TFAWS Passive Thermal Paper Session

Interface Conductance Under a Real Electronics Box

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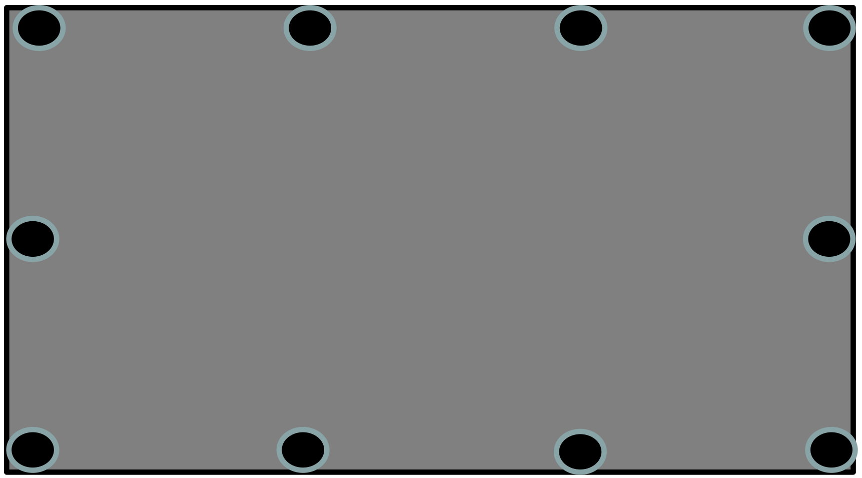
The “Issue”

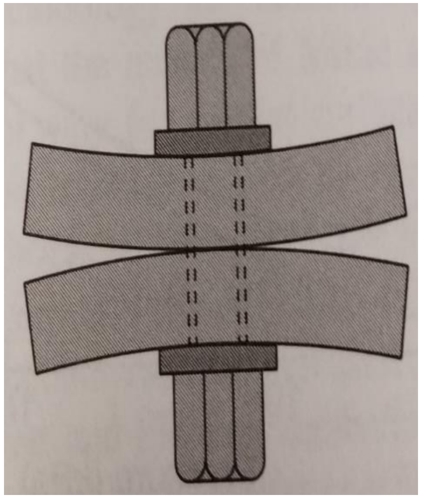
- Vendor material contact conductance data is “inflated” for real-world Electronics boxes (large surface areas).
  - They use 1” X 1” samples under ideal high pressures.
  - Unrealistic for Spacecraft E-boxes in a vacuum.

- However, Electronics boxes are bolted along its **perimeter**
  - Creating potato chipping (separation) in the box’s center.
    - **Reduction of contact = reduction of contact conductance (in a vacuum)**



"Potato Chipping" between bolts

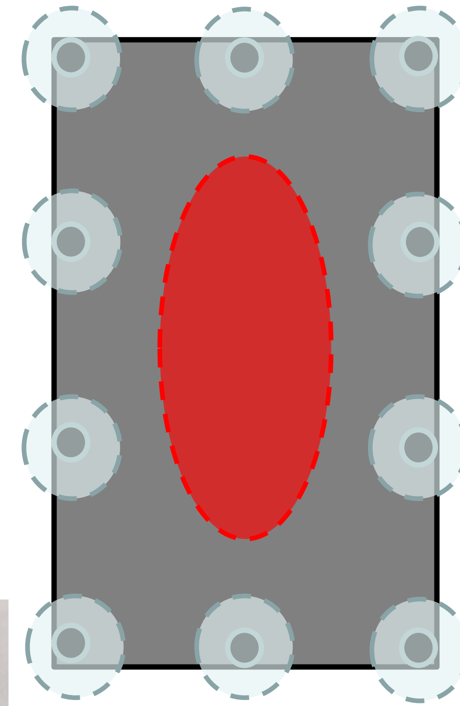
- Bolted dry joints typically have 2.5 bolt diameters of contact
  - For a #8 bolt, this means 0.41" diameter of contact
- Use of interface material will enlarge this footprint, but usually is highly pressure dependent.
- Wet joints do not rely on pressure but can still see separation if not applied thick enough.

