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HYPERVELOCITY IMPACT TESTING OF L-BAND TRUSS CABLE METEOROID SHIELDING ON SKYLAB

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16. ABSTRACT

The purpose of this series of tests was to determine if the L-band truss cable meteoroid shielding as currently designed and supplied for Skylab provides adequate protection when it is at the expected space environment temperature of -118°C (-180°F).

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HYPERVELOCITY IMPACT TESTING OF L-BAND TRUSS CABLE METEOROID SHIELDING ON SKYLAB

INTRODUCTION

A series of tests was performed to determine if the L-band truss cable meteoroid shielding as it is currently designed and supplied for Skylab would provide adequate protection at the expected space environment temperature of -118°C (-180°F).

TEST SPECIMENS

Simulated cable bundles were wrapped with a Raychem flurol compound called NBG. This NBG material forms the meteoroid shielding on the L-band truss cables for Skylab.

A strip of NBG is 0.161 cm (0.024 in.) thick and 2.8 cm (1.1 in.) wide. It is wrapped around the cable so that each winding overlaps half of the previous winding. In this manner the cable is protected by two layers of NBG over almost the entire length of the cable.

Thermocouples were embedded in these cable bundles, two thermocouples per bundle, each located approximately one-third of the length toward the center of the bundle from either end. The leads on the thermocouples were approximately 1 m long to allow proper installation in the impact chamber. The thermocouples were utilized to monitor the temperature of the bundle at the time of impact.

TEST PROCEDURE

To provide an accurate method for determining the temperature of the material at the time it was impacted, it was decided to use a method which did not depend on the accuracy of a calibration curve or the risk of an undetected malfunction of the thermocouple used.

The method was to take two separate bundles, each having two thermocouples, and connect one thermocouple in one bundle to one of the thermocouples in the other bundle by twisting the two leads of one of the metals together and connecting the two leads of the other metal across a digital voltmeter. The same procedure was followed for the two remaining thermocouples in the two separate bundles.

When the thermocouples functioned properly and both bundles were at the same temperature, the readings were zero. Either bundle could be used as the reference and the remaining bundle as the test specimen.

Since room temperature varies, it was decided that the reference temperature should be liquid helium, selected because it was readily available and stable. Therefore, both bundles were placed in a liquid helium bath and allowed to cool to that temperature. (The redundant thermocouples proved valuable because two of the thermocouples failed to function properly when cooled.) The test specimen was then removed from the bath and mounted in the impact chamber. (The leads were fed through the range wall prior to the cooling process so that the range could be closed and evacuated without removing the reference bundle from the bath or affecting any of the connections.) The voltage difference between the two bundles was monitored as a function of time and pressure in the impact chamber. The results are plotted in Figure 1.

It was found from the tables for this particular type of thermocouple (Cromel-Constantine) that a voltage difference of 0.0025 V existed between the desired temperature of -118° C (-180° F) and the temperature of liquid helium.

As this difference was approached, the accelerator was armed and fired. The command "fire" in Figure 1 is the time at which the acceleration process was activated. Impact occurs within 3 or 4 msec after that command. Therefore, it is obvious that the "fire" point represents the temperature of the bundle at impact.

In Figure 1 it can be seen that on shot 72-128, which was the first shot in this series, the temperature rise from time 0 to about 5 min is different from that on shots 72-131 and 72-133 because the range components were higher in ambient temperature on the first shot than on the others. On subsequent shots the dewar, or liquid helium container, was placed in contact with the impact chamber during the bundle cooling period; therefore, the range components were cooler at time 0 on all shots after 72-128.

