dr. Elsner)
     #                              dated 21. 08. 1989:
     #                              Functions E,EH:  Nusselt expressions
     #   Version 2.09      12. 03. 1992    M. Sander     MBB / KT224
     #                        - Function subroutine E expanded to zero length of
     #                          heat exchanger (for effective switch off)
     #   Version 3.00      24. 02. 1994    M. Sander    DASA / RTT222
     #                        - Recoded for ESATAN 4.5 up.
     # --------------------------------------------------------------------------
     #          THIS FUNCTION CALCULATES THE EXPONENTIAL FACTOR FOR THE DIFFERENT
     #          PIPE PARTS
     # --------------------------------------------------------------------------
     # MASS    kg/s    : MASS FLOW RATE
     # D       m       : PIPE DIAMETER
     # LENGT   m       : LENGTH OF THE PIPE
     # RAD     m       : BEND RADIUS OF PIPE
     # TM      K       : AVERAGE TEMPERATURE OF HELIUM
     # TWALL   K       : WALL TEMPERATURE
     #
     # CPHEC  J/kg*K  : SPECIFIC HEAT OF HELIUM               # CONSTANTS
     # ETA    kg/(m*s) : DYNAMIC VISCOSITY OF HELIUM
     # ETAW   kg/(m*s) : DYNAMIC VISCOSITY OF HELIUM AT TWALL
     # LAM    W/m*K    : THERMAL CONDUCTIVITY OF HELIUM (interpolated)
     # LAMW   W/m*K    : THERMAL CONDUCTIVITY OF HELIUM (interpolated at TWALL)
     # NU      -       : NUSSELT-NUMBER
     # RE      -       : REYNOLDS-NUMBER
     # REK     -       : CRITICAL REYNOLDS-NUMBER
     # PR      -       : PRANDTL-NUMBER
     # PRW     -       : PRANDTL-NUMBER AT TWALL
     # --------------------------------------------------------------------------
     #2345678 1 2345678 2 2345678 3 2345678 4 2345678 5 2345678 6 2345678 7 2
     # D E F I N I T I O N S
         DOUBLE PRECISION MASS, D, LENGT, RAD, TM
         DOUBLE PRECISION ETA, LAM, NU, RE, REK, PR, PI, XI
         DOUBLE PRECISION TWALL, ETAW, LAMW, PRW, HELP

         PI = 3.141593D0

     #   Version 2.09      12. 03. 1992    M. Sander     MBB / KT224
     #                        - Function subroutine E expanded to zero length of
     #                          heat exchanger (for effective switch off)
     # --------------------------------------------------------------------------
     # TERMINATION IF LENGT EQUALS ZERO                            Version 2.09

         IF (LENGT .LT. 1.D-10) THEN
            EFAC = 1.D0
            GO TO 99999                          #    ---> EXIT
         END IF
     # --------------------------------------------------------------------------
     # CALCULATION OF EQUATION PARAMETERS
     #   VISCOSITY,RE-NUMBER AND CRITICAL RE-NUMBER
         ETA  = INTRP1 ( TM,    ETAHE, 1 ) * 1.0D-07   # [kg/m*s]
         ETAW = INTRP1 ( TWALL, ETAHE, 1 ) * 1.0D-07   # [kg/m*s]
         RE   = 4.0D0*MASS/PI/D/ETA
         IF ( RAD .NE. .0D0 )
         @    REK = 2320.D0*(1.D0+8.6D0*(D/2.D0/RAD)**0.45D0)  # REK FOR BEND PIPE
```

```
#     LAMBDA

        LAM  = INTRP1 ( TM,     LAMHE1, 1 )
        LAMW = INTRP1 ( TWALL, LAMHE1, 1 )

#     PRANDTL-NUMBER
      PR   = ETA  * CPHEC / LAM
      PRW  = ETAW * CPHEC / LAMW

#     NUSSELT-NUMBER ACCORDING TO LINDE PROPOSAL  (Changes acc. Dr. Elsner)
      IF ( RAD .EQ. 0.0D0 ) THEN                      # --> STRAIGHT PIPE
         IF ( RE .LE. 2320.D0 ) THEN                       # LAMINAR FLOW
            NU = 3.66D0 + 0.0677D0 * ( PR * RE * D/LENGT )**1.33D0
      *                   / (1.D0 + 0.1D0 * PR * (RE*D/LENGT)**0.83D0 )
         ELSE                                              # TURBULENT FLOW
            XI = (1.82D0*LOG10(RE)-1.64D0)**(-2.D0)
            NU = XI/8.D0 * (RE-1000.D0)
      @            * PR * ( 1.D0+ (D/LENGT)**(2.D0/3.D0) )
      @                              /
      @             (1.D0 + 12.7D0 *
      @               (XI/8.D0)**0.5D0 * (PR**(2.D0/3.D0) -1.D0) )

         END IF                   #    LAMINAR/TURBULENT
       ELSE                                    # --> BEND PIPE
         IF (RE .LT. REK) THEN                        # LAMINAR FLOW
            HELP = 0.5D0 + 0.2903D0 * (D*0.5D0/RAD)**0.194D0
            NU   = 3.66D0 +
      @              0.08D0 * ( 1.D0 + 0.8D0 * (D*0.5D0/RAD)**0.9D0 ) *
      @                     RE**HELP * PR**0.333D0 * (PR/PRW)**0.14D0

         ELSE                                         # TURBULENT FLOW

            XI = 0.3164D0 / RE**0.25D0  +  0.03D0 * SQRT(D*0.5D0/RAD)
            NU = 0.125D0 * XI * RE * PR * (PR/PRW)**14
      @                          /
      @     ( 1.D0 + 12.7D0*SQRT(0.125D0*XI) * (PR**0.6666D0 - 1.D0)  )

         END IF                   #    LAMINAR/TURBULENT
       END IF                     #    STRAIGHT/BENDED


# ---------------------------------------------------------------------------
#  TERMINATION IF THERE IS NO MASS FLOW
      IF (MASS .LT. 1.D-10) THEN
         EFAC = .0D0
         GO TO 99999                          #    ---> EXIT
      END IF
# ---------------------------------------------------------------------------
#  CALCULATION OF THE EXPONENTIAL FACTOR
      EFAC = NU*LAM*PI*LENGT / (CPHEC*MASS)
      IF (EFAC .GT. 15.D0)  THEN
        EFAC = .0D0
      ELSE IF (EFAC .EQ. .0D0)  THEN
        EFAC = 1.D0
      ELSE
        EFAC = EXP(-EFAC)
      END IF

99999 CONTINUE
      RETURN
      END
#
```

```
#***********************************************************************
#*  THERMAL CONDUCTIVITY OF HELIUM GAS [W/m*K] :  --> 100 mbar = 10000 Pa <-- *
#*    REFERENCE:  NBS TN 631 (Thermophysical properties of Helium4 ... )     *
#***********************************************************************
 LAMHE1( 2 , 47 ) =
     0.2D0,     0.25D-3,     0.4D0,     1.23D-3,     0.6D0,     2.33D-3,
     0.8D0,     2.64D-3,     1.0D0,     2.69D-3,     1.2D0,     2.79D-3,
     1.4D0,     2.96D-3,     1.6D0,     3.20D-3,     1.8D0,     3.48D-3,
     2.0D0,     3.82D-3,     2.4D0,     4.59D-3,     2.8D0,     5.45D-3,
     3.2D0,     6.34D-3,     3.6D0,     7.24D-3,     4.0D0,     8.11D-3,
     4.5D0,     9.15D-3,     5.0D0,    10.11D-3,     5.5D0,    11.01D-3,
     6.0D0,    11.84D-3,     7.0D0,    13.37D-3,     8.0D0,    14.77D-3,
     9.0D0,    16.07D-3,    10.0D0,    17.30D-3,    12.0D0,    19.59D-3,
    14.0D0,    21.73D-3,    16.0D0,    23.74D-3,    20.0D0,    27.49D-3,
    25.0D0,    31.78D-3,    30.0D0,    35.74D-3,    35.0D0,    39.47D-3,
    40.0D0,    43.00D-3,    50.0D0,    49.59D-3,    60.0D0,    55.72D-3,
    70.0D0,    61.50D-3,    80.0D0,    66.99D-3,   100.0D0,    77.29D-3,
   120.0D0,    86.90D-3,   140.0D0,    95.97D-3,   160.0D0,   104.59D-3,
   180.0D0,   112.83D-3,   200.0D0,   120.76D-3,   225.0D0,   130.28D-3,
   250.0D0,   139.44D-3,   275.0D0,   148.28D-3,   300.0D0,   156.84D-3,
   350.0D0,   172.00D-3,   400.0D0,   189.00D-3;
#
#***********************************************************************
#*  THERMAL CONDUCTIVITY OF HELIUM GAS [W/m*K] :  --> 1.0 bar = 100000 Pa <-- *
#*    REFERENCE:  NBS TN 631 (Thermophysical properties of Helium4 ... )     *
#***********************************************************************
LAMHE2(2,20) =
     0.00D0,1.0D-6,          4.50D0,0.0106D0,
     5.00D0,0.0111D0,        5.50D0,0.0118D0,
     6.00D0,0.0125D0,        7.00D0,0.0138D0,
     8.00D0,0.0151D0,       10.00D0,0.0175D0,
    15.00D0,0.0225D0,       20.00D0,0.0267D0,
    25.00D0,0.0306D0,       30.00D0,0.0341D0,
    40.00D0,0.0407D0,       50.00D0,0.0468D0,
    75.00D0,0.0607D0,      100.00D0,0.0736D0,
   150.00D0,0.0969D0,      200.00D0,0.1180D0,
   300.00D0,0.1550D0,      400.00D0,0.1890D0;
#
#   Version 2.05     27. 04. 1990    M. Sander    MBB / KT224
#                     - Table ETAHE changed: peak at 5.1 K removed
#***********************************************************************
#*   DYNAMIC VISCOSITY OF HELIUM GAS [10**7 KG/M*S] : -> 100 mbar = 10000 Pa *
#*     REFERENCE: NBS TN 631 (Thermophysical properties of Helium4 ... )     *
#***********************************************************************
ETAHE (2,39)=
     0.00D0, 1.D-6,          1.50D0,  3.00D0,
     2.50D0,  6.38D0,        3.00D0,  7.80D0,
     4.00D0, 10.30D0,        5.00D0, 12.60D0,
     5.10D0, 12.83D0,                      # linear interpolated   old: 25.20,
     5.20D0, 13.07D0,                      # linear interpolated   old: 22.30,
     5.30D0, 13.30D0,        5.50D0, 13.70D0,
     6.00D0, 14.70D0,        7.00D0, 16.70D0,
     8.00D0, 18.50D0,        9.00D0, 20.20D0,
    10.00D0, 21.90D0,       12.00D0, 25.00D0,
    14.00D0, 27.90D0,       16.00D0, 30.50D0,
    18.00D0, 33.10D0,       20.00D0, 35.50D0,
    25.00D0, 41.00D0,       30.00D0, 46.10D0,
    40.00D0, 55.20D0,       50.00D0, 63.40D0,
    60.00D0, 71.00D0,       70.00D0, 78.10D0,
    80.00D0, 84.90D0,       90.00D0, 91.40D0,
   100.00D0, 97.70D0,      125.00D0,111.00D0,
   150.00D0,125.00D0,      175.00D0,138.00D0,
   200.00D0,151.00D0,      225.00D0,164.00D0,
   250.00D0,176.00D0,      275.00D0,188.00D0,
   300.00D0,199.00D0,      350.00D0,222.00D0,
   400.00D0,243.00D0;
#
```
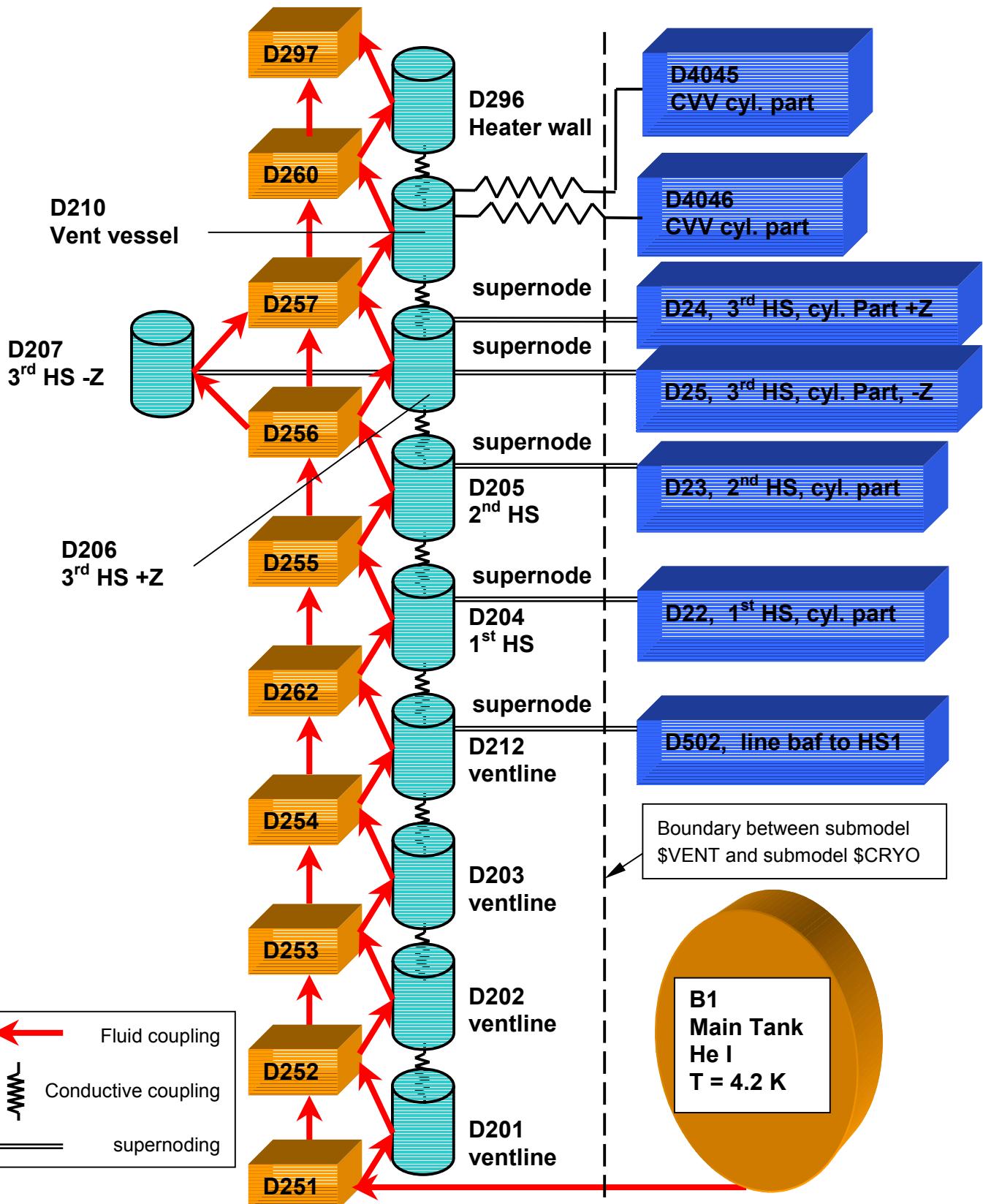
Figure 4-12: Thermal nodes and thermal network of submodel $VENT (main tank ventline) with interfaces to submodel $CRYO

4.4   Submodel "PAYLOAD"

4.4.1   General PAYLOAD-TMM Description

The submodel "PAYLOAD" comprises of the HERSCHEL OB with the instruments, the instrument shield and shield MLI. The thermal node indentifiers and thermal node definitions are shown in Figure 4-14. The submodel "PAYLOAD" is identical to the relevant part in the HPLM TMM (see RD 03) with the exception that the L0-cooling straps from the instrument L0-interfaces to the tank interfaces reflect the latest requirements of the instrument SPIRE (see AD 03) and §3.3. The resulting strap dimensions are defined in § 4.2.5.

Note: In Figure 4-14 the L0-cooling straps are schematically connecting the instrument L0-interfaces with the auxiliary tank. In reality the auxiliary tank is smaller than the OB. Therefore the EQM-straps have to be tailored in order to achieve flight-representative temperatures at the instrument L0-interfaces.

Level-0-interfaces: #765, #760, #781, #811, #820, #819, # 912

Level-1-interfaces: not depicted in Fig. 4-7

Level 2-interfaces: OB-thermal nodes (#371 thru # 381)

The geometrical-mathematical model in ESARAD-format in order to compute the radiative heat exchange within the instrument/test-adapter-cavity is shown in Figure 4-16 thru Figure 4-18.

The thermal node distributions as illustrated in Figure 4-20 thru Figure 4-24 within the instruments are compliant to RD 14 and identical to those used in the HPLM TMM (see RD 03).

The instrument dissipations underlying all analysis in this report are the in-orbit averages incl. 20 % uncertainty as defined in RD 14. They are compiled in Table 4-1.
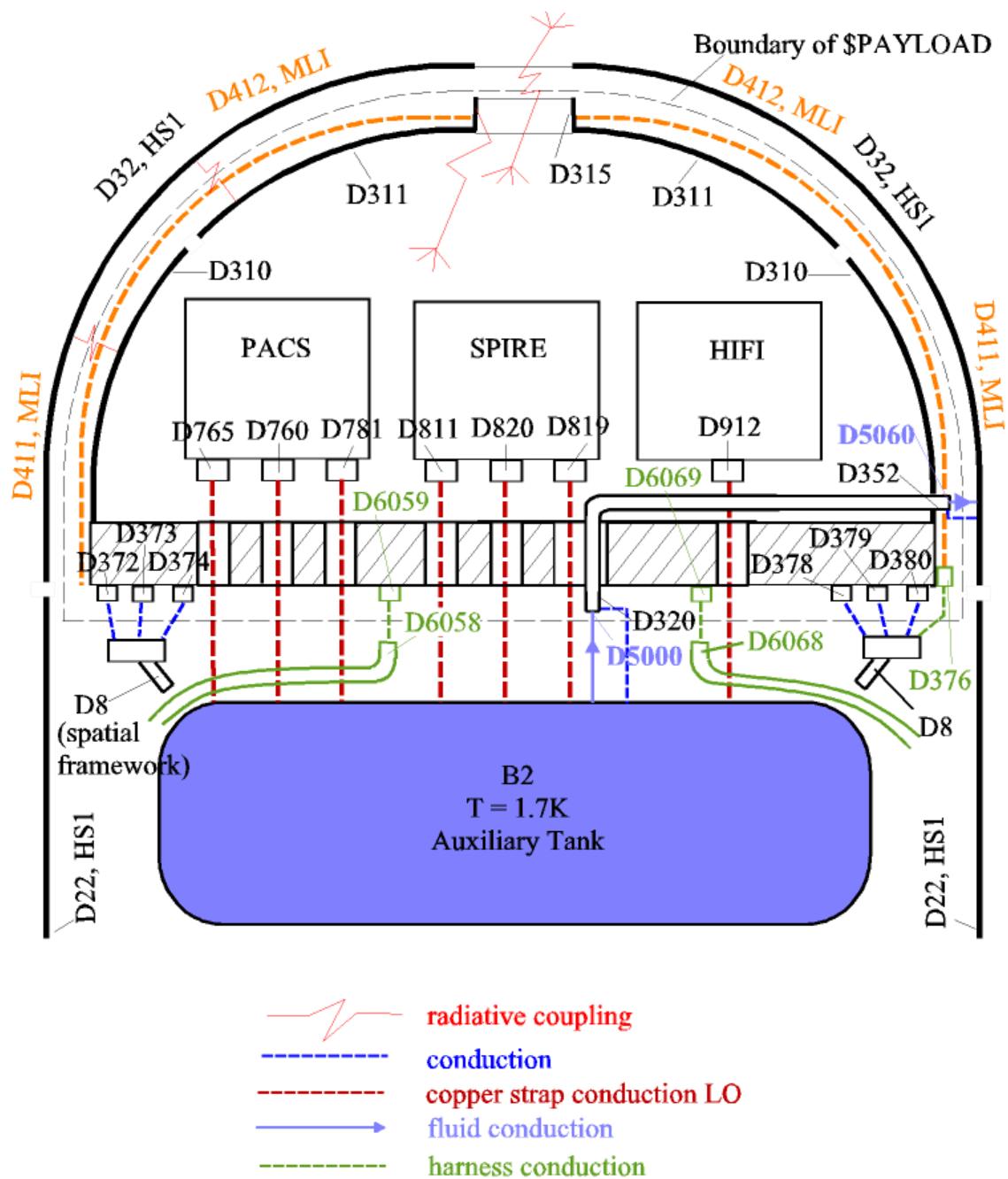
Figure 4-14: Thermal nodes distribution of HERSCHEL-PL TMM $PAYLOAD with interfaces to TMM $CRYO

INFRARED EMISSIVITY

1.000
0.878
0.755
0.633
0.510
0.387
0.265
0.142
0.020

311 OB Shield / inside
412 Shield MLI / outside

310 OB Shield / inside
411 Shield MLI / outside

PACS

HIFI

710

INFRARED EMISSIVITY

1.000
0.878
0.755
0.633
0.510
0.387
0.265
0.142
0.020

910

803

801

802

SPIRE

INFRARED EMISSIVITY

1.000
0.878
0.755
0.633
0.510
0.387
0.265
0.142
0.020

371

373

374

372

Optical
Bench

375

376

377

378

379

380

381

Figure 4-16: Nodal distribution of ESARAD model of HERSCHEL payload

| Beam Pattern as shown in [RD 01] | Instrument shield baffle in TMM (node 315) |
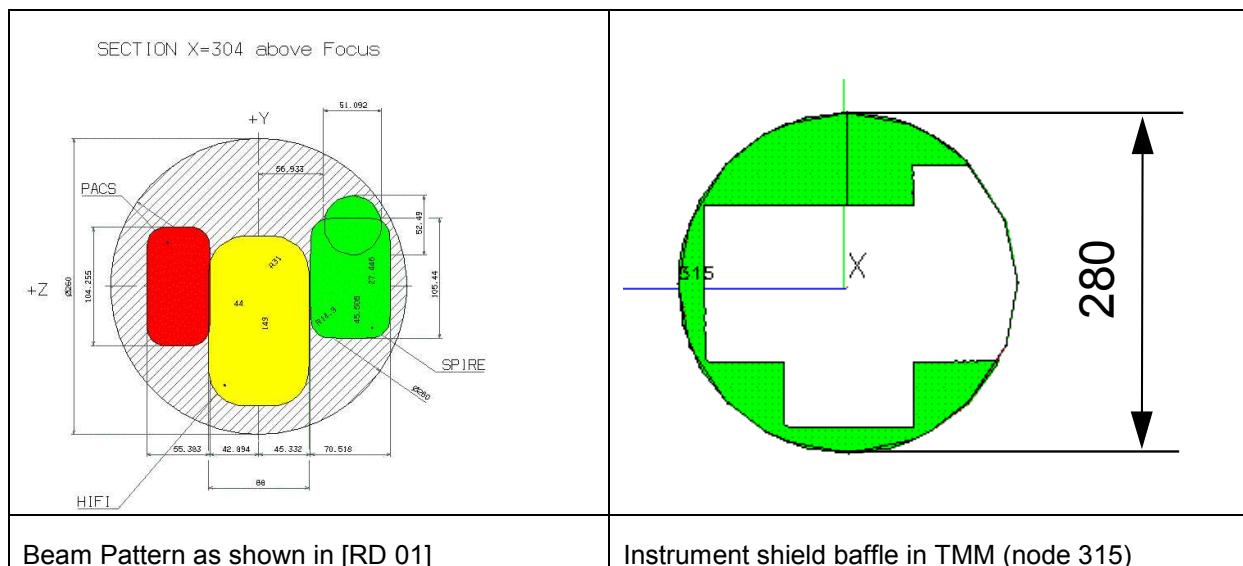
Figure 4-18:   Beam Pattern for the three Instruments
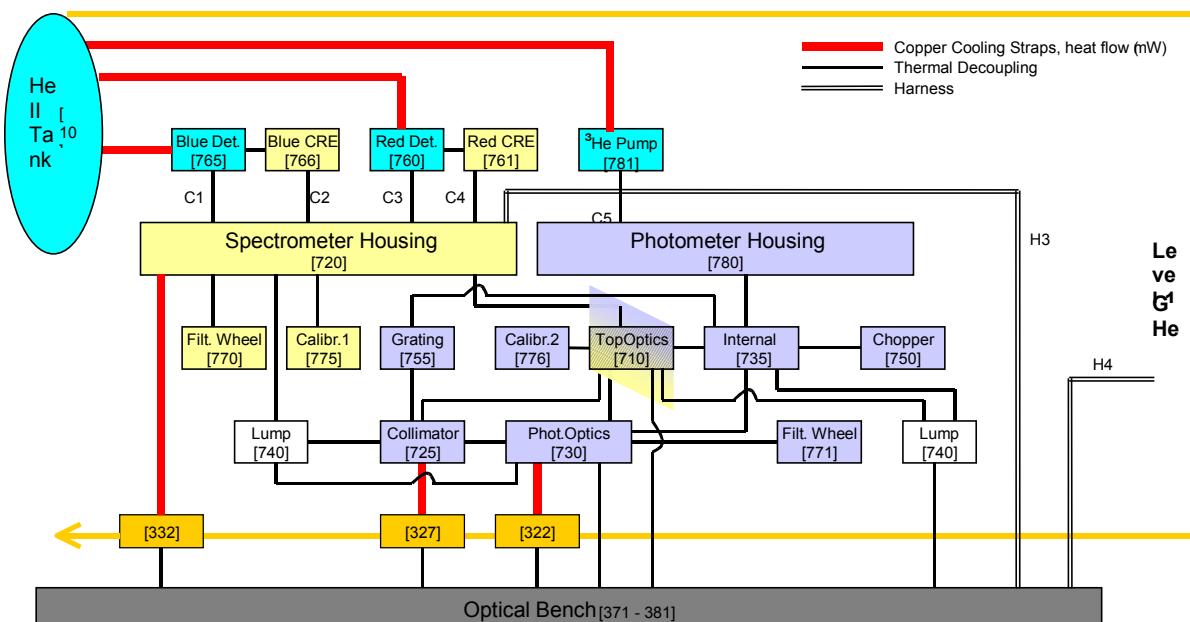
Figure 4-20:   Thermal nodes distribution of instrument "PACS"

Figure 4-22 (diagram)

Legend:
- Copper Cooling Straps, heat flow (mW)
- Thermal Decoupling
- Harness

Nodes include: LHe Tank (1.7 K), SM Detect. encl. [811], PM Detect. encl. [810], Cooler Evap. HS [820], Cooler Pump HS [819], Cooler Pump [816], SM Detect. [813], PM Detect. [812], Cooler Evap. [818], Cooler Shunt [817], BSM [805], PM Calib. [807], SMECm [806], SM Calib. [808], Shutter [809], GHe Ventline wall [338], SPIRE Optical Bench [803], RF-Filterbox [804], PM JFETs [801], SM JFET [802], Optical Bench [371 - 381]. Harness labels: H3, H2, H2, H4, H5, C4.

Figure 4-22:   Thermal nodes distribution of instrument "SPIRE"

Figure 4-24 (diagram)

Legend:
- Copper Cooling Straps, heat flow (mW)
- Thermal Decoupling
- Harness

*) FPU direct mounted on OB: 1.9 W/K

Nodes include: LHe Tank (1.7 K), L0-boundary [912], 2K Level [900], FPU Structure [910], Harness 2aint. point [914], Internal Assy. [920], Harness internal point [905], GHe Ventline wall [339], L1-boundary [913], Harness 2bint. point [915], Optical Bench [371 - 381]. Harness labels: H3, H4, *).

Figure 4-24:   Thermal nodes distribution of instrument "HIFI"

```
# Instrument Dissipation
#----------------------------------
#
# Average Power dissipation for Steady State
#
# PACS
#
        QI750 = 2.00E-03 * 1.2 / 6.0                     # Chopper
        QI755 = 5.00E-03 * 1.2 / 6.0                     # Grating
        QI761 = 1.50E-03 * 1.2 / 6.0                     # Red  Detector CRE
        QI765 = 0.80E-03       / 6.0                     # Blue Detector Heater
        QI766 = 1.50E-03 * 1.2 / 6.0                     # Blue Detector CRE
        QI770 = 0.03E-03 * 1.2                           # Filter Wheel 1
        QI771 = 0.03E-03 * 1.2                           # Filter Wheel 2
        QI775 = 0.80E-03 * 1.2 / 3.0                     # Black Body 1
        QI776 = 0.80E-03 * 1.2 / 3.0                     # Black Body 2
        QI781 = (6.0E-03 + 0.41E-3) * 1.2/6.0 + 758.0*1.2 /(46.*60.*60.)/6.
                                                         # Photometer Buffer
#
        QI720= 0.75*PA3OHM*PA3L
#
#
# SPIRE
#
        QI801 = 1.2 * 49.000D-3 /6.0 + 0.75*SP5OHM*SP5L   # PM JFET
        QI802 = 1.2 * 14.1D-3   /6.0                      # SM JFET
        QI805 = 1.2 * 5.0D-3    /6.0                      # BSM
        QI806 = 1.2 * 2.4D-3    /6.0                      # SMECm
        QI807 = 1.2 * 0.1D-3    /6.0                      # PM cal
        QI808 = 1.2 * 2.0D-3    /6.0                      # SM cal
        QI816 = 758.0 * 1.2 /(46.*60.*60.)/3.            # Pump
        QI817 = 1.2 * 0.01D-3   /6.0                      # Shunt
        QI819 = 1.2 * 0.4D-3    /6.0                      # Pump HS
#
        QI804=  0.75*SP3OHM*SP3L
#
#
# HIFI
#
# HIFI dissipation data is upgraded according to document FPSS-0166, 21 sept. 2001
# JDa 24/09/2001
        QI900 =  k_diss*0.34D-3                   # HIFI (2 K)
        QI905 =  k_diss*0.89D-3                   # HIFI Ohmic harness 1 dissip.
        QI910 =  k_diss*39.08D-3 + 0.75*HI3OHM*HI3L # HIFI (FPU)
        QI914 =  k_diss*0.89D-3                   # HIFI Ohmic harness 2a dissip.
        QI915 =  k_diss*0.0D-3                    # HIFI Ohmic harness 2b dissip.
        QI920 =  k_diss*0.0D-3                    # HIFI (Level 1)
#

k_diss = 0.333333*1.2;
```

Table 4-1:   Average dissipations of instruments (from RD 14)

4.4.2   OB-Ventline Modelling

A different but thermally equivalent ventline modelling technique compared to the ISO-cryostat (see § 4.3) is used for the OB-ventline applying a different but similar heat transfer equation (Nu= f(Re,Pr)). It is identical to that used in the HPLM (see RD 03). The thermal network of the OB-ventline is illustrated in Figure 4-26. The original ESATAN program code is listed below:

```
# Conduction in ventline wall: cross-section / pipe-section-length * conductivity
# of alu
#
  GL(320, 321) = 39.6D-6/0.425D0*INTRP1(.5*(T320+T321),TAB8,1);   #
  GL(321, 322) = 39.6D-6/0.035D0*INTRP1(.5*(T321+T322),TAB8,1);   #
  GL(322, 323) = 39.6D-6/0.035D0*INTRP1(.5*(T322+T323),TAB8,1);   #
  GL(323, 324) = 39.6D-6/0.135D0*INTRP1(.5*(T323+T324),TAB8,1);   #
  GL(324, 325) = 39.6D-6/0.610D0*INTRP1(.5*(T324+T325),TAB8,1);   #
  GL(325, 326) = 39.6D-6/0.525D0*INTRP1(.5*(T325+T326),TAB8,1);   #
  GL(326, 327) = 39.6D-6/0.035D0*INTRP1(.5*(T326+T327),TAB8,1);   #
  GL(327, 328) = 39.6D-6/0.035D0*INTRP1(.5*(T327+T328),TAB8,1);   #
  GL(328, 329) = 39.6D-6/0.195D0*INTRP1(.5*(T328+T329),TAB8,1);   #
  GL(329, 330) = 39.6D-6/0.240D0*INTRP1(.5*(T329+T330),TAB8,1);   #
  GL(330, 331) = 39.6D-6/0.095D0*INTRP1(.5*(T330+T331),TAB8,1);   #
  GL(331, 332) = 39.6D-6/0.035D0*INTRP1(.5*(T331+T332),TAB8,1);   #
  GL(332, 333) = 39.6D-6/0.035D0*INTRP1(.5*(T332+T333),TAB8,1);   #
  GL(333, 334) = 39.6D-6/0.180D0*INTRP1(.5*(T333+T334),TAB8,1);   #
  GL(334, 335) = 39.6D-6/0.360D0*INTRP1(.5*(T334+T335),TAB8,1);   #
  GL(335, 336) = 39.6D-6/0.410D0*INTRP1(.5*(T335+T336),TAB8,1);   #
  GL(336, 337) = 39.6D-6/0.230D0*INTRP1(.5*(T336+T337),TAB8,1);   #
  GL(337, 338) = 39.6D-6/0.035D0*INTRP1(.5*(T337+T338),TAB8,1);   #
  GL(338, 339) = 39.6D-6/0.035D0*INTRP1(.5*(T338+T339),TAB8,1);   #
  GL(339, 340) = 39.6D-6/0.230D0*INTRP1(.5*(T339+T340),TAB8,1);   #
  GL(340, 341) = 39.6D-6/0.460D0*INTRP1(.5*(T340+T341),TAB8,1);   #
  GL(341, 342) = 39.6D-6/0.560D0*INTRP1(.5*(T341+T342),TAB8,1);   #
  GL(342, 343) = 39.6D-6/0.330D0*INTRP1(.5*(T342+T343),TAB8,1);   #
  GL(343, 344) = 39.6D-6/0.035D0*INTRP1(.5*(T343+T344),TAB8,1);   #
  GL(344, 345) = 39.6D-6/0.035D0*INTRP1(.5*(T344+T345),TAB8,1);   #
  GL(345, 346) = 39.6D-6/0.250D0*INTRP1(.5*(T345+T346),TAB8,1);   #
  GL(346, 347) = 39.6D-6/0.700D0*INTRP1(.5*(T346+T347),TAB8,1);   #
  GL(347, 348) = 39.6D-6/0.660D0*INTRP1(.5*(T347+T348),TAB8,1);   #
  GL(348, 349) = 39.6D-6/0.475D0*INTRP1(.5*(T348+T349),TAB8,1);   #
  GL(349, 350) = 39.6D-6/0.460D0*INTRP1(.5*(T349+T350),TAB8,1);   #
  GL(350, 351) = 39.6D-6/0.670D0*INTRP1(.5*(T350+T351),TAB8,1);   #
  GL(351, 352) = 39.6D-6/0.755D0*INTRP1(.5*(T351+T352),TAB8,1);   #
#

#**********************************************************************
#   TABLE 8:  AL LIKE 6061 SHIELDS BAFFLE   ( Lambda in [W/m * K] )
#**********************************************************************
#
#                    - New values for table 8 (AL 6061) according to
#                      Fax SE/SP/IS 2813/88 by A. Rocaboy, dated 31. 05. 1988
#                      "resultats des mesures de conductivite thermique
#                       du 6061 etat T651"
#
TAB8 ( 2 , 8 ) =
   5.7D0,   10.3D0,      11.5D0,   21.9D0,      21.0D0,   41.7D0,
  36.0D0,   68.8D0,      78.0D0,  108.0D0,     156.0D0,  134.0D0,
 296.0D0,  174.0D0,     400.0D0,  174.0D0;
#
```

```
# ---------------------------------------------------------------------------
#
#                             FLUID Conductances
#
# ---------------------------------------------------------------------------
#
#       Optical Bench:  GHe Ventline Level 1
#
  GF( 5000, 5010 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #320
  GF( 5010, 5011 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #321
  GF( 5011, 5012 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #322
  GF( 5012, 5013 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #323
  GF( 5013, 5014 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #324
  GF( 5014, 5020 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #325
  GF( 5020, 5021 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #326
  GF( 5021, 5022 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #327
  GF( 5022, 5023 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #328
  GF( 5023, 5024 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #329
  GF( 5024, 5030 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #330
  GF( 5030, 5031 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #331
  GF( 5031, 5032 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #332
  GF( 5032, 5033 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #333
  GF( 5033, 5034 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #334
  GF( 5034, 5035 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #335
  GF( 5035, 5040 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #336
  GF( 5040, 5041 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #337
  GF( 5041, 5042 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #338
  GF( 5042, 5043 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #339
  GF( 5043, 5044 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #340
  GF( 5044, 5045 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #341
  GF( 5045, 5050 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #342
  GF( 5050, 5051 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #343
  GF( 5051, 5052 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #344
  GF( 5052, 5053 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #345
  GF( 5053, 5054 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #346
  GF( 5054, 5055 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #347
  GF( 5055, 5056 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #348
  GF( 5056, 5057 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #349
  GF( 5057, 5058 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #350
  GF( 5058, 5059 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #351
  GF( 5059, 5060 ) = MFLO2 * CPHEC;       #  inlet --> outlet of wall pipe node #352
#
# Conductors between pipe wall nodes and helium downstream node within relevant
# pipe section
# Heat transfer by forced convection, laminar flow, J. Hinger, 30.10.2001
#                            mass flow rate
#                            |       Wall temperature
#                            |       |       Upstream helium temp.
#                            |       |       |       Downstream helium temp.
#                            |       |       |       |       Pipe length between up-&
#                            |       |       |       |       downstream helium node
#                            |       |       |       |       |
  GL(  320, 5010 ) = HTRANS( MFLO2, T320, T5000, T5010, 0.700D0); #
  GL(  321, 5011 ) = HTRANS( MFLO2, T321, T5010, T5011, 0.050D0); #
  GL(  322, 5012 ) = HTRANS( MFLO2, T322, T5011, T5012, 0.020D0); #
  GL(  323, 5013 ) = HTRANS( MFLO2, T323, T5012, T5013, 0.050D0); #
  GL(  324, 5014 ) = HTRANS( MFLO2, T324, T5013, T5014, 0.220D0); #
  GL(  325, 5020 ) = HTRANS( MFLO2, T325, T5014, T5020, 1.000D0); #
  GL(  326, 5021 ) = HTRANS( MFLO2, T326, T5020, T5021, 0.050D0); #
  GL(  327, 5022 ) = HTRANS( MFLO2, T327, T5021, T5022, 0.020D0); #
  GL(  328, 5023 ) = HTRANS( MFLO2, T328, T5022, T5023, 0.050D0); #
  GL(  329, 5024 ) = HTRANS( MFLO2, T329, T5023, T5024, 0.340D0); #
  GL(  330, 5030 ) = HTRANS( MFLO2, T330, T5024, T5030, 0.140D0); #
```

```
   GL(  331, 5031 ) = HTRANS( MFLO2, T331, T5030, T5031, 0.050D0); #
   GL(  332, 5032 ) = HTRANS( MFLO2, T332, T5031, T5032, 0.020D0); #
   GL(  333, 5033 ) = HTRANS( MFLO2, T333, T5032, T5033, 0.050D0); #
   GL(  334, 5034 ) = HTRANS( MFLO2, T334, T5033, T5034, 0.310D0); #
   GL(  335, 5035 ) = HTRANS( MFLO2, T335, T5034, T5035, 0.410D0); #
   GL(  336, 5040 ) = HTRANS( MFLO2, T336, T5035, T5040, 0.410D0); #
   GL(  337, 5041 ) = HTRANS( MFLO2, T337, T5040, T5041, 0.050D0); #
   GL(  338, 5042 ) = HTRANS( MFLO2, T338, T5041, T5042, 0.020D0); #
   GL(  339, 5043 ) = HTRANS( MFLO2, T339, T5042, T5043, 0.050D0); #
   GL(  340, 5044 ) = HTRANS( MFLO2, T340, T5043, T5044, 0.410D0); #
   GL(  341, 5045 ) = HTRANS( MFLO2, T341, T5044, T5045, 0.510D0); #
   GL(  342, 5050 ) = HTRANS( MFLO2, T342, T5045, T5050, 0.610D0); #
   GL(  343, 5051 ) = HTRANS( MFLO2, T343, T5050, T5051, 0.050D0); #
   GL(  344, 5052 ) = HTRANS( MFLO2, T344, T5051, T5052, 0.020D0); #
   GL(  345, 5053 ) = HTRANS( MFLO2, T345, T5052, T5053, 0.050D0); #
   GL(  346, 5054 ) = HTRANS( MFLO2, T346, T5053, T5054, 0.450D0); #
   GL(  347, 5055 ) = HTRANS( MFLO2, T347, T5054, T5055, 0.950D0); #
   GL(  348, 5056 ) = HTRANS( MFLO2, T348, T5055, T5056, 0.370D0); #
   GL(  349, 5057 ) = HTRANS( MFLO2, T349, T5056, T5057, 0.580D0); #
   GL(  350, 5058 ) = HTRANS( MFLO2, T350, T5057, T5058, 0.340D0); #
   GL(  351, 5059 ) = HTRANS( MFLO2, T351, T5058, T5059, 1.000D0); #
   GL(  352, 5060 ) = HTRANS( MFLO2, T352, T5059, T5060, 0.510D0); #
#


#
     DOUBLE PRECISION FUNCTION HTRANS( MASSFL, TWALL, TFLUI1, TFLUI2, LPIPE)
#
#    Author: J. Hinger, 30.10.2001
#
#    HTRANS computes the thermal conductance between pipe wall node and downstream
#    fluid node
#    by forced convection within a pipe with hydrodynamic fully developed velocity
#    profile
#    and laminar flow and constant wall temperature, according to VDI-Wärmeatlas,
#    5. Auflage 1988
#    A constant wall temperature is assumed for the pipe section this function is
#    applied to
#
     DOUBLE PRECISION MASSFL, TWALL, TFLUI1, TFLUI2, LPIPE
     DOUBLE PRECISION PIII, TREF, ETA_HE, LAM_HE, DIAMI, REYNLD
     DOUBLE PRECISION PRANDT, NUSSD, FACTOR, ALPHA, XPON
#
#    Input parameters
#
#    MASSFL                     helium mass flow rate (kg/s)
#    TWALL  Temperature of pipe wall (K)
#    TFLUI1 Fluid inlet temperature (K)
#    TFLUI2 Fluid outlet temperature (K)
#    LPIPE  pipe length between inlet and outlet fluid node (m)
#
#    Local variables
#
#    PI    3.1415926
#    TREF        Reference temperature for fluid properties in boundary layer (K)
#    ETA_HE      dynamic viscosity of helium gas (N s / m2)
#    LAM_HE      conductivity of gaseous helium (W/(mK))
#    DIAMI       internal pipe diameter (m)
#    REYNLD      Reynolds Number, related to pipe internal diameter
#    PRANDT      Prandtl Number of helium gas
#    CPHEC       mass-specific capacity at const. pressure of helium gas (J/(kgK))
#    NUSSD       Nusselt number related to internal pipe diameter
#    FACTOR      Abbreviation
#    ALPHA       Film coefficient for forced convection (W/(m2K))
```

```
#     XPON          exponent in heat transfer function
#
#
      PIII = 3.1415927D0
      TREF  = .5D0*(.5D0*(TFLUI1+TFLUI2)+TWALL)
      ETA_HE = INTRP1(TREF, GHEMTAB, 1)
      LAM_HE = INTRP1(TREF, GHELTAB, 1)
#
      DIAMI  = 0.012
      REYNLD = 4.D0*MASSFL/(PIII*DIAMI*ETA_HE)
      PRANDT = ETA_HE * CPHEC / LAM_HE
      FACTOR = REYNLD*PRANDT*DIAMI/LPIPE
      NUSSD  = 3.65D0 + (0.19D0*FACTOR**.8D0)/(1.D0 + 0.117D0*FACTOR**0.467D0)
      ALPHA  = NUSSD * LAM_HE / DIAMI
#
      IF (MASSFL .LE. 0.) THEN               # avoid "division by zero" error for
MDOT = 0 run KW
         HTRANS = 0.
      ELSE
         XPON   = ALPHA*PIII*DIAMI*LPIPE/(MASSFL*CPHEC)
         IF (XPON.LE.3.D0) THEN
          HTRANS = MASSFL * CPHEC * ( EXP(XPON) - 1.D0 )
         ELSE
          HTRANS = MASSFL * CPHEC * 19.09D0    # avoid numerical instabilities
         END IF

