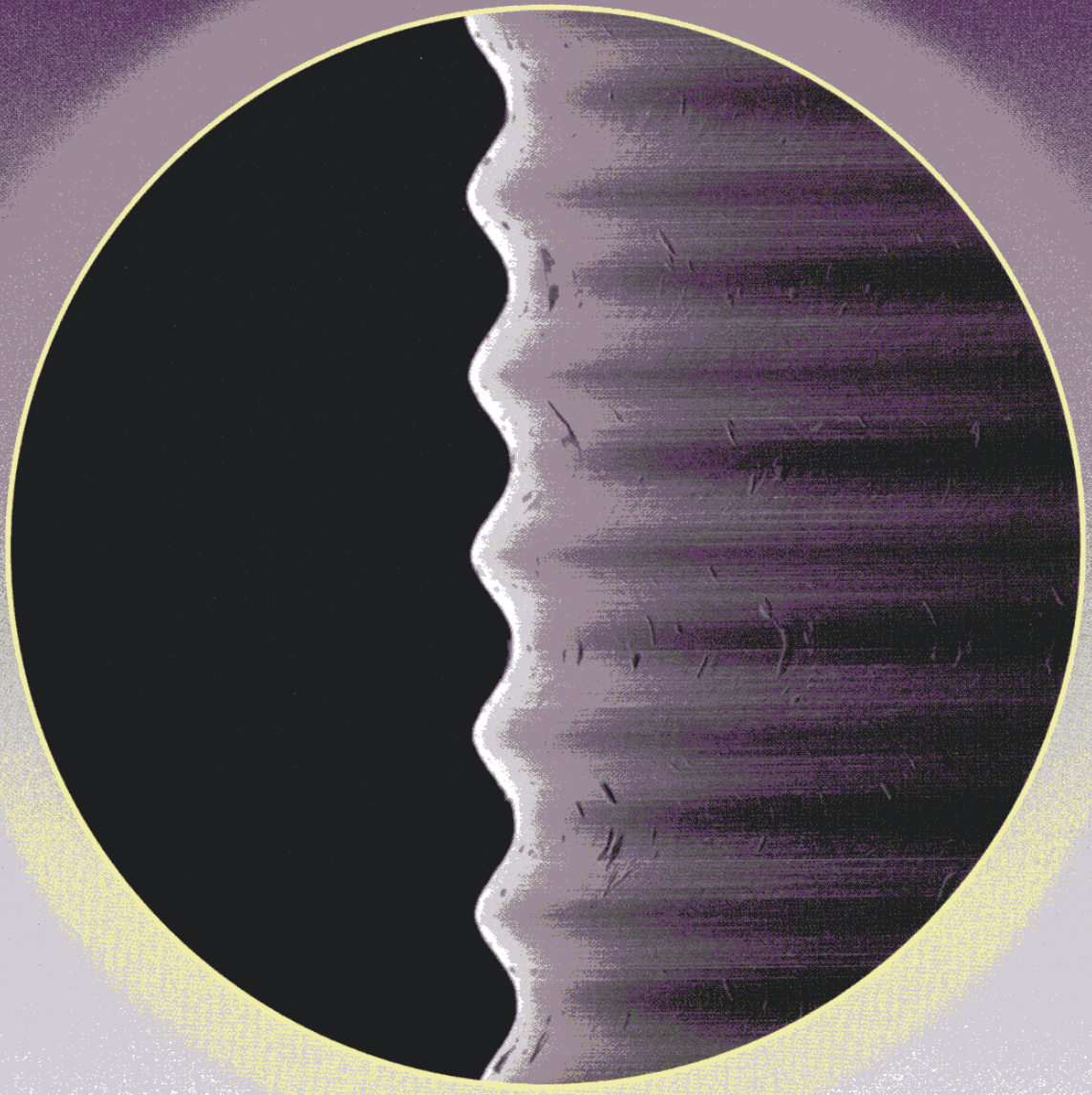
nuclear weapons journal



Winter 2004

- Validation Experiments
- Atlas
- Shock-Driven Instability
- Ion Beam Analysis
- Monitoring HE Aging
- Teflon Impact Response

