Armando: The Final Subcritical Experiment in the Stallion Series

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Introduction

Armando was the final subcritical experiment (SCE) in the Stallion series. The Stallion series of experiments (Vito/Etna, Mario, Rocco, and Armando) were designed to evaluate high-explosive (HE) driven properties of cast and wrought plutonium; the cast and wrought materials being representative of the materials produced via the different manufacturing processes employed at Rocky Flats and LANL. Specific properties investigated were ejecta production, spall features, and surface temperatures. Ejecta is defined as the small particulate matter "ejected" from the surface of a solid when a strong shock wave interacts with the surface. Spall is a general term for bulk material failure near the surface of a solid created by a strong shock interacting with the surface. Both of these phenomena depend upon the material properties: material strength, grain size, impurities, etc., as well as the strength and temporal profile of the shock pressure. The surface temperature is an important constraint upon the final state of the shock-driven metal that will be important in a full understanding of the behavior of the material.

Vito/Etna was a joint experiment conducted with the Aldermaston Weapons Establishment (AWE) located in the United Kingdom that concentrated on ejecta. Rocco and Mario were separate cast and wrought experiments that examined the phenomena of interest with a suite of point diagnostics. These diagnostics provided either specific time arrival information at a single spatial point or a continuous time record of some material property at a single spatial point. Armando was designed to complement and extend the measurements of Rocco and Mario by combining the two experiments into a single package and radiographing the behavior at two separate times along equivalent lines of sight. The paraphrased paradigm is: a picture is worth a thousand pins.

Diagnostics and Package Composition

HE diagnostics equivalent to those used on Rocco and Mario were implemented to verify identical HE performance. These consisted of a series of shorting switches combined with a microwave interferometer strip laid out symmetrically on the HE package to measure detonation times and velocities. Point VISARs (Velocity Interferometer System for Any Reflector) and optical pyrometers (that provide a measure of the surface temperature) were also implemented to verify equivalent behavior of the surface properties. The primary diagnostic for Armando was x-ray radiography along two equivalent axes separated by 60°. Physics packages identical to the Rocco and Mario packages were combined in a HEX package (6-sides or High-Energy X-ray) vertically separated with the free surfaces facing one another.

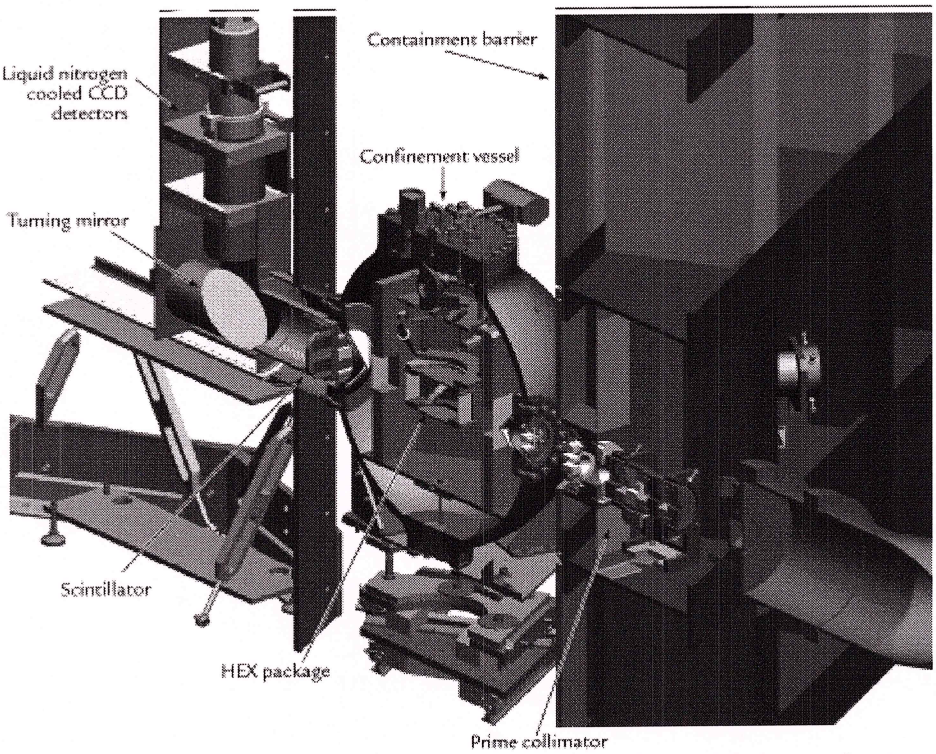
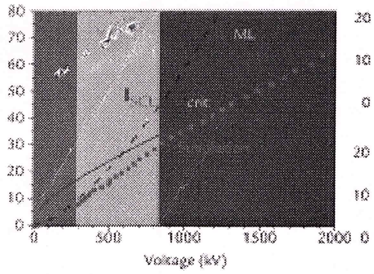


Figure 1. Experimental layout of Armando radiographic system. Starting from the left: the vertical CCD camera, turning mirror, the x-ray to light converting scintillator, the confinement vessel housing the HEX package, the containment barrier, prime collimator, and the cygnus x-ray sources (partially shown).

This geometry allows for exactly equivalent radiographs to be taken of the two materials at the same time in their evolution. The third axis of the HEX package is used for VISAR/pyrometry access.

The experimental package is contained within a 3 ft diam (inside diameter) containment vessel. This vessel and the camera box that houses the scintillator and camera system are placed within a "zero room" created by a large bulkhead completely sealing off the end of the U1a.05 drift. Thin radiographic windows in the bulkhead and vessel allow the x-rays to pass through the package and the containment vessel with minimal attenuation. Originally designed so as to expend the zero room, fielding the experiment within a containment vessel allows for the reuse of the zero room for multiple experiments and provides multiple redundant containment (Figure 1).

