

25.09.01

Ref. : INT-TN-39994 Issue 1
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 To/à : DSRI - S. Brandt, N. Lund, P.A. Jensen, S. Laursen, N. Lund
 ESTEC- P. Jensen, B. Lehmann, S. Roure, G. Sarri
 Cc :
 Subject : Thermal Correlation of JEM-X Thermal Model Based on FM1 TB Test Measurements

References

1. JEM-X EID-B Issue 5 Rev 2 March 2000
 2. Test Report "TV Cycling Test of the JEM-X FM 1" TOS-MCV/2001/2676/In/BL Sep. 01
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1. Background

The JEM-X FM TB/TV test took place in the Estec LAVAF chamber from 4-11 September 2001. A test report describing test details (ref. 2) is available.

From the thermal point of view, two tasks remain:

- 1) to gain confidence that the JEM-X thermal model provided by DSRI is accurate and can be used as a tool to predict thermal behaviour during flight
- 2) to run the JEM-X thermal model with flight boundary conditions and demonstrate that the predicted temperatures are acceptable

A mini correlation exercise was performed to address task 1 above and is described in this note.

2. Summary of Thermal Boundary Conditions Achieved in FM 1 TB Test

In the correlation exercise, the thermal models were run with the boundary conditions measured during the TB test, which are shown in the table below:

| | time (dd.mm.yy.hr.min) | Conductive I/F (C) | PLM Radiative I/F (C) | SVM Radiative I/F (C) | Detector Dissipation (W) | DFEE Dissipation (W) |
|---------|-------------------------------|-----------------------|-----------------------------|-----------------------------|--------------------------------|----------------------------|
| TB Cold | 04.09.01 22:00 | -28.4 | -71.3 | -71.3 | 5.6 | 22.7 |
| TB Hot | 05.09.01 13:57 | 42.3 | 26.7 | 26.7 | 5.6 | 22.7 |

3. Description of Correlation Exercise



The table below explains the correlation steps which were performed:

| iteration | description | Model name | COLD CASE Average error [C] | COLD CASE standard dev of error [C] | HOT CASE Average error [C] | HOT CASE standard dev of error [C] |
|-----------|---|------------|--------------------------------|--|-------------------------------|---------------------------------------|
| 1 | Original DSRI model as per EID-B (ref. 1) | ORIGINAL | -3.3 | 5.9 | -2.5 | 5.0 |
| 2 | <ul style="list-style-type: none"> - new radiative couplings implemented between support structure (nodes P1-P4) and SVM radiative sink (node S2); total value 0.028 m² - new radiative couplings implemented between support structure (nodes P1-P4) and conductive sink (node PM); total value 0.004 m² | Model 2 | -3.5 | 5.9 | -- | -- |
| 3 | same as Model 2 and in addition: <ul style="list-style-type: none"> - introduced Xenon gas natural convection with heat transfer coefficient $h=1.8 \text{ W/m}^2 \text{ K}$ | Model 3 | -3.1 | 5.0 | -- | -- |
| 4 | Same as Model 3 and in addition: <ul style="list-style-type: none"> - increased conductive coupling between Detector Electronics (node DE) and Detector Vessel (node VS) by 2.2 x (ie. from original value 0.25 W/K to final value 0.55 W/K) | Model 4 | -0.8 | 2.4 | -0.1 | 1.5 |

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4. Conclusion

The thermal model provided by DSRI is in general quite accurate. However, several parameter adjustments were made which resulted in improved predictions. A summary of the adjustments is shown below :

- 1) the thermal conductance between the DAE circuit board and the Vessel was multiplied by 2.2 (original value 0.25 W/K, proposed value 0.55 W/K); this is the most important adjustment and it resulted in much improved correlation in the area of the Detector Electronics (node DE)
- 2) a simple estimation of the Xenon gas natural convection inside the Vessel was made resulting in the introduction of a convective heat transfer coefficient of $h=1.8 \text{ W/m}^2 \text{ K}$ between node 10 (Detector Electronics) and 20 (Detector Vessel). The heat transfer due to this effect is only of second order ; 0.2 W transfer from Electronics to Vessel via convection compared to 5.0 W via conduction; *this convection effect is present in ground testing only, and should not be used when performing the flight predictions*
- 3) the radiative heat transfer network was slightly refined to account for radiative exchange between the support structure and the conductive and radiative sinks (see Model 2); the heat transfer due to this effect is only of second order (3 W)

