Development of Lead Free Energy Absorber for Space Shuttle Blast Container

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ABSTRACT

The Space Shuttle is connected to the mobile launch platform (MLP) by four aft skirt hold down studs on each solid rocket booster (SRB). Prior to lift-off, the frangible nuts inside the aft skirt blast containers are severed into two nut halves by two pyrotechnic booster cartridges. This action releases the Space Shuttle and allows the hold down studs to eject through the aft skirt bore and then down into the MLP. USBI has been tasked to upgrade the blast container for two specific reasons: 1. To eliminate lead for environmental concerns, and 2. To reduce the chance of nut recontact with the holddown stud. Nut recontact with the stud has been identified as a likely contributor to stud hang-ups. This upgrade will replace the lead liner with a unique open cell aluminum foam material, that has commercial and military uses. The aluminum foam used as an energy absorber is a proven design in many other aerospace/defense applications. Additional benefits of using the open cell, energy absorbent aluminum foam in place of the solid lead liner are: A. Lead handling / exposure and possible contamination, along with hazardous waste disposal, will be eliminated; B. Approximately 200 lbs. weight savings will be contributed to each Space Shuttle flight by using aluminum foam instead of lead; C. The new aluminum liner is designed to catch all shrapnel from frangible nuts, thus virtually eliminating chance of debris exiting the HDP and causing potential damage to the vehicle; D. Using the lighter aluminum liner instead of lead, allows for easier assembly and disassembly of blast container elements, which also improves safety, operator handling, and the efficiency of operations.

INTRODUCTION

USBI Co. is responsible for the assembly and refurbishment of the non-motor components of the SRB as part of the Space Shuttle system shown in Figures 1 and 2, developed and managed by Marshall Space Flight Center (MSFC) in Huntsville, Alabama. Programs are underway to develop and evaluate environmentally acceptable materials for use on aerospace flight hardware in order to eliminate materials such as lead, and also, by effective re-design, to provide lighter and more efficient systems. The SRB blast container is made primarily from Inconel 718 material and interfaces with either Inconel 718 or aluminum alloy materials. Four (4) Inconel 718 studs are used to attach each of the SRBs to the Mobile Launch Platform (MLP). Each stud is held in place by an upper frangible nut and lower conventional nut. The additional assembly of pyrotechnic initiators and booster cartridges to the frangible nuts allow for detonation on command, which splits the nuts in halves and releases the SRBs and attached Space Shuttle. The present blast container along with a cast Lead liner / Shock absorber, contain the high energy pyrotechnic fragments as well as frangible nut elements after detonation, and protects the Space Shuttle from foreign object damage. This paper discusses the benefits of replacing the cast lead liner with an open cell aluminum foam.

DISCUSSION

Material Selection and Preliminary Testing

An incident had occurred where the lead liner used in the present blast container had corroded, and the lead oxides resulting from corrosion required special hazardous material handling and disposal. USBI Co. is actively pursuing lead abatement programs, and the potential replacement of the lead blast container liner followed those initiatives. A replacement material for the lead blast container liner was sought by the Materials and Process Engineering Department. After an intensive search, Energy Research and Generation, Inc. (ERG, Inc.) located in Oakland, California, was identified as a company that produces a unique type of open cell aluminum alloy foam designed specifically for energy absorption. Open cell aluminum foam allows a larger volume of material to be used in the confines of the blast container without raising chamber pressure. Conventional materials such as honeycomb and closed cell foams were found to be unacceptable. Mechanical Engineering contracted with ERG, Inc. to provide flat test panels of various thicknesses and pore size / density configurations, in preparation for static drop testing. Full size frangible nuts were dropped from appropriate heights onto lead and aluminum foam targets below, simulating the relative impact energies of high velocity nut segments. It was found from these preliminary tests that the aluminum foam provided improved energy absorption over the present lead liner and would potentially save 200 pounds at liftoff. As a result of these successful tests, USBI Co. and NASA-MSFC decided to setup a series of follow-on "Proof-of Principle" tests to determine the dynamic characteristics of the open cell aluminum foam under actual blast container configuration.

