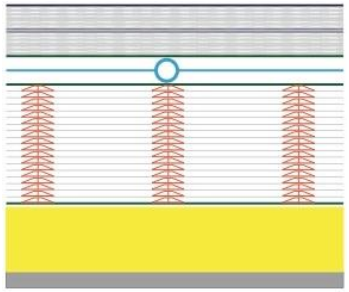
National Aeronautics and Space Administration

Performance of MLI Seams between 293 K and 20 K

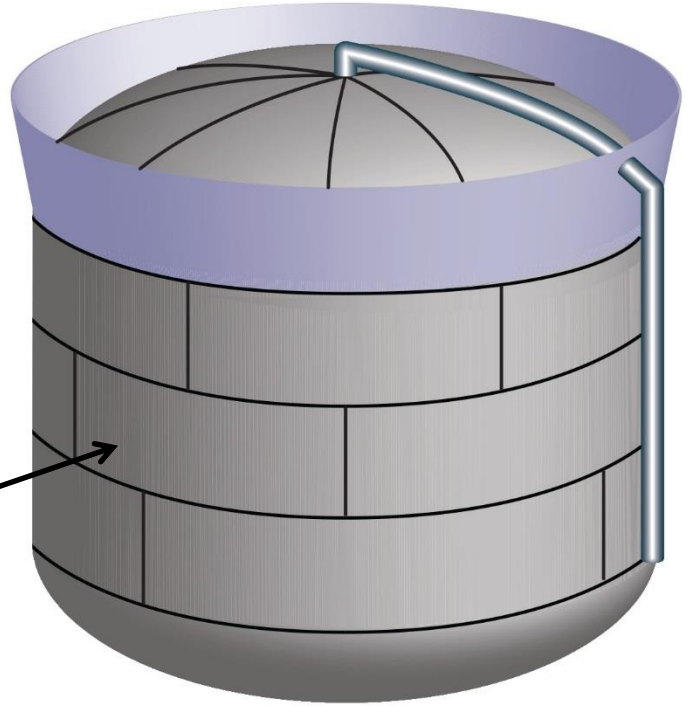
Wesley Johnson and David Chato
Fluid and Cryogenic Systems Branch, Glenn Research Center

2019 Cryogenic Engineering Conference

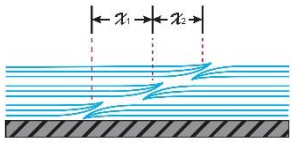
Fundamental Approach for Developing Multilayer Insulation



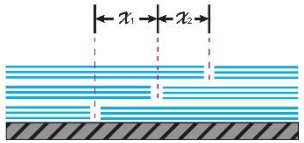
MLI Blankets
- Traditional
- SS-MLI
- IMLI
- Hybrid



