

Cryogenic Temperature Testing of NEA Fuse Wire Mechanism

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Abstract

NEA has over 10 years of continuous innovation in the field of space rated non-pyrotechnic release mechanisms. At the heart of our technology is the NEA patented Fuse Wire Assembly (FWA). NEA utilizes our patented FWA design across all our product lines to initiate the release operation of our restraint and release devices and our battery bypass switches. Most recently, as part of a deep space mission, cryogenic temperature testing was performed on our FWA down at 18° Kelvin (K). The testing discussed in this paper validates that the FWA, which is a critical component of the overall mechanism design, is robust enough to reliably operate in space at extremely low power levels and temperatures. In this paper, NEA will describe the cryogenic temperature tests along with test results. As the space community explores further into our solar system and beyond, this validation testing of our product enables new found confidence that existing technologies can be used for fielding deployable structure in deep space.

Introduction

All major space agencies and organizations are funding missions for spacecrafts to explore our solar system and beyond. As soon as a spacecraft leaves the earth orbiting environment, it experiences extreme cold temperatures with the background radiation of the universe. Today's missions require several staged deployments during multiple phases of their missions, such as entering orbit, decent, landing and deployment of instruments. For today's missions, the restraint and release device must be proven to operate in deep space cryogenic temperatures to ensure mission success.

The NEA release mechanism is used to provide restraint and release functions for critical deployment operations on spacecraft such as solar arrays, antennas, radiators and payloads after launch. The FWA in the release mechanism is a critical element. Each release mechanism's FWA is single or redundantly initiated. Actuation time variation between multiple mechanisms FWA is less than 10 milliseconds when a nominal firing pulse is applied to all units simultaneously.

Basic Design

The patented NEA FWA design is simplistic in operation and design. Upon receiving a specified electrical pulse of 1.2 amps or greater, the fuse wire breaks starting the release sequence of the preloaded release rod. The shock induced by release of the tensile load is typically less than 300 G's. Each FWA is fully refurbished after each ground-based test actuation. The principle of operation is as follows:

- A fuse wire is wrapped between two electric terminals.
- A process controlled load is placed on the fuse wire.
- When current is applied via the spacecraft firing system, the fuse wire heats lowering its yield strength.
- The fuse wire yields once the applied load exceeds the strength of the fuse wire.
- Breaking of the fuse wire allows the release system to activate and allow deployment.

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The electrical characteristics for the fuse wire assembly are time and current dependant as shown in Figure 1.

