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VENTED BOMB TESTS TO CHARACTERIZE PROPELLANT AND COMBUSTIBLE CASE EXTINGUISHMENT

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ABSTRACT

A study was conducted at Safety Consulting Engineers, Inc. to simulate ballistic cycle pressure reduction and its effect on propellant and unpredictable combustible cartridge case (CCC) residue development. A new vented bomb system was developed and designed to simulate a 120 mm propellant/combustible cartridge case ballistic environment to 80,000 psi pressure and associated ballistic times. Full-diameter burst discs were used to suddenly reduce pressure to atmospheric level.

Numerous tests were conducted monitoring chamber pressure time. Residuals, if any, were collected after extinguishments.

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The results of the low pressure testing showed the formation of CCC's residue were dependent on many factors such as localized region of increased density, region of lower nitrocellulose content or foreign material between the propellant and the combustible case.

1. INTRODUCTION[1]

Armed conflict can occur anywhere, any time, in any part of the world. When that happens, highly mobile armament systems must be immediately deployable. And when forces engage, firing crews and their weapons must perform reliably, even under the most adverse conditions. This includes ammunition which will be easier to transport, deploy, load and fire when it includes safe, dependable combustible ordnance products.

Today, combustible ordnance materials find many uses on the battlefield. They replace heavier metal cases in tank ammunition. They replace cloth propellant containers attached to mortar rounds, and they provide rigid propellant containers to replace cloth bags in artillery ammunition. The list is growing longer as experimental applications move from R&D to production.

These products are formed from wood fiber pulp which has been strengthened with resin binders and stabilizers, then heat-molded into rigid, dimensionally stable shapes. Nitrocellulose added to the composition contributes energy to the round's combustion cycle and causes the material to be totally consumed in the process.

Combustible ordnance products yield many important advantages regardless of application:

- Manufacturing facilities require less investment
- Material costs are lower
- Strategic metals are conserved
- Shipping and handling costs are lower
- Lighter weight improves field mobility
- Firing crew fatigue is reduced during rapid load-and-fire sequences
- Strategic scrap materials are denied to enemy scavengers
- Combustion residue is eliminated, even under sustained fire

The positive contributions made by combustible ordnance products to combat effectiveness are leading to accelerated development of this technology for sea and air armament systems.

2. EXPERIMENTAL

Safety Consulting Engineers, Inc., in cooperation with Armtec Defense Products Company, conducted low-pressure testing of the combustible cartridge case material in an attempt to identify factors which could have contributed to the formation of the residue in a gun firing environment. In this experiment, a vented bomb was chosen because the propellant and combustible casing burn could be interrupted by rapid release of the interior pressure. This will prevent consumption of the sample by the retention of the high pressure conditions in a normal closed bomb apparatus. Also, the resultant shape of the time/pressure trace of the vented-bomb could be made to approximate the shape of actual low-pressure firing tests.

2.1 VENTED BOMB TESTS

A series of vented bomb tests were conducted on the case materials to gain a qualitative understanding of how the case materials burn in a gun environment. In field use, the combustible case is normally ignited by the flame of the burning propellant which is contained within the combustible case. Design of the vented bomb utilized in this test is illustrated in Figure 1.

2.1.1 Material Description

Two types of combustible cartridge cases, post impregnated (PI) and beater additive (B/A) are available for the 120 mm tank gun system. Both case types are composed primarily of nitrocellulose fibre (NC), kraft wood fibre, and a resin binder, although the percentage of each ingredient varies according to the specific application. The primary difference between the case types is that the resin is mixed in with the other ingredients before molding in the beater additive case, while the post impregnated case is dipped in resin after molding[2]. The PI case has shell-like, high resin density regions near its outer surfaces and a very low resin density in its interior, while the B/A case has a much more uniform resin density, and is much more flexible.

The B/A combustible cases were used in this study.

2.1.2 Chamber Size

In an effort to closely replicate firing chamber conditions in the vented-bomb apparatus, a device with the same interior diameter as the 120 mm Smoothbore Cannon was constructed. The device chamber length was arbitrarily set at 3 inches.