Proof-of Principle Tests

A series of follow-on "Proof-of-Principle" tests which simulated the SRB hold-down post, with actual blast container hardware and pyrotechnics assembled were performed at the NASA-Kennedy Space Center (KSC) Launch Equipment Test facility (LETF). After blast container assembly and calibration of instrumentation, the hardware was then test fired. Figures 3, 4, 5, and 6 show the set-up required to perform the dynamic testing. Figures 7, 8, 9, and 10 show the results of test firing. Post-test results revealed that the aluminum foam had excellent energy absorption characteristics, and performed as expected. In addition, operator satisfaction was high, in part because of the ease of handling and installation of the light weight aluminum foam energy absorber blast attenuator.

CONCLUSION

Development and "Proof-of Principle" testing of an open cell aluminum foam energy absorber / blast attenuator has been completed. Data reduction continues, and the initial results were excellent. It was found that some aluminum foam densities and pore sizes worked better than others for the SRB frangible nut application. Excellent instrumentation allowed for accurate measurement of exit stud velocities, chamber pressures, and pyrotechnics firing order. Digital cameras, along with high speed and conventional video taping, recorded key elements of the test program and helped with the interpretation of data.

ACKNOWLEDGMENTS

The authors would like to thank the various USBI departments both in Huntsville, Alabama and Kennedy Space Center, Florida for supporting and assisting in program management, production operations, logistics and testing. Many thanks to the NASA-MSFC SRB Program Office personnel who were supportive of this program, and NASA-KSC personnel and contractors, who performed the physical testing, and instrumentation at the LETF. Additional thanks are given to ERG, Inc. management and engineering personnel who helped make this test program a success. A cohesive team composed of USBI Co. Mechanical Engineering, Production Engineering and Operations, Launch Support Services, and Materials and Processes Engineering, as well as NASA-MSFC and NASA-KSC personnel and contractors took part in the successful test program.

