Interface Conductance Under a Real Electronics Box

David E. Steinfeld GSFC/Code 545
Mario S. Martins, GSFC/Lentech

Presented By
David E. Steinfeld

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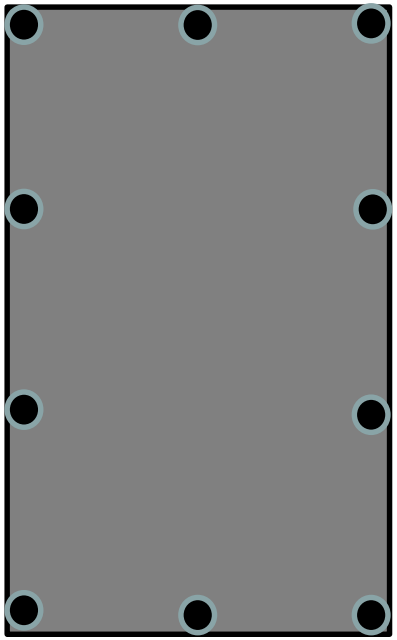
The “Issue”

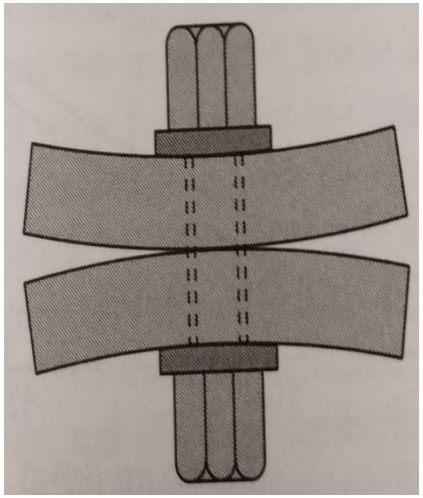
- Vendor material contact conductance data is “inflated” for real-world Electronics boxes (having large surface areas).
  - Vendors use 1” X 1” samples under high pressures.
  - Unrealistic for Spacecraft E-boxes in a vacuum.

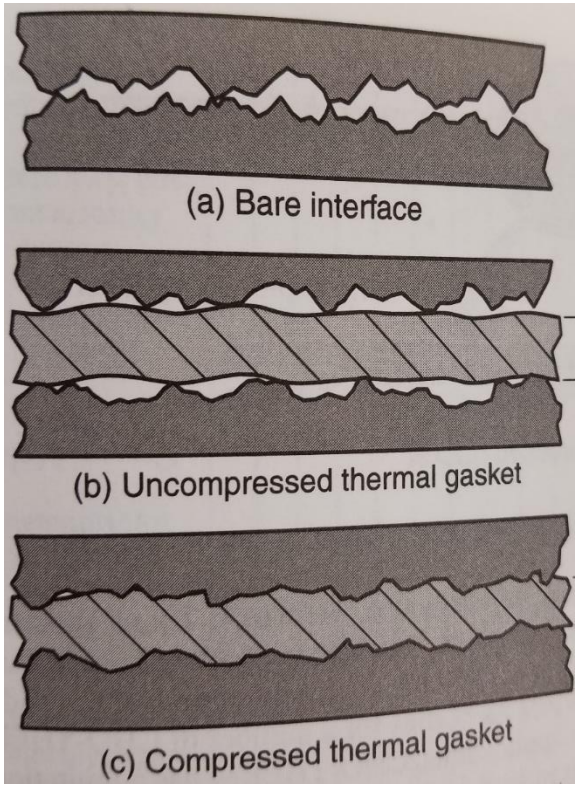
- However, Electronics boxes are bolted along its **perimeter**
  - Creating potato chipping (separation) in the box’s center.
    - **Reduction of contact = reduction of contact conductance (in a vacuum)**



“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.

