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ELECTROSTATIC SENSITIVITY OF CONSOLIDATED MAGNESIUM—TEFLON COMPOSITIONS*

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Summary

The RR119 decoy flare is a consolidated composition of magnesium, Teflon and binder, approximately 2 in. × 3 in. × 5 in. in size and weighs approximately 600 g. Several fires have occurred during manufacture of this flare immediately after the consolidation operation as the pellet is being removed from the lower punch of the consolidation tooling string. The fires have been attributed to an electrostatic discharge from the pellet to the lower punch. Although the conventional tests for determining electrostatic sensitivity would establish the material as relatively insensitive, it was found that voltage discharge through a thin sliver of the material such as flashing on the pellet could, in fact, ignite the composition. The paper describes the fires, the tests conducted relevant to establishing the cause of the fires, and the evaluation of corrective actions taken which included using ionized air to wash the surface of the pellet prior to removal from the press.

Introduction

Infrared decoy flares are generally made with a composition of magnesium, Teflon and binder. This composition has been variously characterized as to the safety hazards it presents. Under most circumstances, the composition is reported to have little or no tendency toward ignition from electrostatic discharge. Recent events at the Longhorn Army Ammunition Plant have altered this perception. Five fires have occurred during manufacture of the RR119 decoy flare. This flare is a consolidated pellet of magnesium, Teflon and binder, approximately 2 in. × 3 in. × 5 in. in size and weighs approximately 600 g. During consolidation, the load is applied on the 2 in. × 5 in. surface. Grooves are pressed into the top and bottom of the pellet using flutes on the surfaces of the upper and lower punches. Additionally, a cavity, into which a Safe and Igniting (S&I) device installs, is formed during the consolidation process by using a side punch.

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Manufacture of RR119 flare pellets

Flare composition is received in conductive rubber buckets with approximately 4.5 lb of composition in each bucket. The material for a pellet is weighed, passed over a magnetic separator and then dispensed into a die on a shielded pre-consolidation press. This press consolidates the material into a "slug" which is approximately the same shape and size as the desired finished pellet (Fig. 1). These slugs are placed in metal ammunition boxes inside a polycarbonate box until ten slugs are completed. The regular lid is then placed on the ammunition box and the box/slugs are moved to another bay.

The final consolidation press bay consists of two consolidation presses located behind a steel plate shield. This shield extends from wall to wall and floor to near ceiling. The presses are side by side approximately three feet apart with a polycarbonate access door in front of each press (Fig. 2).

There is a platform approximately 30 inches high and four feet from front to back extending from wall to wall in front of the shield/presses. Three steps lead from the platform to the bay floor (Fig. 3). On both sides of this platform there is a table with two polycarbonate boxes with lids. One box on each table houses an ammunition box of slugs and the other box houses an ammunition box of consolidated pellets. Each press is serviced by its corresponding table/boxes. When the consolidation press is started in its cycle, the shield opens to give access to the die. The punches have all retracted to make room for the slug (Fig. 4). The polycarbonate surge box containing the slugs is opened and one slug is placed in the die and onto the lower punch. Palm switches are actuated to close the shield door and cause the side and upper punch to move into position. The lower punch

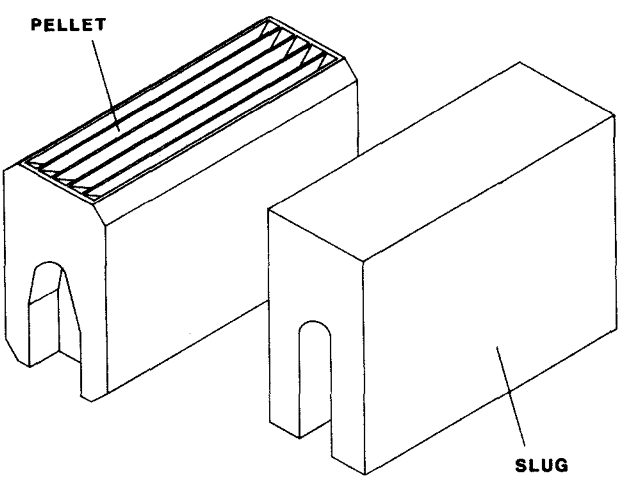

Fig. 1. RR119 consolidated pellet/slug — Depiction of the consolidated RR119 slug and pellet.

