Title: **TMM Correlation for L0 Conductance Measurements**

CI-No: 121 144 -01

Prepared by: K. Wagner Wagner Date: 27.07.07

Checked by: J. Kroeker Kroeker 30.7.07

Product Assurance: R. Stritter 30.07.07

Configuration Control: W. Wietbrock 31.07.07

Project Management: Dr. W. Fricke Fricke 31/07/2007

Distribution: See Distribution List (last page)

Issue	Date	Page	Description of Change	Release
1	28.06.06	all	First Formal Issue	
1.1	26.06.07	22	Bullet “introduce Kapitza resistance also for in orbit conditions” deleted; some supplementary wording	
		25	**Figure 4.4-5** updated	
		20–26	Figure labels of sections 4.3 and 4.4 renamed	
		26	**Figure 4.4-7** updated	
			Table 4.4-1 updated (correction factors of last two columns)	
		27-28	Couplings reworked: correction factors updated, Kapitza resistances deleted	
		29	Bullet “introduce Kapitza resistance also for in orbit conditions” deleted	

Table of Content

Table of Figures

List of Tables

1 Scope

This technical note describes the TMM correlation of the L0 conductance measurement results obtained from the H-EPLM STM TB/TV qualification performed in the LSS chamber at ESTEC in October 2005 and a test performed outside the LSS with 90° tilted CVV in January 2006.

2 Reference Documents and Abbreviations

2.1 Reference Documents

RD 01	H-EPLM STM TB/TV Test Report, Doc.No.: HP-2-ASED-TR-0110,
RD 02	Evaluation of Instrument Thermal Interface Test Results, HP-2-ASED-RP-0180, Issue 1, dated 10.03.2006
RD 03	H-EPLM Thermal Model and Analysis, Doc.No.: HP-2-ASED-RP-0011
RD 04	H-EPLM TMM Issue 4.2 delivered with HP-2-ASED-EM-0547-05, dated 02.12.05

2.2 Relevant Temperature Sensor Nomenclature

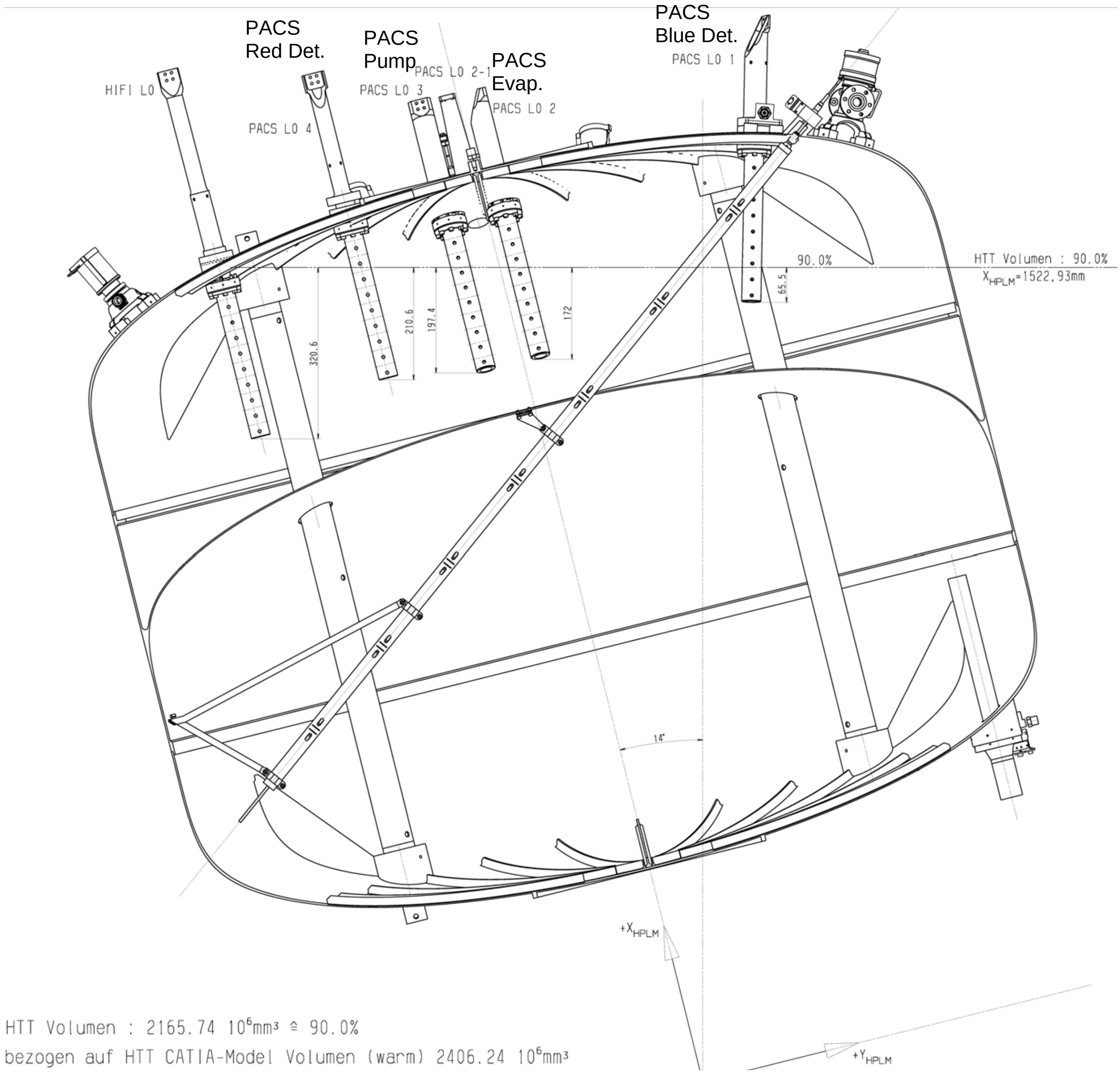
Sensor acronym	*Sensor Location*	*Type*
MT101	TH-HIFI-1, on L0 IF	C100
MT102	TH-HIFI-2, on L0 IF	C100
MT103	TH-HIFI-3, on L1 IF	C100
MT104	TH-HIFI-4, on L1 IF	C100
MT105	TH-HIFI-5, on FPU	C100
MT106	TH-HIFI-6, on FPU	C100
MT107	TH-HIFI-7, on FPU	Pt1000
MT108	TH-LOU-1, on LOU baseplate	Pt1000
MT109	TH-LOU-2, on LOU baseplate	Pt1000
MT110	TH-LOU-3, on LOU baseplate	Pt1000
MT201	TH-SPIRE-1, on detector L0 rigid pod	C100
MT202	TH-SPIRE-2, on detector L0 rigid pod	C100
MT203	TH-SPIRE-3, on cooler evaporator L0 rigid/open tank pod	C100
MT204	TH-SPIRE-4, on cooler evaporator L0 rigid/open tank pod	C100
MT205	TH-SPIRE-5, on cooler pump L0 rigid pod	C100
MT206	TH-SPIRE-6, on cooler pump L0 rigid pod	C100
MT207	TH-SPIRE-7, on SPIRE optical bench	C100
MT208	TH-SPIRE-8, on SPIRE optical bench	C100
MT213	TH-SPIRE-9, on SPIRE optical bench	Pt1000
MT250	TH-S-JFET-1, on S-J-FET baseplate	C100
MT251	TH-S-JFET-2, on S-J-FET baseplate	C100
MT252	TH-S-JFET-3, on S-J-FET baseplate	Pt1000
MT253	TH-P-JFET-1, on P-J-FET baseplate	C100
MT254	TH-P-JFET-2, on P-J-FET baseplate	C100
MT255	TH-P-JFET-3, on P-J-FET baseplate	Pt1000
MT301	TH-PACS-1, on Red Detector Assy (FPFPU.DET)	C100
MT302	TH-PACS-2, on Red Detector Assy (FPFPU.DET)	C100
MT303	TH-PACS-3, on Blue Detector Assy (FPFPU.BOL)	C100
MT304	TH-PACS-4, on Blue Detector Assy (FPFPU.BOL)	C100
MT305	TH-PACS-5, on cooler pump (FPFPU.COOL)	C100
MT306	TH-PACS-6, on cooler pump (FPFPU.COOL)	C100
MT307	TH-PACS-7, on cooler evaporator (FPFPU.COOL)	C100
MT308	TH-PACS-8, on cooler evaporator (FPFPU.COOL)	C100
MT309	TH-PACS-9, on L1-interface of Photometer optics	C100
MT310	TH-PACS-10, on L1-interface of Photometer optics	C100
MT311	TH-PACS-11, on L1-interface of collimator	C100
MT312	TH-PACS-12, on L1-interface of collimator	C100
MT313	TH-PACS-13, on L1-interface of Spectrometer housing	C100
MT314	TH-PACS-14, on L1-interface of Spectrometer housing	C100
MT315	TH-PACS-15, on FPU	Pt1000
T101	DLCM-1, tank lower side; -x-y; integrated in DLCM housing	C100
T102	DLCM-2, tank lower side; -x+y; integrated in DLCM housing	C100
T103	HTT lower side; -x+z-y; nearby outside	Pt1000

Sensor acronym	***Sensor Location***	***Type***
T104	DLCM-2, tank lower side; -x+y; integrated in DLCM housing	C100
T105	DLCM-1, tank lower side; -x-y; integrated in DLCM housing	C100
T106	HTT lower side; -x-z+y; nearby outside	C100
T107	HTT upper side; +x-z+y; nearby outside	C100
T111	HTT upper side; +x-y-z; integrated into PPS housing	C100
T112	HTT upper side; +x-y-z; integrated into PPS housing	C100
T113	Filling port end piece	C100
T114	Filling port end piece	C100
T202	OB Plate near PACS mounting foot (+z)	C100
T207	OB Plate near HIFI mounting foot (+z/-y)	Pt1000
T208	OB Plate near HIFI mounting foot (+z/-y)	C100
T211	Instrument Shield, close to HIFI	Pt1000
T212	Instrument Shield, close to PACS	C100
T213	Instrument Shield, close to SPIRE	C100
T221	L0 Cooling Strap 1; to PACS RED Detector	C100
T222	L0 Cooling Strap 2; to PACS Sorption Cooler Evaporator	C100
T223	L0 Cooling Strap 3; to PACS Sorption Cooler Pump	C100
T224	L0 Cooling Strap 4; to PACS BLUE Detector	C100
T225	L0 Cooling Strap 5; to SPIRE SM Detector enclosure	C100
T226	L0 Cooling Strap 6; to SPIRE Cooler Pump	C100
T227	L0 Cooling Strap 7; to SPIRE Cooler Evaporator	C100
T228	L0 Cooling Strap 8; to HIFI L0	C100
T231	L1 Ventline upstream strap 1 to PACS Phot.Optics (L1 Inlet)	C100
T232	L1 Ventline downstream strap 1 to PACS Phot.Optics	C100
T233	L1 Ventline downstream strap 2 to PACS Collimator	C100
T234	L1 Ventline downstream strap 3 to PACS Spect.Housing	C100
T235	L1 Ventline upstream strap 4 to SPIRE Optical Bench	C100
T236	L1 Ventline downstream strap 4 to SPIRE Optical Bench	C100
T237	L1 Ventline downstream strap 5 to HIFI interface (L1 outlet)	C100
T242	L1; on Strap 1 on PACS FPU Side	C100
T244	L1, on Strap 5 on HIFI FPU side	C100
T246	L3 Ventline to 6-JFET (JFET-Phot)	C100
T247	L3 Ventline to 2-JFET (JFET-Spec)	C100
T248	L1; on Strap 4 on SPIRE FPU side	C100
T249	On Spire 2-JFET (JFET-Spec)	Pt1000
T250	On Spire 2-JFET (JFET-Spec)	C100
T251	On Spire 6-JFET (JFET-Phot)	Pt1000
T252	On Spire 6-JFET (JFET-Phot)	C100
T253	OB Plate near SPIRE foot (center)	Pt1000
T254	OB Plate near SPIRE foot (center)	C100
T255	OB Plate near SPIRE foot (-z+y)	Pt1000
T256	OB Plate near SPIRE foot (-z+y)	C100
T258	OB Plate near SPIRE foot (-y-z)	C100

3 Test Conditions during L0 Performance Measurements

3.1 Conditions During L0 Performance Measurement in LSS (TP4)

The L0 measurement has been performed during the test phase TP4 on 23.October 2005 applying different electrical heating power on the L0 MTD’s. The spacecraft was tilted by 14° and the helium filling level was about 90%. Inside the helium tank the interfaces of the L0 internal pods with the liquid is shown in **Figure 3.1-1**. Only the HIFI I/F is completely immersed with liquid helium, all others are partly immersed. The distances of the internal pods between HTT I/F and He II liquid line are given in **Figure 3.1-2**. Those distances are used in the TMM for calculation of the L0 I/F conductance values during TP4.