Fundamental Approach for Developing Multilayer Insulation



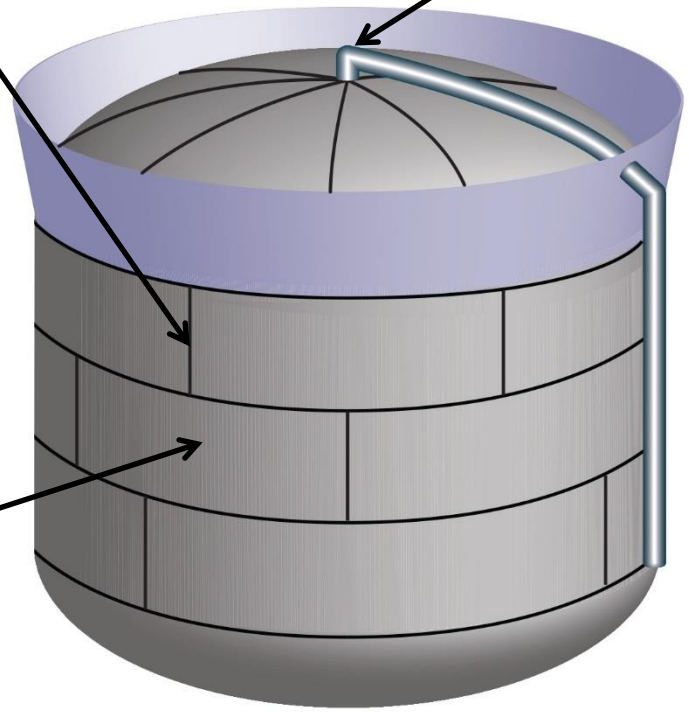
3 Blanket Overlap Staggered



3 Blanket Staggered

Penetration Integration:
- NASA-TP-2012-216315

Seams



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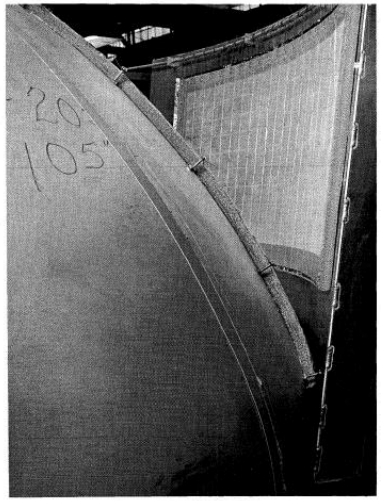
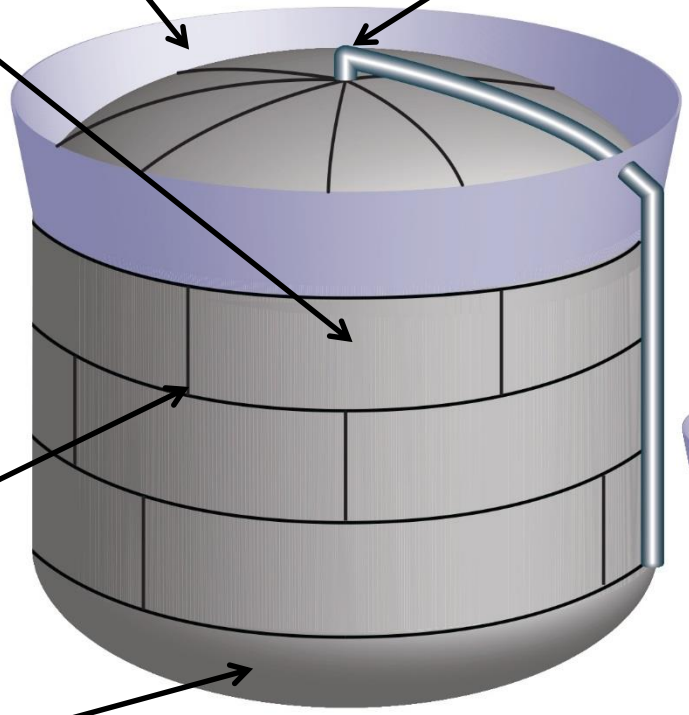


Skirt Integration

Penetration Integration:
- NASA-TP-2012-216315

Seams



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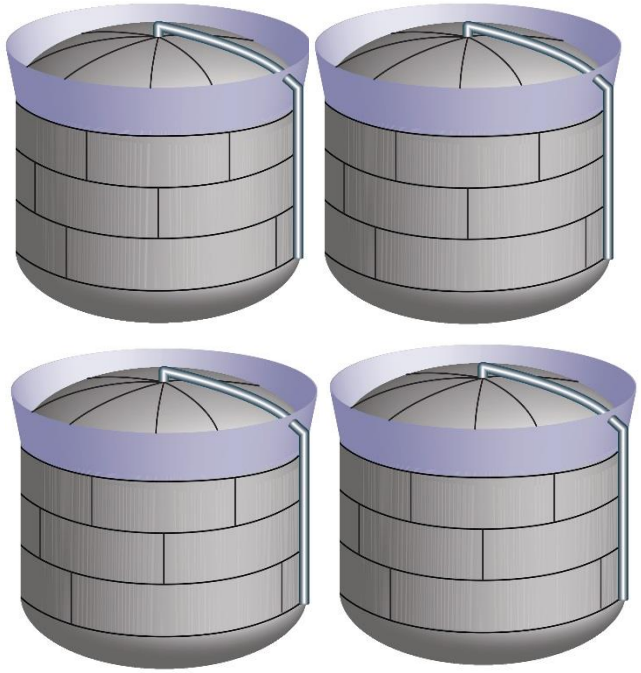
Tape, Pins & Attachments

