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Final Report - SPIRE-REF-REP-000651

FIRST/SPIRE A-FRAME TESTING AT CRYOGENIC TEMPERATURES
(PO: CV130277)

Prepared for

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January 8, 2001

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GENERAL INFORMATION:

Materials Research and Engineering, Inc. (MRE) was contracted by Mullard Space Science Laboratory (MSSL) under Purchase Order CV130277 to evaluate the load bearing capability of A-frame suspension components of FIRST/SPIRE. The A-frame component is shown in Figure 1. Tests were conducted in the x-direction with loads applied at the top lug (indicated by the arrow).

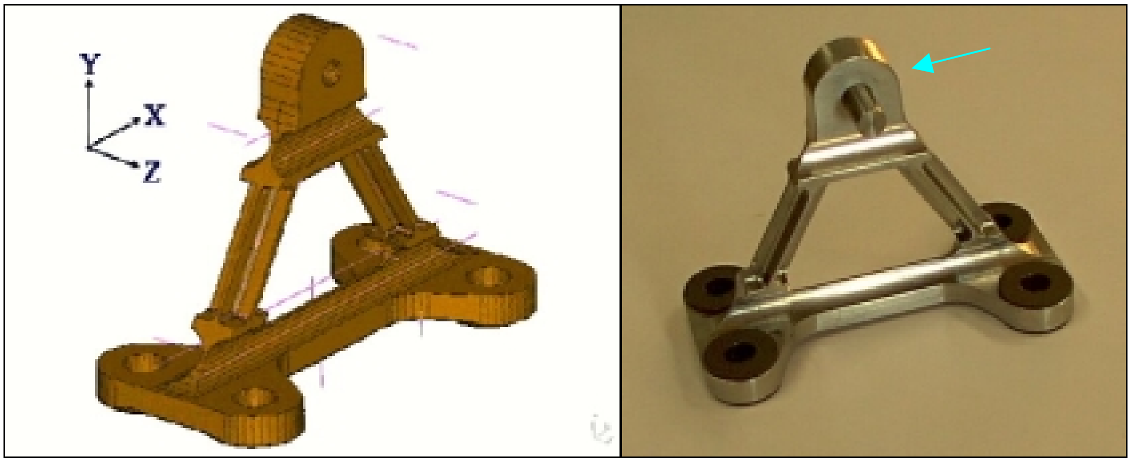

Figure 1. A-Frame Component.

Tests were performed on a 98-kN computer controlled, hydraulic Instron test frame with an 8500 series digital controller. Tests were conducted in displacement control using an actuator speed of 0.127-cm/min. Load and displacement data were recorded by computer during each test. The temperature was controlled with an accuracy of ±1.1K using liquid helium as the cryogenic media. Calibrated type-E thermocouples were used to verify the 9K temperature control.

The test fixture, designed and fabricated by MRE, is shown schematically in Figure 2. It was machined from a single section of 6061 aluminum, and can be seen mounted to the test frame in Figure 3. Tests were conducted in compression reacting against the four mounting rods shown in Figure 3. Lateral out-of-plane movement of the A-frame was restricted through the placement of set screws on each side of the fixture. One set screw is indicated by the arrow in Figure 3.

PROCEDURE AND RESULTS:

Four A-frame components were tested at 9K (-264°C) for the purpose of investigating the load bearing capacity in the x-orientation (see Figure 1). MRE and MSSL agreed upon modifications to the test procedure between each test after a preliminary analysis of the previous test's results occurred. A-frame #2, the first specimen tested, was loaded until extreme material deformation occurred. The load versus displacement data for specimen #2 appears in Figure 4. The deformations resulting from the test can be seen in Figure 5. A maximum load of 11.9-kN was achieved prior to the loss of mechanical stability within the A-frame. Due to the unanticipated rotation of the load cell, out-of-plane rotation occurred. The rotation of the load cell cannot be restricted due to the design of the test frame, but load cell rotation was monitored on subsequent tests and was not observed for the loads reached on the remaining specimens.

For the second specimen, A-frame #1, the first 7.0-kN portion of the load versus displacement curve was focused on. A load/unload curve was performed at approximately 4.5-kN to help determine the yield point of the material. A final unload was performed at just below 7.0-kN so that the first failure mode could be observed. The load versus displacement data for specimen #1 is shown in Figure 6. The tested specimen can be seen in Figure 7.