The effect of gas thermal conduction between Electronics and Vessel through the Xenon at 1.5 bar has also been calculated and is completely negligible compared to the dominating "mechanical" conduction (5.0 W heat transfer) and the second-order convection transfer (0.2 W heat transfer) between Electronics and Vessel. Therefore, gas conduction has not been added to the DSRI thermal model.

With the above simple modifications, the DSRI thermal model is considered to be fully-adequate for predicting thermal behaviour in flight.

ANNEX 1 – Summary of Thermal Results During FM 1 JEM-X TB

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ENVIRONMENT: COLD CASE TB
 TIME: 04.09.01 22:00
 THERMAL MODEL: ORIGINAL (UNADJUSTED WITH RESPECT TO EID-B) THERMAL MODEL

| POWER DISSIPATIONS | |
|--------------------|--------|
| DAE | 5.6 W |
| DFEE | 22.7 W |

| THERMAL MODEL PARAMETER ADJUSTMENTS |
|--------------------------------------|
| none; model identical to EID-B model |

| TC | Descr | Tmeasured (C) | Tpred (C) | Tmeas-Tpred (C) |
|----------|-------------|---------------|-----------|-----------------|
| 7 | Detector | -35.9 | -33.9 | -2.0 |
| 8 | Detector | -36.3 | -33.9 | -2.4 |
| 9 | Detector | -31.2 | -33.9 | 2.7 |
| 10 | Detector | -31.5 | -33.9 | 2.4 |
| 13 | Detector | -39.3 | -33.9 | -5.4 |
| 1 | DFEE | -28.4 | -28.0 | -0.4 |
| 2 | DFEE | -29.4 | -28.0 | -1.4 |
| 3 | DFEE | -28.7 | -28.0 | -0.7 |
| 6 | DFEE | -29.5 | -28.0 | -1.5 |
| Thstor 1 | DAE | -24 | -11.5 | -12.5 |
| Thstor 2 | DAE | -29 | -11.5 | -17.5 |
| thstor | DFEE HV PCB | -29 | -28.0 | -1.0 |
| 14,15,18 | Coldplate | -28.4 | -28.4 | 0.0 |
| 16,17 | TVC Shroud | -71.3 | -71.3 | 0.0 |

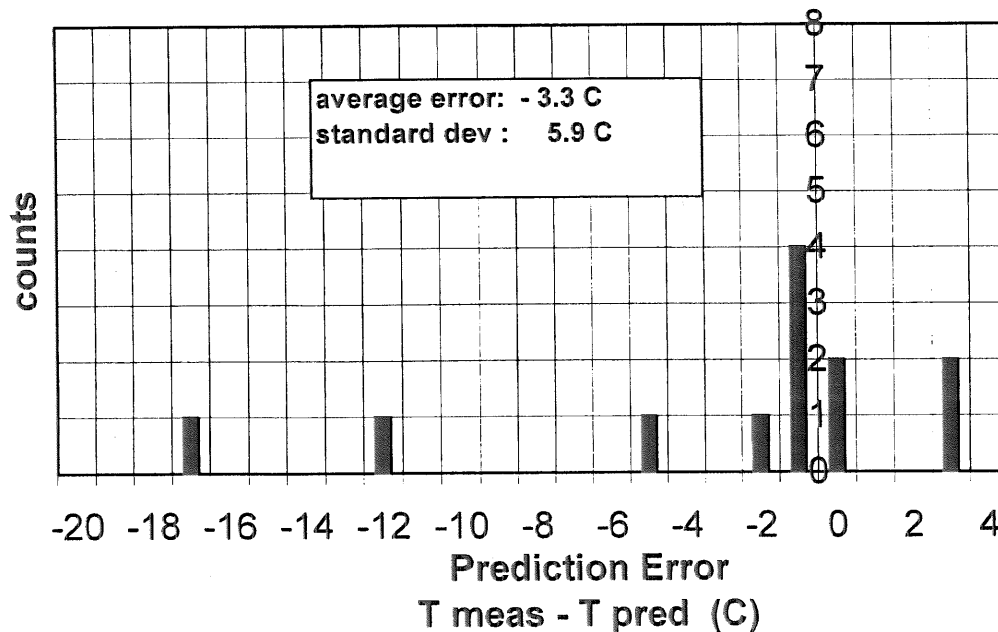
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(*) sensors which belong to statistical sample (12 sensors in total)