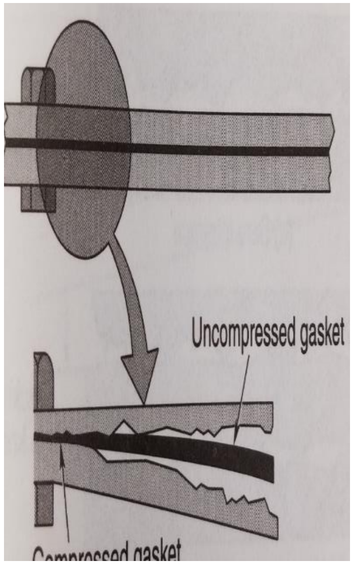


E-Box bottoms "Potato Chip" between bolts

Highly dependent on:

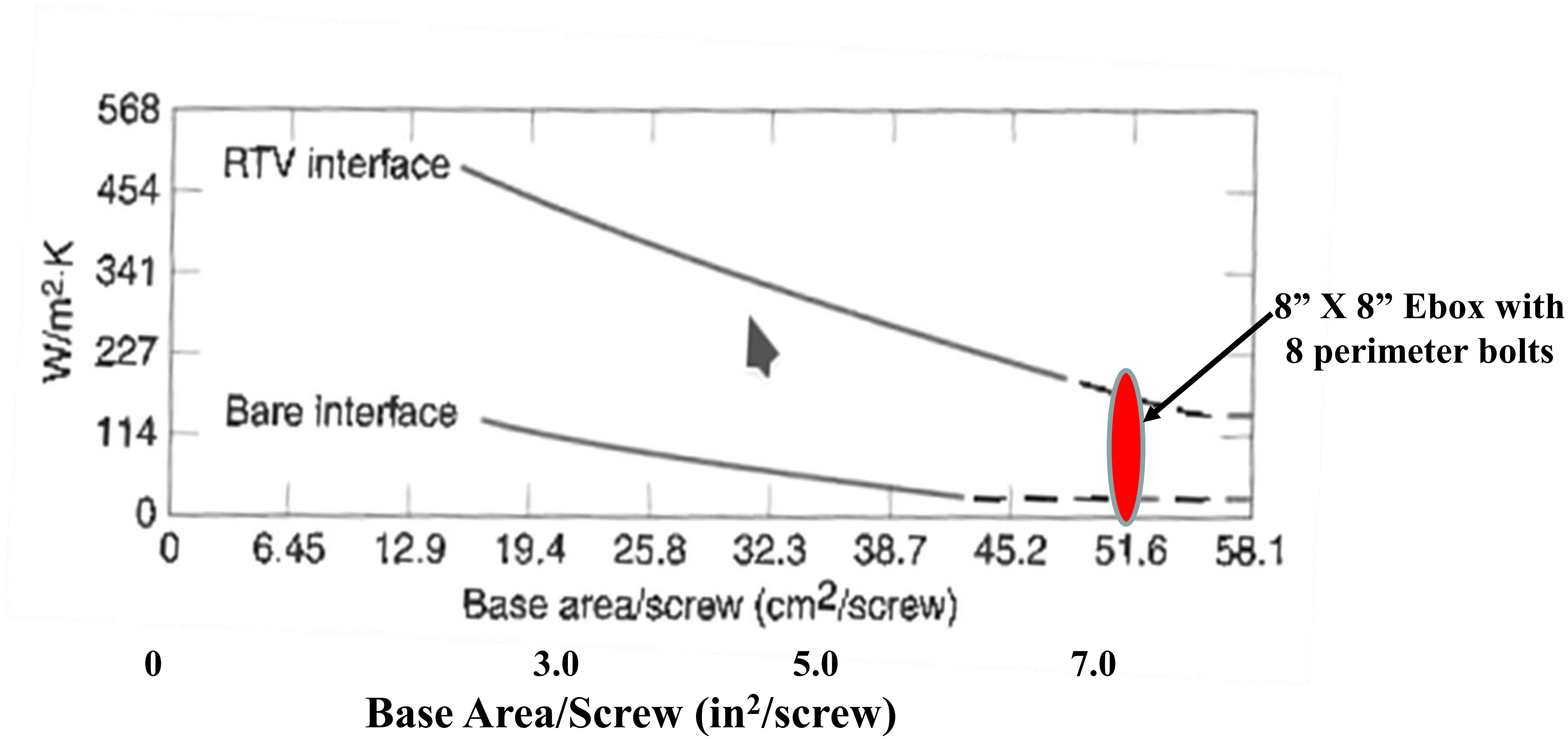
1. Box baseplate thickness
2. Distance between bolts
3. Bolt diameter
4. Bolt Torque
5. Stiffness of Coldplate/radiator
6. Overall Dimensions of box.