A-frame #3 was tested similar to #1, but load/unload curves were performed at 3.0-kN, 4.0-kN, 5.0-kN, and 6.0-kN. A final unload was performed at 8.5-kN. Load versus displacement data for this specimen appear in Figure 8, and the tested specimen is shown in Figure 9. A-frame #4 was tested identical to #3 but with one additional load/unload curve at 1.5-kN. Load versus displacement data for this specimen appears in Figure 10, and the tested specimen is shown in Figure 11. Figure 12 contains a compilation of all four A-frame specimens' load versus displacement data. Abscissa and ordinate axes were scaled so that a one-to-one visual comparison could be made.

CONCLUSIONS AND RECOMMENDATIONS:

No specimen experienced catastrophic fracture during the tests, but results from A-frame #2 demonstrate the instability that occurs at high loads. Results from specimens #1, #3, and #4 indicate that a small degree of permanent deformation occurs between 3.0-kN and 4.0-kN and increases significantly after 4.0-kN.

Materials Research and Engineering, Inc. recommends that cyclic tests be performed on the A-frame components to simulate the launch environment. The yielding of the component can be further investigated through these tests for a better understanding of how it will react to repetitive cyclic loads. Additional tests (tension, compression, bending, etc.) should be considered for the axes not investigated in this test program. Results from these types of mechanical tests can help reinforce and improve the theoretical models of the A-frame component.

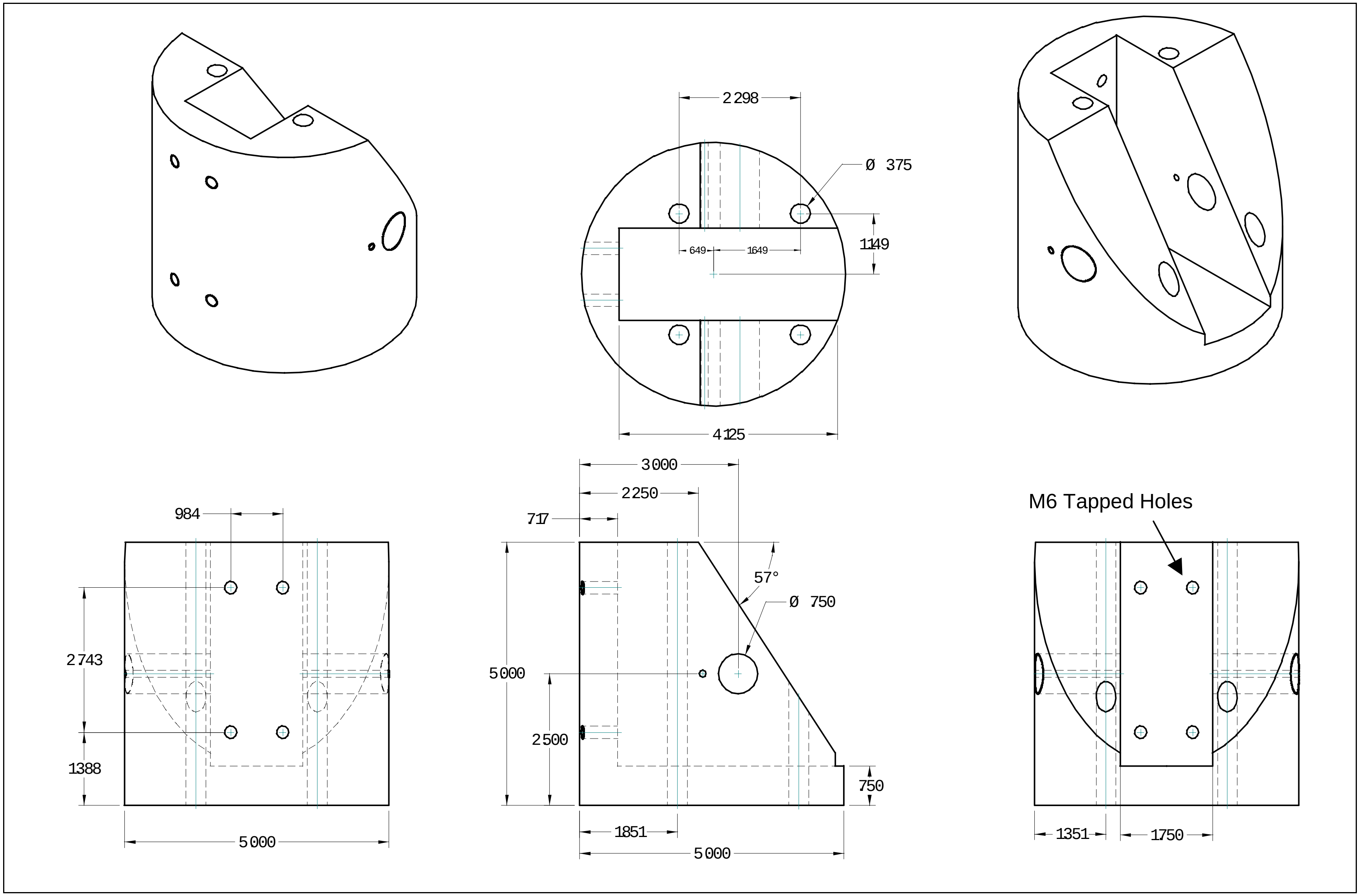

Figure 2. A-Frame Test Fixture (dimensions in inches unless otherwise noted).