      END IF
#
#
      RETURN
      END
#
```
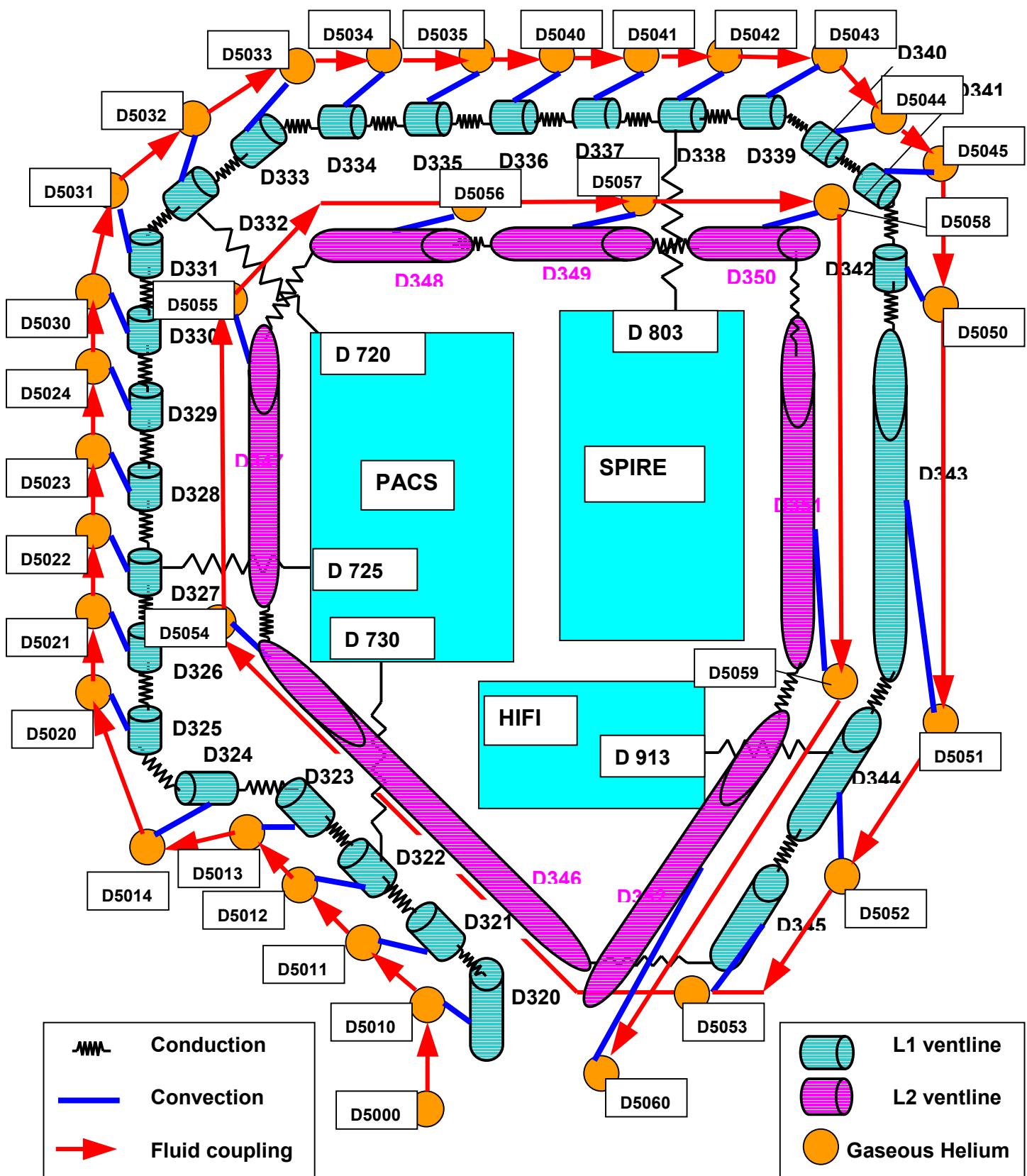
Figure 4-26:   Optical Bench ventline model

4.5   Submodel "CTCE", Cryo Test Cavity for EQM

4.5.1   CTCE Requirements

The CTCE thermal requirements will be specified in RD 19. Preliminary thermal design requirements are taken from a draft version of RD 19 and are summarized hereafter:

- Internal wall of cavity to be cooled < 5 K

- Reflector with low-emissive optical coating e < 0.04, temperature controlled at 60K to 80 K, goal (40 K to 80 K), stable at < 1 K during 5 minutes.

- Black body target highly emissive (e > 0.97) and temperature controlled < 5 K.

For straylight and cleanliness reasons the innermost surface of the cavity (shroud) shall be non-coated, i.e. blank aluminium with a low emissivity of less than 0.05 (TBC). For the top shroud, however, a high emissivity is desired.

Remark: From thermal point of view the emissivity of the cavity walls is of minor importance since in a cavity rays generally are totally absorbed by multireflections at the walls and can rather escape.

4.5.2   CTCE Thermal Design Concepts

From the a.m. thermal as well as optical requirements and the CVV-mechanical interface defined in RD 06 two preliminary thermal design concepts are derived and thermally analysed:

- Design 1: With MLI blankets between vapor-cooled heatshields

- Design 2: Without any MLI-blankets, only vapor-and radiatively cooled heatshields

For both concepts the following common design features/guidelines hold:

- The CTCE is a separate cryostat with a vapor-cooled shroud and a vapor-cooled heatshield within a vacuum-vessel. The helium-vapor is provided by an external dewar at a temperature of 4.2 K (He I) corresponding to a saturation pressure of 990 mbar.

- Preliminary dimensions as shown in Fig. 4-14 and Fig. 4-15

- Internal shroud. Cylindrical part connected to ventline (2 loops around perimeter).
  Blank alu, 1 mm thickness, emissivity = 0.05 for all shroud surfaces incl. Top shroud (consevative "hot case" assumption for instruments).

- 270 mm diameter baffle (1mm alu, emissivity 0.05) penetrating the cryostat opening
  and shielding the EQM-cryostat heatshields. Thermally very well connected to vapor-cooled shroud.

- Top shroud (circular disc, 1mm thick alu) thermally very well connected to vapor-cooled cylindrical part, emissivity = 0.05

- Vapor-cooled heatshields Cylindrical part connected to ventline (2 loops around perimeter). Blank alu, 1 mm thickness, emissivity = 0.05

- Heatshield mounted on vessel via 8 VESPEL-standoffs of 10 x 2 mm^2 cross-section, 25 mm height each.

- Shroud mounted on heatshiled via 8 VESPEL-standoffs of 10 x 2 mm^2 cross-section, 25 mm height each.

- Reflector interface brackets (alu) mounted on vessel by 3 low-conductive joints, each. An example for such a joint design is given in Figure 4-36. Alternatively the reflector can be mounted via 3 struts on a common optical bench.

- Reflector (rear side emissivity =.05 diffusive, front side 0.05 specular). Shall be temperature controlled at 40 to 80 K. Hence it follows that it must be extremely good decoupled from the vacuum vessel that is at ambient temperature (290 K). This is performed by using VESPEL (polyimide)-tubes as struts (d= 20 mm, t= 1 mm). The integral conductivity over a temperature range of 40K to 300 K of VESPEL is 0.254 W/(mK) compared to 0.649 W/(mK) of S-glass-fibre-composite.
  The struts shall not directly be mounted to the vessel, but mounted to a bracket or an optical bench.This optical bench shall be coupled to the ventlines coming from the shrouds as illustrated in Figure 4-32. The optical bench or brackets shall be thermally decoupled from the vessel using low-conductive joints. An example of such a joint is given in Figure 4-36.

4.5.2.1 CTCE Design Concept 1

This design shown in Figure 4-28 stands out for using MLI-blankets as thermal insulation between the vapor-cooled shroud and the vapor-cooled heatshield.

- MLI-blankets between vessel and heatshield, attached on heatshield.
  Conductance twice as high as for HERSCHEL assumed (conservative assumption)

- MLI-blankets between heatshield and shroud, attached on shroud.
  Conductance twice as high as for HERSCHEL assumed (conservative assumption)

D930 "Vessel dome"

D1330 "CTA HS top MLI "

D1130 "CTA top HS "

D1030 "CTA Shroud top MLI "

D1230 "CTA top shroud "

D1240 "CTA Reflector"

D921- 928 "cyl. vessel"

D1321- 1328 "CTA HS cyl. MLI "

D1121- 1128 "CTA cyl. HS "
vapor-cooled

D1221- 1228 "CTA Shroud cyl."
vapor-cooled

D1021- 1028 "Shroud cyl. MLI "

D1011- 1018 "Shroud bottom MLI "

D1311- 1318 "CTA HS bottom MLI "

D901- 908 "vessel flange"

Submodel $CRYO:
D4061- 4068 "CVV / CTA flange"

∅ 1107
∅ 1050
∅ 1000
∅ 370

Heatshield ventline
Shroud ventline

1090
1200
1275

150
150

D1211 "Baffle shroud up"
D1201 "Baffle shroud low"

∅ 270
∅ 280
∅ 850

Figure 4-28:   CTCE-design1 outline and thermal nodes distribution

4.5.2.2 CTCE Design Concept 2

Instead of MLI-blankets 3 additional but only passively cooled heatshiels as shown in Fig. 4-15 are used. The advantage of such a design is:

- to save time and costs by avoiding expensive class-100 MLI blankets manufacturing, shipment and integration

- heatshield are easy to clean and have low risks of particle contamination compared to conventional MLI-spacers (Dacron) when cutting it.
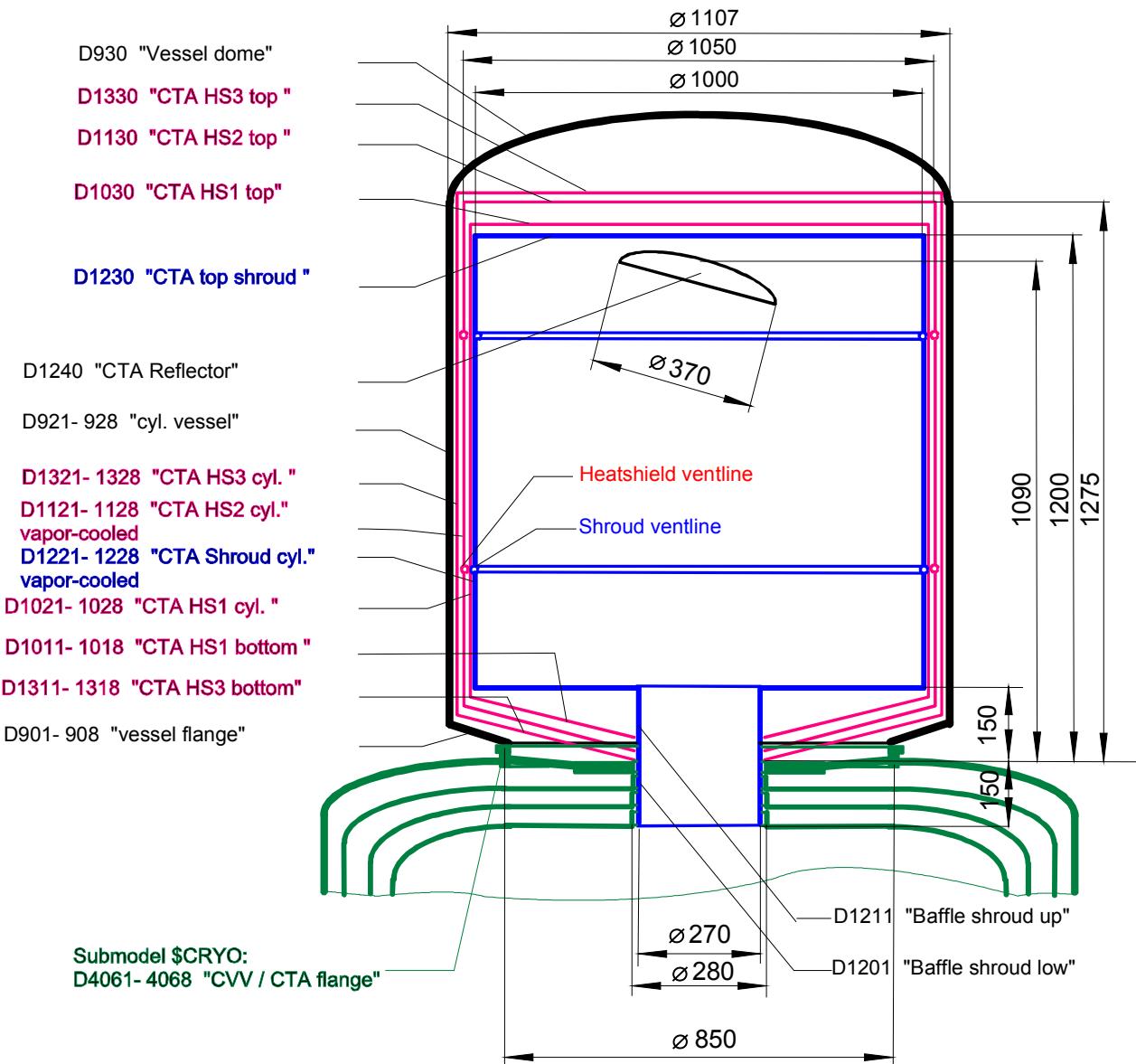
Figure 4-30:   CTCE-design2 outline and thermal nodes distribution

4.5.3   CTCE Ventline Design and Modelling

The ventline for the CTCE shroud, optical bench (or reflector strut I/F brackets) and heatshield cooling is modelled as illustrated in Figure 4-34. The ventline heat exchange computation method is identical to the one used for the payload OB ventline as defined in § 4.4.2.

Note: It has been demonstrated by thermal analysis that it is not possible to directly mount the reflector by low-conductive struts to the CTCE-vessel. This is due to the fact that the CTCE vessel is at ambient temperature and too much heat would be conducted into the reflector although a low conductive material such as VESPEL or glass-fibre would be used for the struts. As a result the reflector temperature would reach more than 100 K violating the 40K – 80 K requirement. In order to avoid a further expensive cooling system (liquid nitrogen) it is mandatory to mount the reflector-struts to an interface bracket or optical bench that in turn is connected to the existing ventline. In this way instead of an additional LN2-cooling-system only a low-cost electrical heater on the reflector is required. The temperature level of the reflector can be adjusted by adjusting the heater power of this heater.

The thermal design concept of the reflector attachment is shown in Figure 4-32. Instead of I/F brackets a common optical bench can be designed.
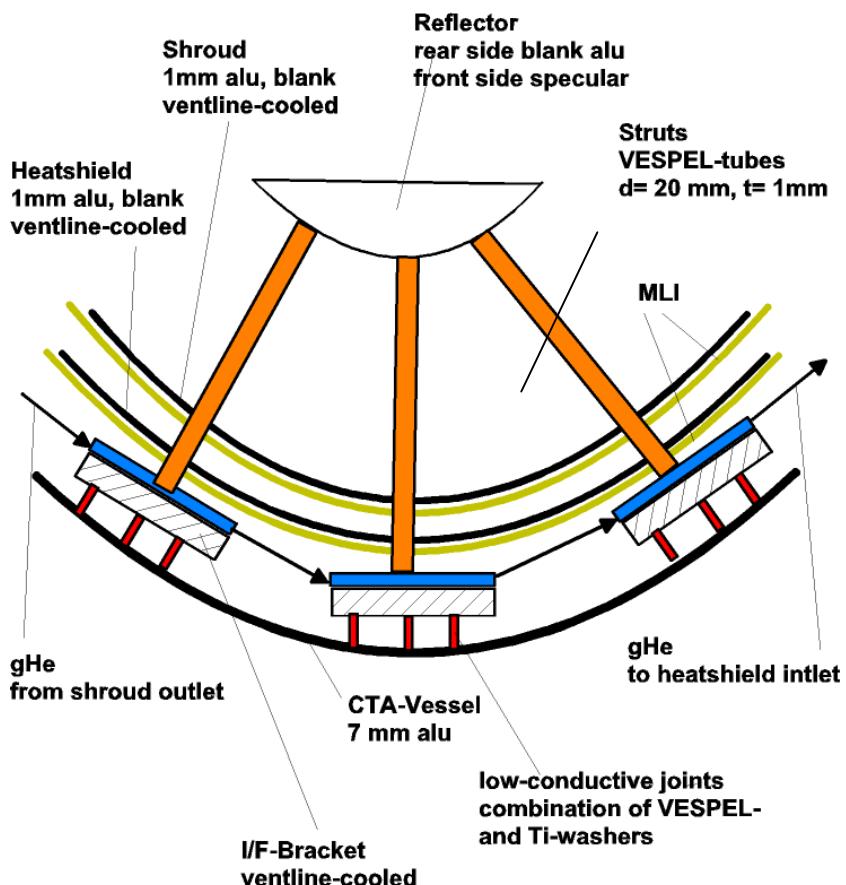
Figure 4-32:   Thermal design of Reflector attachment

D2015

D2014

D1125

D2016

D1124

D1126

D2005

D2004

D1225

D2006

D2013

D1127

D1224

D1226

D2003

D1223

D1227

D1123

D2007

D1222

D1228

D2017

D2002

D1221

D2008

D1128

D2001

D1122

D2012

D1121

D2011

D2018

outlet

**B2000
"CTA-Shroud Dewar"
T = 4.2 K**

D2023

D2022

D2021

**D1270
"Reflector I/F-bracket 3"**

**D1260
"Reflector I/F-bracket 2"**

**D1250
"Reflector I/F-bracket 1"**

D927 "CTA-vessel"

D926 "CTA-vessel"

D925 "CTA-vessel"

⋀⋁⋀ **Conduction**	**Shroud ventline**
▬▬ **Convection**	**HS ventline**
➡ **Fluid coupling**	● **Gaseous Helium**

Figure 4-34:   CTA ventline model

14/02/02   17:46   DORNIER FN RST 41 → +49 7545 8189767   NR.371   P01

J. Hlinger, 13.02.2002

Ø10
Ø8.5
Ø 6.2
Ø 5.2

3.6

Zylinderschraube
LN29950 J 05 50 B
aus Titanlegierung

Scheibe
LN9016 - 05
Thermal Washer
(VESPEL)

Reflector
Interface
Bracket

Thermal Bush
(VESPEL)

Scheibe
aus
Ti 5Al4V

Bracket on
CTA-Vessel

Ø20

—5—

Figure 4-36:   Example for a low-conductive joint.

4.5.4   Geometrical-mathematical Model of Cryogenic Test Cavity

The cavity-model in ESARAD-format is illustrated in Figure 4-19. It is used to compute the radiative exchange factors within the cavity formed by the CTCE-shrouds and the HERSCHEL-payload within the instrument shield. This model is identical for the CTCE design 1 as well as for design 2.

The thermal nodes distribution of the ESATAN-TMM are included in Figure 4-14.
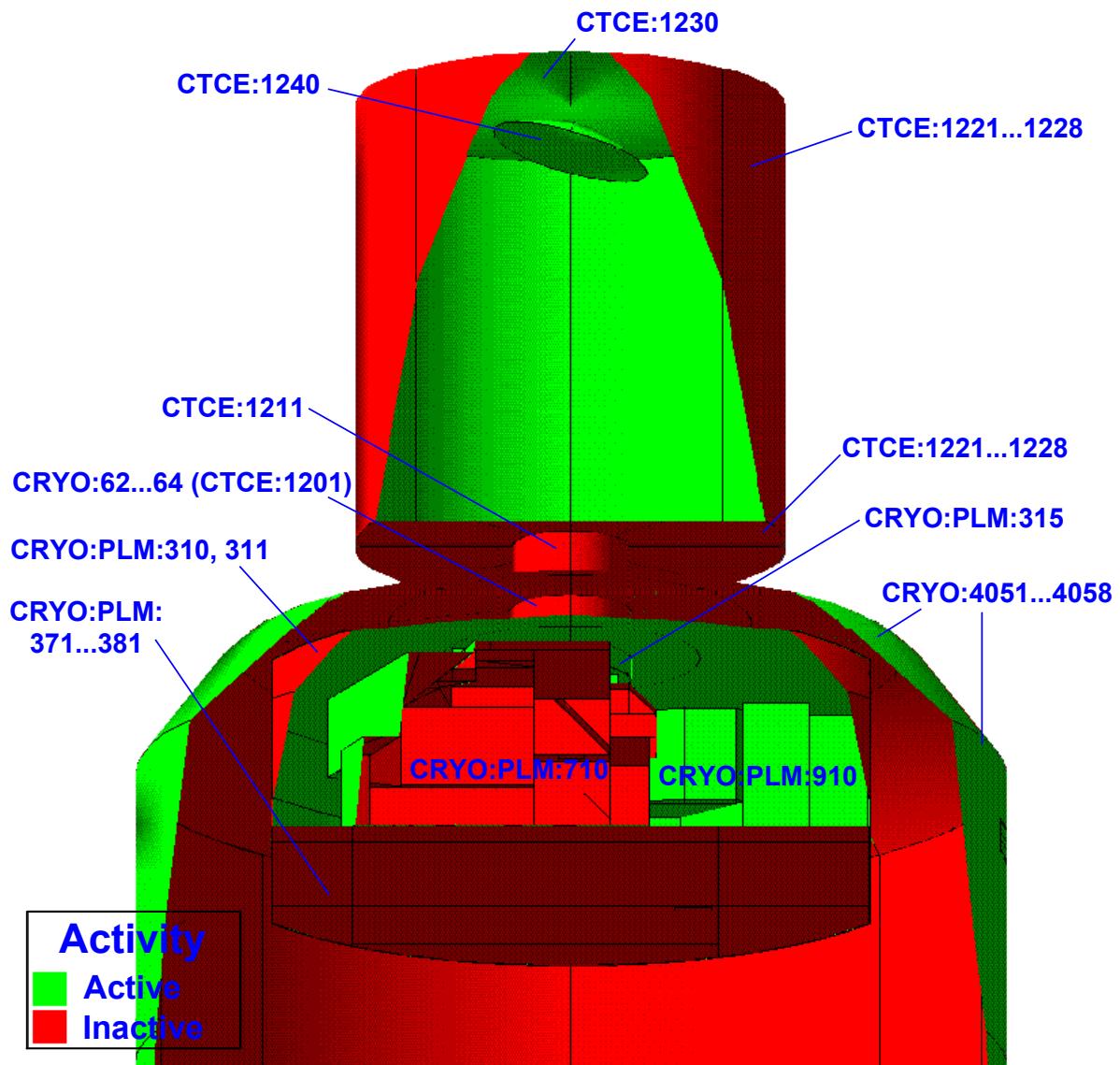
Figure 4-38:   ESARAD-model of CTCE/cryostat cavity

4.6   Submodel "CPLATE", CTA Cold Plate for EQM

As an alternative to the CTCE cryostat design a simple vacuum-tight plate with a helium-cooled mirror support plate has been proposed on the CTA meeting held at ESTEC on 26.04.2002. The thermal model is illustrated in Figure 4-40.
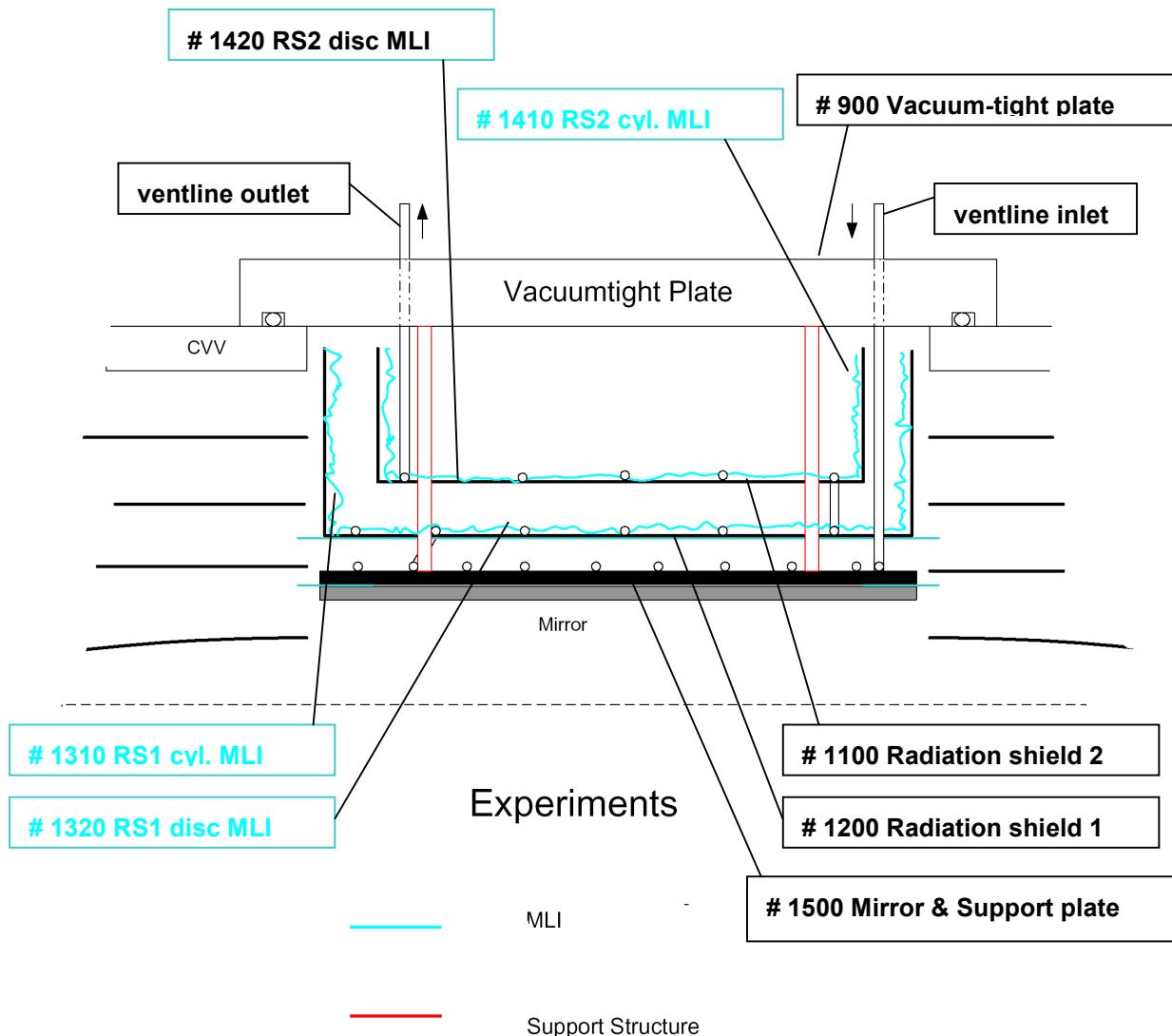
Figure 4-40:   Vacuum-tight Plate Design, Thermal network

4.6.1   CTA Coldplate Requirements

Several optical mirror surfaces have been identified on the CTA meeting held at ESTEC on 26.04.2002. From thermal point of view two extreme emissivities e = 0.9 (blackened) and e = 0.04 (sandblasted, honeycomb, Fresnel etc.) diffusive and e = 0.04 specular are relevant. In the following analysis e = 0.9 and e = 0.04 (diffusive) are considered.

The temperature stability requirement is ± 1 K during 10 s which is judged to be no problem.

There are no temperature level requirements specified yet. However, the goal is to achieve temperatures lower than 10 K at the mirror.

4.6.2   CTA Coldplate Design concept

Only a preliminary design concept is available. For thermal modelling the following assumptions have been taken:

- 30 mm thick alu vacuum-tight plate closely coupled to CVV

- Mirror and mirror plate made of a 10 mm thick alu plate, D = 280 mm, respectively

- radiation shields made of 1 mm thick alu sheets

- Mirror plate mounted to vacuum-tight plate via 9 VESPEL (Polyimide) tubes, Da/Di= 20/16 mm , l = 100 mm.

- ventline SST-pipe, Da/Di = 5/4 mm, thoroughly thermally decoupled from vacuum-tight plate.

- Radiation shields connected by low-conductive VESPEL-standoffs.

- MLI performance as assumed for CTCE-cryostat design concept 1.

- Ventline modelling equivalent to CTCE-cryostat concept but with fewer nodes.

- External HeI-Dewar at 4.2 K assumed

5   Thermal Analysis Results

The following parameters are not adjusted during the test. They are 'adjusted' by the ventline design and are dictated by the environment, i.e. ambient pressure:

- Pressure within main tank (in analysis 4.2 K, in reality 4.2 to 4.4 K)

- Pressure of tank within external dewar (in analysis 4.2 K, in reality 4.2 to 4.4 K). If lower temperatures are requested a second vacuum pump is available

There are the following parameters to be adjusted during the test:

- Pressure within EQM-aux. tank by vacuum-pump ➔ adjustment of aux. tank temperature (currenrtly 1.7 K)

- Heater power of main tank ➔ adjustment of main tank mass-flow rate

- Heater power of aux. Tank ➔ adjustment of flight-representative value of approx. 2.1 mg/s

- Heater power of tank within external dewar ➔ adjustment of mass flow rate

- Heater power of reflector ➔ adjustment of temperature

The thermal-mathematical model is capable to adjust all these parameters in order to fulfill the following requirements:

- Instrument L0-temperatures within requirements

- Instrument L1-temperatures within requirements

- Instrument L2-temperatures within requirements

- CTCE-shroud less than 5 K

- Reflector within CTCE adjustable at 40K to 80 K

The two CTCE-design concepts 1 and 2 have been analysed

5.1   CTCE-Design-1 Case 1

CTCE-design1 means: MLI-design concept for CTCE as defined in § 4.5.2.1

Case 1 means: EQM-aux. Tank heater power = 0 mW

The input parameters are compiled in Table 5-1and a brief temperature results summary is given in Table 5-3. The complete ESATAN-output-file listing is appended. The respective node numbers and labels are referenced in the thermal design and thermal-mathematical model descriptions in § 4

Input parameter	
Main Tank temperature	4.2 K
EQM-aux. Tank temperature	1.7 K
External Hel dewar temp. for CTCE-shroud cooling	4.2 K
Main Tank heater power	2000 mW
EQM-auxiliary tank heater power	0 mW
CTCE-shroud He-mass flow rate	100 mg/s
Reflector heater power	0 mW

Table 5-1:   Input parameters

Submodel	Node #	Node Label	T (K)	T_{max} (K) required	Requirement fulfilled
CRYO	12, 22, 32	Heatshield 1	10 - 16	NA	NA
CRYO	13, 23, 33	Heatshield 2	22 - 38	NA	NA
CRYO	14, 15, 24, 25, 34, 35	Heatshield 3	97 - 142	NA	NA
CRYO	4001 - 4078	CVV	293	NA	NA
CRYO	4090	LOU window	290	NA	NA
CRYO:PLM	371 - 381	Optical Bench	12 -13	15	yes

Submodel	Node #	Node Label	T (K)	T_{max} (K) required	Require ment fulfilled
CRYO:PLM	811	SPIRE SM Detector enclosure	1.80	1.8	yes
CRYO:PLM	819	SPIRE Cooler Pump HS	1.78	1.8	yes
CRYO:PLM	820	SPIRE Cooler Evaporator HS	1.73	1.8	yes
CRYO:PLM	765	PACS Blue Detector	1.73	3.5	yes
CRYO:PLM	760	PACS Red Detector	1.71	1.75	yes
CRYO:PLM	781	PACS He-Pump	1.78	2.20	yes
CRYO:PLM	912	HIFI l0-Boundary	1.89	2.00	yes
CRYO:PLM	803	SPIRE Optical Bench	6.0	4.5	**No 1)**
CRYO:PLM	730	PACS Photometer Optics	3.5	5	yes
CRYO:PLM	725	PACS Collimator	3.5	5	yes
CRYO:PLM	720	PACS Spectrom. Housing	3.5	5	yes
CRYO:PLM	913	HIFI L1-interface	7.4	6	**no**
CRYO:PLM	801	SPIRE PM JFET enclosure	15	13	yes
CRYO:PLM	802	SPIRE SM JFET enclosure	15	13	yes
CRYO:PLM	910	HIFI FPU Structure	20	13	yes
CTCE	901 -930	CTCE vessel	292	NA	NA
CTCE	1221 - 1230	CTA-shroud	4.5 – 5.1	5	yes
CTCE	1121 – 1130	CTA- heatshield	50 - 65	NA	NA
CTCE	1240	CTA-Reflector	21	40 -80	**no *)**
CTCE	1250, 1260, 1270	Reflector interface brackets (or optical bench)	19 - 25	NA	NA

	Mass-flow rate (mg/s)	*required mass-flow rate (mg/s)*	*Requirement fulfilled*
Out of main tank	98	NA**)	NA
Out of EQM-auxiliary tank	1.57	2.1	**no ***)**
Out of external He-dewar for CTA-shroud cooling	100	NA **)	NA

1) requirement not yet approved by ASED

*) can easily be controlled at 40 –80 K by electically heating

**) to be verified whether pressure drop is not too high

***) can easily be increased by electrical heating

Table 5-3:   Brief results summary

```
EUROPEAN  SPACE  AGENCY  THERMAL  ANALYSIS  NETWORK
(VERSION 8.5.0)                          PAGE    1    14 FEBRUARY 2002
14:01:04                                                      EQM4


##########################################
#
#  Main Tank heater power:      2000 mW
#  Aux. Tank heater power:         0 mW
#  CTCE-shroud mass flow rate:   100 mg/s
#  Reflector HTR power:            0 mW
#
##########################################

+EQM4:CRYO


        NODE                    LABEL        T        QI         QR        C

           1     MAIN TANK                 4.200   0.00000    2.00000     0.000
           2     AUX TANK                  1.700   0.00000    0.00000     0.000
           5     Ti-head       lo   5     11.286   0.00000    0.00000    71.074
           6     belt fitting  lo   6     10.677   0.00000    0.00000    63.244
           7     strut tank end lo  7      4.359   0.00000    0.00000    21.851
           8     Ti-head       up   8     12.453   0.00000    0.00000    80.973
           9     belt fitting  up   9     11.845   0.00000    0.00000    72.852
          10     strut tank end up  10     4.413   0.00000    0.00000    22.132
          12     HS 1 BULK 12             10.584   0.00000    0.00000    13.997
          13     HS 2 BULK 13             22.919   0.00000    0.00000   138.905
          14     HS 3 BULK +Z 14         119.405   0.00000    0.00000  2765.069
          15     HS 3 BULK -Z 15         119.371   0.00000    0.00000  2764.425
          22     HS 1 CYL 22              10.510   0.00000    0.00000    44.559
          23     HS 2 CYL 23              21.909   0.00000    0.00000   327.392
          24     HS 3 CYL +Z 24           97.432   0.00000    0.00000  6843.058
          25     HS 3 CYL -Z 25           97.330   0.00000    0.00000  6833.728
          32     HS 1 CONE 32             15.534   0.00000    0.00000    91.723
          33     HS 2 CONE 33             37.938   0.00000    0.00000  1503.855
          34     HS 3 CONE +Z 34         142.204   0.00000    0.00000  7722.538
          35     HS 3 CONE -Z 35         142.410   0.00000    0.00000  7722.538
          42     HS 1 HIFI Baf. int.      25.647   0.00000    0.00000     2.930
          52     HS 1 HIFI Baf. ext.      32.973   0.00000    0.00000     2.674
          53     HS 2 HIFI Baf.           57.531   0.00000    0.00000    10.606
          54     HS 3 HIFI Baf.          175.182   0.00000    0.00000    45.557
          62     HS 1 Tele BAF            15.562   0.00000    0.00000     0.346
          63     HS 2 Tele BAF            38.124   0.00000    0.00000     5.521
          64     HS 3 Tele BAF           142.110   0.00000    0.00000    81.043
         101     MLI MAIN TANK LO 101      5.164   0.00000    0.00000    15.675
         105     MLI MAIN TANK CY 105      4.732   0.00000    0.00000    43.316
         106     MLI MAIN TANK UP 106     37.082   0.00000    0.00000   112.572
         112     MLI HS 1 BULK 112        20.265   0.00000    0.00000    39.833
         113     MLI HS 2 BULK 113       114.964   0.00000    0.00000   381.490
         114     MLI HS 3 BULK +Z 114    287.450   0.00000    0.00000   706.436
         115     MLI HS 3 BULK -Z 115    287.427   0.00000    0.00000   706.378
         122     MLI HS 1 CYL 122         19.202   0.00000    0.00000   122.659
         123     MLI HS 2 CYL 123         93.569   0.00000    0.00000   967.500
         124     MLI HS 3 CYL +Z 124     286.651   0.00000    0.00000  2100.812
         125     MLI HS 3 CYL -Z 125     285.591   0.00000    0.00000  2093.042
         132     MLI HS 1 CONE 132        51.481   0.00000    0.00000   249.729
         133     MLI HS 2 CONE 133       137.697   0.00000    0.00000  1124.793
         134     MLI HS 3 CONE +Z 134    287.292   0.00000    0.00000  1702.056
         135     MLI HS 3 CONE -Z 135    287.272   0.00000    0.00000  1701.936
         440     filling tube    440     271.525   0.00000    0.00000     0.000
         441     filling tube    441     252.223   0.00000    0.00000     0.000
         442     filling tube    442     245.518   0.00000    0.00000     0.000
```

```
 443    filling tube   443     242.458  0.00000  0.00000     0.000
 447    empty tube     447      15.522  0.00000  0.00000     0.000
 452    empty tube     452      10.869  0.00000  0.00000     0.000
 502    line baf to HS1 502      4.201  0.00000  0.00000     0.000
 642    MLI filling tube 642    120.438  0.00000  0.00000     0.766
 643    MLI filling tube 643    119.020  0.00000  0.00000     0.743
 647    MLI filling tube 647     25.824  0.00000  0.00000     1.245
 652    MLI filling tube 652     23.559  0.00000  0.00000     0.459
1000    HS 1 SUSP BOLT 1000      19.621  0.00000  0.00000     0.000
2000    HS 2 SUSP BOLT 2000      67.854  0.00000  0.00000     0.000
3000    HS 3 SUSP BOLT 3000     189.799  0.00000  0.00000     0.000
4001    CVV lower bulk 4001     292.764  0.00000  0.00000  4399.463
4002    CVV lower bulk 4002     292.771  0.00000  0.00000  4399.491
4003    CVV lower bulk 4003     292.771  0.00000  0.00000  4399.491
4004    CVV lower bulk 4004     292.764  0.00000  0.00000  4399.462
4005    CVV lower bulk 4005     292.750  0.00000  0.00000  4399.407
4006    CVV lower bulk 4006     292.749  0.00000  0.00000  4399.403
4007    CVV lower bulk 4007     292.758  0.00000  0.00000  4399.441
4008    CVV lower bulk 4008     292.760  0.00000  0.00000  4399.449
4011    CVV lower bulk 4011     292.707  0.00000  0.00000  1668.975
4012    CVV lower bulk 4012     292.740  0.00000  0.00000  1669.025
4013    CVV lower bulk 4013     292.741  0.00000  0.00000  1669.027
4014    CVV lower bulk 4014     292.717  0.00000  0.00000  1668.991
4015    CVV lower bulk 4015     292.654  0.00000  0.00000  1668.893
4016    CVV lower bulk 4016     292.654  0.00000  0.00000  1668.893
4017    CVV lower bulk 4017     292.705  0.00000  0.00000  1668.971
4018    CVV lower bulk 4018     292.700  0.00000  0.00000  1668.964
4031    CVV cyl lower  4031     292.553  0.00000  0.00000 13706.678
4032    CVV cyl lower  4032     292.660  0.00000  0.00000 13708.038
4033    CVV cyl lower  4033     292.663  0.00000  0.00000 13708.073
4034    CVV cyl lower  4034     292.599  0.00000  0.00000 13707.260
4035    CVV cyl lower  4035     292.391  0.00000  0.00000 13704.643
4036    CVV cyl lower  4036     292.396  0.00000  0.00000 13704.702
4037    CVV cyl lower  4037     292.568  0.00000  0.00000 13706.873
4038    CVV cyl lower  4038     292.537  0.00000  0.00000 13706.477
4041    CVV cyl upper  4041     292.694  0.00000  0.00000 19514.607
4042    CVV cyl upper  4042     292.699  0.00000  0.00000 19514.695
4043    CVV cyl upper  4043     292.633  0.00000  0.00000 19513.510
4044    CVV cyl upper  4044     292.215  0.00000  0.00000 19506.001
4045    CVV cyl upper  4045     289.655  0.00000  0.00000 19459.994
4046    CVV cyl upper  4046     289.649  0.00000  0.00000 19459.899
4047    CVV cyl upper  4047     292.186  0.00000  0.00000 19505.469
4048    CVV cyl upper  4048     292.603  0.00000  0.00000 19512.975
4051    CVV upper bulk 4051     292.714  0.00000  0.00000 19050.967
4052    CVV upper bulk 4052     292.627  0.00000  0.00000 19049.441
4053    CVV upper bulk 4053     292.618  0.00000  0.00000 19049.276
4054    CVV upper bulk 4054     292.669  0.00000  0.00000 19050.185
4055    CVV upper bulk 4055     292.589  0.00000  0.00000 19048.773
4056    CVV upper bulk 4056     292.545  0.00000  0.00000 19047.996
4057    CVV upper bulk 4057     292.681  0.00000  0.00000 19050.383
4058    CVV upper bulk 4058     292.719  0.00000  0.00000 19051.062
4061    CVV/CTA flange 4061     292.330  0.00000  0.00000     0.000
4062    CVV/CTA flange 4062     292.307  0.00000  0.00000     0.000
4063    CVV/CTA flange 4063     292.286  0.00000  0.00000     0.000
4064    CVV/CTA flange 4064     292.263  0.00000  0.00000     0.000
4065    CVV/CTA flange 4065     292.240  0.00000  0.00000     0.000
4066    CVV/CTA flange 4066     292.244  0.00000  0.00000     0.000
4067    CVV/CTA flange 4067     292.298  0.00000  0.00000     0.000
4068    CVV/CTA flange 4068     292.326  0.00000  0.00000     0.000
4071    CVV flange disc 4071    292.174  0.00000  0.00000     0.000
4072    CVV flange disc 4072    292.161  0.00000  0.00000     0.000
4073    CVV flange disc 4073    292.144  0.00000  0.00000     0.000
4074    CVV flange disc 4074    292.126  0.00000  0.00000     0.000
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4075      CVV flange disc  4075   292.114  0.00000  0.00000    0.000
4076      CVV flange disc  4076   292.121  0.00000  0.00000    0.000
4077      CVV flange disc  4077   292.150  0.00000  0.00000    0.000
4078      CVV flange disc  4078   292.171  0.00000  0.00000    0.000
4090      CVV Lo window          289.928  0.00000  0.00000   15.604
4631      SUSP TI  lo   4631     282.780  0.00000  0.00000   84.266
4632      SUSP TI  lo   4632     282.879  0.00000  0.00000   84.277
4633      SUSP TI  lo   4633     282.882  0.00000  0.00000   84.277
4634      SUSP TI  lo   4634     282.822  0.00000  0.00000   84.271
4635      SUSP TI  lo   4635     282.632  0.00000  0.00000   84.250
4636      SUSP TI  lo   4636     282.636  0.00000  0.00000   84.251
4637      SUSP TI  lo   4637     282.794  0.00000  0.00000   84.268
4638      SUSP TI  lo   4638     282.765  0.00000  0.00000   84.264
4641      SUSP TI  up   4641     282.910  0.00000  0.00000   84.280
4642      SUSP TI  up   4642     282.914  0.00000  0.00000   84.280
4643      SUSP TI  up   4643     282.854  0.00000  0.00000   84.274
4644      SUSP TI  up   4644     282.469  0.00000  0.00000   84.233
4645      SUSP TI  up   4645     280.114  0.00000  0.00000   83.982
4646      SUSP TI  up   4646     280.109  0.00000  0.00000   83.982
4647      SUSP TI  up   4647     282.442  0.00000  0.00000   84.230
4648      SUSP TI  up   4648     282.826  0.00000  0.00000   84.271
4731      CABLE PLUG   4731      281.499  0.00073  0.00000   93.529
4732      CABLE PLUG   4732      291.588  0.00000  0.00000   97.058
4733      CABLE PLUG   4733      291.591  0.00000  0.00000   97.059
4734      CABLE PLUG   4734      291.527  0.00000  0.00000   97.036
4735      CABLE PLUG   4735      291.321  0.00000  0.00000   96.964
4736      CABLE PLUG   4736      292.396  0.00000  0.00000   97.340
4737      CABLE PLUG   4737      292.568  0.00000  0.00000   97.401
4738      CABLE PLUG   4738      283.622  0.00010  0.00000   94.271
6051      X2 SI Harness 51       245.203  0.00073  0.00000    0.000
6052      X2 SI Harness 52       205.933  0.00073  0.00000    0.000
6053      X2 SI Harness 53       162.824  0.00073  0.00000    0.000
6054      X2 SI Harness 54       113.891  0.00073  0.00000    0.000
6055      X2 SI at HS1  55        50.553  0.00250  0.00000    0.000
6056      X3 SI Harness 56        45.903  0.00250  0.00000    0.000
6057      X3 SI Harness 57        39.539  0.00250  0.00000    0.000
6058      X3 SI Harness 58        30.392  0.00250  0.00000    0.000
6061      X2 JF Harness 61       246.339  0.00010  0.00000    0.000
6062      X2 JF Harness 62       205.932  0.00010  0.00000    0.000
6063      X2 JF Harness 63       161.456  0.00010  0.00000    0.000
6064      X2 JF Harness 64       110.710  0.00010  0.00000    0.000
6065      X2 JF at HS1  65        42.548  0.00024  0.00000    0.000
6066      X3 JF Harness 66        38.265  0.00024  0.00000    0.000
6067      X3 JF Harness 67        33.338  0.00024  0.00000    0.000
6068      X3 JF Harness 68        27.402  0.00024  0.00000    0.000
9999      AMBIENT                293.000  0.00000  0.00000    0.000
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+EQM4:CRYO:V

