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DEVELOPMENT OF AN IMPROVED PROTECTIVE COVER/LIGHT BLOCK FOR MULTILAYER INSULATION

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16. ABSTRACT

This task was directed toward demonstrating the feasibility of using a scrim-reinforced, single metallized, 4-mil Tedlar film as a replacement for the Teflon coated Beta-cloth/single metallized 3-mil Kapton film presently used as the protective cover/light block for multilayer insulation (MLI) on the Orbiter, Spacelab, and other space applications. The proposed Tedlar concept will be lighter and potentially lower in cost. Thermal analysis with the proposed concept was much simpler than with the present system. Tests have already demonstrated that white Tedlar has low alpha (adsorption) degradation in space from U.V. This study indicated that proposed concept was 4400 percent cheaper with nominal weight savings of 50 percent.

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DEVELOPMENT OF AN IMPROVED PROTECTIVE COVER/LIGHT BLOCK FOR MULTILAYER INSULATION

I. INTRODUCTION

The outer cover presently used with the multilayer insulation system on the Orbiter, Spacelab, and other space hardware consists of a Teflon-coated Beta-cloth with an aluminized Kapton film. Both of these materials are very expensive and also require a minimum purchase/minimum cost, which makes them even less economically attractive. Beta cloth (outside layer) can only be bought in 5000 ft^2 quantity at a minimum cost of $15,000. The aluminized Kapton film (light block layer) has a minimum purchase requirement of 3500 ft^2 at a cost of $28,000 to $43,000. These materials are expensive because of limited suppliers, material construction, and manufacturing costs combined with very low use levels. In comparison, Tedlar film, a common material in wide use, has a minimum purchase of 200 lb at $46.00/lb. A more detailed cost and weight comparison may be found in Figure 1. Preliminary tests indicated that a much-improved protective cover/light block would result from the use of various Tedlar films reinforced with certain scrim materials. This system potentially has lower weight, is more thermally efficient, is significantly cheaper, and has off the shelf availability. This report evaluates all pertinent facets of this concept and defines a new system which could significantly reduce the need for the Beta cloth/Kapton film assembly now used in many aerospace applications.

II. EXPERIMENTAL

A. Material Identifications

Sample assemblies and identities are shown below:

Sample One – 200-BS-30-WH with 108 glass scrim/aluminized.

Sample Two – 200-BS-30-WH with 108 glass scrim/not aluminized.

Sample Three – 400-BS-30-WH with Nomex scrim/aluminized.

Sample Four – 400-BS-30-WH with Nomex scrim/not aluminized.

Sample Five – 200-BL-30-CW used as is no scrim/not aluminized.

Sample Six – 200-BL-50-CW used as is no scrim/not aluminized.

B. Sample Description

1. 200-BS-30-WH (Sample 1 and 2)

This sample was one of the special laminates prepared by Sheldahl Corporation for this study. Major differences between these two samples were scrim material, Tedlar thickness, and different TiO_2 pigmentation. This sample used 2-mil Tedlar with style 108 fiberglass and Sheldahl polyester adhesive (A002900). About 100 linear yards were prepared and about 50 yards were aluminized to a minimum thickness of 250 Å. This laminate weighed 6.3 oz/yd^2.

2. 400-BS-30-WH (Samples 3 and 4)

This is the other sample laminated by Sheldahl Corporation. It consists of a 4-mil Tedlar film, a polyester adhesive (A002900), and a Leno weave (16 x 15) Nomex scrim material (Sheldahl number 5-25701). Laminate weighs about 4.5 oz/yd^2 and meets JSC SPEC 08962 Rev. U. About 100 linear yards were prepared with 50 yards aluminized to a minimum thickness of 250 Å. Figure 2 is a simple sketch of the above two laminates. Physical properties of this sample in tensile, elongation, and tear are shown in Figure 5.

3. 200-BL-30-CW (Sample 5)

This sample obtained later in the program was not aluminized and had no scrim reinforcement.