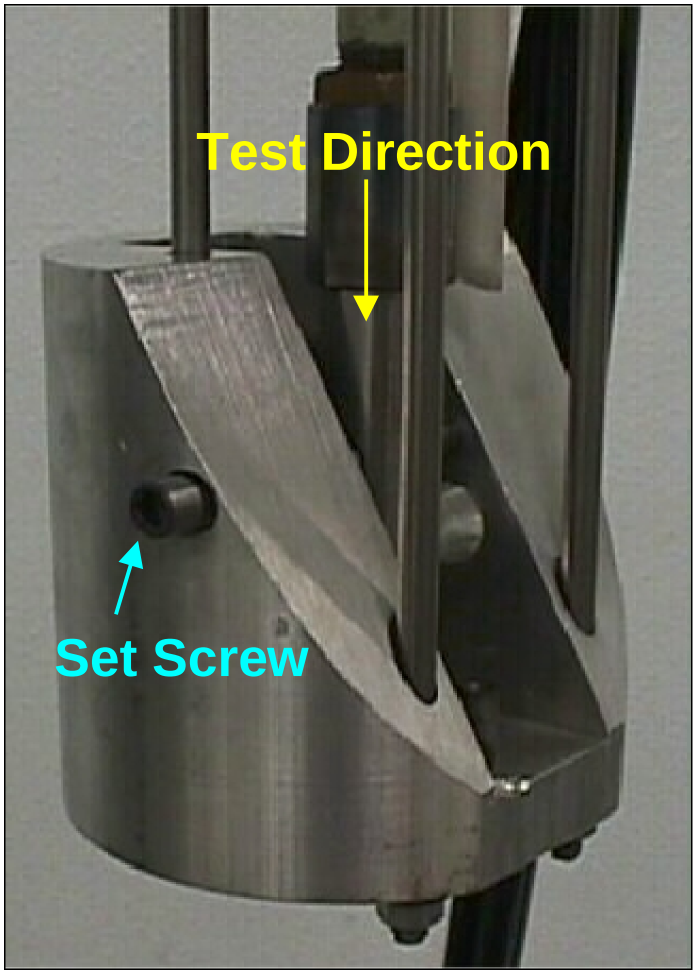

Figure 3. A-Frame Fixture Mounted on Test Frame.