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   NODE                      LABEL      T       QI        QR        C

    201     OSS-TUBE         201      4.200   0.00000   0.00000   0.000
    202     BAFFLE LO        202      4.200   0.00000   0.00000   0.000
    203     BAFFLE UP        203      4.200   0.00000   0.00000   0.000
    204     1ST HS           204     10.510   0.00000   0.00000   0.000
    205     2ND HS           205     21.909   0.00000   0.00000   0.000
    206     3RD HS +z        206     97.432   0.00000   0.00000   0.000
    207     3RD HS -z        207     97.330   0.00000   0.00000   0.000
    210     VENT VESSEL      210    209.693   0.00000   0.00000   0.000
    212     BAFFLE - 1ST HS  212      4.201   0.00000   0.00000   0.000
    251     TANK     HE-OUT  251      4.200   0.00000   0.00000   0.000
    252     OSS      HE-OUT  252      4.200   0.00000   0.00000   0.000
    253     BAFFLE LO HE-OUT 253      4.200   0.00000   0.00000   0.000
    254     BAFFLE UP HE-OUT 254      4.200   0.00000   0.00000   0.000
    255     1ST HS    HE-OUT 255     10.510   0.00000   0.00000   0.000
    256     2ND HS    HE-OUT 256     21.889   0.00000   0.00000   0.000
    257     3RD HS    HE-OUT 257     97.381   0.00000   0.00000   0.000
    260     VESSEL    HE-OUT 260    209.693   0.00000   0.00000   0.000
    262     BAF - HS1 HE-OUT 262      4.200   0.00000   0.00000   0.000
    296     HEATER    WALL   296    293.000   0.00000   0.00000   0.000
    297     HEATER    HE-OUT 297    209.693   0.00000   0.00000   0.000
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+EQM4:CRYO:PLM

NODE	LABEL	T	QI	QR	C
310	Instr. Shield Cyl.	12.837	0.00000	0.00000	10.589
311	Instr. Shield Top	12.846	0.00000	0.00000	13.694
315	Instr. Shield Baffle	12.860	0.00000	0.00000	0.883
320	Vline wall Tank-PACS	1.793	0.00000	0.00000	0.007
321	Vline wall PACS I/F 1	2.652	0.00000	0.00000	0.001
322	Vline wall PACS I/F 1	2.970	0.00000	0.00000	0.000
323	Vline wall PACS I/F 1	2.792	0.00000	0.00000	0.001
324	Vline wall PACSI/F1/2	2.630	0.00000	0.00000	0.003
325	Vline wall PACSI/F1/2	2.686	0.00000	0.00000	0.016
326	Vline wall PACS I/F 2	3.098	0.00000	0.00000	0.001
327	Vline wall PACS I/F 2	3.262	0.00000	0.00000	0.000
328	Vline wall PACS I/F 2	3.185	0.00000	0.00000	0.001
329	Vline wall PACSI/F2/3	3.126	0.00000	0.00000	0.007
330	Vline wall PACSI/F2/3	3.192	0.00000	0.00000	0.003
331	Vline wall PACS I/F 3	3.311	0.00000	0.00000	0.001
332	Vline wall PACS I/F 3	3.401	0.00000	0.00000	0.000
333	Vline wall PACS I/F 3	3.370	0.00000	0.00000	0.001
334	Vline wall PACS-SPIRE	3.353	0.00000	0.00000	0.007
335	Vline wall PACS-SPIRE	3.392	0.00000	0.00000	0.009
336	Vline wall PACS-SPIRE	3.635	0.00000	0.00000	0.010
337	Vline wall SPIRE	4.786	0.00000	0.00000	0.002
338	Vline wall SPIRE	5.431	0.00000	0.00000	0.001
339	Vline wall SPIRE	5.201	0.00000	0.00000	0.002
340	Vline wall SPIRE-HIFI	5.057	0.00000	0.00000	0.014
341	Vline wall SPIRE-HIFI	5.081	0.00000	0.00000	0.017
342	Vline wall SPIRE-HIFI	5.272	0.00000	0.00000	0.023
343	Vline wall HIFI	6.555	0.00000	0.00000	0.003
344	Vline wall HIFI	7.165	0.00000	0.00000	0.001
345	Vline wall HIFI	7.570	0.00000	0.00000	0.004
346	Vline Lev.2 OB	11.738	0.00000	0.00000	0.111
347	Vline Lev.2 OB	12.543	0.00000	0.00000	0.277
348	Vline Lev.2 OB	12.610	0.00000	0.00000	0.109
349	Vline Lev.2 OB	12.652	0.00000	0.00000	0.172
350	Vline Lev.2 OB	12.666	0.00000	0.00000	0.101
351	Vline Lev.2 OB	12.665	0.00000	0.00000	0.298
352	Vline Lev.2 OB	12.689	0.00000	0.00000	0.153
371	Opt. Bench +Z	12.618	0.00000	0.00000	10.334
372	Opt. Bench +Z -Y	12.569	0.00000	0.00000	9.463
373	Opt. Bench +Z mid	12.622	0.00000	0.00000	24.244
374	Opt. Bench +Z +Y	12.630	0.00000	0.00000	3.917
375	Opt. Bench -Y	12.671	0.00000	0.00000	17.803
376	Opt. Bench centre	12.653	0.00000	0.00000	42.918
377	Opt. Bench +Y	12.658	0.00000	0.00000	9.449
378	Opt. Bench -Z -Y	12.692	0.00000	0.00000	9.684
379	Opt. Bench -Z mid	12.670	0.00000	0.00000	24.463
380	Opt. Bench -Z +Y	12.671	0.00000	0.00000	3.947
381	Opt. Bench -Z	12.665	0.00000	0.00000	10.426
390	I.Shld HIFI Baf. ext.	12.901	0.00000	0.00000	0.413
391	I.Shld HIFI Baf. int.	12.840	0.00000	0.00000	0.145
411	MLI on OB-Shield side	14.391	0.00000	0.00000	32.744
412	MLI on OB-Shield top	14.395	0.00000	0.00000	42.281
710	PACS-Top Optic	3.527	0.00000	0.00000	2.200
720	PACS-Spectrometer	3.524	0.00003	0.00000	2.488
725	PACS-Collimator	3.521	0.00000	0.00000	2.515
730	PACS-Photometer Optic	3.519	0.00000	0.00000	1.518
735	PACS-Internal	3.525	0.00000	0.00000	2.109
740	PACS-Lump	3.525	0.00000	0.00000	0.000
750	PACS-Chopper	3.529	0.00040	0.00000	0.133

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755    PACS-Grating Assy          3.528   0.00100   0.00000     0.906
760    PACS-Red  Detector         1.706   0.00000   0.00000     0.230
761    PACS-Red  Detect. CRE      3.533   0.00030   0.00000     0.033
765    PACS-Blue Detector         1.732   0.00013   0.00000     0.234
766    PACS-Blue Detect. CRE      3.533   0.00030   0.00000     0.033
770    PACS-Filter Wh. Blue       3.525   0.00004   0.00000     0.154
771    PACS-Filter Wh. Photo      3.519   0.00004   0.00000     0.154
775    PACS-Calib. Source 1       3.528   0.00032   0.00000     0.022
776    PACS-Calib. Source 2       3.530   0.00032   0.00000     0.022
780    PACS-Photometer Housi      3.521   0.00000   0.00000     1.165
781    PACS-Photometer CooPu      1.784   0.00220   0.00000     0.147
791    PACS-STST-Strut 1,1       10.385   0.00000   0.00000     0.398
792    PACS-STST-Strut 4,1       10.382   0.00000   0.00000     0.619
793    PACS-STST-Strut 5,1       10.385   0.00000   0.00000     0.310
794    PACS-Kevlar-Strut Red  1   2.866   0.00000   0.00000     0.015
795    PACS-Kevlar-Strut Blue 1   2.870   0.00000   0.00000     0.015
796    PACS-HarnessRed Det.Int1   3.045   0.00000   0.00000     0.000
797    PACS-HarnessBlueDet.Int1   3.051   0.00000   0.00000     0.000
798    PACS-HarnessBlue1.7->4,1   2.773   0.00000   0.00000     0.000
801    SPIRE PM JFET ENCL        12.698   0.01026   0.00000    14.773
802    SPIRE SM JFET ENCL        12.674   0.00282   0.00000     4.800
803    SPIRE Optical Bench        6.010   0.00000   0.00000    15.030
804    SPIRE RF Filter Box        6.015   0.00428   0.00000     0.735
805    SPIRE Beam St. Mech        6.011   0.00100   0.00000     0.551
806    SPIRE SMECm                6.011   0.00048   0.00000     0.651
807    SPIRE PM calibrator        6.011   0.00002   0.00000     0.000
808    SPIRE SM calibrator       10.277   0.00040   0.00000     0.000
809    SPIRE Shutter              6.010   0.00000   0.00000     0.000
810    SPIRE PM Detector en       1.835   0.00000   0.00000     0.461
811    SPIRE SM Detector en       1.804   0.00000   0.00000     0.274
812    SPIRE PM Detectors         1.753   0.00000   0.00000     0.401
813    SPIRE SM detector          1.753   0.00000   0.00000     0.254
816    SPIRE Cooler Pump          1.892   0.00183   0.00000     0.000
817    SPIRE Cooler shunt         1.731   0.00000   0.00000     0.000
818    SPIRE Cooler evap          1.753   0.00000   0.00000     0.000
819    SPIRE Cooler pump HS       1.779   0.00008   0.00000     0.000
820    SPIRE Cooler evap HS       1.731   0.00000   0.00000     0.000
900    HIFI 2K level              1.898   0.00014   0.00000     0.030
905    HIFI Harness 1 int.point   6.759   0.00036   0.00000     0.000
910    HIFI FPU Structure        12.683   0.01602   0.00000   139.753
912    HIFI L0 boundary node      1.888   0.00000   0.00000     0.000
913    HIFI L1 boundary node      7.379   0.00000   0.00000     0.000
914    HIFI Harness 2a int.poin  13.564   0.00036   0.00000     0.000
915    HIFI Harness 2b int.poin  10.392   0.00000   0.00000     0.000
920    HIFI Internal Assy.        7.382   0.00000   0.00000     0.035
5000   GHe tank outlet            1.700   0.00000   0.00000     0.000
5010   GHe PACS I/F 1 in          1.788   0.00000   0.00000     0.000
5011   GHe PACS I/F 1             2.141   0.00000   0.00000     0.000
5012   GHe PACS I/F 1             2.353   0.00000   0.00000     0.000
5013   GHe PACS I/F 1 out         2.547   0.00000   0.00000     0.000
5014   GHe PACS I/F 1/2           2.618   0.00000   0.00000     0.000
5020   GHe PACS I/F 2 in          2.683   0.00000   0.00000     0.000
5021   GHe PACS I/F 2             2.879   0.00000   0.00000     0.000
5022   GHe PACS I/F 2             2.989   0.00000   0.00000     0.000
5023   GHe PACS I/F 2 out         3.085   0.00000   0.00000     0.000
5024   GHe PACS I/F 2/3           3.124   0.00000   0.00000     0.000
5030   GHe PACS I/F 3 in          3.178   0.00000   0.00000     0.000
5031   GHe PACS I/F 3             3.245   0.00000   0.00000     0.000
5032   GHe PACS I/F 3             3.292   0.00000   0.00000     0.000
5033   GHe PACS I/F 3 out         3.332   0.00000   0.00000     0.000
5034   GHe PACS-SPIRE             3.352   0.00000   0.00000     0.000
5035   GHe PACS-SPIRE             3.390   0.00000   0.00000     0.000
5040   GHe SPIRE I/F in           3.623   0.00000   0.00000     0.000
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5041      GHe SPIRE I/F            4.296    0.00000    0.00000    0.000
5042      GHe SPIRE I/F            4.716    0.00000    0.00000    0.000
5043      GHe SPIRE I/F out        5.013    0.00000    0.00000    0.000
5044      GHe SPIRE-HIFI           5.055    0.00000    0.00000    0.000
5045      GHe SPIRE-HIFI           5.080    0.00000    0.00000    0.000
5050      GHe HIFI I/F in          5.263    0.00000    0.00000    0.000
5051      GHe HIFI I/F             6.129    0.00000    0.00000    0.000
5052      GHe HIFI I/F             6.583    0.00000    0.00000    0.000
5053      GHe HIFI I/F out         7.293    0.00000    0.00000    0.000
5054      GHe Lev.2 OB            11.517    0.00000    0.00000    0.000
5055      GHe Lev.2 OB            12.492    0.00000    0.00000    0.000
5056      GHe Lev.2 OB            12.604    0.00000    0.00000    0.000
5057      GHe Lev.2 OB            12.649    0.00000    0.00000    0.000
5058      GHe Lev.2 OB            12.665    0.00000    0.00000    0.000
5059      GHe Lev.2 OB            12.665    0.00000    0.00000    0.000
5060      GHe Lev.2 OB            12.688    0.00000    0.00000    0.000
6059      X3 SI Harness 59       13.557    0.00406    0.00000    0.000
6069      X3 JF Harness 69       19.605    0.00040    0.00000    0.000
9999      Ambient Air           293.000    0.00000    0.00000    0.000
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+EQM4:CTCE
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NODE	LABEL	T	QI	QR	C
901	vessel flange 901	292.340	0.00000	0.00000	905.667
902	vessel flange 902	292.321	0.00000	0.00000	905.651
903	vessel flange 903	292.297	0.00000	0.00000	905.632
904	vessel flange 904	292.260	0.00000	0.00000	905.601
905	vessel flange 905	292.238	0.00000	0.00000	905.583
906	vessel flange 906	292.248	0.00000	0.00000	905.591
907	vessel flange 907	292.306	0.00000	0.00000	905.639
908	vessel flange 908	292.335	0.00000	0.00000	905.663
921	cyl. vessel 921	292.402	0.00000	0.00000	8551.714
922	cyl. vessel 922	292.384	0.00000	0.00000	8551.566
923	cyl. vessel 923	292.335	0.00000	0.00000	8551.181
924	cyl. vessel 924	292.140	0.00000	0.00000	8549.650
925	cyl. vessel 925	292.106	0.00000	0.00000	8549.379
926	cyl. vessel 926	292.141	0.00000	0.00000	8549.657
927	cyl. vessel 927	292.336	0.00000	0.00000	8551.191
928	cyl. vessel 928	292.385	0.00000	0.00000	8551.579
930	vessel dome 930	292.404	0.00000	0.00000	19146.645
1011	Shroud bottom MLI	31.090	0.00000	0.00000	0.000
1012	Shroud bottom MLI	31.054	0.00000	0.00000	0.000
1013	Shroud bottom MLI	34.574	0.00000	0.00000	0.000
1014	Shroud bottom MLI	38.888	0.00000	0.00000	0.000
1015	Shroud bottom MLI	42.625	0.00000	0.00000	0.000
1016	Shroud bottom MLI	45.249	0.00000	0.00000	0.000
1017	Shroud bottom MLI	45.706	0.00000	0.00000	0.000
1018	Shroud bottom MLI	42.427	0.00000	0.00000	0.000
1021	Shroud cyl. MLI	31.090	0.00000	0.00000	0.000
1022	Shroud cyl. MLI	31.054	0.00000	0.00000	0.000
1023	Shroud cyl. MLI	34.574	0.00000	0.00000	0.000
1024	Shroud cyl. MLI	38.888	0.00000	0.00000	0.000
1025	Shroud cyl. MLI	42.625	0.00000	0.00000	0.000
1026	Shroud cyl. MLI	45.249	0.00000	0.00000	0.000
1027	Shroud cyl. MLI	45.706	0.00000	0.00000	0.000
1028	Shroud cyl. MLI	42.427	0.00000	0.00000	0.000
1030	Shroud top MLI	49.195	0.00000	0.00000	0.000
1121	CTA cyl. HS 1121	49.777	0.00000	0.00000	226.528
1122	CTA cyl. HS 1122	49.751	0.00000	0.00000	226.250
1123	CTA cyl. HS 1122	52.822	0.00000	0.00000	259.355
1124	CTA cyl. HS 1122	56.553	0.00000	0.00000	299.560
1125	CTA cyl. HS 1122	59.765	0.00000	0.00000	334.187
1126	CTA cyl. HS 1122	62.038	0.00000	0.00000	359.643
1127	CTA cyl. HS 1122	62.425	0.00000	0.00000	363.997
1128	CTA cyl. HS 1122	59.592	0.00000	0.00000	332.323
1130	CTA top HS 1130	65.197	0.00000	0.00000	587.186
1201	CTA Shroud lo Baf	6.196	0.00000	0.00000	0.178
1211	CTA Shroud up Baf	4.881	0.00000	0.00000	0.101
1221	CTA cy.Shroud 1221	4.511	0.00000	0.00000	0.000
1222	CTA cy.Shroud 1222	4.479	0.00000	0.00000	0.000
1223	CTA cy.Shroud 1223	4.547	0.00000	0.00000	0.000
1224	CTA cy.Shroud 1224	4.559	0.00000	0.00000	0.000
1225	CTA cy.Shroud 1225	4.645	0.00000	0.00000	0.000
1226	CTA cy.Shroud 1226	4.646	0.00000	0.00000	0.000
1227	CTA cy.Shroud 1227	4.715	0.00000	0.00000	0.000
1228	CTA cy.Shroud 1228	4.655	0.00000	0.00000	0.000
1230	CTA topShroud 1230	5.142	0.00000	0.00000	0.696
1240	CTA Reflector	21.075	0.00000	0.00000	32.737
1250	Refl. I/F bracket 1	19.672	0.00000	0.00000	0.000
1252	Refl. I/F br.1 pos.2	168.852	0.00000	0.00000	0.000
1253	Refl. I/F br.1 pos.3	170.212	0.00000	0.00000	0.000

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1254      Refl. I/F br.1 pos.4      137.880  0.00000  0.00000   0.000
1255      Refl. I/F br.1 pos.5      140.087  0.00000  0.00000   0.000
1256      Refl. I/F br.1 pos.6      222.619  0.00000  0.00000   0.000
1257      Refl. I/F br.1 pos.7      224.341  0.00000  0.00000   0.000
1260      Refl. I/F bracket 2        22.109  0.00000  0.00000   0.000
1262      Refl. I/F br.2 pos.2      169.578  0.00000  0.00000   0.000
1263      Refl. I/F br.2 pos.3      170.935  0.00000  0.00000   0.000
1264      Refl. I/F br.2 pos.4      138.433  0.00000  0.00000   0.000
1265      Refl. I/F br.2 pos.5      140.630  0.00000  0.00000   0.000
1266      Refl. I/F br.2 pos.6      222.816  0.00000  0.00000   0.000
1267      Refl. I/F br.2 pos.7      224.532  0.00000  0.00000   0.000
1270      Refl. I/F bracket 3        24.617  0.00000  0.00000   0.000
1272      Refl. I/F br.3 pos.2      169.838  0.00000  0.00000   0.000
1273      Refl. I/F br.3 pos.3      171.186  0.00000  0.00000   0.000
1274      Refl. I/F br.3 pos.4      139.175  0.00000  0.00000   0.000
1275      Refl. I/F br.3 pos.5      141.358  0.00000  0.00000   0.000
1276      Refl. I/F br.3 pos.6      223.129  0.00000  0.00000   0.000
1277      Refl. I/F br.3 pos.7      224.837  0.00000  0.00000   0.000
1311      CTA HS bottom MLI         268.518  0.00000  0.00000   0.000
1312      CTA HS bottom MLI         268.503  0.00000  0.00000   0.000
1313      CTA HS bottom MLI         268.499  0.00000  0.00000   0.000
1314      CTA HS bottom MLI         268.494  0.00000  0.00000   0.000
1315      CTA HS bottom MLI         268.496  0.00000  0.00000   0.000
1316      CTA HS bottom MLI         268.518  0.00000  0.00000   0.000
1317      CTA HS bottom MLI         268.559  0.00000  0.00000   0.000
1318      CTA HS bottom MLI         268.565  0.00000  0.00000   0.000
1321      CTA HS cyl. MLI           268.789  0.00000  0.00000   0.000
1322      CTA HS cyl. MLI           268.772  0.00000  0.00000   0.000
1323      CTA HS cyl. MLI           268.741  0.00000  0.00000   0.000
1324      CTA HS cyl. MLI           268.580  0.00000  0.00000   0.000
1325      CTA HS cyl. MLI           268.566  0.00000  0.00000   0.000
1326      CTA HS cyl. MLI           268.612  0.00000  0.00000   0.000
1327      CTA HS cyl. MLI           268.795  0.00000  0.00000   0.000
1328      CTA HS cyl. MLI           268.823  0.00000  0.00000   0.000
1330      CTA HS top MLI            272.875  0.00000  0.00000   0.000
2000      CTA-Shroud Dewar            4.200  0.00000  0.00000   0.000
2001      GHe Shroud 1221 out         4.252  0.00000  0.00000   0.000
2002      GHe Shroud 1222 out         4.291  0.00000  0.00000   0.000
2003      GHe Shroud 1223 out         4.334  0.00000  0.00000   0.000
2004      GHe Shroud 1224 out         4.373  0.00000  0.00000   0.000
2005      GHe Shroud 1225 out         4.419  0.00000  0.00000   0.000
2006      GHe Shroud 1226 out         4.458  0.00000  0.00000   0.000
2007      GHe Shroud 1227 out         4.503  0.00000  0.00000   0.000
2008      GHe Shroud 1228 out         4.529  0.00000  0.00000   0.000
2011      GHe HS 1121 out            29.692  0.00000  0.00000   0.000
2012      GHe HS 1122 out            38.875  0.00000  0.00000   0.000
2013      GHe HS 1123 out            45.597  0.00000  0.00000   0.000
2014      GHe HS 1124 out            51.064  0.00000  0.00000   0.000
2015      GHe HS 1125 out            55.502  0.00000  0.00000   0.000
2016      GHe HS 1126 out            58.889  0.00000  0.00000   0.000
2017      GHe HS 1127 out            60.735  0.00000  0.00000   0.000
2018      GHe HS 1128 out            60.142  0.00000  0.00000   0.000
2021      GHe I/F bracket 1250 out    7.886  0.00000  0.00000   0.000
2022      GHe I/F bracket 1260 out   11.238  0.00000  0.00000   0.000
2023      GHe I/F bracket 1270 out   14.572  0.00000  0.00000   0.000
9999      AMBIENT                   293.000  0.00000  0.00000   0.000
```

```
Heat Balance for PAYLOAD incl. Instrument Shield MLI
====================================================
                         Level 0: from Aux. Tank into instruments      -19.444  [mW]

                         Level 2: from spatial framework into OB         -6.564  [mW]

              Level 1/2: from Aux. Tank into OB via ventline wall        -0.108  [mW]

                    Level 2: from HS1 into OB via ventline wall           0.114  [mW]

                              Level 2: via harness into OB               26.688  [mW]

         via radiation from HS1 upper bulkhead onto Instrument MLI        0.170  [mW]

           via radiation from Cryostat cavity onto OB lower side          5.090  [mW]

                 via radiation from HS1-baffle into payload               0.006  [mW]

                 via radiation from HS2-baffle into payload               0.023  [mW]

                 via radiation from HS3-baffle into payload               1.505  [mW]
            via radiation from CTCE-4K-shrouds into payload              -0.023  [mW]

         via radiation from CTCE lower-shroud baffle into payload        -0.003  [mW]
         via radiation from CTCE upper-shroud baffle into payload        -0.003  [mW]
             via radiation from CTCE reflector into payload               0.010  [mW]
             via radiation from CVV-LOU-Window onto HIFI-Baffle          19.948  [mW]
             via radiation from CVV-LOU-Window onto HIFI-FPU             14.512  [mW]
             Vent line cooling power (out of payload)                    89.539  [mW]
         Transferred by convection from PL-ventline on helium           89.615  [mW]
                         total dissipation of PACS                        5.070  [mW]
                        total dissipation of SPIRE                       21.167  [mW]
                         total dissipation of HIFI                       16.867  [mW]
                         Harness dissipation on OB                        4.462  [mW]
                  Payload Heat Imbalance (shall be 0)                     -0.052  [mW]

Heat Balance for Main Tank Ventline
===================================
              conducted and radiated into ventline attached to HS1     3205.572  [mW]
              conducted and radiated into ventline attached to HS2     5781.441  [mW]
          conducted and radiated into ventline attached to HS3 +Z     19190.511  [mW]
          conducted and radiated into ventline attached to HS3 -Z     19164.532  [mW]
                  conducted into ventline walls from CVV              57061.522  [mW]
              conducted and radiated into line baf to HS 1                0.151  [mW]
          Main Tank Ventline cooling power (out of ventline)        104403.846  [mW]
                  Via convection into ventline walls               -104413.886  [mW]
              Main Tank Ventline Imbalance (shall be 0)                   -0.117  [mW]

Heat Balance for CTCE
=====================
          Convective heat transfer onto CTCE-external insulation      27237.430  [mW]
                  Conducted from CVV into CTCE-structure               -277.187  [mW]
          Radiated from Payload into CTCE-shrouds incl. baffles           0.029  [mW]
                  Radiated from HS-baffles onto CTCE-shroud             48.698  [mW]
          Radiated from CVV flange disc within cavity onto CTCE-MLI    2061.674  [mW]
                     Radiated from Payload onto reflector               -0.010  [mW]
                  Conducted from CTCE-structure into CTCE-shrouds        0.000  [mW]
                        Cooling power of CTCE-shrouds                 29070.640  [mW]
                         CTCE Imbalance (shall be 0)                     -0.006  [mW]

Heat Balance for Reflector within CTCE
======================================
                 via struts from CTCE-I/F brackets into reflector        0.120  [mW]
                 by radiation from CTCE-shrouds into reflector          -0.114  [mW]
                 by radiation from Payload into reflector               -0.010  [mW]
                              reflector heater power                     0.000  [mW]
                     reflector total imbalance (shall be 0)             -0.004  [mW]
```

```
Heat Balance for whole Cryostat including Payload,Ventlines and CTCE
===================================================================
                      Convective heat transfer onto external walls    133411.506 [mW]
                          total heat transferred on gaseous helium    133564.025 [mW]
                             evaporation power in main and aux. tank     2081.064 [mW]
                                  Total istrument power dissipation       43.104 [mW]
                total main & auxiliary tank and reflector heater power     2000.000 [mW]
                             heater power of CVV lower bulkhead HTR        0.000 [mW]
                              total harness dissipation within system       19.601 [mW]
                                      Cooling power of CTCE-shrouds     29070.640 [mW]
                           Cryostat total imbalance (shall be 0)         -170.878 [mW]

Heat Balance for Main Tank
==========================
                                 Main tank dissipation + heater power     2000.000 [mW]
                                    heat from Aux. tank via mech. I/F       -0.451 [mW]
                                            radiated from aux. tank        0.000 [mW]
                                     conducted from spatial framework       35.657 [mW]
                                          transferred through MLI          9.755 [mW]
                                            conducted from rest            0.290 [mW]
                         radiated from spatial framework and HSs           0.076 [mW]
                          conducted from main tank ventline wall           0.000 [mW]
                                         radiated from payload             0.000 [mW]
                                      total heat into main tank         2045.327 [mW]

Heat Balance for Auxiliary Tank
===============================
                                  Aux. tank dissipation + heater power        0.000 [mW]
                                     heat from Main tank via mech. I/F        0.451 [mW]
                                            radiated from Main tank           0.000 [mW]
                         radiated from spatial framework and HSs             0.015 [mW]
                                      conducted from payload L0              19.444 [mW]
                                      conducted from payload L2               0.108 [mW]
                                            radiated from payload             0.019 [mW]
                                       conducted from filling tube            0.007 [mW]
                                   radiated from MLI filling tube            15.692 [mW]
                                       total heat into Aux. tank             35.737 [mW]

Heat flows into Tanks
=====================

                                             Into Main Tank          2045.327 [mW]
                                             Into Aux. Tank            35.737 [mW]

Helium evaporation mass flow rates
==================================

                                             Out of Main Tank           97.769 [mg/s]
                                             Out of Aux. Tank            1.568 [mg/s]
                       Out of external He- dewar for CTA-shroud cooling    100.000 [mg/s]
```

5.2   CTCE-Design-1 Case 2

CTCE-design1 means: MLI-design concept for CTCE as defined in § 4.5.2.1

Case 2 means: EQM-aux. Tank heater power = 14 mW

The input parameters are compiled in Table 5-5and a brief temperature results summary is given in Table 5-7. The complete ESATAN-output-file listing is appended. The respective node numbers and labels are referenced in the thermal design and thermal-mathematical model descriptions in § 4

Input parameter	
Main Tank temperature	4.2 K
EQM-aux. Tank temperature	1.7 K
External Hel dewar temp. for CTCE-shroud cooling	4.2 K
Main Tank heater power	2000 mW
EQM-auxiliary tank heater power	14 mW
CTCE-shroud He-mass flow rate	100 mg/s
Reflector heater power	0 mW

Table 5-5:   Input parameters

Submodel	Node #	Node Label	T (K)	T_{max} (K) required	Requirement fulfilled
CRYO	12, 22, 32	Heatshield 1	10 – 16	NA	NA
CRYO	13, 23, 33	Heatshield 2	22 – 38	NA	NA
CRYO	14, 15, 24, 25, 34, 35	Heatshield 3	98 – 143	NA	NA
CRYO	4001 - 4078	CVV	293	NA	NA
CRYO	4090	LOU window	290	NA	NA
CRYO:PLM	371 - 381	Optical Bench	11 –12	15	yes

Submodel	Node #	Node Label	T (K)	T_{max} (K) required	Require ment fulfilled
CRYO:PLM	811	SPIRE SM Detector enclosure	1.78	1.8	yes
CRYO:PLM	819	SPIRE Cooler Pump HS	1.77	1.8	yes
CRYO:PLM	820	SPIRE Cooler Evaporator HS	1.73	1.8	yes
CRYO:PLM	765	PACS Blue Detector	1.72	3.5	yes
CRYO:PLM	760	PACS Red Detector	1.70	1.75	yes
CRYO:PLM	781	PACS He-Pump	1.78	2.20	yes
CRYO:PLM	912	HIFI l0-Boundary	1.85	2.00	yes
CRYO:PLM	803	SPIRE Optical Bench	5.3	4.5	**No 1)**
CRYO:PLM	730	PACS Photometer Optics	3.2	5	yes
CRYO:PLM	725	PACS Collimator	3.2	5	yes
CRYO:PLM	720	PACS Spectrom. Housing	3.2	5	yes
CRYO:PLM	913	HIFI L1-interface	6.1	6	**No 2)**
CRYO:PLM	801	SPIRE PM JFET enclosure	12	13	yes
CRYO:PLM	802	SPIRE SM JFET enclosure	12	13	yes
CRYO:PLM	910	HIFI FPU Structure	12	13	yes
CTCE	901 -930	CTCE vessel	292	NA	NA
CTCE	1221 - 1230	CTA-shroud	4.5 – 5.1	5	yes
CTCE	1121 – 1130	CTA- heatshield	50 – 65	NA	NA
CTCE	1240	CTA-Reflector	21	40 -80	**No *)**
CTCE	1250, 1260, 1270	Reflector interface brackets (or optical bench)	20 - 25	NA	NA

	Mass-flow rate (mg/s)	*required mass-flow rate (mg/s)*	*Requirement fulfilled*
Out of main tank	98	NA**)	NA
Out of EQM-auxiliary tank	2.0	2.1	yes
Out of external He-dewar for CTA-shroud cooling	100	NA **)	NA

1)   requirement not yet approved by ASED

2)   can be fulfilled b slightly increasing the mass flow rate to 2.1 mg/s.

*) temperature can easily be increased by electrically heating

**) to be verified whether pressure drop is not too high

***) can easily be increased by electrical heating

Table 5-7:   Brief results summary

```
EUROPEAN  SPACE  AGENCY  THERMAL  ANALYSIS  NETWORK
(VERSION 8.5.0)                          PAGE    1    14 FEBRUARY 2002
14:18:57                                                        EQM4


#########################################
#
#  Main Tank heater power:      2000 mW
#  Aux. Tank heater power:        14 mW
#  CTCE-shroud mass flow rate:   100 mg/s
#  Reflector HTR power:            0 mW
#
#########################################



+EQM4:CRYO


        NODE                      LABEL        T        QI        QR        C

           1      MAIN TANK                   4.200   0.00000   2.00000     0.000
           2      AUX TANK                    1.700   0.00000   0.01400     0.000
           5      Ti-head      lo   5        11.290   0.00000   0.00000    71.111
           6      belt fitting lo   6        10.681   0.00000   0.00000    63.280
           7      strut tank end lo  7        4.359   0.00000   0.00000    21.852
           8      Ti-head      up   8        11.317   0.00000   0.00000    71.335
           9      belt fitting up   9        10.708   0.00000   0.00000    63.499
          10      strut tank end up 10        4.360   0.00000   0.00000    21.858
          12      HS 1 BULK 12               10.597   0.00000   0.00000    14.056
          13      HS 2 BULK 13               22.984   0.00000   0.00000   140.213
          14      HS 3 BULK +Z 14           119.584   0.00000   0.00000  2768.515
          15      HS 3 BULK -Z 15           119.551   0.00000   0.00000  2767.874
          22      HS 1 CYL 22                10.523   0.00000   0.00000    44.749
          23      HS 2 CYL 23                21.971   0.00000   0.00000   330.815
          24      HS 3 CYL +Z 24             97.636   0.00000   0.00000  6861.636
          25      HS 3 CYL -Z 25             97.534   0.00000   0.00000  6852.337
          32      HS 1 CONE 32               15.545   0.00000   0.00000    91.935
          33      HS 2 CONE 33               38.010   0.00000   0.00000  1511.225
          34      HS 3 CONE +Z 34           142.349   0.00000   0.00000  7729.252
          35      HS 3 CONE -Z 35           142.555   0.00000   0.00000  7729.252
          42      HS 1 HIFI Baf. int.        25.657   0.00000   0.00000     2.933
          52      HS 1 HIFI Baf. ext.        32.990   0.00000   0.00000     2.678
          53      HS 2 HIFI Baf.             57.606   0.00000   0.00000    10.633
          54      HS 3 HIFI Baf.            175.289   0.00000   0.00000    45.571
          62      HS 1 Tele BAF              15.572   0.00000   0.00000     0.347
          63      HS 2 Tele BAF              38.197   0.00000   0.00000     5.548
          64      HS 3 Tele BAF             142.255   0.00000   0.00000    81.113
         101      MLI MAIN TANK LO 101        5.168   0.00000   0.00000    15.689
         105      MLI MAIN TANK CY 105        4.735   0.00000   0.00000    43.340
         106      MLI MAIN TANK UP 106       37.069   0.00000   0.00000   112.532
         112      MLI HS 1 BULK 112          20.330   0.00000   0.00000    39.960
         113      MLI HS 2 BULK 113         115.138   0.00000   0.00000   382.065
         114      MLI HS 3 BULK +Z 114      287.452   0.00000   0.00000   706.440
         115      MLI HS 3 BULK -Z 115      287.428   0.00000   0.00000   706.381
         122      MLI HS 1 CYL 122           19.263   0.00000   0.00000   123.049
         123      MLI HS 2 CYL 123           93.766   0.00000   0.00000   969.535
         124      MLI HS 3 CYL +Z 124       286.653   0.00000   0.00000  2100.824
         125      MLI HS 3 CYL -Z 125       285.595   0.00000   0.00000  2093.073
         132      MLI HS 1 CONE 132          51.504   0.00000   0.00000   249.841
         133      MLI HS 2 CONE 133         137.835   0.00000   0.00000  1125.916
         134      MLI HS 3 CONE +Z 134      287.294   0.00000   0.00000  1702.067
         135      MLI HS 3 CONE -Z 135      287.274   0.00000   0.00000  1701.948
         440      filling tube    440       271.528   0.00000   0.00000     0.000
```

```
 441    filling tube    441     252.225   0.00000   0.00000      0.000
 442    filling tube    442     245.520   0.00000   0.00000      0.000
 443    filling tube    443     242.460   0.00000   0.00000      0.000
 447    empty tube      447      15.532   0.00000   0.00000      0.000
 452    empty tube      452      10.866   0.00000   0.00000      0.000
 502    line baf to HS1 502       4.201   0.00000   0.00000      0.000
 642    MLI filling tube 642    120.439   0.00000   0.00000      0.766
 643    MLI filling tube 643    119.021   0.00000   0.00000      0.743
 647    MLI filling tube 647     25.816   0.00000   0.00000      1.245
 652    MLI filling tube 652     23.550   0.00000   0.00000      0.459
1000    HS 1 SUSP BOLT  1000     19.629   0.00000   0.00000      0.000
2000    HS 2 SUSP BOLT  2000     67.893   0.00000   0.00000      0.000
3000    HS 3 SUSP BOLT  3000    189.811   0.00000   0.00000      0.000
4001    CVV lower bulk  4001    292.764   0.00000   0.00000   4399.464
4002    CVV lower bulk  4002    292.771   0.00000   0.00000   4399.491
4003    CVV lower bulk  4003    292.771   0.00000   0.00000   4399.491
4004    CVV lower bulk  4004    292.764   0.00000   0.00000   4399.462
4005    CVV lower bulk  4005    292.750   0.00000   0.00000   4399.407
4006    CVV lower bulk  4006    292.749   0.00000   0.00000   4399.404
4007    CVV lower bulk  4007    292.759   0.00000   0.00000   4399.442
4008    CVV lower bulk  4008    292.760   0.00000   0.00000   4399.449
4011    CVV lower bulk  4011    292.707   0.00000   0.00000   1668.975
4012    CVV lower bulk  4012    292.740   0.00000   0.00000   1669.026
4013    CVV lower bulk  4013    292.741   0.00000   0.00000   1669.028
4014    CVV lower bulk  4014    292.717   0.00000   0.00000   1668.991
4015    CVV lower bulk  4015    292.654   0.00000   0.00000   1668.893
4016    CVV lower bulk  4016    292.654   0.00000   0.00000   1668.894
4017    CVV lower bulk  4017    292.705   0.00000   0.00000   1668.971
4018    CVV lower bulk  4018    292.700   0.00000   0.00000   1668.964
4031    CVV cyl lower   4031    292.553   0.00000   0.00000  13706.679
4032    CVV cyl lower   4032    292.661   0.00000   0.00000  13708.039
4033    CVV cyl lower   4033    292.663   0.00000   0.00000  13708.075
4034    CVV cyl lower   4034    292.599   0.00000   0.00000  13707.263
4035    CVV cyl lower   4035    292.392   0.00000   0.00000  13704.653
4036    CVV cyl lower   4036    292.397   0.00000   0.00000  13704.712
4037    CVV cyl lower   4037    292.569   0.00000   0.00000  13706.878
4038    CVV cyl lower   4038    292.537   0.00000   0.00000  13706.479
4041    CVV cyl upper   4041    292.694   0.00000   0.00000  19514.609
4042    CVV cyl upper   4042    292.699   0.00000   0.00000  19514.697
4043    CVV cyl upper   4043    292.633   0.00000   0.00000  19513.515
4044    CVV cyl upper   4044    292.216   0.00000   0.00000  19506.024
4045    CVV cyl upper   4045    289.662   0.00000   0.00000  19460.131
4046    CVV cyl upper   4046    289.657   0.00000   0.00000  19460.035
4047    CVV cyl upper   4047    292.187   0.00000   0.00000  19505.494
4048    CVV cyl upper   4048    292.604   0.00000   0.00000  19512.981
4051    CVV upper bulk  4051    292.714   0.00000   0.00000  19050.968
4052    CVV upper bulk  4052    292.627   0.00000   0.00000  19049.443
4053    CVV upper bulk  4053    292.618   0.00000   0.00000  19049.279
4054    CVV upper bulk  4054    292.670   0.00000   0.00000  19050.189
4055    CVV upper bulk  4055    292.589   0.00000   0.00000  19048.780
4056    CVV upper bulk  4056    292.545   0.00000   0.00000  19048.003
4057    CVV upper bulk  4057    292.681   0.00000   0.00000  19050.386
4058    CVV upper bulk  4058    292.719   0.00000   0.00000  19051.064
4061    CVV/CTA flange  4061    292.330   0.00000   0.00000      0.000
4062    CVV/CTA flange  4062    292.307   0.00000   0.00000      0.000
4063    CVV/CTA flange  4063    292.286   0.00000   0.00000      0.000
4064    CVV/CTA flange  4064    292.263   0.00000   0.00000      0.000
4065    CVV/CTA flange  4065    292.240   0.00000   0.00000      0.000
4066    CVV/CTA flange  4066    292.244   0.00000   0.00000      0.000
4067    CVV/CTA flange  4067    292.299   0.00000   0.00000      0.000
4068    CVV/CTA flange  4068    292.326   0.00000   0.00000      0.000
4071    CVV flange disc 4071    292.174   0.00000   0.00000      0.000
4072    CVV flange disc 4072    292.162   0.00000   0.00000      0.000
```

```
4073      CVV flange disc   4073     292.144   0.00000   0.00000     0.000
4074      CVV flange disc   4074     292.126   0.00000   0.00000     0.000
4075      CVV flange disc   4075     292.114   0.00000   0.00000     0.000
4076      CVV flange disc   4076     292.121   0.00000   0.00000     0.000
4077      CVV flange disc   4077     292.150   0.00000   0.00000     0.000
4078      CVV flange disc   4078     292.171   0.00000   0.00000     0.000
4090      CVV Lo window              289.929   0.00000   0.00000    15.604
4631      SUSP TI   lo   4631        282.781   0.00000   0.00000    84.266
4632      SUSP TI   lo   4632        282.880   0.00000   0.00000    84.277
4633      SUSP TI   lo   4633        282.883   0.00000   0.00000    84.277
4634      SUSP TI   lo   4634        282.824   0.00000   0.00000    84.271
4635      SUSP TI   lo   4635        282.633   0.00000   0.00000    84.250
4636      SUSP TI   lo   4636        282.638   0.00000   0.00000    84.251
4637      SUSP TI   lo   4637        282.795   0.00000   0.00000    84.268
4638      SUSP TI   lo   4638        282.766   0.00000   0.00000    84.265
4641      SUSP TI   up   4641        282.911   0.00000   0.00000    84.280
4642      SUSP TI   up   4642        282.916   0.00000   0.00000    84.281
4643      SUSP TI   up   4643        282.855   0.00000   0.00000    84.274
4644      SUSP TI   up   4644        282.471   0.00000   0.00000    84.233
4645      SUSP TI   up   4645        280.122   0.00000   0.00000    83.983
4646      SUSP TI   up   4646        280.118   0.00000   0.00000    83.983
4647      SUSP TI   up   4647        282.444   0.00000   0.00000    84.230
4648      SUSP TI   up   4648        282.828   0.00000   0.00000    84.271
4731      CABLE PLUG    4731         281.499   0.00073   0.00000    93.529
4732      CABLE PLUG    4732         291.588   0.00000   0.00000    97.058
4733      CABLE PLUG    4733         291.591   0.00000   0.00000    97.059
4734      CABLE PLUG    4734         291.527   0.00000   0.00000    97.036
4735      CABLE PLUG    4735         291.321   0.00000   0.00000    96.964
4736      CABLE PLUG    4736         292.397   0.00000   0.00000    97.341
4737      CABLE PLUG    4737         292.569   0.00000   0.00000    97.401
4738      CABLE PLUG    4738         283.622   0.00010   0.00000    94.272
6051      X2 SI Harness 51           245.203   0.00073   0.00000     0.000
6052      X2 SI Harness 52           205.934   0.00073   0.00000     0.000
6053      X2 SI Harness 53           162.825   0.00073   0.00000     0.000
6054      X2 SI Harness 54           113.892   0.00073   0.00000     0.000
6055      X2 SI at HS1  55            50.556   0.00250   0.00000     0.000
6056      X3 SI Harness 56            45.804   0.00250   0.00000     0.000
6057      X3 SI Harness 57            39.314   0.00250   0.00000     0.000
6058      X3 SI Harness 58            29.953   0.00250   0.00000     0.000
6061      X2 JF Harness 61           246.339   0.00010   0.00000     0.000
6062      X2 JF Harness 62           205.932   0.00010   0.00000     0.000
6063      X2 JF Harness 63           161.456   0.00010   0.00000     0.000
6064      X2 JF Harness 64           110.711   0.00010   0.00000     0.000
6065      X2 JF at HS1  65            42.549   0.00024   0.00000     0.000
6066      X3 JF Harness 66            38.138   0.00024   0.00000     0.000
6067      X3 JF Harness 67            33.046   0.00024   0.00000     0.000
6068      X3 JF Harness 68            26.869   0.00024   0.00000     0.000
9999      AMBIENT                    293.000   0.00000   0.00000     0.000
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+EQM4:CRYO:V