4. 200-BL-50-CW (Sample 6)

This sample obtained later in the program was not aluminized and had no scrim reinforcement.

C. Material Test List

Tests used in this study are detailed below:

1) Solar absorptance

2) Reflectance

3) Transmittance

4) Emissivity

5) Specular reflectance

6) Mechanical properties – tear and tensile strength

7) Drape (handling properties)

8) Flammability in air per NHB 8060.1A

9) Vacuum outgassing per JSC Spec 0022B.

III. RESULTS AND DISCUSSION

A. Solar Optical Results

Originally, two Tedlar films and two scrim materials, Nomex and fiberglass, were evaluated with and without an aluminized coating on the bottom surfaces. Evaluation of the 2-mil Tedlar was discontinued after first optical measurements were available. This material initially thought to be identical to the 4-mil Tedlar, was not usable because DuPont had also changed the TiO_2 pigment formulation resulting in unacceptable optical properties. The visual color difference of this 2-mil sample was easily observed to be grayer than the 4-mil Tedlar.

Two other samples of 2-mil Tedlar samples were added to this test program. None of these samples were as stable in solar exposure as the original Tedlar sample, which had minor solar degradation after 4500 equivalent sun hours (ESH). Review of test procedures and discussions with DuPont technical personnel failed to resolve the solar property differences.

B. Mechanical/Physical Test Evaluations

Mechanical property tests indicated that the Leno weave Nomex scrim addition significantly improved the tear resistance of the Tedlar film.

The individual samples all failed the NHB 8060.1A flammability test but passed the Tedlar/MLI blanket configuration test. These materials also passed the VCM and weight loss in vacuum evaluations.

C. Space Simulation Test Evaluations

1. Description of Test Facility

All of these space simulation tests were conducted by Mr. Don Wilkes in the MSFC long term vacuum test facilities located in SSL which consists of a clean vacuum system, solar simulator, and in-situ reflectance measuring system. The vacuum system is made from stainless steel with all metal seals except for the valves and the sample manipulators. This is an ion pumped system which results in a very clean vacuum. An integral sample airlock enables changing or adding a sample to a test without breaking vacuum. The solar simulator is an unfiltered mercury-xenon arc lamp providing one thermal sun and 3.5 uv suns on the test samples. This solar simulator provides modest accelerated test rate of the damaging portion of the solar spectrum while maintaining normal thermal inputs, thus avoiding test result bias due to thermal effects.

The reflectance measuring system consists of a computer-controlled Beckman DK-2A spectrophotometer with a Gier-Dunkle vacuum integrating sphere attachment to provide in-situ total hemispherical reflectance measurements over the range 250 to 2500 nm. A Hewlett Packard HP-1000 computer system controls the wavelength scanning, takes the measurements from the DK-2A, and stores the data in its database for later analysis and plotting.

Two separate environmental simulation tests were done on the Tedlar test samples in the long-term test facilities. Several thicknesses and configurations of the Tedlar/Nomex, Tedlar/glass, and Tedlar alone were exposed to simulated solar-vacuum environment and their total hemispherical reflectance measured in-situ before and after each phase of the test. The exposure tests were run in 250 and 500 ESH (equivalent sun hours) increments. In low Earth orbit, the average solar orbital exposure is about 25 percent or 6 hours per day. A 250 ESH exposure would then correspond to about 40 days in low Earth orbit.

2. Test Procedures

a. 250 ESH Evaluation. Several specimens of the Tedlar/Nomex, Tedlar/glass, Tedlar, and Tedlar tape were exposed to a simulated solar-vacuum environment and the results are shown in Table 1. Two sequential 250 ESH (equivalent sun hour) exposure tests were conducted and the optical properties of the test samples were measured in-situ (i.e., in vacuum) before and after each exposure. Two Tedlar samples were added to the test and were only exposed to the second 250 ESH test. These new samples were airlocked into the chamber and did not require exposing the chamber to air.

