FSP – Mechanical Design

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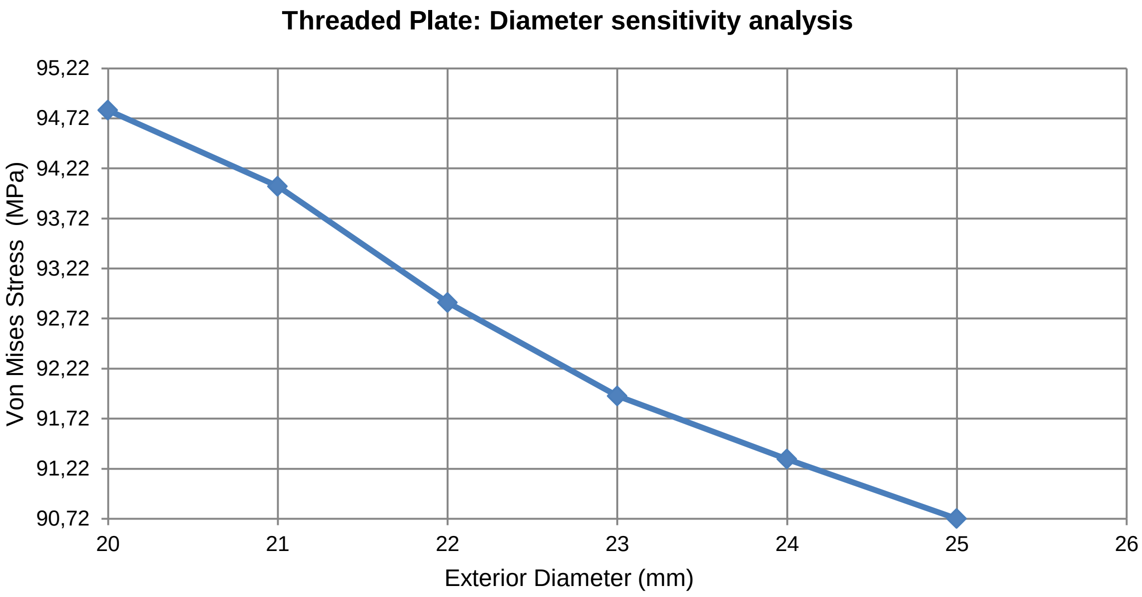
Mechanical analysis - Threaded Plate

Sensitivity analysis

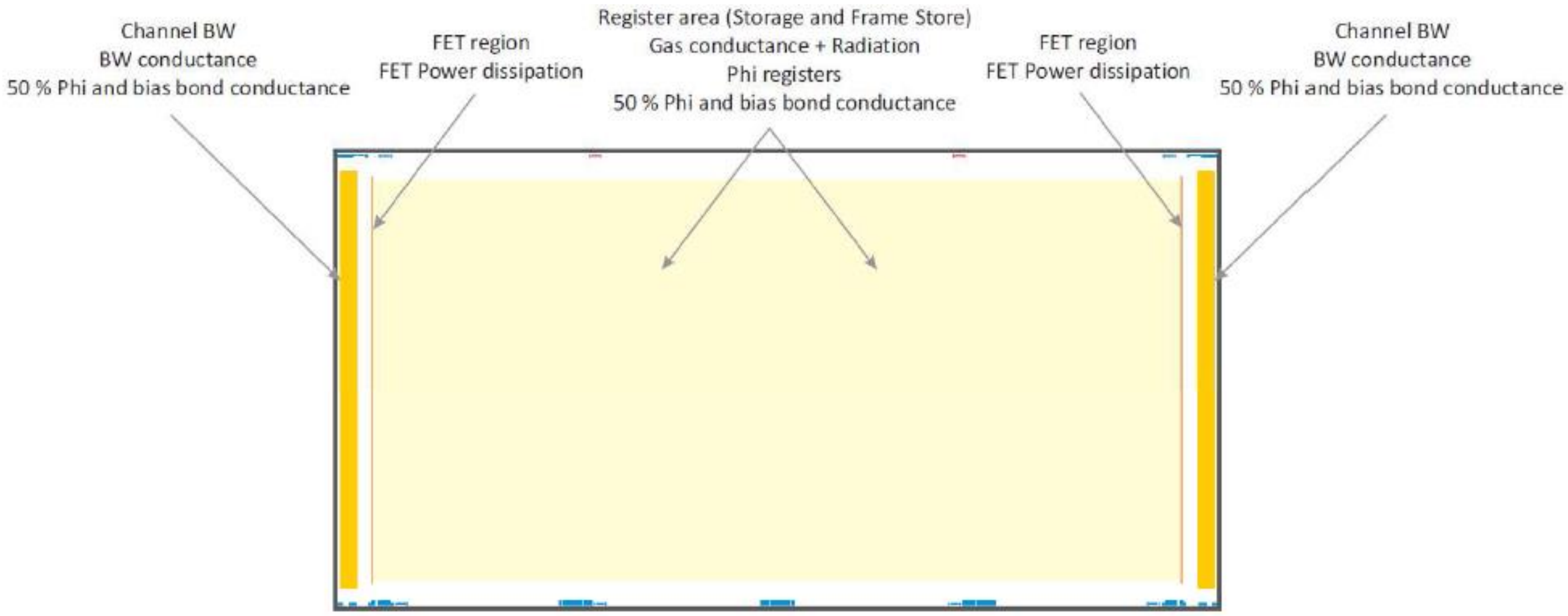
- The analysis shows a lineal relation between the exterior diameter and the stresses in the threaded plate.
- In all cases the stresses obtained are by far below the maximum allowable stress, which is 360 MPa according to the design criterion for A2-70 Stainless Steel.
- The corresponding stresses on the Cooling block (not represented here) meet also the design requirements in all instances.