-3.3
5.9

average error
standard dev

FM 1 JEM-X ORIGINAL THERMAL MODEL: COLD CASE TB ERROR DISTRIBUTION OF TEMPERATURE PREDICTIONS



ENVIRONMENT : COLD CASE TB
 TIME: 04.09.01 22:00
 THERMAL MODEL: THERMAL MODEL "2"

| POWER DISSIPATIONS | |
|--------------------|--------|
| DAE | 5.6 W |
| DFEE | 22.7 W |

| THERMAL MODEL PARAMETER ADJUSTMENTS |
|---|
| 1-new rad couplings btw. supp structure (nodes P1-P4) and SVM rad sink (node S2); total value 0.028 m ² |
| 2-new rad couplings btw. supp structure (nodes P1-P4) and conductive sink (node PM); total value 0.004 m ² |

| TC | Descr | Tmeasured (C) | Tpred (C) | Tmeas-Tpred (C) |
|----------|-------------|---------------|-----------|-----------------|
| 7 | Detector | -35.9 | -33.9 | -2.0 |
| 8 | Detector | -36.3 | -33.9 | -2.4 |
| 9 | Detector | -31.2 | -33.9 | 2.7 |
| 10 | Detector | -31.5 | -33.9 | 2.4 |
| 13 | Detector | -39.3 | -33.9 | -5.4 |
| 1 | DFEE | -28.4 | -27.5 | -0.9 |
| 2 | DFEE | -29.4 | -27.5 | -1.9 |
| 3 | DFEE | -28.7 | -27.5 | -1.2 |
| 6 | DFEE | -29.5 | -27.5 | -2.0 |
| Thstor 1 | DAE | -24 | -11.5 | -12.5 |
| Thstor 2 | DAE | -29 | -11.5 | -17.5 |
| thstor | DFEE HV PCB | -29 | -27.5 | -1.5 |
| 14,15,18 | Coldplate | -28.4 | -28.4 | 0.0 |
| 16,17 | TVC Shroud | -71.3 | -71.3 | 0.0 |

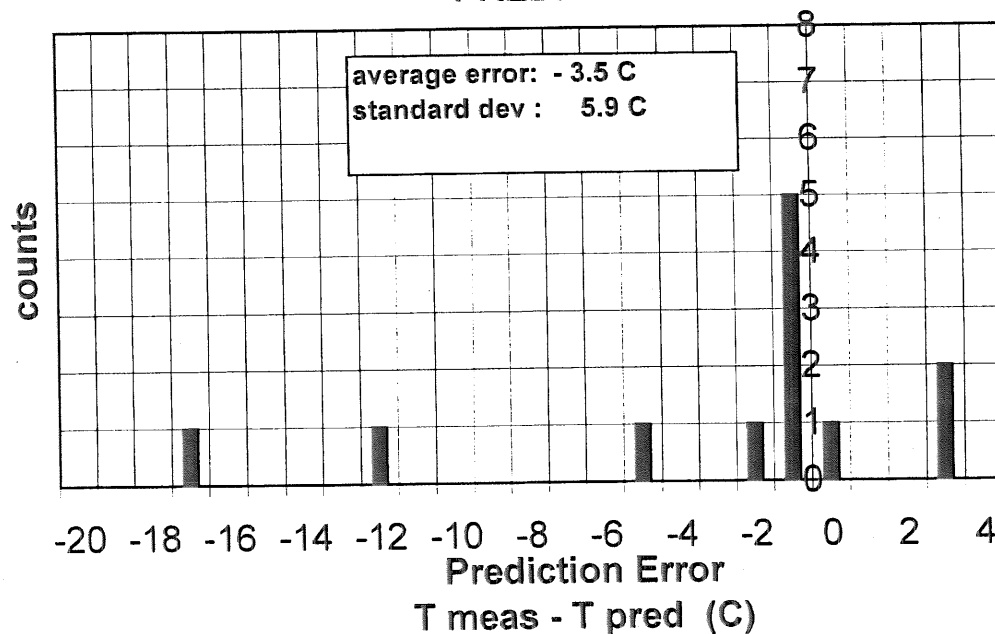
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(*) sensors which belong to statistical sample (12 sensors in total)

