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Semiconductor Bridge Initiators Igniting Multicomponent Propelling Charges

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13. ABSTRACT *(Maximum 200 words)*

Safe operation of a gun system incorporating multicomponent charges requires a good ignition system. One such proposed system for large-caliber guns involves the use of semiconductor bridge initiators (SCBIs) to commence the interior ballistic cycle. This simulator study demonstrated the feasibility of using SCBIs to simultaneously ignite multicomponent propelling charges. The flamespread simulator (76-mm I.D.) at the U.S. Army Research Laboratory, at Aberdeen Proving Ground, MD, was used to simulate ignition of a multicomponent charge. Use of up to three distinct increments was possible in this simulator. Each increment contained an SCBI in a black powder basepad on top of inert propellant. The firing voltage was applied through a modified M83 headstock to the first increment. The other increments made physical and electrical contact to the first increment by electrically conductive Velcro (a conductive polymer material that would leave no residue in gun firings). Pressure-time histories were obtained from pressure gauges located in the wall of the simulator near the location of each basepad. Pressure-time histories of SCBI initiation of the basepads showed smooth, nearly simultaneous ignition of each of the basepads. The method of indirect electrical contact between increments showed no adverse effects, thus allowing completely separate propelling increments to utilize electrical ignition in each increment. The use of electrically conductive organic polymers is being investigated to replace metallic wiring within each increment.

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1. INTRODUCTION

Gun propulsion systems rely heavily upon a good ignition system. One such proposed system for large-caliber guns involves the use of semiconductor bridge initiators (SCBIs) to commence the interior ballistic cycle. The SCBI is physically small and has an inherently small time delay for initiation; newer versions can have a digitally programmable time delay. These features are ideal for multipoint, controlled sequence ignition of propellant beds or for ignition of multi-increment propelling charges. This simulator study demonstrates the feasibility of using SCBIs to simultaneously ignite multi-increment propelling charges.

Electrically initiated ammunition typically utilizes a small bridgewire to ignite subsequent igniter material, pyrotechnics, or propellants. There has been a lot of research to prevent accidental activation of the bridgewire assembly when the ammunition is exposed to radio-frequency or other large-field electrical environments. One approach to surmount this problem is the use of an SCBI as the electrical initiator component. The SCBI has demonstrated adequate resistance to these environments and has qualified as a tentative Hazards of Electromagnetic Radiation to Ordnance (HERO) igniter (Hartman and McCampbell 1992). As with conventional igniters, this safety feature is only one of the considerations to be examined for successful ignition.

A single-increment propelling charge can produce excessive pressure waves if the ignition stimulus is improperly applied (May and Horst 1978); a multi-increment charge has an even greater possibility to produce excessive pressure waves since each component interface produces additional ignition impediments (Williams and Chang 1993; Chang, Grosh, and Deas 1993). One method to overcome ignition impediments due to component interfaces is to place an ignition source in each component. This method of necessity requires that the igniter be small and that the firing impetus be transmitted successfully to each igniter. Electrical impulses are easier to transmit to each component than are percussion impulses. The SCBI igniter satisfies these two requirements if electrical connections can be made between components.

This report discusses a means of making physical and electrical connections between the separate components of a multi-increment charge. The pressure-time histories of up to three charge components ignited simultaneously are presented. A possible means of replacing the metallic wiring within each component is also discussed.

2. EXPERIMENTAL

The flamespread chamber (Kooker, Chang, and Howard 1992; Kooker, Howard, and Chang 1994) has been described elsewhere, and only its salient features are discussed here. The flamespread chamber (Figure 1) consisted of a transparent acrylic tube (interior diameter of 76 mm with an axial dimension of 350 mm) contained in a steel confinement casing that was designed (for safety purposes) to withstand pressures generated within the acrylic tube that are in excess of 70 MPa (10,000 psig). The acrylic chamber was fitted with a rupture disk rated at 21 MPa (3,000 psig). Therefore, the highest expected pressure was in the neighborhood of 21 MPa (3,000 psig). Ports were machined in the steel casing and the acrylic tube for pressure transducers. Each of the pressure transducers was at the same axial position as the basepad.