Thermal Analysis - Problem statement

Definition

- Goal: Average CCD temperature = **-35°C**.
- Loads: Total heat load = **11 W**, not uniformly distributed.
- Boundary conditions:
  - Operating parameters of the thermoelectric cooler (see slide #5).
  - Temperature at the evaporator surface of the heat pipes (see slide #5).
  - NO Environment radiation.

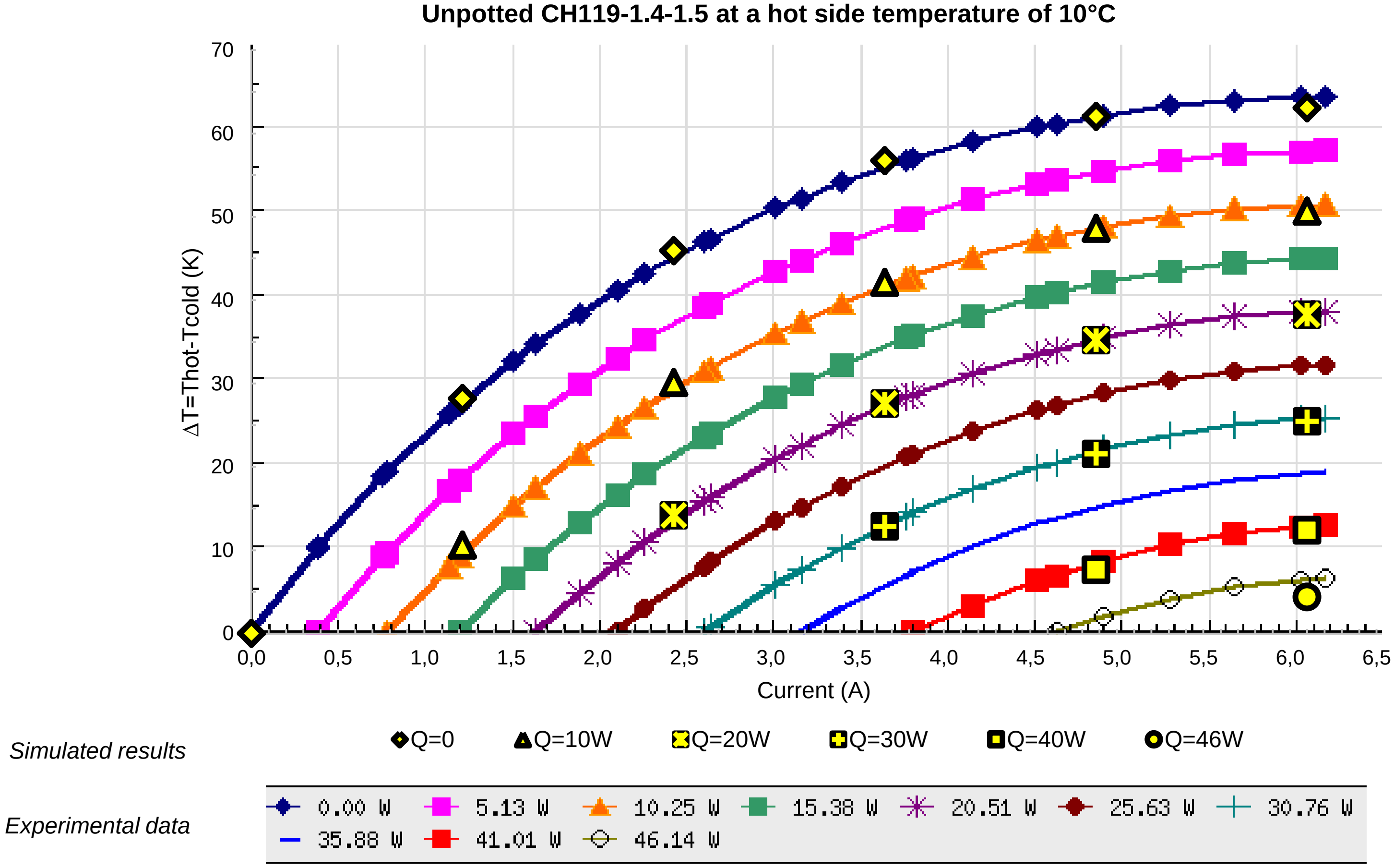


Register area dissipation: 1.1 W +1 W + 0.3 W + 2.5 W = 4.9 W
FET region dissipation: 1.5 W each
Channel BW region: 1.4 W + 0.15 W each

Thermal Analysis – Validation of the TEC Model

Performance validation of the simulation model

- The TEC CH-119-1.4-1.5 (with center hole) has been modeled using the geometry and performance characteristics provided by the manufacturer (Vmax, Imax, Qmax and ΔTmax for 27 and 50°C hot side temperature).