-3.5
5.9

average error
standard dev

THERMAL MODEL "2": COLD CASE TB ERROR DISTRIBUTION OF TEMPERATURE PREDICTIONS



ENVIRONMENT : COLD CASE TB
 TIME: 09.01.01 09:43
 THERMAL MODEL: THERMAL MODEL "3"

| POWER DISSIPATIONS | |
|--------------------|--------|
| DAE | 5.6 W |
| DFEE | 22.7 W |

| THERMAL MODEL PARAMETER ADJUSTMENTS |
|---|
| same as model 2 and in addition: 1 - introduced Xenon gas natural convection coeff. $h = 1.8 \text{ W/m}^2 \cdot \text{K}$ |

| TC | Descr | Tmeasured (C) | Tpred (C) | Tmeas-Tpred (C) |
|----------|-------------|---------------|-----------|-----------------|
| 7 | Detector | -35.9 | -33.9 | -2.0 |
| 8 | Detector | -36.3 | -33.9 | -2.4 |
| 9 | Detector | -31.2 | -33.9 | 2.7 |
| 10 | Detector | -31.5 | -33.9 | 2.4 |
| 13 | Detector | -39.3 | -33.9 | -5.4 |
| 1 | DFEE | -28.4 | -27.5 | -0.9 |
| 2 | DFEE | -29.4 | -27.5 | -1.9 |
| 3 | DFEE | -28.7 | -27.5 | -1.2 |
| 6 | DFEE | -29.5 | -27.5 | -2.0 |
| Thstor 1 | DAE | -24 | -14.1 | -9.9 |
| Thstor 2 | DAE | -29 | -14.1 | -14.9 |
| thstor | DFEE HV PCB | -29 | -27.5 | -1.5 |
| 14,15,18 | Coldplate | -28.4 | -28.4 | 0.0 |
| 16,17 | TVC Shroud | -71.3 | -71.3 | 0.0 |

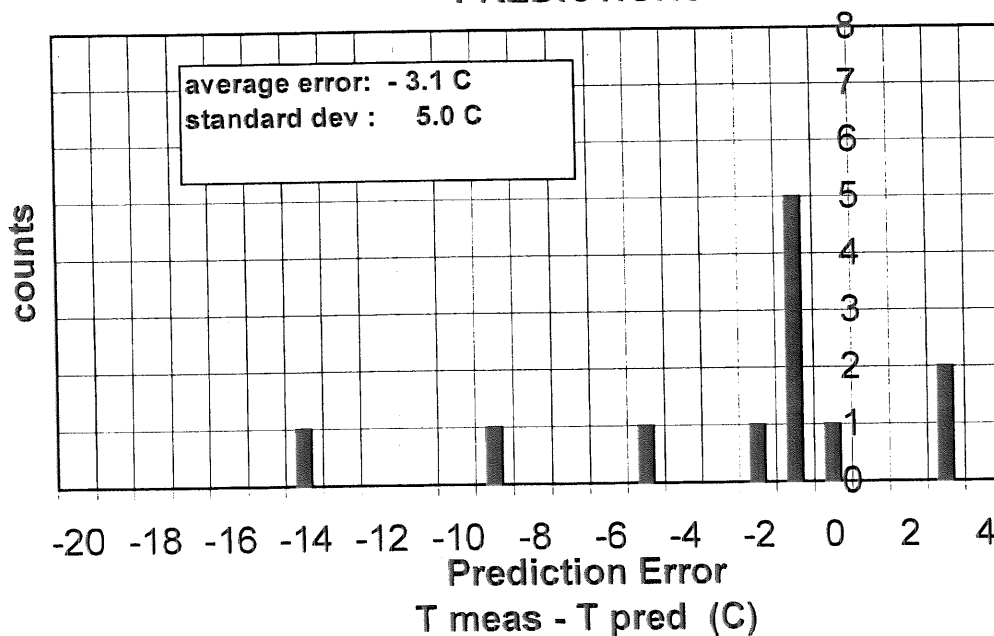
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(*) sensors which belong to statistical sample (12 sensors in total)