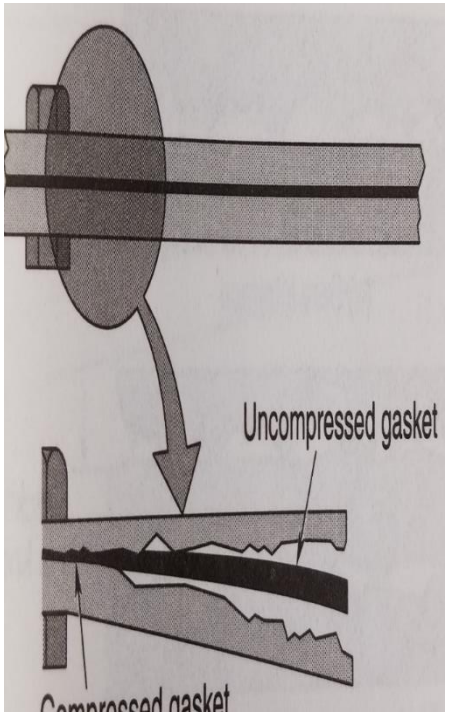


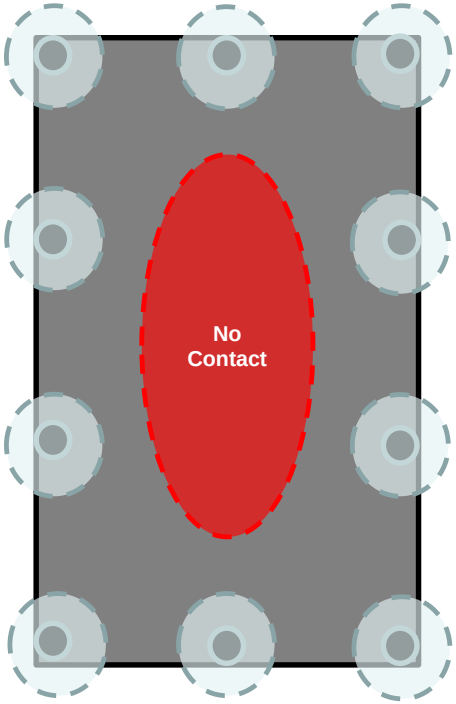


E-Box bottoms will “Potato Chip” between bolts

Conduction Highly dependent upon:

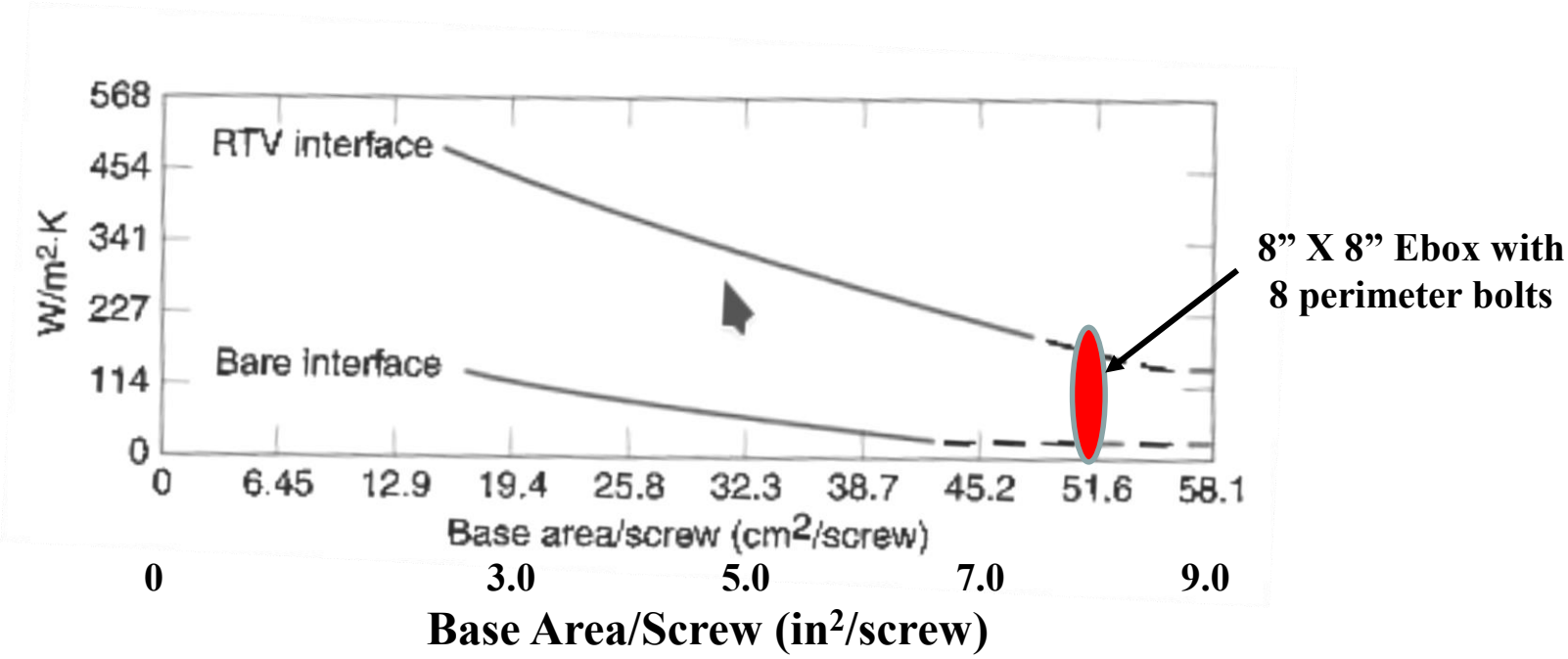
1. Box baseplate thickness
2. Distance between bolts
3. Bolt diameter
4. Bolt Torque
5. Stiffness of Coldplate/radiator
6. Overall Dimensions of box.