- For a fixed hot side temperature of **+10°C**, the temperature difference between the hot and cold side has been numerically obtained for different heat loads. As it can be seen, the simulated results match the experimental data.



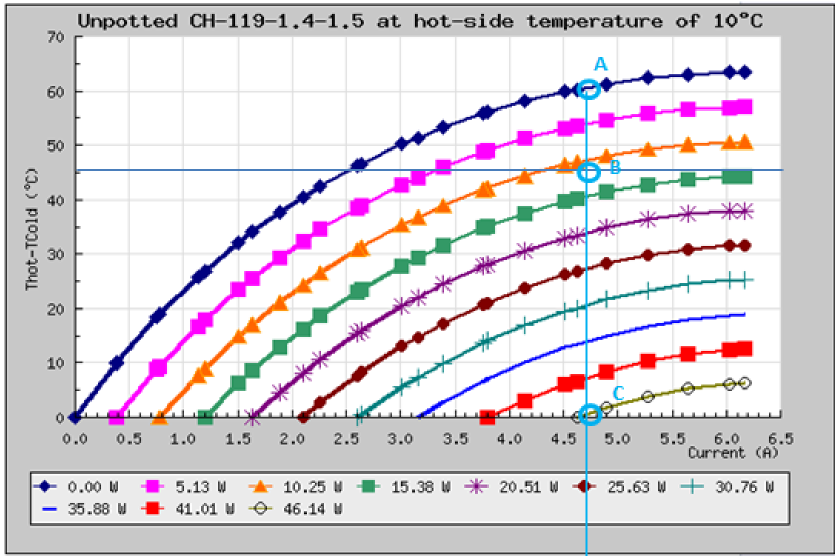
Thermal Analysis – Operation of the TEC

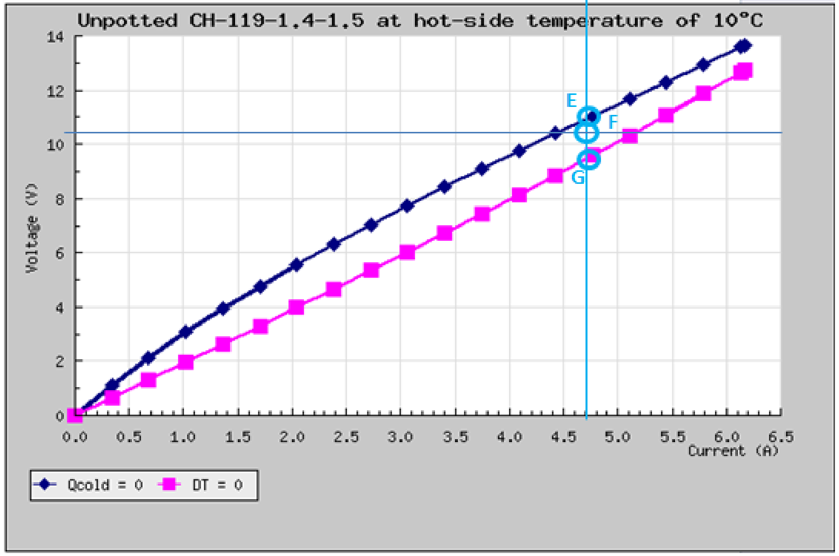
Determination of the optimal operational parameters of the thermoelectric cooler

- In order to obtain an average temperature of -35°C at the CCD, and because of the thermal resistance in the Cooling block, the temperature at the cold side must be lower: **-35.7°C**.
- The evacuated heat load includes an additional 1W from possible losses through the screw assembly.
- The operational parameters are obtained graphically using the manufacturer curves.