The construction of the device in this manner allows the testing of a 3-inch ring of undisturbed 120 mm combustible cartridge case sidewall material. Because the gun chamber diameter was chosen as the device chamber diameter, the same air gap remains between the chamber wall and the outer surface of the combustible cartridge case material. Maintenance of identical gaps allows study of the effects, or amount, of exterior wall ignition during firing.

The known, existing vented-bomb device designs were reviewed prior to initiating the design of a new device. The existing devices are constructed with a very small chamber of approximately 2 inches in diameter.

When loading a vented-bomb chamber of 2-inch diameter with 120 mm CCC material, it is only possible to test a segment of the circumference of the casing material. Additionally, this material segment is normally modified by the cutting of longitudinal V-shaped grooves along the interior wall of the segment. The grooves allow the outer circumference of the segment to be reduced to fit the 2-inch diameter chamber.

Modification of the material sample as described above, alters the burning rate by exposing additional surface area to the propellant flame. It also alters the interior burning pattern of the sample because of the cut-out sections of material. Also, the separation between the surface of the sample and the chamber wall is eliminated, which alters or eliminates potential ignition of the sample on the outer surface.

2.1.3 Pressure Limitations

The vented-bomb was designed to have a maximum working pressure of 80,000 psi. This allows for a substantial safety margin since the tests were anticipated to be performed at below 30,000 psi.

2.1.4 Venting Method

A design which utilizes a full-diameter burst disc was chosen. Several iterations of burst-discs were tested with the final units being simple, flat steel discs that were machined to a specific thickness and hardened to provided repeatable burst pressures.

2.1.5 Ignition System

Ignition of the propellant in the vented-bomb was accomplished by using an electrically operated squib to ignite a small primer charge. The final residue tests utilized 5 gm of black powder (BP) as the igniter material. This BP was contained in the center region of the DIGLRP propellant bundle.

Experimentation with igniter materials was performed until the leading edge of the vented-bomb testing pressure/time curve approximated that seen in actual low-pressure gun firings.

2.1.6 Propellant Loading

Preliminary tests were performed with various propellant loading densities. Since the tests were intended to duplicate 120 mm High Energy Anti-Tank (HEAT) round firing conditions, only DIGLRP propellant was utilized.

The sticks of DIGLRP propellant were cut to approximately 3 inches in length and bundled into a cylindrical shape and placed in the center of the vented-bomb chamber.

After experimentation, the final residue generation tests were performed using 110 pieces of DIGLRP as the propellant charge.

2.1.7 Pressure Sensing

A single pressure transducer was used to record the internal pressure of the vented-bomb. This information was fed to a computer for development of the time/pressure traces.

2.2 TEST PROCEDURE

2.2.1 Sample Preparation

Beater additive (B/A) 120 mm CCC's were produced which had regions of increased density, regions of decreased NC content and increased coating thickness. Special production techniques were utilized to introduce the defects into the cases.

Once the cases were produced, rings of material of the proper length were cut from the case body sidewall to precisely fit the chamber of the vented-bomb test apparatus. The region of the case ring where the defects were introduced was identified on each of the samples.

The density variation of the samples ranged from 0.85 gm/cc to 1.2 gm/cc. The depleted NC regions ranged from 0% NC to 50% NC. The coating was varied from the normal 2 mils to 10 mils thickness.

After manufacture, these samples were sealed in plastic bags and transported to the test site for storage. They were stored under cover but not under controlled temperature and humidity conditions.

2.2.2 Procedure Details

Each test sequence consisted of firing the vented-bomb with a single sample of modified combustible cartridge case material. The material was fired using DIGLRP propellant which was ignited by a small igniter charge. During the test sequence the various combinations of igniter material and propellant were tested. These combinations were tested to develop a combination which would produce a pressure/time profile in the vented-bomb chamber which closely approximated that of an actual low-pressure gun firing.