NODE		LABEL	T	QI	QR	C
201	OSS-TUBE	201	4.200	0.00000	0.00000	0.000
202	BAFFLE LO	202	4.200	0.00000	0.00000	0.000
203	BAFFLE UP	203	4.200	0.00000	0.00000	0.000
204	1ST HS	204	10.523	0.00000	0.00000	0.000
205	2ND HS	205	21.971	0.00000	0.00000	0.000
206	3RD HS +z	206	97.636	0.00000	0.00000	0.000
207	3RD HS -z	207	97.534	0.00000	0.00000	0.000
210	VENT VESSEL	210	209.896	0.00000	0.00000	0.000
212	BAFFLE - 1ST HS	212	4.201	0.00000	0.00000	0.000
251	TANK HE-OUT	251	4.200	0.00000	0.00000	0.000
252	OSS HE-OUT	252	4.200	0.00000	0.00000	0.000
253	BAFFLE LO HE-OUT	253	4.200	0.00000	0.00000	0.000
254	BAFFLE UP HE-OUT	254	4.200	0.00000	0.00000	0.000
255	1ST HS HE-OUT	255	10.523	0.00000	0.00000	0.000
256	2ND HS HE-OUT	256	21.951	0.00000	0.00000	0.000
257	3RD HS HE-OUT	257	97.585	0.00000	0.00000	0.000
260	VESSEL HE-OUT	260	209.896	0.00000	0.00000	0.000
262	BAF - HS1 HE-OUT	262	4.200	0.00000	0.00000	0.000
296	HEATER WALL	296	293.000	0.00000	0.00000	0.000
297	HEATER HE-OUT	297	209.896	0.00000	0.00000	0.000

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+EQM4:CRYO:PLM

NODE	LABEL	T	QI	QR	C
310	Instr. Shield Cyl.	11.537	0.00000	0.00000	8.100
311	Instr. Shield Top	11.548	0.00000	0.00000	10.485
315	Instr. Shield Baffle	11.564	0.00000	0.00000	0.677
320	Vline wall Tank-PACS	1.755	0.00000	0.00000	0.007
321	Vline wall PACS I/F 1	2.395	0.00000	0.00000	0.001
322	Vline wall PACS I/F 1	2.641	0.00000	0.00000	0.000
323	Vline wall PACS I/F 1	2.478	0.00000	0.00000	0.001
324	Vline wall PACSI/F1/2	2.309	0.00000	0.00000	0.003
325	Vline wall PACSI/F1/2	2.339	0.00000	0.00000	0.013
326	Vline wall PACS I/F 2	2.709	0.00000	0.00000	0.001
327	Vline wall PACS I/F 2	2.860	0.00000	0.00000	0.000
328	Vline wall PACS I/F 2	2.771	0.00000	0.00000	0.001
329	Vline wall PACSI/F2/3	2.682	0.00000	0.00000	0.006
330	Vline wall PACSI/F2/3	2.747	0.00000	0.00000	0.002
331	Vline wall PACS I/F 3	2.879	0.00000	0.00000	0.001
332	Vline wall PACS I/F 3	2.983	0.00000	0.00000	0.000
333	Vline wall PACS I/F 3	2.936	0.00000	0.00000	0.001
334	Vline wall PACS-SPIRE	2.895	0.00000	0.00000	0.006
335	Vline wall PACS-SPIRE	2.918	0.00000	0.00000	0.007
336	Vline wall PACS-SPIRE	3.080	0.00000	0.00000	0.008
337	Vline wall SPIRE	4.029	0.00000	0.00000	0.001
338	Vline wall SPIRE	4.579	0.00000	0.00000	0.001
339	Vline wall SPIRE	4.325	0.00000	0.00000	0.001
340	Vline wall SPIRE-HIFI	4.118	0.00000	0.00000	0.012
341	Vline wall SPIRE-HIFI	4.131	0.00000	0.00000	0.015
342	Vline wall SPIRE-HIFI	4.239	0.00000	0.00000	0.018
343	Vline wall HIFI	5.181	0.00000	0.00000	0.002
344	Vline wall HIFI	5.734	0.00000	0.00000	0.001
345	Vline wall HIFI	6.042	0.00000	0.00000	0.003
346	Vline Lev.2 OB	10.088	0.00000	0.00000	0.070
347	Vline Lev.2 OB	11.143	0.00000	0.00000	0.203
348	Vline Lev.2 OB	11.258	0.00000	0.00000	0.081
349	Vline Lev.2 OB	11.327	0.00000	0.00000	0.130
350	Vline Lev.2 OB	11.354	0.00000	0.00000	0.076
351	Vline Lev.2 OB	11.358	0.00000	0.00000	0.225
352	Vline Lev.2 OB	11.383	0.00000	0.00000	0.116
371	Opt. Bench +Z	11.274	0.00000	0.00000	7.719
372	Opt. Bench +Z -Y	11.207	0.00000	0.00000	7.014
373	Opt. Bench +Z mid	11.286	0.00000	0.00000	18.149
374	Opt. Bench +Z +Y	11.303	0.00000	0.00000	2.940
375	Opt. Bench -Y	11.353	0.00000	0.00000	13.427
376	Opt. Bench centre	11.335	0.00000	0.00000	32.336
377	Opt. Bench +Y	11.340	0.00000	0.00000	7.122
378	Opt. Bench -Z -Y	11.386	0.00000	0.00000	7.336
379	Opt. Bench -Z mid	11.362	0.00000	0.00000	18.496
380	Opt. Bench -Z +Y	11.364	0.00000	0.00000	2.985
381	Opt. Bench -Z	11.359	0.00000	0.00000	7.884
390	I.Shld HIFI Baf. ext.	11.611	0.00000	0.00000	0.318
391	I.Shld HIFI Baf. int.	11.541	0.00000	0.00000	0.111
411	MLI on OB-Shield side	13.890	0.00000	0.00000	31.603
412	MLI on OB-Shield top	13.894	0.00000	0.00000	40.809
710	PACS-Top Optic	3.159	0.00000	0.00000	1.888
720	PACS-Spectrometer	3.156	0.00003	0.00000	2.135
725	PACS-Collimator	3.154	0.00000	0.00000	2.159
730	PACS-Photometer Optic	3.153	0.00000	0.00000	1.304
735	PACS-Internal	3.158	0.00000	0.00000	1.811
740	PACS-Lump	3.157	0.00000	0.00000	0.000
750	PACS-Chopper	3.162	0.00040	0.00000	0.114

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755    PACS-Grating Assy          3.161    0.00100   0.00000     0.778
760    PACS-Red  Detector         1.704    0.00000   0.00000     0.230
761    PACS-Red  Detect. CRE      3.168    0.00030   0.00000     0.029
765    PACS-Blue Detector         1.723    0.00013   0.00000     0.233
766    PACS-Blue Detect. CRE      3.168    0.00030   0.00000     0.029
770    PACS-Filter Wh. Blue       3.157    0.00004   0.00000     0.133
771    PACS-Filter Wh. Photo      3.153    0.00004   0.00000     0.132
775    PACS-Calib. Source 1       3.160    0.00032   0.00000     0.019
776    PACS-Calib. Source 2       3.162    0.00032   0.00000     0.019
780    PACS-Photometer Housi      3.155    0.00000   0.00000     1.001
781    PACS-Photometer CooPu      1.781    0.00220   0.00000     0.147
791    PACS-STST-Strut 1,1        9.169    0.00000   0.00000     0.326
792    PACS-STST-Strut 4,1        9.165    0.00000   0.00000     0.507
793    PACS-STST-Strut 5,1        9.169    0.00000   0.00000     0.254
794    PACS-Kevlar-Strut Red  1   2.614    0.00000   0.00000     0.014
795    PACS-Kevlar-Strut Blue 1   2.618    0.00000   0.00000     0.014
796    PACS-HarnessRed Det.Int1   2.549    0.00000   0.00000     0.000
797    PACS-HarnessBlueDet.Int1   2.556    0.00000   0.00000     0.000
798    PACS-HarnessBlue1.7->4,1   2.540    0.00000   0.00000     0.000
801    SPIRE PM JFET ENCL        11.393    0.01026   0.00000    11.194
802    SPIRE SM JFET ENCL        11.367    0.00282   0.00000     3.631
803    SPIRE Optical Bench        5.194    0.00000   0.00000    10.163
804    SPIRE RF Filter Box        5.198    0.00428   0.00000     0.498
805    SPIRE Beam St. Mech        5.195    0.00100   0.00000     0.373
806    SPIRE SMECm                5.194    0.00048   0.00000     0.441
807    SPIRE PM calibrator        5.195    0.00002   0.00000     0.000
808    SPIRE SM calibrator        9.460    0.00040   0.00000     0.000
809    SPIRE Shutter              5.194    0.00000   0.00000     0.000
810    SPIRE PM Detector en       1.799    0.00000   0.00000     0.452
811    SPIRE SM Detector en       1.776    0.00000   0.00000     0.269
812    SPIRE PM Detectors         1.742    0.00000   0.00000     0.398
813    SPIRE SM detector          1.742    0.00000   0.00000     0.252
816    SPIRE Cooler Pump          1.887    0.00183   0.00000     0.000
817    SPIRE Cooler shunt         1.725    0.00000   0.00000     0.000
818    SPIRE Cooler evap          1.742    0.00000   0.00000     0.000
819    SPIRE Cooler pump HS       1.774    0.00008   0.00000     0.000
820    SPIRE Cooler evap HS       1.725    0.00000   0.00000     0.000
900    HIFI 2K level              1.859    0.00014   0.00000     0.030
905    HIFI Harness 1 int.point   6.029    0.00036   0.00000     0.000
910    HIFI FPU Structure        11.366    0.01602   0.00000   105.524
912    HIFI L0 boundary node      1.852    0.00000   0.00000     0.000
913    HIFI L1 boundary node      5.991    0.00000   0.00000     0.000
914    HIFI Harness 2a int.poin  12.664    0.00036   0.00000     0.000
915    HIFI Harness 2b int.poin   9.077    0.00000   0.00000     0.000
920    HIFI Internal Assy.        5.995    0.00000   0.00000     0.025
5000   GHe tank outlet            1.700    0.00000   0.00000     0.000
5010   GHe PACS I/F 1 in          1.752    0.00000   0.00000     0.000
5011   GHe PACS I/F 1             1.967    0.00000   0.00000     0.000
5012   GHe PACS I/F 1             2.104    0.00000   0.00000     0.000
5013   GHe PACS I/F 1 out         2.236    0.00000   0.00000     0.000
5014   GHe PACS I/F 1/2           2.290    0.00000   0.00000     0.000
5020   GHe PACS I/F 2 in          2.336    0.00000   0.00000     0.000
5021   GHe PACS I/F 2             2.476    0.00000   0.00000     0.000
5022   GHe PACS I/F 2             2.562    0.00000   0.00000     0.000
5023   GHe PACS I/F 2 out         2.642    0.00000   0.00000     0.000
5024   GHe PACS I/F 2/3           2.678    0.00000   0.00000     0.000
5030   GHe PACS I/F 3 in          2.724    0.00000   0.00000     0.000
5031   GHe PACS I/F 3             2.786    0.00000   0.00000     0.000
5032   GHe PACS I/F 3             2.832    0.00000   0.00000     0.000
5033   GHe PACS I/F 3 out         2.874    0.00000   0.00000     0.000
5034   GHe PACS-SPIRE             2.893    0.00000   0.00000     0.000
5035   GHe PACS-SPIRE             2.917    0.00000   0.00000     0.000
5040   GHe SPIRE I/F in           3.072    0.00000   0.00000     0.000
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5041      GHe SPIRE I/F              3.520   0.00000   0.00000   0.000
5042      GHe SPIRE I/F              3.826   0.00000   0.00000   0.000
5043      GHe SPIRE I/F out          4.072   0.00000   0.00000   0.000
5044      GHe SPIRE-HIFI             4.115   0.00000   0.00000   0.000
5045      GHe SPIRE-HIFI             4.131   0.00000   0.00000   0.000
5050      GHe HIFI I/F in            4.234   0.00000   0.00000   0.000
5051      GHe HIFI I/F               4.735   0.00000   0.00000   0.000
5052      GHe HIFI I/F               5.064   0.00000   0.00000   0.000
5053      GHe HIFI I/F out           5.624   0.00000   0.00000   0.000
5054      GHe Lev.2 OB               9.865   0.00000   0.00000   0.000
5055      GHe Lev.2 OB              11.079   0.00000   0.00000   0.000
5056      GHe Lev.2 OB              11.249   0.00000   0.00000   0.000
5057      GHe Lev.2 OB              11.323   0.00000   0.00000   0.000
5058      GHe Lev.2 OB              11.352   0.00000   0.00000   0.000
5059      GHe Lev.2 OB              11.358   0.00000   0.00000   0.000
5060      GHe Lev.2 OB              11.382   0.00000   0.00000   0.000
6059      X3 SI Harness 59         12.220   0.00406   0.00000   0.000
6069      X3 JF Harness 69         18.609   0.00040   0.00000   0.000
9999      Ambient Air             293.000   0.00000   0.00000   0.000
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+EQM4:CTCE

NODE	LABEL	T	QI	QR	C
901	vessel flange 901	292.340	0.00000	0.00000	905.667
902	vessel flange 902	292.321	0.00000	0.00000	905.651
903	vessel flange 903	292.297	0.00000	0.00000	905.632
904	vessel flange 904	292.260	0.00000	0.00000	905.601
905	vessel flange 905	292.239	0.00000	0.00000	905.583
906	vessel flange 906	292.248	0.00000	0.00000	905.591
907	vessel flange 907	292.306	0.00000	0.00000	905.639
908	vessel flange 908	292.335	0.00000	0.00000	905.663
921	cyl. vessel 921	292.402	0.00000	0.00000	8551.714
922	cyl. vessel 922	292.384	0.00000	0.00000	8551.566
923	cyl. vessel 923	292.335	0.00000	0.00000	8551.181
924	cyl. vessel 924	292.140	0.00000	0.00000	8549.650
925	cyl. vessel 925	292.106	0.00000	0.00000	8549.379
926	cyl. vessel 926	292.141	0.00000	0.00000	8549.657
927	cyl. vessel 927	292.336	0.00000	0.00000	8551.191
928	cyl. vessel 928	292.385	0.00000	0.00000	8551.579
930	vessel dome 930	292.404	0.00000	0.00000	19146.645
1011	Shroud bottom MLI	31.091	0.00000	0.00000	0.000
1012	Shroud bottom MLI	31.055	0.00000	0.00000	0.000
1013	Shroud bottom MLI	34.574	0.00000	0.00000	0.000
1014	Shroud bottom MLI	38.888	0.00000	0.00000	0.000
1015	Shroud bottom MLI	42.626	0.00000	0.00000	0.000
1016	Shroud bottom MLI	45.250	0.00000	0.00000	0.000
1017	Shroud bottom MLI	45.706	0.00000	0.00000	0.000
1018	Shroud bottom MLI	42.427	0.00000	0.00000	0.000
1021	Shroud cyl. MLI	31.091	0.00000	0.00000	0.000
1022	Shroud cyl. MLI	31.055	0.00000	0.00000	0.000
1023	Shroud cyl. MLI	34.574	0.00000	0.00000	0.000
1024	Shroud cyl. MLI	38.888	0.00000	0.00000	0.000
1025	Shroud cyl. MLI	42.626	0.00000	0.00000	0.000
1026	Shroud cyl. MLI	45.250	0.00000	0.00000	0.000
1027	Shroud cyl. MLI	45.706	0.00000	0.00000	0.000
1028	Shroud cyl. MLI	42.427	0.00000	0.00000	0.000
1030	Shroud top MLI	49.196	0.00000	0.00000	0.000
1121	CTA cyl. HS 1121	49.777	0.00000	0.00000	226.532
1122	CTA cyl. HS 1122	49.751	0.00000	0.00000	226.254
1123	CTA cyl. HS 1122	52.823	0.00000	0.00000	259.359
1124	CTA cyl. HS 1122	56.553	0.00000	0.00000	299.564
1125	CTA cyl. HS 1122	59.766	0.00000	0.00000	334.191
1126	CTA cyl. HS 1122	62.038	0.00000	0.00000	359.647
1127	CTA cyl. HS 1122	62.425	0.00000	0.00000	364.002
1128	CTA cyl. HS 1122	59.593	0.00000	0.00000	332.327
1130	CTA top HS 1130	65.197	0.00000	0.00000	587.192
1201	CTA Shroud lo Baf	6.202	0.00000	0.00000	0.179
1211	CTA Shroud up Baf	4.882	0.00000	0.00000	0.101
1221	CTA cy.Shroud 1221	4.511	0.00000	0.00000	0.000
1222	CTA cy.Shroud 1222	4.479	0.00000	0.00000	0.000
1223	CTA cy.Shroud 1223	4.548	0.00000	0.00000	0.000
1224	CTA cy.Shroud 1224	4.559	0.00000	0.00000	0.000
1225	CTA cy.Shroud 1225	4.645	0.00000	0.00000	0.000
1226	CTA cy.Shroud 1226	4.646	0.00000	0.00000	0.000
1227	CTA cy.Shroud 1227	4.715	0.00000	0.00000	0.000
1228	CTA cy.Shroud 1228	4.655	0.00000	0.00000	0.000
1230	CTA topShroud 1230	5.142	0.00000	0.00000	0.696
1240	CTA Reflector	21.072	0.00000	0.00000	32.717
1250	Refl. I/F bracket 1	19.672	0.00000	0.00000	0.000
1252	Refl. I/F br.1 pos.2	168.852	0.00000	0.00000	0.000
1253	Refl. I/F br.1 pos.3	170.212	0.00000	0.00000	0.000

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1254      Refl. I/F br.1 pos.4      137.880   0.00000   0.00000   0.000
1255      Refl. I/F br.1 pos.5      140.087   0.00000   0.00000   0.000
1256      Refl. I/F br.1 pos.6      222.619   0.00000   0.00000   0.000
1257      Refl. I/F br.1 pos.7      224.341   0.00000   0.00000   0.000
1260      Refl. I/F bracket 2        22.109   0.00000   0.00000   0.000
1262      Refl. I/F br.2 pos.2      169.578   0.00000   0.00000   0.000
1263      Refl. I/F br.2 pos.3      170.935   0.00000   0.00000   0.000
1264      Refl. I/F br.2 pos.4      138.433   0.00000   0.00000   0.000
1265      Refl. I/F br.2 pos.5      140.630   0.00000   0.00000   0.000
1266      Refl. I/F br.2 pos.6      222.816   0.00000   0.00000   0.000
1267      Refl. I/F br.2 pos.7      224.532   0.00000   0.00000   0.000
1270      Refl. I/F bracket 3        24.618   0.00000   0.00000   0.000
1272      Refl. I/F br.3 pos.2      169.838   0.00000   0.00000   0.000
1273      Refl. I/F br.3 pos.3      171.186   0.00000   0.00000   0.000
1274      Refl. I/F br.3 pos.4      139.175   0.00000   0.00000   0.000
1275      Refl. I/F br.3 pos.5      141.358   0.00000   0.00000   0.000
1276      Refl. I/F br.3 pos.6      223.129   0.00000   0.00000   0.000
1277      Refl. I/F br.3 pos.7      224.837   0.00000   0.00000   0.000
1311      CTA HS bottom MLI         268.518   0.00000   0.00000   0.000
1312      CTA HS bottom MLI         268.503   0.00000   0.00000   0.000
1313      CTA HS bottom MLI         268.499   0.00000   0.00000   0.000
1314      CTA HS bottom MLI         268.494   0.00000   0.00000   0.000
1315      CTA HS bottom MLI         268.497   0.00000   0.00000   0.000
1316      CTA HS bottom MLI         268.518   0.00000   0.00000   0.000
1317      CTA HS bottom MLI         268.559   0.00000   0.00000   0.000
1318      CTA HS bottom MLI         268.565   0.00000   0.00000   0.000
1321      CTA HS cyl. MLI           268.789   0.00000   0.00000   0.000
1322      CTA HS cyl. MLI           268.772   0.00000   0.00000   0.000
1323      CTA HS cyl. MLI           268.741   0.00000   0.00000   0.000
1324      CTA HS cyl. MLI           268.580   0.00000   0.00000   0.000
1325      CTA HS cyl. MLI           268.566   0.00000   0.00000   0.000
1326      CTA HS cyl. MLI           268.612   0.00000   0.00000   0.000
1327      CTA HS cyl. MLI           268.795   0.00000   0.00000   0.000
1328      CTA HS cyl. MLI           268.823   0.00000   0.00000   0.000
1330      CTA HS top MLI            272.875   0.00000   0.00000   0.000
2000      CTA-Shroud Dewar            4.200   0.00000   0.00000   0.000
2001      GHe Shroud 1221 out         4.253   0.00000   0.00000   0.000
2002      GHe Shroud 1222 out         4.291   0.00000   0.00000   0.000
2003      GHe Shroud 1223 out         4.335   0.00000   0.00000   0.000
2004      GHe Shroud 1224 out         4.373   0.00000   0.00000   0.000
2005      GHe Shroud 1225 out         4.420   0.00000   0.00000   0.000
2006      GHe Shroud 1226 out         4.459   0.00000   0.00000   0.000
2007      GHe Shroud 1227 out         4.503   0.00000   0.00000   0.000
2008      GHe Shroud 1228 out         4.529   0.00000   0.00000   0.000
2011      GHe HS 1121 out            29.693   0.00000   0.00000   0.000
2012      GHe HS 1122 out            38.875   0.00000   0.00000   0.000
2013      GHe HS 1123 out            45.597   0.00000   0.00000   0.000
2014      GHe HS 1124 out            51.065   0.00000   0.00000   0.000
2015      GHe HS 1125 out            55.502   0.00000   0.00000   0.000
2016      GHe HS 1126 out            58.889   0.00000   0.00000   0.000
2017      GHe HS 1127 out            60.735   0.00000   0.00000   0.000
2018      GHe HS 1128 out            60.142   0.00000   0.00000   0.000
2021      GHe I/F bracket 1250 out    7.887   0.00000   0.00000   0.000
2022      GHe I/F bracket 1260 out   11.238   0.00000   0.00000   0.000
2023      GHe I/F bracket 1270 out   14.572   0.00000   0.00000   0.000
9999      AMBIENT                   293.000   0.00000   0.00000   0.000
```

```
Heat Balance for PAYLOAD incl. Instrument Shield MLI
====================================================
                       Level 0: from Aux. Tank into instruments     -15.975 [mW]
                       Level 2: from spatial framework into OB         0.069 [mW]
            Level 1/2: from Aux. Tank into OB via ventline wall       -0.064 [mW]
                  Level 2: from HS1 into OB via ventline wall          0.157 [mW]
                              Level 2: via harness into OB            27.148 [mW]
          via radiation from HS1 upper bulkhead onto Instrument MLI    0.234 [mW]
             via radiation from Cryostat cavity onto OB lower side     5.132 [mW]
                    via radiation from HS1-baffle into payload         0.007 [mW]
                    via radiation from HS2-baffle into payload         0.023 [mW]
                    via radiation from HS3-baffle into payload         1.511 [mW]
               via radiation from CTCE-4K-shrouds into payload        -0.015 [mW]
          via radiation from CTCE lower-shroud baffle into payload    -0.002 [mW]
          via radiation from CTCE upper-shroud baffle into payload    -0.002 [mW]
                  via radiation from CTCE reflector into payload       0.011 [mW]
                 via radiation from CVV-LOU-Window onto HIFI-Baffle   19.953 [mW]
                    via radiation from CVV-LOU-Window onto HIFI-FPU   14.512 [mW]
                       Vent line cooling power (out of payload)      102.030 [mW]
             Transferred by convection from PL-ventline on helium    102.077 [mW]
                                total dissipation of PACS              5.070 [mW]
                               total dissipation of SPIRE            21.167 [mW]
                                total dissipation of HIFI            16.867 [mW]
                                  Harness dissipation on OB            4.462 [mW]
                        Payload Heat Imbalance (shall be 0)           -1.762 [mW]


Heat Balance for Main Tank Ventline
===================================
                  conducted and radiated into ventline attached to HS1      3204.627 [mW]
                  conducted and radiated into ventline attached to HS2      5791.873 [mW]
            conducted and radiated into ventline attached to HS3 +Z        19179.208 [mW]
            conducted and radiated into ventline attached to HS3 -Z        19153.378 [mW]
                          conducted into ventline walls from CVV           56921.430 [mW]
                      conducted and radiated into line baf to HS 1             0.152 [mW]
             Main Tank Ventline cooling power (out of ventline)           104250.767 [mW]
                           Via convection into ventline walls            -104260.686 [mW]
                      Main Tank Ventline Imbalance (shall be 0)               -0.100 [mW]


Heat Balance for CTCE
=====================
                  Convective heat transfer onto CTCE-external insulation    27236.651 [mW]
                        Conducted from CVV into CTCE-structure               -276.405 [mW]
              Radiated from Payload into CTCE-shrouds incl. baffles            0.018 [mW]
                      Radiated from HS-baffles onto CTCE-shroud              48.897 [mW]
          Radiated from CVV flange disc within cavity onto CTCE-MLI        2061.679 [mW]
                          Radiated from Payload onto reflector               -0.011 [mW]
                  Conducted from CTCE-structure into CTCE-shrouds             0.000 [mW]
                              Cooling power of CTCE-shrouds                29070.834 [mW]
                            CTCE Imbalance (shall be 0)                      -0.005 [mW]


Heat Balance for Reflector within CTCE
======================================
                          via struts from CTCE-I/F brackets into reflector     0.120 [mW]
                      by radiation from CTCE-shrouds into reflector           -0.114 [mW]
                        by radiation from Payload into reflector              -0.011 [mW]
                                reflector heater power                         0.000 [mW]
                        reflector total imbalance (shall be 0)                -0.004 [mW]


Heat Balance for whole Cryostat including Payload,Ventlines and CTCE
===================================================================
                      Convective heat transfer onto external walls        133260.946 [mW]
                      total heat transferred on gaseous helium            133423.632 [mW]
                      evaporation power in main and aux. tank               2086.521 [mW]
                            Total istrument power dissipation                 43.104 [mW]
                total main & auxiliary tank and reflector heater power       2014.000 [mW]
                          heater power of CVV lower bulkhead HTR              0.000 [mW]
                        total harness dissipation within system             19.601 [mW]
                            Cooling power of CTCE-shrouds                  29070.834 [mW]
                        Cryostat total imbalance (shall be 0)              -172.501 [mW]
```

```
Heat Balance for Main Tank
==========================
                          Main tank dissipation + heater power    2000.000 [mW]
                            heat from Aux. tank via mech. I/F        -0.451 [mW]
                                     radiated from aux. tank         0.000 [mW]
                          conducted from spatial framework          30.638 [mW]
                               transferred through MLI               9.750 [mW]
                                    conducted from rest              0.290 [mW]
                  radiated from spatial framework and HSs            0.077 [mW]
                conducted from main tank ventline wall               0.000 [mW]
                               radiated from payload                 0.000 [mW]
                             total heat into main tank            2040.303 [mW]

Heat Balance for Auxiliary Tank
===============================
                           Aux. tank dissipation + heater power      14.000 [mW]
                             heat from Main tank via mech. I/F         0.451 [mW]
                                     radiated from Main tank           0.000 [mW]
                  radiated from spatial framework and HSs              0.015 [mW]
                             conducted from payload L0                15.975 [mW]
                             conducted from payload L2                 0.064 [mW]
                                   radiated from payload               0.012 [mW]
                             conducted from filling tube               0.007 [mW]
                          radiated from MLI filling tube              15.692 [mW]
                                 total heat into Aux. tank            46.217 [mW]

Heat flows into Tanks
=====================

                                         Into Main Tank           2040.303 [mW]
                                         Into Aux. Tank             46.217 [mW]

Helium evaporation mass flow rates
==================================

                                         Out of Main Tank           97.529 [mg/s]
                                         Out of Aux. Tank            2.028 [mg/s]
                    Out of external He- dewar for CTA-shroud cooling 100.000 [mg/s]
```

5.3   CTCE-Design-1 Case 3

CTCE-design1 means: MLI-design concept for CTCE as defined in § 4.5.2.1

Case 3 means: EQM-aux. Tank heater power = 14 mW

                                  Reflector heater power =   40 mW

The input parameters are compiled in Table 5-9and a brief temperature results summary is given in Table 5-11. The complete ESATAN-output-file listing is appended. The respective node numbers and labels are referenced in the thermal design and thermal-mathematical model descriptions in § 4

Input parameter	
Main Tank temperature	4.2 K
EQM-aux. Tank temperature	1.7 K
External Hel dewar temp. for CTCE-shroud cooling	4.2 K
Main Tank heater power	2000 mW
EQM-auxiliary tank heater power	14 mW
CTCE-shroud He-mass flow rate	100 mg/s
Reflector heater power	40 mW

Table 5-9:   Input parameters

Submodel	Node #	Node Label	T (K)	T_{max} (K) Required	Require ment fulfilled
CRYO	12, 22, 32	Heatshield 1	10 – 16	NA	NA
CRYO	13, 23, 33	Heatshield 2	22 – 38	NA	NA
CRYO	14, 15, 24, 25, 34, 35	Heatshield 3	98 – 143	NA	NA
CRYO	4001 - 4078	CVV	293	NA	NA
CRYO	4090	LOU window	290	NA	NA
CRYO:PLM	371 - 381	Optical Bench	11 –12	15	yes

Submodel	Node #	Node Label	T (K)	T_{max} (K) Required	Require ment fulfilled
CRYO:PLM	811	SPIRE SM Detector enclosure	1.78	1.8	yes
CRYO:PLM	819	SPIRE Cooler Pump HS	1.77	1.8	yes
CRYO:PLM	820	SPIRE Cooler Evaporator HS	1.73	1.8	yes
CRYO:PLM	765	PACS Blue Detector	1.72	3.5	yes
CRYO:PLM	760	PACS Red Detector	1.70	1.75	yes
CRYO:PLM	781	PACS He-Pump	1.78	2.20	yes
CRYO:PLM	912	HIFI l0-Boundary	1.85	2.00	yes
CRYO:PLM	803	SPIRE Optical Bench	5.2	4.5	**No 1)**
CRYO:PLM	730	PACS Photometer Optics	3.2	5	yes
CRYO:PLM	725	PACS Collimator	3.2	5	yes
CRYO:PLM	720	PACS Spectrom. Housing	3.2	5	yes
CRYO:PLM	913	HIFI L1-interface	6.0	6	yes
CRYO:PLM	801	SPIRE PM JFET enclosure	11	13	yes
CRYO:PLM	802	SPIRE SM JFET enclosure	11	13	yes
CRYO:PLM	910	HIFI FPU Structure	11	13	yes
CTCE	901 -930	CTCE vessel	292	NA	NA
CTCE	1221 - 1230	CTA-shroud	4.6 – 5.3	5	yes
CTCE	1121 – 1130	CTA- heatshield	68 – 88	NA	NA
CTCE	1240	CTA-Reflector	82	40 -80	yes
CTCE	1250, 1260, 1270	Reflector interface brackets (or optical bench)	20 – 25	NA	NA

	Mass-flow rate (mg/s)	*required mass-flow rate (mg/s)*	*Requirement fulfilled*
Out of main tank	98	NA**)	NA
Out of EQM-auxiliary tank	2.0	2.1	yes
Out of external He-dewar for CTA-shroud cooling	100	NA **)	NA

1) requirement not yet approved by ASED

**) to be verified whether pressure drop is not too high

Table 5-11:   Brief results summary

```
EUROPEAN  SPACE  AGENCY  THERMAL  ANALYSIS  NETWORK (VERSION 8.5.0)
PAGE    1  20 FEBRUARY 2002 13:23:37
```

EQM4

```
##########################################
#
#  Main Tank heater power:      2000 mW
#  Aux. Tank heater power:        14 mW
#  CTCE-shroud mass flow rate:   100 mg/s
#  Reflector HTR power:           40 mW
#
##########################################
```

+EQM4:CRYO

NODE	LABEL			T	QI	QR	C
1	MAIN TANK			4.200	0.00000	2.00000	0.000
2	AUX TANK			1.700	0.00000	0.01400	0.000
5	Ti-head	lo	5	11.290	0.00000	0.00000	71.108
6	belt fitting	lo	6	10.681	0.00000	0.00000	63.278
7	strut tank end	lo	7	4.359	0.00000	0.00000	21.852
8	Ti-head	up	8	11.402	0.00000	0.00000	72.057
9	belt fitting	up	9	10.793	0.00000	0.00000	64.202
10	strut tank end	up	10	4.364	0.00000	0.00000	21.877
12	HS 1 BULK 12			10.597	0.00000	0.00000	14.052
13	HS 2 BULK 13			22.980	0.00000	0.00000	140.121
14	HS 3 BULK +Z 14			119.571	0.00000	0.00000	2768.274
15	HS 3 BULK -Z 15			119.538	0.00000	0.00000	2767.632
22	HS 1 CYL 22			10.522	0.00000	0.00000	44.736
23	HS 2 CYL 23			21.966	0.00000	0.00000	330.577
24	HS 3 CYL +Z 24			97.622	0.00000	0.00000	6860.336
25	HS 3 CYL -Z 25			97.520	0.00000	0.00000	6851.034
32	HS 1 CONE 32			15.544	0.00000	0.00000	91.924
33	HS 2 CONE 33			38.005	0.00000	0.00000	1510.711
34	HS 3 CONE +Z 34			142.339	0.00000	0.00000	7728.782
35	HS 3 CONE -Z 35			142.545	0.00000	0.00000	7728.782
42	HS 1 HIFI Baf. int.			25.657	0.00000	0.00000	2.933
52	HS 1 HIFI Baf. ext.			32.989	0.00000	0.00000	2.678
53	HS 2 HIFI Baf.			57.601	0.00000	0.00000	10.631
54	HS 3 HIFI Baf.			175.281	0.00000	0.00000	45.570
62	HS 1 Tele BAF			15.572	0.00000	0.00000	0.347
63	HS 2 Tele BAF			38.192	0.00000	0.00000	5.546
64	HS 3 Tele BAF			142.244	0.00000	0.00000	81.108
101	MLI MAIN TANK LO 101			5.168	0.00000	0.00000	15.688
105	MLI MAIN TANK CY 105			4.735	0.00000	0.00000	43.338
106	MLI MAIN TANK UP 106			37.070	0.00000	0.00000	112.535
112	MLI HS 1 BULK 112			20.325	0.00000	0.00000	39.951
113	MLI HS 2 BULK 113			115.125	0.00000	0.00000	382.024
114	MLI HS 3 BULK +Z 114			287.452	0.00000	0.00000	706.439
115	MLI HS 3 BULK -Z 115			287.428	0.00000	0.00000	706.381
122	MLI HS 1 CYL 122			19.258	0.00000	0.00000	123.022
123	MLI HS 2 CYL 123			93.752	0.00000	0.00000	969.392
124	MLI HS 3 CYL +Z 124			286.653	0.00000	0.00000	2100.823
125	MLI HS 3 CYL -Z 125			285.595	0.00000	0.00000	2093.071
132	MLI HS 1 CONE 132			51.503	0.00000	0.00000	249.833
133	MLI HS 2 CONE 133			137.825	0.00000	0.00000	1125.837
134	MLI HS 3 CONE +Z 134			287.294	0.00000	0.00000	1702.066
135	MLI HS 3 CONE -Z 135			287.274	0.00000	0.00000	1701.947
440	filling tube 440			271.528	0.00000	0.00000	0.000

```
 441    filling tube    441     252.225  0.00000  0.00000     0.000
 442    filling tube    442     245.520  0.00000  0.00000     0.000
 443    filling tube    443     242.460  0.00000  0.00000     0.000
 447    empty tube      447      15.532  0.00000  0.00000     0.000
 452    empty tube      452      10.866  0.00000  0.00000     0.000
 502    line baf to HS1 502       4.201  0.00000  0.00000     0.000
 642    MLI filling tube 642    120.439  0.00000  0.00000     0.766
 643    MLI filling tube 643    119.021  0.00000  0.00000     0.743
 647    MLI filling tube 647     25.817  0.00000  0.00000     1.245
 652    MLI filling tube 652     23.551  0.00000  0.00000     0.459
1000    HS 1 SUSP BOLT  1000     19.629  0.00000  0.00000     0.000
2000    HS 2 SUSP BOLT  2000     67.891  0.00000  0.00000     0.000
3000    HS 3 SUSP BOLT  3000    189.811  0.00000  0.00000     0.000
4001    CVV lower bulk  4001    292.764  0.00000  0.00000  4399.464
4002    CVV lower bulk  4002    292.771  0.00000  0.00000  4399.491
4003    CVV lower bulk  4003    292.771  0.00000  0.00000  4399.491
4004    CVV lower bulk  4004    292.764  0.00000  0.00000  4399.462
4005    CVV lower bulk  4005    292.750  0.00000  0.00000  4399.407
4006    CVV lower bulk  4006    292.749  0.00000  0.00000  4399.404
4007    CVV lower bulk  4007    292.759  0.00000  0.00000  4399.442
4008    CVV lower bulk  4008    292.760  0.00000  0.00000  4399.449
4011    CVV lower bulk  4011    292.707  0.00000  0.00000  1668.975
4012    CVV lower bulk  4012    292.740  0.00000  0.00000  1669.026
4013    CVV lower bulk  4013    292.741  0.00000  0.00000  1669.028
4014    CVV lower bulk  4014    292.717  0.00000  0.00000  1668.991
4015    CVV lower bulk  4015    292.654  0.00000  0.00000  1668.893
4016    CVV lower bulk  4016    292.654  0.00000  0.00000  1668.894
4017    CVV lower bulk  4017    292.705  0.00000  0.00000  1668.971
4018    CVV lower bulk  4018    292.700  0.00000  0.00000  1668.964
4031    CVV cyl lower   4031    292.553  0.00000  0.00000 13706.679
4032    CVV cyl lower   4032    292.661  0.00000  0.00000 13708.039
4033    CVV cyl lower   4033    292.663  0.00000  0.00000 13708.074
4034    CVV cyl lower   4034    292.599  0.00000  0.00000 13707.263
4035    CVV cyl lower   4035    292.392  0.00000  0.00000 13704.652
4036    CVV cyl lower   4036    292.397  0.00000  0.00000 13704.711
4037    CVV cyl lower   4037    292.569  0.00000  0.00000 13706.877
4038    CVV cyl lower   4038    292.537  0.00000  0.00000 13706.479
4041    CVV cyl upper   4041    292.694  0.00000  0.00000 19514.609
4042    CVV cyl upper   4042    292.699  0.00000  0.00000 19514.697
4043    CVV cyl upper   4043    292.633  0.00000  0.00000 19513.515
4044    CVV cyl upper   4044    292.216  0.00000  0.00000 19506.022
4045    CVV cyl upper   4045    289.662  0.00000  0.00000 19460.121
4046    CVV cyl upper   4046    289.657  0.00000  0.00000 19460.026
4047    CVV cyl upper   4047    292.187  0.00000  0.00000 19505.492
4048    CVV cyl upper   4048    292.604  0.00000  0.00000 19512.980
4051    CVV upper bulk  4051    292.714  0.00000  0.00000 19050.968
4052    CVV upper bulk  4052    292.627  0.00000  0.00000 19049.443
4053    CVV upper bulk  4053    292.618  0.00000  0.00000 19049.278
4054    CVV upper bulk  4054    292.670  0.00000  0.00000 19050.188
4055    CVV upper bulk  4055    292.589  0.00000  0.00000 19048.779
4056    CVV upper bulk  4056    292.545  0.00000  0.00000 19048.002
4057    CVV upper bulk  4057    292.681  0.00000  0.00000 19050.386
4058    CVV upper bulk  4058    292.719  0.00000  0.00000 19051.064
4061    CVV/CTA flange  4061    292.330  0.00000  0.00000     0.000
4062    CVV/CTA flange  4062    292.307  0.00000  0.00000     0.000
4063    CVV/CTA flange  4063    292.286  0.00000  0.00000     0.000
4064    CVV/CTA flange  4064    292.263  0.00000  0.00000     0.000
4065    CVV/CTA flange  4065    292.240  0.00000  0.00000     0.000
4066    CVV/CTA flange  4066    292.244  0.00000  0.00000     0.000
4067    CVV/CTA flange  4067    292.299  0.00000  0.00000     0.000
4068    CVV/CTA flange  4068    292.326  0.00000  0.00000     0.000
4071    CVV flange disc 4071    292.174  0.00000  0.00000     0.000
4072    CVV flange disc 4072    292.162  0.00000  0.00000     0.000
```