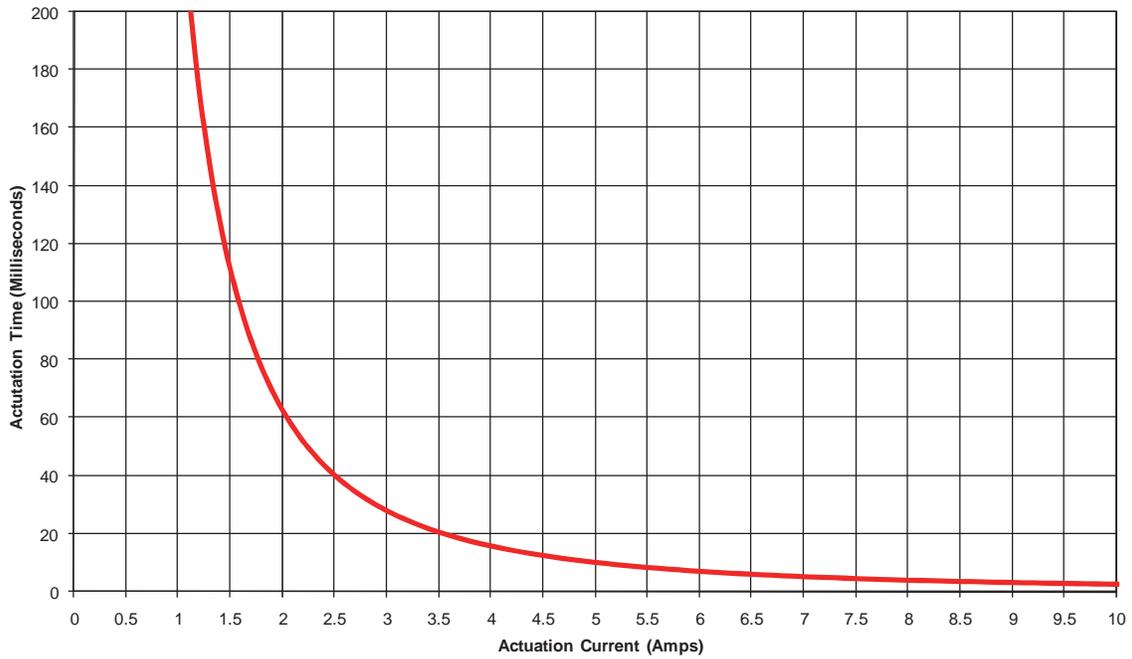


Figure 1: NEA Mechanism Actuation Curve

Extensive test data has shown that time for release is not significantly influenced by external operating temperature. See Figure 2 for data.

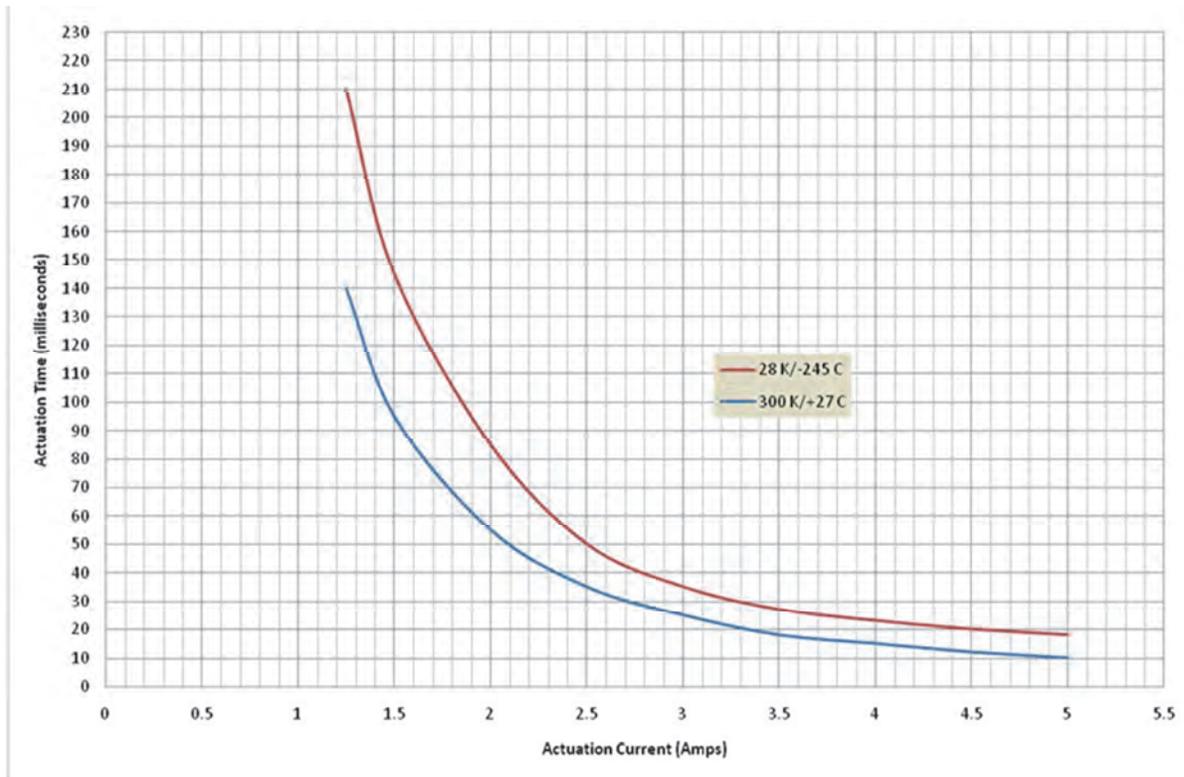


Figure 2: Fuse Wire Actuation Time vs. Temperature Curve

Cryogenic Temperature Testing

The intent of the Cryogenic Temperature testing was to verify if a typical NEA release mechanism could withstand cryogenic temperatures and successfully actuate to release the preload at these temperatures. Two units were used for the Cryogenic Temperature Test. These two units were flight worthy NEA 9103 release mechanisms. A preload of 11,120 N (2,500 pounds) was applied as shown in Figure 4.