In each firing, the material sample was placed in the vented-bomb chamber along with the propellant, igniter material, and electric squib. Refer to Photograph 1 for the arrangement of these materials in the vented-bomb chamber. As indicated in the photograph, the propellant was centered in the chamber to insure an even distribution of propellant flame to the inner surface of the combustible case sample. Also, the igniter material was placed in the center of the propellant bundle. After re-assembly of the vented-bomb, the ignition was started by the use of a remotely activated electrical squib.

Upon activation of the electrical squib, a computer system monitored and recorded the pressure in the chamber through the use of a fast transient response pressure transducer. This data was then stored on disk for a permanent record and also displayed on the computer monitor for evaluation at the site. Refer to Figure 2 for a typical pressure/time trace of a vented-bomb test firing.

After each test firing, the vented-bomb apparatus was disassembled, cleaned, and the spent venting disk was discarded. The Teflon O-Ring utilized for sealing the chamber was also replaced after each test firing.

At 18,000 ±2% psi venting pressure, the combustible case material, performing similar to the propellant, extinguished immediately upon being ejected from the vented-bomb chamber. This allowed recovery of material that was intact except for the material that was missing due to combustion during the firing sequence.

The unburned combustible cartridge case material was collected after each firing from the area around the vented-bomb. These pieces of post-firing residue material were photographed, and then sections of the material were encapsulated and cut with a diamond saw to produce an undisturbed cross section of the residue. Photographs and explanations are shown in this paper.

3.0 TEST RESULTS and CONCLUSIONS

Results of the low-pressure vented-bomb testing showed that the following factors have contributed to the development of the residue from B/A combustible cartridge case:

- Region of increased density
- Region of reduced NC content
- Presence of foreign material between the propellant and interior combustible case

These tests also indicated that the coating thickness would not have been a contributing factor.

The most likely causal factor indicated by the testing was the presence of a foreign material (such as masking tape or aluminized duct tape) which interrupted the flame between the propellant and the interior combustible case wall. Refer to Figure 3 showing the progression of material consumption during the firing sequence. The delay in flame propagation, which resulted in the residue, could also have been caused by an uneven ignition of the propellant.

REFERENCES

1. Excerpts from "This is Armtec" brochure,

2. Armtec Defense Products Co., "Combustible Ordnance in the United States," Sub Panel 2, Panel IV, NATO, November 1984.

3. The Society of the Plastics Industry, Inc., "Pressure Vessel

   Test", Suggested Relative Hazard Classification of Org. Peroxides by Org. Peroxide Producers Safety Division.