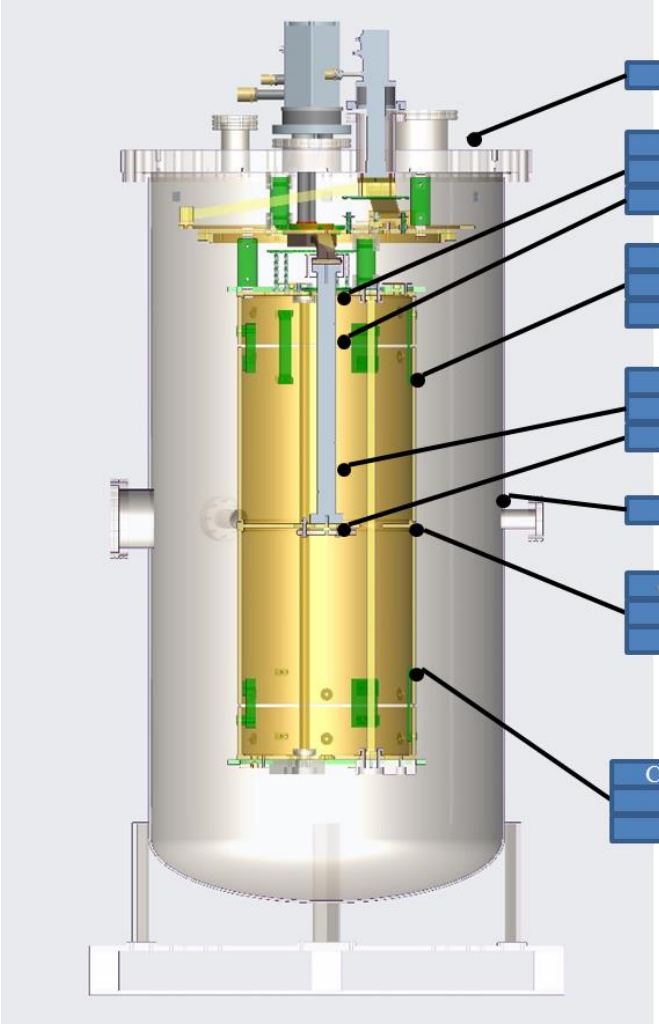
Repeatability



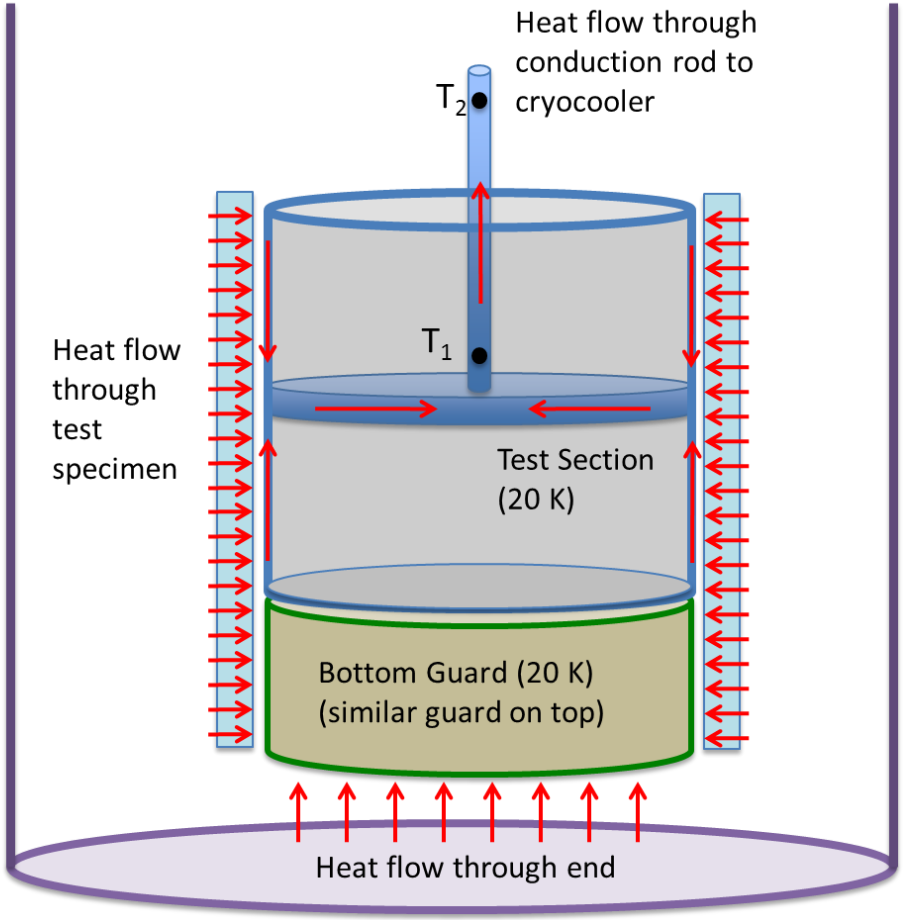
Introduction

- **Performance is lost in multilayer insulation systems due to joints and seams in the insulation blankets:**
  - Recognized as a concern since the introduction of multilayer insulation.
  - Insulating large tanks more seams required as the tank dimensions exceed the roll widths available
- **Over the years mitigation techniques have been developed:**
  - These include overlapping every layer, or precision cutting to minimize the gap
  - However labor intensive and time consuming.
- **Shu investigated “cracks” in MLI in early 90s at liquid nitrogen temperatures**