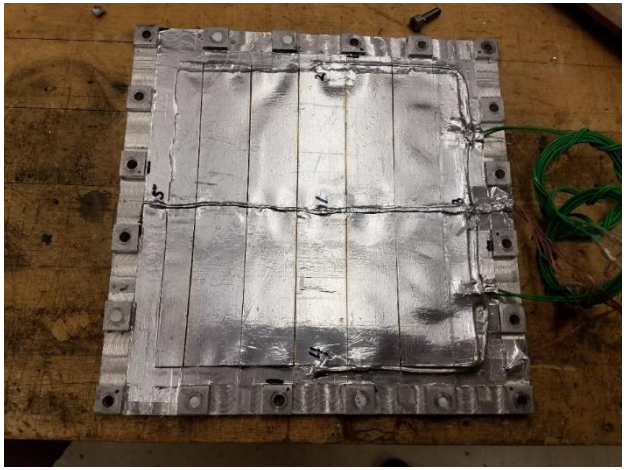
Some Empirical Data for E-Boxes

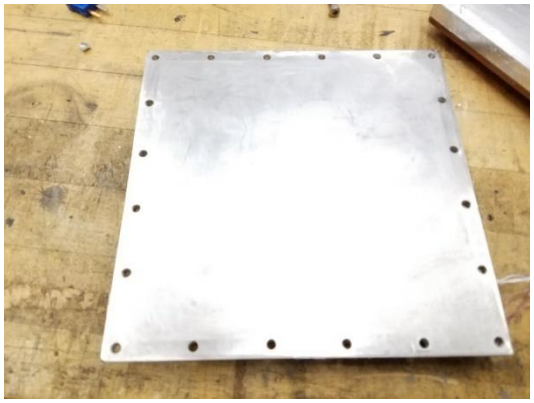
- Check out Spacecraft Thermal Control Handbook, Chapter 8



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
  - Machined as flat as possible at Goddard’s Building 5 machine shop
    - Prevented “skewed” results from a pre-bowed plate