-3.1
5.0

average error
standard dev

THERMAL MODEL "3": COLD CASE TB ERROR DISTRIBUTION OF TEMPERATURE PREDICTIONS



| | |
|----------------|-------------------|
| ITEM | FM 1 JEM-X |
| ENVIRONMENT : | COLD CASE TB |
| TIME: | 04.09.01 22:00 |
| THERMAL MODEL: | THERMAL MODEL "4" |

| POWER DISSIPATIONS | |
|--------------------|--------|
| DAE | 5.6 W |
| DFEE | 22.7 W |

THERMAL MODEL PARAMETER ADJUSTMENTS

same as model 3 and in addition:

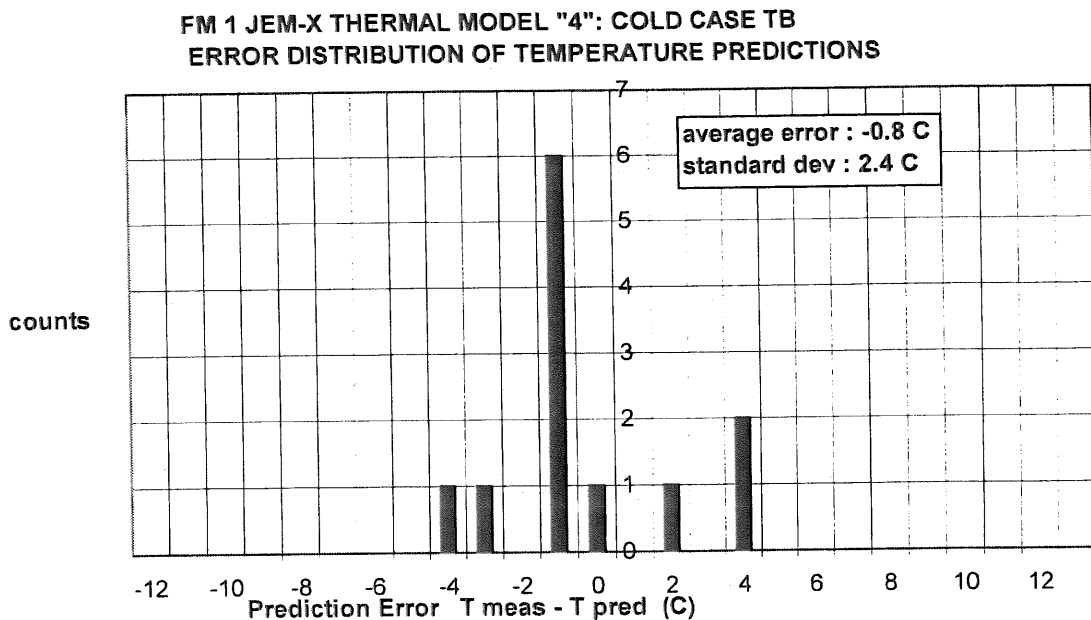
1 - conductance between Detector Electronics and Detector Vessel multiplied x 2.2 (original value 0.25 W/K, final value 0.55 W/K)