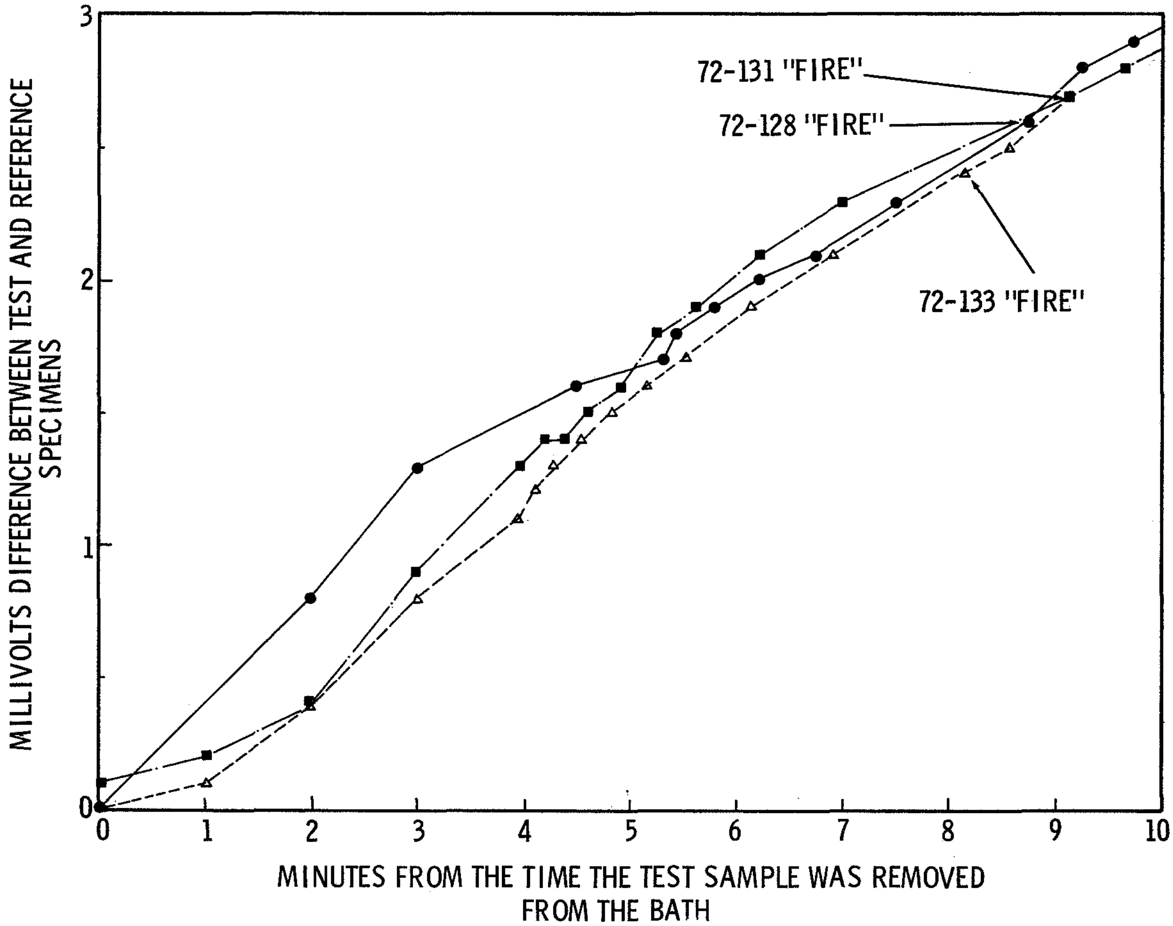

Figure 1. Temperature of the test specimen as a function of time as measured by the voltage difference between the thermocouple readings.

RESULTS

The damage sustained when three of the described test specimens, at -118° C (-180° F), were impacted by spherical projectiles is shown in Figure 2. The projectiles were glass spheres 0.0420 cm in diameter, with a density of 2.5 gm/cm^3, a mass of 9.7×10^{-5} gm, and were traveling at velocities between 5.24 and 7.28 km/sec.*

*The mass and velocity were dictated by Mr. Jack Braly's (McDonnell Douglas Co.) calculations of this Skylab component's exposure to the meteoroid environment.