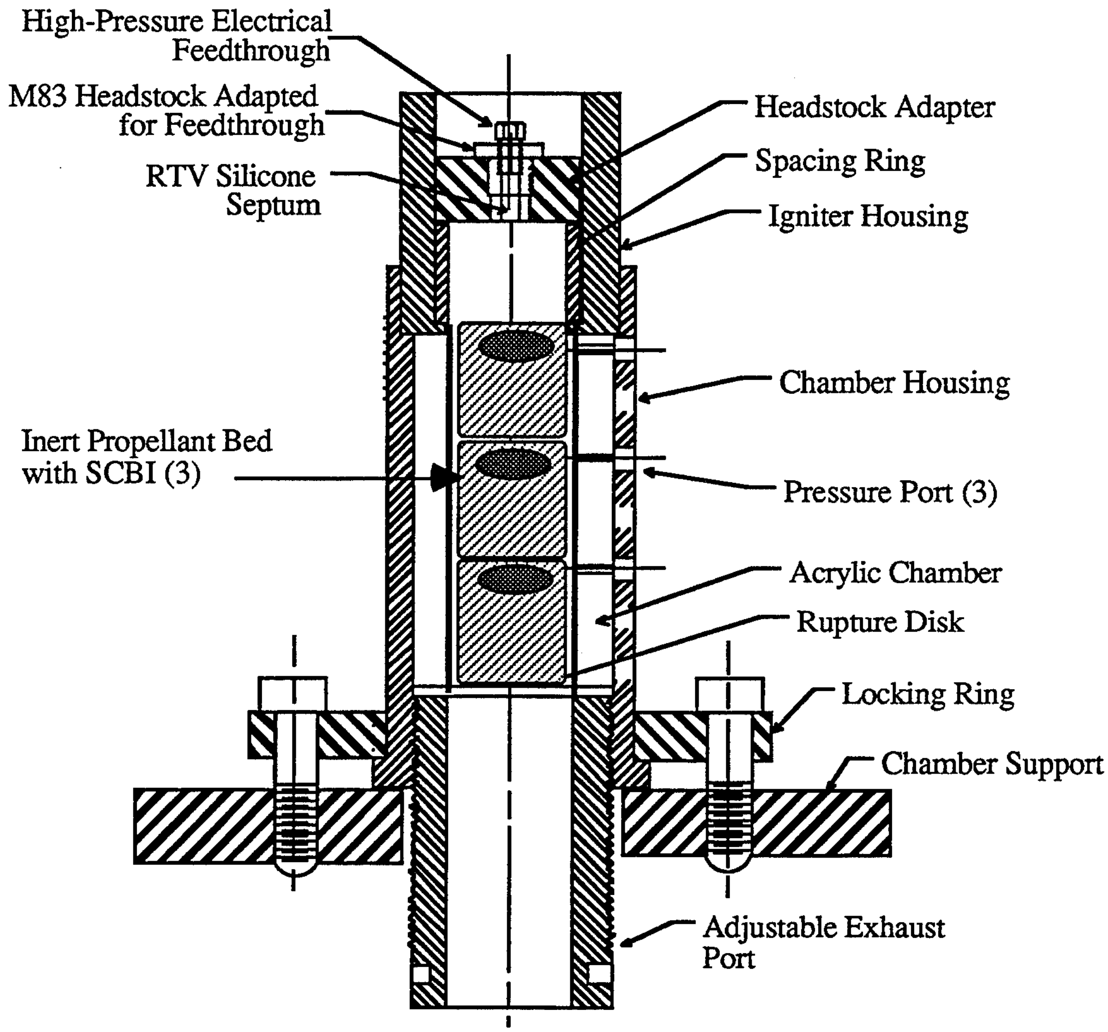

Figure 1. Cross-sectional view of flamespread simulator.

For these experiments, three separate charge increments constructed of cardboard filled with inert propellant grains were placed in the acrylic casing. Each increment also contained a basepad and copper wiring that transmitted the electrical impulse from one end of the increment to the other end. The basepad containing an SCBI and approximately 10 g of Class 3 (C3) black powder was placed on top of the inert propellant grains (Figure 2). The SCBI was electrically connected to two patches of electrically conductive Velcro™ located at each end of the increment. The firing line entered the simulator via a high-pressure electrical feedthrough in the top of the simulator.