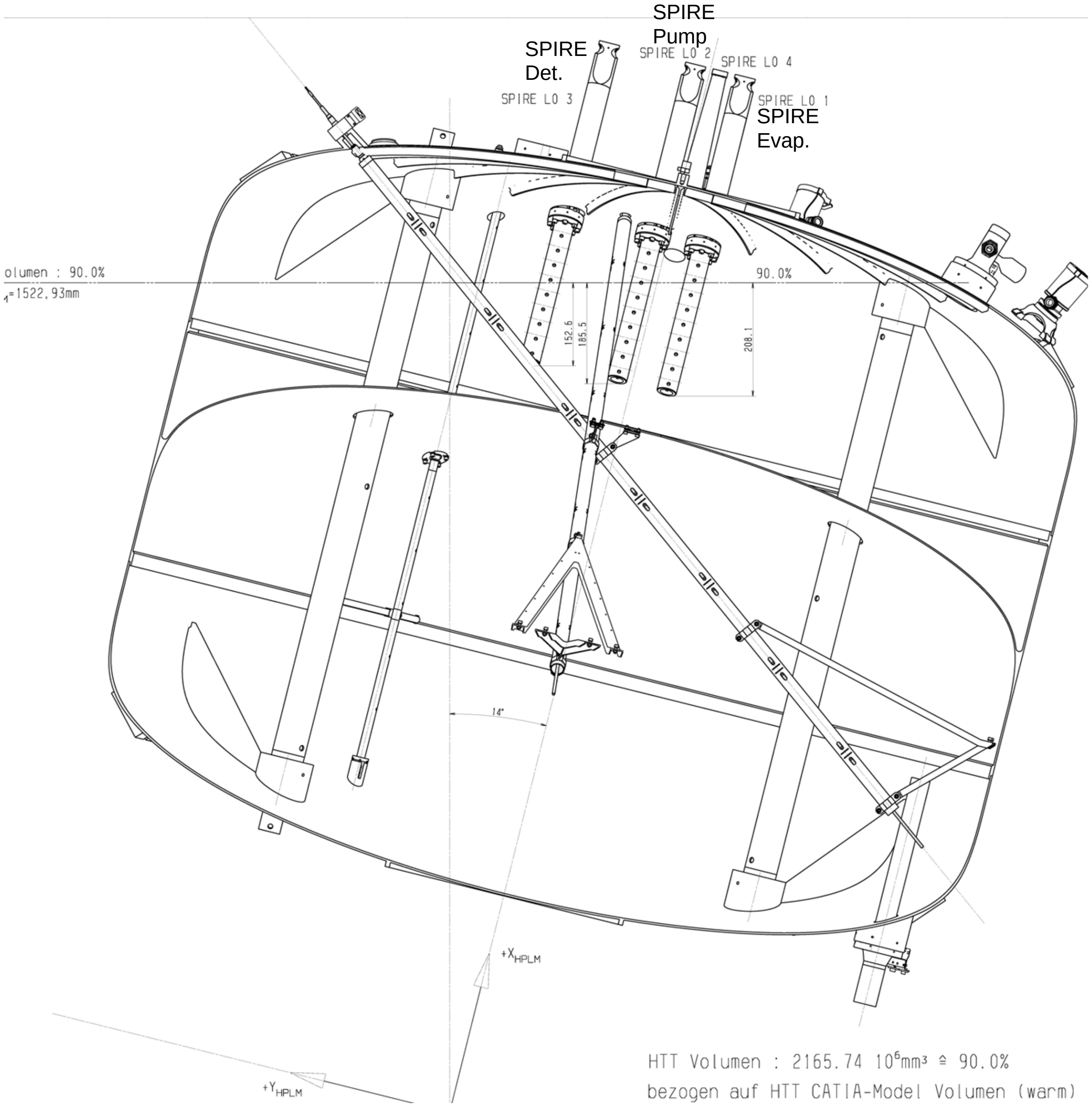
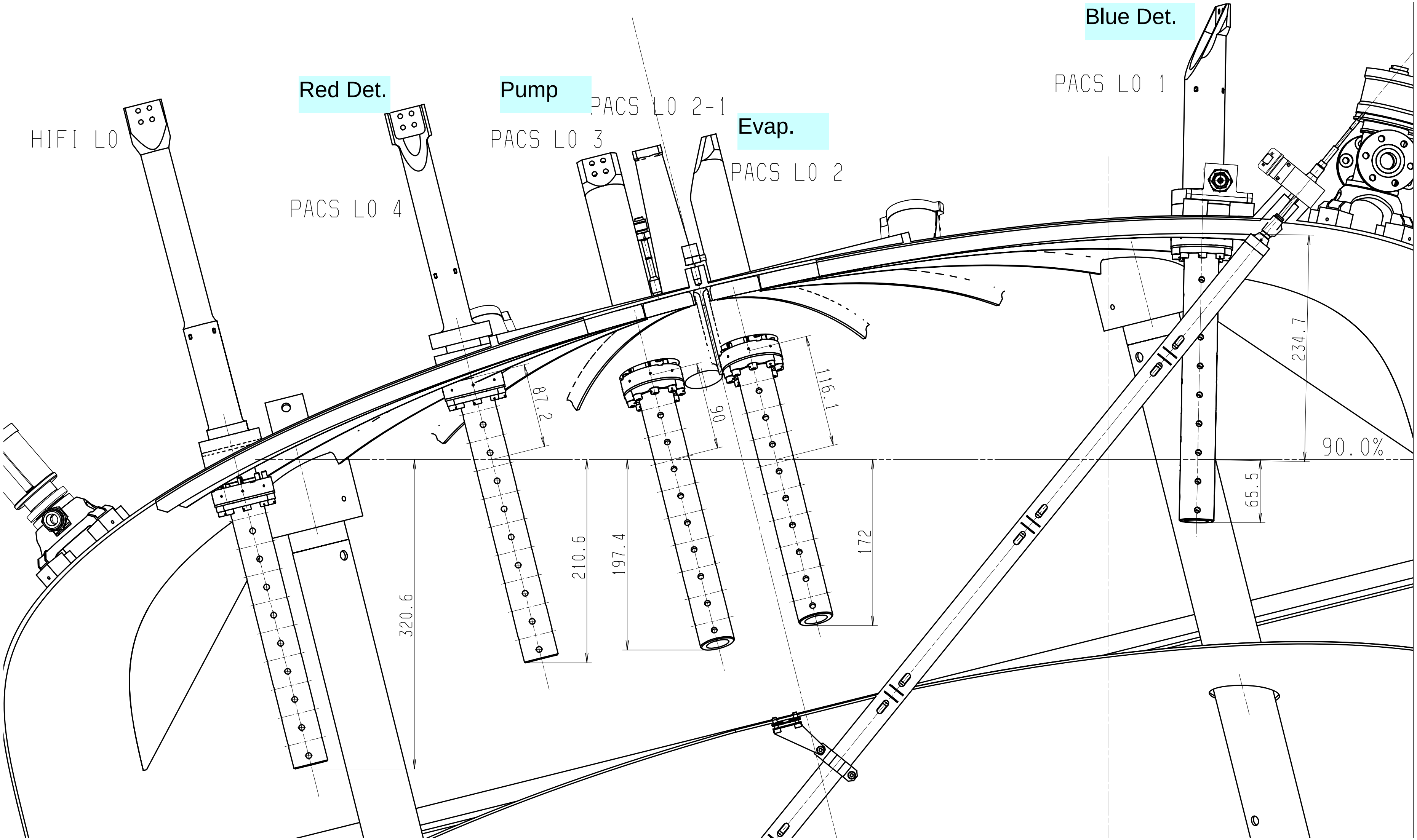


Figure 3.1-1: Helium Liquid Level Line at 14° Tilt and 90% Filling Charge


Blue Det.
Red Det.
Pump
Evap.
HIFI LO
PACS LO 4
PACS LO 3
PACS LO 2-1
PACS LO 2
PACS LO 1
87.2
90
116.1
234.7
90.0%
65.5
320.6
210.6
197.4
172