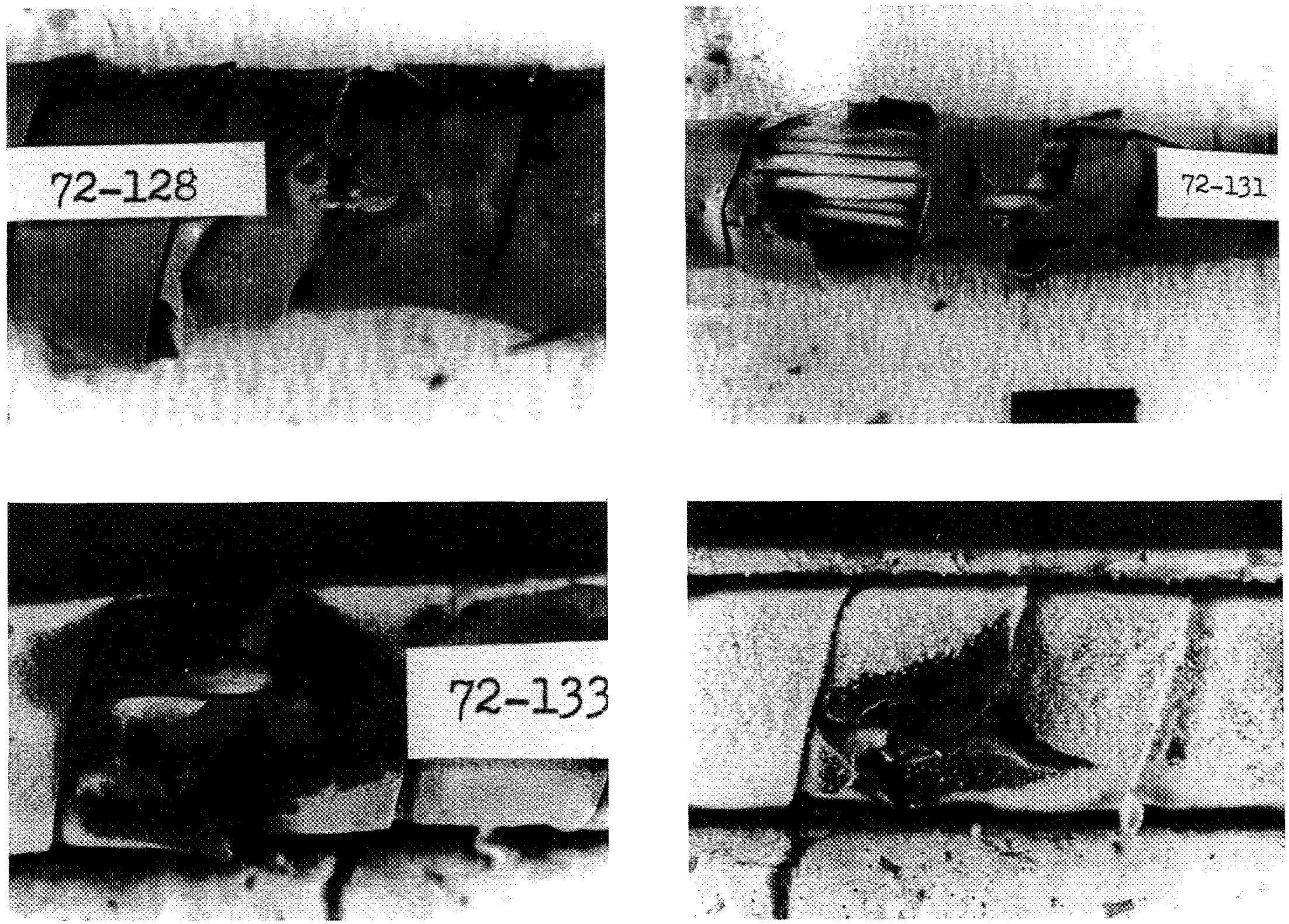

Figure 2. Damage sustained by three test specimens at -118° C (-180° F) when impacted by hypervelocity projectiles.

All three bundles show the same general characteristics:

1. The NBG material is shattered and stripped away from the cabling by the impacting projectile and subsequent interactions, thereby exposing a section of the cabling.

2. No damage, however, is visible on the cabling itself. Even in 72-131, where there were mutliple impacts in the same region exposing a very large section of cabling, no visible damage to the cabling itself is evident.

Pieces of the shattered NBG material shown in Figure 3 reveal some of the characteristics of the fragmenting process.