The Tedlar-vapor deposited aluminum-Nomex and the Tedlar-Nomex laminates both performed essentially the same in these tests. The Tedlar-Nomex samples had a slightly better initial α_s (solar absorptance) but differences were small and could be due to batch variations. The aluminum coating on the back of the one type laminate was added to make the material completely opaque but the 4-mil Tedlar layer does not require the light block and the aluminum had no effect on the stability of the material and is therefore not needed for this usage.

b. 1250 ESH Evaluation. Three samples each of 4-mil Tedlar/Nomex and of 2-mil Tedlar/glass material were exposed to three sequential 250 ESH tests followed by a 500 ESH test for a total of 1250 ESH. Results for these tests are shown in Table 2 and Figures 3 and 4. The 4-mil material had slightly better initial solar absorptance than did the 2-mil material but the changes in α_s are about the same for both thicknesses.

3. Results and Discussion

These new materials, developed under this program to be used as the cover material for MLI blankets, are suitable for use on short term Shuttle missions. They would not be stable enough, however, for long multilayer missions. The addition of the backing Nomex to the Tedlar for tear strength did not alter the optical properties of the Tedlar outer layer or their stability to simulated low Earth orbit exposure.

The special laminate sample, 400-BS-30-WH with Leno weave Nomex (no aluminum coating), was used by Mr. Cupples, MDTSCO, to fabricate a Nuclear Radiation Monitor cover. A discussion and drawing concerning this operation is found in the Appendix.

IV. CONCLUSIONS

The subject Tedlar/Nomex sample has several significant advantages over the Beta cloth/Kapton currently in use. These include:

1) 4400 percent cheaper than current system.

2) Nominal 50 percent less weight.

3) OPAQUE-no light transmittance.

4) No light block required.

5) Aluminized coating not necessary.

6) All materials are readily available at reasonable coat and quantity minimums.

7) Simpler system for thermal analysis.

There are some features which may be undesirable and some of these may preclude the use of this sample for some flight applications. These include:

1) Solar absorptivity (α_s) degradation is borderline after 750 hr exposure and would require re-evaluation for longer flights.

2) Mechanical application would be more difficult on irregular or contoured shapes. Flat or cylindrical pieces present few problems.

TABLE 1. LONG TERM TEST FACILITY TEST LT020182

Material	Sample Number	Initial		250 ESH		500 ESH	
		E_T	α_s	α_s	$\Delta\alpha_s$	α_s	$\Delta\alpha_s$
4 mil Tedlar/Alum. /Nomex	27	0.89	0.261	0.307	0.046	0.343	0.082
4 mil Tedlar/Alum./Nomex	1	0.89	0.262	0.315	0.053	0.353	0.091
4 mil Tedlar/Alum./Nomex	32	0.89	0.263	0.321	0.058	0.350	0.087
4 mil Tedlar/Nomex	23	0.91	0.255	0.302	0.047	0.339	0.084
4 mil Tedlar/Nomex	18	0.90	0.257	0.296	0.039	0.329	0.072
4 mil Tedlar/Nomex	33	0.90	0.259	0.312	0.053	0.347	0.088
Tedlar Tape No. 838	28	0.89	0.411	0.451	0.040	0.488	0.077
Tedlar Tape No. 838	11	0.89	0.413	0.445	0.032	0.477	0.064
Tedlar (200 BL – 30 CW)	30	–	0.264	0.310	0.046	–	–
Tedlar (200 BL – 50 CW)	50	–	0.278	0.330	0.052	–	–