The Cygnus sources extend down the drift externally to the zero room. They are composed of a Marx bank system contained in large oil-filled tanks that pulse-charge adjacent pulse-forming lines (PFL). The output of the PFL is a short pulse (~ 60 ns), large-amplitude (~ 1 MV) electrical pulse that propagates down an 8 in. diam, water-filled, coaxial transmission line. This electrical pulse is coupled into the inductive voltage adder (IVA) cells that add the voltage in parallel to produce a 2.25 MV, low-impedance drive pulse for the rod-pinch diode. This last stage of voltage addition is accomplished in a high-vacuum suitable for diode operation. The expertise of Sandia National Laboratories (SNL) and Titan/Pulse Sciences Division (PSD) were instrumental in applying the technology developed at SNL to realize a robust and flexible pulse-powered driver capable of operating reliably underground.



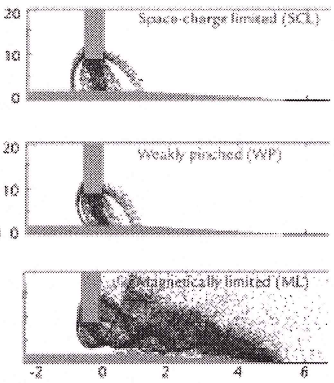
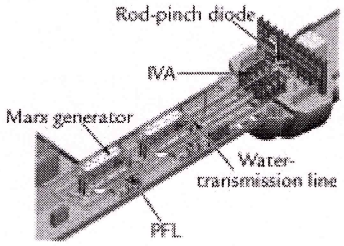


Figure 4. For sufficiently high voltage, a low-impedance current source will enable the diode to operate in the ML flow regime. The electron trajectories are strongly modified by the self-magnet field and propagate to the end of the anode producing an intense, small spot of x-rays. Dimensions are in millimeters. Figure courtesy of NRL.

Figure 2. Layout of Cygnus x-ray sources in U1a.05 drift. Confinement vessel and camera box are not shown in this view.



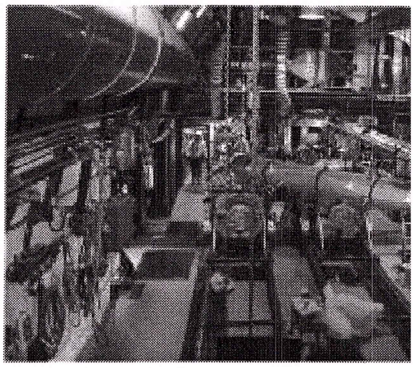


Figure 3. A view of the U1a.05 drift. The "z… bulkhead is seen with the two IVA structures … water-filled coaxial transmission lines in the f…

Radiography and Detector Systems

The radiography employed on Armando represents a significant advance in the performance of medium-energy radiography. It has been the result of a multiyear, multi-Laboratory effort involving LANL, SNL, Bechtel Nevada (BN), the Naval Research Laboratory (NRL), AWE, Titan/PSD, and Mission Research Corporation (MRC). Many innovations have been combined to lead to this advance in performance, but perhaps the most important has been the effective realization of the rod-pinch diode originally developed at NRL. The rod pinch has a similar geometry to standard x-ray diodes in use in industrial flash x-ray sources for several decades. However, researchers at NRL realized that when operated at low impedance (Z), the diode would transition from classic space charge limited (SCL) flow into magnetically limited (ML) flow whereby the electrons would be transported to the end of the central anode rod and then "pinch" producing a very bright, small diameter x-ray source (Figure 4). The Cygnus x-ray source was designed to provide a low-impedance (high-current) source of voltage to effectively drive the diode into the ML regime. Measurements have demonstrated a 1 mm diam x-ray spot size producing 4 rad at 1 m in a reproducible manner.

The detector system is equally innovative. It combines technologies developed for Dual-Axis Radiographic Hydrodynamic Test (DARHT) and proton radiography to create a very high-resolution imaging system. It functions by converting the x-rays transmitted through the experimental package into visible light in a tiled LSO (lutetium oxyorthosilicate) scintillator. The light produced is transported by a low-f/# lens system to a LN_2-cooled charged-coupled-device (CCD) chip that captures and records the image. In order to preserve maximum image resolution, the combined CCD camera system is not gated; all time resolution therefore derives from the flash nature of the illuminating x-ray pulse. While providing optimum resolution, this technique introduces a risk to the experiment, in that the scintillator-camera combination must be maintained in a light tight configuration throughout the HE detonation and long enough thereafter (~ 90 s) for the information to be read out of the CCD camera system to a remote data logging computer.

Results

The results of Armando have provided valuable data for stockpile stewardship. The HE diagnostics demonstrated identical performance of the HE detonation in all four packages: Rocco, Mario, and Armando cast and wrought. The VISAR measurement demonstrated that the measured surface velocity was reproduced within error bars. The radiography provided detailed subsurface data on the spalled material with a resolution and precision previously unobtainable. Radiographic data was obtained at two times allowing comparison with the VISAR data. The inferred velocity was in excellent agreement, further enhancing confidence in the accuracy of the results.

Acknowledgment

A great many people in many divisions (Physics, Dynamic Experimentation, Engineering Sciences and Applications, Material Science and Technology, Applied Physics, Nuclear Materials Technology, Health, Safety, and Radiation Protection, and Earth and Environmental Sciences) at LANL worked in a very productive partnership with SNL, Titan PSD, NRL, MRC, and BN to develop the technology and execute the Armando SCE. It is not possible to call out every individual in this format, but their efforts and dedication to this project are deeply appreciated.

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