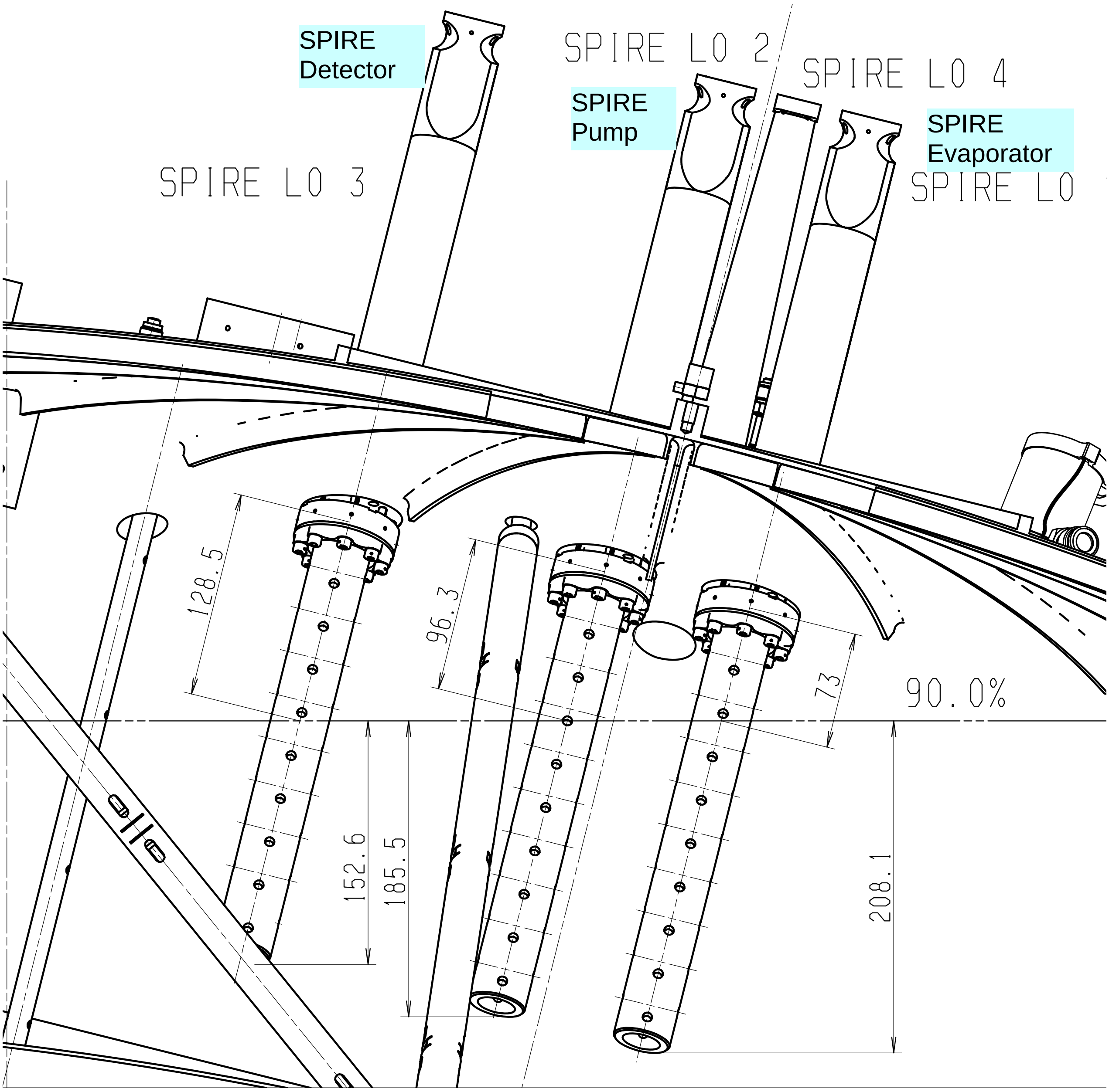
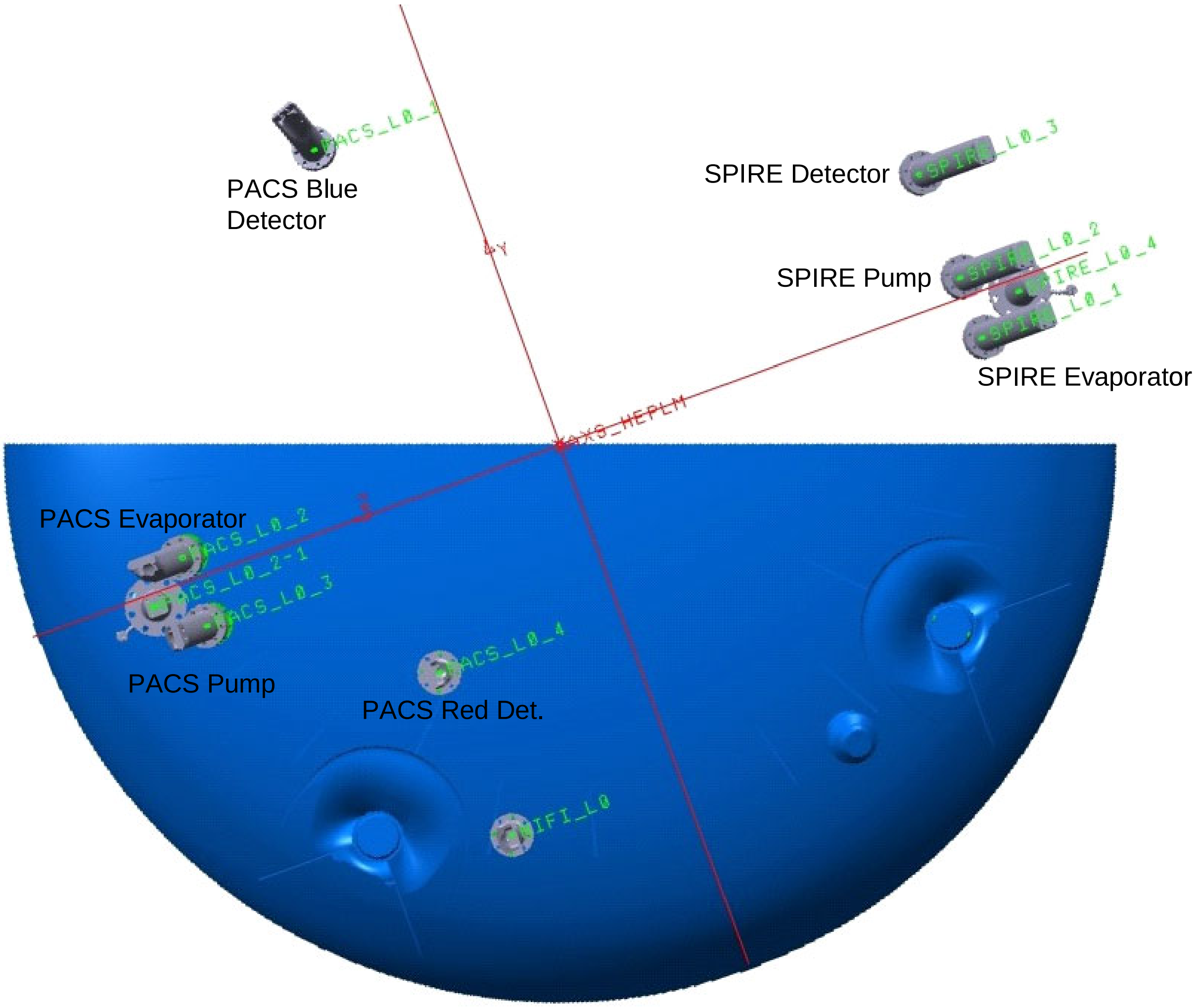


Figure 3.1-2: Distances of HTT Internal Pods to Helium Liquid Level Line during TP4

3.2 Test Conditions with 90° tilted CVV outside LSS

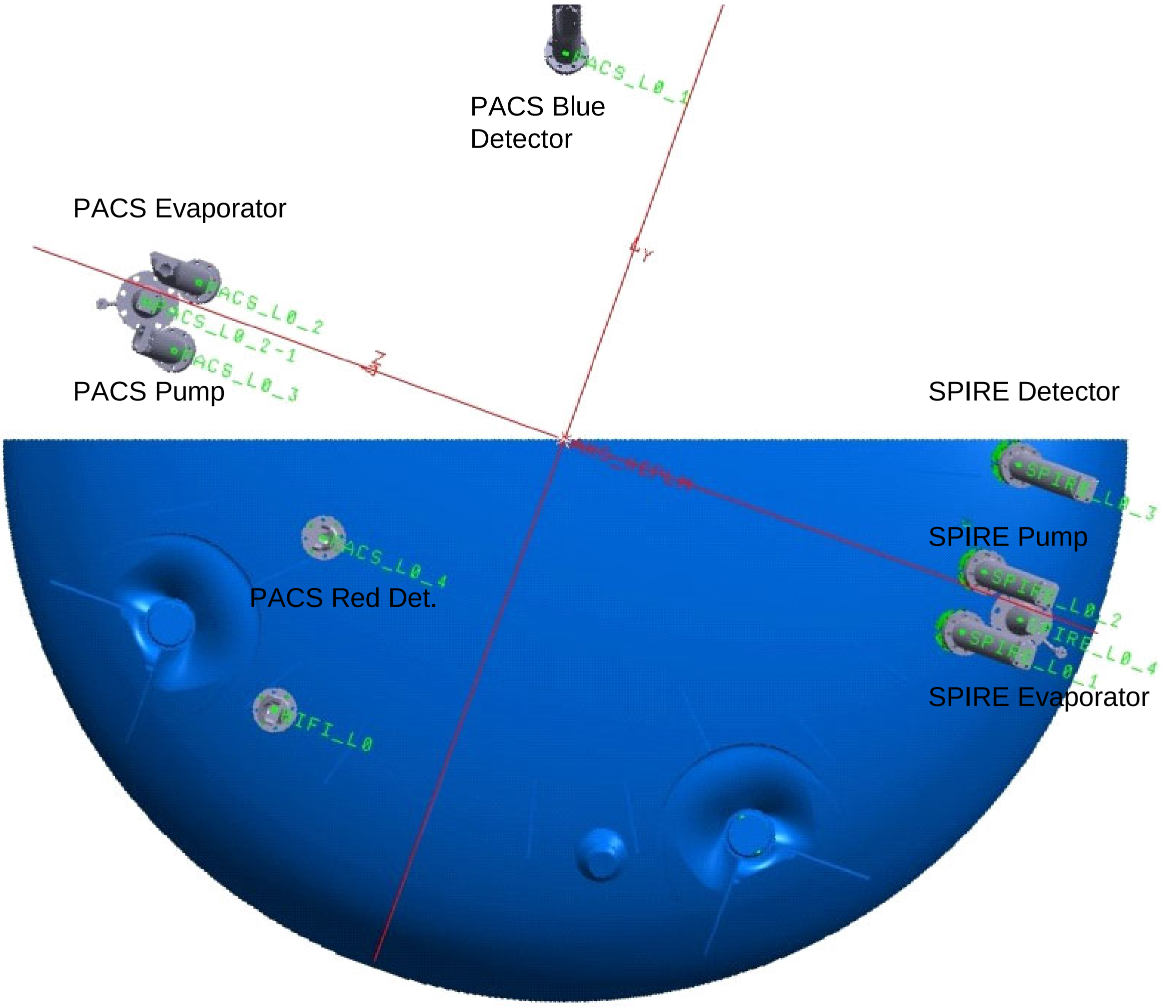
Since the open pods of the PACS and SPIRE Evaporator interfaces could not be immersed with liquid helium using the set-up inside the LSS an extra test has been conducted outside the LSS. Therefore the CVV has been tilted by 90° and then rotated by +20° and -20° to enable immersion of the PACS and SPIRE open pods with liquid helium as shown in **Figure 3.2-1** and **Figure 3.2-2**, respectively. This extra L0 test has been conducted on the 5.January 2006 at ESTEC premises.

During the extra test the opportunity has been taken to measure again the L0 performance of the PACS Pump, the PACS Red Detector, the SPIRE Pump and the SPIRE Detector for a completely wetted internal pod. This allows extrapolating the performance of those interfaces for in orbit conditions. The detailed test evaluation is described in [RD 02].