TABLE 2. LONG TERM TEST FACILITY TEST LT112382

Material	Sample Number	Initial	250 ESH		500 ESH		750 ESH		1250 ESH	
		α_s	α_s	$\Delta\alpha_s$	α_s	$\Delta\alpha_s$	α_s	$\Delta\alpha_s$	α_s	$\Delta\alpha_s$
4 mil Tedlar	11	0.248	0.261	0.013	0.302	0.054	0.342	0.094	0.385	0.137
2 mil Tedlar	14	0.271	0.298	0.027	0.335	0.064	0.372	0.101	0.417	0.146
4 mil Tedlar	15	0.245	0.260	0.015	0.306	0.061	0.343	0.098	0.392	0.147
2 mil Tedlar	9	0.265	0.294	0.029	0.334	0.069	0.372	0.107	0.414	0.149
4 mil Tedlar	6	0.250	0.263	0.013	0.305	0.055	0.358	0.108	0.411	0.161
2 mil Tedlar	5	0.278	0.295	0.017	0.330	0.052	0.379	0.101	0.424	0.146

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COST COMPARISONS

The primary advantages of Tedlar when compared to Beta cloth is that of cost. The following cost comparisons are provided based on recent government procurements of the Beta cloth/light block combination. The Tedlar prices are based on 4 mil Tedlar without modification:

	Beta Cloth + Light Block	4 Mil Tedlar
Cost /Ft^2	$11.10	$0.24

The components of the Beta cloth/light block cost are:

ITEM	COST
Beta Cloth (STM - 0484-01)	$3.00/$Ft^2$
Light Block (STM-0961-040101) 3 Mil Single Aluminized Kapton)	$8.10/$Ft^2$

The minimum buy quantity from the vendors are:

MATERIAL	MIN BUY	MIN COST
Beta Cloth	5000 Ft^2	$15,000
Light Block	3500 Ft^2	$28,350 - $43,300
Tedlar	200 Lbs	$46

From these data, it is apparent the price ratio of a Beta cloth cover system is approximately 44 times more expensive than basic Tedlar cover. Although the MT cost will exceed the basic Tedlar cost, it is anticipated that the cost savings using MT will still be significant.

WEIGHT COMPARISON

The weight savings using MT* versus Beta cloth is not large. However, since even small weight savings are meaningful, it should be highlighted.

WEIGHT CHART	
MT	Beta Cloth
0.5 Oz/Ft^2	1.3 Oz/Ft^2

* MT = Modified Tedlar.

Figure 1. Cost and weight comparisons.