| TC | Descr | Tmeasured (C) | Tpred (C) | Tmeas-Tpred (C) |
|----------|------------------|---------------|-----------|-----------------|
| 7 | Detector | -35.9 | -34.7 | -1.2 |
| 8 | Detector | -36.3 | -34.7 | -1.6 |
| 9 | Detector | -31.2 | -34.7 | 3.5 |
| 10 | Detector | -31.5 | -34.7 | 3.2 |
| 13 | Detector | -39.3 | -34.7 | -4.6 |
| 1 | DFEE | -28.4 | -27.7 | -0.7 |
| 2 | DFEE | -29.4 | -27.7 | -1.7 |
| 3 | DFEE | -28.7 | -27.7 | -1.0 |
| 6 | DFEE | -29.5 | -27.7 | -1.8 |
| Thstor 1 | DAE _E | -24.0 | -25.1 | 1.1 |
| Thstor 2 | DAE | -29 | -25.1 | -3.9 |
| thstor | DFEE HV PCB | -29 | -27.7 | -1.3 |
| 14,15,18 | Coldplate | -28.4 | -28.4 | 0.0 |
| 16,17 | TVC Shroud | -71.3 | -71.3 | 0.0 |

(*) sensors which belong to statistical sample (12 sensors in total)

-0.8
2.4

average error
standard dev



ENVIRONMENT : HOT CASE TB
 TIME: 05.09.01 13:57
 THERMAL MODEL: JEM-X ORIGINAL (UNADJUSTED WITH RESPECT TO EID-B) THERMAL MODEL

| POWER DISSIPATIONS | |
|--------------------|--------|
| DAE | 5.6 W |
| DFEE | 22.7 W |

| THERMAL MODEL ADJUSTMENTS |
|--------------------------------------|
| none; model identical to EID-B model |

| TC | Descr | Tmeasured (C) | Tpred (C) | Tmeas-Tpred (C) |
|----------|-------------|---------------|-----------|-----------------|
| 7 | Detector | 38.9 | 39.2 | -0.3 |
| 8 | Detector | 38.5 | 39.2 | -0.7 |
| 9 | Detector | 41.1 | 39.2 | 1.9 |
| 10 | Detector | 40.9 | 39.2 | 1.7 |
| 13 | Detector | 36.1 | 39.2 | -3.1 |
| 1 | DFEE | 43 | 43.2 | -0.2 |
| 2 | DFEE | 42.2 | 43.2 | -1.0 |
| 3 | DFEE | 42.8 | 43.2 | -0.4 |
| 6 | DFEE | 42.1 | 43.2 | -1.1 |
| Thstor 1 | DAE | 48.9 | 61.6 | -12.7 |
| Thstor 2 | DAE | 48.9 | 61.6 | -12.7 |
| thstor | DFEE HV PCB | 42.5 | 43.2 | -0.7 |
| 14,15,18 | Coldplate | 42.3 | 42.3 | 0.0 |
| 16,17 | TVC Shroud | 26.7 | 26.7 | -0.1 |

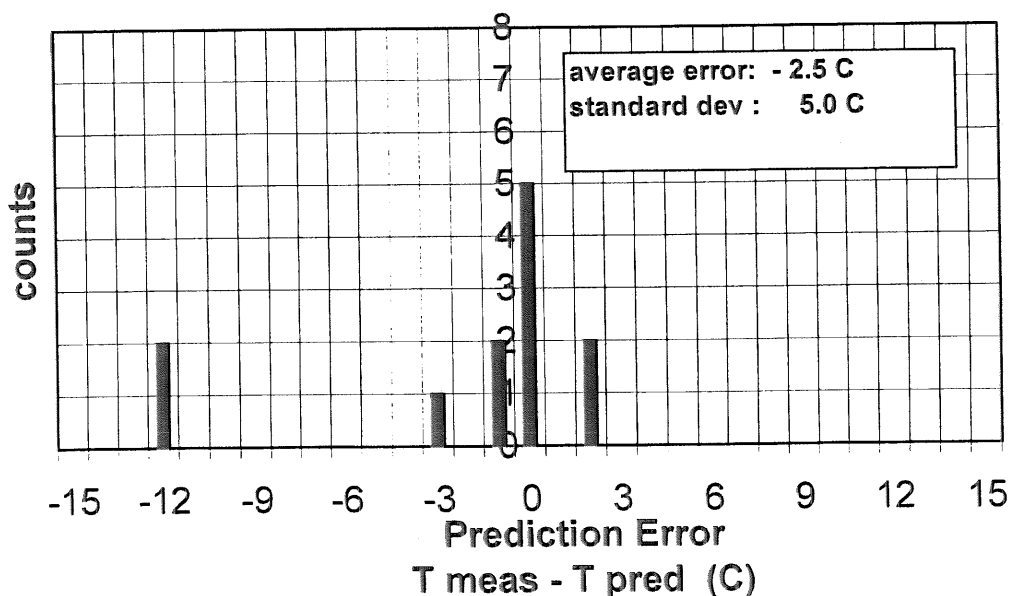
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(*) sensors which belong to statistical sample (12 sensors in total)