It was thought that a few impacts at room temperature could "shed more light" on the characteristics of failure of this material due to hypervelocity impacts. Therefore, three additional shots were performed for this purpose. The results are shown in Figures 4 and 5. The designations "1st" and "2nd" in these figures are references to the position when impacted. The layer impacted directly by the sphere is the first layer impacted; therefore, it is labeled "1st". The layer under this is labeled "2nd". Figure 4 shows an impact of one projectile on two layers of NBG at room temperature.

Fortunately, on shot 72-136 it was possible to obtain one impact of a sphere on a double layer labeled "a" and two impacts on a single layer labeled "b" and "c". The cable under impacts "b" and "c" is also shown in Figure 5.

Comparison of the double layer impacts at -118° C (-180° F) and at room temperature (Figures 3, 4, and 5) shows similar characteristics. Basically, the only difference is that at lower temperatures the material shatters because it is very brittle at these temperatures.

Further study of this process is beyond the purpose of this test series.

CONCLUSIONS

It was concluded that the L-band truss cable meteoroid shielding as currently designed and supplied for Skylab does provide adequate protection when it is at a temperature of -118° C (-180° F).

A table for each test shot described in this paper is presented as Tables 1 through 5.

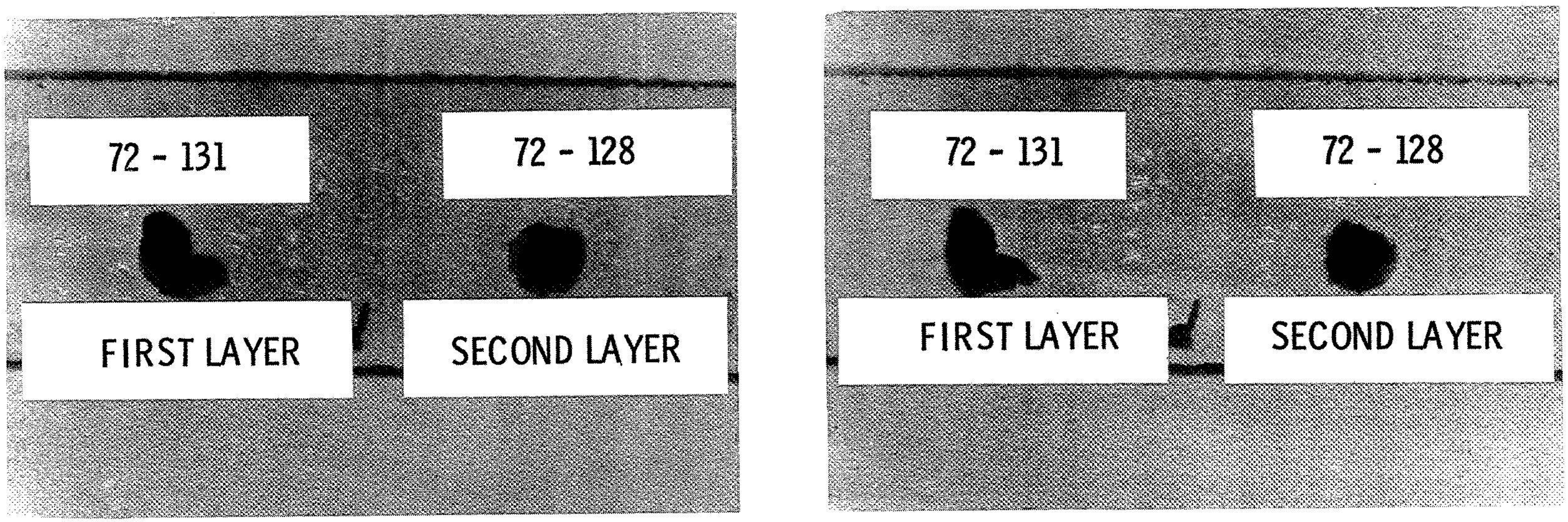

Figure 3. Pieces of the shattered NBG material impacted at -118° C (-180° F); the photograph on the right is lighted from the left, and the one on the left is lighted from the right; both photographs are of the same two pieces.