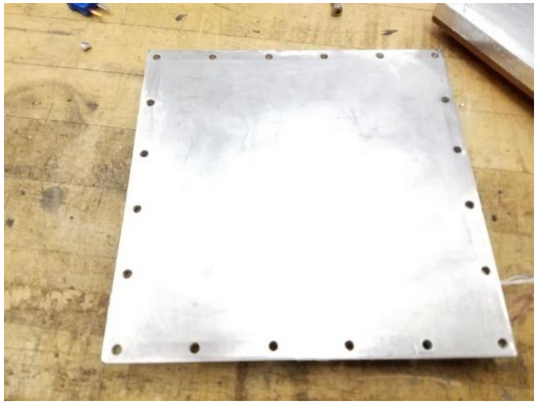
Some Empirical Data for E-Boxes

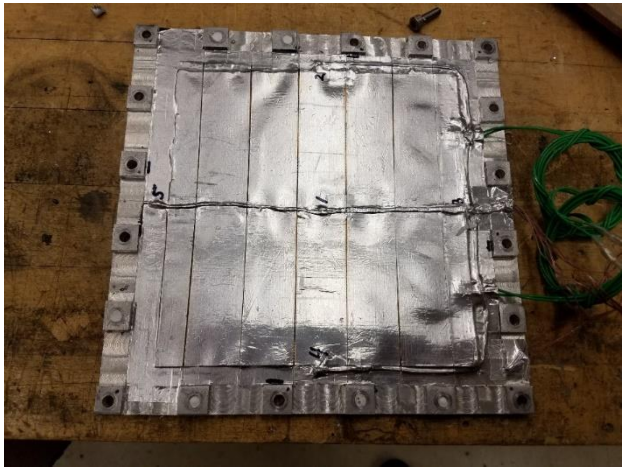
- Check out Spacecraft Thermal Control Handbook, Chapter 8



Lets Do a Test !

- An 8”X 8” plate (simulating an E-box baseplate) was fabricated
  - Typical 1/8” plate thickness
  - Increased to ¼” at bolts to simulate “stiffness” of sidewalls.
  - 20 bolt holes were placed around perimeter
    - Only used 8 bolts for testing
      - More representative of a real Ebox
  - Machined as flat as Building 5 could do.