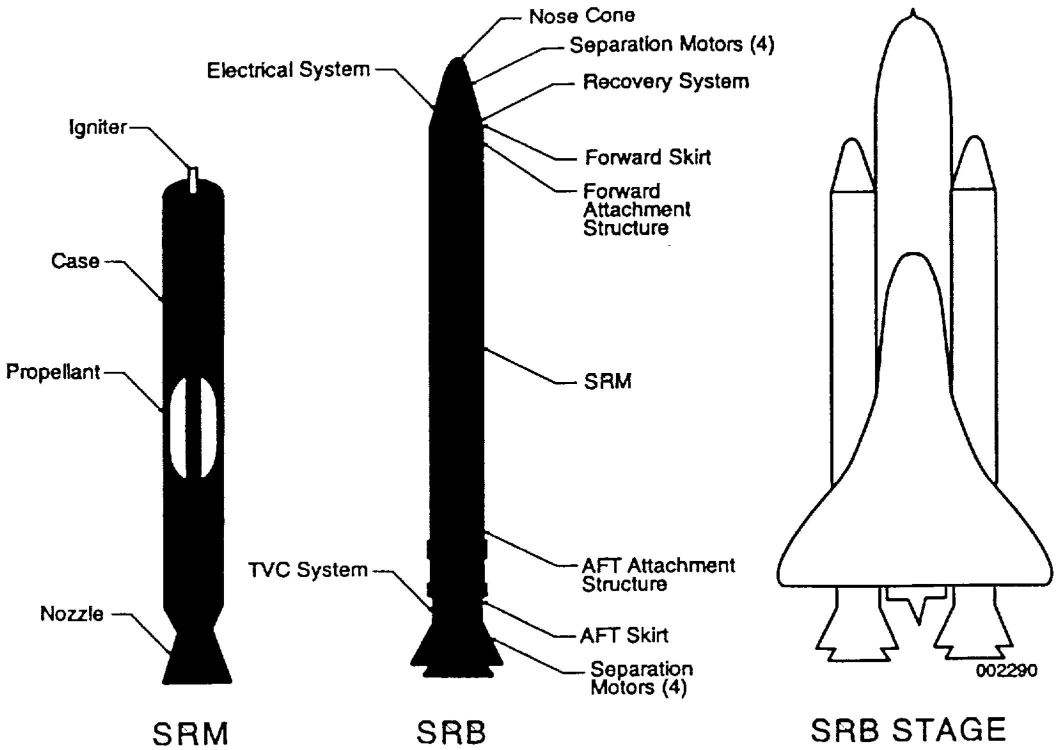

Figure 1. Space Shuttle Vehicle and Solid Rocket Booster

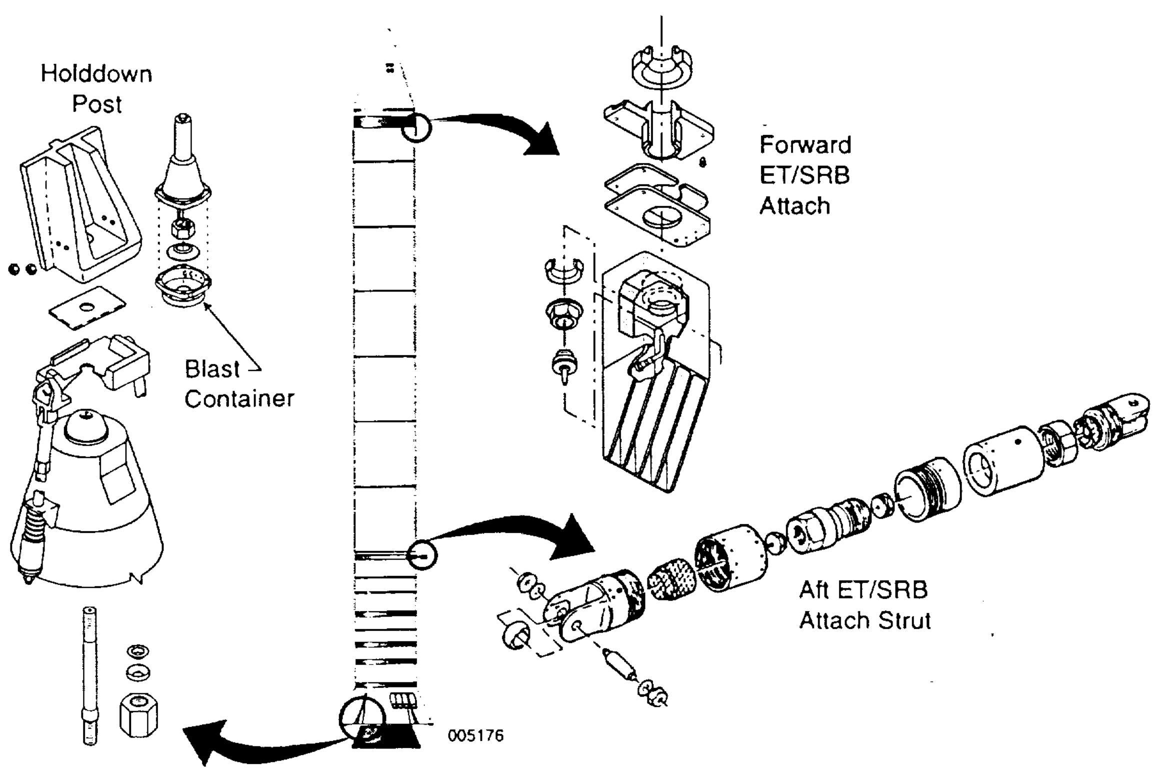

Figure 2. Solid Rocket Booster with Blast Container