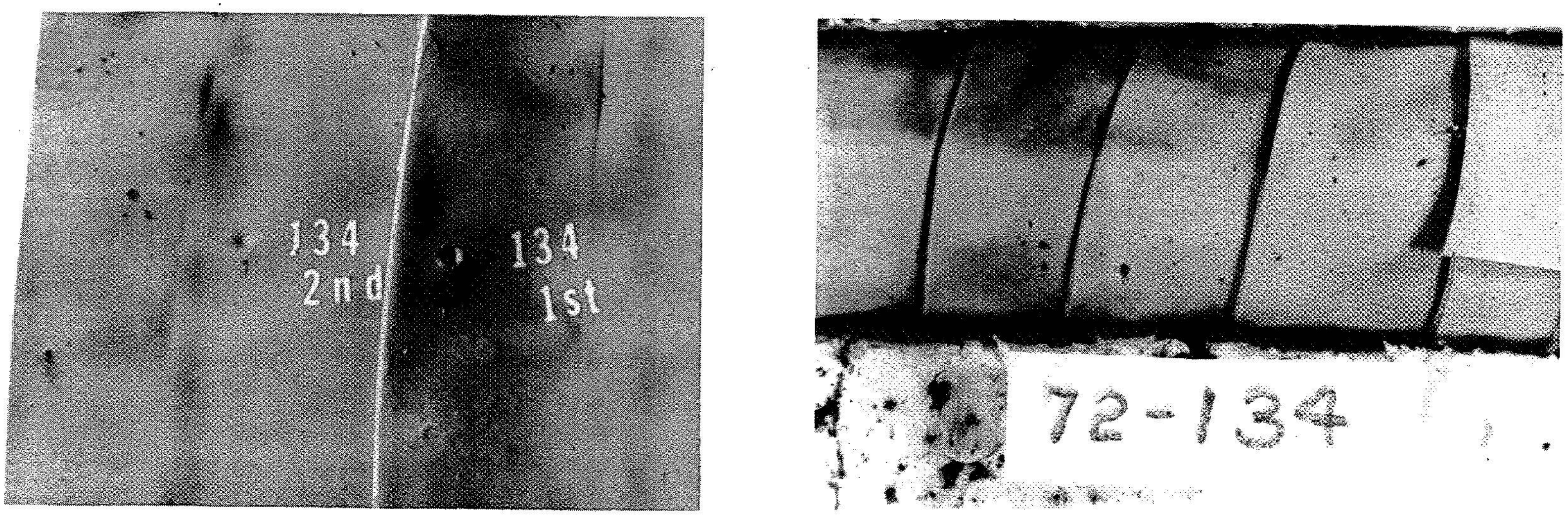

Figure 4. Damage to NBG material at room temperature [approximately 20° C (68° F)]; the designations "1st" and "2nd" refer to their position when impacted, "1st" being the layer directly impacted and "2nd" being the layer under the "1st".

