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MATERIALS INVESTIGATION OF STS-3 PARACHUTE FAILURE

By Ronald L. Nichols
Materials and Processes Laboratory

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16. ABSTRACT

Main parachute, No. 2 of SRB A-12 on STS-3, sustained damage during deployment or initial inflation that resulted in its collapse and failure to sustain load. During an investigation of the materials from this parachute, optical and scanning electron microscope analyses were conducted. This examination identified stains and abrasions on vent lines that appear to have been a result of friction contact with its flotation bag lanyard. Mechanical testing of the vent band indicated a reduction in strength of 37 percent obviously due to structural overload, heat, and ocean water exposure. It is concluded from this and other available data that entanglement of parachutes No. 1 and No. 2 during deployment caused adequate structural damage to main parachute No. 2 to render it unable to carry load.

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FAILURE DESCRIPTION

Parachute No. 2 on SRB A-12 was noted to have sustained significant structural damage during SRB reentry. Investigation of the available data relative to this parachute indicates that the frustrum was tilted at a significant angle during deployment of the main parachutes. All three canopies began to carry load, but approximately 2.5 sec after deployment parachute No. 2 ceased carrying load. This data was gathered from reentry film and load cells at the SRB-parachute interfaces. Additionally, it was observed that the flotation devices were detached from parachutes No. 1 and No. 2. Parachute No. 1 was detached from the SRB by the separation nut pyrotechnic devices, and it subsequently sank prior to arrival of the retrieval vessel. Parachute No. 2 did not detach from the SRB even though the separation nuts fired as scheduled. This allowed for the retrieval of parachute No. 2. It was returned to the Parachute Refurbishment Facility where it was washed and dried according to normal procedure and spread to allow observation of the damage. Figure 1 identifies those structural elements of the SRB main parachute involved in this investigation.

VENT LINE

The vent lines are extensions of the radial structural components and extend across the apex of the canopy above the vent. One vent line that connects radials 3 and 51 together was completely severed. A green stain was apparent on the vent lines extending from the radial No. 42 to No. 59 forming a triangular pattern near the vent band. A vent band was broken at approximately 3 in. from the intersection of radial No. 51. The broken vent line is heavily stained with a green color. Figure 2 shows the failed vent line and the heavily stained area.

Samples of all the green material that may have caused the vent line stains were analyzed under an optical microscope and compared to the green stained fibers deposited on the vent line. The green materials analyzed came from the parachute flotation covers, its webbing, the shock absorber lines, and the lanyard that attaches the vent lines to the flotation bag risers. The optical microscope analysis consisted of comparing the fiber diameter, texture, and color. The lanyard fibers appeared to match the stains most closely. The stained fibers on the vent line and fibers from the lanyard were compared utilizing the Scanning Electron Microscope (SEM). Figure 3 shows fibers from the lanyard that attached the vent lines to the flotation bags. Figure 4 depicts fibers from the green stained area of the broken vent line. The SEM pictures of these fibers appear to be similar in size, texture, and color.

Tensile specimens were made from the broken vent line from the failed parachute. The average breaking strength of these samples was 3300 lb when pulled to failure on an Instron tensile testing machine at 10 in./min. The vent line material is initially rated at 6000 lb.

Two vent lines were removed from parachute No. 2 and tested in tension to destruction. These vent lines were located at approximately 90 deg to the failed one. The results of this testing is shown in the following table.

Sample No.	Breaking Strength (lb)
1	5800
2	6000
3	5425
4	5217
Average =	5610

These vent lines located 90 deg to the heavily loaded one indicated breaking strengths only 7 percent below the rated load carrying capability of this webbing.

Degradation was expected in the strength of the vent line material as it was loaded near its rated load capability. Samples of a nylon webbing of MIL-W-4088D (3500 lb rating) were tested to destruction. An additional set was loaded to 80 percent of the average breaking strength and held for 30 sec. The load was released and the samples were pulled to failure. The results of these tests are as follows.