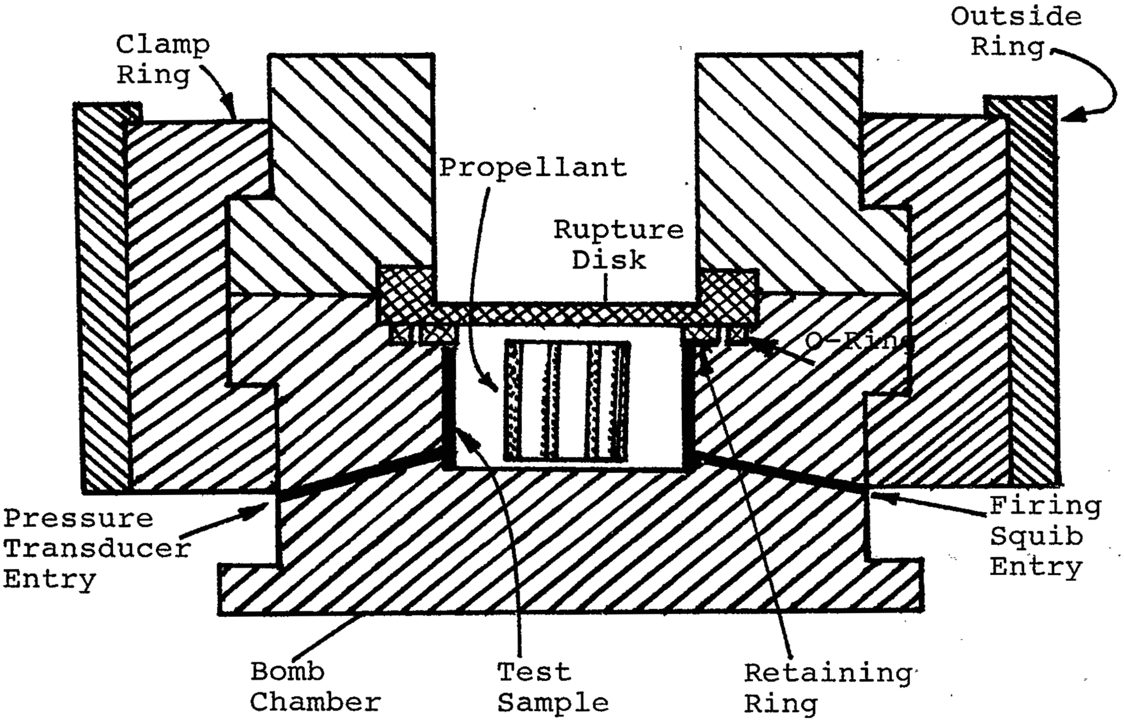


Figure 1. Cross section of Vented-Bomb Chamber Test setup.