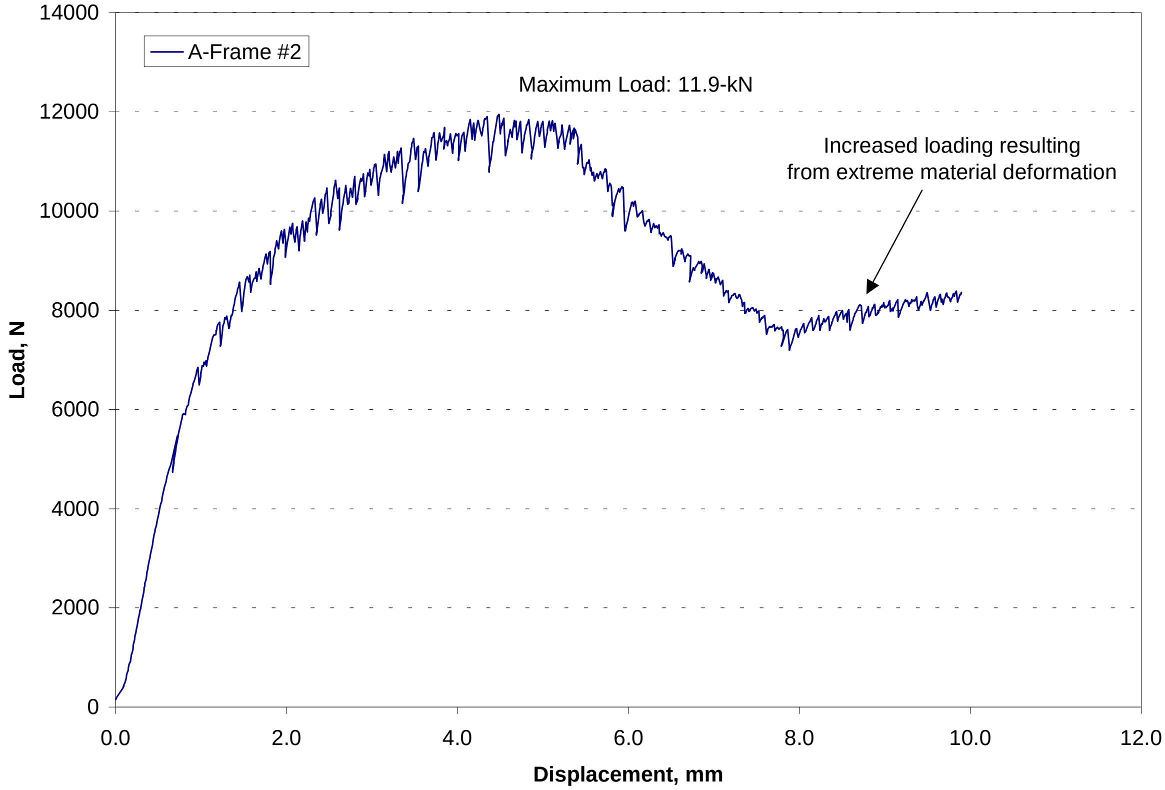

Figure 4. A-Frame #2 Load Versus Displacement.

Figure 5. A-Frame #2, Post-Test.

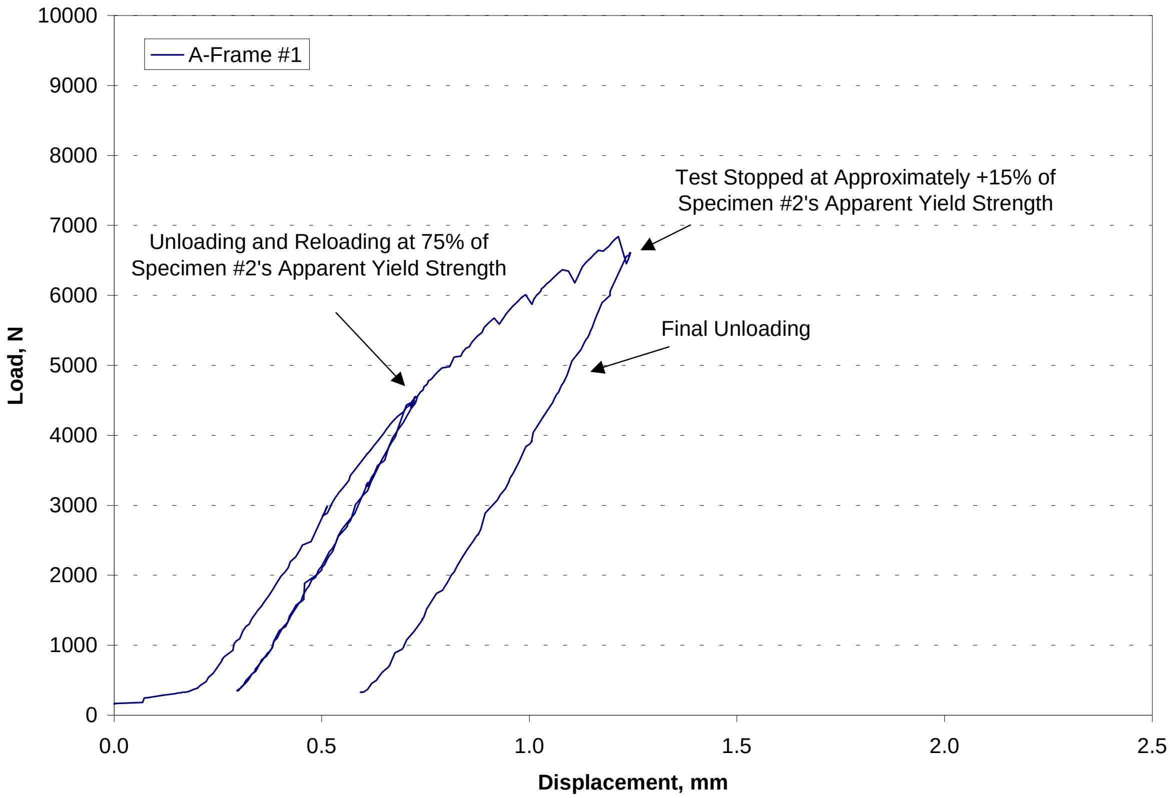

Figure 6. A-Frame #1 Load Versus Displacement.