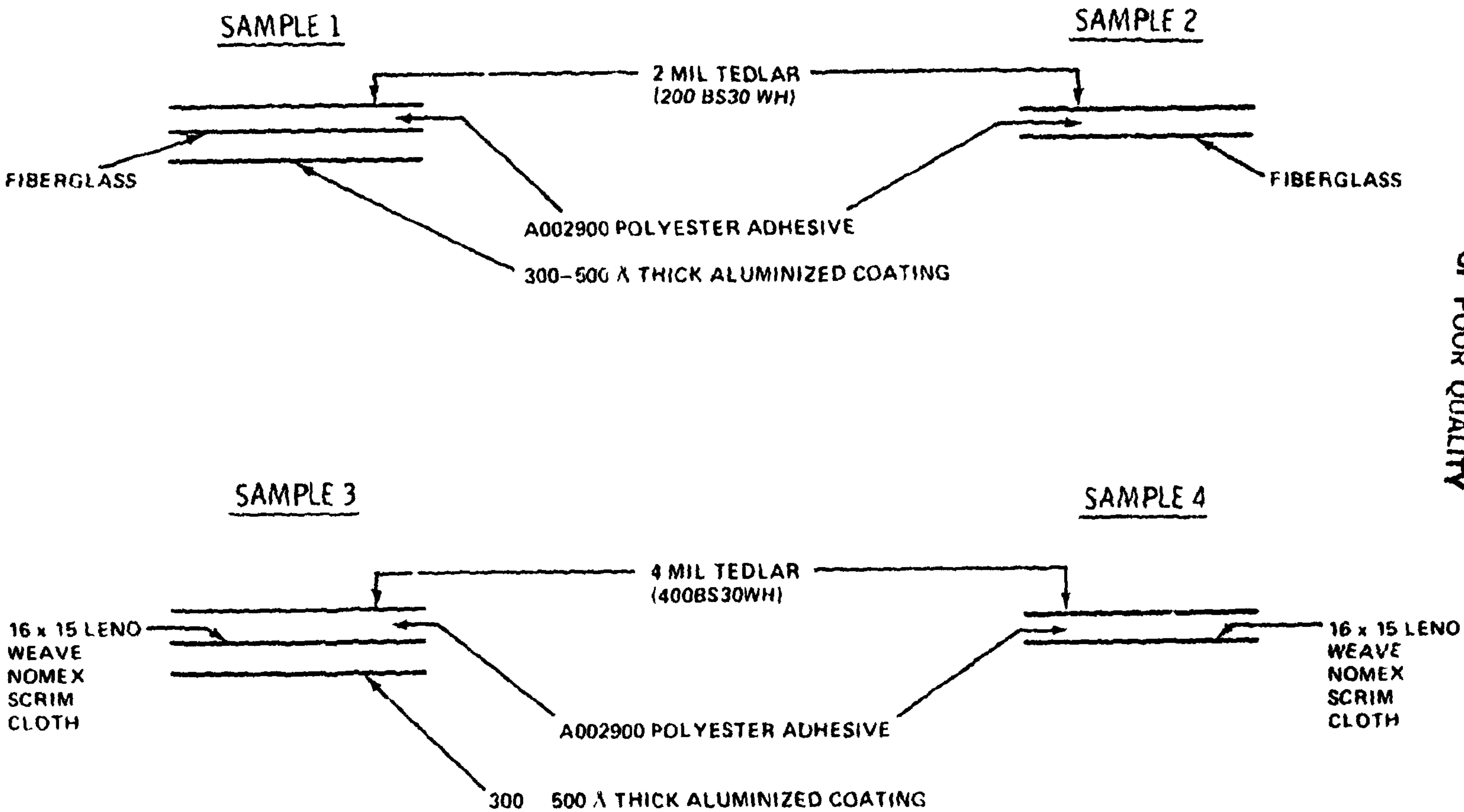

Figure 2. *Modified tedlar sample configurations.*