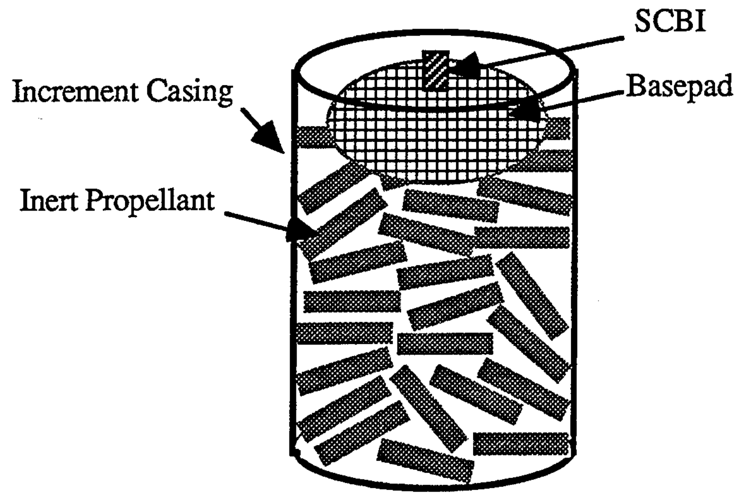

Figure 2. Schematic of inert charge increment containing SCBI and black powder.

3. RESULTS AND DISCUSSION

Figure 3 shows the placement of the Velcro™ pads for these experiments. The placement on the face of the increment was arbitrary (the only consideration was that a hook patch attached to a weave patch) and would not be the same as in the final design. The pads are essentially a polymeric material that can easily be cut to any shape (possibly disks of different diameters). However, since Velcro™ is composed of two distinct elements (the hook cloth and the weave cloth), the proper electrical continuity can be maintained from increment to increment by consistently attaching the same wire lead to the hook or to the weave element.

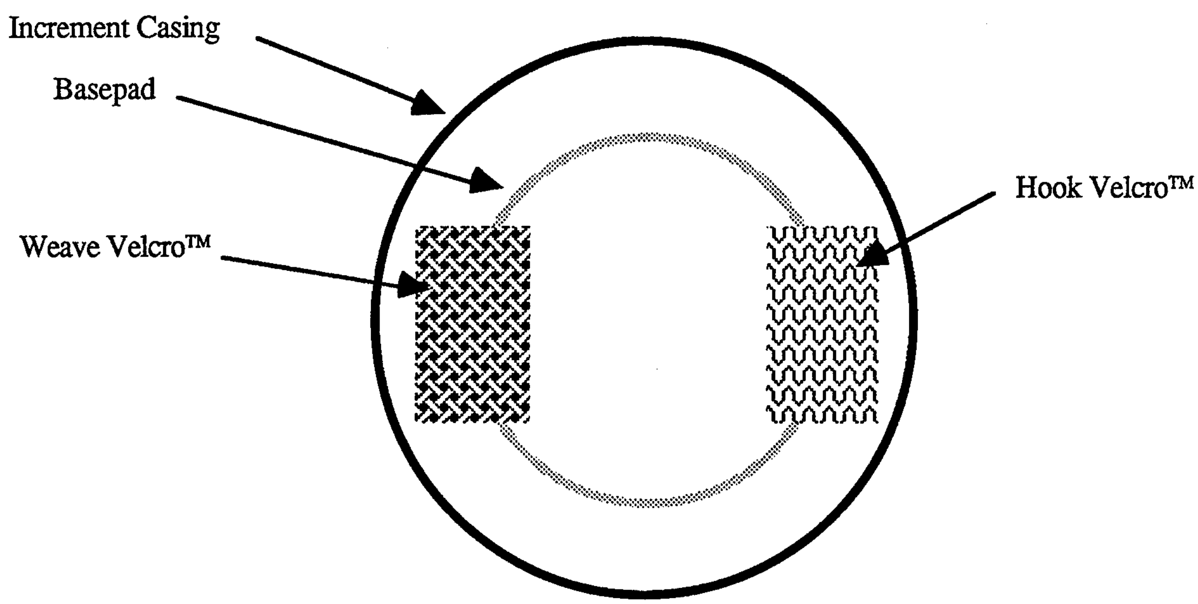

Figure 3. End view of inert charge increment showing Velcro™ placement.