- **Recently Fesmire and Johnson re-examined the seams issue with a liquid nitrogen test rig at KSC and confirmed many of the previous findings.**
- **This effort extends the seams work into liquid hydrogen temperatures and studies a broader range of proposed seam configurations.**

Calorimeter Description

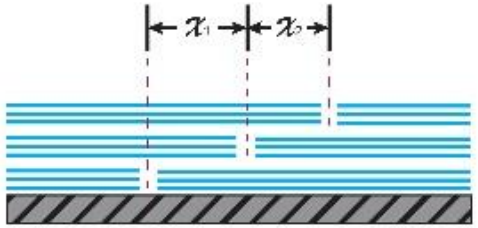


Warm Cylinder (90 K)

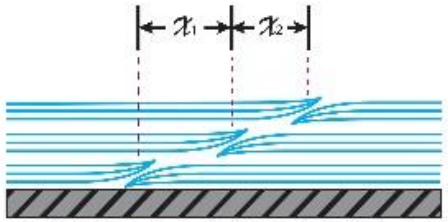


Test Matrix

Test Number	Description	MLI Layers	Seam Construction	Offset, x, (in)
1	Overlap seam	50	1 stagger	2
2	Interleaved Seam	50	N/A	N/A
3	Butt seam	50	Straight	0
4	Butt seam	50	1 stagger	2
5	Butt seam	50	1 stagger	4
6	Interleaved Seam	20	N/A	N/A
7	Overlap Seam	20	1 stagger	2
8	Butt Seam	20	1 stagger	2
9	Butt Seam	20	Straight	0