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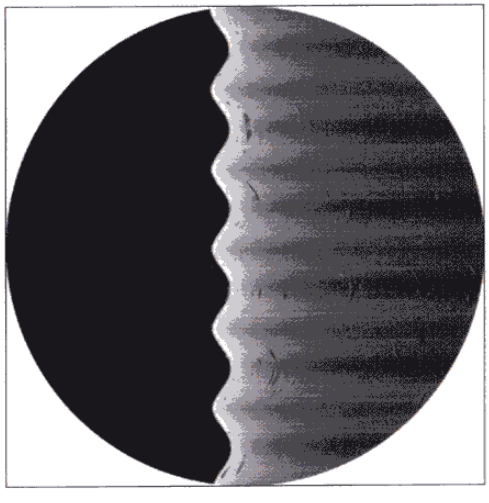

About the cover: Scanning electron micrograph (SEM) of the unstable interface in a Richtmyer-Meshkov hydrodynamic experiment performed using the OMEGA laser, showing a portion of the cylindrical target before the experiment. The laser strikes a layer of epoxy left of the figure and drives a strong shock into the cylinder, causing an implosion and initiating instability at this interface.The sinusoidal perturbations, machined into a thin aluminum layer, have a wavelength of 9 μm and peak-to-peak amplitude of 2 μm. *SEM courtesy of Norm Elliott, MST-7.*

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Correction: The "Backward Glance" in the September/October 2003 issue stated that George Gamov remained a Russian citizen after he fled the Soviet Union in 1933. In fact, he and his wife Rho (Luybov Vokhminzeva) became naturalized American citizens as soon as possible. They were proud of their American citizenship and traveled widely with their American passports. Only under Soviet law and in that territory did they remain Russian citizens. (We thank George's son, Igor, and his wife Elfriede for this information.)

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NNSA
National Nuclear Security Administration

Monitoring High Explosives Aging—Partnering with Pantex

Stewardship of the nation's nuclear stockpile presents unique challenges as weapons age beyond their originally intended lifetimes. These challenges include identifying and monitoring age-related changes in weapon components and determining which aging phenomena will eventually affect safety, reliability, or performance.

surveillance **provides information** on **how HE ages** that is **critical** to accurately **predicting aging** phenomena **inside nuclear weapons**

Surveillance activities, as executed under the Enhanced Surveillance Campaign (ESC) and Directed Stockpile Work (DSW), support Life Extension Programs and the Annual Assessment by determining when components must be replaced. High explosive (HE) surveillance under DSW is responsible for measuring properties of HE obtained from weapon systems removed from the stockpile explicitly for such purposes. The BWXT Pantex Plant near Amarillo, Texas, conducts surveillance on maincharge and booster HE according to LANL requirements. The HE in detonators and actuators is packaged and shipped to LANL, where surveillance on those components is carried out. This article focuses on HE surveillance activities at Pantex.

All the HE core surveillance tests described in this article take place at the BWXT Pantex Plant under LANL guidance and are the responsibility of the Directed Stockpile Work-Stockpile Evaluation Program.

LANL scientists and engineers first develop the test procedures, which are then implemented at Pantex. LANL scientists, engineers, modelers, and designers use the test results to assess the current health of the US nuclear weapons stockpile.

The test protocol for HE surveillance at Pantex includes nondestructive and destructive techniques. Several HE properties must be measured to ensure that all possible signs of aging are monitored. Design requirements call for charge shape, density, and composition to remain within specified limits. Additionally, HE must maintain structural integrity and mechanical strength.

Every main charge assembly is visually inspected as it is removed from the warhead. Technicians look for cracks, scratches, chips, discoloration, and any other irregularity. Handling during assembly and

disassembly may cause some defects, while others are attributed to aging. All anomalies are photographed and recorded. Because conventional HE return charges (PBX 9501) are not reaccepted after surveillance, gross surface defects are detected with the aid of a blue dye solution. Insensitive HE charges (PBX 9502), however, can be reinspected and reused, so visual inspection is done without dye. Complete dye removal is difficult, and reaccepted charges cannot contain even traces of dye.