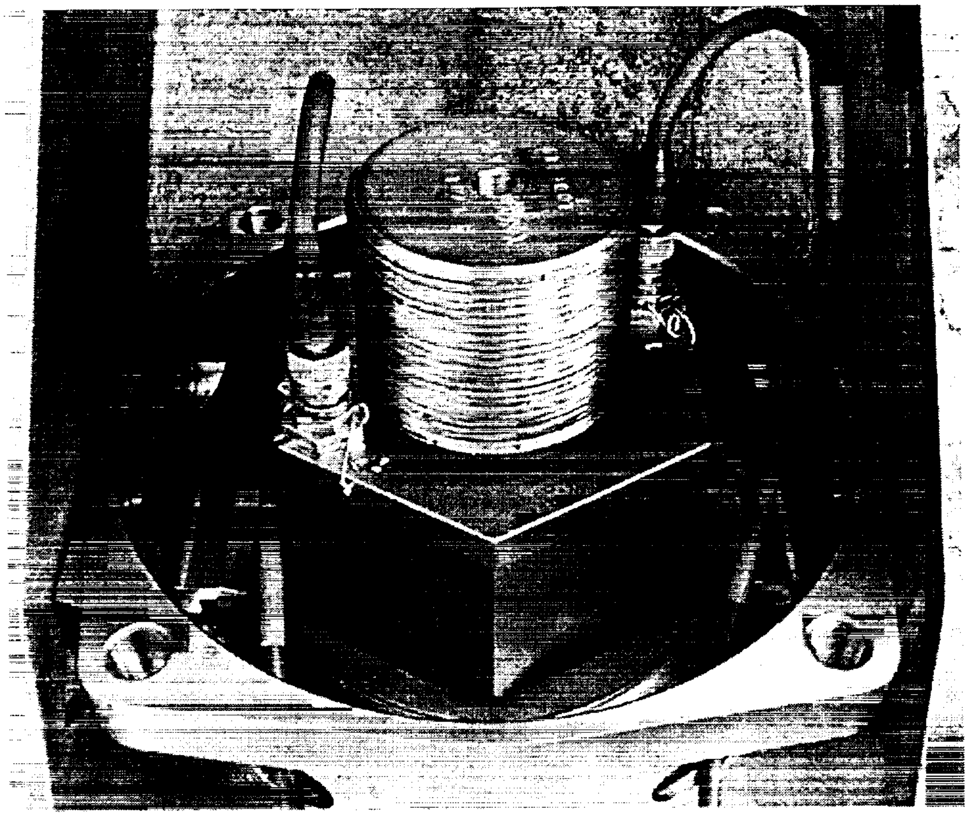

Figure 3. Holddown Stud, Frangible Nut, Booster Cartridges

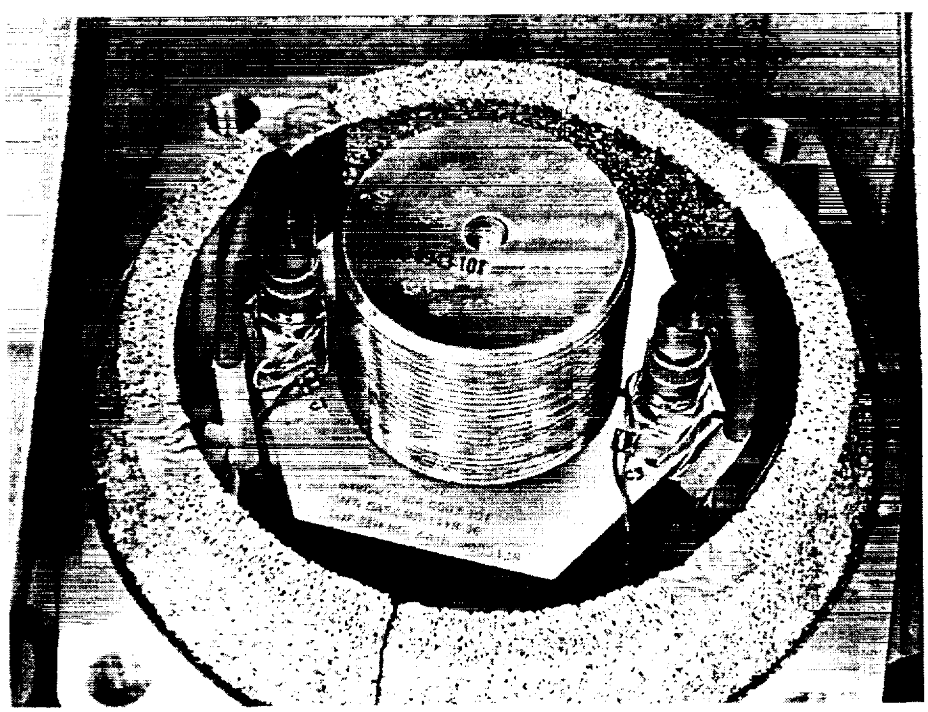

Figure 4. Aluminum Foam in Place