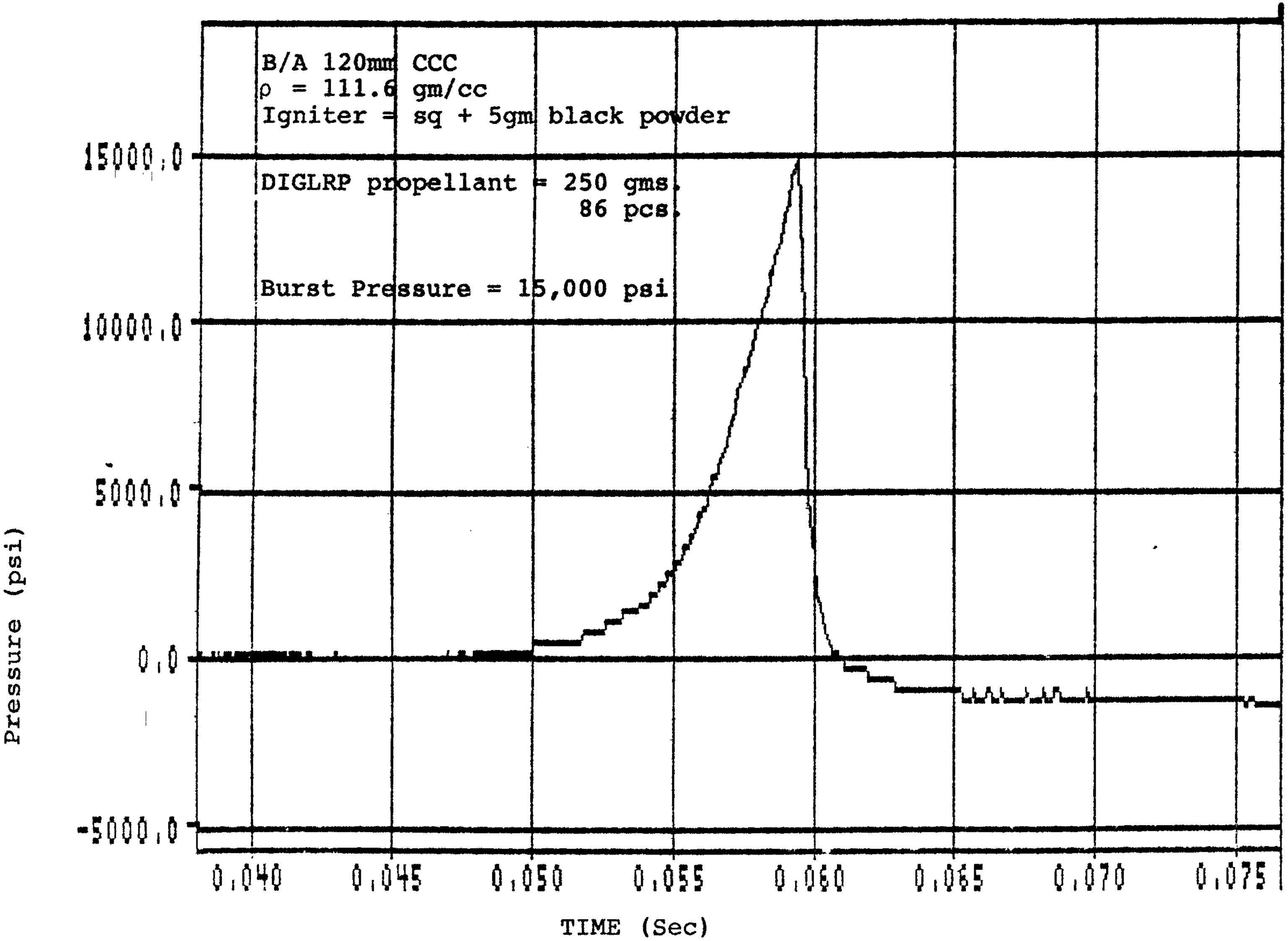


Figure 2. Typical pressure/time trace from vented-bomb firing of B/A 120 mm combustible case.

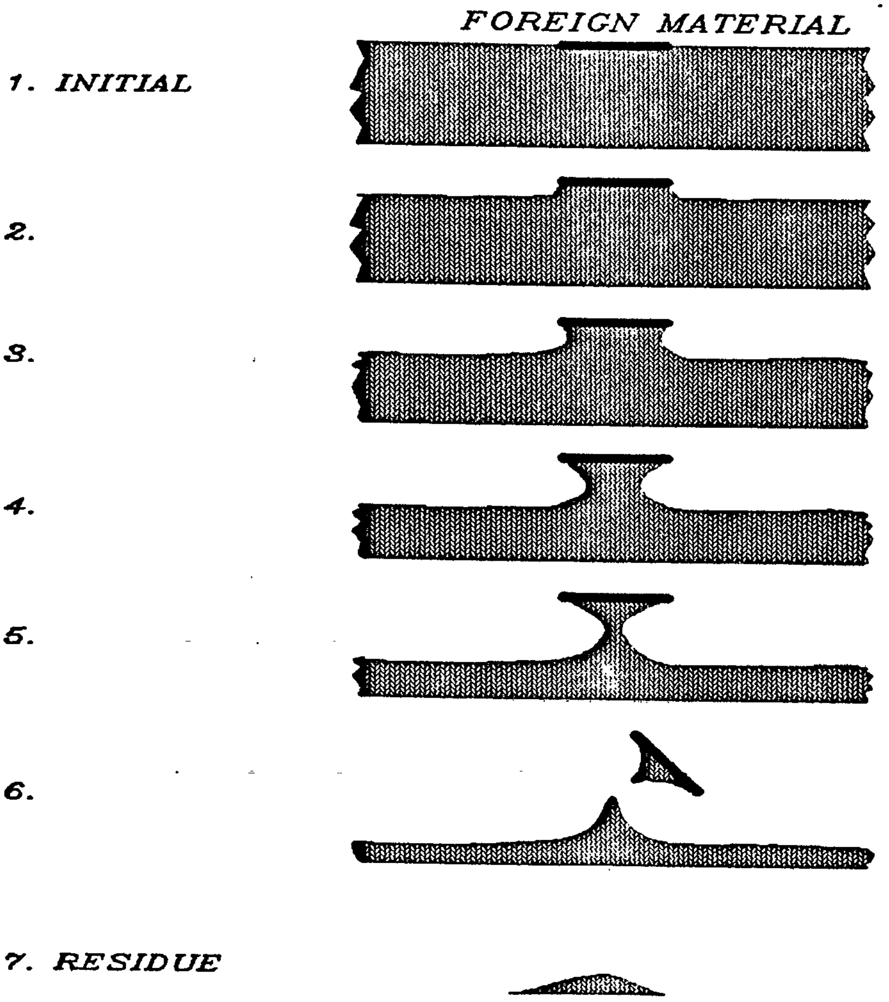
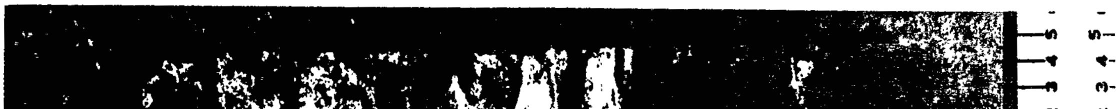


Figure 3. Residue Formation due to foreign material impeding flame front of propellant burn.