```
4073      CVV flange disc  4073    292.144   0.00000   0.00000      0.000
4074      CVV flange disc  4074    292.127   0.00000   0.00000      0.000
4075      CVV flange disc  4075    292.114   0.00000   0.00000      0.000
4076      CVV flange disc  4076    292.121   0.00000   0.00000      0.000
4077      CVV flange disc  4077    292.150   0.00000   0.00000      0.000
4078      CVV flange disc  4078    292.171   0.00000   0.00000      0.000
4090      CVV Lo window            289.929   0.00000   0.00000     15.604
4631      SUSP TI   lo   4631      282.781   0.00000   0.00000     84.266
4632      SUSP TI   lo   4632      282.880   0.00000   0.00000     84.277
4633      SUSP TI   lo   4633      282.883   0.00000   0.00000     84.277
4634      SUSP TI   lo   4634      282.823   0.00000   0.00000     84.271
4635      SUSP TI   lo   4635      282.633   0.00000   0.00000     84.250
4636      SUSP TI   lo   4636      282.637   0.00000   0.00000     84.251
4637      SUSP TI   lo   4637      282.795   0.00000   0.00000     84.268
4638      SUSP TI   lo   4638      282.766   0.00000   0.00000     84.265
4641      SUSP TI   up   4641      282.911   0.00000   0.00000     84.280
4642      SUSP TI   up   4642      282.915   0.00000   0.00000     84.281
4643      SUSP TI   up   4643      282.855   0.00000   0.00000     84.274
4644      SUSP TI   up   4644      282.471   0.00000   0.00000     84.233
4645      SUSP TI   up   4645      280.122   0.00000   0.00000     83.983
4646      SUSP TI   up   4646      280.117   0.00000   0.00000     83.982
4647      SUSP TI   up   4647      282.444   0.00000   0.00000     84.230
4648      SUSP TI   up   4648      282.828   0.00000   0.00000     84.271
4731      CABLE PLUG    4731       281.499   0.00073   0.00000     93.529
4732      CABLE PLUG    4732       291.588   0.00000   0.00000     97.058
4733      CABLE PLUG    4733       291.591   0.00000   0.00000     97.059
4734      CABLE PLUG    4734       291.527   0.00000   0.00000     97.036
4735      CABLE PLUG    4735       291.321   0.00000   0.00000     96.964
4736      CABLE PLUG    4736       292.397   0.00000   0.00000     97.341
4737      CABLE PLUG    4737       292.569   0.00000   0.00000     97.401
4738      CABLE PLUG    4738       283.622   0.00010   0.00000     94.272
6051      X2 SI Harness 51         245.203   0.00073   0.00000      0.000
6052      X2 SI Harness 52         205.934   0.00073   0.00000      0.000
6053      X2 SI Harness 53         162.825   0.00073   0.00000      0.000
6054      X2 SI Harness 54         113.892   0.00073   0.00000      0.000
6055      X2 SI at HS1  55          50.556   0.00250   0.00000      0.000
6056      X3 SI Harness 56          45.811   0.00250   0.00000      0.000
6057      X3 SI Harness 57          39.330   0.00250   0.00000      0.000
6058      X3 SI Harness 58          29.983   0.00250   0.00000      0.000
6061      X2 JF Harness 61         246.339   0.00010   0.00000      0.000
6062      X2 JF Harness 62         205.932   0.00010   0.00000      0.000
6063      X2 JF Harness 63         161.456   0.00010   0.00000      0.000
6064      X2 JF Harness 64         110.711   0.00010   0.00000      0.000
6065      X2 JF at HS1  65          42.549   0.00024   0.00000      0.000
6066      X3 JF Harness 66          38.147   0.00024   0.00000      0.000
6067      X3 JF Harness 67          33.067   0.00024   0.00000      0.000
6068      X3 JF Harness 68          26.908   0.00024   0.00000      0.000
9999      AMBIENT                  293.000   0.00000   0.00000      0.000
```

==

+EQM4:CRYO:V

NODE	LABEL		T	QI	QR	C
201	OSS-TUBE	201	4.200	0.00000	0.00000	0.000
202	BAFFLE LO	202	4.200	0.00000	0.00000	0.000
203	BAFFLE UP	203	4.200	0.00000	0.00000	0.000
204	1ST HS	204	10.522	0.00000	0.00000	0.000
205	2ND HS	205	21.966	0.00000	0.00000	0.000
206	3RD HS +z	206	97.622	0.00000	0.00000	0.000
207	3RD HS -z	207	97.520	0.00000	0.00000	0.000
210	VENT VESSEL	210	209.882	0.00000	0.00000	0.000
212	BAFFLE - 1ST HS	212	4.201	0.00000	0.00000	0.000
251	TANK HE-OUT	251	4.200	0.00000	0.00000	0.000
252	OSS HE-OUT	252	4.200	0.00000	0.00000	0.000
253	BAFFLE LO HE-OUT	253	4.200	0.00000	0.00000	0.000
254	BAFFLE UP HE-OUT	254	4.200	0.00000	0.00000	0.000
255	1ST HS HE-OUT	255	10.522	0.00000	0.00000	0.000
256	2ND HS HE-OUT	256	21.947	0.00000	0.00000	0.000
257	3RD HS HE-OUT	257	97.571	0.00000	0.00000	0.000
260	VESSEL HE-OUT	260	209.882	0.00000	0.00000	0.000
262	BAF - HS1 HE-OUT	262	4.200	0.00000	0.00000	0.000
296	HEATER WALL	296	293.000	0.00000	0.00000	0.000
297	HEATER HE-OUT	297	209.882	0.00000	0.00000	0.000

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+EQM4:CRYO:PLM

NODE	LABEL	T	QI	QR	C
310	Instr. Shield Cyl.	11.648	0.00000	0.00000	8.314
311	Instr. Shield Top	11.672	0.00000	0.00000	10.789
315	Instr. Shield Baffle	11.702	0.00000	0.00000	0.699
320	Vline wall Tank-PACS	1.756	0.00000	0.00000	0.007
321	Vline wall PACS I/F 1	2.408	0.00000	0.00000	0.001
322	Vline wall PACS I/F 1	2.660	0.00000	0.00000	0.000
323	Vline wall PACS I/F 1	2.493	0.00000	0.00000	0.001
324	Vline wall PACSI/F1/2	2.320	0.00000	0.00000	0.003
325	Vline wall PACSI/F1/2	2.350	0.00000	0.00000	0.014
326	Vline wall PACS I/F 2	2.728	0.00000	0.00000	0.001
327	Vline wall PACS I/F 2	2.883	0.00000	0.00000	0.000
328	Vline wall PACS I/F 2	2.791	0.00000	0.00000	0.001
329	Vline wall PACSI/F2/3	2.700	0.00000	0.00000	0.006
330	Vline wall PACSI/F2/3	2.766	0.00000	0.00000	0.002
331	Vline wall PACS I/F 3	2.901	0.00000	0.00000	0.001
332	Vline wall PACS I/F 3	3.008	0.00000	0.00000	0.000
333	Vline wall PACS I/F 3	2.960	0.00000	0.00000	0.001
334	Vline wall PACS-SPIRE	2.918	0.00000	0.00000	0.006
335	Vline wall PACS-SPIRE	2.941	0.00000	0.00000	0.008
336	Vline wall PACS-SPIRE	3.106	0.00000	0.00000	0.008
337	Vline wall SPIRE	4.082	0.00000	0.00000	0.001
338	Vline wall SPIRE	4.650	0.00000	0.00000	0.001
339	Vline wall SPIRE	4.388	0.00000	0.00000	0.001
340	Vline wall SPIRE-HIFI	4.175	0.00000	0.00000	0.012
341	Vline wall SPIRE-HIFI	4.189	0.00000	0.00000	0.015
342	Vline wall SPIRE-HIFI	4.296	0.00000	0.00000	0.018
343	Vline wall HIFI	5.243	0.00000	0.00000	0.002
344	Vline wall HIFI	5.802	0.00000	0.00000	0.001
345	Vline wall HIFI	6.113	0.00000	0.00000	0.003
346	Vline Lev.2 OB	10.183	0.00000	0.00000	0.072
347	Vline Lev.2 OB	11.243	0.00000	0.00000	0.208
348	Vline Lev.2 OB	11.358	0.00000	0.00000	0.083
349	Vline Lev.2 OB	11.427	0.00000	0.00000	0.133
350	Vline Lev.2 OB	11.454	0.00000	0.00000	0.078
351	Vline Lev.2 OB	11.458	0.00000	0.00000	0.231
352	Vline Lev.2 OB	11.483	0.00000	0.00000	0.118
371	Opt. Bench +Z	11.375	0.00000	0.00000	7.915
372	Opt. Bench +Z -Y	11.306	0.00000	0.00000	7.191
373	Opt. Bench +Z mid	11.386	0.00000	0.00000	18.606
374	Opt. Bench +Z +Y	11.403	0.00000	0.00000	3.014
375	Opt. Bench -Y	11.452	0.00000	0.00000	13.756
376	Opt. Bench centre	11.435	0.00000	0.00000	33.136
377	Opt. Bench +Y	11.441	0.00000	0.00000	7.299
378	Opt. Bench -Z -Y	11.486	0.00000	0.00000	7.515
379	Opt. Bench -Z mid	11.462	0.00000	0.00000	18.952
380	Opt. Bench -Z +Y	11.464	0.00000	0.00000	3.059
381	Opt. Bench -Z	11.459	0.00000	0.00000	8.079
390	I.Shld HIFI Baf. ext.	11.722	0.00000	0.00000	0.326
391	I.Shld HIFI Baf. int.	11.653	0.00000	0.00000	0.114
411	MLI on OB-Shield side	13.932	0.00000	0.00000	31.699
412	MLI on OB-Shield top	13.941	0.00000	0.00000	40.946
710	PACS-Top Optic	3.187	0.00000	0.00000	1.912
720	PACS-Spectrometer	3.185	0.00003	0.00000	2.162
725	PACS-Collimator	3.182	0.00000	0.00000	2.186
730	PACS-Photometer Optic	3.181	0.00000	0.00000	1.320
735	PACS-Internal	3.186	0.00000	0.00000	1.834
740	PACS-Lump	3.186	0.00000	0.00000	0.000
750	PACS-Chopper	3.190	0.00040	0.00000	0.115

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755    PACS-Grating Assy         3.189   0.00100  0.00000    0.787
760    PACS-Red  Detector        1.704   0.00000  0.00000    0.230
761    PACS-Red  Detect. CRE     3.196   0.00030  0.00000    0.029
765    PACS-Blue Detector        1.724   0.00013  0.00000    0.233
766    PACS-Blue Detect. CRE     3.196   0.00030  0.00000    0.029
770    PACS-Filter Wh. Blue      3.185   0.00004  0.00000    0.134
771    PACS-Filter Wh. Photo     3.181   0.00004  0.00000    0.134
775    PACS-Calib. Source 1      3.188   0.00032  0.00000    0.019
776    PACS-Calib. Source 2      3.191   0.00032  0.00000    0.019
780    PACS-Photometer Housi     3.183   0.00000  0.00000    1.013
781    PACS-Photometer CooPu     1.781   0.00220  0.00000    0.147
791    PACS-STST-Strut 1,1       9.261   0.00000  0.00000    0.329
792    PACS-STST-Strut 4,1       9.257   0.00000  0.00000    0.512
793    PACS-STST-Strut 5,1       9.261   0.00000  0.00000    0.256
794    PACS-Kevlar-Strut Red  1  2.634   0.00000  0.00000    0.014
795    PACS-Kevlar-Strut Blue 1  2.638   0.00000  0.00000    0.014
796    PACS-HarnessRed Det.Int1  2.567   0.00000  0.00000    0.000
797    PACS-HarnessBlueDet.Int1  2.573   0.00000  0.00000    0.000
798    PACS-HarnessBlue1.7->4,1  2.558   0.00000  0.00000    0.000
801    SPIRE PM JFET ENCL       11.492   0.01026  0.00000   11.467
802    SPIRE SM JFET ENCL       11.467   0.00282  0.00000    3.720
803    SPIRE Optical Bench       5.278   0.00000  0.00000   10.670
804    SPIRE RF Filter Box       5.283   0.00428  0.00000    0.522
805    SPIRE Beam St. Mech       5.279   0.00100  0.00000    0.391
806    SPIRE SMECm               5.279   0.00048  0.00000    0.462
807    SPIRE PM calibrator       5.279   0.00002  0.00000    0.000
808    SPIRE SM calibrator       9.545   0.00040  0.00000    0.000
809    SPIRE Shutter             5.278   0.00000  0.00000    0.000
810    SPIRE PM Detector en      1.802   0.00000  0.00000    0.453
811    SPIRE SM Detector en      1.778   0.00000  0.00000    0.270
812    SPIRE PM Detectors        1.743   0.00000  0.00000    0.398
813    SPIRE SM detector         1.743   0.00000  0.00000    0.252
816    SPIRE Cooler Pump         1.888   0.00183  0.00000    0.000
817    SPIRE Cooler shunt        1.726   0.00000  0.00000    0.000
818    SPIRE Cooler evap         1.743   0.00000  0.00000    0.000
819    SPIRE Cooler pump HS      1.774   0.00008  0.00000    0.000
820    SPIRE Cooler evap HS      1.726   0.00000  0.00000    0.000
900    HIFI 2K level             1.861   0.00014  0.00000    0.030
905    HIFI Harness 1 int.point  6.063   0.00036  0.00000    0.000
910    HIFI FPU Structure       11.465   0.01602  0.00000  108.103
912    HIFI L0 boundary node     1.854   0.00000  0.00000    0.000
913    HIFI L1 boundary node     6.059   0.00000  0.00000    0.000
914    HIFI Harness 2a int.poin 12.721   0.00036  0.00000    0.000
915    HIFI Harness 2b int.poin  9.163   0.00000  0.00000    0.000
920    HIFI Internal Assy.       6.064   0.00000  0.00000    0.025
5000   GHe tank outlet           1.700   0.00000  0.00000    0.000
5010   GHe PACS I/F 1 in         1.753   0.00000  0.00000    0.000
5011   GHe PACS I/F 1            1.971   0.00000  0.00000    0.000
5012   GHe PACS I/F 1            2.111   0.00000  0.00000    0.000
5013   GHe PACS I/F 1 out        2.246   0.00000  0.00000    0.000
5014   GHe PACS I/F 1/2          2.301   0.00000  0.00000    0.000
5020   GHe PACS I/F 2 in         2.348   0.00000  0.00000    0.000
5021   GHe PACS I/F 2            2.490   0.00000  0.00000    0.000
5022   GHe PACS I/F 2            2.578   0.00000  0.00000    0.000
5023   GHe PACS I/F 2 out        2.661   0.00000  0.00000    0.000
5024   GHe PACS I/F 2/3          2.697   0.00000  0.00000    0.000
5030   GHe PACS I/F 3 in         2.744   0.00000  0.00000    0.000
5031   GHe PACS I/F 3            2.806   0.00000  0.00000    0.000
5032   GHe PACS I/F 3            2.854   0.00000  0.00000    0.000
5033   GHe PACS I/F 3 out        2.897   0.00000  0.00000    0.000
5034   GHe PACS-SPIRE            2.916   0.00000  0.00000    0.000
5035   GHe PACS-SPIRE            2.939   0.00000  0.00000    0.000
5040   GHe SPIRE I/F in          3.098   0.00000  0.00000    0.000
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5041      GHe SPIRE I/F          3.559   0.00000   0.00000   0.000
5042      GHe SPIRE I/F          3.876   0.00000   0.00000   0.000
5043      GHe SPIRE I/F out      4.129   0.00000   0.00000   0.000
5044      GHe SPIRE-HIFI         4.173   0.00000   0.00000   0.000
5045      GHe SPIRE-HIFI         4.188   0.00000   0.00000   0.000
5050      GHe HIFI I/F in        4.291   0.00000   0.00000   0.000
5051      GHe HIFI I/F           4.796   0.00000   0.00000   0.000
5052      GHe HIFI I/F           5.128   0.00000   0.00000   0.000
5053      GHe HIFI I/F out       5.694   0.00000   0.00000   0.000
5054      GHe Lev.2 OB           9.960   0.00000   0.00000   0.000
5055      GHe Lev.2 OB          11.179   0.00000   0.00000   0.000
5056      GHe Lev.2 OB          11.350   0.00000   0.00000   0.000
5057      GHe Lev.2 OB          11.423   0.00000   0.00000   0.000
5058      GHe Lev.2 OB          11.452   0.00000   0.00000   0.000
5059      GHe Lev.2 OB          11.458   0.00000   0.00000   0.000
5060      GHe Lev.2 OB          11.481   0.00000   0.00000   0.000
6059      X3 SI Harness 59      12.317   0.00406   0.00000   0.000
6069      X3 JF Harness 69      18.684   0.00040   0.00000   0.000
9999      Ambient Air          293.000   0.00000   0.00000   0.000
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+EQM4:CTCE

NODE	LABEL	T	QI	QR	C
901	vessel flange 901	292.340	0.00000	0.00000	905.667
902	vessel flange 902	292.321	0.00000	0.00000	905.651
903	vessel flange 903	292.297	0.00000	0.00000	905.632
904	vessel flange 904	292.260	0.00000	0.00000	905.601
905	vessel flange 905	292.239	0.00000	0.00000	905.583
906	vessel flange 906	292.248	0.00000	0.00000	905.591
907	vessel flange 907	292.306	0.00000	0.00000	905.639
908	vessel flange 908	292.335	0.00000	0.00000	905.663
921	cyl. vessel 921	292.402	0.00000	0.00000	8551.714
922	cyl. vessel 922	292.384	0.00000	0.00000	8551.566
923	cyl. vessel 923	292.335	0.00000	0.00000	8551.181
924	cyl. vessel 924	292.140	0.00000	0.00000	8549.651
925	cyl. vessel 925	292.106	0.00000	0.00000	8549.380
926	cyl. vessel 926	292.141	0.00000	0.00000	8549.657
927	cyl. vessel 927	292.336	0.00000	0.00000	8551.192
928	cyl. vessel 928	292.385	0.00000	0.00000	8551.579
930	vessel dome 930	292.404	0.00000	0.00000	19146.645
1011	Shroud bottom MLI	31.179	0.00000	0.00000	0.000
1012	Shroud bottom MLI	31.147	0.00000	0.00000	0.000
1013	Shroud bottom MLI	34.670	0.00000	0.00000	0.000
1014	Shroud bottom MLI	38.985	0.00000	0.00000	0.000
1015	Shroud bottom MLI	42.721	0.00000	0.00000	0.000
1016	Shroud bottom MLI	45.343	0.00000	0.00000	0.000
1017	Shroud bottom MLI	45.798	0.00000	0.00000	0.000
1018	Shroud bottom MLI	42.518	0.00000	0.00000	0.000
1021	Shroud cyl. MLI	31.179	0.00000	0.00000	0.000
1022	Shroud cyl. MLI	31.147	0.00000	0.00000	0.000
1023	Shroud cyl. MLI	34.670	0.00000	0.00000	0.000
1024	Shroud cyl. MLI	38.985	0.00000	0.00000	0.000
1025	Shroud cyl. MLI	42.721	0.00000	0.00000	0.000
1026	Shroud cyl. MLI	45.343	0.00000	0.00000	0.000
1027	Shroud cyl. MLI	45.798	0.00000	0.00000	0.000
1028	Shroud cyl. MLI	42.518	0.00000	0.00000	0.000
1030	Shroud top MLI	49.297	0.00000	0.00000	0.000
1121	CTA cyl. HS 1121	49.845	0.00000	0.00000	227.268
1122	CTA cyl. HS 1122	49.823	0.00000	0.00000	227.026
1123	CTA cyl. HS 1122	52.896	0.00000	0.00000	260.153
1124	CTA cyl. HS 1122	56.627	0.00000	0.00000	300.365
1125	CTA cyl. HS 1122	59.839	0.00000	0.00000	334.982
1126	CTA cyl. HS 1122	62.110	0.00000	0.00000	360.456
1127	CTA cyl. HS 1122	62.495	0.00000	0.00000	364.788
1128	CTA cyl. HS 1122	59.660	0.00000	0.00000	333.057
1130	CTA top HS 1130	65.262	0.00000	0.00000	588.274
1201	CTA Shroud lo Baf	6.256	0.00000	0.00000	0.181
1211	CTA Shroud up Baf	4.943	0.00000	0.00000	0.102
1221	CTA cy.Shroud 1221	4.560	0.00000	0.00000	0.000
1222	CTA cy.Shroud 1222	4.530	0.00000	0.00000	0.000
1223	CTA cy.Shroud 1223	4.602	0.00000	0.00000	0.000
1224	CTA cy.Shroud 1224	4.619	0.00000	0.00000	0.000
1225	CTA cy.Shroud 1225	4.709	0.00000	0.00000	0.000
1226	CTA cy.Shroud 1226	4.714	0.00000	0.00000	0.000
1227	CTA cy.Shroud 1227	4.786	0.00000	0.00000	0.000
1228	CTA cy.Shroud 1228	4.726	0.00000	0.00000	0.000
1230	CTA topShroud 1230	5.329	0.00000	0.00000	0.776
1240	CTA Reflector	82.140	0.00000	0.04000	1074.921
1250	Refl. I/F bracket 1	19.734	0.00000	0.00000	0.000
1252	Refl. I/F br.1 pos.2	168.862	0.00000	0.00000	0.000
1253	Refl. I/F br.1 pos.3	170.222	0.00000	0.00000	0.000

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1254      Refl. I/F br.1 pos.4      137.893   0.00000   0.00000   0.000
1255      Refl. I/F br.1 pos.5      140.100   0.00000   0.00000   0.000
1256      Refl. I/F br.1 pos.6      222.624   0.00000   0.00000   0.000
1257      Refl. I/F br.1 pos.7      224.346   0.00000   0.00000   0.000
1260      Refl. I/F bracket 2        22.178   0.00000   0.00000   0.000
1262      Refl. I/F br.2 pos.2      169.594   0.00000   0.00000   0.000
1263      Refl. I/F br.2 pos.3      170.951   0.00000   0.00000   0.000
1264      Refl. I/F br.2 pos.4      138.451   0.00000   0.00000   0.000
1265      Refl. I/F br.2 pos.5      140.647   0.00000   0.00000   0.000
1266      Refl. I/F br.2 pos.6      222.823   0.00000   0.00000   0.000
1267      Refl. I/F br.2 pos.7      224.539   0.00000   0.00000   0.000
1270      Refl. I/F bracket 3        24.692   0.00000   0.00000   0.000
1272      Refl. I/F br.3 pos.2      169.856   0.00000   0.00000   0.000
1273      Refl. I/F br.3 pos.3      171.204   0.00000   0.00000   0.000
1274      Refl. I/F br.3 pos.4      139.198   0.00000   0.00000   0.000
1275      Refl. I/F br.3 pos.5      141.382   0.00000   0.00000   0.000
1276      Refl. I/F br.3 pos.6      223.138   0.00000   0.00000   0.000
1277      Refl. I/F br.3 pos.7      224.846   0.00000   0.00000   0.000
1311      CTA HS bottom MLI         268.518   0.00000   0.00000   0.000
1312      CTA HS bottom MLI         268.504   0.00000   0.00000   0.000
1313      CTA HS bottom MLI         268.500   0.00000   0.00000   0.000
1314      CTA HS bottom MLI         268.494   0.00000   0.00000   0.000
1315      CTA HS bottom MLI         268.497   0.00000   0.00000   0.000
1316      CTA HS bottom MLI         268.518   0.00000   0.00000   0.000
1317      CTA HS bottom MLI         268.560   0.00000   0.00000   0.000
1318      CTA HS bottom MLI         268.565   0.00000   0.00000   0.000
1321      CTA HS cyl. MLI           268.789   0.00000   0.00000   0.000
1322      CTA HS cyl. MLI           268.772   0.00000   0.00000   0.000
1323      CTA HS cyl. MLI           268.741   0.00000   0.00000   0.000
1324      CTA HS cyl. MLI           268.581   0.00000   0.00000   0.000
1325      CTA HS cyl. MLI           268.567   0.00000   0.00000   0.000
1326      CTA HS cyl. MLI           268.613   0.00000   0.00000   0.000
1327      CTA HS cyl. MLI           268.795   0.00000   0.00000   0.000
1328      CTA HS cyl. MLI           268.824   0.00000   0.00000   0.000
1330      CTA HS top MLI            272.875   0.00000   0.00000   0.000
2000      CTA-Shroud Dewar            4.200   0.00000   0.00000   0.000
2001      GHe Shroud 1221 out         4.261   0.00000   0.00000   0.000
2002      GHe Shroud 1222 out         4.307   0.00000   0.00000   0.000
2003      GHe Shroud 1223 out         4.357   0.00000   0.00000   0.000
2004      GHe Shroud 1224 out         4.402   0.00000   0.00000   0.000
2005      GHe Shroud 1225 out         4.455   0.00000   0.00000   0.000
2006      GHe Shroud 1226 out         4.500   0.00000   0.00000   0.000
2007      GHe Shroud 1227 out         4.550   0.00000   0.00000   0.000
2008      GHe Shroud 1228 out         4.581   0.00000   0.00000   0.000
2011      GHe HS 1121 out            29.775   0.00000   0.00000   0.000
2012      GHe HS 1122 out            38.960   0.00000   0.00000   0.000
2013      GHe HS 1123 out            45.681   0.00000   0.00000   0.000
2014      GHe HS 1124 out            51.146   0.00000   0.00000   0.000
2015      GHe HS 1125 out            55.582   0.00000   0.00000   0.000
2016      GHe HS 1126 out            58.966   0.00000   0.00000   0.000
2017      GHe HS 1127 out            60.809   0.00000   0.00000   0.000
2018      GHe HS 1128 out            60.212   0.00000   0.00000   0.000
2021      GHe I/F bracket 1250 out    7.945   0.00000   0.00000   0.000
2022      GHe I/F bracket 1260 out   11.303   0.00000   0.00000   0.000
2023      GHe I/F bracket 1270 out   14.644   0.00000   0.00000   0.000
9999      AMBIENT                   293.000   0.00000   0.00000   0.000
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Heat Balance for PAYLOAD incl. Instrument Shield MLI
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                            Level 0: from Aux. Tank into instruments      -16.236 [mW]
                            Level 2: from spatial framework into OB         -0.397 [mW]
              Level 1/2: from Aux. Tank into OB via ventline wall           -0.065 [mW]
                    Level 2: from HS1 into OB via ventline wall              0.154 [mW]
                               Level 2: via harness into OB                 27.116 [mW]
         via radiation from HS1 upper bulkhead onto Instrument MLI           0.229 [mW]
             via radiation from Cryostat cavity onto OB lower side           5.129 [mW]
                    via radiation from HS1-baffle into payload               0.007 [mW]
                    via radiation from HS2-baffle into payload               0.023 [mW]
                    via radiation from HS3-baffle into payload               1.511 [mW]
                via radiation from CTCE-4K-shrouds into payload             -0.015 [mW]
        via radiation from CTCE lower-shroud baffle into payload            -0.002 [mW]
        via radiation from CTCE upper-shroud baffle into payload            -0.002 [mW]
                    via radiation from CTCE reflector into payload           2.651 [mW]
                 via radiation from CVV-LOU-Window onto HIFI-Baffle         19.952 [mW]
                    via radiation from CVV-LOU-Window onto HIFI-FPU         14.512 [mW]
                         Vent line cooling power (out of payload)          103.667 [mW]
             Transferred by convection from PL-ventline on helium          103.722 [mW]
                                          total dissipation of PACS           5.070 [mW]
                                         total dissipation of SPIRE         21.167 [mW]
                                          total dissipation of HIFI         16.867 [mW]
                                          Harness dissipation on OB           4.462 [mW]
                             Payload Heat Imbalance (shall be 0)            -1.533 [mW]

Heat Balance for Main Tank Ventline
======================================
              conducted and radiated into ventline attached to HS1       3204.711 [mW]
              conducted and radiated into ventline attached to HS2       5791.142 [mW]
           conducted and radiated into ventline attached to HS3 +Z      19180.000 [mW]
           conducted and radiated into ventline attached to HS3 -Z      19154.160 [mW]
                        conducted into ventline walls from CVV          56931.238 [mW]
                    conducted and radiated into line baf to HS 1             0.152 [mW]
              Main Tank Ventline cooling power (out of ventline)        104261.505 [mW]
                            Via convection into ventline walls          -104271.432 [mW]
                      Main Tank Ventline Imbalance (shall be 0)             -0.101 [mW]

Heat Balance for CTCE
======================
              Convective heat transfer onto CTCE-external insulation     27236.032 [mW]
                        Conducted from CVV into CTCE-structure            -276.497 [mW]
              Radiated from Payload into CTCE-shrouds incl. baffles          0.019 [mW]
                        Radiated from HS-baffles onto CTCE-shroud          48.883 [mW]
           Radiated from CVV flange disc within cavity onto CTCE-MLI     2061.649 [mW]
                          Radiated from Payload onto reflector           -2.651 [mW]
                 Conducted from CTCE-structure into CTCE-shrouds          40.000 [mW]
                              Cooling power of CTCE-shrouds            29107.424 [mW]
                               CTCE Imbalance (shall be 0)                 0.011 [mW]

Heat Balance for Reflector within CTCE
=======================================
                    via struts from CTCE-I/F brackets into reflector       -11.020 [mW]
                    by radiation from CTCE-shrouds into reflector         -26.316 [mW]
                        by radiation from Payload into reflector           -2.651 [mW]
                                        reflector heater power             40.000 [mW]
                          reflector total imbalance (shall be 0)            0.012 [mW]

Heat Balance for whole Cryostat including Payload,Ventlines and CTCE
=====================================================================
                      Convective heat transfer onto external walls     133270.748 [mW]
                      total heat transferred on gaseous helium         133472.596 [mW]
                      evaporation power in main and aux. tank            2087.135 [mW]
                             Total istrument power dissipation            43.104 [mW]
           total main & auxiliary tank and reflector heater power        2054.000 [mW]
                           heater power of CVV lower bulkhead HTR           0.000 [mW]
                      total harness dissipation within system            19.601 [mW]
                             Cooling power of CTCE-shrouds             29107.424 [mW]
                      Cryostat total imbalance (shall be 0)             -172.278 [mW]
```

```
Heat Balance for Main Tank
==========================
                           Main tank dissipation + heater power      2000.000 [mW]
                            heat from Aux. tank via mech. I/F           -0.451 [mW]
                                        radiated from aux. tank          0.000 [mW]
                             conducted from spatial framework           30.989 [mW]
                                      transferred through MLI            9.751 [mW]
                                       conducted from rest               0.290 [mW]
                      radiated from spatial framework and HSs            0.077 [mW]
                      conducted from main tank ventline wall             0.000 [mW]
                                     radiated from payload               0.000 [mW]
                                    total heat into main tank         2040.655 [mW]

Heat Balance for Auxiliary Tank
===============================
                           Aux. tank dissipation + heater power         14.000 [mW]
                            heat from Main tank via mech. I/F             0.451 [mW]
                                       radiated from Main tank            0.000 [mW]
                      radiated from spatial framework and HSs            0.015 [mW]
                               conducted from payload L0                16.236 [mW]
                               conducted from payload L2                 0.065 [mW]
                                     radiated from payload               0.013 [mW]
                               conducted from filling tube               0.007 [mW]
                             radiated from MLI filling tube             15.692 [mW]
                                     total heat into Aux. tank          46.480 [mW]

Heat flows into Tanks
=====================

                                            Into Main Tank           2040.655 [mW]
                                            Into Aux. Tank             46.480 [mW]

Helium evaporation mass flow rates
==================================

                                          Out of Main Tank             97.546 [mg/s]
                                          Out of Aux. Tank              2.039 [mg/s]
                  Out of external He- dewar for CTA-shroud cooling    100.000 [mg/s]
```

5.4   CTCE-Design-2 Case 2 b

CTCE-design2 means: Radiativey and vapor-cooled heatshield-design concept without any
MLI for CTCE as defined in § 4.5.2.2

Case 2 b means: EQM-aux. Tank heater power = 14 mW

CTCE-shroud He-mass flow rate = 150 mg/s

Reflector heater power = 50 mW

The input parameters are compiled in Table 5-13and a brief temperature results summary is given in
Table 5-15. The complete ESATAN-output-file listing is appended. The respective node numbers and
labels are referenced in the thermal design and thermal-mathematical model descriptions in § 4

Input parameter	
Main Tank temperature	4.2 K
EQM-aux. Tank temperature	1.7 K
External Hel dewar temp. for CTCE-shroud cooling	4.2 K
Main Tank heater power	2000 mW
EQM-auxiliary tank heater power	14 mW
CTCE-shroud He-mass flow rate	150 mg/s
Reflector heater power	50 mW

Table 5-13:   Input parameters

Submodel	Node #	Node Label	T (K)	T_{max} (K) required	Require ment fulfilled
CRYO	12, 22, 32	Heatshield 1	10 – 16	NA	NA
CRYO	13, 23, 33	Heatshield 2	23 – 38	NA	NA
CRYO	14, 15, 24, 25, 34, 35	Heatshield 3	98 – 143	NA	NA
CRYO	4001 - 4078	CVV	293	NA	NA
CRYO	4090	LOU window	290	NA	NA
CRYO:PLM	371 - 381	Optical Bench	11 –12	15	yes

Submodel	Node #	Node Label	T (K)	T_{max} (K) required	Require ment fulfilled
CRYO:PLM	811	SPIRE SM Detector enclosure	1.78	1.8	yes
CRYO:PLM	819	SPIRE Cooler Pump HS	1.78	1.8	yes
CRYO:PLM	820	SPIRE Cooler Evaporator HS	1.73	1.8	yes
CRYO:PLM	765	PACS Blue Detector	1.72	3.5	yes
CRYO:PLM	760	PACS Red Detector	1.70	1.75	yes
CRYO:PLM	781	PACS He-Pump	1.78	2.20	yes
CRYO:PLM	912	HIFI l0-Boundary	1.86	2.00	yes
CRYO:PLM	803	SPIRE Optical Bench	5.3	4.5	**No 1)**
CRYO:PLM	730	PACS Photometer Optics	3.2	5	yes
CRYO:PLM	725	PACS Collimator	3.2	5	yes
CRYO:PLM	720	PACS Spectrom. Housing	3.2	5	yes
CRYO:PLM	913	HIFI L1-interface	6.1	6	**No 2)**
CRYO:PLM	801	SPIRE PM JFET enclosure	12	13	yes
CRYO:PLM	802	SPIRE SM JFET enclosure	12	13	yes
CRYO:PLM	910	HIFI FPU Structure	12	13	yes
CTCE	901 -930	CTCE vessel	292	NA	NA
CTCE	1221 - 1230	CTA-shroud	4.4 – 4.8	5	yes
CTCE	1121 – 1130	CTA- heatshield	47 – 66	NA	NA
CTCE	1240	CTA-Reflector	88	40 -80	**No *)**
CTCE	1250, 1260, 1270	Reflector interface brackets (or optical bench)	18 – 21	NA	NA

	Mass-flow rate (mg/s)	*required mass-flow rate (mg/s)*	*Requirement fulfilled*
Out of main tank	98	NA**)	NA
Out of EQM-auxiliary tank	2.0	2.1	yes
Out of external He-dewar for CTA-shroud cooling	150	NA **)	NA

1)   requirement not yet approved by ASED

2)   can be fulfilled b slightly increasing the mass flow rate to 2.1 mg/s.

*) can easily be controlled at lower temperature by reducing electrical heater power

**) to be verified whether pressure drop is not too high

Table 5-15:   Brief results summary

```
EUROPEAN  SPACE  AGENCY  THERMAL  ANALYSIS  NETWORK
(VERSION 8.5.0)                          PAGE    1
 21 FEBRUARY 2002                                    10:23:41

############################################################################
#  EQM5:  CTA with radiatively and vapor-cooled heatshields without any MLI
#
#  Main Tank heater power:      2000 mW
#  Aux. Tank heater power:        14 mW
#  CTCE-shroud mass flow rate:   150 mg/s
#  Reflector HTR power:           50 mW
#
############################################################################


+EQM5


        NODE                    LABEL       T        QI        QR         C

        9999    AMBIENT                   293.000  0.00000   0.00000     0.000
           1    MAIN TANK                   4.200  0.00000   2.00000     0.000
           2    AUX TANK                    1.700  0.00000   0.01400     0.000
           5    Ti-head       lo    5      11.289  0.00000   0.00000    71.103
           6    belt fitting  lo    6      10.681  0.00000   0.00000    63.273
           7    strut tank end lo   7       4.359  0.00000   0.00000    21.852
           8    Ti-head       up    8      11.466  0.00000   0.00000    72.602
           9    belt fitting  up    9      10.858  0.00000   0.00000    64.733
          10    strut tank end up   10      4.367  0.00000   0.00000    21.892
          12    HS 1 BULK 12               10.595  0.00000   0.00000    14.047
          13    HS 2 BULK 13               22.973  0.00000   0.00000   139.980
          14    HS 3 BULK +Z 14           119.552  0.00000   0.00000  2767.890
          15    HS 3 BULK -Z 15           119.518  0.00000   0.00000  2767.248
          22    HS 1 CYL 22                10.521  0.00000   0.00000    44.722
          23    HS 2 CYL 23                21.960  0.00000   0.00000   330.208
          24    HS 3 CYL +Z 24             97.599  0.00000   0.00000  6858.268
          25    HS 3 CYL -Z 25             97.497  0.00000   0.00000  6848.963
          32    HS 1 CONE 32               15.542  0.00000   0.00000    91.882
          33    HS 2 CONE 33               37.992  0.00000   0.00000  1509.405
          34    HS 3 CONE +Z 34           142.307  0.00000   0.00000  7727.312
          35    HS 3 CONE -Z 35           142.513  0.00000   0.00000  7727.312
          42    HS 1 HIFI Baf. int.        25.653  0.00000   0.00000     2.931
          52    HS 1 HIFI Baf. ext.        32.982  0.00000   0.00000     2.676
          53    HS 2 HIFI Baf.             57.583  0.00000   0.00000    10.625
          54    HS 3 HIFI Baf.            175.249  0.00000   0.00000    45.566
          62    HS 1 Tele BAF              15.570  0.00000   0.00000     0.346
          63    HS 2 Tele BAF              38.179  0.00000   0.00000     5.541
          64    HS 3 Tele BAF             142.213  0.00000   0.00000    81.093
         101    MLI MAIN TANK LO 101        5.167  0.00000   0.00000    15.687
         105    MLI MAIN TANK CY 105        4.734  0.00000   0.00000    43.337
         106    MLI MAIN TANK UP 106       37.068  0.00000   0.00000   112.530
         112    MLI HS 1 BULK 112          20.318  0.00000   0.00000    39.938
         113    MLI HS 2 BULK 113         115.106  0.00000   0.00000   381.960
         114    MLI HS 3 BULK +Z 114      287.452  0.00000   0.00000   706.439
         115    MLI HS 3 BULK -Z 115      287.428  0.00000   0.00000   706.381
         122    MLI HS 1 CYL 122           19.252  0.00000   0.00000   122.980
         123    MLI HS 2 CYL 123           93.730  0.00000   0.00000   969.166
         124    MLI HS 3 CYL +Z 124       286.652  0.00000   0.00000  2100.815
         125    MLI HS 3 CYL -Z 125       285.594  0.00000   0.00000  2093.062
         132    MLI HS 1 CONE 132          51.497  0.00000   0.00000   249.804
         133    MLI HS 2 CONE 133         137.795  0.00000   0.00000  1125.590
         134    MLI HS 3 CONE +Z 134      287.262  0.00000   0.00000  1701.879
```

```
 135    MLI HS 3 CONE -Z 135    287.242  0.00000  0.00000  1701.760
 440    filling tube     440    271.512  0.00000  0.00000     0.000
 441    filling tube     441    252.212  0.00000  0.00000     0.000
 442    filling tube     442    245.509  0.00000  0.00000     0.000
 443    filling tube     443    242.449  0.00000  0.00000     0.000
 447    empty tube       447     15.530  0.00000  0.00000     0.000
 452    empty tube       452     10.866  0.00000  0.00000     0.000
 502    line baf to HS1  502      4.201  0.00000  0.00000     0.000
 642    MLI filling tube 642    120.434  0.00000  0.00000     0.766
 643    MLI filling tube 643    119.015  0.00000  0.00000     0.743
 647    MLI filling tube 647     25.815  0.00000  0.00000     1.245
 652    MLI filling tube 652     23.549  0.00000  0.00000     0.459
1000    HS 1 SUSP BOLT  1000     19.628  0.00000  0.00000     0.000
2000    HS 2 SUSP BOLT  2000     67.886  0.00000  0.00000     0.000
3000    HS 3 SUSP BOLT  3000    189.809  0.00000  0.00000     0.000
4001    CVV lower bulk  4001    292.764  0.00000  0.00000  4399.464
4002    CVV lower bulk  4002    292.771  0.00000  0.00000  4399.491
4003    CVV lower bulk  4003    292.771  0.00000  0.00000  4399.491
4004    CVV lower bulk  4004    292.764  0.00000  0.00000  4399.462
4005    CVV lower bulk  4005    292.750  0.00000  0.00000  4399.407
4006    CVV lower bulk  4006    292.749  0.00000  0.00000  4399.404
4007    CVV lower bulk  4007    292.758  0.00000  0.00000  4399.441
4008    CVV lower bulk  4008    292.760  0.00000  0.00000  4399.449
4011    CVV lower bulk  4011    292.707  0.00000  0.00000  1668.975
4012    CVV lower bulk  4012    292.740  0.00000  0.00000  1669.025
4013    CVV lower bulk  4013    292.741  0.00000  0.00000  1669.028
4014    CVV lower bulk  4014    292.717  0.00000  0.00000  1668.991
4015    CVV lower bulk  4015    292.654  0.00000  0.00000  1668.893
4016    CVV lower bulk  4016    292.654  0.00000  0.00000  1668.894
4017    CVV lower bulk  4017    292.705  0.00000  0.00000  1668.971
4018    CVV lower bulk  4018    292.700  0.00000  0.00000  1668.964
4031    CVV cyl lower   4031    292.553  0.00000  0.00000 13706.677
4032    CVV cyl lower   4032    292.660  0.00000  0.00000 13708.037
4033    CVV cyl lower   4033    292.663  0.00000  0.00000 13708.072
4034    CVV cyl lower   4034    292.599  0.00000  0.00000 13707.261
4035    CVV cyl lower   4035    292.392  0.00000  0.00000 13704.650
4036    CVV cyl lower   4036    292.397  0.00000  0.00000 13704.709
4037    CVV cyl lower   4037    292.568  0.00000  0.00000 13706.875
4038    CVV cyl lower   4038    292.537  0.00000  0.00000 13706.477
4041    CVV cyl upper   4041    292.693  0.00000  0.00000 19514.587
4042    CVV cyl upper   4042    292.698  0.00000  0.00000 19514.675
4043    CVV cyl upper   4043    292.632  0.00000  0.00000 19513.493
4044    CVV cyl upper   4044    292.215  0.00000  0.00000 19505.999
4045    CVV cyl upper   4045    289.660  0.00000  0.00000 19460.089
4046    CVV cyl upper   4046    289.655  0.00000  0.00000 19459.994
4047    CVV cyl upper   4047    292.186  0.00000  0.00000 19505.469
4048    CVV cyl upper   4048    292.602  0.00000  0.00000 19512.958
4051    CVV upper bulk  4051    292.694  0.00000  0.00000 19050.624
4052    CVV upper bulk  4052    292.608  0.00000  0.00000 19049.101
4053    CVV upper bulk  4053    292.598  0.00000  0.00000 19048.936
4054    CVV upper bulk  4054    292.650  0.00000  0.00000 19049.845
4055    CVV upper bulk  4055    292.570  0.00000  0.00000 19048.435
4056    CVV upper bulk  4056    292.525  0.00000  0.00000 19047.658
4057    CVV upper bulk  4057    292.661  0.00000  0.00000 19050.041
4058    CVV upper bulk  4058    292.700  0.00000  0.00000 19050.719
4061    CVV/CTA flange  4061    292.123  0.00000  0.00000     0.000
4062    CVV/CTA flange  4062    292.101  0.00000  0.00000     0.000
4063    CVV/CTA flange  4063    292.080  0.00000  0.00000     0.000
4064    CVV/CTA flange  4064    292.058  0.00000  0.00000     0.000
4065    CVV/CTA flange  4065    292.034  0.00000  0.00000     0.000
4066    CVV/CTA flange  4066    292.039  0.00000  0.00000     0.000
4067    CVV/CTA flange  4067    292.092  0.00000  0.00000     0.000
4068    CVV/CTA flange  4068    292.120  0.00000  0.00000     0.000
```

```
4071     CVV flange disc  4071    291.924  0.00000  0.00000    0.000
4072     CVV flange disc  4072    291.911  0.00000  0.00000    0.000
4073     CVV flange disc  4073    291.894  0.00000  0.00000    0.000
4074     CVV flange disc  4074    291.877  0.00000  0.00000    0.000
4075     CVV flange disc  4075    291.864  0.00000  0.00000    0.000
4076     CVV flange disc  4076    291.871  0.00000  0.00000    0.000
4077     CVV flange disc  4077    291.899  0.00000  0.00000    0.000
4078     CVV flange disc  4078    291.920  0.00000  0.00000    0.000
4090     CVV Lo window            289.911  0.00000  0.00000   15.603
4631     SUSP TI   lo   4631      282.781  0.00000  0.00000   84.266
4632     SUSP TI   lo   4632      282.880  0.00000  0.00000   84.277
4633     SUSP TI   lo   4633      282.882  0.00000  0.00000   84.277
4634     SUSP TI   lo   4634      282.823  0.00000  0.00000   84.271
4635     SUSP TI   lo   4635      282.633  0.00000  0.00000   84.250
4636     SUSP TI   lo   4636      282.637  0.00000  0.00000   84.251
4637     SUSP TI   lo   4637      282.795  0.00000  0.00000   84.268
4638     SUSP TI   lo   4638      282.766  0.00000  0.00000   84.265
4641     SUSP TI   up   4641      282.910  0.00000  0.00000   84.280
4642     SUSP TI   up   4642      282.914  0.00000  0.00000   84.280
4643     SUSP TI   up   4643      282.854  0.00000  0.00000   84.274
4644     SUSP TI   up   4644      282.470  0.00000  0.00000   84.233
4645     SUSP TI   up   4645      280.120  0.00000  0.00000   83.983
4646     SUSP TI   up   4646      280.115  0.00000  0.00000   83.982
4647     SUSP TI   up   4647      282.443  0.00000  0.00000   84.230
4648     SUSP TI   up   4648      282.826  0.00000  0.00000   84.271
4731     CABLE PLUG    4731       281.499  0.00073  0.00000   93.529
4732     CABLE PLUG    4732       291.588  0.00000  0.00000   97.058
4733     CABLE PLUG    4733       291.591  0.00000  0.00000   97.059
4734     CABLE PLUG    4734       291.527  0.00000  0.00000   97.036
4735     CABLE PLUG    4735       291.321  0.00000  0.00000   96.964
4736     CABLE PLUG    4736       292.397  0.00000  0.00000   97.341
4737     CABLE PLUG    4737       292.568  0.00000  0.00000   97.401
4738     CABLE PLUG    4738       283.622  0.00010  0.00000   94.271
6051     X2 SI Harness 51         245.203  0.00073  0.00000    0.000
6052     X2 SI Harness 52         205.934  0.00073  0.00000    0.000
6053     X2 SI Harness 53         162.824  0.00073  0.00000    0.000
6054     X2 SI Harness 54         113.892  0.00073  0.00000    0.000
6055     X2 SI at HS1  55          50.556  0.00250  0.00000    0.000
6056     X3 SI Harness 56          45.816  0.00250  0.00000    0.000
6057     X3 SI Harness 57          39.342  0.00250  0.00000    0.000
6058     X3 SI Harness 58          30.006  0.00250  0.00000    0.000
6061     X2 JF Harness 61         246.339  0.00010  0.00000    0.000
6062     X2 JF Harness 62         205.932  0.00010  0.00000    0.000
6063     X2 JF Harness 63         161.456  0.00010  0.00000    0.000
6064     X2 JF Harness 64         110.711  0.00010  0.00000    0.000
6065     X2 JF at HS1  65          42.549  0.00024  0.00000    0.000
6066     X3 JF Harness 66          38.154  0.00024  0.00000    0.000
6067     X3 JF Harness 67          33.084  0.00024  0.00000    0.000
6068     X3 JF Harness 68          26.938  0.00024  0.00000    0.000
9999     AMBIENT                  293.000  0.00000  0.00000    0.000
```