Various Thermal Interface Materials Were Tested

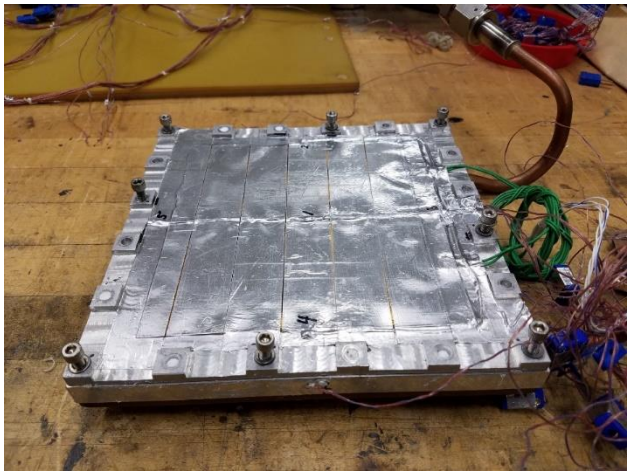
- Bare joint (#8 bolts) — Dry Joint
- Chotherm 1671
- Choseal 1285
- T-Pli 220
- T-Pli 210
- Egraf
- Grafoil
- Indium Foil
- Berquist Sil-Pad K10
- Berquist Hi-Flow 300
- Mouser Gap Pad
- Micro Faze 3A6
- Nusil 2946 (various thicknesses) — Wet Joint

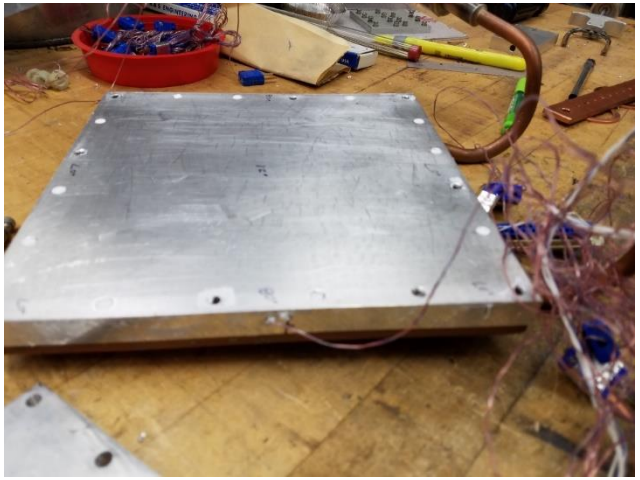
Compressible interface materials

Thermal Vacuum Chamber used for the Tests

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-143H mold release agent; typical of Goddard procedures





Typical Temperature Results

Labview system recorded:
10 thermocouples and heater power

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

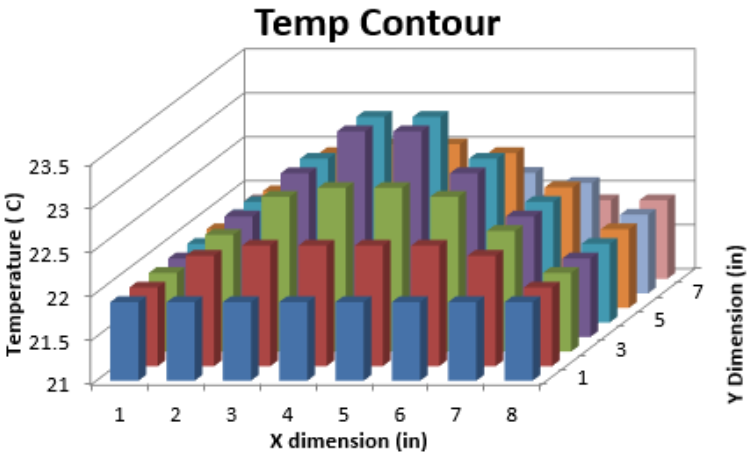
NuSil with around 0.007" thick layer, test results today:
P= 26.2V X 1.83A = 48.0W
Using 8 Screws:
TC1= 24.63C
TC2= 22.15
TC3= 22.31
TC4= 22.39
TC5= 22.48
TC6= 22.71
TC7= 22.11
TC8= 22.04
TC9= 22.14
TC10=22.21C

Determining "Average" Temperatures

- An Excel File was created to populate the 8" X 8" baseplate into 64 "nodes" based on thermocouple data