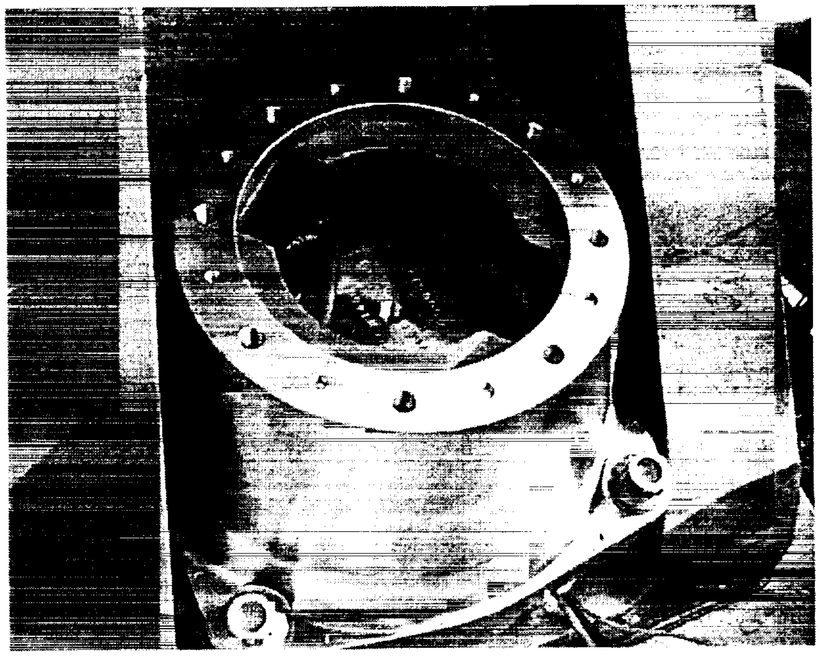

Figure 5. Top Section of Blast Container Assembled

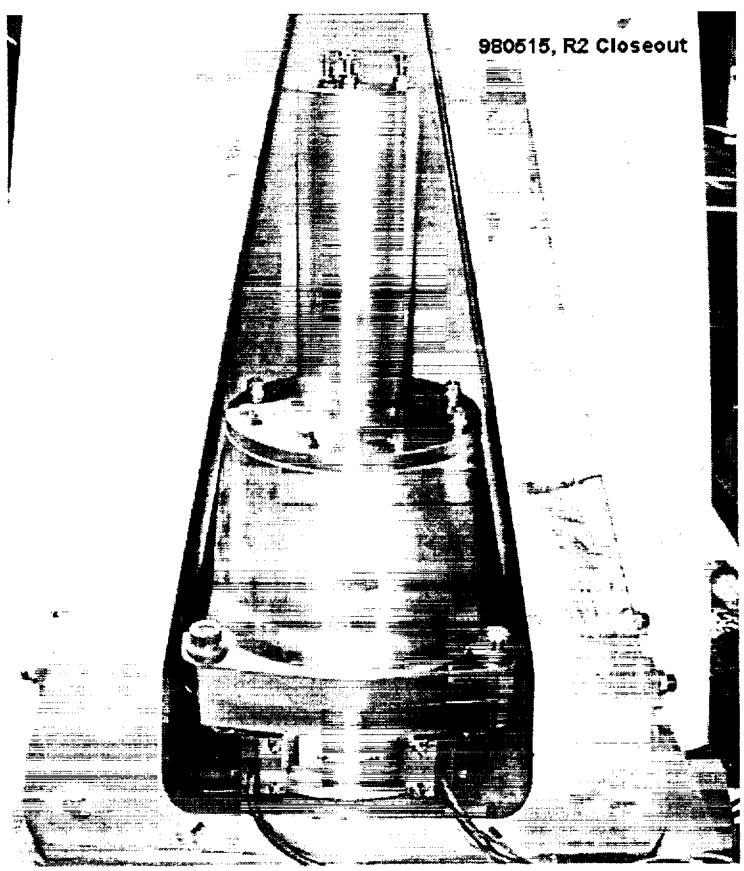

Figure 6. Final Assembly with Spring Housing