	No. Preload		Preloaded to 3172 lb
Sample No.	Breaking Strength		Breaking Strength
1	3700		4360
2	3840		4355
3	4080		4475
4	4240		4400
Average =	3965	Average =	4397

A decrease in strength after preloading was anticipated; however, this did not occur. This test does not represent the abrasive action that would have occurred due to dynamic motion during STS-3 flight.

VENT BAND

The vent band is composed of two lengths of 2 in. wide webbing, overlaid and sewn together. It limits the volume of vent at the apex of the canopy. The vent band failed at radial No. 3. No other obvious damage was noted during our analysis of the failed vent band. The vent band was cut into 30 in. test samples and pulled to failure in an Instron tensile test machine. The tensile test data is shown as follows.

Specimen No.	UTS (lb)
1L	2830
2L	2685
3L	2330
4L	1610
5L	2800
6L	2450
1S	2745
2S	2775
Average =	2528

The average breaking strength of these specimens is 2528 lb indicating a reduction in strength of approximately 37 percent below the 4000 lb rating for this webbing. The loading, thermal, and salt water exposures have apparently degraded the vent band material significantly

HORIZONTAL RIBBONS

The horizontal ribbons of gore No. 3 failed from the vent band to the tenth horizontal from the skirt band. Several horizontals near the vent band exhibited failures in two locations indicating loads applied rapidly, shear type loads present, or possibly both. The nylon horizontals near the vent band are rated at 1000 lb, while those near the skirt band are 450 lb ribbons.

The failure surfaces of the horizontal ribbons were analyzed under an optical microscope comparing those ribbons at the vent band with those at other locations. Often nylon fibers crystallize and become opaque when they are rapidly failed in tension. Presence of opaque fibers would indicate the failure rate of the fibers. No crystallization of the nylon fibers was detected at any location. All samples analyzed exhibited melting and the formation of a small sphere at the fracture surface of the fibers as is common with tensile failure of nylon fibers under slower loading rates. No obvious difference in fiber failure appearance was noted relative to the location of the horizontals on the canopy.

RUBBER BUMPER

A rubber bumper is located on the lower rim of the frustrum to serve as a bumper for the frustrum location aid (FLA). The rubber bumper shown in Figure 5 has significant stains on its upper surfaces that may have been caused by rubbing contact with the parachute as it was deployed. Viewing of the films to determine the angle of the frustrum during deployment indicates that parachute No. 2 may have contacted the rubber bumper. Figure 6 shows the stains on the rubber bumper. They appear to be deposites of molten material characteristic of nylon. Efforts expended did not result in the positive identification of the source of these stains.

CONCLUSIONS

Based on green stains found on the vent bands and motion photograph obtained during SRB reentry, it appears that the parachute failure was initiated by overloading a vent line when the parachute flotation bags of parachutes No. 1 and No. 2 became entangled. This entanglement probably resulted in stretching of the vent line beyond its elastic limit. When it failed, the load was transferred first to the vent band and, after vent band failure, to the horizontal ribbons as the radial contracted, resulting in failure of the horizontal ribbons. The available evidence indicates that the horizontal ribbons near the vent band were severed early in the failure sequence with propagation toward the skirt band from aerodynamic loads during the continuation of descent. This conclusion is derived from matching stains and fibers found on the broken vent line to those of the flotation bag lanyard, the loads data obtained during flight on the SRB tape recorder, and long range motion picture coverage of the reentry of the A-12 hardware.

It appears at this point that the FLA bumper damage did not contribute to the parachute failure. Additionally, no evidence was found in the build records nor from testing of materials from main parachute No. 2 that indicated that any substandard materials contributed to the parachute's failure.