Input	
Max. Temperature difference, ΔTmax (K)	70
Evacuated heat load, Qc (W)	12
Temperature on the cold side, Tcold (°C)	-35.7
Temperature on the hot side, Thot (°C)	+10
Operational parameters	
Current, I (A)	**4.7**
Voltage, V (V)	**10.4**
Output	
Waste heat load, Qp (W)	48.88

- Taking in account the assembly thermal resistances, the temperature at the heat pipe evaporator should be +**5°C** in order to obtain a +10°C temperature on the hot side of the TEC module.



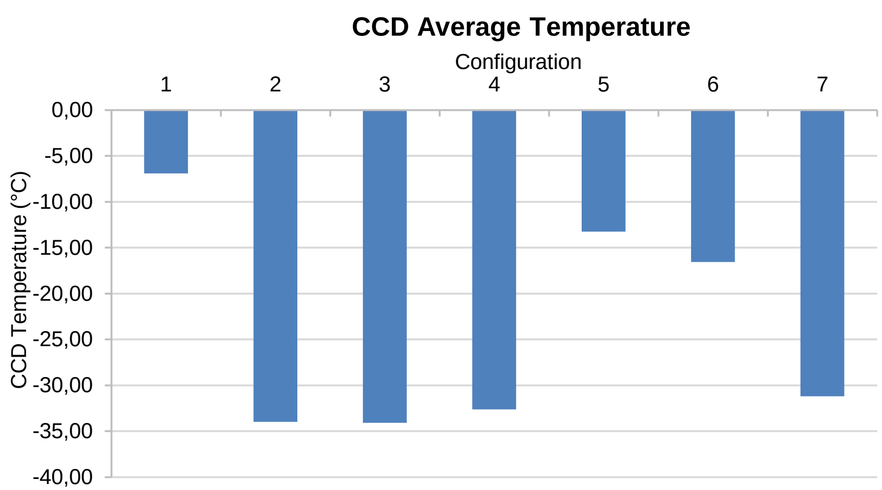


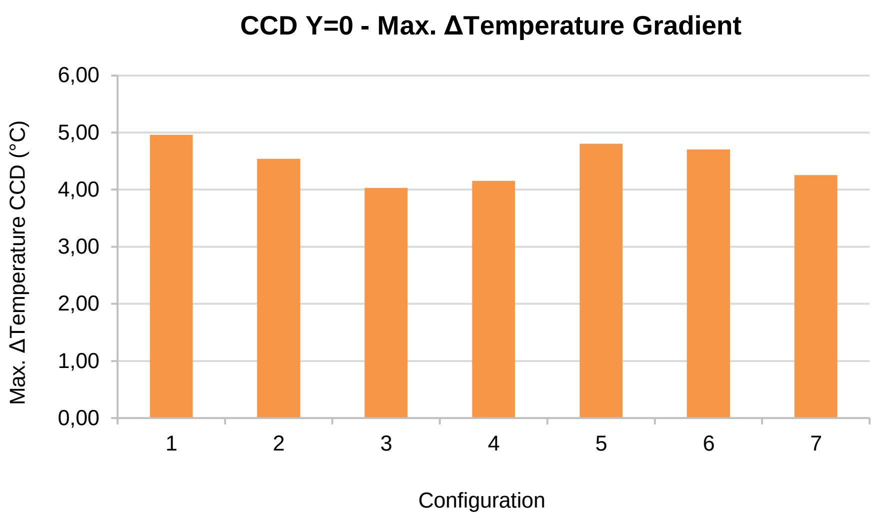
Thermal Analysis – Simulation results

Analysis of the simulation results

- For the selected parameters, **4.7A** and a **+5°C** temperature on the heat pipe evaporator, an average temperature on the CCD of **-6.91°C** is obtained.
- This result significantly differs from what was expected. Through a detailed analysis it has been found that this deviation is due to a thermal leakage through the contact surface between Cooling block and FPA. The results obtained for different assembly configurations are summarized in the following table.