Horizontal CVV counter-clockwise rotated by 20° with 50% Filling Charge in the HTT

Figure 3.2-1: Helium Liquid Level Line during PACS L0 Testing



Horizontal CVV clockwise rotated by20° with 50% Filling Charge in the HTT

Figure 3.2-2: Helium Liquid Level Line during SPIRE L0 Testing

4 Measured Performance versus TMM Prediction

4.1 L0 Conductance Calculation in TMM for TP4 Test Configuration

The L0 conductance values for TP4 test conditions are calculated in the subroutine “eplm_var1.d” of TMM Issue 4.2 [RD 04] modified by the adapted lengths of the non-immersed parts of the internal pods as described in section 3.1. The subroutine is shown following (in this case used for conductance calculations at 1.737 K mean temperature).

```
###########################################################################
#
#                H-EPLM STM TB/TV Test Thermal Detailed Model
#
#   ESATAN include file
#
#   Filename:  eplm_var1.d
#
#   Author:    K. Wagner <Klaus.Wagner@astrium.eads.net>
#
#   Issue:     4
#   Revision:  2
#   Status:    02.12.2005
#
###########################################################################
#
# Change Record (changes since issue 4 rev. 2 from 02.12.05/HP-2-ASED-EM-0547-05)
#
#############################################################################################################
# #
      IF ((GPLTO .EQ. 'X') .OR. (GPLTO .EQ. 'Y')) THEN
#       set L0 interface conductances acc. to test conditions assumptions (ref.: HP-2-AIRL-AN-0004),
#       considering internal pods (contact pod - HTT, pod internal, Kapitza)

#       PACS MTD Red detector:
        GL(PACS:721, 71) = k_40* 2.*2.*INTRP1((T:PACS:721+T71 )/2., TCCAlCu , 1)
        GL(      71, 10) = k_40* 1./(
     &                1./(  75.D-6/0.136*INTRP1(1.737D0, TAB12   , 1)) + 1./(4.*2.*INTRP1(1.737D0, TCCAlCu, 1)) +
     &                1./( 452.D-6/0.284*INTRP1(1.737D0, TLAL1050, 1)) + 1./(      INTRP1(1.737D0 , TCCHTT , 1)) +
     &                1./(         8.*3.*INTRP1(1.737D0, TCCAlAl , 1)) + 1./(531.D-6/0.087*INTRP1(1.737D0, TLAL1050,1)) + 1./4.9)
#
#       PACS MTD Blue detector:
        GL(PACS:723, 72) = k_40* 2.*2.*INTRP1((T:PACS:723+T72 )/2., TCCAlCu , 1)
```

```
        GL(      72, 10) = k_40* 1./(
     &                1./(  88.D-6/0.222*INTRP1(1.737D0, TAB12   , 1)) + 1./(4.*2.*INTRP1(1.737D0, TCCAlCu, 1)) +
     &                1./( 580.D-6/0.235*INTRP1(1.737D0, TLAL1050, 1)) + 1./(      INTRP1(1.737D0, TCCHTT , 1)) +
     &                1./(         8.*3.*INTRP1(1.737D0, TCCAlAl , 1)) + 1./(531.D-6/0.235*INTRP1(1.737D0, TLAL1050,1)) + 1./4.9)
#       PACS MTD Cooler pump:
        GL(PACS:761, 74) = k_40* 2.*2.*INTRP1((T:PACS:761+T74 )/2., TCCCuCu , 1)
        GL(      74, 10) = k_40* 1./(
     &                1./(  67.D-6/0.215*INTRP1(1.737D0, TAB12   , 1)) + 1./(4.*2.*INTRP1(1.737D0, TCCAlCu, 1)) +
     &                1./(1130.D-6/0.235*INTRP1(1.737D0, TLAL1050, 1)) + 1./(      INTRP1(1.737D0 , TCCHTT , 1)) +
     &                1./(         8.*3.*INTRP1(1.737D0, TCCAlAl , 1)) + 1./(531.D-6/0.09*INTRP1(1.737D0, TLAL1050,1)) + 1./4.9)
#       PACS MTD Cooler evap. (open pod set inactive):
        GL(PACS:762, 73) = k_40* 2.*2.*INTRP1((T:PACS:762+T73 )/2., TCCCuCu , 1)
        GL(      73, 10) = k_40* 1./(
     &                1./( 200.D-6/0.216*INTRP1(1.737D0, TAB12   , 1)) +
     &                                                                        1./(4.*2.*INTRP1(1.737D0, TCCAlCu, 1)) +
     &                1./(1130.D-6/0.235*INTRP1(1.737D0, TLAL1050, 1)) + 1./(      INTRP1(1.737D0   , TCCHTT , 1)) +
     &                1./(         8.*3.*INTRP1(1.737D0, TCCAlAl , 1)) + 1./(531.D-6/0.116*INTRP1(1.737D0, TLAL1050,1)) + 1./4.9)

#       HIFI MTD detector:
        GL(HIFI:949, 92) = k_40* 4.*2.*INTRP1(1.737D0, TCCAlCu , 1)
        GL(      92, 91) = k_40*  75.D-6/0.236*INTRP1(1.737D0, TAB12   , 1)
        GL(      91, 10) = k_40* 1./(                                         1./(2.*2.*INTRP1(1.737D0, TCCAlCu, 1)) +
     &                1./( 392.D-6/0.404*INTRP1(1.737D0, TLAL1050, 1)) + 1./(      INTRP1(1.737D0, TCCHTT , 1)) + 1./4.9)
#
#
#       SPIRE MTD enclosure L0:

        GL(SPIRE:814, 10) = k_40* 1./(
     &                1./(4.*2.*INTRP1(1.737D0  , TCCAlCu, 1)) + 1./(960.D-6/0.340*INTRP1(1.737D0, TLAL1050, 1)) +
     &                1./(      INTRP1(1.737D0  , TCCHTT , 1)) +
     &                1./(8.*3.*INTRP1(1.737D0  , TCCAlAl, 1)) + 1./(531.D-6/0.1285*INTRP1(1.737D0, TLAL1050, 1)) + 1./4.9)
#       SPIRE MTD pump L0:
        GL(SPIRE:815, 10) = k_40* 1./(
     &                1./(4.*2.*INTRP1(1.737D0 , TCCAlCu, 1)) + 1./(960.D-6/0.340*INTRP1(1.737D0, TLAL1050, 1)) +
     &                1./(      INTRP1(1.737D0 , TCCHTT , 1)) +
     &                1./(8.*3.*INTRP1(1.737D0 , TCCAlAl, 1)) + 1./(531.D-6/0.0963*INTRP1(1.737D0, TLAL1050, 1)) + 1./4.9)
#       SPIRE MTD evap L0 (open pod set inactive):
        GL(SPIRE:816, 10) = k_40* 1./(
     &                1./(4.*2.*INTRP1(1.737D0, TCCAlCu, 1)) + 1./(960.D-6/0.340*INTRP1(1.737D0, TLAL1050, 1)) +
     &                1./(      INTRP1(1.737D0, TCCHTT , 1)) +
     &                1./(8.*3.*INTRP1(1.737D0, TCCAlAl, 1)) + 1./(531.D-6/0.073*INTRP1(1.737D0, TLAL1050, 1)) + 1./4.9)

      END IF
#
```

4.2 L0 Conductance Calculation in TMM Issue 4.2 for in Orbit Conditions

The L0 conductance values for in orbit conditions are calculated in the subroutine “eplm_ifcpl.d” considering a fully immersed HTT upper bulkhead. The corresponding subroutine used in TMM Issue 4 Rev. 2 [RD 04] is given following:

```
###########################################################################
#
#                H-EPLM STM TB/TV Test Thermal Detailed Model
#
#   ESATAN include file
#
#   Filename:  eplm_ifcpl.d
#
#   Author:    K. Wagner <Klaus.Wagner@astrium.eads.net>
#
#   Issue:     4
#   Revision:  2
#   Status:    02.12.2005
#
###########################################################################
#
# Change Record (changes since issue 4 rev. 2 from 02.12.05/HP-2-ASED-EM-0547-05)
#
#############################################################################################################
#
#
#  interface couplings to cooling straps
#  --------------------------------------
#
#  Level 0 cooling straps (references: HP-2-AIRL-HO-0010, dated 05.02.2004,
#                                      HP-2-AIRL-AN-0004, iss. 4, dated 08.12.2003)
#
#                         No. of bolts * force [kN] * instr.-braid contact
#                         braid conductance (Cu  flex. strap)                     No. of bolts * force [kN] * braid-pod    contact
#                         pod   conductance (Al1050)                              pod+HTT contact+cond. (20kN per pod)
# PACS MTD Red detector:
  GL(PACS:721, 71) = k_40* 2.*2.*INTRP1((T:PACS:721+T71 )/2., TCCAlCu , 1);
  GL(      71, 10) = k_40* 1./(
                      1./(  75.D-6/0.136*INTRP1((T71+T10)/2., TAB12    , 1)) + 1./(4.*2.*INTRP1((T71+T10)/2., TCCAlCu, 1)) +
                      1./( 452.D-6/0.284*INTRP1((T71+T10)/2., TLAL1050, 1)) + 1./(      INTRP1( T10        , TCCHTT , 1)));
# PACS MTD Blue detector:
```

```
  GL(PACS:723, 72) = k_40* 2.*2.*INTRP1((T:PACS:723+T72 )/2., TCCAlCu , 1);
  GL(      72, 10) = k_40* 1./(
                      1./(  88.D-6/0.222*INTRP1((T72+T10)/2., TAB12    , 1)) + 1./(4.*2.*INTRP1((T72+T10)/2., TCCAlCu, 1)) +
                      1./( 580.D-6/0.235*INTRP1((T72+T10)/2., TLAL1050, 1)) + 1./(      INTRP1( T10         , TCCHTT , 1)));
# PACS MTD Cooler pump:
  GL(PACS:761, 74) = k_40* 2.*2.*INTRP1((T:PACS:761+T74 )/2., TCCCuCu , 1);
  GL(      74, 10) = k_40* 1./(
                      1./(  67.D-6/0.215*INTRP1((T74+T10)/2., TAB12    , 1)) + 1./(4.*2.*INTRP1((T74+T10)/2., TCCAlCu, 1)) +
                      1./(1130.D-6/0.235*INTRP1((T74+T10)/2., TLAL1050, 1)) + 1./(      INTRP1( T10         , TCCHTT , 1)));
# PACS MTD Cooler evap. (incl. open pod):
  GL(PACS:762, 73) = k_40* 2.*2.*INTRP1((T:PACS:762+T73 )/2., TCCCuCu , 1);
  GL(      73, 10) = k_40* 1./(
                      1./( 200.D-6/0.216*INTRP1((T73+T10)/2., TAB12    , 1)) +
                      1./(
                      1./(                                                    1./(4.*2.*INTRP1((T73+T10)/2., TCCAlCu, 1)) +
                      1./(1130.D-6/0.235*INTRP1((T73+T10)/2., TLAL1050, 1)) + 1./(      INTRP1( T10         , TCCHTT , 1)))+
                      1./(                                                    1./(5.*2.*INTRP1((T73+T10)/2., TCCAlCu, 1)) +
                      1./( 531.D-6/0.015*INTRP1((T73+T10)/2., TLAL6063, 1)))));
# HIFI MTD detector:
  GL(HIFI:949, 92) = k_40* 4.*2.*INTRP1((T:HIFI:949+T92 )/2., TCCAlCu , 1);
  GL(      92, 91) = k_40*  75.D-6/0.236*INTRP1((T92+T91)/2., TAB12    , 1);
  GL(      91, 10) = k_40* 1./(                                               1./(2.*2.*INTRP1((T91+T10)/2., TCCAlCu, 1)) +
                      1./( 392.D-6/0.404*INTRP1((T91+T10)/2., TLAL1050, 1)) + 1./(      INTRP1( T10         , TCCHTT , 1)));
#
#                         No. of bolts * force [kN] * braid-pod contact           pod   conductance (Al1050)
#                         pod+HTT contact+cond. (20kN per pod)
# SPIRE MTD enclosure L0:
  GL(SPIRE:814, 10) = k_40* 1./(
                      1./(4.*2.*INTRP1( T:SPIRE:814       , TCCAlCu, 1)) + 1./(960.D-6/0.340*INTRP1((T:SPIRE:814+T10)/2., TLAL1050, 1)) +
                      1./(      INTRP1( T10               , TCCHTT , 1)));
# SPIRE MTD pump L0:
  GL(SPIRE:815, 10) = k_40* 1./(
                      1./(4.*2.*INTRP1( T:SPIRE:815       , TCCAlCu, 1)) + 1./(960.D-6/0.340*INTRP1((T:SPIRE:815+T10)/2., TLAL1050, 1)) +
                      1./(      INTRP1( T10               , TCCHTT , 1)));
# SPIRE MTD evap L0 (incl. open pod):
  GL(SPIRE:816, 10) = k_40* 1./(
                      1./(4.*2.*INTRP1( T:SPIRE:816       , TCCAlCu, 1)) + 1./(960.D-6/0.340*INTRP1((T:SPIRE:816+T10)/2., TLAL1050, 1)) +
                      1./(      INTRP1( T10               , TCCHTT , 1)))+
                      1./(
                      1./(4.*2.*INTRP1( T:SPIRE:816       , TCCAlCu, 1)) + 1./(531.D-6/0.015*INTRP1((T:SPIRE:816+T10)/2., TLAL6063, 1)));
#
```

4.3 L0 I/F TMM Correlation for TP4 Test Configuration

The comparison of measured conductance values versus calculated values obtained from the uncorrelated TMM Issue 4 Rev.2 (acc. to section 4.1) is given in **Figure 4.3-1**. The evaluation of the thermal conductance values from measured data during TP4 in the LSS is described in [RD 02]. A very good correspondence exists for the PACS Red Detector I/F and for the HIFI L0 I/F.