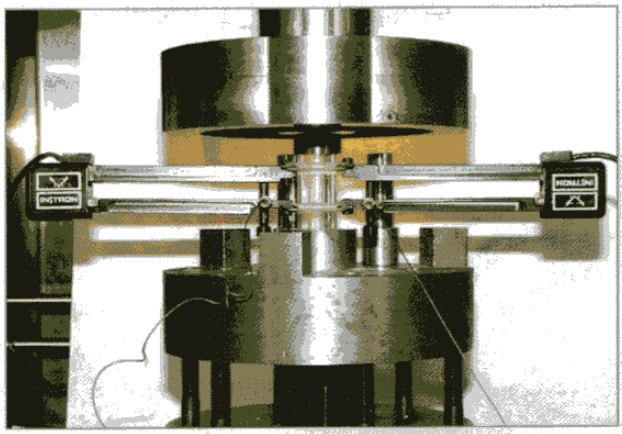
Survelliance identifies and examines signs of aging in components removed from weapons during disassembly at the Pantex Plant.

After each charge is visually inspected, its density is hydrostatically measured. The density is calculated by measuring forces present during "wet" and "dry" weighing. The dry weight is recorded first. Then a charge is placed in a wire basket and submerged in a water bath containing a small amount of wetting agent. Once the charge is submerged, the wet weight is measured. Booster densities are similarly measured using a smaller basket and water bath. Since densities are typically reported to ±1 mg/cm^3, a system capable of distinguishing density variations of ±0.1 mg/cm^3 is desired. To achieve this level of accuracy, several sources of systematic and random error must be minimized. This is done by thoughtful design of the measuring system to eliminate the influence of factors such as waves and water surface tension, by frequent calibration checks using a density master, and by operator diligence. Measured densities are compared to original values and accepted tolerances.

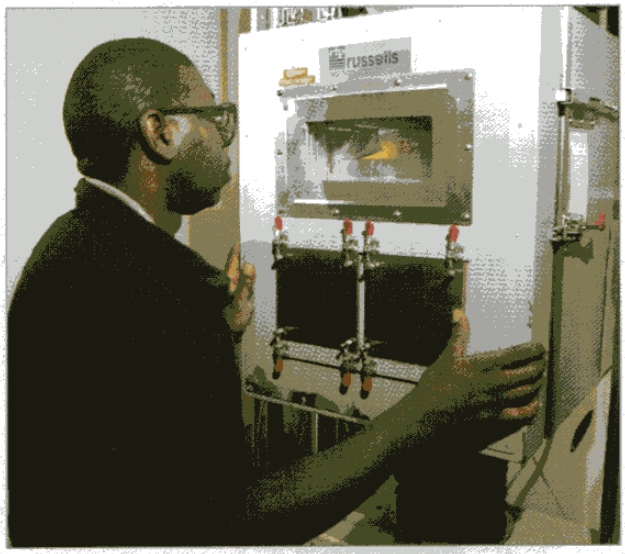
All charges are then gauged using a Coordinate Measurement Machine (CMM). Gauging is performed to examine whether forces applied during weapon assembly cause the HE to change shape over time. The CMM measures surface deviation from an ideal charge shape at a series of points covering the entire charge. Both inner and outer surfaces are gauged. Charges are machined to extremely tight tolerances, and the CMM can detect deviations of less than the thickness of a sheet of paper.

After gauging is completed, the forward and aft charges from two warheads are wet-machined to obtain specimens for additional testing. Common practice in HE machining is for water to continuously flow over the explosive and tooling to protect the safety of personnel and facilities. Mechanical test specimens must be thoroughly dried to eliminate the influence of absorbed water on mechanical strength. Quasi-static tensile and compression tests are run at low and high temperatures to evaluate mechanical properties near the stockpile-to-target-sequence temperature extremes. Ultimate stress, percent strain at ultimate stress, and elastic modulus are recorded. Mechanical properties vary from one HE lot to another and must be considered when examining data for aging trends.

An HE machinist gauges a tensile specimen to check for tolerance.



A cylindrical specimen machined from a main charge high explosive is ready for quasi-static compression testing.



A mechanical testing technician closes an environmental chamber door and sets temperature before initiating a quasi-static tension or compression test.

High-explosive "dog bone" specimens after quasi-static tension testing.