Configuration	Description	Temperature hot (°C)	Temperature cold (°C)	ΔT=T hot-Tcold (°C)	Av. Temperature CCD (°C)	Max. ΔTemperature CCD-Section Y=0 (°C)
1	Complete assembly	7,44	-9,62	17,07	-6,91	4,96
2	Basic = Backbone + TEC + Si-Block + CCD	7,21	-35,28	42,49	-33,98	4,54
3	Basic + Screw assembly	7,22	-34,10	41,32	-34,10	4,03
4	Basic + Screw assembly + TIM TEC-Si-Block	7,23	-34,26	41,49	-32,61	4,15
5	Complete + TIM Si-Block-FPA [t=0.2mm k=0.25W/mK]	7,38	-15,70	23,09	-13,24	4,80
6	Complete + TIM Si-Block-FPA [t=0.4mm k=0.25W/mK]	7,35	-18,89	26,24	-16,57	4,70
7	Complete + TIM Si-Block-FPA [t=0.4mm k=0W/mK]	7,23	-32,93	40,16	-31,20	4,26

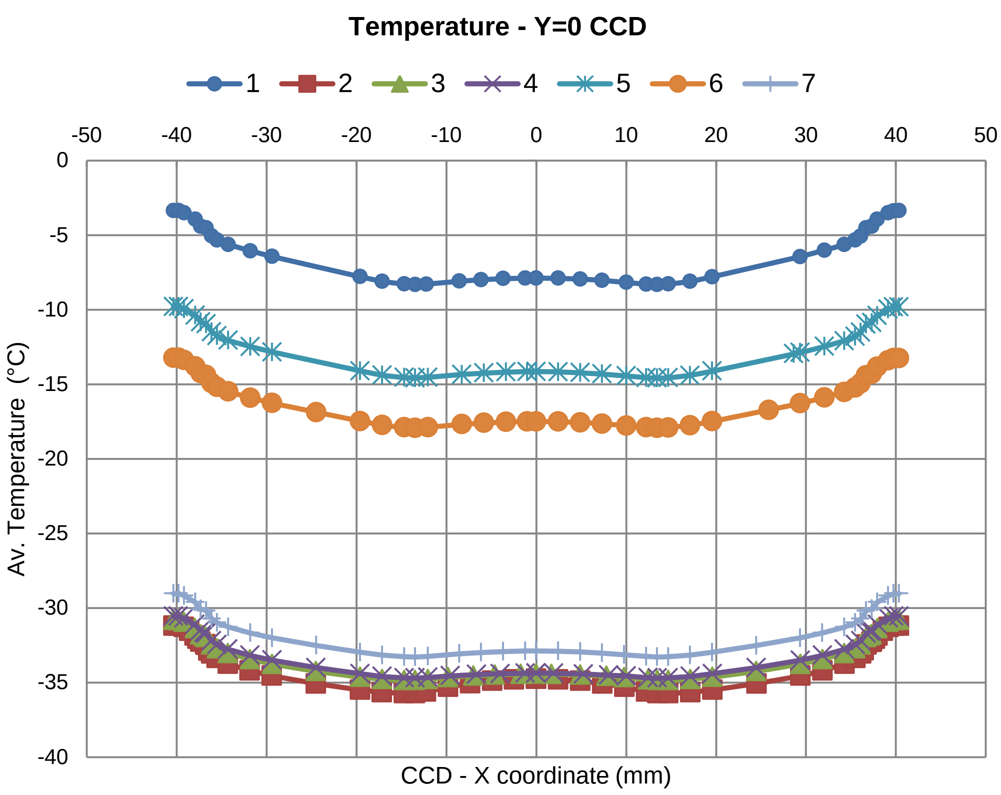


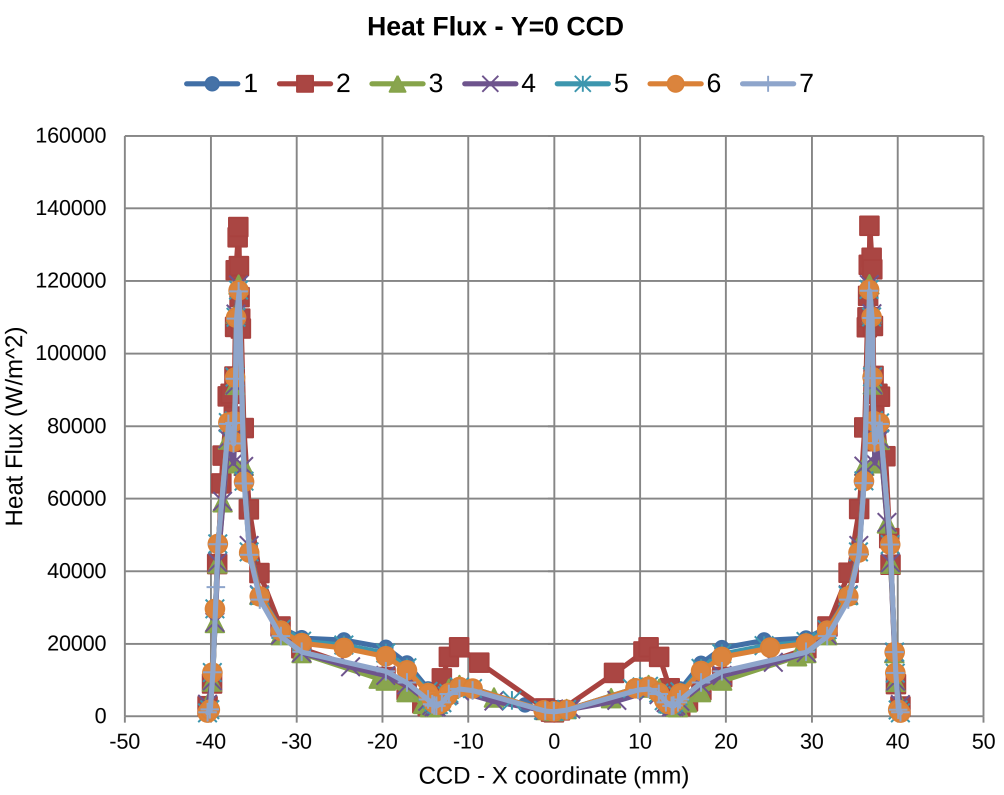


Thermal Analysis – Simulation results

Average temperature and heat flux profile on the CCD

- The graphs below correspond to the temperature and heat flux profile at a Y=0 section of the CCD for different assembly configurations.
- The maximum temperature gradient remains almost constant with a mean value of **4.54°C**.