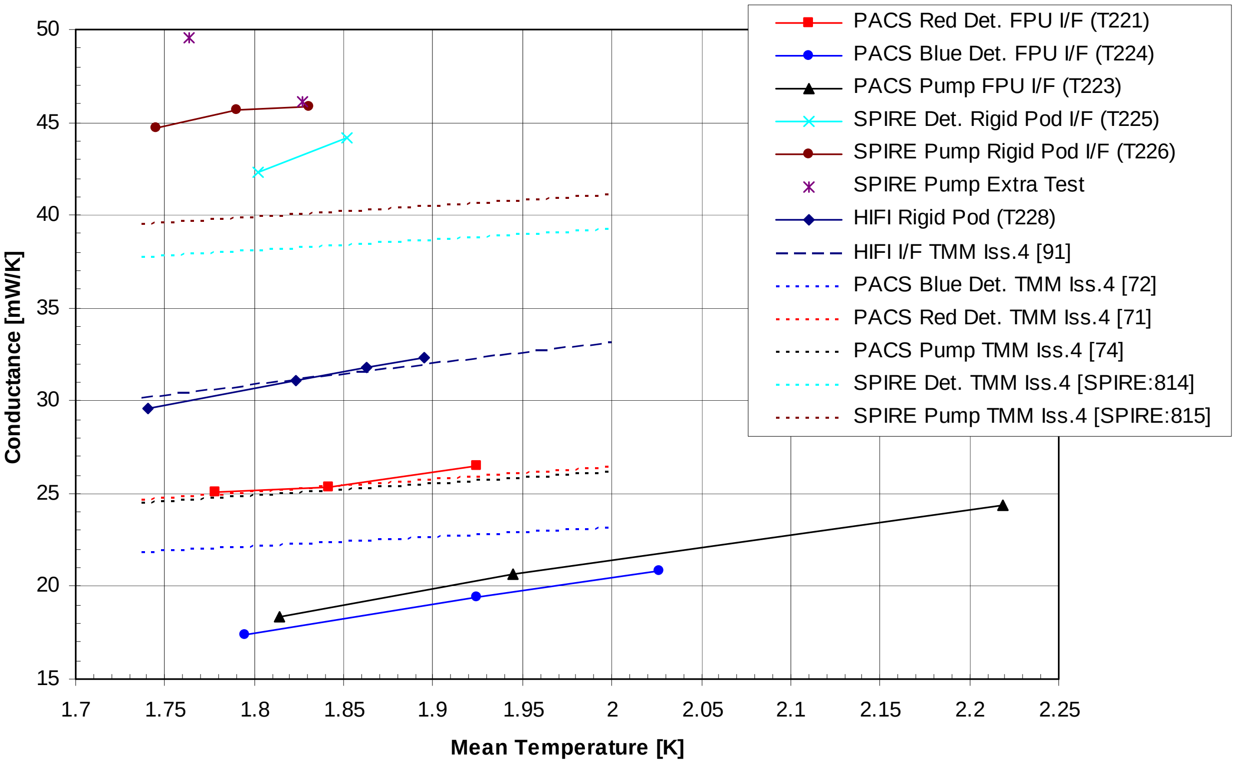


Figure 4.3-1: Conductance measurements versus predictions with uncorrelated TMM for TP4

To achieve a better correlation also for the other L0 conductance values two modifications are applied:

- for the material properties of the HTT wall and the internal pods the mean temperature (between He and instrument I/F) is used instead of the He temperature
- correction factors as listed in **Table 4.3-1** are introduced

The results obtained with the above modifications are presented in **Figure 4.3-2** showing a good correlation for all L0 conductance values with the exception of the PACS and SPIRE Evaporators.

The results for the Evaporators (open pods in parallel to rigid pods) are shown in **Figure 4.3-3**. The decrease in thermal conductance for higher temperature indicates that a superfluid film on the open pod is partly burnt away at higher heater power. A proper correlation should take into account such helium effects in dependence of heating power and probably many other parameters. For the TP4 conditions the correction factor for the PACS Evaporator rigid pod is set to 1.0 and for the SPIRE Evaporator the factor evaluated for the SPIRE pump is taken (almost identical design). The open pods are set inactive.

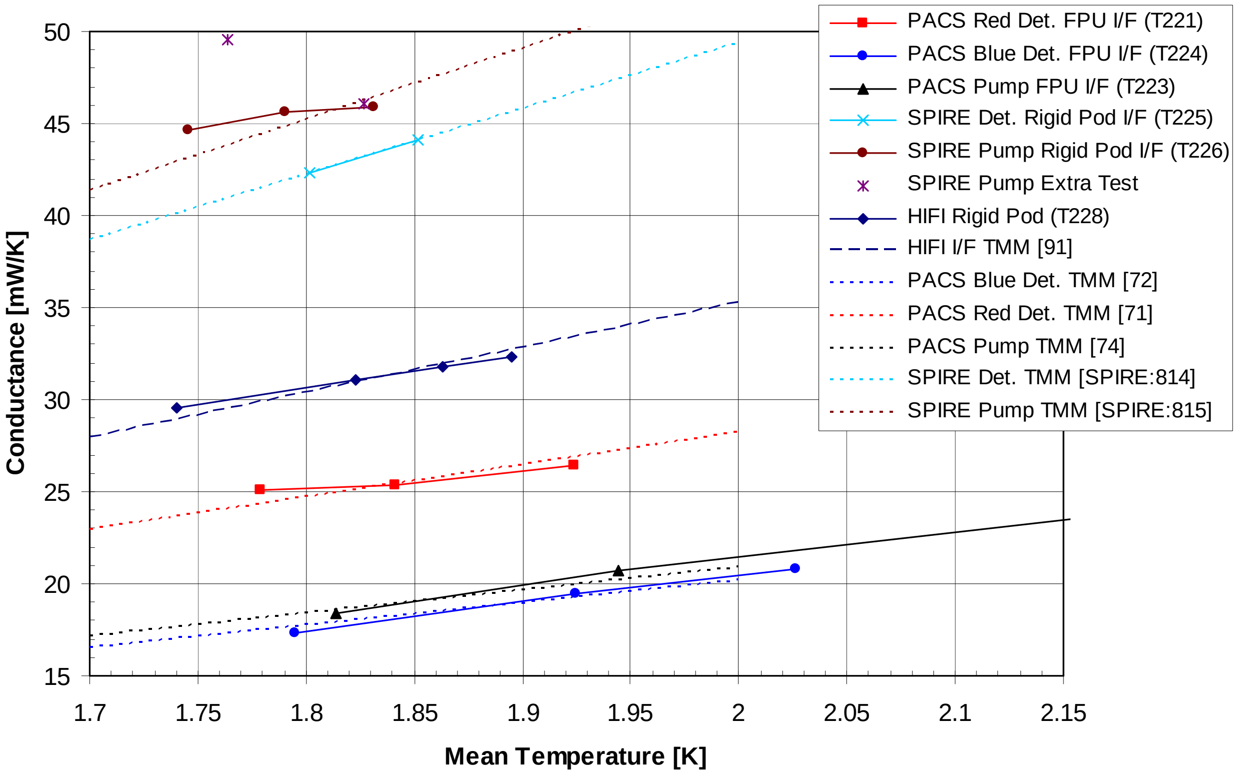


Figure 4.3-2: Conductance measurements versus calculations with correlated TMM for TP4

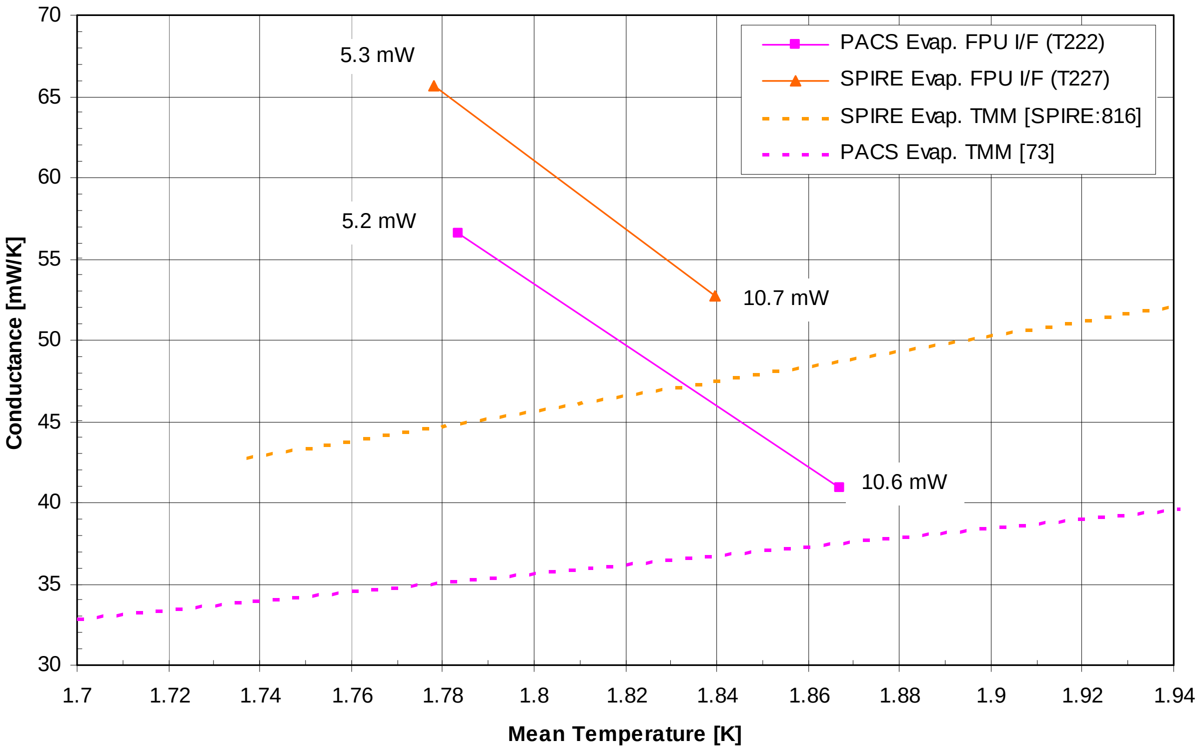


Figure 4.3-3: Evaporator conductance measurements versus calculations with correlated TMM for TP4

Instrument L0 Interface	Temp. Sensor	TMM Node	Distance of internal pod to liquid He II	Proposed correction factor for Conductance
PACS Red Detector	T221	[71]	87 mm	0.96
PACS Blue Detector	T224	[72]	235 mm	0.78
PACS Cooler Pump	T223	[74]	90 mm	0.72
PACS Cooler Evapor.	T222	[73]	116 mm	1.0 (open pod not immersed)
SPIRE Detector	T225	[SPIRE:814]	129 mm	1.062
SPIRE Pump	T226	[SPIRE:815]	96 mm	1.085
SPIRE Evaporator	T227	[SPIRE:816]	73 mm	1.085 (open pod not immersed)
HIFI	T228	[91]	0 mm	0.96

Table 4.3-1: L0 I/F TMM Correlation for TP4 Test Configuration in LSS

4.4 L0 I/F TMM Correlation for 90° tilted CVV Test Configuration

The test results obtained from the tilted CVV test with the HTT upper bulkhead I/F fully immersed with liquid He [for details see RD 02] are shown in **Figure 4.4-1** and **Figure 4.4-2** in comparison to the results obtained during TP4 inside the LSS. Especially for the PACS I/F’s no big difference can be observed for the two test conditions. The reason is very likely that a helium superfluid film along the internal pods and/or the HTT upper bulkhead improves the heat transfer inside the HTT during TP4 significantly.