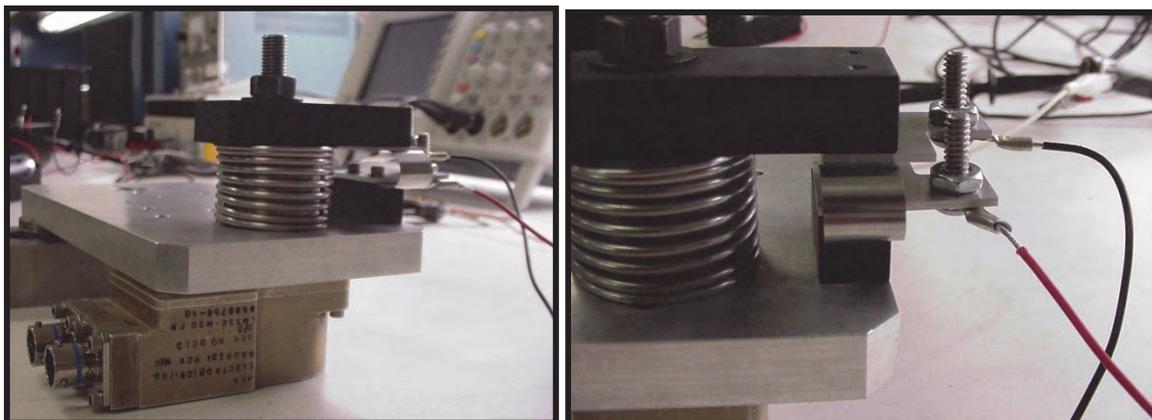


Figure 1: Cryogenic Temperature Benchtop Setup for the NEA Mechanisms

A voltage of 1.5 Vdc from a D-size battery was set across the switch plates. A 0.13-mm (0.005-in) thick stainless steel leaf spring was included as a temperature compensation element. When the mechanism was actuated, the ejection spring forced the insulator and corresponding switch plate away and caused

an open circuit. This verified successful release of the preload. The noise from the hardware hitting the bottom of the chamber also served as evidence of successful release of the preload.

The fuse wire resistances were taken at lab ambient temperature.