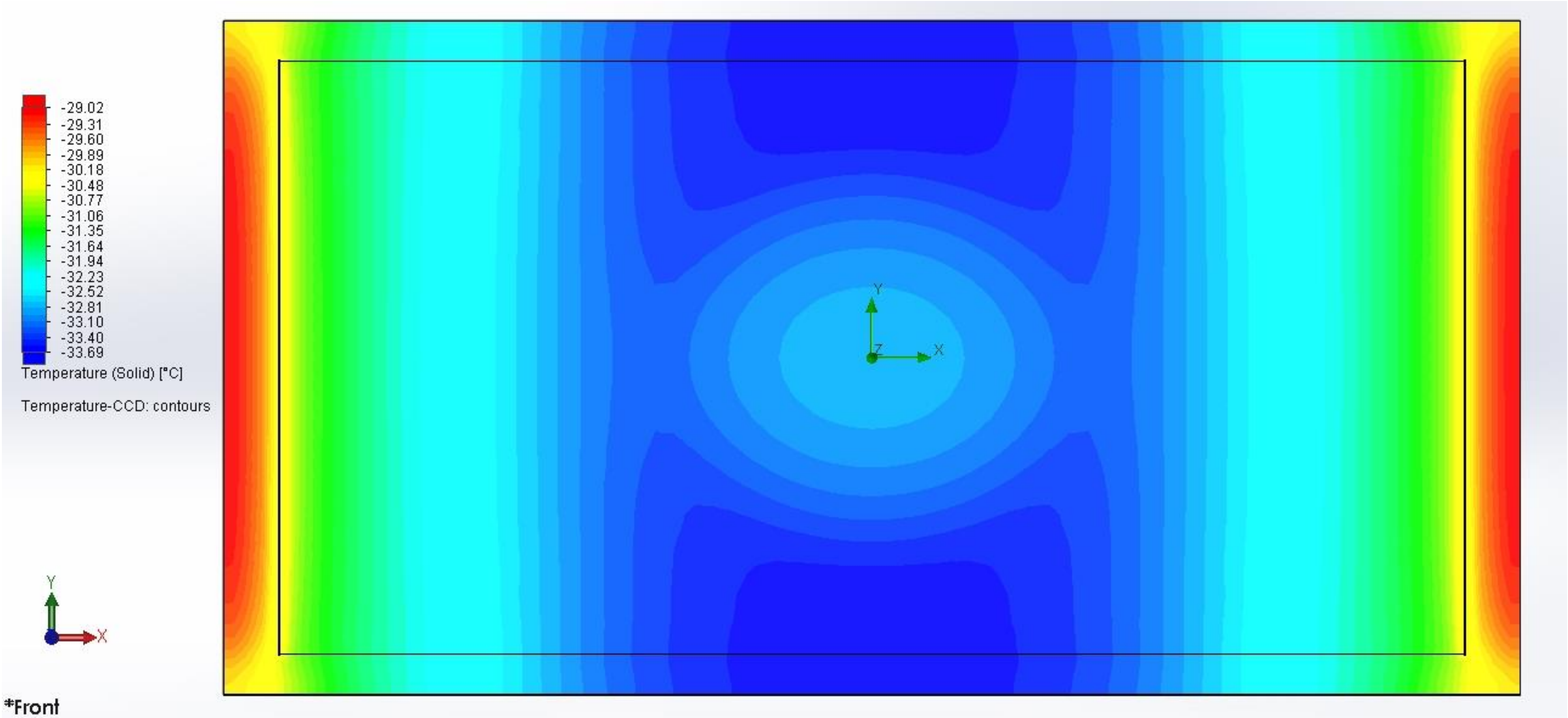




Thermal Analysis – Study case

Configuration #7: Temperature distribution

- The results obtained for the configuration #7 are here presented. Although a thermal interface material which is a perfect insulator is obviously not real, it can be representative of a new design with a negligible thermal leakage.
- The following image shows the temperature distribution on the CCD for the this configuration.