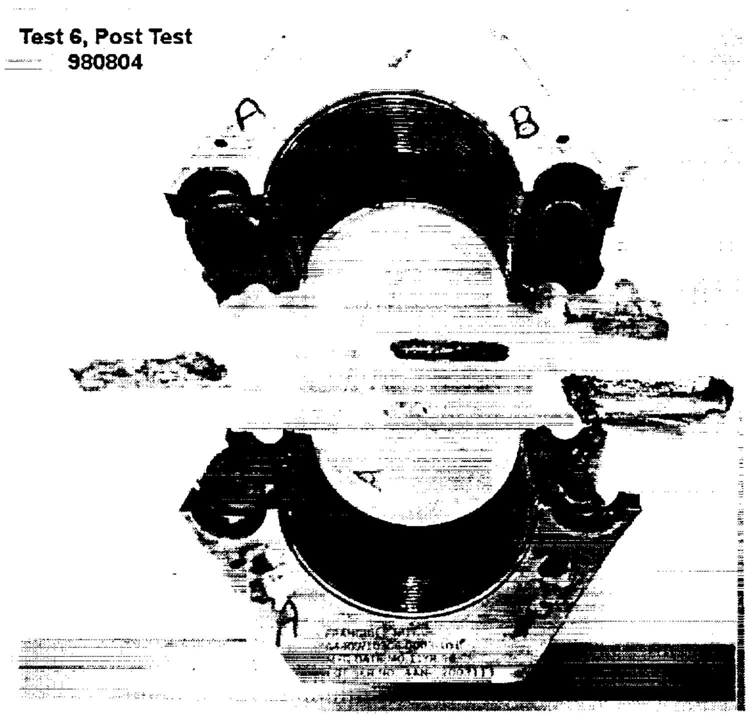

Figure 7. Post Test Frangible Nut Segments and Webs

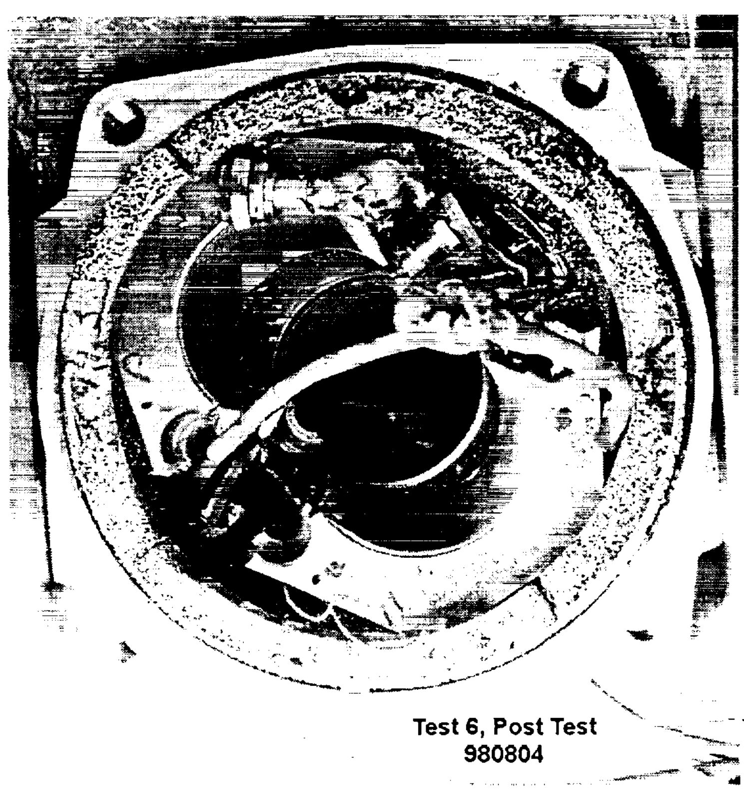

Figure 8. Post Test Showing Foam Impact, Frangible Nut, etc.