-2.5
5.0

average error
standard dev

JEM-X QM ORIGINAL THERMAL MODEL: HOT CASE TB ERROR DISTRIBUTION OF TEMPERATURE PREDICTIONS



ITEM FM 1 JEM-X
 ENVIRONMENT : HOT CASE TB
 TIME: 05.09.01 13:57
 THERMAL MODEL: JEM-X QM THERMAL MODEL "4"

| POWER DISSIPATIONS | |
|--------------------|--------|
| DAE | 5.6 W |
| DFEE | 22.7 W |

THERMAL MODEL PARAMETER ADJUSTMENTS
 same as model 3 and in addition:
 1 - conductance between Detector Electronics and Detector Vessel
 multiplied x 2.2 (original value 0.25 W/K, final value 0.55 W/K)

| TC | Descr | Tmeasured (C) | Tpred (C) | Tmeas-Tpred (C) |
|----------|-------------|---------------|-----------|-----------------|
| 7 | Detector | 38.9 | 38.7 | 0.2 |
| 8 | Detector | 38.5 | 38.7 | -0.2 |
| 9 | Detector | 41.1 | 38.7 | 2.4 |
| 10 | Detector | 40.9 | 38.7 | 2.2 |
| 13 | Detector | 36.1 | 38.7 | -2.6 |
| 1 | DFEE | 43 | 43.5 | -0.5 |
| 2 | DFEE | 42.2 | 43.5 | -1.3 |
| 3 | DFEE | 42.8 | 43.5 | -0.7 |
| 6 | DFEE | 42.1 | 43.5 | -1.4 |
| Thstor 1 | DAE | 48.9 | 48.1 | 0.8 |
| Thstor 2 | DAE | 48.9 | 48.1 | 0.8 |
| thstor | DFEE HV PCB | 42.5 | 43.5 | -1.0 |
| 14,15,18 | Coldplate | 42.3 | 42.3 | 0.0 |
| 16,17 | TVC Shroud | 26.7 | 26.7 | 0.0 |

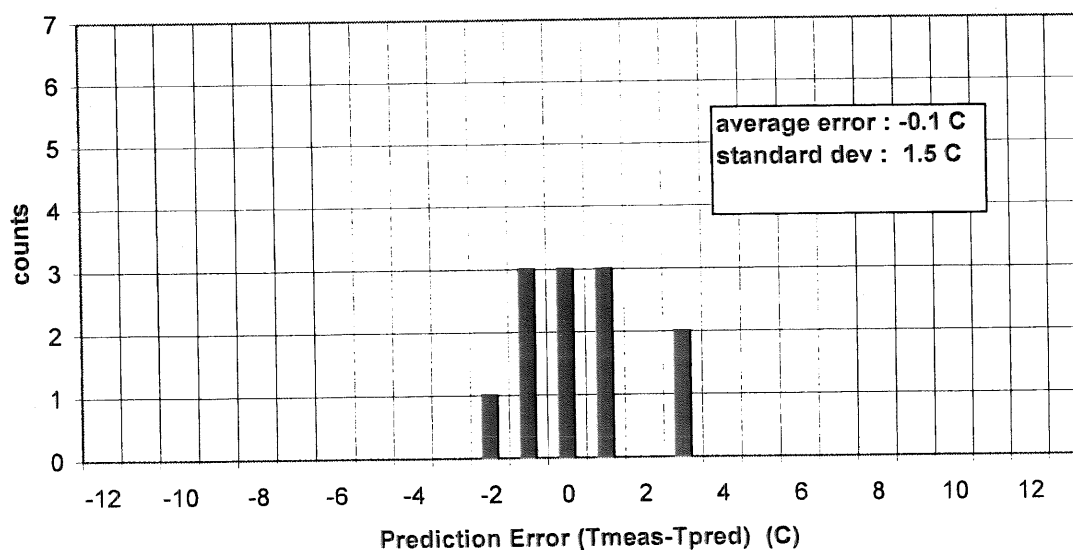
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(*) sensors which belong to statistical sample (12 sensors in total)