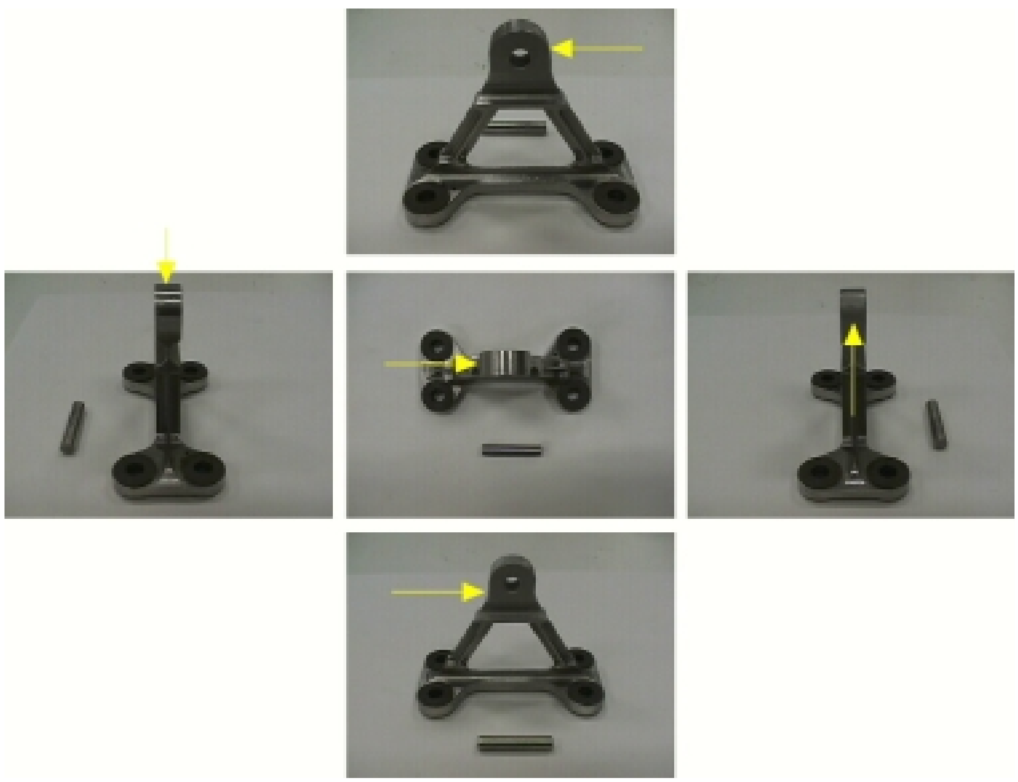

Figure 7. A-Frame #1; Post-Test.