Calculation of the conductance values for this test case with the TP4 correction factors (see **Table 4.3-1**) lead not to a good correlation, see **Figure 4.4-3**. Therefore, other correction factors as given in **Table 4.4-1** are introduced to achieve a better correlation for the tilted CVV test case. The results are shown in **Figure 4.4-4**.

Figure 4.4-5 and **Figure 4.4-6** show the conductance for the PACS and SPIRE Evaporator with a good correlation using a correction factor of 0.52 for both Evaporators.

Since the difference of the measured conductance values is rather small for the two test conditions a TMM modification applicable for both cases is proposed. This allows conductance calculation with common formulas both for in orbit conditions as for TB/TV test conditions (with ~90% He filling charge). In detail the following modifications shall be performed:

- use the mean temperature (between He and Instrument I/F) for the material properties of the HTT wall instead of the He temperature only
- introduce correction factors as listed in **Table 4.4-1**, last column (see also section 4.5)
- neglect the thermal resistance of the internal pods (inside the HTT) also for TB/TV

The obtained results for the TP4 TB/TV conditions are shown in **Figure 4.4-7** showing still an acceptable correlation.

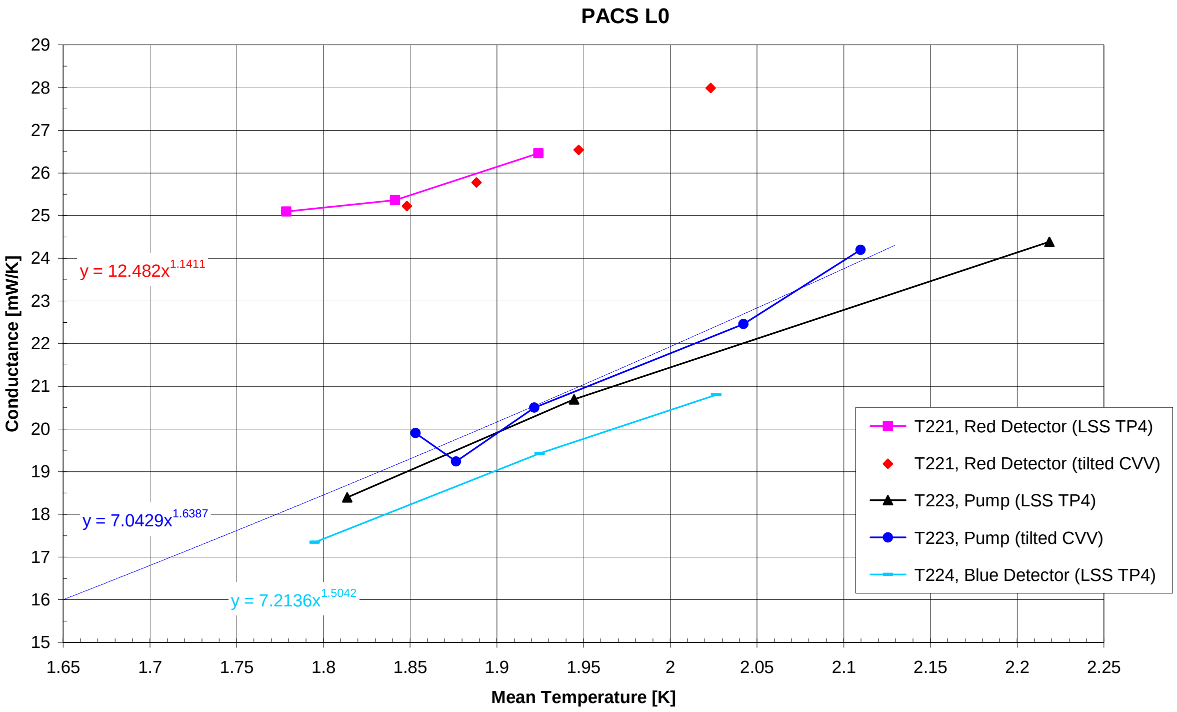


Figure 4.4-1: Measured PACS L0 conductance for the different test configurations

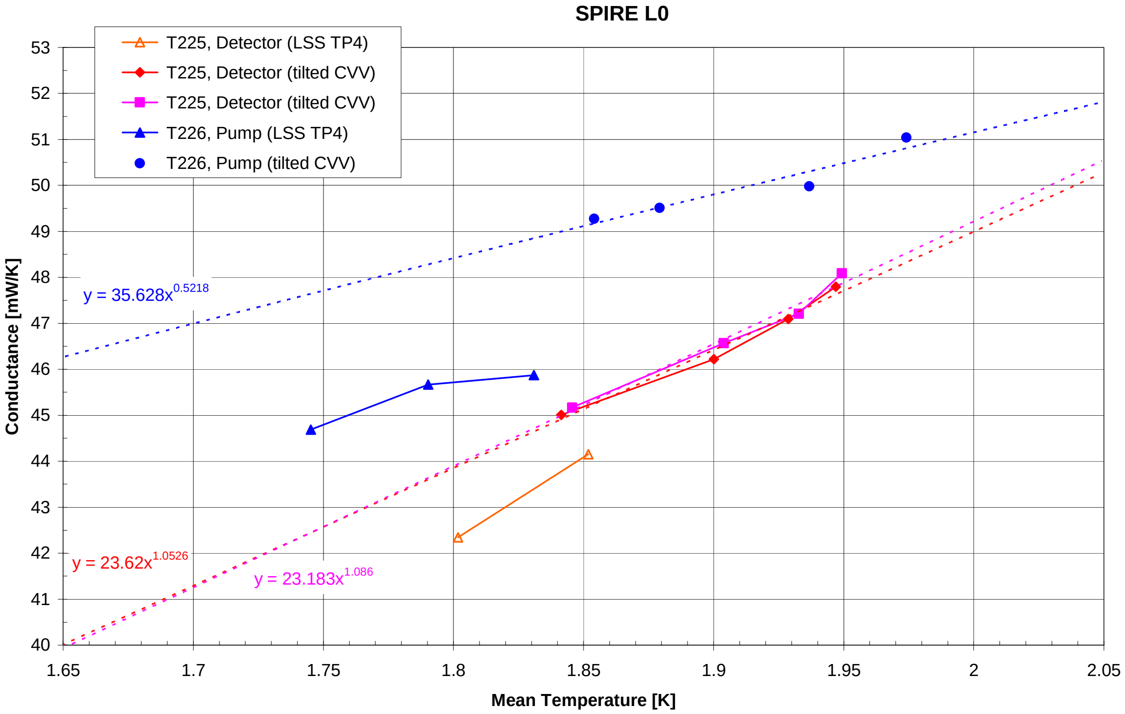


Figure 4.4-2: Measured SPIRE L0 conductance for the different test configurations

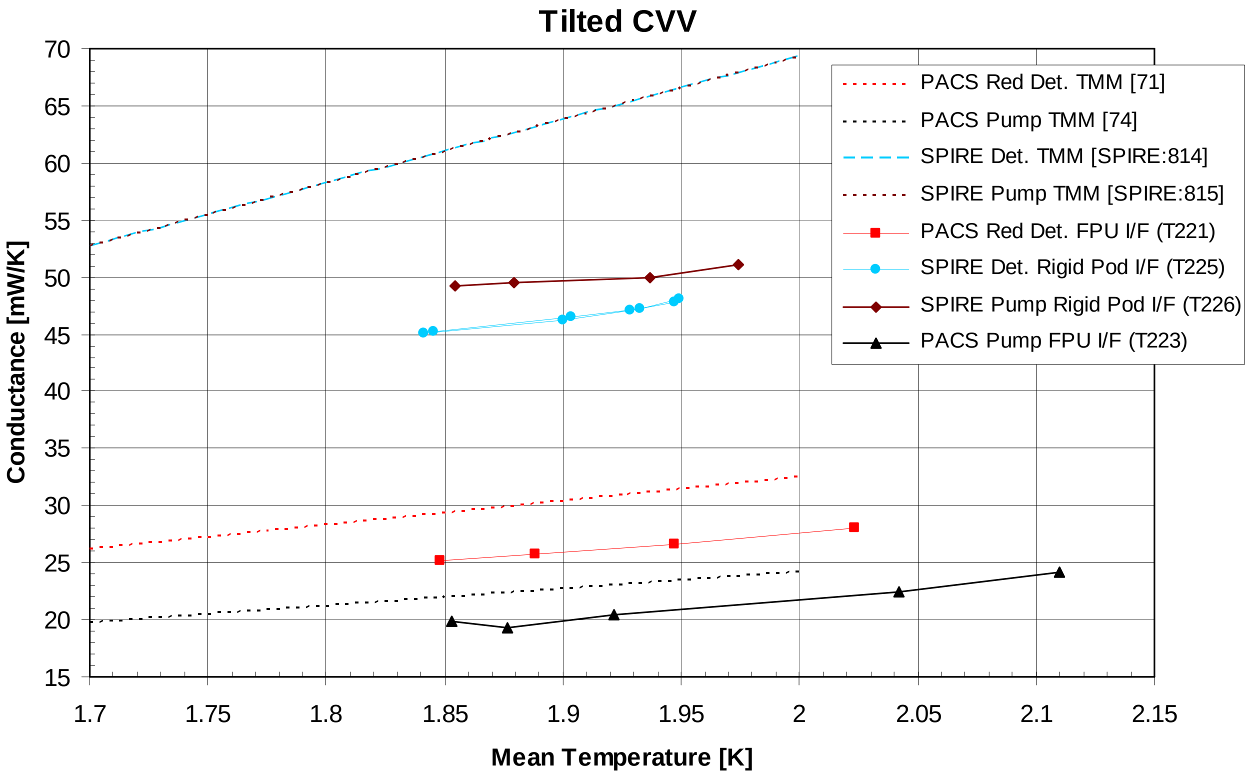


Figure 4.4-3: Conductance measurements versus calculations for 90° tilted CVV using TP4 correction factors