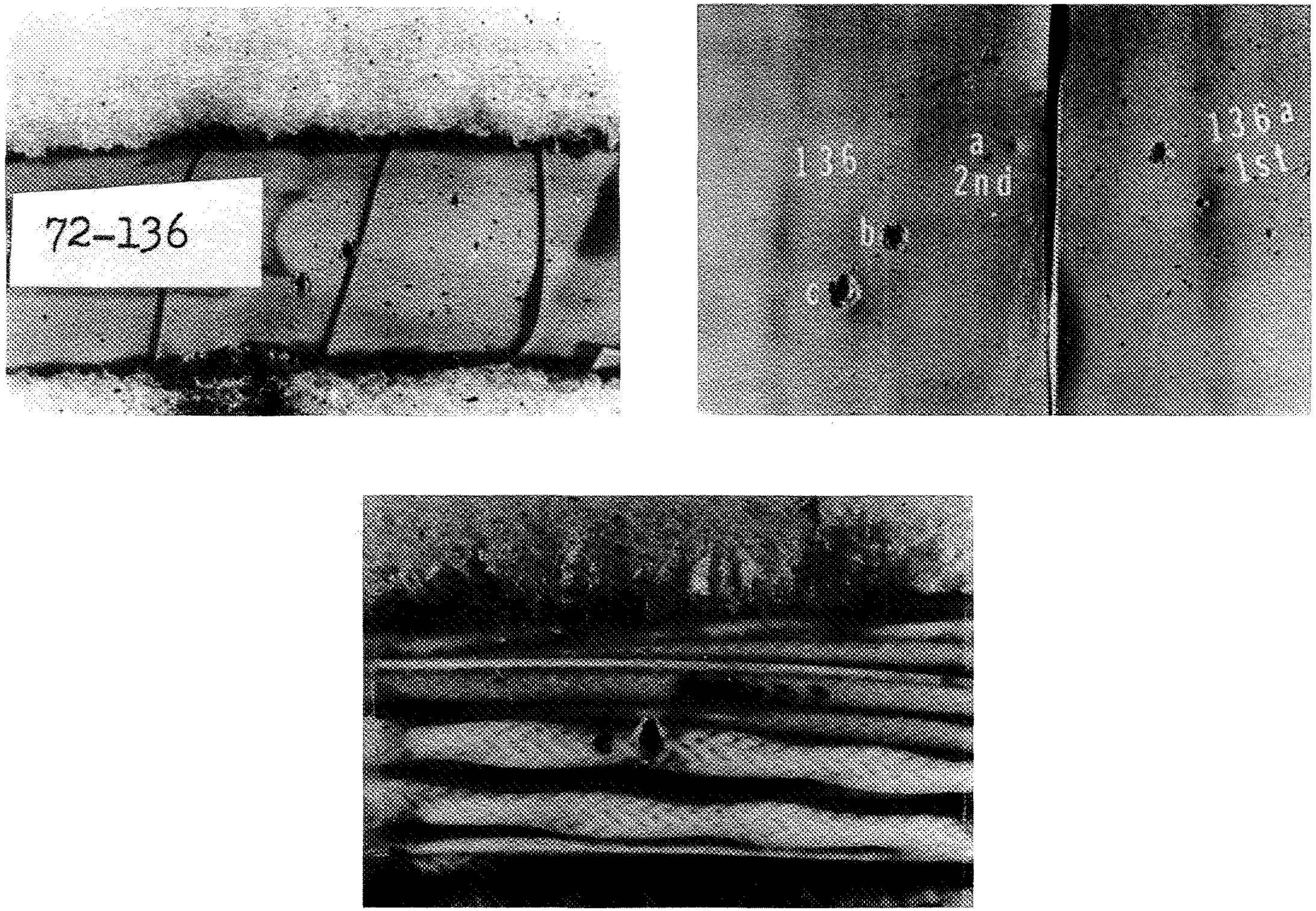

Figure 5. Damage to NBG material and underlying cable at room temperature [approximately 20° C (68° F)]; the designations "1st" and "2nd" refer to their position when impacted and "a", "b", and "c" refer to three separate impacts.

TABLE 1. SHOT REFERENCE NO. 72-128, NOVEMBER 28, 1972

	Time (hr:min;sec)	Time Elapsed from Bath (min)	Voltage (V)	Pressure in Range (mm of Hg)
	2:34;15	0	0.0000	
	2:36;15	2.0	0.0008	
	2:37;15	3.0	0.0013	
	2:38;45	4.5	0.0016	100
		(4.71)[a]		90
		(4.94)[a]		80
		(5.32)[a]	0.0017	70
		(5.45)[a]	0.0018	60
		(5.79)[a]	0.0019	50
		(6.19)[a]	0.0020	40
		(6.75)[a]	0.0021	30
		(7.52)[a]	0.0023	20
		(8.90)[a]	0.0026	12
"FIRE"	2:43;0	8.75	0.0026	
		Time Elapsed after "FIRE" (min)		
	2:43;30	0.5	0.0028	
	2:44;0	1.0	0.0029	
	2:44;30	1.5	0.0030	
	2:45;0	2.0	0.0031	
	2:45;30	2.5		
		3.0		

Projectile Parameters:

0.0420 cm in diameter
2.5 gm/cm^3 = density (soda-lime glass)
9.7 x 10^{-5} gm = mass
7.28 km/sec = velocity

a. These times are estimated from a graph plotted of five records of evacuation of the chamber as a function of time.