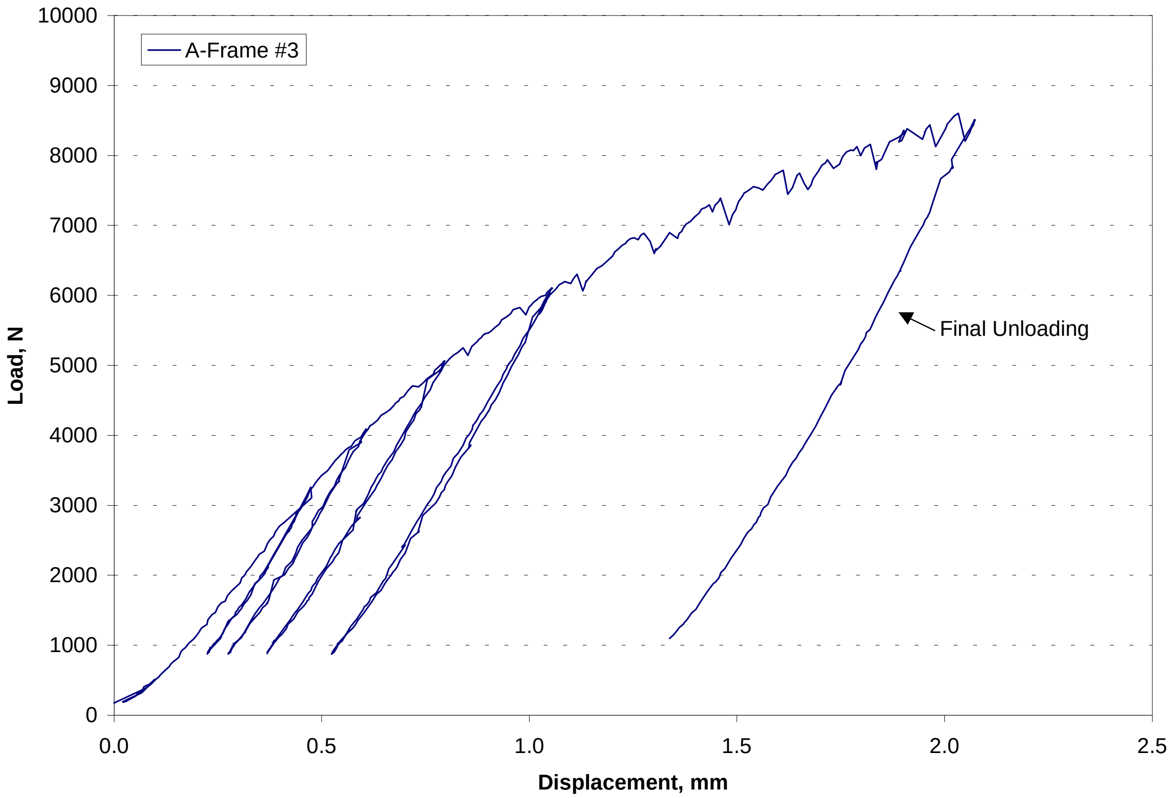

Figure 8. A-Frame #3 Load Versus Displacement.

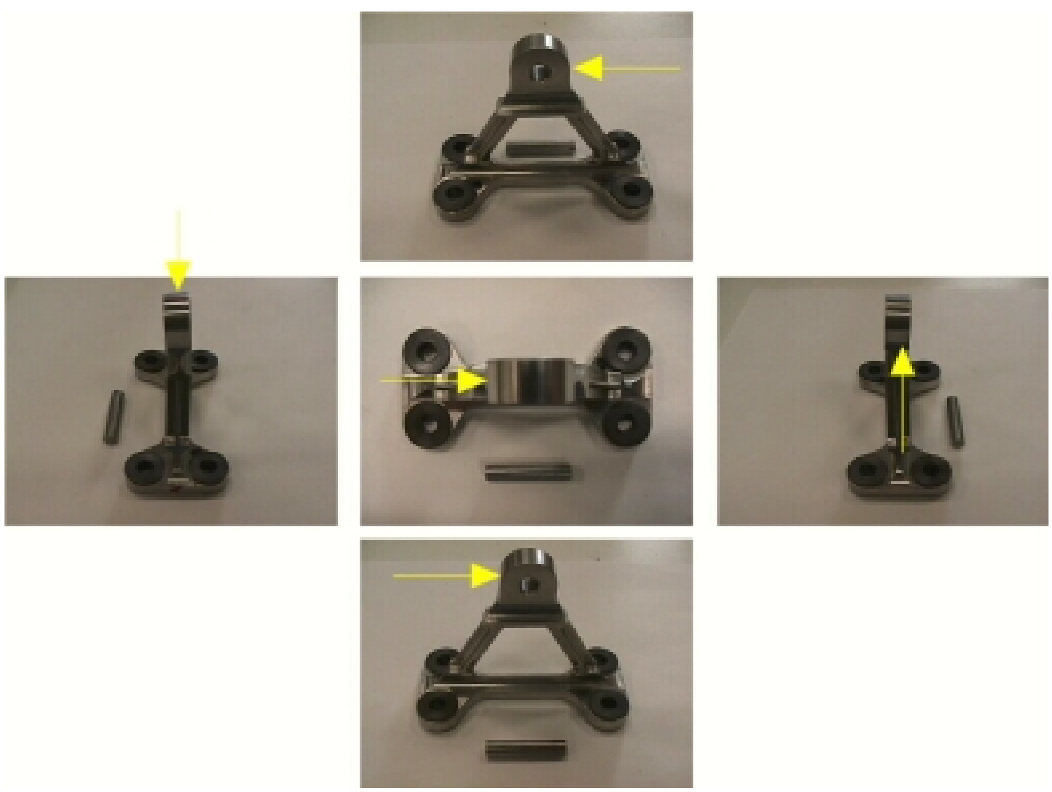

Figure 9. A-Frame #3; Post-Test.