3 Blanket Staggered

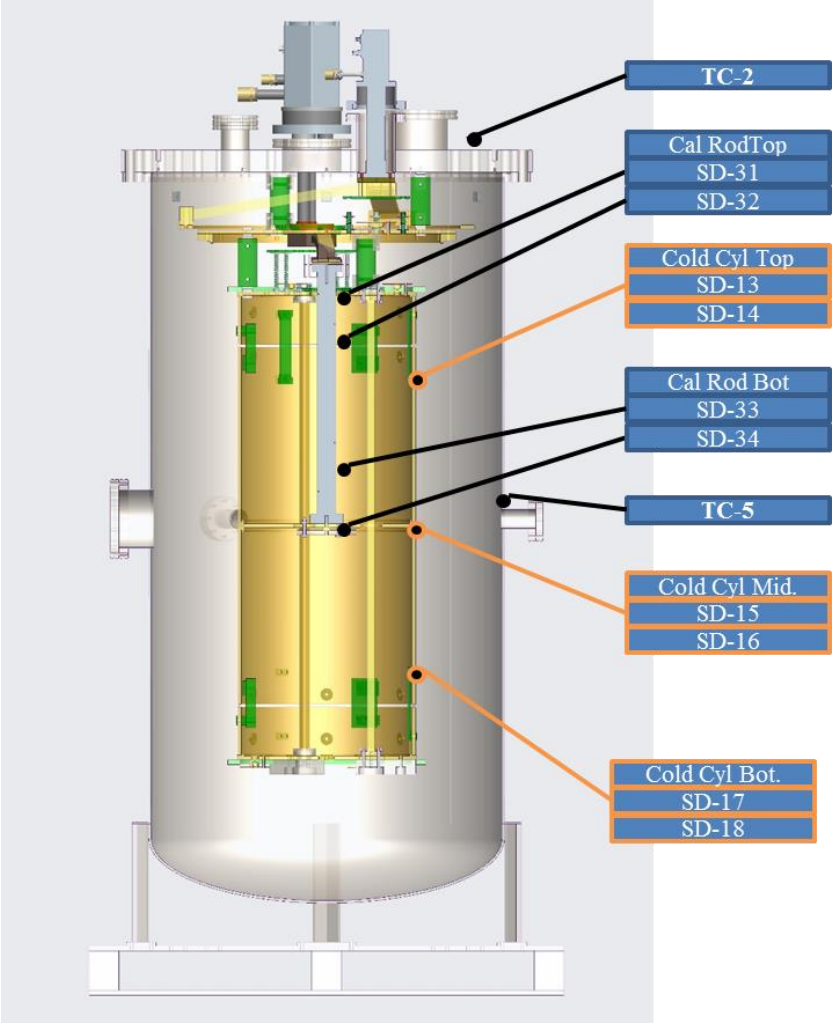


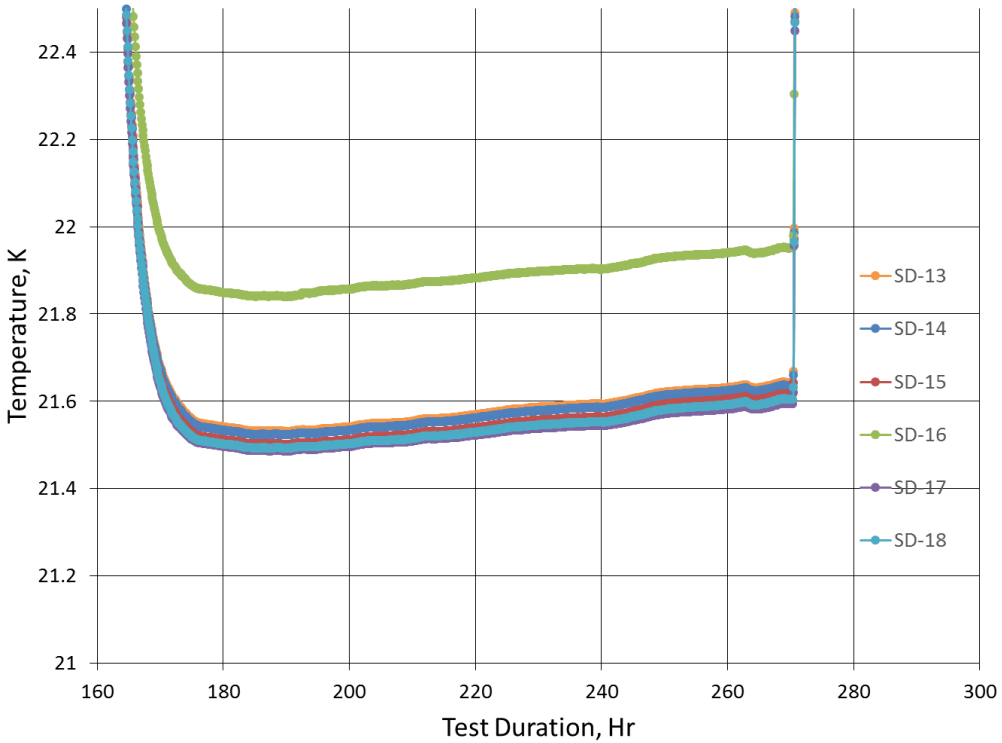
3 Blanket Overlap Staggered

Blanket Descriptions

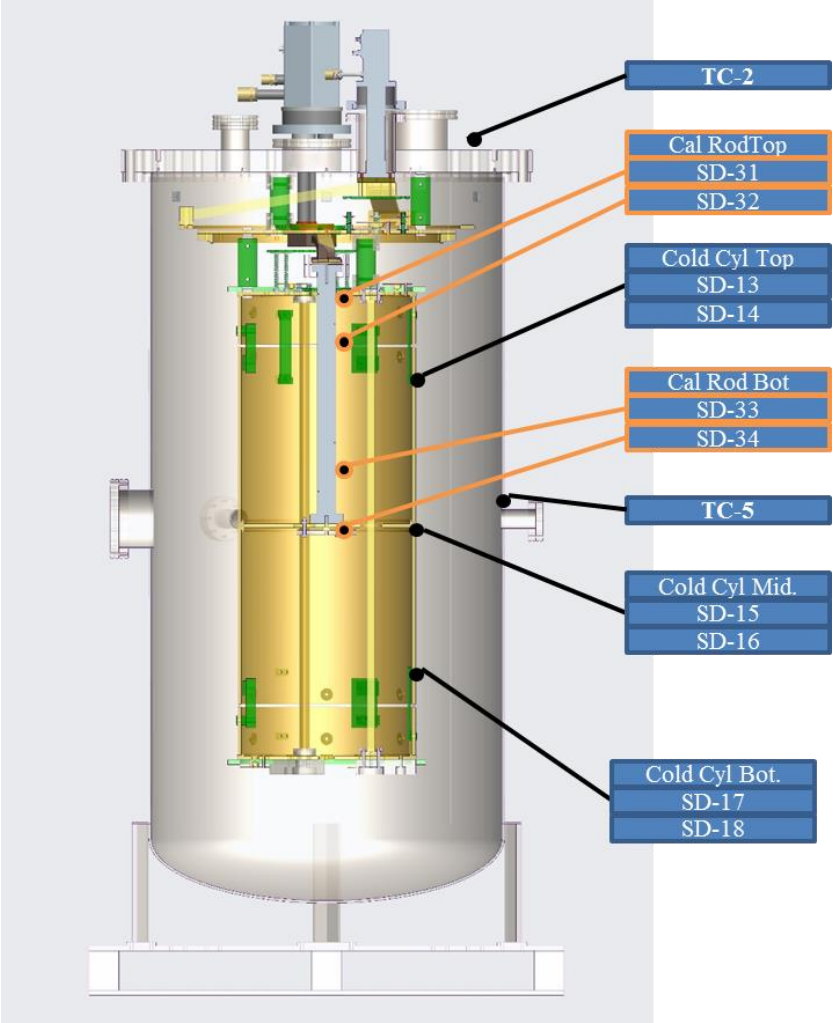
Feature	Yetispace	Existing Blankets
Number of layers (total)	20	50
Number of sub-blankets	2	2
Number of layers per sub-blanket	10	25
Reflector Substrate	Polyester	Polyester
Reflector Deposited Metal	Aluminum	Aluminum
Reflector thickness	0.00635 mm (0.25 mil)	0.00635 mm (0.25 mil)
# spacers thicknesses per reflector	2	2
Spacer Material	Dacron B2A	Polyester
Spacer Thickness	0.1778 mm	0.1778 mm
Covers thickness	5 mil	5 mil
Design Sub-blanket Thickness	0.42 cm	1.59 cm
Design layer density	24 lay/cm	16 lay/cm