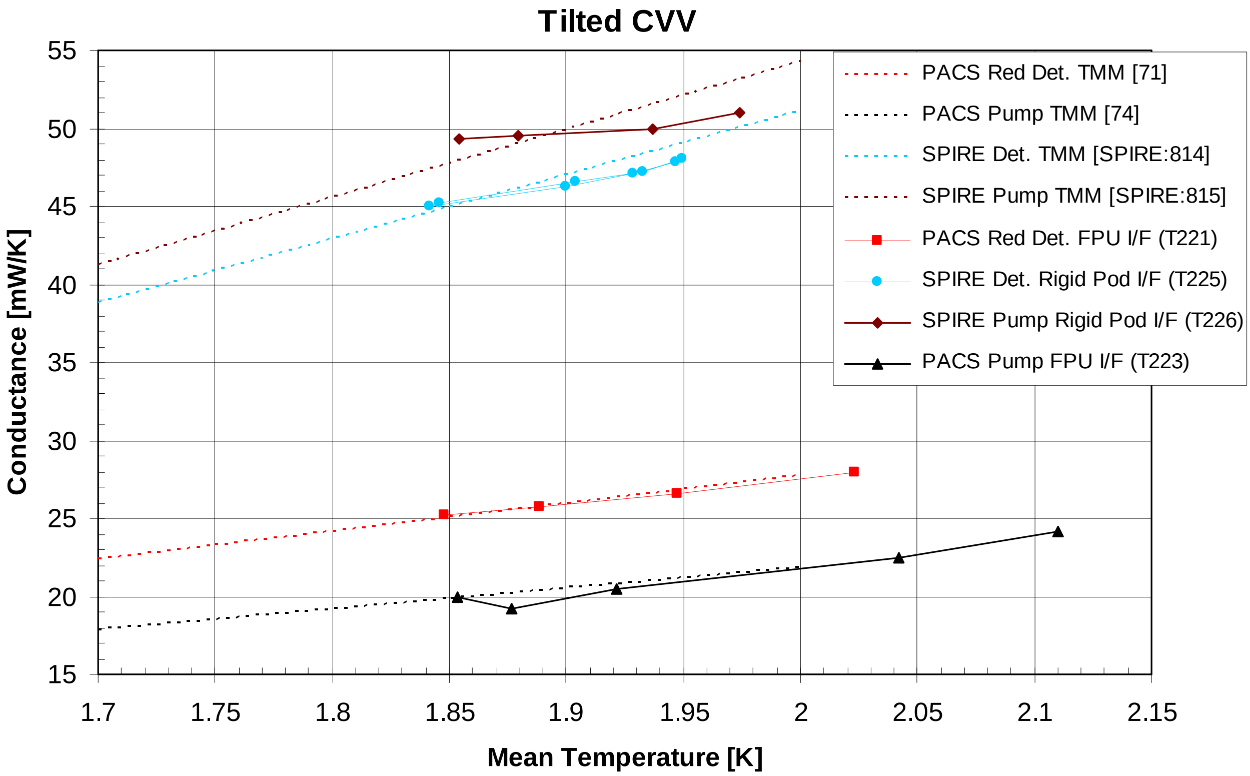


Figure 4.4-4: Conductance measurements versus calculations for 90° tilted CVV using correction factors for 90° tilted CVV

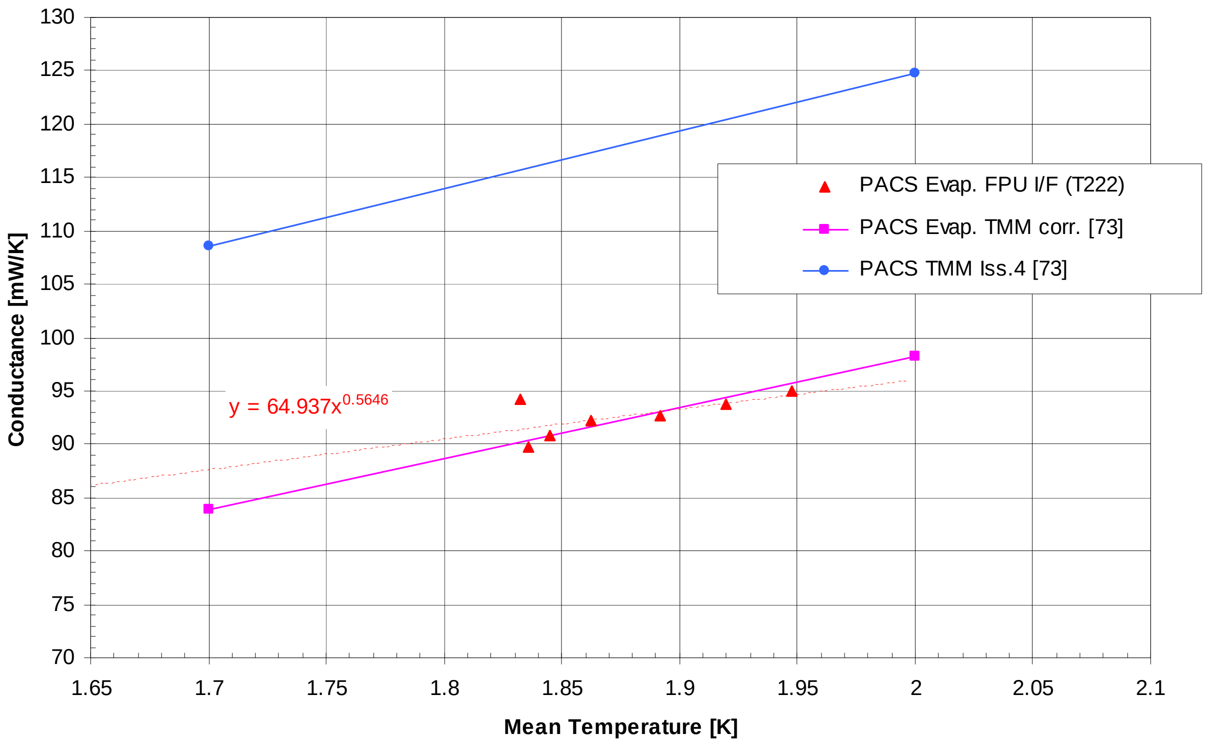


Figure 4.4-5: PACS evaporator conductance measurements versus calculations with uncorrelated and correlated TMM for 90° tilted CVV

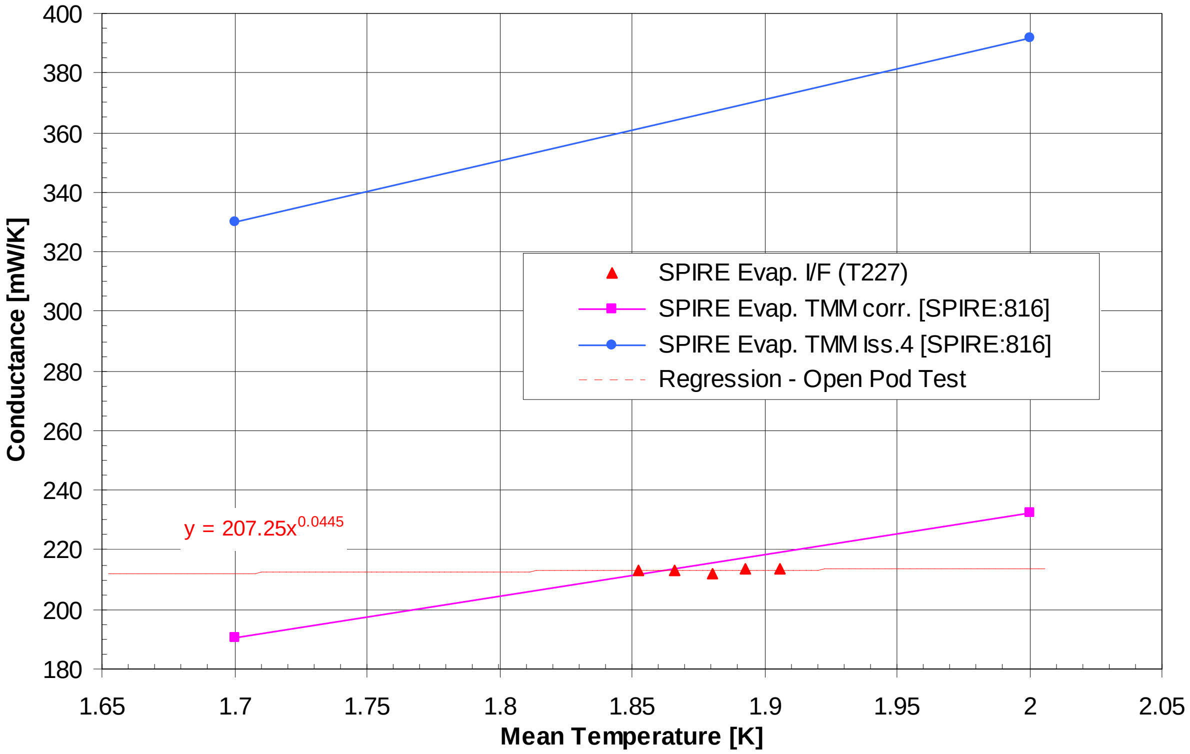


Figure 4.4-6: SPIRE evaporator conductance measurements versus calculations with uncorrelated and correlated TMM for 90° tilted CVV

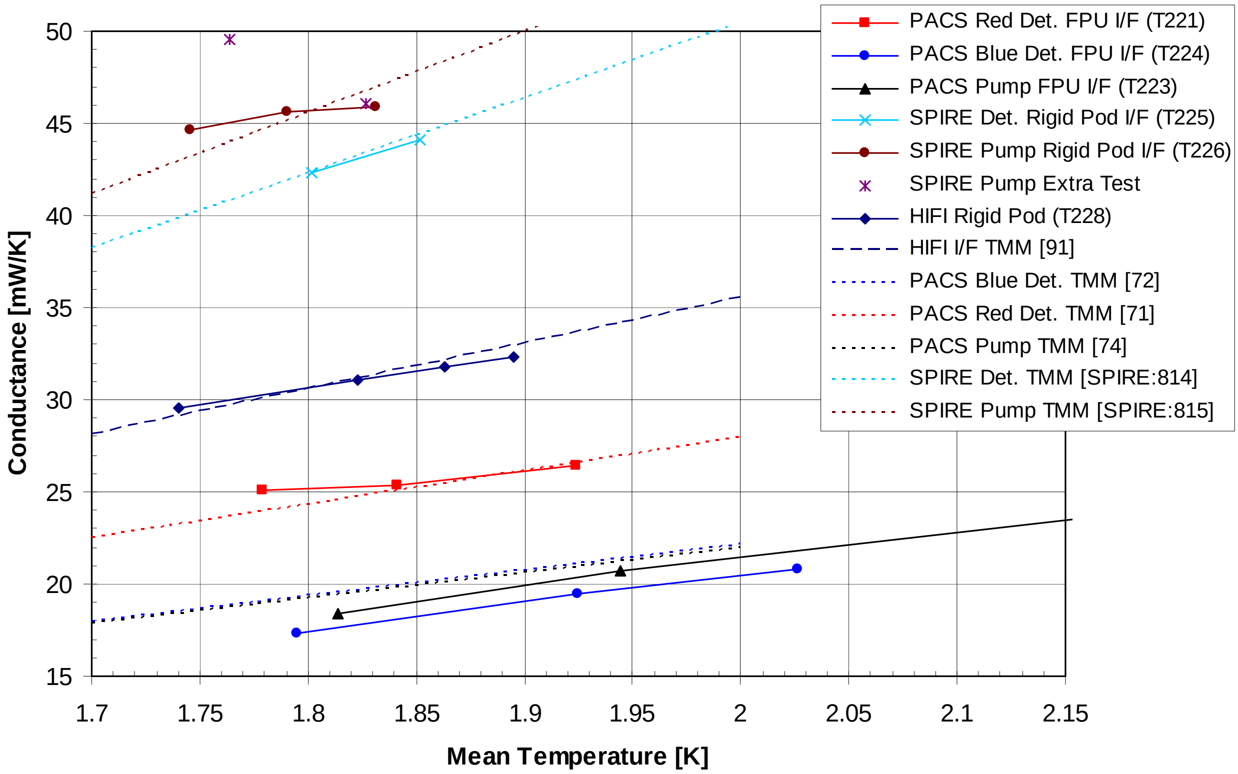


Figure 4.4-7: Conductance measurements versus calculations for TP4 with correction factors for 90° tilted CVV and neglected thermal resistance of internal pods