Specimens for chemical composition and binder molecular weight determinations are machined from several different locations within each charge to check for variations throughout the HE. Many factors such as trapped water, radiation, and chemical compatibility can degrade the constituents in HE formulations over time. The high explosive (HMX, TATB, or RDX) composition is measured gravimetrically. Binder, plasticizer, and stabilizer compositions are determined using high-performance liquid chromatography. Binder molecular weight is determined using size exclusion chromatography/gel permeation chromatography equipped with a refractive index detector. Booster compositions and binder molecular weights are also measured. Changes in composition can alter the performance of the HE, while molecular weight changes can also influence the safety and mechanical strength.

In addition to chemical and mechanical analysis, three small-scale tests are implemented to detect changes in thermal stability (two tests) and impact sensitivity (one test).

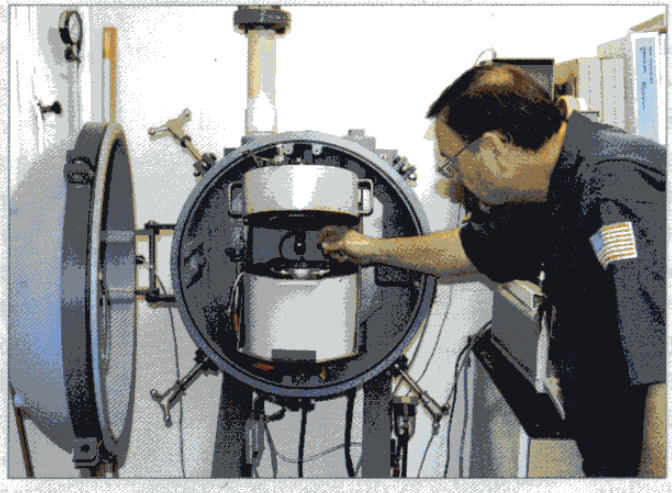
To measure thermal stability, isothermal accelerated rate calorimetry is a measure of HE bulk thermal property, and differential scanning calorimetry (DSC) characterizes the HE and binder behavior. Operated in the modulated mode, DSC separates changes in heat capacity such as melting and glass transitions from kinetic transitions such as phase changes, decomposition, and binder endothermic relaxations. Both of these tests are used to identify if and when aged HE becomes less thermally stable.

Sensitivity changes can have consequences in the storage, transportation, handling, and deployment of weapons. Historically, surveillance chose not to measure HE sensitivity. The primary reason has been that HE sensitivity, as a measured property, is not well defined. Sudden decomposition can result from many different stimuli, and uncontrolled factors often challenge test reproducibility. During development, significant time, resources, and expense were devoted to characterizing the sensitivity of HE used in nuclear weapons. Experts felt that as long as the chemical and physical properties

A chemical technician measures binder molecular weight using size exclusion chromatography/gel permeation chromatography.

did not change with time, sensitivity also remained unchanged. Although this assumption has held, the operational environment under which weapons research is now conducted has changed significantly over the years. In response, surveillance has implemented a small-scale sensitivity test.

The drop-weight impact test examines changes in sensitivity due to mechanical impact. Many tests are employed in an attempt to characterize HE response to mechanical forces such as crushing, pinching, and scraping. All have advantages and drawbacks. In the test, a small amount of HE is placed on a steel anvil, and a steel striker is dropped onto the HE. A microphone determines whether the HE reacted when the striker made contact. Subsequent drops are repeated, each time with a new HE sample and with the striker hoisted to a different height depending on the previous test result. Statistical analysis determines a 50% height, which is a height at which half of the samples would react if drops were repeated at that height. This drop-weight test establishes a good beginning on testing HE sensitivity.



A chemical technician loads the accelerated rate calorimetry chamber.

Through strong collaboration with HE Enhanced Surveillance, DSW core surveillance activities are continuously being revised to establish a comprehensive program. New diagnostics are under development to detect aging effects as early and as accurately as possible. For example, efforts in ESC focus on developing additional sensitivity tests, especially those pertaining to safety and assessing changes with age. Surveillance provides LANL scientists, engineers, modelers, and designers with information on how HE ages inside weapons that is critical to accurately predicting HE aging phenomena and their impact on nuclear weapon performance.

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All photos courtesy of the BWXT Pantex Plant. The dedicated individuals at Pantex are committed to maintaining the health of the nation's nuclear weapons stockpile by providing quality measurements of the properties of high explosives.