TABLE 2. SHOT REFERENCE NO. 72-131, NOVEMBER 30, 1972

	Time (hr:min;sec)	Time Elapsed from Bath (min)	Voltage (V)	Pressure in Range (mm of Hg)
	12:53;0	0	0.0001	
	12:54;0	1.0	0.0002	
	12:55;0	2.0	0.0004	
	12:56;0	3.0	0.0009	
	12:56;57	3.95	0.0013	100
	12:57;10	4.17	0.0014	90
	12:57;23	4.38	0.0014	80
	12:57;37	4.62	0.0015	70
	12:58;55	4.92	0.0016	60
	12:58;15	5.25	0.0018	50
	12:58;40	5.67	0.0019	40
	12:59;12	6.20	0.0021	30
	1:00;0	7.00	0.0023	20
"FIRE"	1:02;10	9.15	0.0027	12
		Time Elapsed after "FIRE" (min)		
	1:02;40	0.5	0.0029	
	1:03;10	1.0	0.0030	
	1:03:40	1.5	0.0031	
	1:04;10	2.0	0.0032	
		2.5		
		3.0		

Projectile Parameters:

0.0420 cm in diameter
2.5 gm/cm^3 = density (soda-lime glass)
9.7 x 10^{-5} gm = mass
5.24 km/sec = velocity

TABLE 3. SHOT REFERENCE NO. 72-133, DECEMBER 5, 1972

	Time (hr:min;sec)	Time Elapsed from Bath (min)	Voltage (V)	Pressure in Range (mm of Hg)
	1:15;0	0	0.0000	
	1:15;13[a]			
	1:16;0	1.0	0.0001	
	1:17;0	2.0	0.0004	
	1:18;0	3.0	0.0008	
	1:18;57	3.95	0.0011	100
	1:19;04	4.07	0.0012	90
	1:19;17	4.28	0.0013	80
	1:19;31	4.52	0.0014	70
	1:19;49	4.82	0.0015	60
	1:20;09	5.15	0.0016	50
	1:20;33	5.55	0.0017	40
	1:21;07	6.12	0.0019	30
	1:21;54	6.90	0.0021	20
"FIRE"	1:23;05	8.08	0.0024	12
		Time Elapsed after "FIRE" (min)		
	1:23;35	0.5	0.0025	
	1:24;05	1.0	0.0027	
	1:24;35	1.5	0.0028	
	1:25;05	2.0	0.0029	
		2.5		
		3.0		

Projectile Parameters:

0.0420 cm in diameter
2.5 gm/cm^3 = density (soda-lime glass)
9.7 x 10^{-5} gm = mass
6.49 km/sec = velocity

a. Door to chamber closed and evacuation begun

TABLE 4. SHOT REFERENCE NO. 72-134, DECEMBER 5, 1972

	Time (hr:min;sec)	Time Elapsed from Bath (min)	Voltage (V)	Pressure in Range (mm of Hg)
		ROOM TEMPERATURE		
				100
				90
				80
				70
				60
				50
				40
				30
				20
				12
"FIRE"				
		Time Elapsed after "FIRE" (min)		
		0.5		
		1.0		
		1.5		
		2.0		
		2.5		
		3.0		

Projectile Parameters:

0.0420 cm in diameter
2.5 gm/cm^3 = density (soda-lime glass)
9.7 x 10^{-5} gm = mass
7.40 km/sec = velocity

TABLE 5. SHOT REFERENCE NO. 72-136, DECEMBER 7, 1972

	Time (hr:min;sec)	Time Elapsed from Bath (min)	Voltage (V)	Pressure in Range (mm of Hg)
		ROOM TEMPERATURE		
				100
				90
				80
				70
				60
				50
				40
				30
				20
				12
"FIRE"				
		Time Elapsed after "FIRE" (min)		
		0.5		
		1.0		
		1.5		
		2.0		
		2.5		
		3.0		

<u>Projectile Parameters:</u>

0.0420 cm in diameter
2.5 gm/cm^3 = density (soda-lime glass)
9.7 x 10^{-5} gm = mass
6.82 km/sec = velocity

APPROVAL

HYPERVELOCITY IMPACT TESTING OF L-BAND TRUSS CABLE METEOROID SHIELDING ON SKYLAB

By David W. Jex

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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