===

+EQM5:CRYO:V

NODE		LABEL	T	QI	QR	C
201	OSS-TUBE	201	4.200	0.00000	0.00000	0.000
202	BAFFLE LO	202	4.200	0.00000	0.00000	0.000
203	BAFFLE UP	203	4.200	0.00000	0.00000	0.000
204	1ST HS	204	10.521	0.00000	0.00000	0.000
205	2ND HS	205	21.960	0.00000	0.00000	0.000
206	3RD HS +z	206	97.599	0.00000	0.00000	0.000
207	3RD HS -z	207	97.497	0.00000	0.00000	0.000
210	VENT VESSEL	210	209.866	0.00000	0.00000	0.000
212	BAFFLE - 1ST HS	212	4.201	0.00000	0.00000	0.000
251	TANK HE-OUT	251	4.200	0.00000	0.00000	0.000
252	OSS HE-OUT	252	4.200	0.00000	0.00000	0.000
253	BAFFLE LO HE-OUT	253	4.200	0.00000	0.00000	0.000
254	BAFFLE UP HE-OUT	254	4.200	0.00000	0.00000	0.000
255	1ST HS HE-OUT	255	10.521	0.00000	0.00000	0.000
256	2ND HS HE-OUT	256	21.940	0.00000	0.00000	0.000
257	3RD HS HE-OUT	257	97.548	0.00000	0.00000	0.000
260	VESSEL HE-OUT	260	209.866	0.00000	0.00000	0.000
262	BAF - HS1 HE-OUT	262	4.200	0.00000	0.00000	0.000
296	HEATER WALL	296	293.000	0.00000	0.00000	0.000
297	HEATER HE-OUT	297	209.866	0.00000	0.00000	0.000

==

+EQM5:CRYO:PLM

NODE	LABEL	T	QI	QR	C
310	Instr. Shield Cyl.	11.728	0.00000	0.00000	8.465
311	Instr. Shield Top	11.754	0.00000	0.00000	10.993
315	Instr. Shield Baffle	11.789	0.00000	0.00000	0.713
320	Vline wall Tank-PACS	1.755	0.00000	0.00000	0.007
321	Vline wall PACS I/F 1	2.394	0.00000	0.00000	0.001
322	Vline wall PACS I/F 1	2.641	0.00000	0.00000	0.000
323	Vline wall PACS I/F 1	2.476	0.00000	0.00000	0.001
324	Vline wall PACSI/F1/2	2.306	0.00000	0.00000	0.003
325	Vline wall PACSI/F1/2	2.335	0.00000	0.00000	0.013
326	Vline wall PACS I/F 2	2.707	0.00000	0.00000	0.001
327	Vline wall PACS I/F 2	2.859	0.00000	0.00000	0.000
328	Vline wall PACS I/F 2	2.769	0.00000	0.00000	0.001
329	Vline wall PACSI/F2/3	2.678	0.00000	0.00000	0.006
330	Vline wall PACSI/F2/3	2.743	0.00000	0.00000	0.002
331	Vline wall PACS I/F 3	2.876	0.00000	0.00000	0.001
332	Vline wall PACS I/F 3	2.982	0.00000	0.00000	0.000
333	Vline wall PACS I/F 3	2.934	0.00000	0.00000	0.001
334	Vline wall PACS-SPIRE	2.891	0.00000	0.00000	0.006
335	Vline wall PACS-SPIRE	2.913	0.00000	0.00000	0.007
336	Vline wall PACS-SPIRE	3.083	0.00000	0.00000	0.008
337	Vline wall SPIRE	4.095	0.00000	0.00000	0.001
338	Vline wall SPIRE	4.685	0.00000	0.00000	0.001
339	Vline wall SPIRE	4.412	0.00000	0.00000	0.001
340	Vline wall SPIRE-HIFI	4.191	0.00000	0.00000	0.012
341	Vline wall SPIRE-HIFI	4.204	0.00000	0.00000	0.015
342	Vline wall SPIRE-HIFI	4.313	0.00000	0.00000	0.018
343	Vline wall HIFI	5.271	0.00000	0.00000	0.002
344	Vline wall HIFI	5.839	0.00000	0.00000	0.001
345	Vline wall HIFI	6.152	0.00000	0.00000	0.003
346	Vline Lev.2 OB	10.253	0.00000	0.00000	0.074
347	Vline Lev.2 OB	11.319	0.00000	0.00000	0.212
348	Vline Lev.2 OB	11.435	0.00000	0.00000	0.085
349	Vline Lev.2 OB	11.503	0.00000	0.00000	0.135
350	Vline Lev.2 OB	11.530	0.00000	0.00000	0.080
351	Vline Lev.2 OB	11.535	0.00000	0.00000	0.235
352	Vline Lev.2 OB	11.559	0.00000	0.00000	0.121
371	Opt. Bench +Z	11.451	0.00000	0.00000	8.062
372	Opt. Bench +Z -Y	11.380	0.00000	0.00000	7.324
373	Opt. Bench +Z mid	11.461	0.00000	0.00000	18.950
374	Opt. Bench +Z +Y	11.479	0.00000	0.00000	3.069
375	Opt. Bench -Y	11.526	0.00000	0.00000	14.004
376	Opt. Bench centre	11.510	0.00000	0.00000	33.741
377	Opt. Bench +Y	11.516	0.00000	0.00000	7.433
378	Opt. Bench -Z -Y	11.561	0.00000	0.00000	7.651
379	Opt. Bench -Z mid	11.538	0.00000	0.00000	19.298
380	Opt. Bench -Z +Y	11.540	0.00000	0.00000	3.114
381	Opt. Bench -Z	11.535	0.00000	0.00000	8.226
390	I.Shld HIFI Baf. ext.	11.800	0.00000	0.00000	0.332
391	I.Shld HIFI Baf. int.	11.732	0.00000	0.00000	0.116
411	MLI on OB-Shield side	13.960	0.00000	0.00000	31.764
412	MLI on OB-Shield top	13.971	0.00000	0.00000	41.034
710	PACS-Top Optic	3.161	0.00000	0.00000	1.890
720	PACS-Spectrometer	3.158	0.00003	0.00000	2.137
725	PACS-Collimator	3.156	0.00000	0.00000	2.160
730	PACS-Photometer Optic	3.155	0.00000	0.00000	1.305
735	PACS-Internal	3.159	0.00000	0.00000	1.812
740	PACS-Lump	3.159	0.00000	0.00000	0.000
750	PACS-Chopper	3.163	0.00040	0.00000	0.114

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 755    PACS-Grating Assy          3.163   0.00100   0.00000     0.778
 760    PACS-Red  Detector         1.704   0.00000   0.00000     0.230
 761    PACS-Red  Detect. CRE      3.170   0.00030   0.00000     0.029
 765    PACS-Blue Detector         1.723   0.00013   0.00000     0.233
 766    PACS-Blue Detect. CRE      3.170   0.00030   0.00000     0.029
 770    PACS-Filter Wh. Blue       3.159   0.00004   0.00000     0.133
 771    PACS-Filter Wh. Photo      3.155   0.00004   0.00000     0.132
 775    PACS-Calib. Source 1       3.161   0.00032   0.00000     0.019
 776    PACS-Calib. Source 2       3.164   0.00032   0.00000     0.019
 780    PACS-Photometer Housi      3.157   0.00000   0.00000     1.001
 781    PACS-Photometer CooPu      1.781   0.00220   0.00000     0.147
 791    PACS-STST-Strut 1,1        9.320   0.00000   0.00000     0.331
 792    PACS-STST-Strut 4,1        9.316   0.00000   0.00000     0.515
 793    PACS-STST-Strut 5,1        9.320   0.00000   0.00000     0.258
 794    PACS-Kevlar-Strut Red  1   2.616   0.00000   0.00000     0.014
 795    PACS-Kevlar-Strut Blue 1   2.620   0.00000   0.00000     0.014
 796    PACS-HarnessRed Det.Int1   2.550   0.00000   0.00000     0.000
 797    PACS-HarnessBlueDet.Int1   2.557   0.00000   0.00000     0.000
 798    PACS-HarnessBlue1.7->4,1   2.541   0.00000   0.00000     0.000
 801    SPIRE PM JFET ENCL        11.568   0.01026   0.00000    11.674
 802    SPIRE SM JFET ENCL        11.543   0.00282   0.00000     3.788
 803    SPIRE Optical Bench        5.332   0.00000   0.00000    10.994
 804    SPIRE RF Filter Box        5.337   0.00428   0.00000     0.538
 805    SPIRE Beam St. Mech        5.333   0.00100   0.00000     0.403
 806    SPIRE SMECm                5.333   0.00048   0.00000     0.477
 807    SPIRE PM calibrator        5.333   0.00002   0.00000     0.000
 808    SPIRE SM calibrator        9.599   0.00040   0.00000     0.000
 809    SPIRE Shutter              5.332   0.00000   0.00000     0.000
 810    SPIRE PM Detector en       1.805   0.00000   0.00000     0.454
 811    SPIRE SM Detector en       1.780   0.00000   0.00000     0.270
 812    SPIRE PM Detectors         1.744   0.00000   0.00000     0.398
 813    SPIRE SM detector          1.744   0.00000   0.00000     0.253
 816    SPIRE Cooler Pump          1.888   0.00183   0.00000     0.000
 817    SPIRE Cooler shunt         1.726   0.00000   0.00000     0.000
 818    SPIRE Cooler evap          1.744   0.00000   0.00000     0.000
 819    SPIRE Cooler pump HS       1.775   0.00008   0.00000     0.000
 820    SPIRE Cooler evap HS       1.726   0.00000   0.00000     0.000
 900    HIFI 2K level              1.862   0.00014   0.00000     0.030
 905    HIFI Harness 1 int.point   6.084   0.00036   0.00000     0.000
 910    HIFI FPU Structure        11.540   0.01602   0.00000   110.051
 912    HIFI L0 boundary node      1.855   0.00000   0.00000     0.000
 913    HIFI L1 boundary node      6.099   0.00000   0.00000     0.000
 914    HIFI Harness 2a int.poin  12.762   0.00036   0.00000     0.000
 915    HIFI Harness 2b int.poin   9.224   0.00000   0.00000     0.000
 920    HIFI Internal Assy.        6.104   0.00000   0.00000     0.026
5000    GHe tank outlet            1.700   0.00000   0.00000     0.000
5010    GHe PACS I/F 1 in          1.752   0.00000   0.00000     0.000
5011    GHe PACS I/F 1             1.965   0.00000   0.00000     0.000
5012    GHe PACS I/F 1             2.101   0.00000   0.00000     0.000
5013    GHe PACS I/F 1 out         2.233   0.00000   0.00000     0.000
5014    GHe PACS I/F 1/2           2.288   0.00000   0.00000     0.000
5020    GHe PACS I/F 2 in          2.333   0.00000   0.00000     0.000
5021    GHe PACS I/F 2             2.472   0.00000   0.00000     0.000
5022    GHe PACS I/F 2             2.558   0.00000   0.00000     0.000
5023    GHe PACS I/F 2 out         2.639   0.00000   0.00000     0.000
5024    GHe PACS I/F 2/3           2.674   0.00000   0.00000     0.000
5030    GHe PACS I/F 3 in          2.720   0.00000   0.00000     0.000
5031    GHe PACS I/F 3             2.782   0.00000   0.00000     0.000
5032    GHe PACS I/F 3             2.828   0.00000   0.00000     0.000
5033    GHe PACS I/F 3 out         2.871   0.00000   0.00000     0.000
5034    GHe PACS-SPIRE             2.889   0.00000   0.00000     0.000
5035    GHe PACS-SPIRE             2.912   0.00000   0.00000     0.000
5040    GHe SPIRE I/F in           3.074   0.00000   0.00000     0.000
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5041      GHe SPIRE I/F            3.552   0.00000   0.00000   0.000
5042      GHe SPIRE I/F            3.881   0.00000   0.00000   0.000
5043      GHe SPIRE I/F out        4.144   0.00000   0.00000   0.000
5044      GHe SPIRE-HIFI           4.189   0.00000   0.00000   0.000
5045      GHe SPIRE-HIFI           4.204   0.00000   0.00000   0.000
5050      GHe HIFI I/F in          4.308   0.00000   0.00000   0.000
5051      GHe HIFI I/F             4.819   0.00000   0.00000   0.000
5052      GHe HIFI I/F             5.157   0.00000   0.00000   0.000
5053      GHe HIFI I/F out         5.729   0.00000   0.00000   0.000
5054      GHe Lev.2 OB            10.028   0.00000   0.00000   0.000
5055      GHe Lev.2 OB            11.255   0.00000   0.00000   0.000
5056      GHe Lev.2 OB            11.426   0.00000   0.00000   0.000
5057      GHe Lev.2 OB            11.499   0.00000   0.00000   0.000
5058      GHe Lev.2 OB            11.529   0.00000   0.00000   0.000
5059      GHe Lev.2 OB            11.534   0.00000   0.00000   0.000
5060      GHe Lev.2 OB            11.557   0.00000   0.00000   0.000
6059      X3 SI Harness 59        12.389   0.00406   0.00000   0.000
6069      X3 JF Harness 69        18.741   0.00040   0.00000   0.000
9999      Ambient Air            293.000   0.00000   0.00000   0.000
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+EQM5:CTCE

NODE	LABEL	T	QI	QR	C
901	vessel flange 901	292.124	0.00000	0.00000	905.487
902	vessel flange 902	292.106	0.00000	0.00000	905.472
903	vessel flange 903	292.082	0.00000	0.00000	905.452
904	vessel flange 904	292.046	0.00000	0.00000	905.422
905	vessel flange 905	292.023	0.00000	0.00000	905.403
906	vessel flange 906	292.033	0.00000	0.00000	905.412
907	vessel flange 907	292.090	0.00000	0.00000	905.459
908	vessel flange 908	292.120	0.00000	0.00000	905.484
921	cyl. vessel 921	292.129	0.00000	0.00000	8549.561
922	cyl. vessel 922	292.119	0.00000	0.00000	8549.482
923	cyl. vessel 923	292.062	0.00000	0.00000	8549.034
924	cyl. vessel 924	291.877	0.00000	0.00000	8547.579
925	cyl. vessel 925	291.835	0.00000	0.00000	8547.243
926	cyl. vessel 926	291.877	0.00000	0.00000	8547.580
927	cyl. vessel 927	292.063	0.00000	0.00000	8549.042
928	cyl. vessel 928	292.120	0.00000	0.00000	8549.492
930	vessel dome 930	292.106	0.00000	0.00000	19141.380
1011	CTA HS1 bottom	43.105	0.00000	0.00000	0.000
1012	CTA HS1 bottom	43.101	0.00000	0.00000	0.000
1013	CTA HS1 bottom	43.102	0.00000	0.00000	0.000
1014	CTA HS1 bottom	43.112	0.00000	0.00000	0.000
1015	CTA HS1 bottom	43.121	0.00000	0.00000	0.000
1016	CTA HS1 bottom	43.128	0.00000	0.00000	0.000
1017	CTA HS1 bottom	43.128	0.00000	0.00000	0.000
1018	CTA HS1 bottom	43.119	0.00000	0.00000	0.000
1021	CTA HS1 cyl.	43.082	0.00000	0.00000	0.000
1022	CTA HS1 cyl.	43.087	0.00000	0.00000	0.000
1023	CTA HS1 cyl.	43.081	0.00000	0.00000	0.000
1024	CTA HS1 cyl.	43.107	0.00000	0.00000	0.000
1025	CTA HS1 cyl.	43.118	0.00000	0.00000	0.000
1026	CTA HS1 cyl.	43.136	0.00000	0.00000	0.000
1027	CTA HS1 cyl.	43.133	0.00000	0.00000	0.000
1028	CTA HS1 cyl.	43.120	0.00000	0.00000	0.000
1030	CTA HS1 top	43.147	0.00000	0.00000	0.000
1121	CTA HS2 cyl. 1121	47.604	0.00000	0.00000	203.115
1122	CTA HS2 cyl. 1122	46.673	0.00000	0.00000	193.075
1123	CTA HS2 cyl. 1122	49.442	0.00000	0.00000	222.921
1124	CTA HS2 cyl. 1122	53.004	0.00000	0.00000	261.316
1125	CTA HS2 cyl. 1122	56.597	0.00000	0.00000	300.036
1126	CTA HS2 cyl. 1122	59.306	0.00000	0.00000	329.239
1127	CTA HS2 cyl. 1122	60.452	0.00000	0.00000	341.799
1128	CTA HS2 cyl. 1122	58.004	0.00000	0.00000	315.199
1130	CTA HS2 top 1130	66.028	0.00000	0.00000	601.075
1201	CTA Shroud lo Baf	6.124	0.00000	0.00000	0.176
1211	CTA Shroud up Baf	4.780	0.00000	0.00000	0.100
1221	CTA cy.Shroud 1221	4.457	0.00000	0.00000	0.000
1222	CTA cy.Shroud 1222	4.415	0.00000	0.00000	0.000
1223	CTA cy.Shroud 1223	4.478	0.00000	0.00000	0.000
1224	CTA cy.Shroud 1224	4.453	0.00000	0.00000	0.000
1225	CTA cy.Shroud 1225	4.517	0.00000	0.00000	0.000
1226	CTA cy.Shroud 1226	4.492	0.00000	0.00000	0.000
1227	CTA cy.Shroud 1227	4.552	0.00000	0.00000	0.000
1228	CTA cy.Shroud 1228	4.506	0.00000	0.00000	0.000
1230	CTA topShroud 1230	4.790	0.00000	0.00000	0.619
1240	CTA Reflector	87.630	0.00000	0.05000	1173.727
1250	Refl. I/F bracket 1	17.797	0.00000	0.00000	0.000
1252	Refl. I/F br.1 pos.2	168.420	0.00000	0.00000	0.000
1253	Refl. I/F br.1 pos.3	169.783	0.00000	0.00000	0.000

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1254    Refl. I/F br.1 pos.4      137.402  0.00000  0.00000  0.000
1255    Refl. I/F br.1 pos.5      139.613  0.00000  0.00000  0.000
1256    Refl. I/F br.1 pos.6      222.276  0.00000  0.00000  0.000
1257    Refl. I/F br.1 pos.7      224.000  0.00000  0.00000  0.000
1260    Refl. I/F bracket 2        19.450  0.00000  0.00000  0.000
1262    Refl. I/F br.2 pos.2      168.779  0.00000  0.00000  0.000
1263    Refl. I/F br.2 pos.3      170.139  0.00000  0.00000  0.000
1264    Refl. I/F br.2 pos.4      137.684  0.00000  0.00000  0.000
1265    Refl. I/F br.2 pos.5      139.889  0.00000  0.00000  0.000
1266    Refl. I/F br.2 pos.6      222.362  0.00000  0.00000  0.000
1267    Refl. I/F br.2 pos.7      224.083  0.00000  0.00000  0.000
1270    Refl. I/F bracket 3        21.141  0.00000  0.00000  0.000
1272    Refl. I/F br.3 pos.2      168.935  0.00000  0.00000  0.000
1273    Refl. I/F br.3 pos.3      170.291  0.00000  0.00000  0.000
1274    Refl. I/F br.3 pos.4      138.079  0.00000  0.00000  0.000
1275    Refl. I/F br.3 pos.5      140.278  0.00000  0.00000  0.000
1276    Refl. I/F br.3 pos.6      222.542  0.00000  0.00000  0.000
1277    Refl. I/F br.3 pos.7      224.259  0.00000  0.00000  0.000
1311    CTA HS3 bottom            255.658  0.00000  0.00000  0.000
1312    CTA HS3 bottom            255.657  0.00000  0.00000  0.000
1313    CTA HS3 bottom            255.645  0.00000  0.00000  0.000
1314    CTA HS3 bottom            255.644  0.00000  0.00000  0.000
1315    CTA HS3 bottom            255.639  0.00000  0.00000  0.000
1316    CTA HS3 bottom            255.649  0.00000  0.00000  0.000
1317    CTA HS3 bottom            255.655  0.00000  0.00000  0.000
1318    CTA HS3 bottom            255.664  0.00000  0.00000  0.000
1321    CTA HS3 cyl.              255.790  0.00000  0.00000  0.000
1322    CTA HS3 cyl.              255.849  0.00000  0.00000  0.000
1323    CTA HS3 cyl.              255.766  0.00000  0.00000  0.000
1324    CTA HS3 cyl.              255.811  0.00000  0.00000  0.000
1325    CTA HS3 cyl.              255.741  0.00000  0.00000  0.000
1326    CTA HS3 cyl.              255.821  0.00000  0.00000  0.000
1327    CTA HS3 cyl.              255.785  0.00000  0.00000  0.000
1328    CTA HS3 cyl.              255.861  0.00000  0.00000  0.000
1330    CTA HS3 top               256.925  0.00000  0.00000  0.000
2000    CTA-Shroud Dewar            4.200  0.00000  0.00000  0.000
2001    GHe Shroud 1221 out         4.234  0.00000  0.00000  0.000
2002    GHe Shroud 1222 out         4.257  0.00000  0.00000  0.000
2003    GHe Shroud 1223 out         4.286  0.00000  0.00000  0.000
2004    GHe Shroud 1224 out         4.308  0.00000  0.00000  0.000
2005    GHe Shroud 1225 out         4.336  0.00000  0.00000  0.000
2006    GHe Shroud 1226 out         4.356  0.00000  0.00000  0.000
2007    GHe Shroud 1227 out         4.382  0.00000  0.00000  0.000
2008    GHe Shroud 1228 out         4.399  0.00000  0.00000  0.000
2011    GHe HS 1121 out            22.946  0.00000  0.00000  0.000
2012    GHe HS 1122 out            31.069  0.00000  0.00000  0.000
2013    GHe HS 1123 out            37.719  0.00000  0.00000  0.000
2014    GHe HS 1124 out            43.527  0.00000  0.00000  0.000
2015    GHe HS 1125 out            48.683  0.00000  0.00000  0.000
2016    GHe HS 1126 out            52.965  0.00000  0.00000  0.000
2017    GHe HS 1127 out            56.024  0.00000  0.00000  0.000
2018    GHe HS 1128 out            56.831  0.00000  0.00000  0.000
2021    GHe I/F bracket 1250 out    6.643  0.00000  0.00000  0.000
2022    GHe I/F bracket 1260 out    8.885  0.00000  0.00000  0.000
2023    GHe I/F bracket 1270 out   11.121  0.00000  0.00000  0.000
9999    AMBIENT                   293.000  0.00000  0.00000  0.000
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Heat Balance for PAYLOAD incl. Instrument Shield MLI
====================================================
                      Level 0: from Aux. Tank into instruments     -16.376 [mW]
                     Level 2: from spatial framework into OB         -0.751 [mW]
          Level 1/2: from Aux. Tank into OB via ventline wall        -0.064 [mW]
                  Level 2: from HS1 into OB via ventline wall         0.152 [mW]
                             Level 2: via harness into OB            27.090 [mW]
         via radiation from HS1 upper bulkhead onto Instrument MLI    0.225 [mW]
            via radiation from Cryostat cavity onto OB lower side     5.126 [mW]
                    via radiation from HS1-baffle into payload        0.007 [mW]
                    via radiation from HS2-baffle into payload        0.023 [mW]
                    via radiation from HS3-baffle into payload        1.509 [mW]
              via radiation from CTCE-4K-shrouds into payload        -0.016 [mW]
       via radiation from CTCE lower-shroud baffle into payload      -0.002 [mW]
       via radiation from CTCE upper-shroud baffle into payload      -0.002 [mW]
                via radiation from CTCE reflector into payload        3.435 [mW]
                via radiation from CVV-LOU-Window onto HIFI-Baffle   19.947 [mW]
                   via radiation from CVV-LOU-Window onto HIFI-FPU   14.509 [mW]
                      Vent line cooling power (out of payload)      104.778 [mW]
           Transferred by convection from PL-ventline on helium    104.803 [mW]
                                     total dissipation of PACS        5.070 [mW]
                                    total dissipation of SPIRE       21.167 [mW]
                                     total dissipation of HIFI       16.867 [mW]
                                   Harness dissipation on OB          4.462 [mW]
                      Payload Heat Imbalance (shall be 0)            -2.399 [mW]


Heat Balance for Main Tank Ventline
===================================
              conducted and radiated into ventline attached to HS1      3204.600 [mW]
              conducted and radiated into ventline attached to HS2      5789.032 [mW]
           conducted and radiated into ventline attached to HS3 +Z     19178.463 [mW]
           conducted and radiated into ventline attached to HS3 -Z     19152.609 [mW]
                      conducted into ventline walls from CVV           56941.782 [mW]
                  conducted and radiated into line baf to HS 1             0.152 [mW]
           Main Tank Ventline cooling power (out of ventline)         104266.691 [mW]
                        Via convection into ventline walls           -104276.644 [mW]
                    Main Tank Ventline Imbalance (shall be 0)             -0.052 [mW]


Heat Balance for CTCE
=====================
              Convective heat transfer onto CTCE-external insulation    37835.264 [mW]
                      Conducted from CVV into CTCE-structure              142.094 [mW]
            Radiated from Payload into CTCE-shrouds incl. baffles          0.020 [mW]
                   Radiated from HS-baffles onto CTCE-shroud             48.839 [mW]
         Radiated from CVV flange disc within cavity onto CTCE-MLI     2953.528 [mW]
                       Radiated from Payload onto reflector              -3.435 [mW]
            Conducted from CTCE-structure into CTCE-shrouds             50.000 [mW]
                        Cooling power of CTCE-shrouds                  41025.563 [mW]
                          CTCE Imbalance (shall be 0)                     0.748 [mW]
Heat Balance for Reflector within CTCE
======================================
                  via struts from CTCE-I/F brackets into reflector     -12.460 [mW]
                 by radiation from CTCE-shrouds into reflector         -34.088 [mW]
                   by radiation from Payload into reflector             -3.435 [mW]
                             reflector heater power                     50.000 [mW]
                   reflector total imbalance (shall be 0)                0.017 [mW]


Heat Balance for whole Cryostat including Payload,Ventlines and CTCE
===================================================================
                  Convective heat transfer onto external walls       145184.516 [mW]
                  total heat transferred on gaseous helium           145397.031 [mW]
                  evaporation power in main and aux. tank              2087.536 [mW]
                       Total istrument power dissipation                 43.104 [mW]
         total main & auxiliary tank and reflector heater power        2064.000 [mW]
                  heater power of CVV lower bulkhead HTR                  0.000 [mW]
                  total harness dissipation within system              19.601 [mW]
                        Cooling power of CTCE-shrouds                  41025.563 [mW]
                  Cryostat total imbalance (shall be 0)                -173.346 [mW]
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Heat Balance for Main Tank
==========================
                          Main tank dissipation + heater power    2000.000 [mW]
                             heat from Aux. tank via mech. I/F       -0.451 [mW]
                                     radiated from aux. tank          0.000 [mW]
                             conducted from spatial framework        31.256 [mW]
                                    transferred through MLI           9.750 [mW]
                                      conducted from rest             0.290 [mW]
                     radiated from spatial framework and HSs          0.077 [mW]
                      conducted from main tank ventline wall          0.000 [mW]
                                   radiated from payload              0.000 [mW]
                                   total heat into main tank       2040.921 [mW]
Heat Balance for Auxiliary Tank
===============================
                          Aux. tank dissipation + heater power       14.000 [mW]
                            heat from Main tank via mech. I/F          0.451 [mW]
                                    radiated from Main tank            0.000 [mW]
                     radiated from spatial framework and HSs          0.015 [mW]
                                 conducted from payload L0            16.376 [mW]
                                 conducted from payload L2             0.064 [mW]
                                    radiated from payload              0.013 [mW]
                                conducted from filling tube            0.007 [mW]
                             radiated from MLI filling tube           15.689 [mW]
                                   total heat into Aux. tank          46.615 [mW]
Heat flows into Tanks
=====================

                                        Into Main Tank             2040.921 [mW]
                                        Into Aux. Tank               46.615 [mW]
Helium evaporation mass flow rates
==================================

                                        Out of Main Tank             97.558 [mg/s]
                                        Out of Aux. Tank              2.045 [mg/s]
                     Out of external He- dewar for CTA-shroud cooling  150.000 [mg/s]
```

5.5   CTA Cold Plate Design 1

CTA Cold Plate Design 1 means: Mirror black (emissivity = 0.9)

The input parameters are compiled in Table 5-17 and a brief temperature results summary is given in Table 5-18. The complete ESATAN-output-file listing is appended for the 10 mg/s case. The respective node numbers and labels are referenced in the thermal design and thermal-mathematical model descriptions in § 4

Input parameter	
Main Tank temperature	4.2 K
EQM-aux. Tank temperature	1.7 K
External Hel dewar temp. for CTA-cold plate cooling	4.2 K
Main Tank heater power	2000 mW
EQM-auxiliary tank heater power	14 mW
CTA-cold plate He-mass flow rate	0 to 50 mg/s

Table 5-17:   Input parameters

Thermal node	Description	0 mg/s	1 mg/s	10 mg/s	50 mg/s
900	Vacuum tight plate	292 K	292 K	291 K	289 K
1100	Radiation Shield 2	239 K	186 K	23 K	10 K
1200	Radiation Shield 1	173 K	104 K	6 K	5 K
1500	Mirror (black)	126 K	52 K	5 K	4.7 K
371 - 381	HOB	20 K	11.5 K	11 K	11 K

Table 5-18:   Temperature results summary, CTA Cold Plate Design 1

```
EUROPEAN  SPACE  AGENCY  THERMAL  ANALYSIS  NETWORK
(VERSION 8.5.0)                           PAGE    1
 7 MAY 2002                                              14:27:58
EQM6


##############################################################################
#  EQM6:  CTA Cold Plate
#         CTA-ventline-cooling switched on
#
#  Main Tank heater power:      2000 mW
#  Aux. Tank heater power:        14 mW
#  CTA-shroud mass flow rate:     10 mg/s
#
##############################################################################




+EQM6


         NODE                    LABEL       T        QI        QR         C

         9999      AMBIENT                293.000  0.00000   0.00000     0.000
            1      MAIN TANK                4.200  0.00000   2.00000     0.000
            2      AUX TANK                 1.700  0.00000   0.01400     0.000
            5      Ti-head       lo   5    11.288  0.00000   0.00000    71.093
            6      belt fitting  lo   6    10.679  0.00000   0.00000    63.263
            7      strut tank end lo  7     4.359  0.00000   0.00000    21.851
            8      Ti-head       up   8    11.044  0.00000   0.00000    69.021
            9      belt fitting  up   9    10.433  0.00000   0.00000    61.239
           10      strut tank end up  10    4.349  0.00000   0.00000    21.798
           12      HS 1 BULK 12            10.597  0.00000   0.00000    14.055
           13      HS 2 BULK 13            22.974  0.00000   0.00000   140.014
           14      HS 3 BULK +Z 14        119.555  0.00000   0.00000  2767.948
           15      HS 3 BULK -Z 15        119.521  0.00000   0.00000  2767.306
           22      HS 1 CYL 22             10.523  0.00000   0.00000    44.747
           23      HS 2 CYL 23             21.961  0.00000   0.00000   330.301
           24      HS 3 CYL +Z 24          97.603  0.00000   0.00000  6858.580
           25      HS 3 CYL -Z 25          97.501  0.00000   0.00000  6849.281
           32      HS 1 CONE 32            15.538  0.00000   0.00000    91.795
           33      HS 2 CONE 33            37.974  0.00000   0.00000  1507.540
           34      HS 3 CONE +Z 34        142.245  0.00000   0.00000  7724.449
           35      HS 3 CONE -Z 35        142.451  0.00000   0.00000  7724.449
           42      HS 1 HIFI Baf. int.     25.641  0.00000   0.00000     2.928
           52      HS 1 HIFI Baf. ext.     32.963  0.00000   0.00000     2.671
           53      HS 2 HIFI Baf.          57.545  0.00000   0.00000    10.611
           54      HS 3 HIFI Baf.         175.170  0.00000   0.00000    45.556
           62      HS 1 Tele BAF           15.565  0.00000   0.00000     0.346
           63      HS 2 Tele BAF           38.160  0.00000   0.00000     5.535
           64      HS 3 Tele BAF          142.152  0.00000   0.00000    81.063
          101      MLI MAIN TANK LO 101     5.168  0.00000   0.00000    15.688
          105      MLI MAIN TANK CY 105     4.735  0.00000   0.00000    43.340
          106      MLI MAIN TANK UP 106    37.055  0.00000   0.00000   112.492
          112      MLI HS 1 BULK 112       20.320  0.00000   0.00000    39.941
          113      MLI HS 2 BULK 113      115.109  0.00000   0.00000   381.970
          114      MLI HS 3 BULK +Z 114   287.451  0.00000   0.00000   706.439
          115      MLI HS 3 BULK -Z 115   287.428  0.00000   0.00000   706.380
          122      MLI HS 1 CYL 122        19.254  0.00000   0.00000   122.992
          123      MLI HS 2 CYL 123        93.733  0.00000   0.00000   969.200
          124      MLI HS 3 CYL +Z 124    286.648  0.00000   0.00000  2100.791
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 125    MLI HS 3 CYL -Z 125       285.591   0.00000   0.00000   2093.041
 132    MLI HS 1 CONE 132          51.483   0.00000   0.00000    249.737
 133    MLI HS 2 CONE 133         137.735   0.00000   0.00000   1125.106
 134    MLI HS 3 CONE +Z 134      287.131   0.00000   0.00000   1701.105
 135    MLI HS 3 CONE -Z 135      287.113   0.00000   0.00000   1700.994
 440    filling tube    440       271.450   0.00000   0.00000      0.000
 441    filling tube    441       252.163   0.00000   0.00000      0.000
 442    filling tube    442       245.464   0.00000   0.00000      0.000
 443    filling tube    443       242.406   0.00000   0.00000      0.000
 447    empty tube      447        15.525   0.00000   0.00000      0.000
 452    empty tube      452        10.862   0.00000   0.00000      0.000
 502    line baf to HS1 502         4.201   0.00000   0.00000      0.000
 642    MLI filling tube 642      120.412   0.00000   0.00000      0.766
 643    MLI filling tube 643      118.994   0.00000   0.00000      0.743
 647    MLI filling tube 647       25.806   0.00000   0.00000      1.244
 652    MLI filling tube 652       23.540   0.00000   0.00000      0.459
1000    HS 1 SUSP BOLT  1000       19.625   0.00000   0.00000     48.203
2000    HS 2 SUSP BOLT  2000       67.886   0.00000   0.00000    229.721
3000    HS 3 SUSP BOLT  3000      189.807   0.00000   0.00000    737.487
4001    CVV lower bulk  4001      292.764   0.00000   0.00000   4399.463
4002    CVV lower bulk  4002      292.771   0.00000   0.00000   4399.490
4003    CVV lower bulk  4003      292.771   0.00000   0.00000   4399.491
4004    CVV lower bulk  4004      292.764   0.00000   0.00000   4399.462
4005    CVV lower bulk  4005      292.750   0.00000   0.00000   4399.407
4006    CVV lower bulk  4006      292.749   0.00000   0.00000   4399.403
4007    CVV lower bulk  4007      292.758   0.00000   0.00000   4399.441
4008    CVV lower bulk  4008      292.760   0.00000   0.00000   4399.449
4011    CVV lower bulk  4011      292.707   0.00000   0.00000   1668.975
4012    CVV lower bulk  4012      292.740   0.00000   0.00000   1669.025
4013    CVV lower bulk  4013      292.741   0.00000   0.00000   1669.027
4014    CVV lower bulk  4014      292.717   0.00000   0.00000   1668.991
4015    CVV lower bulk  4015      292.654   0.00000   0.00000   1668.893
4016    CVV lower bulk  4016      292.654   0.00000   0.00000   1668.893
4017    CVV lower bulk  4017      292.704   0.00000   0.00000   1668.971
4018    CVV lower bulk  4018      292.700   0.00000   0.00000   1668.964
4031    CVV cyl lower   4031      292.552   0.00000   0.00000  13706.669
4032    CVV cyl lower   4032      292.660   0.00000   0.00000  13708.029
4033    CVV cyl lower   4033      292.663   0.00000   0.00000  13708.065
4034    CVV cyl lower   4034      292.598   0.00000   0.00000  13707.254
4035    CVV cyl lower   4035      292.392   0.00000   0.00000  13704.644
4036    CVV cyl lower   4036      292.396   0.00000   0.00000  13704.703
4037    CVV cyl lower   4037      292.568   0.00000   0.00000  13706.868
4038    CVV cyl lower   4038      292.536   0.00000   0.00000  13706.470
4041    CVV cyl upper   4041      292.688   0.00000   0.00000  19514.499
4042    CVV cyl upper   4042      292.693   0.00000   0.00000  19514.587
4043    CVV cyl upper   4043      292.627   0.00000   0.00000  19513.406
4044    CVV cyl upper   4044      292.210   0.00000   0.00000  19505.918
4045    CVV cyl upper   4045      289.657   0.00000   0.00000  19460.027
4046    CVV cyl upper   4046      289.651   0.00000   0.00000  19459.931
4047    CVV cyl upper   4047      292.181   0.00000   0.00000  19505.386
4048    CVV cyl upper   4048      292.597   0.00000   0.00000  19512.871
4051    CVV upper bulk  4051      292.614   0.00000   0.00000  19049.217
4052    CVV upper bulk  4052      292.528   0.00000   0.00000  19047.699
4053    CVV upper bulk  4053      292.520   0.00000   0.00000  19047.557
4054    CVV upper bulk  4054      292.573   0.00000   0.00000  19048.502
4055    CVV upper bulk  4055      292.493   0.00000   0.00000  19047.100
4056    CVV upper bulk  4056      292.448   0.00000   0.00000  19046.306
4057    CVV upper bulk  4057      292.583   0.00000   0.00000  19048.663
4058    CVV upper bulk  4058      292.620   0.00000   0.00000  19049.321
4061    CVV/CTA flange  4061      291.279   0.00000   0.00000    322.774
4062    CVV/CTA flange  4062      291.256   0.00000   0.00000    322.767
4063    CVV/CTA flange  4063      291.252   0.00000   0.00000    322.766
4064    CVV/CTA flange  4064      291.262   0.00000   0.00000    322.769
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4065      CVV/CTA flange   4065      291.241   0.00000   0.00000    322.763
4066      CVV/CTA flange   4066      291.232   0.00000   0.00000    322.760
4067      CVV/CTA flange   4067      291.267   0.00000   0.00000    322.771
4068      CVV/CTA flange   4068      291.282   0.00000   0.00000    322.775
4071      CVV flange disc  4071      290.808   0.00000   0.00000   1526.232
4072      CVV flange disc  4072      290.801   0.00000   0.00000   1526.223
4073      CVV flange disc  4073      290.799   0.00000   0.00000   1526.220
4074      CVV flange disc  4074      290.800   0.00000   0.00000   1526.221
4075      CVV flange disc  4075      290.794   0.00000   0.00000   1526.213
4076      CVV flange disc  4076      290.793   0.00000   0.00000   1526.211
4077      CVV flange disc  4077      290.803   0.00000   0.00000   1526.225
4078      CVV flange disc  4078      290.809   0.00000   0.00000   1526.233
4090      CVV Lo window              289.838   0.00000   0.00000     15.602
4631      SUSP TI   lo     4631      282.780   0.00000   0.00000     84.266
4632      SUSP TI   lo     4632      282.879   0.00000   0.00000     84.277
4633      SUSP TI   lo     4633      282.882   0.00000   0.00000     84.277
4634      SUSP TI   lo     4634      282.823   0.00000   0.00000     84.271
4635      SUSP TI   lo     4635      282.632   0.00000   0.00000     84.250
4636      SUSP TI   lo     4636      282.637   0.00000   0.00000     84.251
4637      SUSP TI   lo     4637      282.794   0.00000   0.00000     84.268
4638      SUSP TI   lo     4638      282.765   0.00000   0.00000     84.265
4641      SUSP TI   up     4641      282.905   0.00000   0.00000     84.279
4642      SUSP TI   up     4642      282.910   0.00000   0.00000     84.280
4643      SUSP TI   up     4643      282.849   0.00000   0.00000     84.273
4644      SUSP TI   up     4644      282.466   0.00000   0.00000     84.233
4645      SUSP TI   up     4645      280.117   0.00000   0.00000     83.982
4646      SUSP TI   up     4646      280.112   0.00000   0.00000     83.982
4647      SUSP TI   up     4647      282.438   0.00000   0.00000     84.230
4648      SUSP TI   up     4648      282.822   0.00000   0.00000     84.271
4731      CABLE PLUG       4731      281.498   0.00073   0.00000     93.529
4732      CABLE PLUG       4732      291.587   0.00000   0.00000     97.057
4733      CABLE PLUG       4733      291.590   0.00000   0.00000     97.058
4734      CABLE PLUG       4734      291.526   0.00000   0.00000     97.036
4735      CABLE PLUG       4735      291.321   0.00000   0.00000     96.964
4736      CABLE PLUG       4736      292.396   0.00000   0.00000     97.340
4737      CABLE PLUG       4737      292.568   0.00000   0.00000     97.400
4738      CABLE PLUG       4738      283.622   0.00010   0.00000     94.271
6051      X2 SI Harness 51           245.203   0.00073   0.00000      0.000
6052      X2 SI Harness 52           205.933   0.00073   0.00000      0.000
6053      X2 SI Harness 53           162.824   0.00073   0.00000      0.000
6054      X2 SI Harness 54           113.891   0.00073   0.00000      0.000
6055      X2 SI at HS1  55            50.555   0.00250   0.00000      0.000
6056      X3 SI Harness 56            45.785   0.00250   0.00000      0.000
6057      X3 SI Harness 57            39.274   0.00250   0.00000      0.000
6058      X3 SI Harness 58            29.874   0.00250   0.00000      0.000
6061      X2 JF Harness 61           246.338   0.00010   0.00000      0.000
6062      X2 JF Harness 62           205.932   0.00010   0.00000      0.000
6063      X2 JF Harness 63           161.455   0.00010   0.00000      0.000
6064      X2 JF Harness 64           110.710   0.00010   0.00000      0.000
6065      X2 JF at HS1  65            42.547   0.00024   0.00000      0.000
6066      X3 JF Harness 66            38.113   0.00024   0.00000      0.000
6067      X3 JF Harness 67            32.991   0.00024   0.00000      0.000
6068      X3 JF Harness 68            26.769   0.00024   0.00000      0.000
9999      AMBIENT                    293.000   0.00000   0.00000      0.000
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+EQM6:CRYO:V

NODE	LABEL		T	QI	QR	C
201	OSS-TUBE	201	4.200	0.00000	0.00000	0.000
202	BAFFLE LO	202	4.200	0.00000	0.00000	0.000
203	BAFFLE UP	203	4.200	0.00000	0.00000	0.000
204	1ST HS	204	10.523	0.00000	0.00000	0.000
205	2ND HS	205	21.961	0.00000	0.00000	0.000
206	3RD HS +z	206	97.603	0.00000	0.00000	0.000
207	3RD HS -z	207	97.501	0.00000	0.00000	0.000
210	VENT VESSEL	210	209.894	0.00000	0.00000	0.000
212	BAFFLE - 1ST HS	212	4.201	0.00000	0.00000	0.000
251	TANK HE-OUT	251	4.200	0.00000	0.00000	0.000
252	OSS HE-OUT	252	4.200	0.00000	0.00000	0.000
253	BAFFLE LO HE-OUT	253	4.200	0.00000	0.00000	0.000
254	BAFFLE UP HE-OUT	254	4.200	0.00000	0.00000	0.000
255	1ST HS HE-OUT	255	10.523	0.00000	0.00000	0.000
256	2ND HS HE-OUT	256	21.942	0.00000	0.00000	0.000
257	3RD HS HE-OUT	257	97.552	0.00000	0.00000	0.000
260	VESSEL HE-OUT	260	209.894	0.00000	0.00000	0.000
262	BAF - HS1 HE-OUT	262	4.200	0.00000	0.00000	0.000
296	HEATER WALL	296	293.000	0.00000	0.00000	0.000
297	HEATER HE-OUT	297	209.894	0.00000	0.00000	0.000