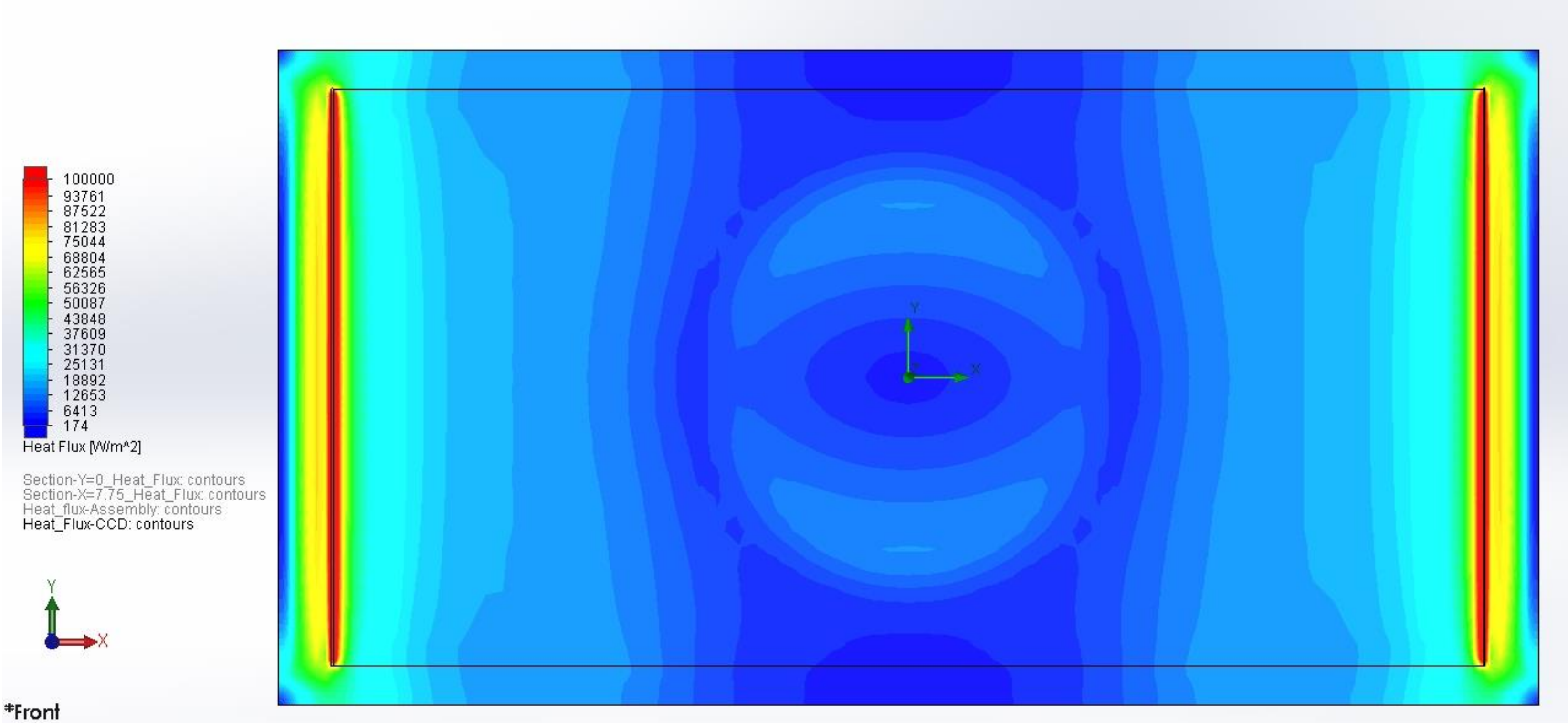


Temperature distribution on the CCD [I=4.7A ;T_HP=+5°C]

Thermal Analysis – Study case

Configuration #7: Heat flux distribution

- This image shows the heat flux distribution on the CCD; with a pronounced effect on the sides due to the heat load corresponding to the FET and BW region. The consequence of the threaded plate, in the center, is obvious but less accused.