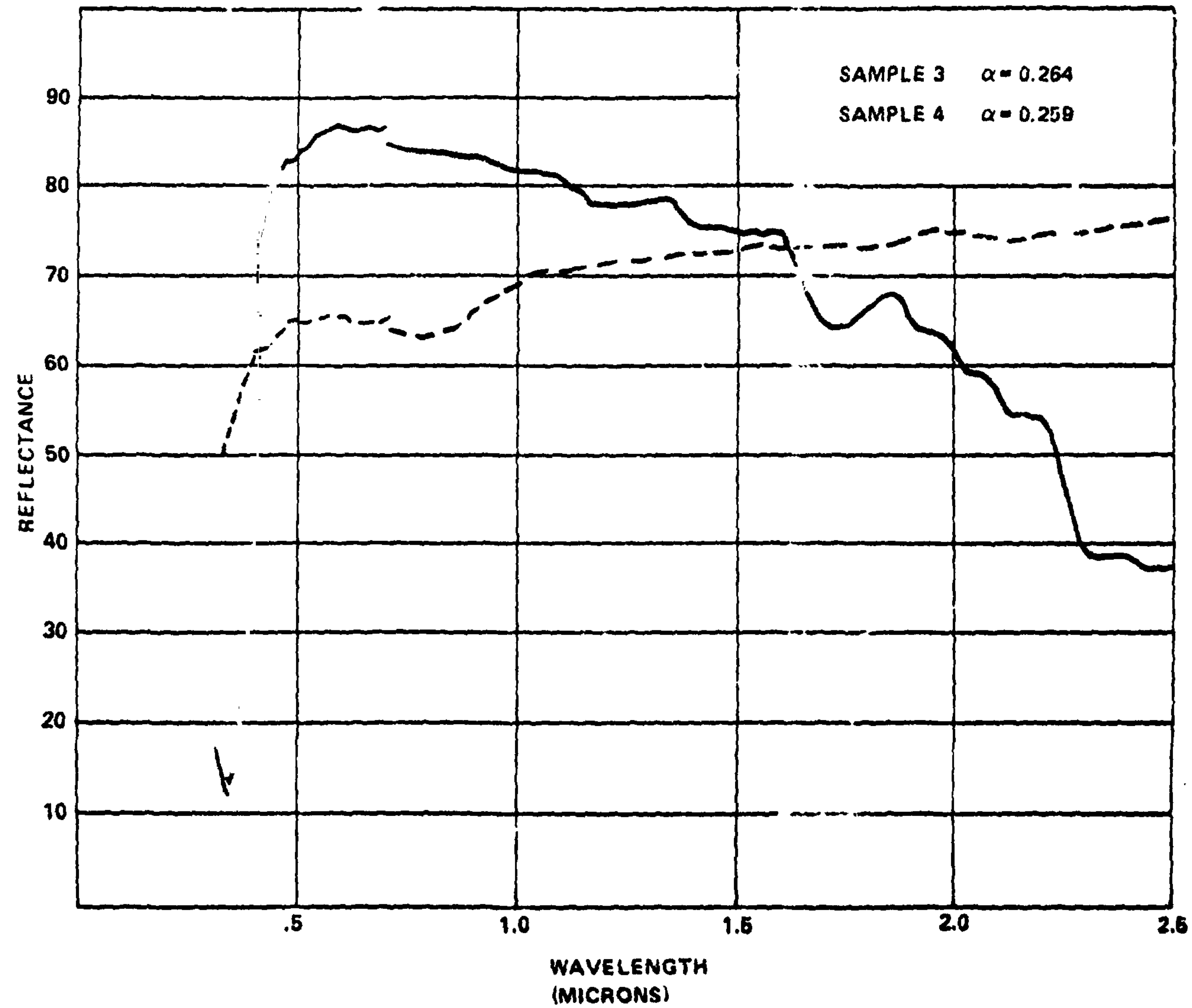

Figure 3. 4 mil Tedlar with Nomex backing-reflectance versus wavelength.

