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Effects of Water Vapor on Thermal Shield Materials

Chemistry and Physics Laboratory
The Ivan A. Getting Laboratories
The Aerospace Corporation
El Segundo, Calif. 90245

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Los Angeles Air Force Station
P.O. Box 92960, Worldway Postal Center
Los Angeles, Calif. 90009

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This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

Arturo G. Fernandez, Lt, USAF
Project Officer

Joseph Gassmann, Major, USAF

FOR THE COMMANDER

Floyd R. Stuart, Colonel, USAF
Deputy for Advanced Space Programs

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Three of the materials commonly used to insulate spacecraft from solar radiation are aluminized mylar, aluminized kapton, and silvered teflon. Damage to or deterioration of these materials would lead to large scale temperature excursions of the spacecraft. One possible mechanism for such deterioration would be the occurrence of high humidity prior to launch. A study was conducted to determine the vulnerability of these materials to humidity. It was found that aluminized mylar and aluminized kapton remain unaffected, but that silvered teflon is seriously damaged in a period of hours.

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I. INTRODUCTION

The vulnerability of several flexible thermal control materials to damage under conditions of high humidity was investigated. Deterioration of these materials would destroy their ability to protect spacecraft from excessive heating caused by orbital solar radiation. Exposure to a humid environment could result from failure of an air conditioning unit at any time prior to launch.

In this study, samples of 1/4 mil aluminized mylar, 1 mil aluminized kapton, and 2 mil silvered teflon, in the form of squares 1/2 to 3 in. on a side, were exposed to various controlled humidities and examined for deterioration. The samples were used, as received, without being cleaned or treated. It was discovered that the aluminized mylar and aluminized kapton were unaffected by the water vapor; whereas, the silvered teflon was severely damaged in a few hours.

II. EFFECT OF SEA WATER VAPOR

An artificial sea water solution was prepared from a standard recipe.[1] One sample of each material was exposed to the vapor of this solution in a sealed container at 24°C for three days. During this time, dry nitrogen was slowly percolated through the solution. The bursting bubbles served to propel the dissolved salts into the vapor,[2] which would otherwise contain only water molecules.

After exposure, each sample was divided in half. One set of samples was exposed to a vacuum for two days. The second set remained in a normal environment for 14 days; then it was also exposed to a vacuum for two days. The reflectivity of the samples in the wavelength region of 1 to 5 μm was measured. This wavelength corresponds to the near-infrared region of the solar spectrum.

Under these conditions, it was found for both sets that the aluminized mylar and aluminized kapton suffered no deterioration; however, the silvered teflon was severely damaged. This damage took the form of a gentle separation of the silver film from the teflon. The separation was made manifest by the appearance and growth of white patches over approximately 50% of the surface area observable from the teflon side. There was no visible effect on the silvered side. Flexing of the material or a gentle contact then caused the silver film to fracture in these areas.

A subsequent test was made on the silvered teflon with the sea water solution replaced by distilled water. The occurrence of damage of the same type and magnitude indicated that the water vapor alone, not the dissolved salts, was responsible for deterioration.

III. EFFECT OF HUMIDITY ON SILVERED TEFLON

In order to determine the range of humidity over which silvered teflon would deteriorate, samples of the material were suspended above aqueous solutions of LiBr in sealed containers. LiBr in water lowers the vapor pressure by a known amount[3] without contributing to the vapor itself.

Table I gives the results of these tests in terms of the percent of the surface area damaged. In experiments 1 and 2, samples were exposed to humidities of 97%, 92%, 87%, 76%, and 55% at 24°C and observed after specified time periods. In experiments 3 and 4, several other samples were observed after 24 and 48 hours, respectively.

There is considerable variation in the measurable damage for different samples exposed to identical conditions. However, it can be noted that severe damage will occur after only a few hours at the higher humidities. Ninety percent humidity at 24°C appears to be the marginal condition under which some damage, but not severe damage, can occur.

It is obvious that the amount of water vapor present, at a given temperature, determines the degree of damage. Table II gives the equivalent humidities, i.e., same water vapor content, at temperatures other than those studied. This chart can be used to predict the degree of damage to be expected under the conditions given. Conditions such as those shown in the second column will produce moderate to severe damage (>5%). The third column presents conditions that produce marginal (0.1 - 5%), whereas the last presents conditions that yield negligible damage (<0.1%). The validity of this table has been verified by testing samples under conditions of 100% humidity at 18°C and 55% humidity at 14°C.

Table I. Damage to Silvered Teflon Caused by Exposure to Humidity

Experiment No.	Time (hr)	Humidity (%)				
		97	92	87	76	55
1	1	0	0	0	0	0
	2	0.1	0	0	0	0
	3.5	1	0	0	0	0
	6	2	0	0	0	0
	24	7	3	0	0	0
	96	10	3	0	0	0
2	1.5	0	0	0	0	0
	2.5	20	0	0	0	0
	5	20	0	0	0	0
	48	60	0.5	0.5	0	0
3	24	12	2	5		
4	48	6			0	0

Table II. Equivalent humidity versus temperature for occurrence of damage to silvered teflon.

Temperature (°C)	Equivalent Humidity		
	Severe Damage (>5%)	Marginal Damage (0.1 - 5%)	Negligible Damage (0.1%)
18			100-78
21		100	92-66
24	97	92-87	76-55
27	82	78-74	65-47
29	71	67-64	58-40
32	66	57-54	48-34
35	51	49-46	41-29
38	44	42-40	35-25

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1. Uhlig, H. H., ed., The Corrosion Handbook, John Wiley and Sons, Inc., 1948, p. 1121.

2. MacIntyre, F., "The Millimeter of the Ocean," Scientific American, May 1974.

3. National Research Council, International Critical Tables, McGraw Hill Book Company, Inc., 1933.

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