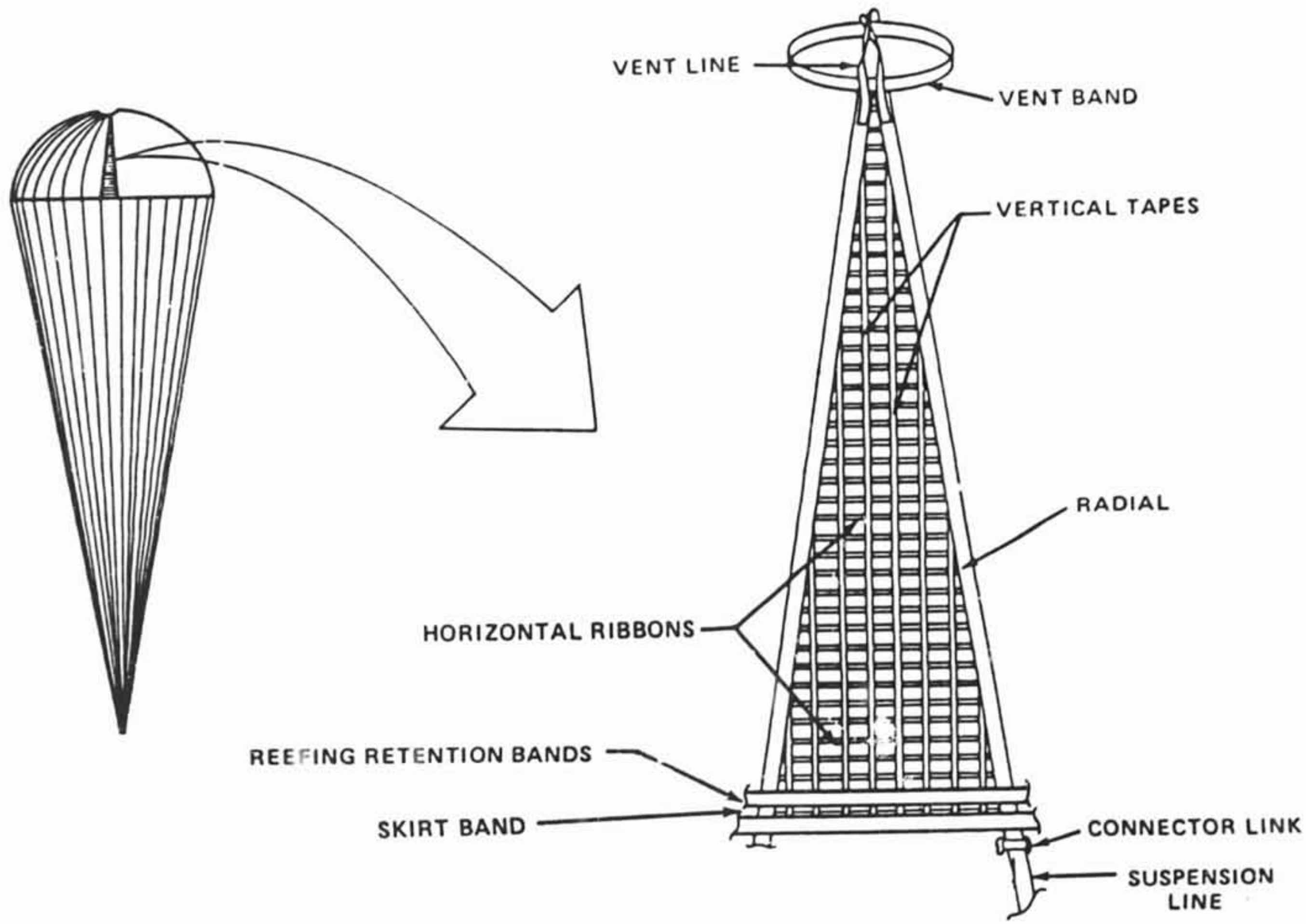

Figure 1. Parachute canopy structural components.

