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Acurex Project 6246

FURTHER STUDY FOR FABRICATION, EVALUATION, AND TESTING OF MONOLAYER WOVEN MATERIALS FOR SPACE SUIT INSULATION

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1. BACKGROUND

NASA currently uses a multilayer insulation (MLI) over EVA pressure suits to provide thermal insulation and micrometeroid protection. Such garments are expensive to fabricate and have relatively short service life due to the fragile multiple layers required. A concept for a monolayer insulation with similar performance was developed and tested (NAS2-9873). The results of this development program indicate that minor modification to the monolayer insulation should improve durability and possibly thermal performance.

2. OBJECTIVE

The purpose of this program was to evaluate improvements to the monolayer woven pile concept in terms of increased durability and thermal performance. Three varieties of the monolayer material were tested for thermal conductance under various conditions simulating those which occur in space. In addition, the tendency of the pile to unravel was subjectively evaluated.

3. TASK 1: FABRICATION

Three samples in all were fabricated. All the samples utilized the same basic construction as described in the final report under Contract NAS2-9873. The samples consist of a tight weave orthofabric base and a "W" weave pile. Each has a pile density of 30 ends/inch, a pile height of 3/16 inches and a 2-ply pile diameter. The three samples differed in construction according to the following:

- Sample 1: Nomex pile woven through nomex side of the base cloth only and a layer of 1 oz white nylon ripstop attached to the pile side by stitching.

- Sample 2: Nomex pile locked through the Gore-Tex side of the base fabric.
- Sample 3: Nomex core, Gore-Tex wrapped pile, locked through the Gore-Tex side of the base cloth.

Sample 1 includes the nylon ripstop as a protection to minimize the tendency of the pile threads to snag and consequently unravel.

So that a pile protection layer would not be needed, samples 2 and 3 were fabricated by weaving the pile threads through the Gore-Tex side of the base cloth. It was anticipated that this would tend to lock the pile threads in place and thereby make the fabric inherently less subject to unraveling.

The technique of weaving the pile threads through the Gore-Tex side does however compromise the reflective properties of that surface. Sample 3, therefore, included the Gore-Tex overwrapped pile thread. The intention here was to preserve the reflective properties of the Gore-Tex side of the base fabric. The thread selected was a 200D 2 ply Nomex overwrapped 18/inch with 200D Gore-Tex. Selection was based on an optimum compromise between maximum thread stiffness and minimum thread diameter.

4. TASK 2: TESTING

The three samples fabricated under task 1 were tested for thermal conductance. In addition, a specimen from sample 1 without the nylon ripstop protection layer was tested at one condition to establish a comparison with the results obtained on Contract NAS2-9873.

Thermal conductance values were determined for each of the three samples at the following conditions:

- Sample temperature approximately 70°F; compression load approximately 0 psi; ambient pressure = 10^{0}, 10^{-1}, 10^{-2}, 10^{-3}, and 10^{-4} torr.

- Ambient pressure $\leq 10^{-4}$ torr; compression load = 0 at sample temperatures of 70°, 125°, and 200°F; compression load = 0.12 psi at sample temperatures of 0° and -100°F.

All tests performed at ambient temperatures of 70°F and above were conducted using the steady state hot plate technique. Those tests performed at 0° and -100°F were conducted using the transient technique. Both procedures and required apparatus are described in detail in "Study for Fabrication, Evaluation and Testing of Monolayer Woven Type Materials for Space Suit Insulation" (NAS2-9873).

5. RESULTS

Results of the Thermal Conductance tests are given in Figures 1 and 2. Figure 1 gives the conductance of the three samples as a function of ambient pressure. Included on the plot is a data point generated using a specimen from sample 1 without the nylon ripstop protection layer. Figure 2 is a plot of thermal conductance as a function of specimen temperature. The discontinuity in Figure 2 (denoted by the dashed lines) denotes the transition between the results of the steady state tests and the results of the transient tests. Also included on both plots is a curve showing results taken from the previous study (NAS2-9873) of the same material as sample 1 without the ripstop (sample 12).