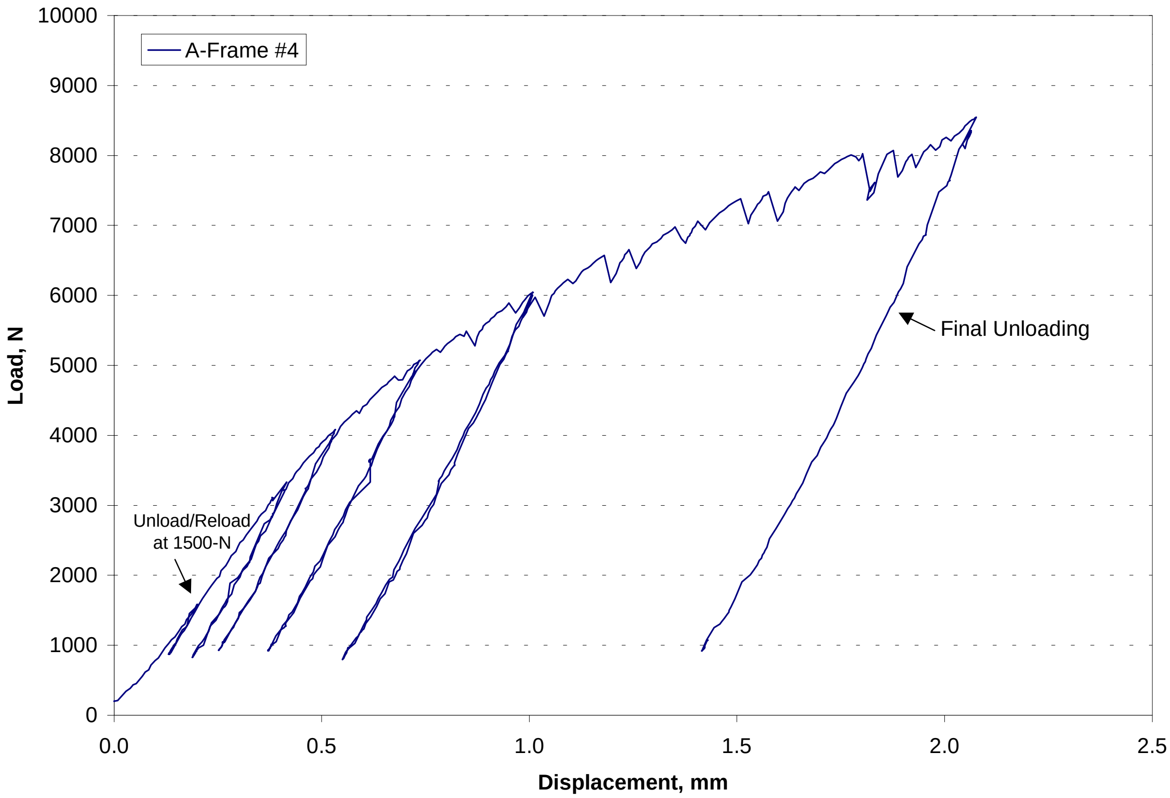

Figure 10. A-Frame #4 Load Versus Displacement.

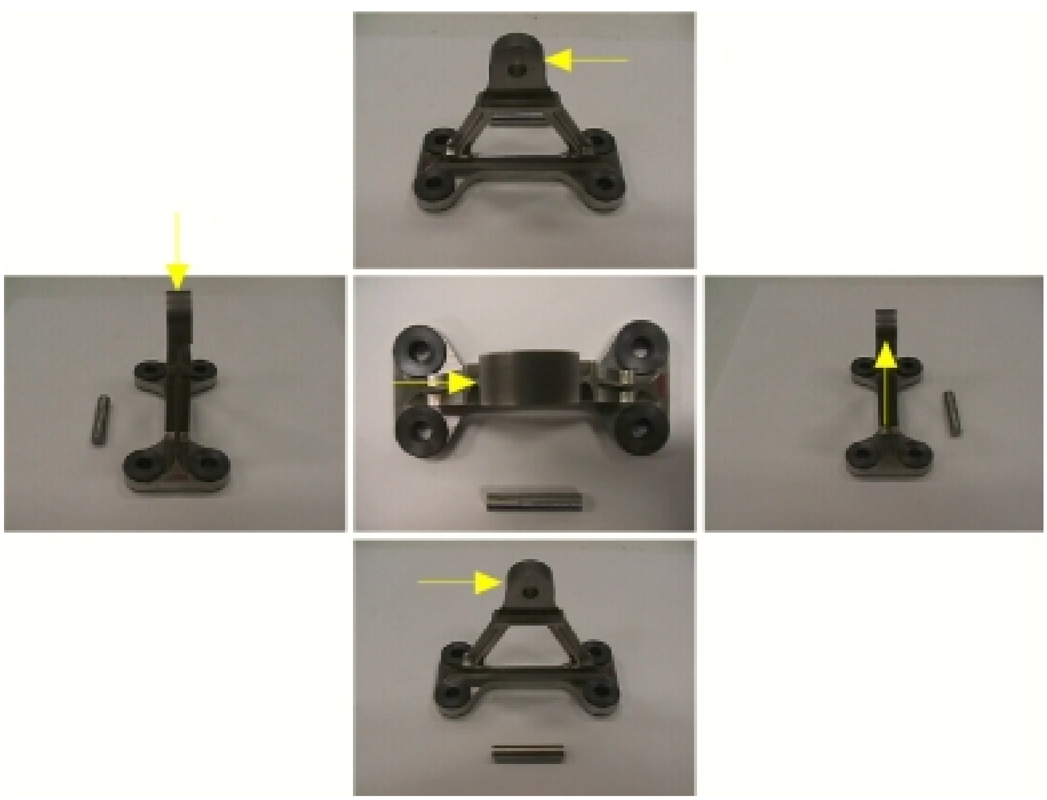

Figure 11. A-Frame #4; Post-Test.