An additional feature of Velcro™ is that once an increment with patches is pushed up to the mating Velcro™ material, the hook and weave pieces intermesh and physically attach to each other. Therefore, separate charge increments can be physically linked together in the gun chamber. This advantage is evident if the round in the gun chamber needs to be retracted for various reasons without firing.

The SCBI initiates by forming a localized plasma—in essence, a short circuit between the leads of the SCBI. Even though SCBIs initiate within a few microseconds of each other, if several units are placed in a parallel circuit as shown in Figure 4 (the case of three increments to be initiated) and one unit initiates slightly faster than the others, other SCBIs can be robbed of the current needed to initiate. A resistor (see Figure 5) was placed in series with the SCBI so that the resistance in each increment was balanced both before and after the SCBI initiation. With the resistor, when an SCBI initiates, that part of the circuit still has an appreciable resistance, and the other parts of the circuit will still operate.

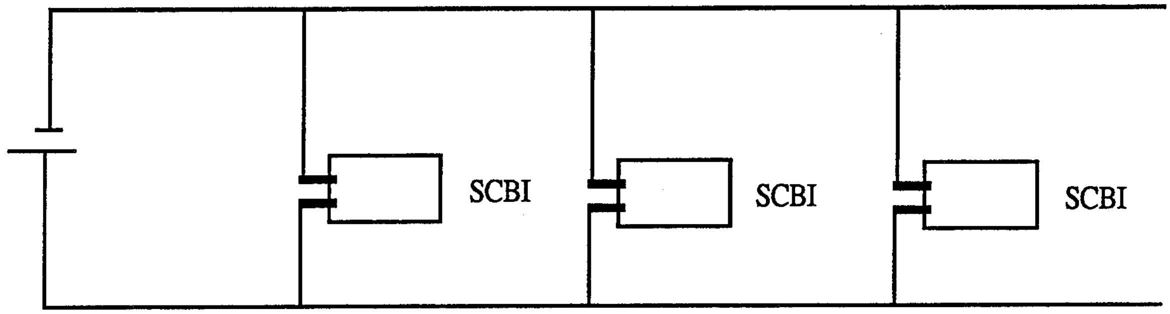

Figure 4. Faulty electrical schematic for a three-increment charge.

The SCBI in each increment was electrically attached to the Velcro™ pads as shown in Figure 5. For the circuit in Figure 5, the resistance in each series part of the circuit prior to firing was measured at 3.3 Ω, and the total circuit resistance for three increments was measured at 1.1 Ω. After these test firings, the total circuit resistance was not large, as is the usual case, but was measured at 0.7 Ω (due to conductive black powder residues). In the case of a live firing, the resistance afterward would be large since the resistors and the SCBI remnants would have exited the gun.