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+EQM6:CRYO:PLM

NODE	LABEL	T	QI	QR	C
310	Instr. Shield Cyl.	11.293	0.00000	0.00000	7.634
311	Instr. Shield Top	11.305	0.00000	0.00000	9.884
315	Instr. Shield Baffle	11.321	0.00000	0.00000	0.638
320	Vline wall Tank-PACS	1.753	0.00000	0.00000	0.007
321	Vline wall PACS I/F 1	2.376	0.00000	0.00000	0.000
322	Vline wall PACS I/F 1	2.618	0.00000	0.00000	0.000
323	Vline wall PACS I/F 1	2.456	0.00000	0.00000	0.000
324	Vline wall PACSI/F1/2	2.286	0.00000	0.00000	0.003
325	Vline wall PACSI/F1/2	2.314	0.00000	0.00000	0.013
326	Vline wall PACS I/F 2	2.681	0.00000	0.00000	0.000
327	Vline wall PACS I/F 2	2.831	0.00000	0.00000	0.000
328	Vline wall PACS I/F 2	2.741	0.00000	0.00000	0.000
329	Vline wall PACSI/F2/3	2.649	0.00000	0.00000	0.005
330	Vline wall PACSI/F2/3	2.714	0.00000	0.00000	0.002
331	Vline wall PACS I/F 3	2.847	0.00000	0.00000	0.000
332	Vline wall PACS I/F 3	2.952	0.00000	0.00000	0.000
333	Vline wall PACS I/F 3	2.904	0.00000	0.00000	0.000
334	Vline wall PACS-SPIRE	2.860	0.00000	0.00000	0.005
335	Vline wall PACS-SPIRE	2.882	0.00000	0.00000	0.007
336	Vline wall PACS-SPIRE	3.035	0.00000	0.00000	0.008
337	Vline wall SPIRE	3.951	0.00000	0.00000	0.000
338	Vline wall SPIRE	4.483	0.00000	0.00000	0.000
339	Vline wall SPIRE	4.232	0.00000	0.00000	0.000
340	Vline wall SPIRE-HIFI	4.022	0.00000	0.00000	0.011
341	Vline wall SPIRE-HIFI	4.035	0.00000	0.00000	0.014
342	Vline wall SPIRE-HIFI	4.136	0.00000	0.00000	0.017
343	Vline wall HIFI	5.032	0.00000	0.00000	0.000
344	Vline wall HIFI	5.559	0.00000	0.00000	0.000
345	Vline wall HIFI	5.851	0.00000	0.00000	0.000
346	Vline Lev.2 OB	9.807	0.00000	0.00000	0.065
347	Vline Lev.2 OB	10.884	0.00000	0.00000	0.189
348	Vline Lev.2 OB	11.004	0.00000	0.00000	0.076
349	Vline Lev.2 OB	11.077	0.00000	0.00000	0.122
350	Vline Lev.2 OB	11.106	0.00000	0.00000	0.072
351	Vline Lev.2 OB	11.112	0.00000	0.00000	0.212
352	Vline Lev.2 OB	11.137	0.00000	0.00000	0.109
371	Opt. Bench +Z	11.023	0.00000	0.00000	7.230
372	Opt. Bench +Z -Y	10.955	0.00000	0.00000	6.561
373	Opt. Bench +Z mid	11.036	0.00000	0.00000	17.009
374	Opt. Bench +Z +Y	11.053	0.00000	0.00000	2.756
375	Opt. Bench -Y	11.106	0.00000	0.00000	12.610
376	Opt. Bench centre	11.088	0.00000	0.00000	30.354
377	Opt. Bench +Y	11.093	0.00000	0.00000	6.684
378	Opt. Bench -Z -Y	11.140	0.00000	0.00000	6.894
379	Opt. Bench -Z mid	11.116	0.00000	0.00000	17.374
380	Opt. Bench -Z +Y	11.118	0.00000	0.00000	2.804
381	Opt. Bench -Z	11.113	0.00000	0.00000	7.406
390	I.Shld HIFI Baf. ext.	11.370	0.00000	0.00000	0.300
391	I.Shld HIFI Baf. int.	11.298	0.00000	0.00000	0.105
411	MLI on OB-Shield side	13.793	0.00000	0.00000	31.382
412	MLI on OB-Shield top	13.797	0.00000	0.00000	40.525
710	PACS-Top Optic	3.133	0.00000	0.00000	1.867
720	PACS-Spectrometer	3.131	0.00003	0.00000	2.110
725	PACS-Collimator	3.128	0.00000	0.00000	2.134
730	PACS-Photometer Optic	3.127	0.00000	0.00000	1.289
735	PACS-Internal	3.132	0.00000	0.00000	1.790
740	PACS-Lump	3.132	0.00000	0.00000	0.000
750	PACS-Chopper	3.136	0.00040	0.00000	0.113

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755    PACS-Grating Assy         3.135  0.00100  0.00000   0.769
760    PACS-Red  Detector        1.704  0.00000  0.00000   0.230
761    PACS-Red  Detect. CRE     3.143  0.00030  0.00000   0.000
765    PACS-Blue Detector        1.723  0.00013  0.00000   0.233
766    PACS-Blue Detect. CRE     3.143  0.00030  0.00000   0.000
770    PACS-Filter Wh. Blue      3.131  0.00004  0.00000   0.131
771    PACS-Filter Wh. Photo     3.127  0.00004  0.00000   0.131
775    PACS-Calib. Source 1      3.134  0.00032  0.00000   0.000
776    PACS-Calib. Source 2      3.137  0.00032  0.00000   0.000
780    PACS-Photometer Housi     3.129  0.00000  0.00000   0.989
781    PACS-Photometer CooPu     1.781  0.00220  0.00000   0.147
791    PACS-STST-Strut 1,1       8.951  0.00000  0.00000   0.318
792    PACS-STST-Strut 4,1       8.947  0.00000  0.00000   0.495
793    PACS-STST-Strut 5,1       8.951  0.00000  0.00000   0.247
794    PACS-Kevlar-Strut Red  1  2.597  0.00000  0.00000   0.000
795    PACS-Kevlar-Strut Blue 1  2.601  0.00000  0.00000   0.000
796    PACS-HarnessRed Det.Int1  2.533  0.00000  0.00000   0.000
797    PACS-HarnessBlueDet.Int1  2.539  0.00000  0.00000   0.000
798    PACS-HarnessBlue1.7->4,1  2.524  0.00000  0.00000   0.000
801    SPIRE PM JFET ENCL       11.147  0.01026  0.00000  10.520
802    SPIRE SM JFET ENCL       11.121  0.00282  0.00000   3.410
803    SPIRE Optical Bench       5.094  0.00000  0.00000   9.567
804    SPIRE RF Filter Box       5.099  0.00428  0.00000   0.469
805    SPIRE Beam St. Mech       5.095  0.00100  0.00000   0.351
806    SPIRE SMECm               5.095  0.00048  0.00000   0.415
807    SPIRE PM calibrator       5.095  0.00002  0.00000   0.000
808    SPIRE SM calibrator       9.361  0.00040  0.00000   0.000
809    SPIRE Shutter             5.094  0.00000  0.00000   0.000
810    SPIRE PM Detector en      1.795  0.00000  0.00000   0.451
811    SPIRE SM Detector en      1.772  0.00000  0.00000   0.269
812    SPIRE PM Detectors        1.741  0.00000  0.00000   0.398
813    SPIRE SM detector         1.741  0.00000  0.00000   0.252
816    SPIRE Cooler Pump         1.887  0.00183  0.00000   0.000
817    SPIRE Cooler shunt        1.725  0.00000  0.00000   0.000
818    SPIRE Cooler evap         1.741  0.00000  0.00000   0.000
819    SPIRE Cooler pump HS      1.773  0.00008  0.00000   0.000
820    SPIRE Cooler evap HS      1.724  0.00000  0.00000   0.000
900    HIFI 2K level             1.853  0.00014  0.00000   0.000
905    HIFI Harness 1 int.point  5.942  0.00036  0.00000   0.000
910    HIFI FPU Structure       11.120  0.01602  0.00000  99.127
912    HIFI L0 boundary node     1.847  0.00000  0.00000   0.000
913    HIFI L1 boundary node     5.817  0.00000  0.00000   0.000
914    HIFI Harness 2a int.poin 12.522  0.00036  0.00000   0.000
915    HIFI Harness 2b int.poin  8.862  0.00000  0.00000   0.000
920    HIFI Internal Assy.       5.821  0.00000  0.00000   0.023
5000   GHe tank outlet           1.700  0.00000  0.00000   0.000
5010   GHe PACS I/F 1 in         1.750  0.00000  0.00000   0.000
5011   GHe PACS I/F 1            1.955  0.00000  0.00000   0.000
5012   GHe PACS I/F 1            2.086  0.00000  0.00000   0.000
5013   GHe PACS I/F 1 out        2.214  0.00000  0.00000   0.000
5014   GHe PACS I/F 1/2          2.267  0.00000  0.00000   0.000
5020   GHe PACS I/F 2 in         2.311  0.00000  0.00000   0.000
5021   GHe PACS I/F 2            2.447  0.00000  0.00000   0.000
5022   GHe PACS I/F 2            2.530  0.00000  0.00000   0.000
5023   GHe PACS I/F 2 out        2.610  0.00000  0.00000   0.000
5024   GHe PACS I/F 2/3          2.645  0.00000  0.00000   0.000
5030   GHe PACS I/F 3 in         2.690  0.00000  0.00000   0.000
5031   GHe PACS I/F 3            2.751  0.00000  0.00000   0.000
5032   GHe PACS I/F 3            2.797  0.00000  0.00000   0.000
5033   GHe PACS I/F 3 out        2.839  0.00000  0.00000   0.000
5034   GHe PACS-SPIRE            2.858  0.00000  0.00000   0.000
5035   GHe PACS-SPIRE            2.881  0.00000  0.00000   0.000
5040   GHe SPIRE I/F in          3.027  0.00000  0.00000   0.000
```

```
5041      GHe SPIRE I/F              3.450   0.00000   0.00000   0.000
5042      GHe SPIRE I/F              3.740   0.00000   0.00000   0.000
5043      GHe SPIRE I/F out          3.977   0.00000   0.00000   0.000
5044      GHe SPIRE-HIFI             4.020   0.00000   0.00000   0.000
5045      GHe SPIRE-HIFI             4.035   0.00000   0.00000   0.000
5050      GHe HIFI I/F in            4.131   0.00000   0.00000   0.000
5051      GHe HIFI I/F               4.595   0.00000   0.00000   0.000
5052      GHe HIFI I/F               4.901   0.00000   0.00000   0.000
5053      GHe HIFI I/F out           5.429   0.00000   0.00000   0.000
5054      GHe Lev.2 OB               9.589   0.00000   0.00000   0.000
5055      GHe Lev.2 OB              10.819   0.00000   0.00000   0.000
5056      GHe Lev.2 OB              10.995   0.00000   0.00000   0.000
5057      GHe Lev.2 OB              11.073   0.00000   0.00000   0.000
5058      GHe Lev.2 OB              11.104   0.00000   0.00000   0.000
5059      GHe Lev.2 OB              11.112   0.00000   0.00000   0.000
5060      GHe Lev.2 OB              11.136   0.00000   0.00000   0.000
6059      X3 SI Harness 59         11.972   0.00406   0.00000   0.000
6069      X3 JF Harness 69         18.422   0.00040   0.00000   0.000
9999      Ambient Air             293.000   0.00000   0.00000   0.000
```

+EQM6:CTCE

NODE	LABEL	T	QI	QR	C
900	Vacuumtight Plate	290.453	0.00000	0.00000	6968.004
1100	Radiation shield 2	23.199	0.00000	0.00000	6.448
1200	Radiation shield 1	6.381	0.00000	0.00000	0.243
1310	RS1 cyl. MLI	8.670	0.00000	0.00000	0.000
1320	RS1 disc MLI	8.670	0.00000	0.00000	0.000
1410	RS2 cyl. MLI	274.852	0.00000	0.00000	0.000
1420	RS2 disc MLI	277.418	0.00000	0.00000	0.000
1500	Mirror&Support	5.268	0.00000	0.00000	1.176
2000	CTA-Shroud Dewar	4.200	0.00000	0.00000	0.000
2001	GHe Shroud 1500 out	5.095	0.00000	0.00000	0.000
2002	GHe Shroud 1200 out	6.230	0.00000	0.00000	0.000
2003	GHe Shroud 1100 out	22.355	0.00000	0.00000	0.000
2004	GHe Shroud 900 out	198.652	0.00000	0.00000	0.000
9999	AMBIENT	293.000	0.00000	0.00000	0.000

```
Heat Balance for PAYLOAD incl. Instrument Shield MLI
====================================================
                      Level 0: from Aux. Tank into instruments      -15.555 [mW]
                      Level 2: from spatial framework into OB         -0.696 [mW]
           Level 1/2: from Aux. Tank into OB via ventline wall        -0.061 [mW]
                 Level 2: from HS1 into OB via ventline wall           0.164 [mW]
                            Level 2: via harness into OB              27.226 [mW]
         via radiation from HS1 upper bulkhead onto Instrument MLI     0.244 [mW]
             via radiation from Cryostat cavity onto OB lower side     5.132 [mW]
                    via radiation from HS1-baffle into payload         0.007 [mW]
                    via radiation from HS2-baffle into payload         0.023 [mW]
                    via radiation from HS3-baffle into payload         1.507 [mW]
                     via radiation from CTA mirror into payload       -0.017 [mW]
             via radiation from CVV-LOU-Window onto HIFI-Baffle       19.928 [mW]
                via radiation from CVV-LOU-Window onto HIFI-FPU       14.494 [mW]
                     Vent line cooling power (out of payload)        102.289 [mW]
            Transferred by convection from PL-ventline on helium     102.318 [mW]
                                 total dissipation of PACS             5.070 [mW]
                                total dissipation of SPIRE            21.167 [mW]
                                 total dissipation of HIFI            16.867 [mW]
                                Harness dissipation on OB              4.462 [mW]
                          Payload Heat Imbalance (shall be 0)         -2.308 [mW]


Heat Balance for Main Tank Ventline
===================================
                conducted and radiated into ventline attached to HS1      3203.507 [mW]
                conducted and radiated into ventline attached to HS2      5785.348 [mW]
             conducted and radiated into ventline attached to HS3 +Z     19166.795 [mW]
             conducted and radiated into ventline attached to HS3 -Z     19140.972 [mW]
                         conducted into ventline walls from CVV          56918.739 [mW]
                 conducted and radiated into line baf to HS 1                0.152 [mW]
             Main Tank Ventline cooling power (out of ventline)        104215.609 [mW]
                          Via convection into ventline walls          -104225.499 [mW]
                      Main Tank Ventline Imbalance (shall be 0)            -0.096 [mW]


Heat Balance for CTA-Cold Plate
===============================
                  Convective heat transfer onto CTA vacuumtight plate      1715.116 [mW]
                  Conducted from CVV into CTA vacuum tight plate           8341.075 [mW]
                       Radiated from Payload onto CTA mirror                  0.017 [mW]
              Radiated from HS-baffles onto CTA-Radiation Shield 1          48.658 [mW]
                          Cooling power of CTA-heatshields               10104.867 [mW]
                              CTCE Imbalance (shall be 0)                    -0.001 [mW]


Heat Balance for whole Cryostat including Payload,Ventlines and CTCE
===================================================================
                    Convective heat transfer onto external walls        114255.055 [mW]
                     total heat transferred on gaseous helium           114422.765 [mW]
                      evaporation power in main and aux. tank              2087.178 [mW]
                            Total istrument power dissipation               43.104 [mW]
                    total main & auxiliary tank heater power              2014.000 [mW]
                        heater power of CVV lower bulkhead HTR               0.000 [mW]
                        total harness dissipation within system            19.601 [mW]
                             Cooling power of CTCE-shrouds               10104.867 [mW]
                        Cryostat total imbalance (shall be 0)             -178.183 [mW]


Heat Balance for Main Tank
==========================
                          Main tank dissipation + heater power           2000.000 [mW]
                                 radiated from aux. tank                     0.000 [mW]
                             conducted from spatial framework              29.525 [mW]
                                transferred through MLI                     9.744 [mW]
                                    conducted from rest                     0.290 [mW]
                        radiated from spatial framework and HSs             0.077 [mW]
                        conducted from main tank ventline wall              0.000 [mW]
                                 radiated from payload                      0.000 [mW]
                                total heat into main tank                2039.636 [mW]
```

```
Heat Balance for Auxiliary Tank
===============================
                            Aux. tank dissipation + heater power      14.000 [mW]
                                  heat from Ti-heads via mech. I/F      2.214 [mW]
                                           radiated from Main tank      0.000 [mW]
                          radiated from spatial framework and HSs       0.015 [mW]
                                      conducted from payload L0        15.555 [mW]
                                      conducted from payload L2         0.061 [mW]
                                           radiated from payload        0.011 [mW]
                                    conducted from filling tube         0.007 [mW]
                                  radiated from MLI filling tube       15.678 [mW]
                                       total heat into Aux. tank       47.543 [mW]

Heat flows into Tanks
=====================

                                              Into Main Tank        2039.636 [mW]
                                              Into Aux. Tank          47.543 [mW]

Helium evaporation mass flow rates
==================================

                                             Out of Main Tank         97.497 [mg/s]
                                             Out of Aux. Tank          2.086 [mg/s]
              Out of external He- dewar for CTA-shroud cooling        10.000 [mg/s]
```

5.6   CTA Cold Plate Design 2

CTA Cold Plate Design 2 means: Mirror goldized (emissivity = 0.05)

The input parameters are compiled in Table 5-19 and a brief temperature results summary is given in Table 5-20. The complete ESATAN-output-file listing is appended for the 10 mg/s case. The respective node numbers and labels are referenced in the thermal design and thermal-mathematical model descriptions in § 4

Input parameter	
Main Tank temperature	4.2 K
EQM-aux. Tank temperature	1.7 K
External Hel dewar temp. for CTA-cold plate cooling	4.2 K
Main Tank heater power	2000 mW
EQM-auxiliary tank heater power	14 mW
CTA-cold plate He-mass flow rate	0 to 50 mg/s

Table 5-19:   Input parameters

Thermal node	Description	0 mg/s	1 mg/s	10 mg/s	50 mg/s
900	Vacuum tight plate	292 K	292 K	291 K	289 K
1100	Radiation Shield 2	250 K	187 K	23 K	10 K
1200	Radiation Shield 1	200 K	106 K	6 K	5 K
1500	**Mirror (goldized)**	193 K	54 K	5 K	4.7 K
371 - 381	HOB	15 K	11 K	11 K	11 K

Table 5-20:   Temperature results summary, CTA Cold Plate Design 2

```
EUROPEAN  SPACE  AGENCY  THERMAL  ANALYSIS  NETWORK
(VERSION 8.5.0)                          PAGE     1
  8 MAY 2002                                          11:17:27
EQM7


##############################################################################
#  EQM0:  CTA Cold Plate, goldized Mirror (emissivity = 0.05)
#         CTA-ventline-cooling switched on
#
#  Main Tank heater power:        2000 mW
#  Aux. Tank heater power:          14 mW
#  CTA-shroud mass flow rate:       10 mg/s
#
##############################################################################




    NODE                       LABEL        T        QI        QR        C

        9999       AMBIENT                293.000   0.00000   0.00000     0.000
           1       MAIN TANK                4.200   0.00000   2.00000     0.000
           2       AUX TANK                 1.700   0.00000   0.01400     0.000
           5       Ti-head       lo   5    11.288   0.00000   0.00000    71.093
           6       belt fitting  lo   6    10.679   0.00000   0.00000    63.263
           7       strut tank end lo  7     4.359   0.00000   0.00000    21.851
           8       Ti-head       up   8    11.044   0.00000   0.00000    69.026
           9       belt fitting  up   9    10.434   0.00000   0.00000    61.244
          10       strut tank end up  10    4.349   0.00000   0.00000    21.798
          12       HS 1 BULK 12            10.597   0.00000   0.00000    14.055
          13       HS 2 BULK 13            22.974   0.00000   0.00000   140.014
          14       HS 3 BULK +Z 14        119.554   0.00000   0.00000  2767.946
          15       HS 3 BULK -Z 15        119.521   0.00000   0.00000  2767.305
          22       HS 1 CYL 22             10.523   0.00000   0.00000    44.747
          23       HS 2 CYL 23             21.961   0.00000   0.00000   330.299
          24       HS 3 CYL +Z 24          97.602   0.00000   0.00000  6858.571
          25       HS 3 CYL -Z 25          97.501   0.00000   0.00000  6849.271
          32       HS 1 CONE 32            15.538   0.00000   0.00000    91.795
          33       HS 2 CONE 33            37.974   0.00000   0.00000  1507.537
          34       HS 3 CONE +Z 34        142.245   0.00000   0.00000  7724.445
          35       HS 3 CONE -Z 35        142.451   0.00000   0.00000  7724.445
          42       HS 1 HIFI Baf. int.     25.641   0.00000   0.00000     2.928
          52       HS 1 HIFI Baf. ext.     32.963   0.00000   0.00000     2.671
          53       HS 2 HIFI Baf.          57.545   0.00000   0.00000    10.611
          54       HS 3 HIFI Baf.         175.170   0.00000   0.00000    45.556
          62       HS 1 Tele BAF           15.565   0.00000   0.00000     0.346
          63       HS 2 Tele BAF           38.160   0.00000   0.00000     5.535
          64       HS 3 Tele BAF          142.152   0.00000   0.00000    81.063
         101       MLI MAIN TANK LO 101     5.168   0.00000   0.00000    15.688
         105       MLI MAIN TANK CY 105     4.735   0.00000   0.00000    43.340
         106       MLI MAIN TANK UP 106    37.055   0.00000   0.00000   112.492
         112       MLI HS 1 BULK 112       20.320   0.00000   0.00000    39.941
         113       MLI HS 2 BULK 113      115.109   0.00000   0.00000   381.970
         114       MLI HS 3 BULK +Z 114   287.451   0.00000   0.00000   706.439
         115       MLI HS 3 BULK -Z 115   287.428   0.00000   0.00000   706.380
         122       MLI HS 1 CYL 122        19.254   0.00000   0.00000   122.992
         123       MLI HS 2 CYL 123        93.733   0.00000   0.00000   969.199
         124       MLI HS 3 CYL +Z 124    286.648   0.00000   0.00000  2100.791
         125       MLI HS 3 CYL -Z 125    285.591   0.00000   0.00000  2093.041
         132       MLI HS 1 CONE 132       51.483   0.00000   0.00000   249.737
         133       MLI HS 2 CONE 133      137.735   0.00000   0.00000  1125.105
         134       MLI HS 3 CONE +Z 134   287.131   0.00000   0.00000  1701.105
         135       MLI HS 3 CONE -Z 135   287.113   0.00000   0.00000  1700.994
```

```
 440    filling tube    440     271.450   0.00000   0.00000      0.000
 441    filling tube    441     252.163   0.00000   0.00000      0.000
 442    filling tube    442     245.464   0.00000   0.00000      0.000
 443    filling tube    443     242.406   0.00000   0.00000      0.000
 447    empty tube      447      15.525   0.00000   0.00000      0.000
 452    empty tube      452      10.862   0.00000   0.00000      0.000
 502    line baf to HS1 502       4.201   0.00000   0.00000      0.000
 642    MLI filling tube 642    120.412   0.00000   0.00000      0.766
 643    MLI filling tube 643    118.994   0.00000   0.00000      0.743
 647    MLI filling tube 647     25.806   0.00000   0.00000      1.244
 652    MLI filling tube 652     23.540   0.00000   0.00000      0.459
1000    HS 1 SUSP BOLT  1000     19.625   0.00000   0.00000     48.203
2000    HS 2 SUSP BOLT  2000     67.886   0.00000   0.00000    229.721
3000    HS 3 SUSP BOLT  3000    189.807   0.00000   0.00000    737.487
4001    CVV lower bulk  4001    292.764   0.00000   0.00000   4399.463
4002    CVV lower bulk  4002    292.771   0.00000   0.00000   4399.490
4003    CVV lower bulk  4003    292.771   0.00000   0.00000   4399.491
4004    CVV lower bulk  4004    292.764   0.00000   0.00000   4399.462
4005    CVV lower bulk  4005    292.750   0.00000   0.00000   4399.407
4006    CVV lower bulk  4006    292.749   0.00000   0.00000   4399.403
4007    CVV lower bulk  4007    292.758   0.00000   0.00000   4399.441
4008    CVV lower bulk  4008    292.760   0.00000   0.00000   4399.449
4011    CVV lower bulk  4011    292.707   0.00000   0.00000   1668.975
4012    CVV lower bulk  4012    292.740   0.00000   0.00000   1669.025
4013    CVV lower bulk  4013    292.741   0.00000   0.00000   1669.027
4014    CVV lower bulk  4014    292.717   0.00000   0.00000   1668.991
4015    CVV lower bulk  4015    292.654   0.00000   0.00000   1668.893
4016    CVV lower bulk  4016    292.654   0.00000   0.00000   1668.893
4017    CVV lower bulk  4017    292.704   0.00000   0.00000   1668.971
4018    CVV lower bulk  4018    292.700   0.00000   0.00000   1668.964
4031    CVV cyl lower   4031    292.552   0.00000   0.00000  13706.669
4032    CVV cyl lower   4032    292.660   0.00000   0.00000  13708.029
4033    CVV cyl lower   4033    292.663   0.00000   0.00000  13708.065
4034    CVV cyl lower   4034    292.598   0.00000   0.00000  13707.254
4035    CVV cyl lower   4035    292.392   0.00000   0.00000  13704.644
4036    CVV cyl lower   4036    292.396   0.00000   0.00000  13704.703
4037    CVV cyl lower   4037    292.568   0.00000   0.00000  13706.868
4038    CVV cyl lower   4038    292.536   0.00000   0.00000  13706.470
4041    CVV cyl upper   4041    292.688   0.00000   0.00000  19514.499
4042    CVV cyl upper   4042    292.693   0.00000   0.00000  19514.587
4043    CVV cyl upper   4043    292.627   0.00000   0.00000  19513.406
4044    CVV cyl upper   4044    292.210   0.00000   0.00000  19505.918
4045    CVV cyl upper   4045    289.657   0.00000   0.00000  19460.027
4046    CVV cyl upper   4046    289.651   0.00000   0.00000  19459.930
4047    CVV cyl upper   4047    292.181   0.00000   0.00000  19505.386
4048    CVV cyl upper   4048    292.597   0.00000   0.00000  19512.871
4051    CVV upper bulk  4051    292.614   0.00000   0.00000  19049.217
4052    CVV upper bulk  4052    292.528   0.00000   0.00000  19047.699
4053    CVV upper bulk  4053    292.520   0.00000   0.00000  19047.557
4054    CVV upper bulk  4054    292.573   0.00000   0.00000  19048.502
4055    CVV upper bulk  4055    292.493   0.00000   0.00000  19047.100
4056    CVV upper bulk  4056    292.448   0.00000   0.00000  19046.306
4057    CVV upper bulk  4057    292.583   0.00000   0.00000  19048.663
4058    CVV upper bulk  4058    292.620   0.00000   0.00000  19049.321
4061    CVV/CTA flange  4061    291.279   0.00000   0.00000    322.774
4062    CVV/CTA flange  4062    291.256   0.00000   0.00000    322.767
4063    CVV/CTA flange  4063    291.252   0.00000   0.00000    322.766
4064    CVV/CTA flange  4064    291.262   0.00000   0.00000    322.769
4065    CVV/CTA flange  4065    291.241   0.00000   0.00000    322.763
4066    CVV/CTA flange  4066    291.232   0.00000   0.00000    322.760
4067    CVV/CTA flange  4067    291.267   0.00000   0.00000    322.771
4068    CVV/CTA flange  4068    291.282   0.00000   0.00000    322.775
4071    CVV flange disc 4071    290.808   0.00000   0.00000   1526.232
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4072      CVV flange disc  4072    290.801  0.00000  0.00000  1526.223
4073      CVV flange disc  4073    290.799  0.00000  0.00000  1526.220
4074      CVV flange disc  4074    290.800  0.00000  0.00000  1526.221
4075      CVV flange disc  4075    290.794  0.00000  0.00000  1526.213
4076      CVV flange disc  4076    290.793  0.00000  0.00000  1526.211
4077      CVV flange disc  4077    290.803  0.00000  0.00000  1526.225
4078      CVV flange disc  4078    290.809  0.00000  0.00000  1526.233
4090      CVV Lo window            289.838  0.00000  0.00000    15.602
4631      SUSP TI  lo   4631       282.780  0.00000  0.00000    84.266
4632      SUSP TI  lo   4632       282.879  0.00000  0.00000    84.277
4633      SUSP TI  lo   4633       282.882  0.00000  0.00000    84.277
4634      SUSP TI  lo   4634       282.823  0.00000  0.00000    84.271
4635      SUSP TI  lo   4635       282.632  0.00000  0.00000    84.250
4636      SUSP TI  lo   4636       282.637  0.00000  0.00000    84.251
4637      SUSP TI  lo   4637       282.794  0.00000  0.00000    84.268
4638      SUSP TI  lo   4638       282.765  0.00000  0.00000    84.265
4641      SUSP TI  up   4641       282.905  0.00000  0.00000    84.279
4642      SUSP TI  up   4642       282.910  0.00000  0.00000    84.280
4643      SUSP TI  up   4643       282.849  0.00000  0.00000    84.273
4644      SUSP TI  up   4644       282.466  0.00000  0.00000    84.233
4645      SUSP TI  up   4645       280.117  0.00000  0.00000    83.982
4646      SUSP TI  up   4646       280.112  0.00000  0.00000    83.982
4647      SUSP TI  up   4647       282.438  0.00000  0.00000    84.230
4648      SUSP TI  up   4648       282.822  0.00000  0.00000    84.271
4731      CABLE PLUG   4731        281.498  0.00073  0.00000    93.529
4732      CABLE PLUG   4732        291.587  0.00000  0.00000    97.057
4733      CABLE PLUG   4733        291.590  0.00000  0.00000    97.058
4734      CABLE PLUG   4734        291.526  0.00000  0.00000    97.036
4735      CABLE PLUG   4735        291.321  0.00000  0.00000    96.964
4736      CABLE PLUG   4736        292.396  0.00000  0.00000    97.340
4737      CABLE PLUG   4737        292.568  0.00000  0.00000    97.400
4738      CABLE PLUG   4738        283.622  0.00010  0.00000    94.271
6051      X2 SI Harness 51         245.203  0.00073  0.00000     0.000
6052      X2 SI Harness 52         205.933  0.00073  0.00000     0.000
6053      X2 SI Harness 53         162.824  0.00073  0.00000     0.000
6054      X2 SI Harness 54         113.891  0.00073  0.00000     0.000
6055      X2 SI at HS1  55          50.555  0.00250  0.00000     0.000
6056      X3 SI Harness 56          45.785  0.00250  0.00000     0.000
6057      X3 SI Harness 57          39.274  0.00250  0.00000     0.000
6058      X3 SI Harness 58          29.875  0.00250  0.00000     0.000
6061      X2 JF Harness 61         246.338  0.00010  0.00000     0.000
6062      X2 JF Harness 62         205.932  0.00010  0.00000     0.000
6063      X2 JF Harness 63         161.455  0.00010  0.00000     0.000
6064      X2 JF Harness 64         110.710  0.00010  0.00000     0.000
6065      X2 JF at HS1  65          42.547  0.00024  0.00000     0.000
6066      X3 JF Harness 66          38.113  0.00024  0.00000     0.000
6067      X3 JF Harness 67          32.991  0.00024  0.00000     0.000
6068      X3 JF Harness 68          26.770  0.00024  0.00000     0.000
9999      AMBIENT                  293.000  0.00000  0.00000     0.000
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+EQM7:CRYO:V

NODE	LABEL		T	QI	QR	C
201	OSS-TUBE	201	4.200	0.00000	0.00000	0.000
202	BAFFLE LO	202	4.200	0.00000	0.00000	0.000
203	BAFFLE UP	203	4.200	0.00000	0.00000	0.000
204	1ST HS	204	10.523	0.00000	0.00000	0.000
205	2ND HS	205	21.961	0.00000	0.00000	0.000
206	3RD HS +z	206	97.602	0.00000	0.00000	0.000
207	3RD HS -z	207	97.501	0.00000	0.00000	0.000
210	VENT VESSEL	210	209.894	0.00000	0.00000	0.000
212	BAFFLE - 1ST HS	212	4.201	0.00000	0.00000	0.000
251	TANK HE-OUT	251	4.200	0.00000	0.00000	0.000
252	OSS HE-OUT	252	4.200	0.00000	0.00000	0.000
253	BAFFLE LO HE-OUT	253	4.200	0.00000	0.00000	0.000
254	BAFFLE UP HE-OUT	254	4.200	0.00000	0.00000	0.000
255	1ST HS HE-OUT	255	10.523	0.00000	0.00000	0.000
256	2ND HS HE-OUT	256	21.942	0.00000	0.00000	0.000
257	3RD HS HE-OUT	257	97.552	0.00000	0.00000	0.000
260	VESSEL HE-OUT	260	209.894	0.00000	0.00000	0.000
262	BAF - HS1 HE-OUT	262	4.200	0.00000	0.00000	0.000
296	HEATER WALL	296	293.000	0.00000	0.00000	0.000
297	HEATER HE-OUT	297	209.894	0.00000	0.00000	0.000

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+EQM7:CRYO:PLM

NODE	LABEL	T	QI	QR	C
310	Instr. Shield Cyl.	11.294	0.00000	0.00000	7.635
311	Instr. Shield Top	11.306	0.00000	0.00000	9.886
315	Instr. Shield Baffle	11.322	0.00000	0.00000	0.638
320	Vline wall Tank-PACS	1.753	0.00000	0.00000	0.007
321	Vline wall PACS I/F 1	2.376	0.00000	0.00000	0.000
322	Vline wall PACS I/F 1	2.618	0.00000	0.00000	0.000
323	Vline wall PACS I/F 1	2.456	0.00000	0.00000	0.000
324	Vline wall PACSI/F1/2	2.286	0.00000	0.00000	0.003
325	Vline wall PACSI/F1/2	2.314	0.00000	0.00000	0.013
326	Vline wall PACS I/F 2	2.681	0.00000	0.00000	0.000
327	Vline wall PACS I/F 2	2.831	0.00000	0.00000	0.000
328	Vline wall PACS I/F 2	2.741	0.00000	0.00000	0.000
329	Vline wall PACSI/F2/3	2.649	0.00000	0.00000	0.005
330	Vline wall PACSI/F2/3	2.714	0.00000	0.00000	0.002
331	Vline wall PACS I/F 3	2.847	0.00000	0.00000	0.000
332	Vline wall PACS I/F 3	2.952	0.00000	0.00000	0.000
333	Vline wall PACS I/F 3	2.904	0.00000	0.00000	0.000
334	Vline wall PACS-SPIRE	2.860	0.00000	0.00000	0.005
335	Vline wall PACS-SPIRE	2.882	0.00000	0.00000	0.007
336	Vline wall PACS-SPIRE	3.035	0.00000	0.00000	0.008
337	Vline wall SPIRE	3.951	0.00000	0.00000	0.000
338	Vline wall SPIRE	4.484	0.00000	0.00000	0.000
339	Vline wall SPIRE	4.232	0.00000	0.00000	0.000
340	Vline wall SPIRE-HIFI	4.022	0.00000	0.00000	0.011
341	Vline wall SPIRE-HIFI	4.036	0.00000	0.00000	0.014
342	Vline wall SPIRE-HIFI	4.136	0.00000	0.00000	0.017
343	Vline wall HIFI	5.033	0.00000	0.00000	0.000
344	Vline wall HIFI	5.559	0.00000	0.00000	0.000
345	Vline wall HIFI	5.851	0.00000	0.00000	0.000
346	Vline Lev.2 OB	9.808	0.00000	0.00000	0.065
347	Vline Lev.2 OB	10.884	0.00000	0.00000	0.189
348	Vline Lev.2 OB	11.005	0.00000	0.00000	0.076
349	Vline Lev.2 OB	11.078	0.00000	0.00000	0.122
350	Vline Lev.2 OB	11.107	0.00000	0.00000	0.072
351	Vline Lev.2 OB	11.113	0.00000	0.00000	0.212
352	Vline Lev.2 OB	11.138	0.00000	0.00000	0.109
371	Opt. Bench +Z	11.024	0.00000	0.00000	7.232
372	Opt. Bench +Z -Y	10.956	0.00000	0.00000	6.562
373	Opt. Bench +Z mid	11.037	0.00000	0.00000	17.012
374	Opt. Bench +Z +Y	11.054	0.00000	0.00000	2.757
375	Opt. Bench -Y	11.107	0.00000	0.00000	12.612
376	Opt. Bench centre	11.089	0.00000	0.00000	30.360
377	Opt. Bench +Y	11.093	0.00000	0.00000	6.686
378	Opt. Bench -Z -Y	11.141	0.00000	0.00000	6.895
379	Opt. Bench -Z mid	11.117	0.00000	0.00000	17.377
380	Opt. Bench -Z +Y	11.118	0.00000	0.00000	2.804
381	Opt. Bench -Z	11.114	0.00000	0.00000	7.407
390	I.Shld HIFI Baf. ext.	11.371	0.00000	0.00000	0.300
391	I.Shld HIFI Baf. int.	11.299	0.00000	0.00000	0.105
411	MLI on OB-Shield side	13.793	0.00000	0.00000	31.383
412	MLI on OB-Shield top	13.797	0.00000	0.00000	40.526
710	PACS-Top Optic	3.133	0.00000	0.00000	1.867
720	PACS-Spectrometer	3.131	0.00003	0.00000	2.110
725	PACS-Collimator	3.128	0.00000	0.00000	2.134
730	PACS-Photometer Optic	3.127	0.00000	0.00000	1.288
735	PACS-Internal	3.132	0.00000	0.00000	1.790
740	PACS-Lump	3.132	0.00000	0.00000	0.000
750	PACS-Chopper	3.136	0.00040	0.00000	0.113

```
755    PACS-Grating Assy        3.135   0.00100   0.00000     0.769
760    PACS-Red  Detector       1.704   0.00000   0.00000     0.230
761    PACS-Red  Detect. CRE    3.143   0.00030   0.00000     0.000
765    PACS-Blue Detector       1.723   0.00013   0.00000     0.233
766    PACS-Blue Detect. CRE    3.143   0.00030   0.00000     0.000
770    PACS-Filter Wh. Blue     3.131   0.00004   0.00000     0.131
771    PACS-Filter Wh. Photo    3.127   0.00004   0.00000     0.131
775    PACS-Calib. Source 1     3.134   0.00032   0.00000     0.000
776    PACS-Calib. Source 2     3.136   0.00032   0.00000     0.000
780    PACS-Photometer Housi    3.129   0.00000   0.00000     0.989
781    PACS-Photometer CooPu    1.781   0.00220   0.00000     0.147
791    PACS-STST-Strut 1,1      8.952   0.00000   0.00000     0.318
792    PACS-STST-Strut 4,1      8.948   0.00000   0.00000     0.495
793    PACS-STST-Strut 5,1      8.951   0.00000   0.00000     0.248
794    PACS-Kevlar-Strut Red  1 2.597   0.00000   0.00000     0.000
795    PACS-Kevlar-Strut Blue 1 2.601   0.00000   0.00000     0.000
796    PACS-HarnessRed Det.Int1 2.533   0.00000   0.00000     0.000
797    PACS-HarnessBlueDet.Int1 2.539   0.00000   0.00000     0.000
798    PACS-HarnessBlue1.7->4,1 2.524   0.00000   0.00000     0.000
801    SPIRE PM JFET ENCL      11.147   0.01026   0.00000    10.522
802    SPIRE SM JFET ENCL      11.122   0.00282   0.00000     3.411
803    SPIRE Optical Bench      5.095   0.00000   0.00000     9.568
804    SPIRE RF Filter Box      5.099   0.00428   0.00000     0.469
805    SPIRE Beam St. Mech      5.095   0.00100   0.00000     0.351
806    SPIRE SMECm              5.095   0.00048   0.00000     0.415
807    SPIRE PM calibrator      5.095   0.00002   0.00000     0.000
808    SPIRE SM calibrator      9.361   0.00040   0.00000     0.000
809    SPIRE Shutter            5.095   0.00000   0.00000     0.000
810    SPIRE PM Detector en     1.795   0.00000   0.00000     0.451
811    SPIRE SM Detector en     1.772   0.00000   0.00000     0.269
812    SPIRE PM Detectors       1.741   0.00000   0.00000     0.398
813    SPIRE SM detector        1.741   0.00000   0.00000     0.252
816    SPIRE Cooler Pump        1.887   0.00183   0.00000     0.000
817    SPIRE Cooler shunt       1.725   0.00000   0.00000     0.000
818    SPIRE Cooler evap        1.741   0.00000   0.00000     0.000
819    SPIRE Cooler pump HS     1.773   0.00008   0.00000     0.000
820    SPIRE Cooler evap HS     1.724   0.00000   0.00000     0.000
900    HIFI 2K level            1.853   0.00014   0.00000     0.000
905    HIFI Harness 1 int.point 5.942   0.00036   0.00000     0.000
910    HIFI FPU Structure      11.121   0.01602   0.00000    99.146
912    HIFI L0 boundary node    1.847   0.00000   0.00000     0.000
913    HIFI L1 boundary node    5.817   0.00000   0.00000     0.000
914    HIFI Harness 2a int.poin 12.522  0.00036   0.00000     0.000
915    HIFI Harness 2b int.poin  8.863  0.00000   0.00000     0.000
920    HIFI Internal Assy.      5.821   0.00000   0.00000     0.023
5000   GHe tank outlet          1.700   0.00000   0.00000     0.000
5010   GHe PACS I/F 1 in        1.750   0.00000   0.00000     0.000
5011   GHe PACS I/F 1           1.955   0.00000   0.00000     0.000
5012   GHe PACS I/F 1           2.086   0.00000   0.00000     0.000
5013   GHe PACS I/F 1 out       2.214   0.00000   0.00000     0.000
5014   GHe PACS I/F 1/2         2.267   0.00000   0.00000     0.000
5020   GHe PACS I/F 2 in        2.311   0.00000   0.00000     0.000
5021   GHe PACS I/F 2           2.447   0.00000   0.00000     0.000
5022   GHe PACS I/F 2           2.530   0.00000   0.00000     0.000
5023   GHe PACS I/F 2 out       2.610   0.00000   0.00000     0.000
5024   GHe PACS I/F 2/3         2.645   0.00000   0.00000     0.000
5030   GHe PACS I/F 3 in        2.690   0.00000   0.00000     0.000
5031   GHe PACS I/F 3           2.751   0.00000   0.00000     0.000
5032   GHe PACS I/F 3           2.797   0.00000   0.00000     0.000
5033   GHe PACS I/F 3 out       2.839   0.00000   0.00000     0.000
5034   GHe PACS-SPIRE           2.858   0.00000   0.00000     0.000
5035   GHe PACS-SPIRE           2.880   0.00000   0.00000     0.000
5040   GHe SPIRE I/F in         3.027   0.00000   0.00000     0.000
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5041      GHe SPIRE I/F            3.449   0.00000   0.00000   0.000
5042      GHe SPIRE I/F            3.740   0.00000   0.00000   0.000
5043      GHe SPIRE I/F out        3.977   0.00000   0.00000   0.000
5044      GHe SPIRE-HIFI           4.020   0.00000   0.00000   0.000
5045      GHe SPIRE-HIFI           4.035   0.00000   0.00000   0.000
5050      GHe HIFI I/F in          4.131   0.00000   0.00000   0.000
5051      GHe HIFI I/F             4.595   0.00000   0.00000   0.000
5052      GHe HIFI I/F             4.902   0.00000   0.00000   0.000
5053      GHe HIFI I/F out         5.429   0.00000   0.00000   0.000
5054      GHe Lev.2 OB             9.590   0.00000   0.00000   0.000
5055      GHe Lev.2 OB            10.820   0.00000   0.00000   0.000
5056      GHe Lev.2 OB            10.996   0.00000   0.00000   0.000
5057      GHe Lev.2 OB            11.074   0.00000   0.00000   0.000
5058      GHe Lev.2 OB            11.105   0.00000   0.00000   0.000
5059      GHe Lev.2 OB            11.113   0.00000   0.00000   0.000
5060      GHe Lev.2 OB            11.136   0.00000   0.00000   0.000
6059      X3 SI Harness 59        11.973   0.00406   0.00000   0.000
6069      X3 JF Harness 69        18.423   0.00040   0.00000   0.000
9999      Ambient Air            293.000   0.00000   0.00000   0.000
```