In observing the trends of these plots it appears that interlocking the pile threads through the Gore Tex sides (samples 2 and 3) sacrifices the thermal performance of the material. This may be due to the shunting effect of the pile threads to the Gore-Tex side of the base fabric. Sample 3 gives the worst performance. The thermal conductance values of sample 3 are particularly high at the low sample temperatures. This may be attributed to the compression load characteristics of the material. As the transient

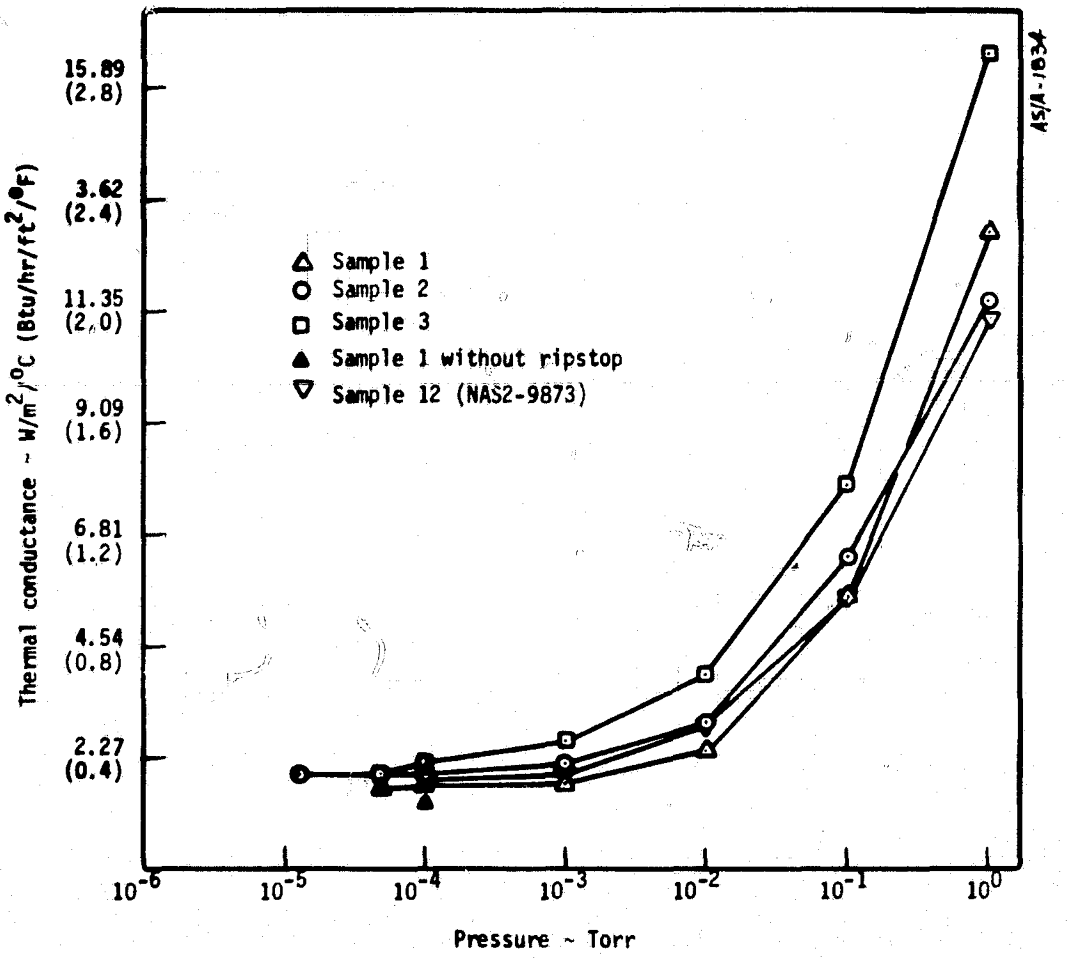

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Figure 1. Thermal Conductance at Zero Compression and 21°C Average Temperature