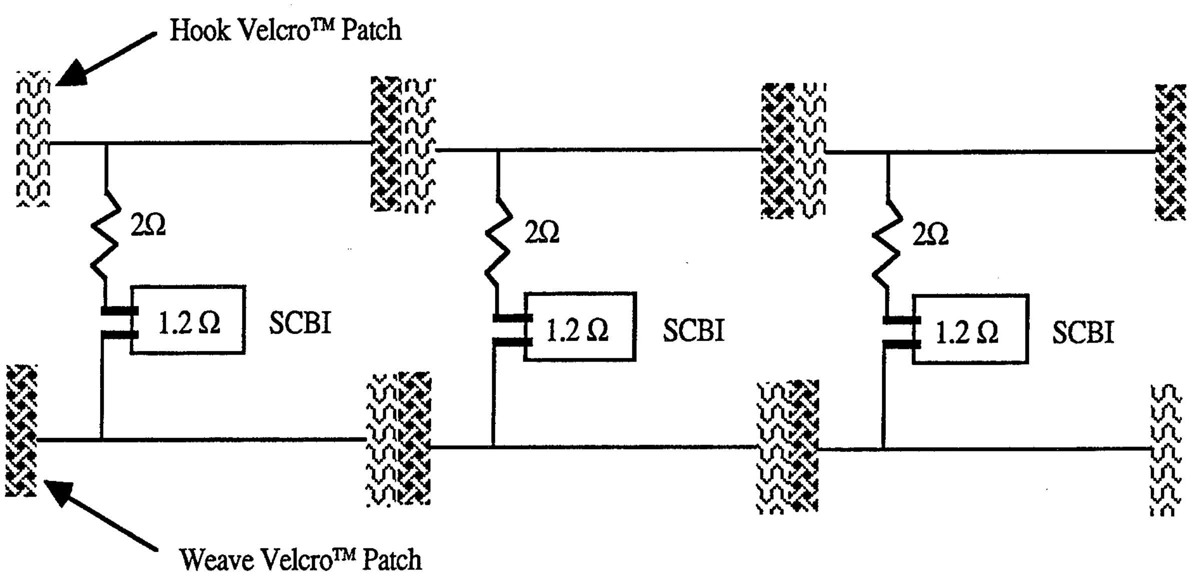

Figure 5. Schematic of electrical components linked together for a three-increment charge.

There is some indication in current multi-increment charge firing (using a different ignition system) that the ignition stimulus does not sequentially progress from one increment to the next until all increments are ignited (Chang, Williams, and Howard 1995); rather, ignition may skip one or more increments and occur out of sequence in another increment. A rearward traveling wave then ignites the skipped increments. This rearward traveling wave can produce a pressure wave that, at best, robs performance or can lead to conditions that have been blamed for gun failures (May and Horst 1978; Horst 1986). Adverse pressure waves can be reduced if a sequential ignition can be achieved.

To achieve sequential ignition with SCBIs, a time-programmable SCBI would be required. At this time, such SCBIs have not yet been procured so sequenced ignition was not evaluated. Therefore, a simultaneous firing sequence for these experiments was attempted. This firing sequence, if successful, would vastly reduce the possibility of formation of adverse pressure waves since the entire propelling charge would ignite at the same time.

Figure 6 shows the pressure-time histories from the three pressure gauges produced by the ignition of C3 black powder in the basepads. The firing voltage was held for 100 ms, but (as shown in Figure 6) this amount of time was excessive, and at most a few milliseconds would have been sufficient. The three pressure traces track quite closely during the ignition event. However, the ignition delay was about 25 ms. While this result is adequate for artillery ammunition, it is not acceptable for tank ammunition at ambient temperature. Using the trend noticed in preliminary investigations of SCBI ignition of black powder (Howard, Chang, and Atkson 1993), it was decided to place the SCBI inside a small basepad containing 0.7 g of Class 5 (C5) black powder. The small basepad was then inserted into the larger basepad containing Class 3 black powder (the original amount of 10 g of Class 3 black powder was unchanged). As readily shown in Figure 7, the smaller grain particle size reduced the ignition delay time to about 15 ms. In addition, the initial pressure rise (83 kPa/ms versus 48 kPa/ms) was also greater with the C5 black powder insert. Efforts to further shorten the ignition delay time are underway (Howard and Chang 1995).