Instrument L0 Interface	Temp. Sensor	TMM Node	Correction factor for TP4	Correction factor for 90° tilted CVV test	Proposed (common) correction factor for in orbit and TB test *
PACS Red Detector	T221	[71]	0.96	0.82	0.82
PACS Blue Detector	T224	[72]	0.78	not tested	0.65 **
PACS Cooler Pump	T223	[74]	0.72	0.65	0.65
PACS Cooler Evapor.	T222	[73]	1.0	0.9 for rigid pod 0.53 for open pod	0.9 for rigid pod 0.53 for open pod
SPIRE Detector	T225	[SPIRE:814]	1.062	0.78	0.78
SPIRE Pump	T226	[SPIRE:815]	1.085	0.84	0.84
SPIRE Evaporator	T227	[SPIRE:816]	1.085	0.84 for rigid pod 0.53 for open pod	0.84 for rigid pod 0.53 for open pod
HIFI	T228	[91]	0.96	not tested	0.96 ***

*) internal pod resistances neglected also for TB test configuration with 90% filling level (i.e. set to zero)

**) assumed to be similar to PACS Cooler Pump

***) expected to be same as for TP4 because the HIFI internal pod was fully immersed during TP4

Table 4.4-1: L0 conductance TMM correlation for test with tilted CVV (outside LSS)

4.5 Proposed L0 Conductance Calculation in TMM for in Orbit and TB/TV Conditions

```
###########################################################################
#
#                H-EPLM STM TB/TV Test Thermal Detailed Model
#
#   ESATAN include file
#
#   Filename:  eplm_ifcpl.d
#
#   Author:    K. Wagner <Klaus.Wagner@astrium.eads.net>
#
#   Issue:     next
#   Revision:  next
#   Status:    new
#
###########################################################################
#
# Change Record (changes since issue 4 rev. 2 are written in red colour)
#
#############################################################################################################
#
#
#  interface couplings to cooling straps
#  --------------------------------------
#
#  Level 0 cooling straps (references: HP-2-AIRL-HO-0010, dated 05.02.2004,
#                                      HP-2-AIRL-AN-0004, iss. 4, dated 08.12.2003)
#
#                        No. of bolts * force [kN] * instr.-braid contact
#                        braid conductance (Cu  flex. strap)                     No. of bolts * force [kN] * braid-pod    contact
#                        pod   conductance (Al1050)                              pod+HTT contact+cond. (20kN per pod)
#
# PACS MTD Red detector:
  GL(PACS:721, 71) = k_40* 2.*2.*INTRP1((T:PACS:721+T71 )/2., TCCAlCu , 1);
  GL(      71, 10) = 0.82* 1./(
                      1./(  75.D-6/0.136*INTRP1((T71+T10)/2., TAB12   , 1)) + 1./(4.*2.*INTRP1((T71+T10)/2., TCCAlCu, 1)) +
                      1./( 452.D-6/0.284*INTRP1((T71+T10)/2., TLAL1050, 1)) + 1./(      INTRP1((T71+T10)/2., TCCHTT , 1)));
#
# PACS MTD Blue detector:
  GL(PACS:723, 72) = k_40* 2.*2.*INTRP1((T:PACS:723+T72 )/2., TCCAlCu , 1);
  GL(      72, 10) = 0.65* 1./(
                      1./(  88.D-6/0.222*INTRP1((T72+T10)/2., TAB12   , 1)) + 1./(4.*2.*INTRP1((T72+T10)/2., TCCAlCu, 1)) +
                      1./( 580.D-6/0.235*INTRP1((T72+T10)/2., TLAL1050, 1)) + 1./(      INTRP1((T72+T10)/2., TCCHTT , 1)));
#
```

```
# PACS MTD Cooler pump:
  GL(PACS:761, 74) = k_40* 2.*2.*INTRP1((T:PACS:761+T74 )/2., TCCCuCu , 1);
  GL(      74, 10) = 0.65* 1./(
                      1./(  67.D-6/0.215*INTRP1((T74+T10)/2., TAB12   , 1)) + 1./(4.*2.*INTRP1((T74+T10)/2., TCCAlCu, 1)) +
                      1./(1130.D-6/0.235*INTRP1((T74+T10)/2., TLAL1050, 1)) + 1./(      INTRP1((T74+T10)/2., TCCHTT , 1)));
#
# PACS MTD Cooler evap. (incl. open pod):
  GL(PACS:762, 73) = k_40* 2.*2.*INTRP1((T:PACS:762+T73 )/2., TCCCuCu , 1);
  GL(      73, 10) = k_40* 1./(
                      1./( 0.9 * 200.D-6/0.216*INTRP1((T73+T10)/2., TAB12   , 1)) +
                      1./(
                      0.9/(                                                    1./(4.*2.*INTRP1((T73+T10)/2., TCCAlCu, 1)) +
                      1./(1130.D-6/0.235*INTRP1((T73+T10)/2., TLAL1050, 1)) + 1./(      INTRP1((T73+T10)/2., TCCHTT , 1)))+
                      0.53/(                                                    1./(5.*2.*INTRP1((T73+T10)/2., TCCAlCu, 1)) +
                      1./( 531.D-6/0.015*INTRP1((T73+T10)/2., TLAL6063, 1)))));
#
# HIFI MTD detector:
  GL(HIFI:949, 92) = k_40* 4.*2.*INTRP1((T:HIFI:949+T92 )/2., TCCAlCu , 1);
  GL(      92, 91) = k_40*  75.D-6/0.236*INTRP1((T92+T91)/2., TAB12   , 1);
  GL(      91, 10) = 0.96* 1./(                                               1./(2.*2.*INTRP1((T91+T10)/2., TCCAlCu, 1)) +
                      1./( 392.D-6/0.404*INTRP1((T91+T10)/2., TLAL1050, 1)) + 1./(      INTRP1((T91+T10)/2., TCCHTT , 1)));
#
#                         No. of bolts * force [kN] * braid-pod contact           pod   conductance (Al1050)
#                         pod+HTT contact+cond. (20kN per pod)
#
# SPIRE MTD enclosure L0:
  GL(SPIRE:814, 10) = 0.78* 1./(
                      1./(4.*2.*INTRP1((T:SPIRE:814+T10)/2., TCCAlCu, 1)) + 1./(960.D-6/0.340*INTRP1((T:SPIRE:814+T10)/2., TLAL1050,
1)) +
                      1./(      INTRP1((T:SPIRE:814+T10)/2. , TCCHTT , 1)));
#
# SPIRE MTD pump L0:
  GL(SPIRE:815, 10) = 0.84* 1./(
                      1./(4.*2.*INTRP1((T:SPIRE:815+T10)/2., TCCAlCu, 1)) + 1./(960.D-6/0.340*INTRP1((T:SPIRE:815+T10)/2., TLAL1050,
1)) +
                      1./(      INTRP1((T:SPIRE:815+T10)/2., TCCHTT , 1)));
#
# SPIRE MTD evap L0 (incl. open pod):
  GL(SPIRE:816, 10) = k_40* (0.84 * 1./(
                      1./(4.*2.*INTRP1((T:SPIRE:816+T10)/2., TCCAlCu, 1)) + 1./(960.D-6/0.340*INTRP1((T:SPIRE:816+T10)/2., TLAL1050,
1)) +
                      1./(      INTRP1((T:SPIRE:816+T10)/2., TCCHTT , 1)))+
                      0.53/(
                      1./(4.*2.*INTRP1((T:SPIRE:816+T10)/2., TCCAlCu, 1)) + 1./(531.D-6/0.015*INTRP1((T:SPIRE:816+T10)/2., TLAL6063,
1))));
#
```

5 Summary and Conclusions

TMM correlation of the L0 conductance calculation has been performed based on the measurement results obtained from the H-EPLM STM TB/TV test in the LSS chamber at ESTEC and from a test outside the LSS with 90° tilted CVV.

A common calculation of the L0 conductance values applicable both for in orbit and for TB/TV test inside LSS (with at least about 90% He fill level) is proposed applying the following modifications in the TMM:

- use the mean temperature (between He and instrument I/F) for the material properties of the HTT wall instead of the He temperature only
- introduce correction factors as listed in **Table 4.4-1**, last column
- neglect the thermal resistance of the internal pods (inside the HTT) also for the TB/TV conditions

The finally proposed L0 conductance correlation is shown in **Figure 4.4-7** for the TP4 TB/TV test and in **Figure 4.4-4** for the 90° tilted CVV test simulating quasi in orbit conditions.

END OF DOCUMENT

	Name	Dep./Comp.		Name	Dep./Comp.
	Alberti von Mathias Dr.	ASG23		Schuler Günter	ASA42
	Baldock Richard	FAE12		Schweickert Gunn	ASG23
	Barlage Bernhard	AED13	X	Sonn Nico	ASG51
	Bayer Thomas	ASA42		Steininger Eric	AED32
	Brune Holger	ASA45	X	Stritter Rene	AED11
	Edelhoff Dirk	AED2		Suess Rudi	OTN/ASA44
	Fehringer Alexander	ASG13		Theunissen Martijn	DSSA
X	Fricke Wolfgang Dr.	AED 65	X	Wagner Klaus	ASG23
	Geiger Hermann	ASA42	X	Wietbrock Walter	AET12
	Grasl Andreas	OTN/ASA44		Wöhler Hans	ASG23
	Grasshoff Brigitte	AET12		Wössner Ulrich	ASE252
	Hamer Simon	Terma			
	Hendry David	Terma			
	Hengstler Reinhold	ASA42			
X	Hinger Jürgen	ASG23			
	Hohn Rüdiger	AED65			
	Hölzle Edgar Dr.	AED32			
	Huber Johann	ASA42			
	Hund Walter	ASE252			
X	Idler Siegmund	AED312			
	Ivády von András	FAE12			
X	Jahn Gerd Dr.	ASG23			
	Kalde Clemens	ASM2			
	Kameter Rudolf	OTN/ASA42			
	Kettner Bernhard	AET42			
	Knoblauch August	AET32		Alcatel Alenia Space Torino	AAS-I
	Koelle Markus	ASA43	X	ESA/ESTEC	ESA
X	Koppe Axel	AED312	X	Thales Alenia Space Cannes	TAS-F
X	Kroeker Jürgen	AED65			
	La Gioia Valentina	Terma		**Instruments:**	
	Lang Jürgen	ASE252	X	MPE (PACS)	MPE
	Langenstein Rolf	AED15	X	RAL (SPIRE)	RAL
X	Langfermann Michael	ASA41	X	SRON (HIFI)	SRON
	Martin Olivier	ASA43			
	Maukisch Jan	ASA43			
	Much Christoph	ASA43		**Subcontractors:**	
	Müller Jörg	ASA42		Alcatel Alenia Space Antwerp	ABSP
	Müller Martin	ASA43		Austrian Aerospace	AAE
	Peltz Heinz-Willi	ASG13		Austrian Aerospace	AAEM
	Pietroboni Karin	AED65		BOC Edwards	BOCE
	Platzer Wilhelm	AED2		Dutch Space Solar Arrays	DSSA
	Reichle Konrad	ASA42		EADS Astrium Sub-Subsyst. & Equipment	ASSE
	Runge Axel	OTN/ASA44		EADS CASA Espacio	CASA
X	Schink Dietmar	AED32		EADS CASA Espacio	ECAS
	Schlosser Christian	OTN/ASA44		European Test Services	ETS
	Schmidt Rudolf	FAE12		Patria New Technologies Oy	PANT
	Schmidt Thomas	AED15		SENER Ingenieria SA	SEN