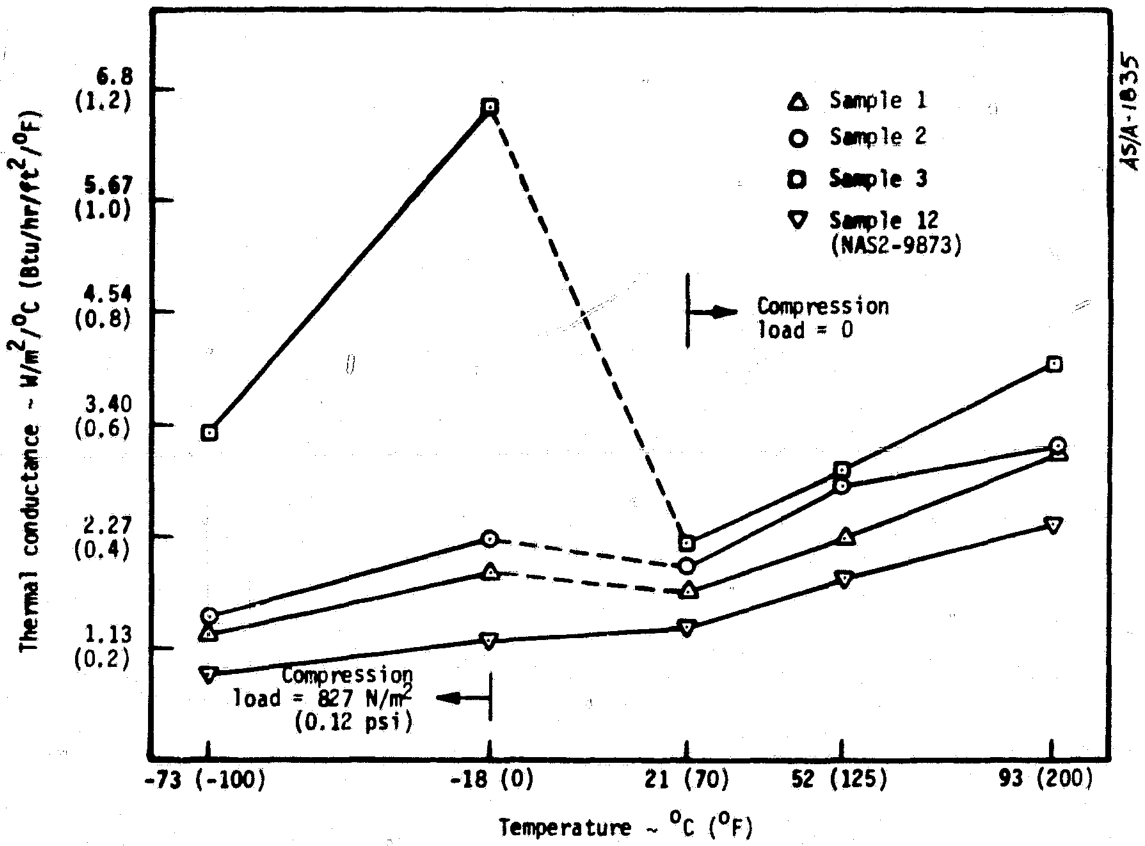

Figure 2. Thermal Conductance as Function of Temperature at Pressure = 10^{-4} Torr

technique inherently produces a higher compression load, a more compressible sample will have a correspondingly higher conductance. In virtually all cases sample 1 gave the lowest thermal conductance value.

A comparison of the results generated for sample 1 and those results generated on contract NAS2-9873 for the same material without the nylon ripstop shows little difference in Figure 1. Figure 2 does, however, show some increase in conductance with the addition of the ripstop. The cause of this discrepancy is unclear.

A subjective evaluation was completed to determine the merits of interlocking the pile threads through the Gore-Tex side of the base fabric. It was anticipated that this technique would minimize the tendency of the threads to pull out and unravel when snagged without sacrificing the thermal performance of the material. This would eliminate the requirement for a snag-protection layer. This was not the case, however. The modified weaving process did not significantly improve the durability of the pile. Furthermore, as evident from the plots, the insulation qualities of the material was decreased.