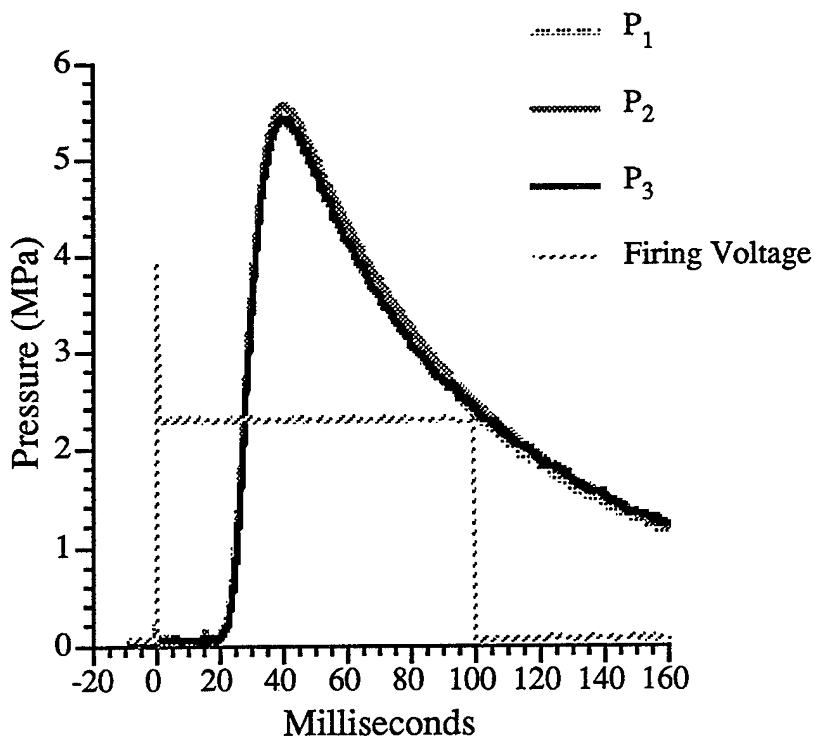

Figure 6. <u>Pressure-time histories of three increments using C3 black powder basepads.</u>

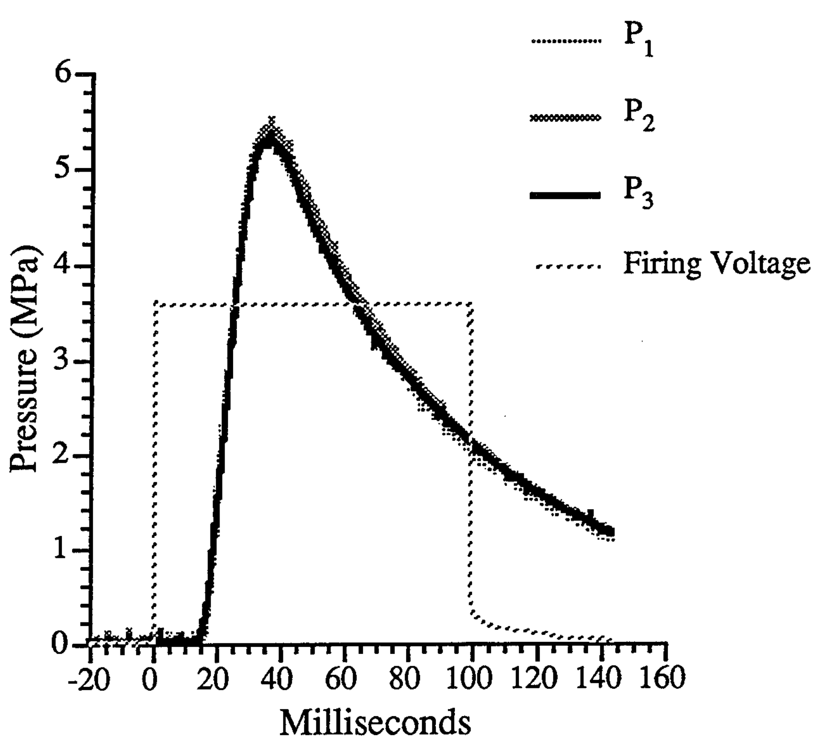

Figure 7. <u>Pressure-time histories of three increments augmented with C5 black powder in the basepads.</u>

It has been suggested that metallic wiring in the increments may introduce residues near the breech area. Preliminary efforts to investigate the use of polyaniline or other suitable polymeric material that would serve as the electrical pathway across the increment are underway. These results will be reported in the future.

4. SUMMARY

SCBIs have been used to successfully achieve simultaneous ignition of the black powder basepads in a multi-increment simulator charge consisting of three increments. The ignition events as recorded by pressure gauges showed essentially identical ignition delay times and initial pressure rises in all three increments. Ignition of Class 3 black powder by the SCBI produced an ignition time delay of approximately 25 ms. When a small quantity of Class 5 black powder was placed about the SCBI and inserted into the Class 3 basepad, the ignition delay time was reduced to approximately 15 ms.

This magnitude of ignition delay time is acceptable for artillery ammunition but may be still too long for tank ammunition. Further work is needed to augment the SCBI output as was done with the C5 black powder in order to shorten the ignition delay time to acceptable levels for tank ammunition. Use of polymeric material to replace metallic components currently utilized for the electrical pathways is under consideration.

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