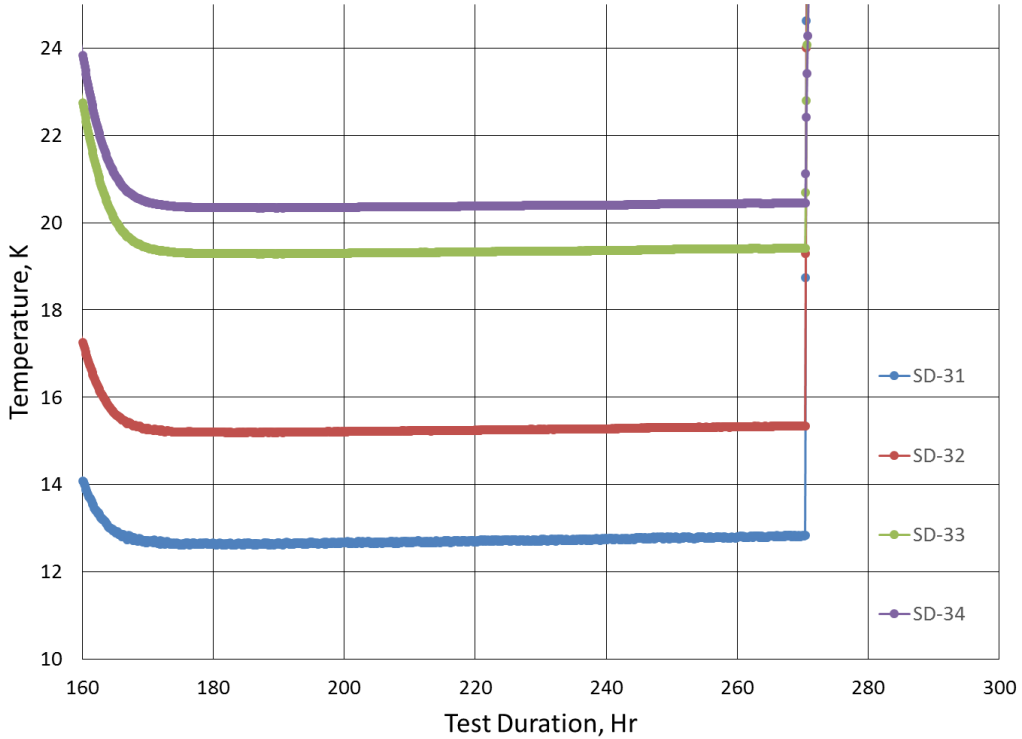
Typical Test Results (1/2)





Typical Test Results (2/2)





50 Layer Test Results

- **Overlapped seams out performed butt seams**
- **Offsetting butt seams didn't seem to provide any benefit**
  - By the time the butt seam is handled, radiation path becomes torturous
- **Minimal difference between the best and worst seams**

Test Number	Run	Q_{total}, watts	T_{avg}, K	K_{avg}, W/m/K	ΔT, K	Q_{net}, W	dQ, W	dQ, W/m
1	Overlap Seams	0.788	21.06	29.8	2.56	0.786	0.040	0.044
2	Interleaved	0.748	19.16	27.3	2.43	0.746	0.000	0.000
3	Full Butt	0.806	18.85	26.9	2.51	0.802	0.056	0.061
4	Butt 2" Offset	0.806	18.85	26.9	2.52	0.803	0.057	0.062
5	Butt 4" Offset	0.810	19.37	27.8	2.56	0.807	0.061	0.067

20 Layer Seam Results

- **Once again, Overlap seam out performed butt seam.**
  - Minimal heat gains into system
- **Offsetting butt seams didn't provide any benefit**

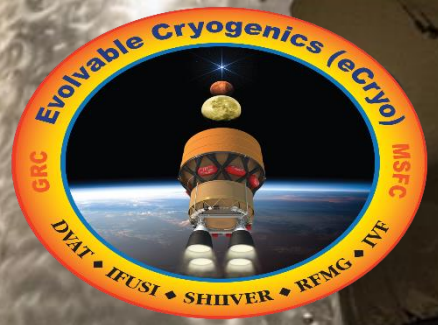
- **Much bigger difference between the best and worst seaming configurations**

Test Number	Run	Q_{total}, watts	T_{avg}, K	K_{avg}, W/m/K	ΔT, K	Q_{net}, W	dQ, W	dQ, W/m
6	Interleaved	1.033	20.38	28.9	3.49	1.012	0	0.000
7	Overlap	1.035	18.62	26.6	3.65	1.015	0.003	0.003
8	Butt 2" Offset	1.222	17.52	25.0	4.21	1.199	0.187	0.205
9	Full Butt	1.160	17.25	24.7	4.09	1.146	0.134	0.147

Conclusions

- **Measured heat loads for the nine tests conducted.**
- **Layer by layer interleaved joint showed the lowest heat leak.**
- **Overlap joint out performed the straight and staggered butt joints.**
- **Surprisingly staggering the butt joint did not decrease the heat load**
  - Increasing the stagger distance didn't help.
  - In fact the test with the largest stagger was worse than straight butt joint, (although this may be due to damage incurred by repeated handling rather the joint itself).
  - Technician installed by "stitch taping" joints every ~5 layers, may have shown that stitch taping is as good as full taping
- **Even worst performing seam only 5% more heat leak than best performing seam at 50 layers**
- **There are significant differences between 20 layers and 50 layers. This shows that the impact of seams is reduced with increased numbers of layers.**

Questions?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