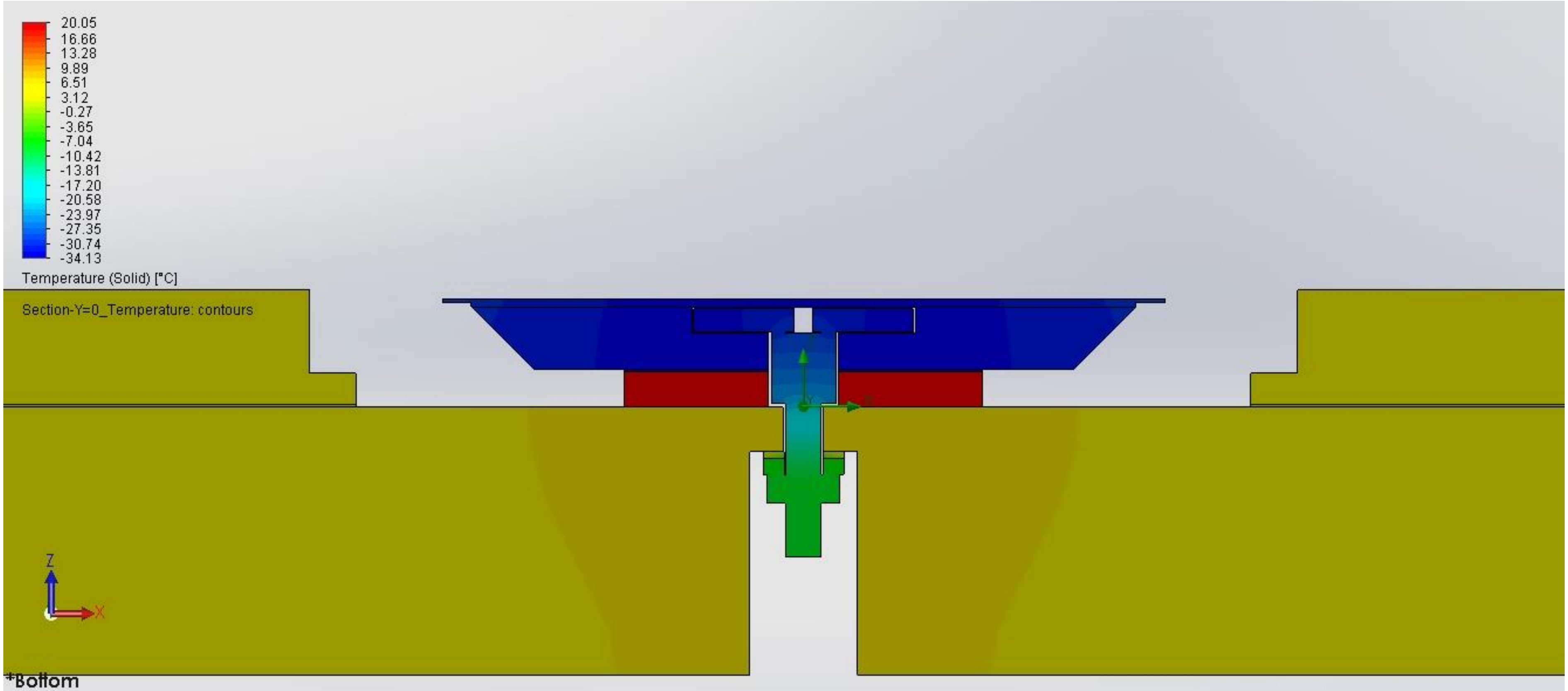


Heat flux distribution on the CCD [I=4.7A ;T_HP=+5°C]

Thermal Analysis – Study case

Configuration #7: Temperature distribution Y=0 section

- In the transversal section we can see the temperature distribution over the entire assembly.
- The average temperature of the backbone is **+5.62°C** and the temperature at the hot side of the TEC is +**7.23°C**.
- The heat loss through the insulating washer is **0.53W**.



Temperature distribution – Y=0 Section [I=4.7A ;T_HP=+5°C]