6. CONCLUSIONS AND RECOMMENDATIONS

The results of the previous program (NAS2-9873) demonstrated the potential of the monolayer woven pile concept as a viable replacement for the presently used multilayer insulation material.

The results of this study provides a solution to the tendency of the pile to unravel when snagged. Sample 1 clearly gives the best thermal performance. The nylon ripstop layer provides protection for the pile without sacrificing thermal performance. It is recommended that a quantity large enough to insure uniform construction of this configuration be produced. A prototype thermal meteoroid garment should then be fabricated to further assess the applicability of the monolayer woven pile fabric as space suit insulation.

APPENDIX

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Thermal Conductivity Transient Test Data Reduction

At 0°F,
$$H = \frac{44.8\ \frac{dT_{(W5-8)}}{dt}\left(\frac{°F}{min}\right)}{\Delta T\ (°F)} \quad \frac{Btu}{hr\text{-}ft^2\text{-}°F}$$

At −100°F,
$$H = \frac{40.2\ \frac{dT_W}{dt}}{\Delta T}$$

$$1\ \frac{Btu}{hr\text{-}ft^2\text{-}°F} = 5.678\ \frac{W}{m^2\text{-}°C}$$

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At Compressive Load = 0.12 psi & $P_{amb} = 10^{-4}$ torr,
Thermal Conductance, W/m²-°C (Btu/hr-ft²-°F)

Sample No.	Temp. °C (°F)	
	−18 (0)	−73 (−100)
1 w/ Nylon Ripstop	1.904 (0.335)	1.271 (0.224)
2	2.254 (0.397)	1.457 (0.257)
3	6.642 (1.170)	3.305 (0.582)

CONDUCTANCE vs. PRESSURE at constant temperature =70°

	1	2	3	4	5	6	7	8	9	10
TEST NUMBER	MATERIAL	SYMBOL		W/M²/°C CONDUCTANCE	BTU/HR-ft²-°F	PRESSURE torr				
1	1W/O	△		1.32	.233	1×10^{-4}				
2	1 W	△		1.65	.291	5×10^{-5}				
3	1 W	△		1.70	.300	10^{-4}				
6	1 W	△		1.70	.300	10^{-3}				
7	1 W	△		2.40	.423	10^{-2}				
8	1 W	△		5.54	.976	10^{-1}				
9	1 W	△		13.00	2.29	10^{0}				
10	2 W/O	○		1.95	.344	1.3×10^{-5}				
11	2	○		1.96	.345	10^{-4}				
14	2	○		2.12	.374	10^{-3}				
15	2	○		2.98	.525	10^{-2}				
16	2	○		6.33	1.12	10^{-1}				
17	2	○		11.54	2.03	10^{0}				
18	3W/O	□		1.91	.337	5×10^{-5}				
19	3	□		2.17	.382	10^{-4}				
22	3	□		2.53	.446	10^{-3}				
23	3	□		3.98	.701	10^{-2}				
24	3	□		7.82	1.38	10^{-1}				
25	3	□		16.53	2.91	10^{0}				

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CONDUCTANCE vs. AVERAGE TEMPERATURE   CONSTANT PRESSURE 10^{-4} torr.

TEST NUMBER.	1 MATERIA	2 SYMBOL	3 AVER. TEMP. °F	PLOT 4 TEMP. °C	5	PLOT 6 $W/M^2/°C$ CONDUCT-ANCE.	7 BTU/hr-ft²-°F	8	9	10	11	12	13	14
1	1 W/O	△	69.2	20.7		1.32	.233							
3	1 W	△	70.8	21.6		1.70	.300							
4	1 W	△	126.7	52.6		2.24	.395							
5	1 W	△	202.1	94.5		3.12	.550							
11	2	○	69.8	21.0		1.96	.345							
12	2	○	125.4	51.9		2.78	.490							
13	2	○	202.4	94.7		3.17	.559							
19	3	□	69.8	21.0		2.17	.382							
20	3	□	124.8	51.6		2.92	.515							
21	3	□	201.4	94.1		4.04	.712							

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