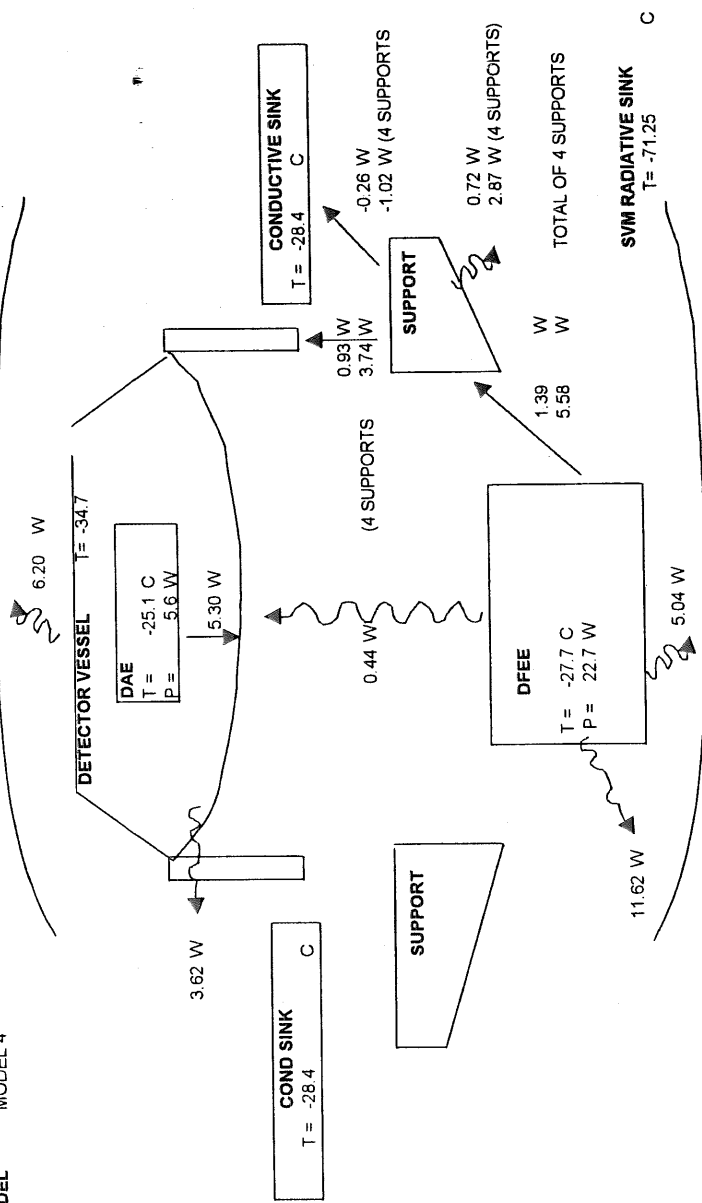
-0.1
1.5

average error
standard dev

FM 1 JEM-X THERMAL MODEL "4": HOT CASE TB ERROR DISTRIBUTION OF TEMPERATURE PREDICTIONS



PLM RADIATIVE SINK
T = -71.25 C



PLM RADIATIVE SINK
T = 26.65 C