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

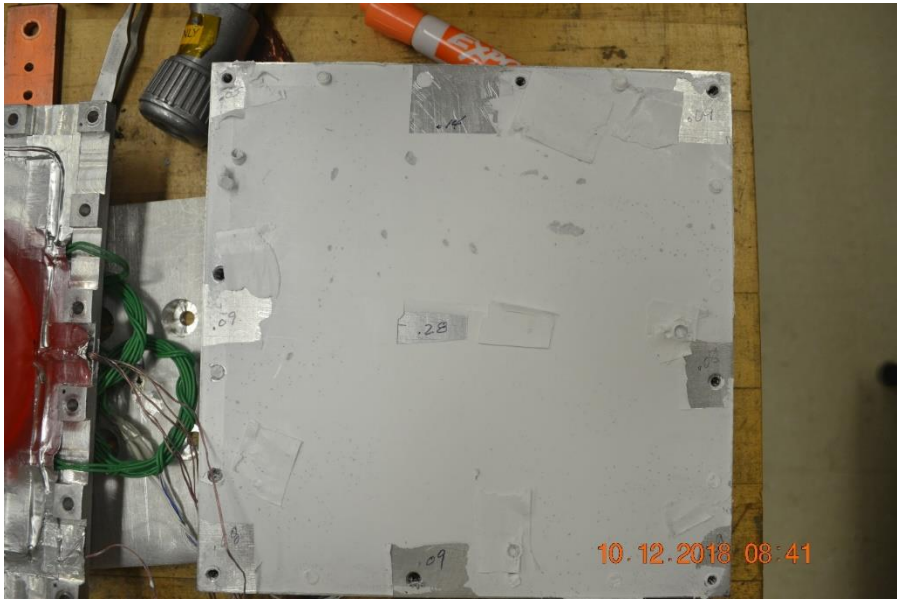
	Interface Material	Box Average (deg C)	Platen Avg (deg C)	delta-T	Watts	W/C	Overall Conductance W/in^2-C	Factor: Relative to Bare Joint
Datasheet G = 1.59 W/in^2-C	NuSil 2946 8 screws 0.025" thk	22.30	21.99	0.31	47.95	155.67	2.43	27.66
	NuSil 2946 8 screws 0.020" thk	22.20	21.76	0.44	47.95	108.97	1.70	19.36
	NuSil 2946 8 screws 0.062" thk	23.09	22.36	0.73	48.10	65.89	1.03	11.71
	NuSil 2946 8 screws 0.010" thk	22.98	22.25	0.73	47.95	65.86	1.03	11.70
	NuSil 2946 20 screws 0.005" thk	23.65	22.23	1.42	47.95	33.86	0.53	6.02
	NuSil 2946 8 screws 0.005" thk	24.08	22.34	1.74	47.95	27.59	0.43	4.90
	Mouser Gap Pad 0.020" thk	25.38	22.55	2.83	47.95	16.95	0.26	3.01
	Micro Faze 3A6 0.006" thk	25.84	22.72	3.12	47.95	15.36	0.24	2.73
	NuSil 2946 no screws 0.005" thk	25.47	22.17	3.30	47.95	14.53	0.23	2.58
	eGraf 0.010" thk	26.04	22.48	3.56	47.95	13.48	0.21	2.39
	eGraf 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 0.010" thk (repeat)	26.89	22.61	4.28	47.95	11.21	0.18	1.99
	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 (bake temp to 40C)	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
	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 conductance can be improved substantially with interface materials.
- But not all materials behave the same!
- Chotherm is not very good
  - But it cuts easily, doesn't create debris, and stores well (flat or rolled)
- T-Pli gives better results than Chotherm, but does not cut well and leaves debris. Probably not worth the benefit.
- Egraf is better than Grafoil
  - May be the best dry joint option, all else considered
  - Relatively cheap, cuts easily, no shelf life, may not need Bakeout, and no silicones
- Nusil is the best, but needs about 20 mils thickness for 8" X 8" footprint
  - Add extra thickness to the box center for larger footprints