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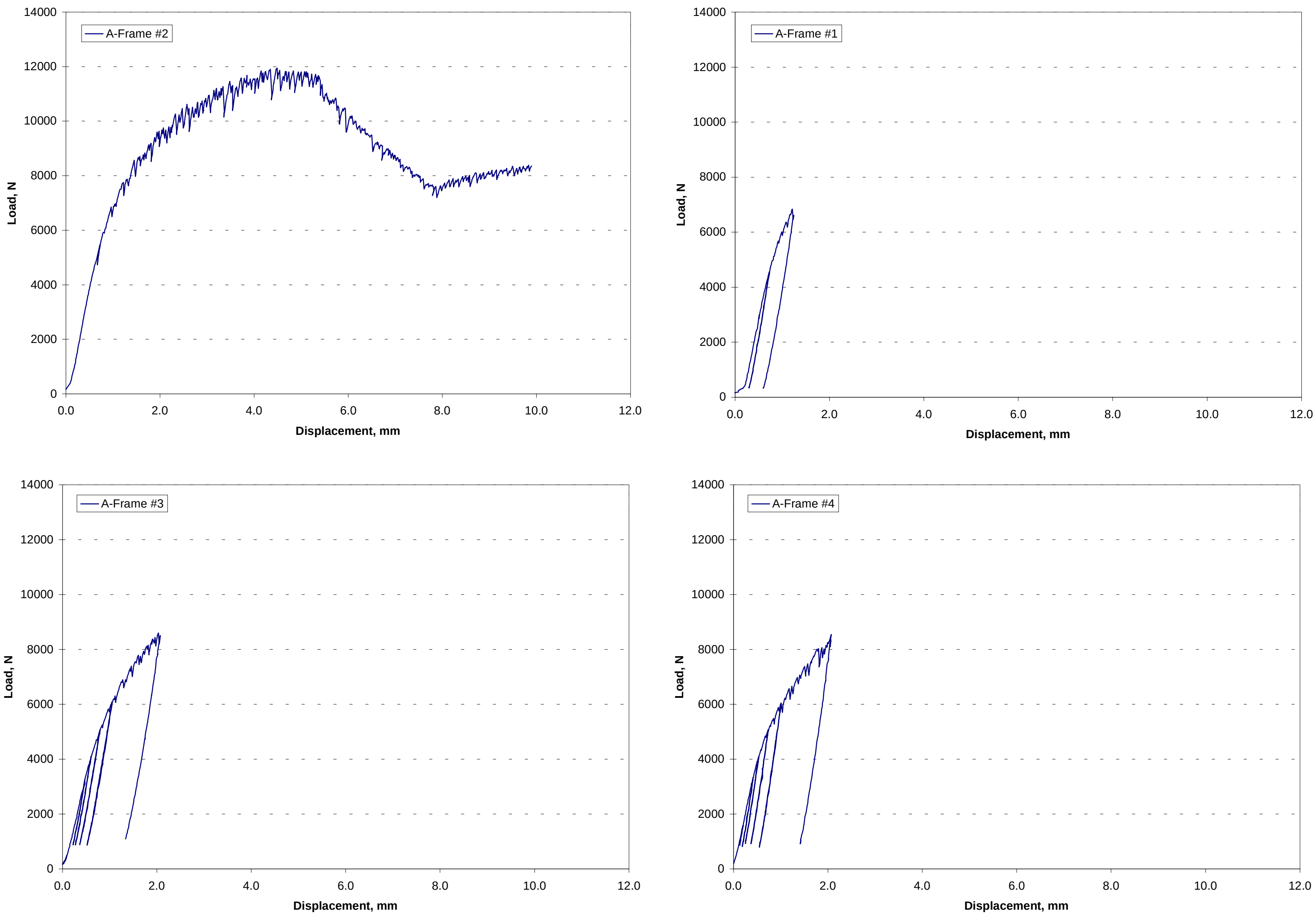

Figure 12. Compilation of All A-Frame Components