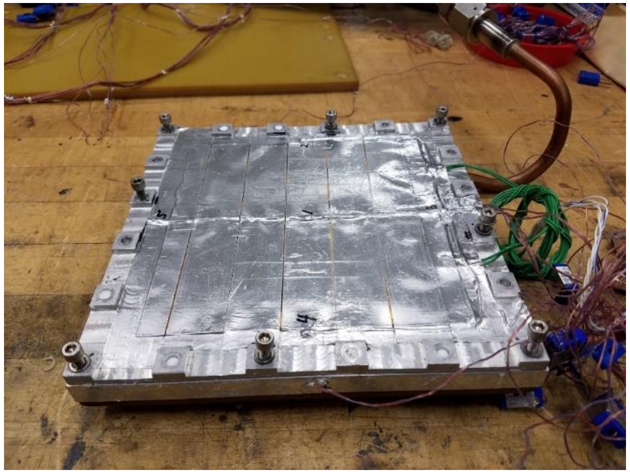
Interface Materials Tested

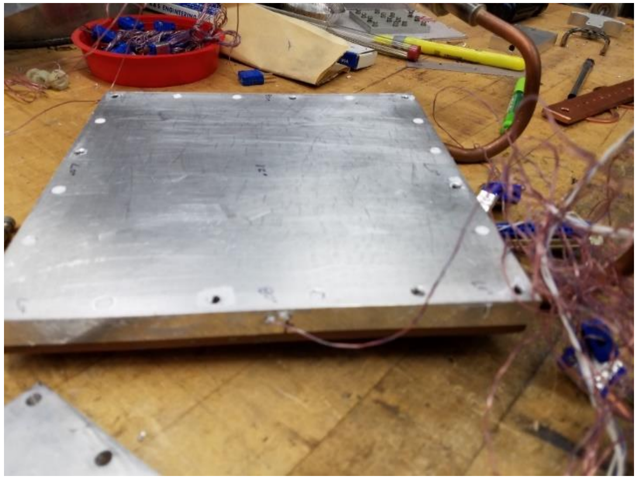
- Bare joint (#8 bolts)
- Chotherm 1671
- Choseal 1285
- T-Pli 220
- T-Pli 210
- Egraf HT1210
- Grafoil
- Indium Foil
- Berquist Sil-Pad K10
- Berquist Hi-Flow 300
- Mouser Gap Pad
- Micro Faze 3A6
- Carbice
  - Sheet and Engineered Shim
- Compresible Egraf HT-3200
- Nusil 2946

Tested in the Waffle Iron Chamber

Test Specifics

- Heaters were placed on the E-Box bottom
  - 48 watts applied (simulate "high end" E-Box power)
- MLI blanket over the test article
- Cold plate had liquid chiller loop to remove heat
  - Room temperature testing (typical of an Ebox)
  - High Vacuum pressure
- Five thermocouples placed on test article, Five on Chiller plate
  - One T/C at Ebox center, four others around perimeter
- #8 bolts torqued down to 40 in-lbs in a star shaped pattern.
- Interface materials were baked out beforehand; typical of Goddard procedures
- Nusil used Miller-Stephenson MS-143 mold release agent; typical of Goddard procedures





Typical Temperature Results

SINGLE layer of 0.010" thick eGraf that recorded on 07/18/17.
Using same voltage as in previous tests, 40 in-lb, using 8 Screws
P= 26.8V X 1.79A = 48.0W
Using 8 Screws:
TC1= 29.87C
TC2= 24.32
TC3= 24.52
TC4= 24.50
TC5= 24.80
TC6= 23.26
TC7= 22.61
TC8= 22.48
TC9= 22.43
TC10=21.63C

NuSil with around 0.007" thick layer, test results today:
P= 26.2V X 1.83A = 48.0W
Using 8 Screws:
TC1= 24.63C
TC2= 22.15
TC3= 22.31
TC4= 22.39
TC5= 22.48
TC6= 22.71
TC7= 22.11
TC8= 22.04
TC9= 22.14
TC10=22.21C