Photograph 1. Arrangement of propellants, igniter material and electric squib inside the vented-bomb chamber.

Photograph 2. Interior view of a residue sample with normal density located on the left and high density located on the right.

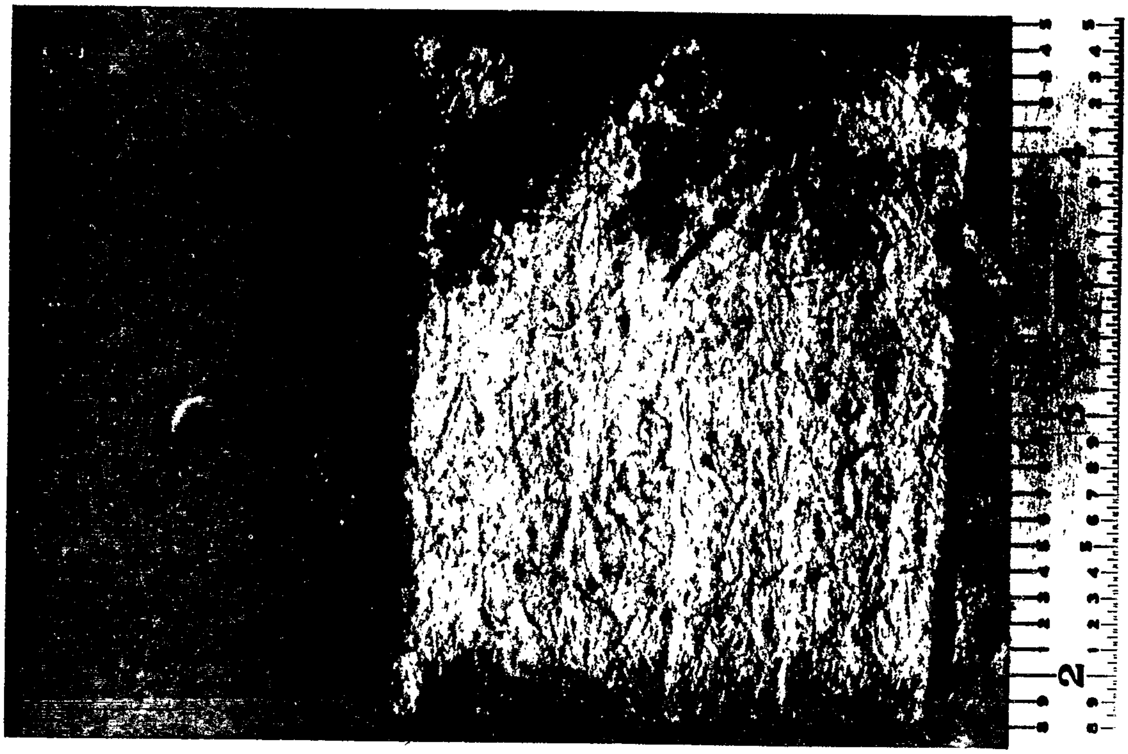


Photograph 3. Exterior view of the same region. Darkened area identified the region as densified.

Photograph 4. Cross-section view of the region with normal density.

Photograph 5. Cross-section view of the region with high density.

Photograph 6. Interior view of a residue sample with normal material region on left and 0% NC material on the right.



Photograph 7. Exterior view of the same region.

Photograph 8. Interior view of a residue with duct tape pressed to the interior.

Photograph 9. Cross-section view of the residue under the tape (unburnt).