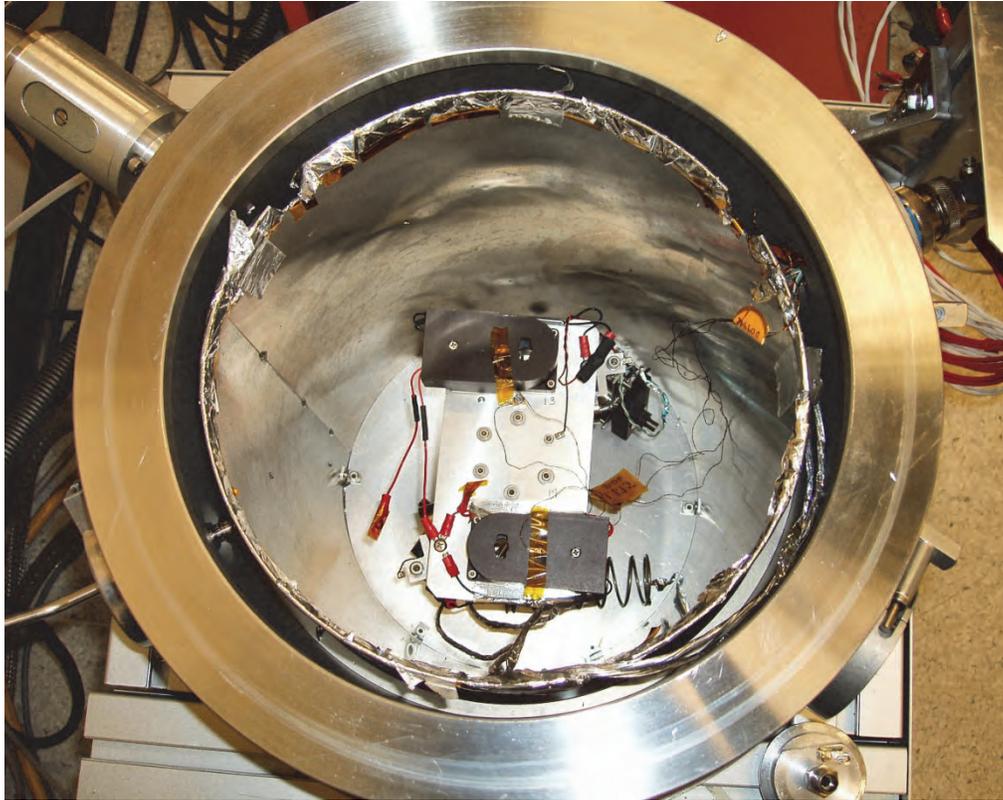


Figure 2: Cryogenic Temperature Test Setup for the NEA Mechanisms

Due to a limited number of chamber output leads, only the redundant circuit was actuated. The redundant circuits were wired so that each shared a common ground. The primary circuits were grounded to the plate so as to assist in reaching the temperature. Thermal diodes were taped to the cover of each unit. Once the test fixture was fastened to the mounting head of the cryogenic chamber, the resistances were measured again at lab ambient temperature.

The chamber as shown in Figure 5 was set to vacuum conditions and the temperature was decreased using liquid helium as the cooling media. The chamber achieved temperature stabilization at the targeted temperature of 10K after approximately 20 hours. After temperature stabilization was met, the unit temperature for both mechanisms was approximately 17K. The temperature of the mounting plate was 10.2K. Fuse wire circuit resistances were taken once again.

The continuity was checked for each of the switch plate circuits. The switch plate circuit for the first mechanism displayed continuity. The switch plate circuit for the second mechanism reads open. It was determined that the second unit would be actuated first, due to the fact that the switch plate circuit was open. Once the second unit was actuated, the switch plate circuit was re-connected. The switch plate pulse dropped from approximately 0.5 V to zero, indicating successful separation. The release rod and associated hardware could be heard hitting the bottom of the chamber. The unit successfully released the preload. The temperature of the unit dropped immediately after actuation.

The first unit was then actuated following the same procedure. Once the unit was actuated, the switch plate circuit voltage dropped from approximately 0.5 V to zero, once again indicating successful separation. The release rod and associated hardware could be heard hitting the bottom of the chamber. The unit successfully released. The pulse for the trigger circuit was shown re-connecting. This was an anomaly in the test setup. The captured scope plots of the actuation events are shown in Figure 6 and Figure 7.