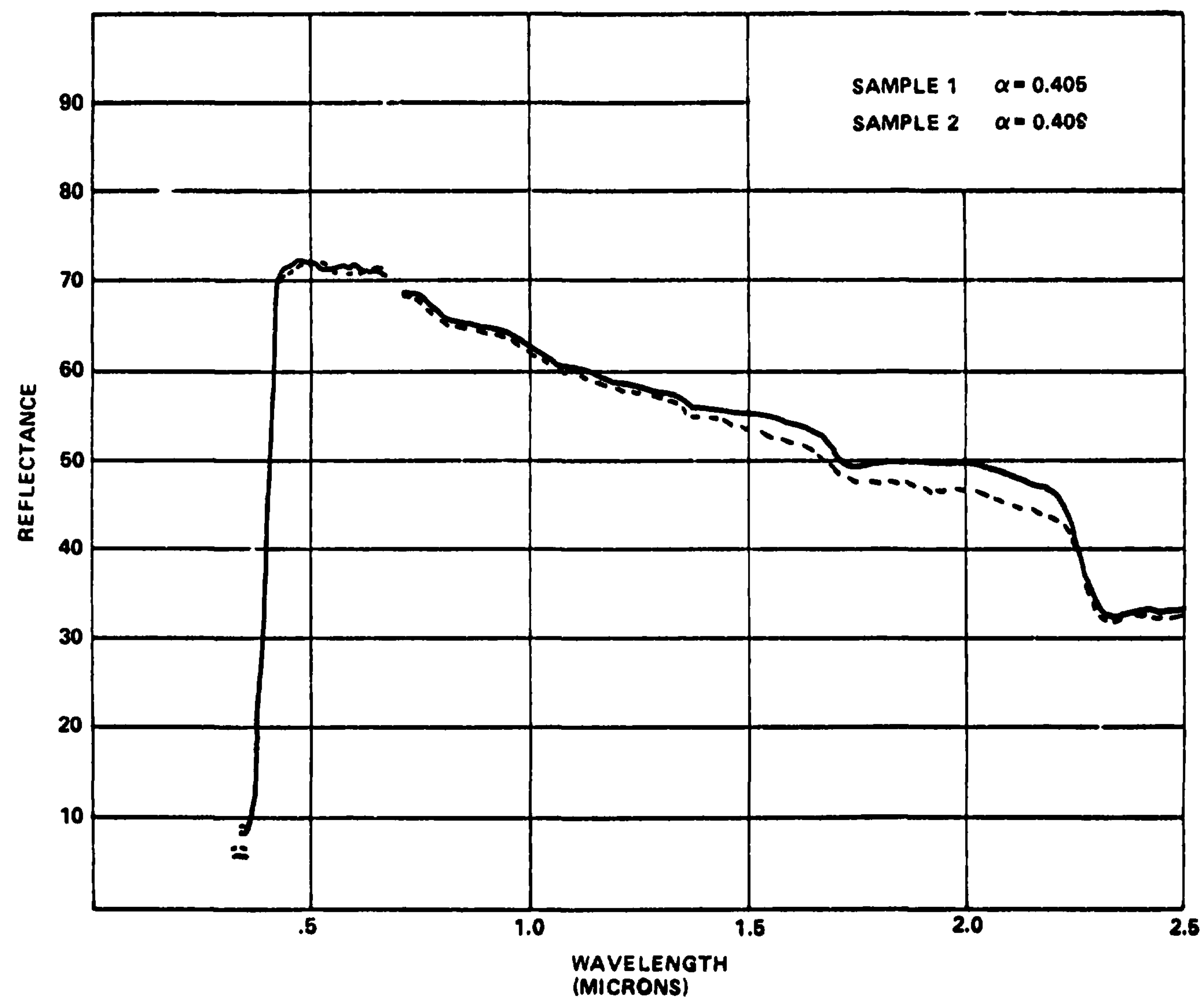

Figure 4. 2 mil Tedlar with fiberglass backing-reflectance versus wavelength.

TENSILE AND ELONGATION (ASTM D-882)

Test Temperature	Tensile (psi)	Elongation	DuPont*
RT			
-240°F	13,500	280%	10,000 psi/250%
+250°F	36,250	55%	
	9,000	230%	

TEAR RESISTANCE (ASTM D-1004)

		DuPont*
RT	4.7 pounds	3.17 pounds
-240°F	9.0 pounds	
+250°F	-	

* DuPont results at RT only
Tech Bulletin TD-2 Rev. 4-82

Figure 5. Physical properties, sample four (page 2).

APPENDIX A

NUCLEAR RADIATION MONITOR

Multilayer Insulation Construction Details

The general construction of Beta cloth covered multilayer insulation assemblies is to roll and sew edges and turn finished seams inboard. This was the first test. A Tedlar shell (Fig. A-1) was constructed by sewing the upper panel and side panel of a cylinder together, placing the scrim cloth backing on the outside. The shell was then turned inside out. The result was a creased and wrinkled shell that was unacceptable (Fig. A-2).

Next, a shell was sewn with seams outboard. The smooth side of the Tedlar was also placed outboard. This construction was neat and wrinkle-free; however, the seams were unsightly. Also, the holes made by the needle permitted considerable light penetration. The last test was to build a shell by joining adjacent panels with tape (Fig. A-3). The panel edges were cut to give relief for curvature, then the edges were crease overlapped. Tape was applied to the inside and outside of the seams. This construction proved neat and strong and was chosen for the insulation design.

The final design of the multilayer insulation assembly consists of an inner insulation blanket with an outer Tedlar shell. The blanket is made of 19 layers of aluminized reflector and 20 layers of polyester mesh separator, sandwiched and sewn between two scrim cloth-backed aluminized kapton layers. Over this slipped a Tedlar shell and adjacent ends of blanket and shell are taped together. Button tufts are applied in the field of the assembly to keep blanket and shell together.