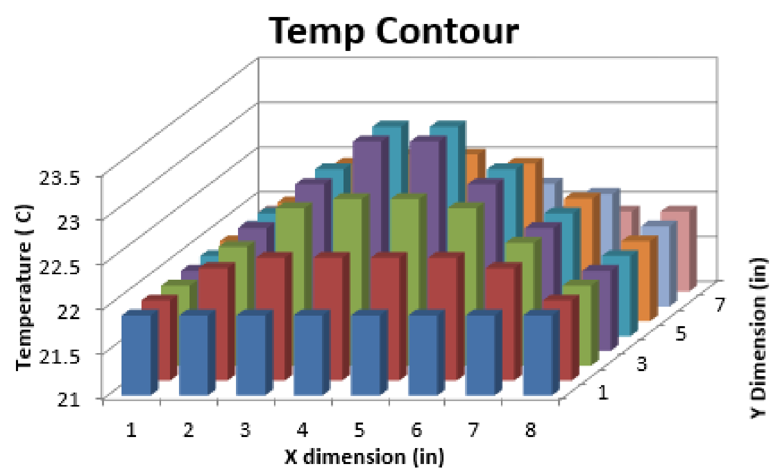
T/C #1: Center of Top Plate
T/C 2-5: Edges of Top Plate
T/C 6: Center of Bottom Plate
T/C 7-10: Edges of Bottom Plate

Determining “Average” Temperatures

- Excel File was created to populate 8” X 8” Ebox into 64 “nodes”

21.895	21.895	21.895	21.895	21.895	21.895	21.895	21.895
21.895	22.25625	22.3285	22.37185	22.37185	22.3285	22.25625	21.895
21.895	22.37185	22.762	22.86315	22.86315	22.762	22.37185	21.895
21.895	22.37185	22.86315	23.34	23.34	22.86315	22.37185	21.895
21.895	22.37185	22.86315	23.34	23.34	22.86315	22.37185	21.895
21.895	22.37185	22.762	22.86315	22.86315	22.762	22.37185	21.895
21.895	22.25625	22.37185	22.37185	22.37185	22.37185	22.25625	21.895
21.895	21.895	21.895	21.895	21.895	21.895	21.895	21.895