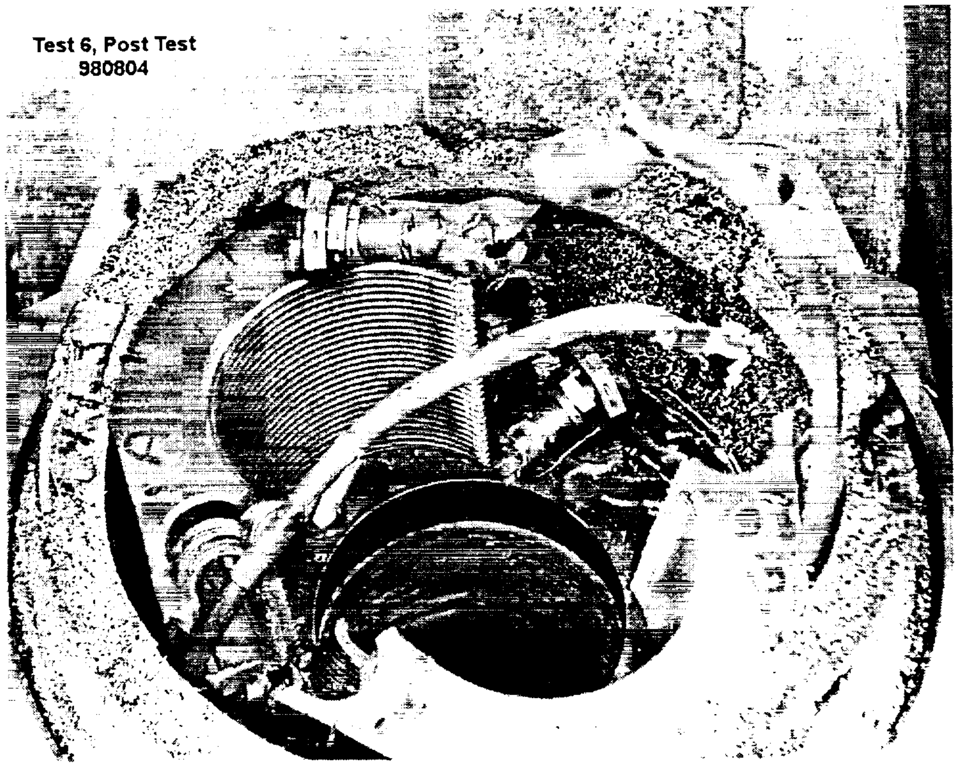

Figure 9. Close-up Showing Foam Impact, Frangible Nut, Pyrotechnics

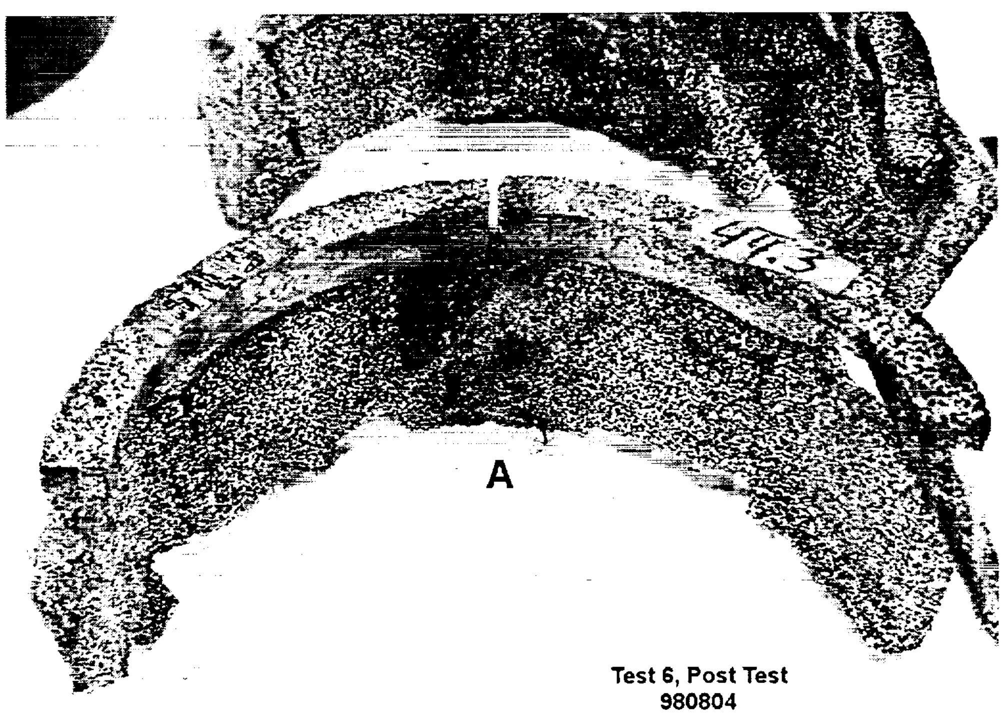

Figure 10. Post-Test Showing Aluminum Foam Energy Absorber