+EQM7:CTCE

NODE	LABEL	T	QI	QR	C
900	Vacuumtight Plate	290.453	0.00000	0.00000	6968.004
1100	Radiation shield 2	23.199	0.00000	0.00000	6.448
1200	Radiation shield 1	6.381	0.00000	0.00000	0.243
1310	RS1 cyl. MLI	8.669	0.00000	0.00000	0.000
1320	RS1 disc MLI	8.669	0.00000	0.00000	0.000
1410	RS2 cyl. MLI	274.852	0.00000	0.00000	0.000
1420	RS2 disc MLI	277.418	0.00000	0.00000	0.000
1500	Mirror&Support	5.268	0.00000	0.00000	1.176
2000	CTA-Shroud Dewar	4.200	0.00000	0.00000	0.000
2001	GHe Shroud 1500 out	5.095	0.00000	0.00000	0.000
2002	GHe Shroud 1200 out	6.229	0.00000	0.00000	0.000
2003	GHe Shroud 1100 out	22.354	0.00000	0.00000	0.000
2004	GHe Shroud 900 out	198.651	0.00000	0.00000	0.000
9999	AMBIENT	293.000	0.00000	0.00000	0.000

```
Heat Balance for PAYLOAD incl. Instrument Shield MLI
====================================================
                      Level 0: from Aux. Tank into instruments     -15.556 [mW]
                     Level 2: from spatial framework into OB         -0.699 [mW]
         Level 1/2: from Aux. Tank into OB via ventline wall         -0.061 [mW]
                Level 2: from HS1 into OB via ventline wall           0.164 [mW]
                               Level 2: via harness into OB          27.226 [mW]
       via radiation from HS1 upper bulkhead onto Instrument MLI      0.244 [mW]
          via radiation from Cryostat cavity onto OB lower side       5.132 [mW]
                via radiation from HS1-baffle into payload            0.007 [mW]
                via radiation from HS2-baffle into payload            0.023 [mW]
                via radiation from HS3-baffle into payload            1.507 [mW]
                via radiation from CTA mirror into payload           -0.001 [mW]
         via radiation from CVV-LOU-Window onto HIFI-Baffle          19.928 [mW]
           via radiation from CVV-LOU-Window onto HIFI-FPU           14.494 [mW]
                  Vent line cooling power (out of payload)          102.299 [mW]
          Transferred by convection from PL-ventline on helium      102.328 [mW]
                                 total dissipation of PACS            5.070 [mW]
                                total dissipation of SPIRE           21.167 [mW]
                                 total dissipation of HIFI           16.867 [mW]
                                   Harness dissipation on OB          4.462 [mW]
                         Payload Heat Imbalance (shall be 0)         -2.324 [mW]


Heat Balance for Main Tank Ventline
===================================
             conducted and radiated into ventline attached to HS1     3203.508 [mW]
             conducted and radiated into ventline attached to HS2     5785.343 [mW]
          conducted and radiated into ventline attached to HS3 +Z    19166.800 [mW]
          conducted and radiated into ventline attached to HS3 -Z    19140.978 [mW]
                        conducted into ventline walls from CVV       56918.808 [mW]
               conducted and radiated into line baf to HS 1             0.152 [mW]
           Main Tank Ventline cooling power (out of ventline)       104215.684 [mW]
                          Via convection into ventline walls       -104225.575 [mW]
                   Main Tank Ventline Imbalance (shall be 0)            -0.096 [mW]


Heat Balance for CTA-Cold Plate
===============================
              Convective heat transfer onto CTA vacuumtight plate      1715.117 [mW]
               Conducted from CVV into CTA vacuum tight plate          8341.082 [mW]
                     Radiated from Payload onto CTA mirror                0.001 [mW]
           Radiated from HS-baffles onto CTA-Radiation Shield 1         48.658 [mW]
                         Cooling power of CTA-heatshields            10104.859 [mW]
                             CTCE Imbalance (shall be 0)                 -0.001 [mW]


Heat Balance for whole Cryostat including Payload,Ventlines and CTCE
===================================================================
                 Convective heat transfer onto external walls      114255.138 [mW]
                  total heat transferred on gaseous helium         114422.843 [mW]
                  evaporation power in main and aux. tank            2087.182 [mW]
                        Total istrument power dissipation              43.104 [mW]
                  total main & auxiliary tank heater power           2014.000 [mW]
                    heater power of CVV lower bulkhead HTR               0.000 [mW]
                    total harness dissipation within system            19.601 [mW]
                          Cooling power of CTCE-shrouds             10104.859 [mW]
                    Cryostat total imbalance (shall be 0)             -178.182 [mW]


Heat Balance for Main Tank
==========================
                       Main tank dissipation + heater power          2000.000 [mW]
                               radiated from aux. tank                  0.000 [mW]
                         conducted from spatial framework             29.528 [mW]
                              transferred through MLI                  9.744 [mW]
                                  conducted from rest                  0.290 [mW]
                  radiated from spatial framework and HSs              0.077 [mW]
                 conducted from main tank ventline wall                0.000 [mW]
                             radiated from payload                     0.000 [mW]
                           total heat into main tank                2039.638 [mW]
```

```
Heat Balance for Auxiliary Tank
===============================
                           Aux. tank dissipation + heater power      14.000 [mW]
                                  heat from Ti-heads via mech. I/F     2.215 [mW]
                                          radiated from Main tank      0.000 [mW]
                     radiated from spatial framework and HSs          0.015 [mW]
                                   conducted from payload L0          15.556 [mW]
                                   conducted from payload L2           0.061 [mW]
                                        radiated from payload          0.011 [mW]
                                  conducted from filling tube          0.007 [mW]
                            radiated from MLI filling tube            15.678 [mW]
                                 total heat into Aux. tank            47.544 [mW]


Heat flows into Tanks
=====================


                                            Into Main Tank         2039.638 [mW]
                                            Into Aux. Tank           47.544 [mW]


Helium evaporation mass flow rates
==================================


                                           Out of Main Tank          97.497 [mg/s]
                                           Out of Aux. Tank           2.086 [mg/s]
                   Out of external He- dewar for CTA-shroud cooling  10.000 [mg/s]
```

5.7   Transient Thermal Analysis

5.7.1   Cool-down of CTCE-Cryostat, Design Concept 2

The cool-down of the CTCE-cryostat (design concept 2) as defined in § 4.5.2.2 is thermally analysed. Herewith the following initial conditions are assumed:

- EQM-Cryostat already cooled-down and in thermodynamic equilibrium

- Main tank heater power = 2000 mW and kept constant

- Auxiliary tank heater power = 14 mW and kept constant

- Instruments permanently dissipating at "average orbit" conditions

- CTCE helium mass flow rate = zero at t < 0 (cooling off)

- CTCE helium mass flow rate = 300 mg/s at t =0 (cooling switched on) and kept constant

Thermal analysis is carried out for a period of 24 hours. It revealed that this is not sufficient to reach steady-state conditions.

The resulting cool-down temperature charts are depicted in Figure 5-1 thru Figure 5-7. The corresponding nodal description can be found in § 4.5.2.2. Note that only the shroud and heatshield 2 is ventline-cooled (Figure 5-2). Heatshield 1 and 3 are only cooled by radiation.

Cool down of CTA vapor-cooled Shroud
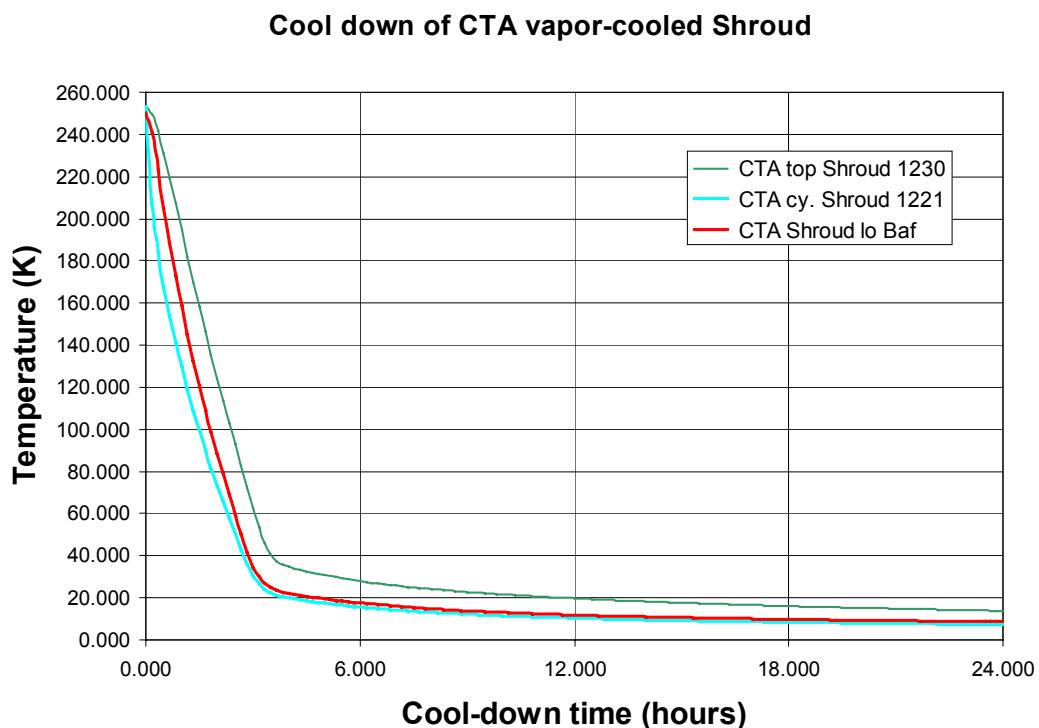
Figure 5-1:   Temperature evolution of CTA-shrouds during cool-down of CTA

Cool down of CTA Heatshields
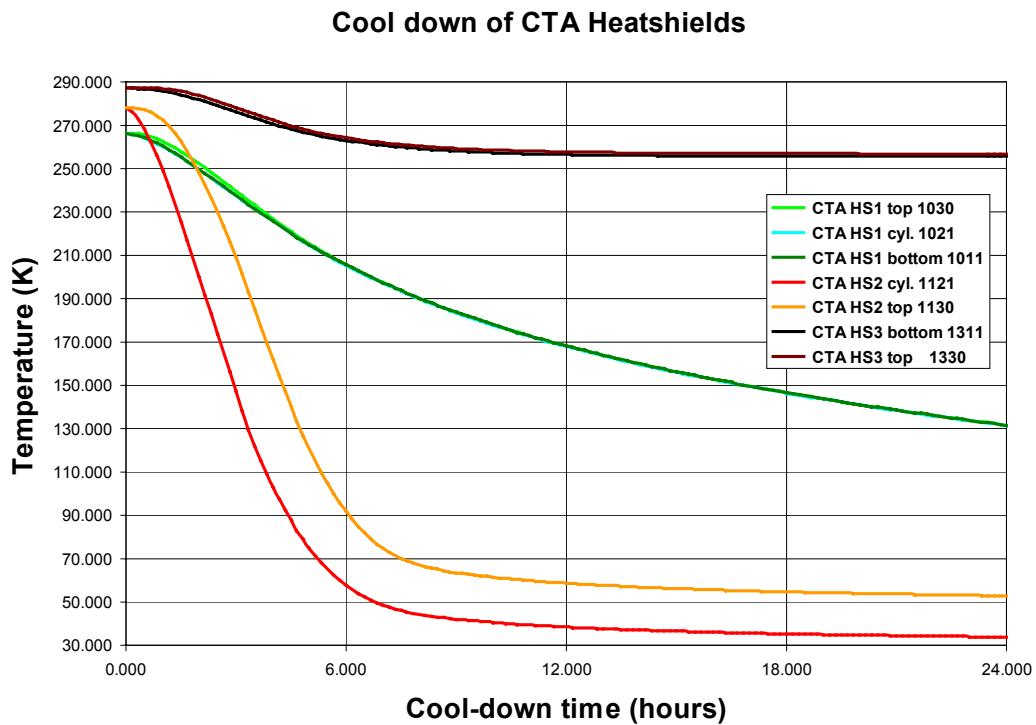
Figure 5-2:   Temperature evolution of CTA-heatshields during cool-down of CTA

Cool down of Reflector and brackets
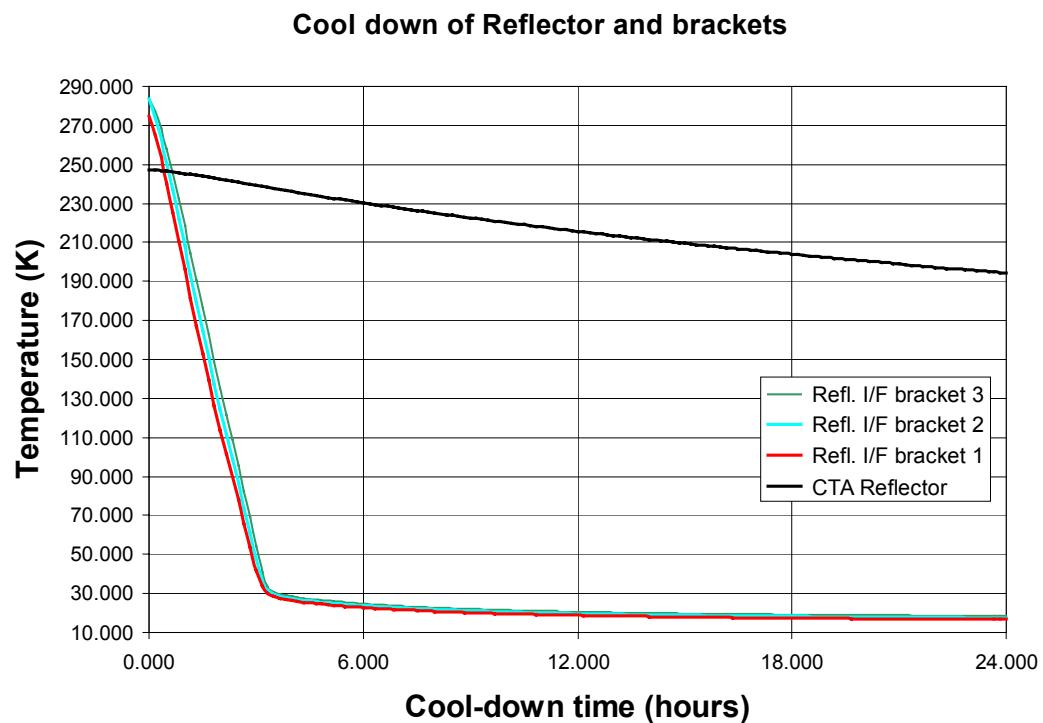
Figure 5-3:   Temperature evolution of CTA-reflector during cool-down of CTA
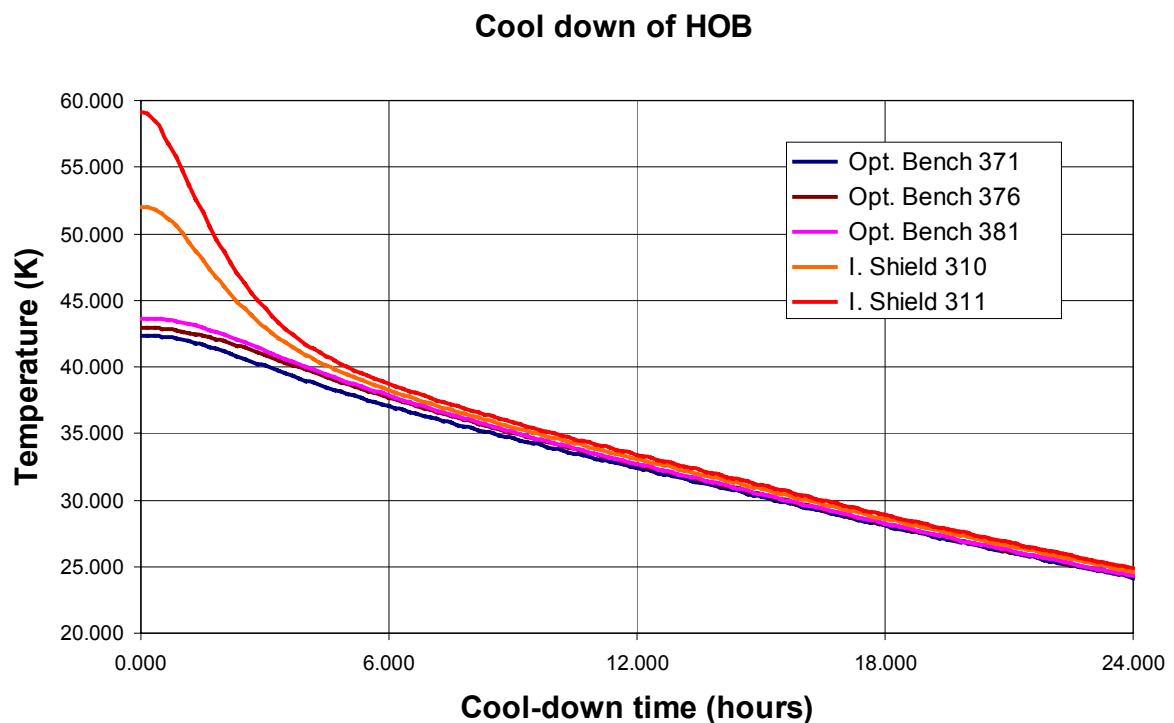
Cool down of HOB

Figure 5-4:   Temperature evolution of HERSCHEL Optical Bench during cool-down of CTA

Cool down of Instrument Level 1 Interfaces
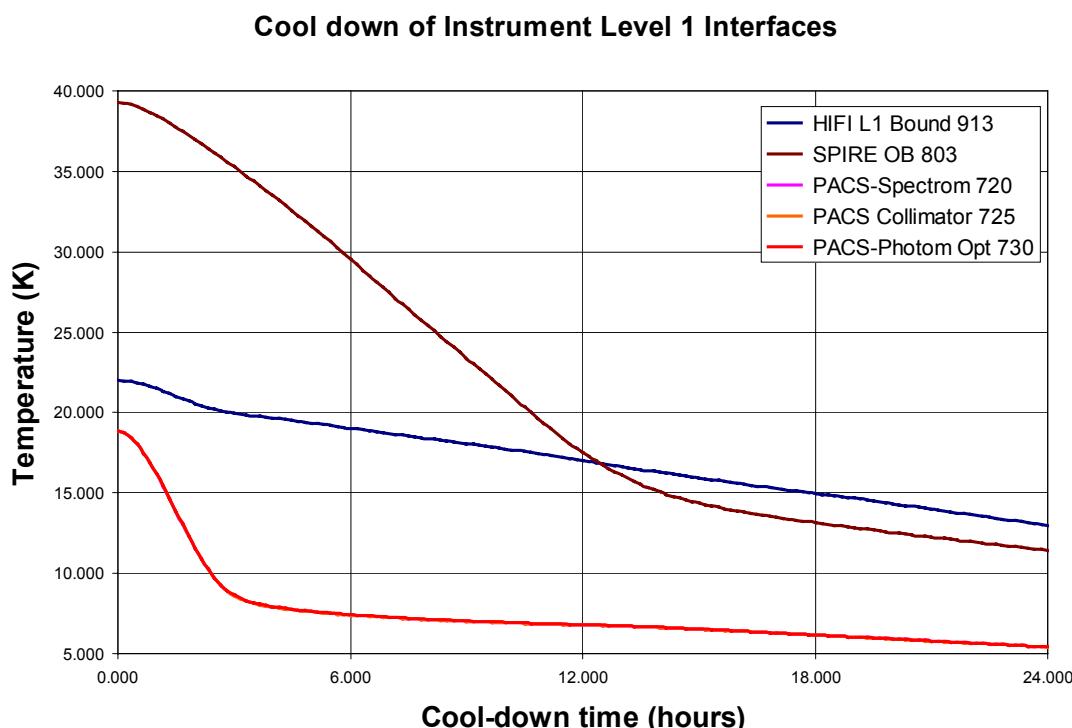
Figure 5-5:   Temperature evolution of Instruments during cool-down of CTA

Cool down of Instrument Level 0 Interfaces
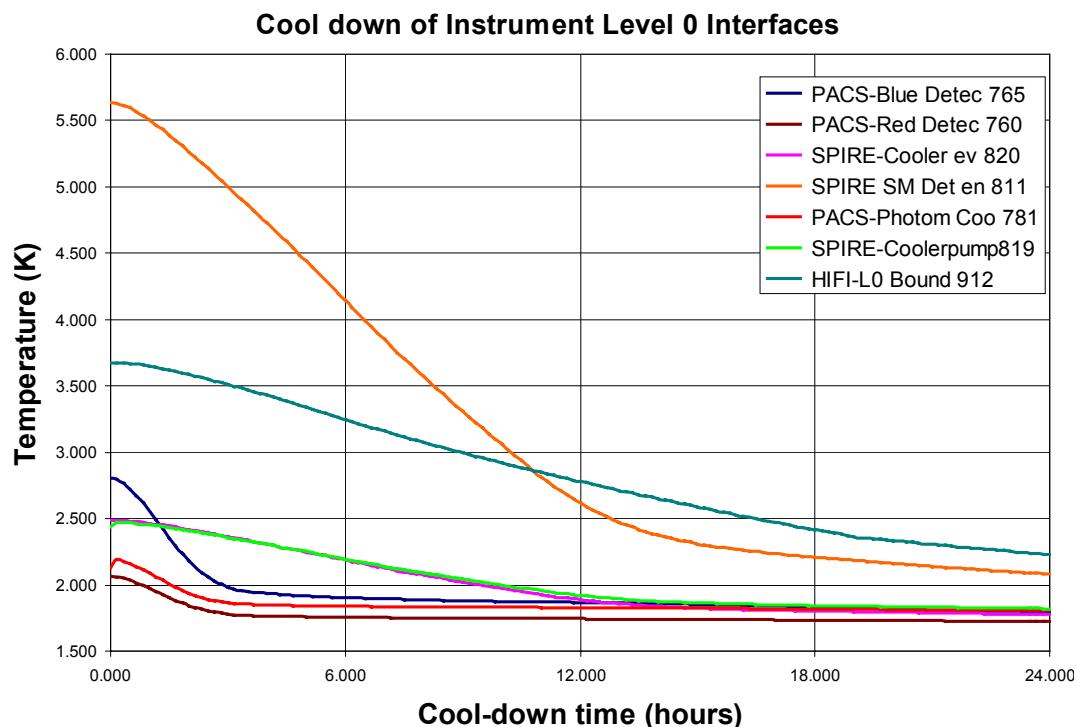
Figure 5-6:   Temperature evolution of Instruments during cool-down of CTA

Cool down of Instrument Level 2 Interfaces
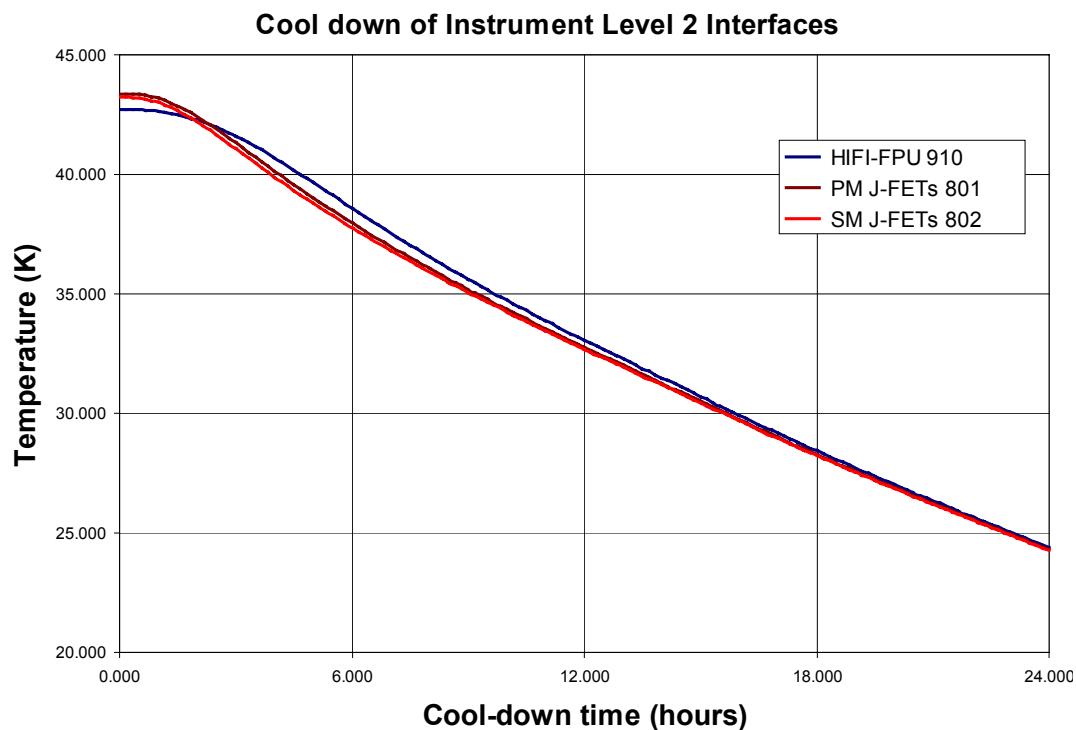
Figure 5-7:   Temperature evolution of Instruments during cool-down of CTA

5.7.2   Cool-down of CTA Cold Plate Design

The cool-down of the CTA cold plate (design 1 with black mirror) as defined in § 4.6 is thermally analysed. Herewith the following initial conditions are assumed:

- EQM-Cryostat already cooled-down and in thermodynamic equilibrium

- Main tank heater power = 2000 mW and kept constant

- Auxiliary tank heater power = 14 mW and kept constant

- Instruments permanently dissipating at "average orbit" conditions

- CTA helium mass flow rate = zero at t < 0 (cooling off)

- CTA helium mass flow rate = 50 mg/s at t =0 (cooling switched on) and kept constant

Thermal analysis is carried out for a period of 24 hours. It revealed that this is not sufficient to reach steady-state conditions. The resulting cool-down temperature charts are depicted in Figure 5-8 thru Figure 5-11.

Cool down of CTA cold plate
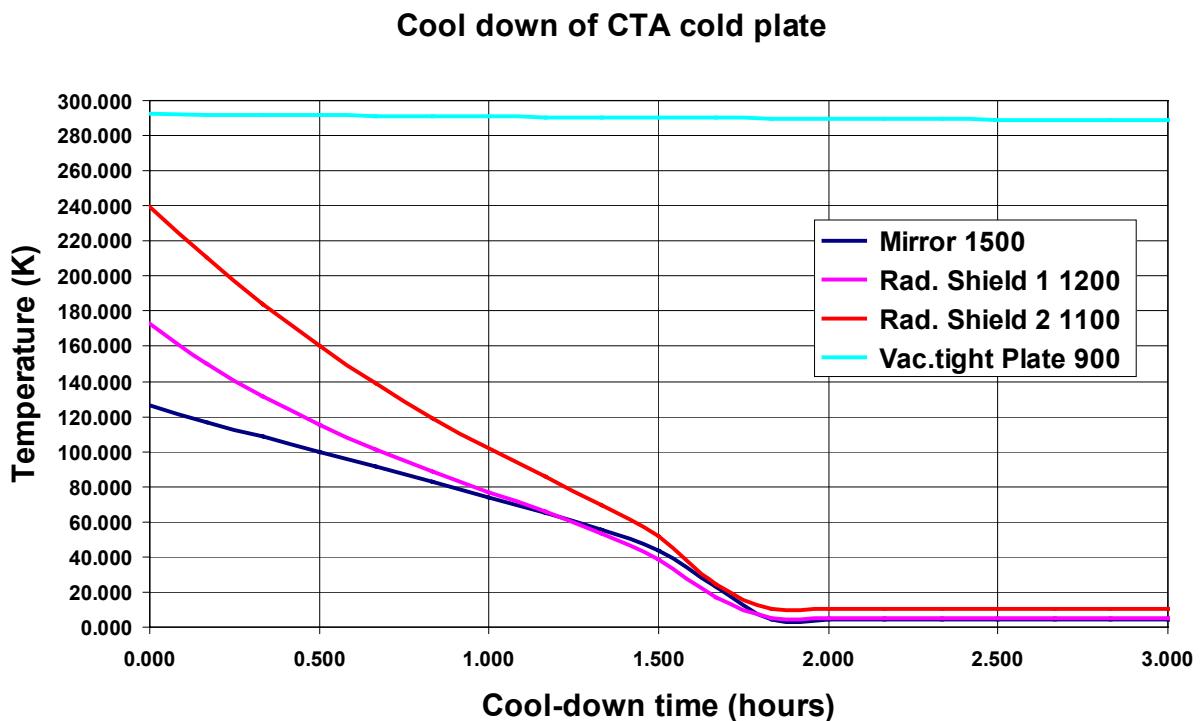
Figure 5-8:   Temperature evolution of CTA during cool-down of CTA
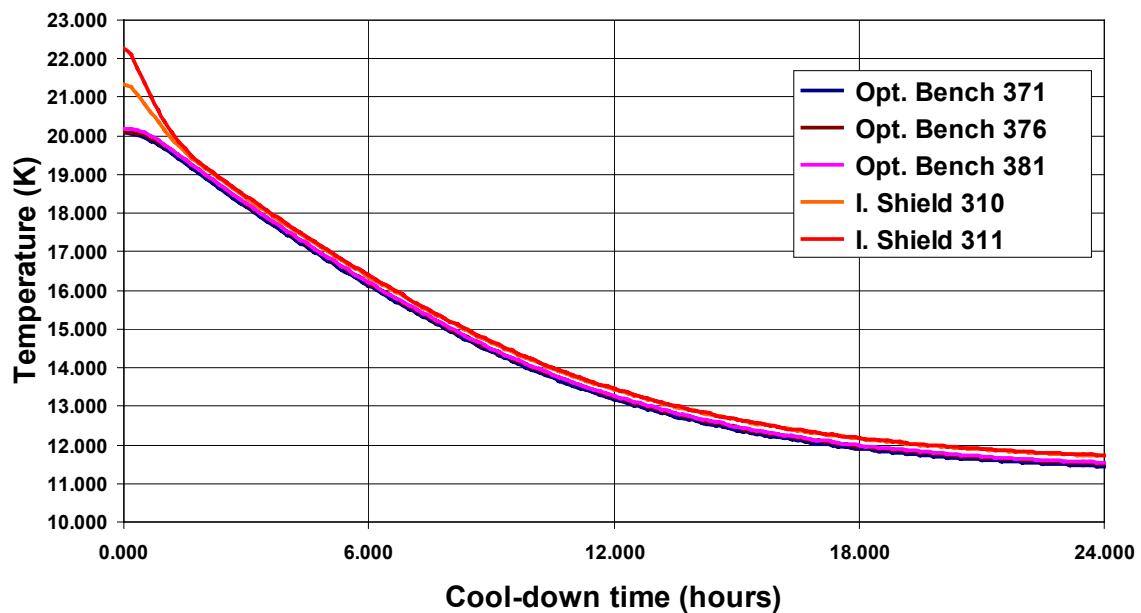
Cool down of HOB

Figure 5-9:   Temperature evolution of HERSCHEL Optical Bench during cool-down of CTA

Cool down of Instrument Level 0 Interfaces
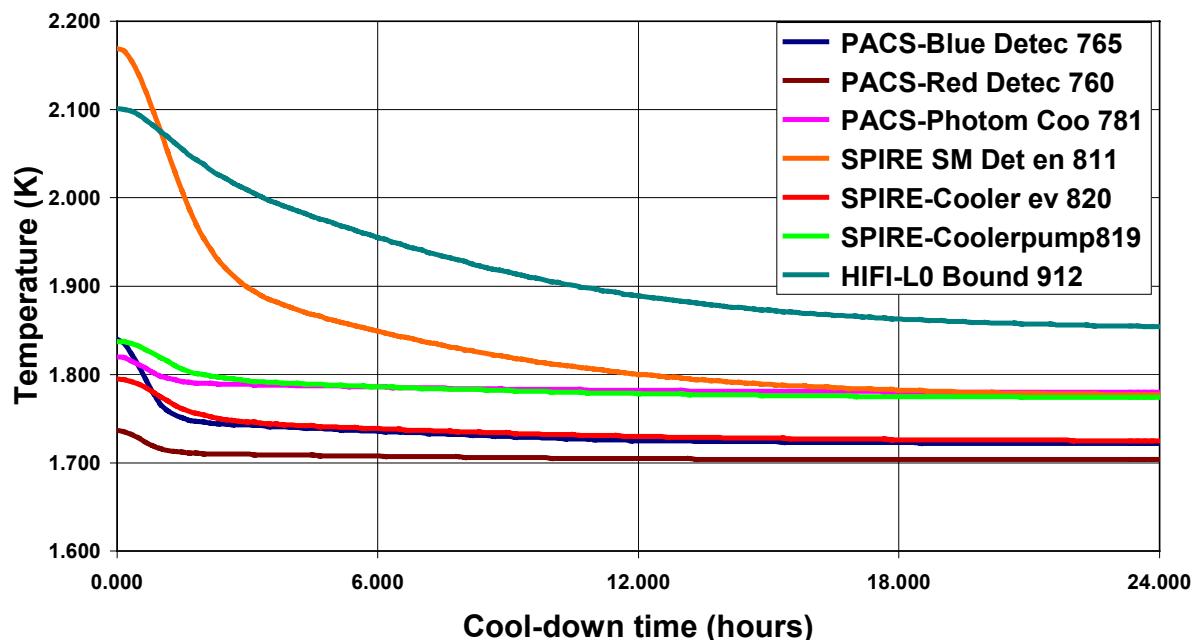
Figure 5-10:   Temperature evolution of Instruments during cool-down of CTA

Cool down of Instrument Level 2 Interfaces
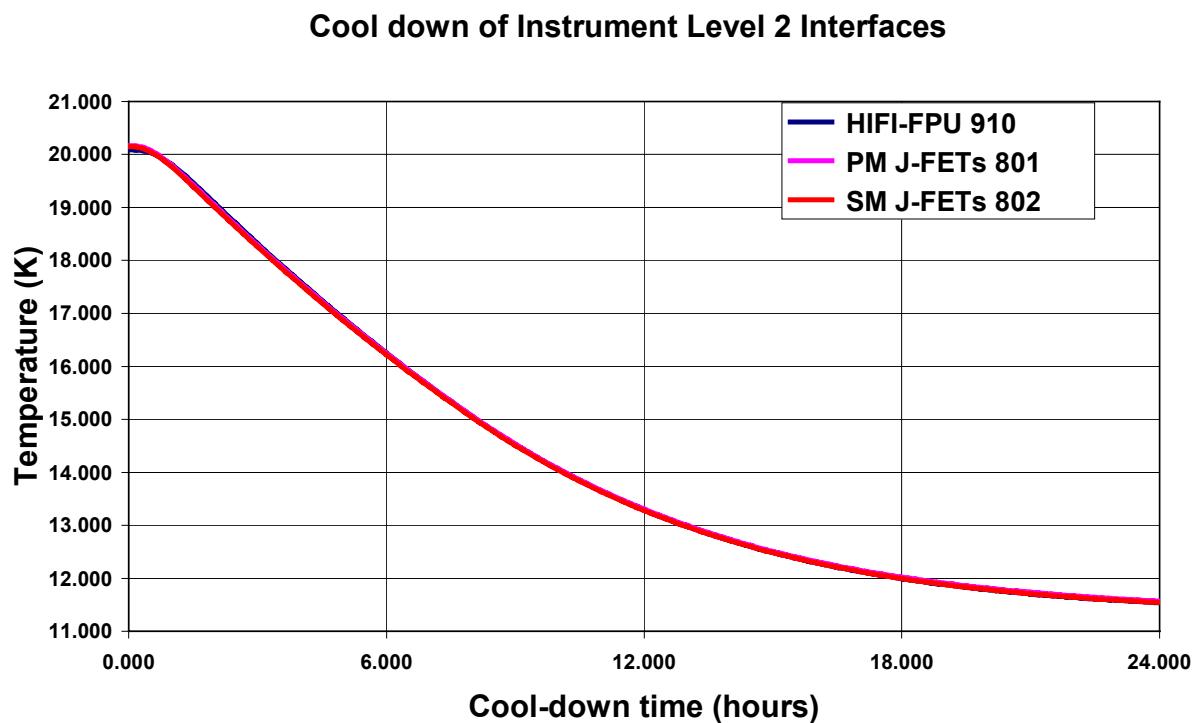
Figure 5-11:   Temperature evolution of Instruments during cool-down of CTA

6 Ventline Pressure Drop Analysis

6.1 Pressure Drop within EQM-Auxiliary Tank Ventline

The pressure drop is assumed to be identical to the HPLM pressure drop (see RD 03). For this reason no extra analysis is performed for the EQM.

6.2 Pressure Drop within the EQM-main Tank Ventline

The pressure in the main tank is 990 mbar corresponding to the saturation pressure at 4.2 K (analysis value). A simplified MATCHCAD-analysis has been performed assuming a linear temperature increase of the helium from 4.2 K to 210 K (at node 297) along a total pipe length of approx. 13 m.

The result is a pressure drop of 19 mbar which is absolutely not critical.

6.3 Pressure Drop within the CTCE Ventline

The pressure in the external dewar is 990 mbar corresponding to the saturation pressure at 4.2 K (analysis value). A simplified MATCHCAD-analysis has been performed assuming a linear temperature increase of the helium from 4.2 K to 60K (at node 2018) along a total pipe length of approx. 16 m.

The result is a pressure drop of only 2.5 mbar which is also absolutely not critical.

7   Conclusions

It has been demonstrated by thermal analysis that the EQM-configuration as proposed in this report is feasible. All thermal requirements in order to achieve the thermal EQM-testobjectives can be fulfilled. The HERSCHEL OB with instruments can be controlled within the required flight-representative temperature ranges. It has also been shown that the required flight-representative mass flow rate through the payload-ventline can be adjusted by adequate heating of the EQM-auxiliary tank. It has also been demonstrated that the main-tank-venting/heating concept is suitable to obtain the adequate heatshield cooling.

It is not necessary to cover the EQM-aux. Tank with MLI blankets which saves a lot of costs. Blank or alodine-coated low-emissive alu (e = 0.05) is sufficient.

It has been shown that the EQM.-auxiliary tank mounting devices underyling this report are adequate. The heat flow across this interface into the aux. tank is very small.

The 4.5 K requirement at the SPIRE level-1 interface has not yet been agreed by ASED. In order to reduce the temperature, there is still a little margin in the mass flow rate. In the analysis 2.0 mg/s are considered corresponding to 14 mW heater power, but 2.1 mg/s are required. Thus, the 2.1 mg/s will be obtained by slightly increasing the heater power, resulting in a small temperature reduction at the L1-interface (#803).

Both proposed CTCE design concepts with and without MLI are feasible from thermal point of view. The reflector needs not to be ventline-cooled during instrument testing when mounted on interface brackets or onto a separate optical bench connected to the ventline as proposed in this report. Transient analysis, however, indicated that weeks of cool-down would be required to reach thermodynamic equilibrium for the reflector. For this reason it is recommended to provide an extra cooling loop for the reflector in order to enhance cool-down. For this purpose a LN2-system would be adequate. To stabilize the reflector at a desired temperature level it is recommended to switch off the LN2-cooling and control the temperature with the help of an electrical heater-system. This would be significantly less comprehensive than bya temperature or mass-flow-controlled ventline system.

From thermal point of view the "vacuum-tight cover plate design" with ventline-cooled mirror and heatshields and MLI in-between is also feasible. Mirror temperatures down to 5 K could be adjusted. To achieve this an adequate thermal isolation between the shields as well as of the ventline from the vacuum-tight plate would be required. Anyway the vacuum-tight plate design without reflector and black body target stands out for its simplicity compared to the CTCE-cryostat design concepts enabling considerable cost savings.

Critical Aspects:

Since the EQM- auxiliary tank is smaller in diameter than the HERSCHEL-OB the overall thermal links connecting the L0- tank interfaces with the instrument L0-interfaces differ from the PFM-design. It is recommended to modify only the rigid parts and to use the same flexible links as for the PFM.

Anyway the thermal performance of the EQM-L0-links shall be at least the same as for the PFM. This can be achieved by an adequate dimensioning of cross-sections and flange areas. This is judged to

be uncritical with regard to mass and mechanical load constraints (EQM sees no vibration tests), however, might be critical due to limited space and due to AIV constraints.

The filling tube should be thoroughly wrapped in MLI since it has been shown by thermal analysis of this report as well as in the ISO-project that the heat flow into the HOB and Aux.-tank is significant.

The CTCE-shroud that is ventline-cooled below 5 K must be thermally very well coupled to the shroud baffle as shown in this report. This baffle is mandatory in order to prevent the instruments from IR-illumination emitted by HS 2 and HS 3 of the HERSCHEL cryostat.

For the same reason the radiation shields of the "vacuum-tight cover plate design" shall be designed as "pots" in order to close the circumferential gaps between the heatshields of the EQM-CVV upper bulkhead.

The ventline pipes of the "vacuum-tight cover plate design" shall be made of low-conductive stainless steel and shall be thermally isolated from the vacuum-tight plate that is at ambient temperature.

E N D   O F   D O C U M E N T

Quantity	Name	Dep./Comp.	Quantity	Name	Dep./Comp.
1	Alberti von Mathias Dr.	ED 544		Runge Axel	OTN/TN 94
	Barlage Bernhard	ED 62		Sachsse Bernt	EC 34
	Bayer Thomas	ED 532		Sagner Udo	OTN/TN 64
1	Faas Horst	ED 516		Schäffler Johannes	OTN/TN 64
	Grasl Andreas	OTN/TN 64		Schink Dietmar	ED 522
	Grasshoff Brigitte	ED 511	1	Schlosser Christian	OTN/TN 64
1	Hartmann Hans Dr.	ED 172	1	Schabbauer Paul Dr.	OTN/ED171
1	Hauser Armin	ED 541		Schweickert Gunn	ED 544
1	Hinger Jürgen	ED 541		Steininger Eric	ED 522
1	Hohn Rüdiger	ED 531	1	Stritter Rene	ED 61
1	Hölzle Edgar	ED 171		Tenhaeff Dieter	ED 544
1	Huber Johann	ED 532		Thörmer Klaus-Horst Dr.	OTN/ED 37
	Hund Walter	ED 556		Wagner Adalbert	OTN/IP 35
1	Idler Siegmund	ED 521	1	Wagner Klaus	ED 541
	Ivády von András	EC 32		Wietbrock, Walter	ED 511
1	Jahn Gerd Dr.	ED 541	1	Wilz Eberhard	OTN/ED 37
1	Kalde Clemens	ED 513		Wöhler Hans	ED 544
	Kameter Rudolf	OTN/TN 64		Ziegler Fred	OTN/ED 522
	Knoblauch August	ED 51		Zipf Ludwig	EC 32
	Koelle Markus	ED 533			
1	Kroeker Jürgen	ED 515			
	Lamprecht Ernst	OTN/TN 72			
	Lang Jürgen	ED 556			
1	Langfermann Michael	ED 531			
	Mack Paul	OTN/TN 64		Pastorino Michel	ASPI Resid.
1	Maier Hans-Ulrich	ED 61			
	Mauch Alfred	ED 544	1	Alcatel (on FTP-Server)	
1	Moritz Konrad Dr.	ED 37	1	ESTEC (on FTP-Server)	
	Müller Lutz	OTN/TN 64			
	Muhl Eckhard	OTN/TN 64			
	Peitzker Helmut	ED 37		APCO	
	Peltz Heinz-Willi	ED 515		MPGE	
	Peters, Gerhard	ED 533		RALA	
	Pietroboni Karin	ED 37		SRON	
	Puttlitz Joachim	OTN/ED 37			
	Raupp Helmut	ED 543			
	Rebholz Reinhold	ED 531			
	Reuß Friedhelm	ED 7			
1	Rühe Wolfgang	ED 3			