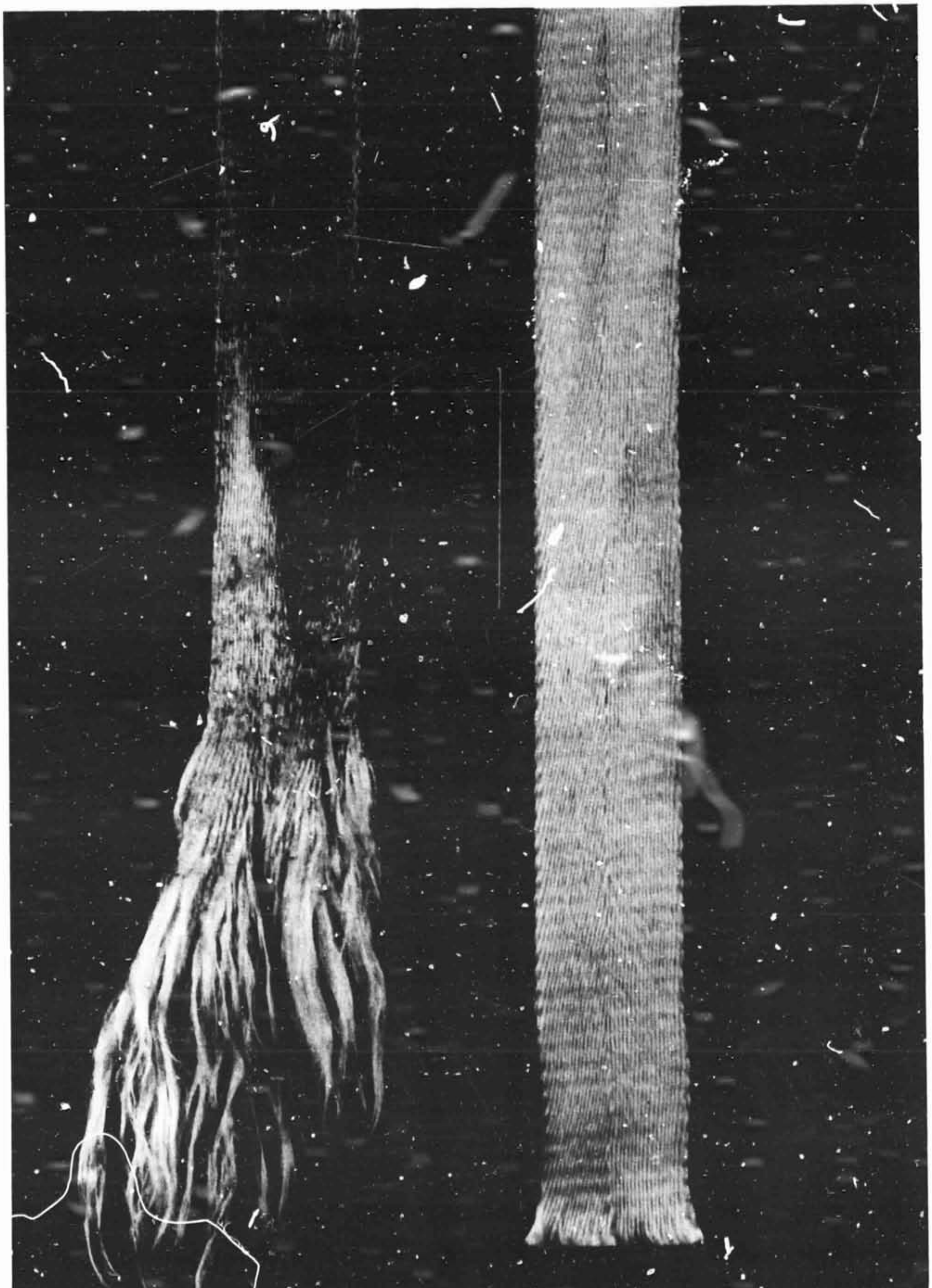

Figure 2. Broken parachute vent line.

Figure 3. Lanyard fibers.

Figure 4. Green fibers from failed vent line.