INPUTS	
23.34	Center Temp
21.90	Avg Edge Temp
22.30	Avg Temp



Results

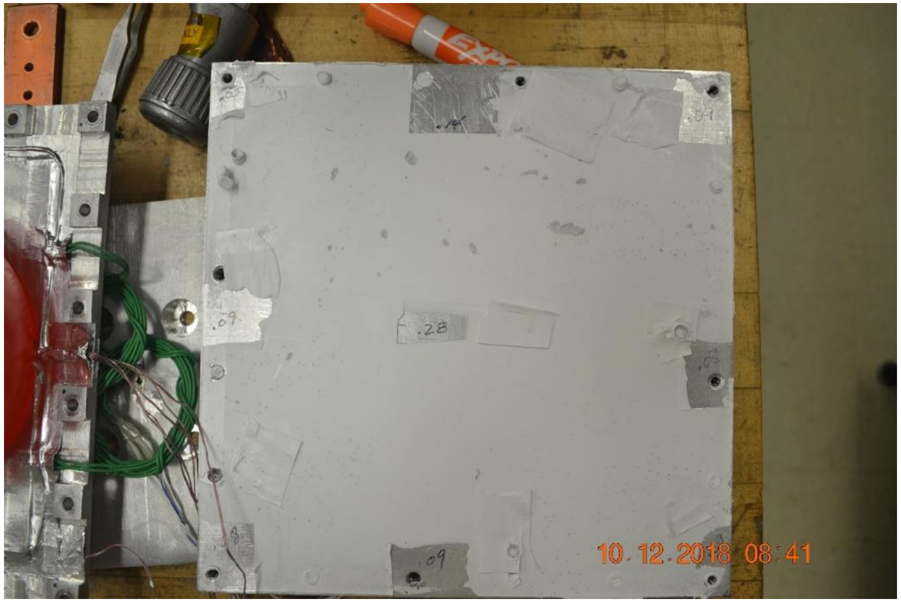
	Interface Material	Box Average (deg C)	Platen Avg (deg C)	delta-T	Watts	W/C	Overall Conductance W/in^2-C	Factor: Relative to Bare Joint
	NuSil 2946, 0.025" initial thk	22.30	21.99	0.31	47.95	155.67	2.43	27.66
Datasheet G = 1.59 W/in^2-C	NuSil 2946, 0.020" initial thk	22.20	21.76	0.44	47.95	108.97	1.70	19.36
	NuSil 2946, 0.062" initial thk	23.09	22.36	0.73	48.10	65.89	1.03	11.71
	NuSil 2946, 0.010" initial thk	22.98	22.25	0.73	47.95	65.86	1.03	11.70
	NuSil 2946, 0.005" initial thk	24.08	22.34	1.74	47.95	27.59	0.43	4.90
	eGraf HT-C3200 (compressible Egraf)	24.39	22.39	2.00	48.02	24.04	0.38	4.27
	Mouser Gap Pad 0.020" thk	25.38	22.55	2.83	47.95	16.95	0.26	3.01
	Carbice Engineered Shim	25.47	22.44	3.03	48.00	15.84	0.25	2.82
	Micro Faze 3A6, 0.006" thk	25.84	22.72	3.12	47.95	15.36	0.24	2.73
	eGraf HT-1210, 0.010" thk	26.04	22.48	3.56	47.95	13.48	0.21	2.39
	eGraf HT-1210, 2 pieces 0.010" thk	26.27	22.55	3.72	47.95	12.90	0.20	2.29
	T-PLI 220 w/o fiberglass	26.21	22.45	3.76	47.95	12.74	0.20	2.26
	eGraf 3 pieces 0.010" thk	26.58	22.79	3.79	47.95	12.66	0.20	2.25
	eGraf HT-1210 (reused sheet)	26.89	22.61	4.28	47.95	11.21	0.18	1.99
	Carbice Sheet	26.95	22.52	4.43	48.03	10.84	0.17	1.93
	eGraf 0.005" thk	27.07	22.56	4.51	47.95	10.63	0.17	1.89
	T-PLI 210 with fiberglass	26.91	22.25	4.66	47.95	10.30	0.16	1.83
	Berquist 300P2 repeat (40^{O}C bake)	27.57	22.63	4.94	47.95	9.71	0.15	1.73
	Grafoil 0.010" thk	28.00	22.47	5.53	47.95	8.66	0.14	1.54
	Therm-a-Gap 579, 0.010" thk	28.16	22.40	5.76	48.02	8.33	0.13	1.48
	Indium 4 pieces, 1" wide 0.010" thk	28.71	22.43	6.28	47.95	7.64	0.12	1.36
	Berquist Sil Pad K10, 0.007" thk	29.30	22.57	6.73	47.95	7.13	0.11	1.27
	Indium 0.005" thk	29.31	22.40	6.91	47.95	6.94	0.11	1.23
Datasheet G = 4.35 W/in^2-C	ChoTherm 1671, 0.015" thk	29.47	22.43	7.04	47.95	6.81	0.11	1.21
	ChoSeal 1285, 0.020" thk	30.48	22.83	7.65	47.95	6.27	0.10	1.11
	Berquist Hi-flow 300P2, 0.005"thk	30.66	22.79	7.87	47.95	6.09	0.10	1.08
Empirical G = 0.10 W/in^2-C	Bare joint	31.01	22.49	8.52	47.95	5.63	0.09	1.00

Nusil Observations

- Thickness matters
  - Not immune to potato chipping in the center
  - Nusil would be thicker in the center than original application thickness
    - “Squeeze out” at edges; “squeeze-in” at center

20 mil Initial Thickness

25 mil Initial Thickness



Overall Conclusions

- Bare joint conductances can be improved substantially using interface materials.
  - But not all materials behave the same!
- Chotherm is not very good for large boxes
  - But it cuts easily, doesn’t create debris, and stores well (flat or rolled)
- Some materials give better results than Chotherm, but does not cut well and leaves debris. Probably not worth the benefit.
- Nusil is the best performer, but needs about 20 mils thickness for 8” X 8” footprint
  - But comes with lots of Contamination Engineering “baggage” during application process
- Some new materials out there which promise “close to Nusil” performance with a solid sheet