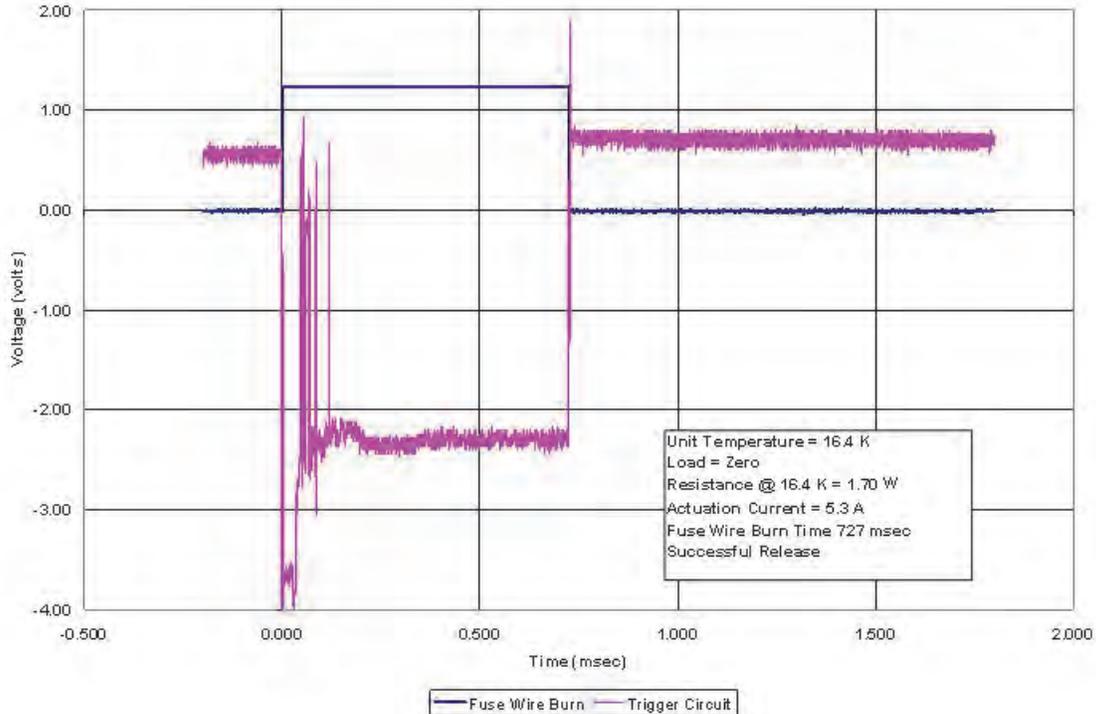


Figure 3: Actuation Plot for the First Release Mechanism

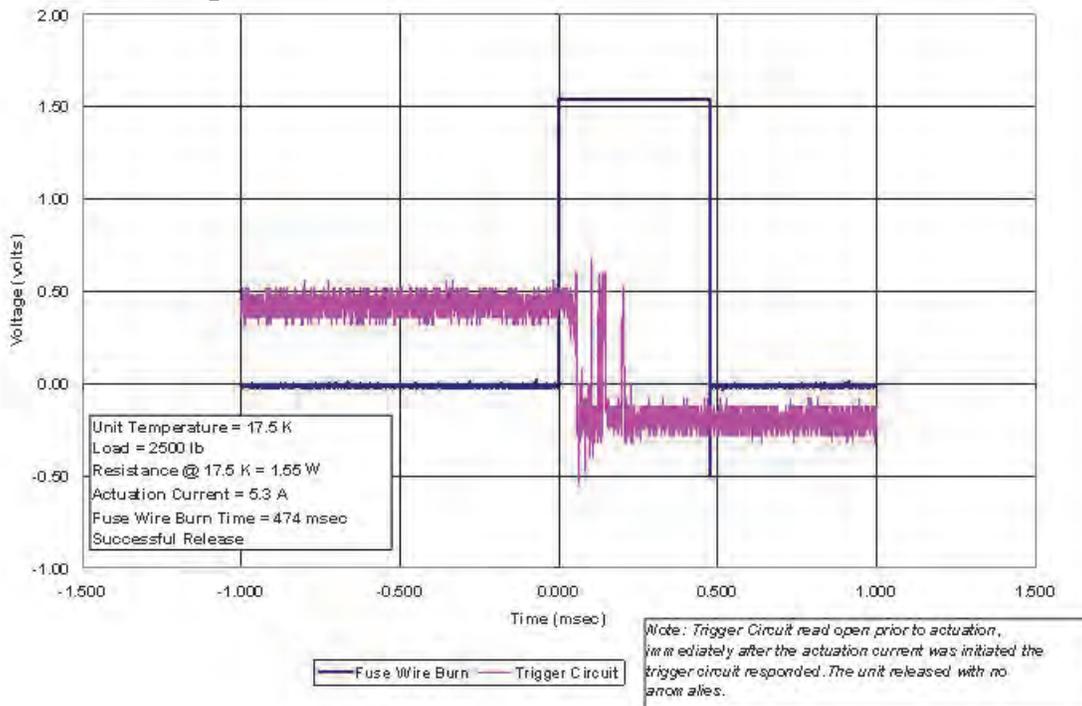


Figure 4: Actuation Plot for the Second Release Mechanism

Conclusions

Cryogenic testing has shown that the NEA FWA and mechanism reliably actuate at cryogenic temperatures. The fuse wire circuit resistance for each of the devices decreased by no greater than 0.3 ohms from lab ambient conditions compared to cryogenic vacuum conditions. The mechanisms successfully released at approximately 16K in both loaded (2,500 lb) and the unloaded conditions. Post test inspections revealed no physical degradation due to actuation. In particular, the restraining wire remained intact which would lead to a typical dissipation of strain energy and therefore a low shock output.