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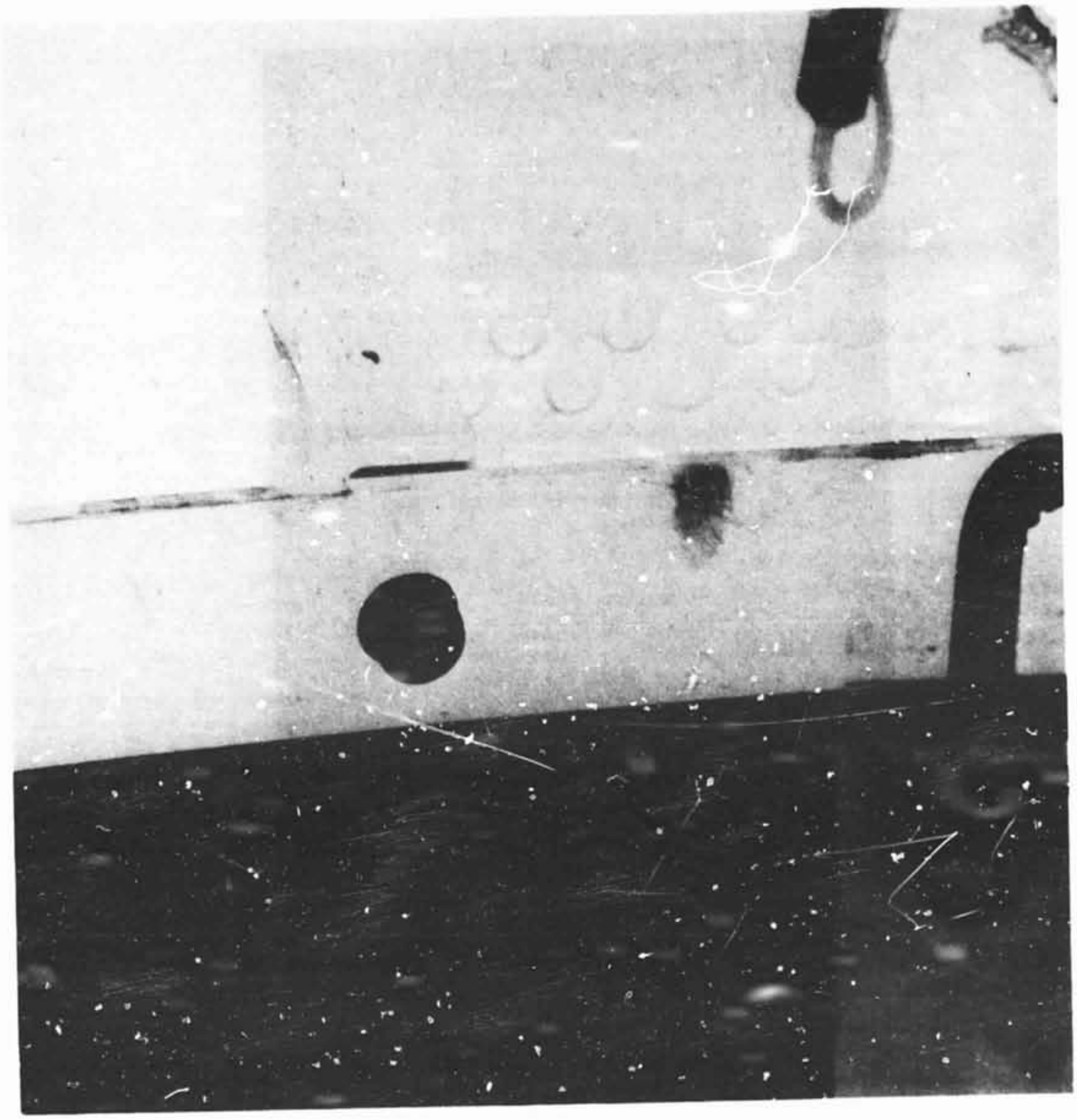

Figure 5. Frustrum location aid bumper.

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Figure 6. Stain on rubber bumper.

APPROVAL

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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.

R. J. Schwinghamer

R. J. SCHWINGHAMER
Director, Materials and Processes Laboratory

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