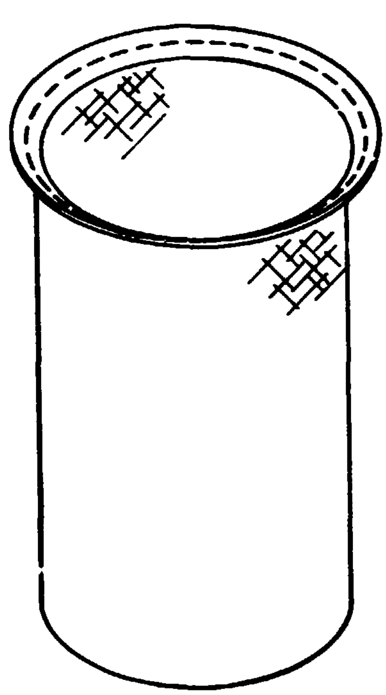

Figure A-1. NRM cover configuration.

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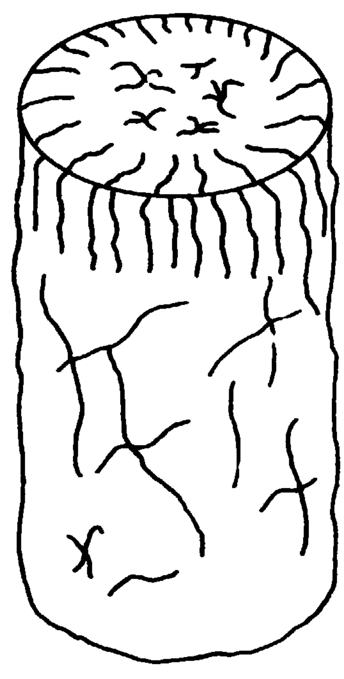

Figure A-2. MT cover appearances.

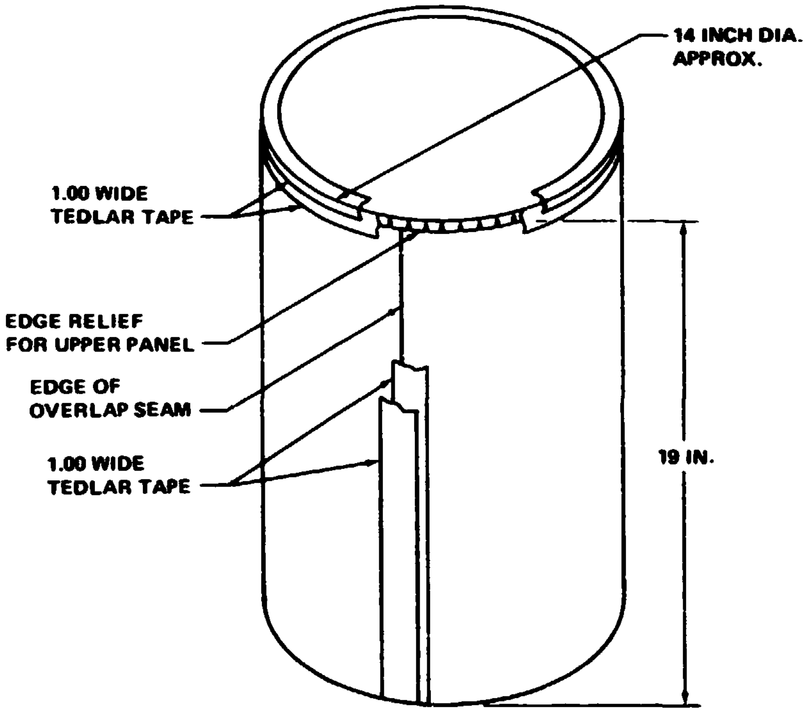

Figure A-3. NRM cover construction.

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APPROVAL

DEVELOPMENT OF AN IMPROVED PROTECTIVE COVER/LIGHT BLOCK FOR MULTILAYER INSULATION

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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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