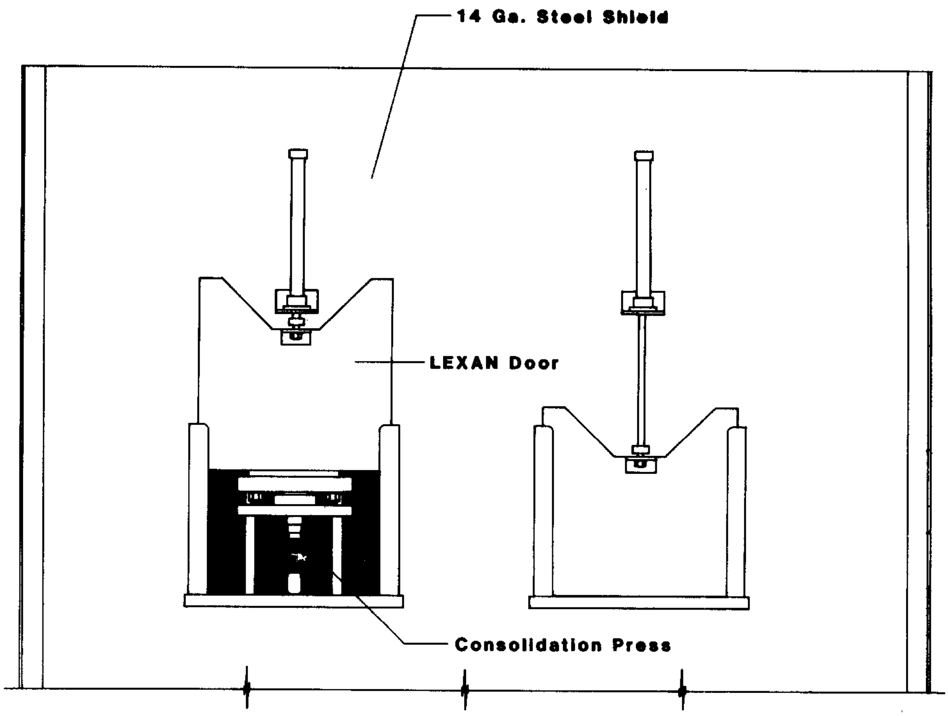

Fig. 2. Shielding for consolidation press — The front of the consolidation presses as the operator sees the polycarbonate access doors.

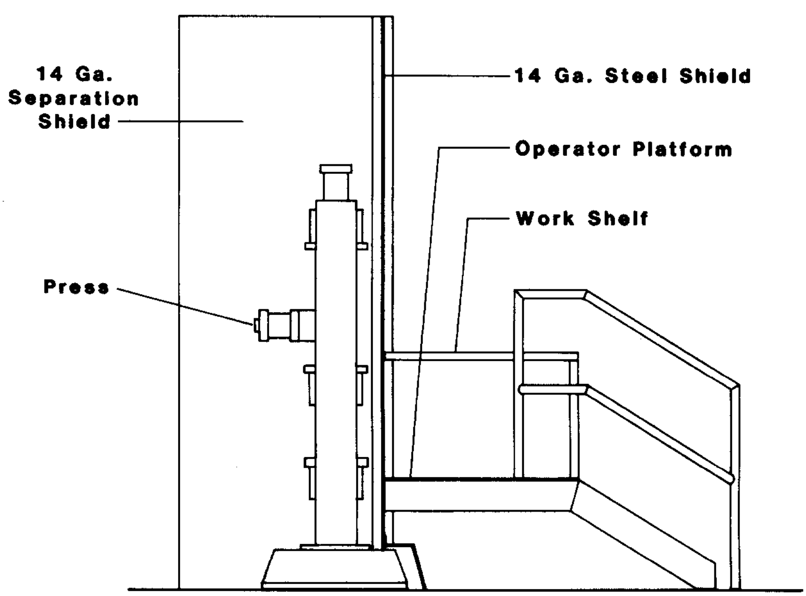

Fig. 3. Shielding for consolidation press — Cross section of bay showing press, shield, and platform.

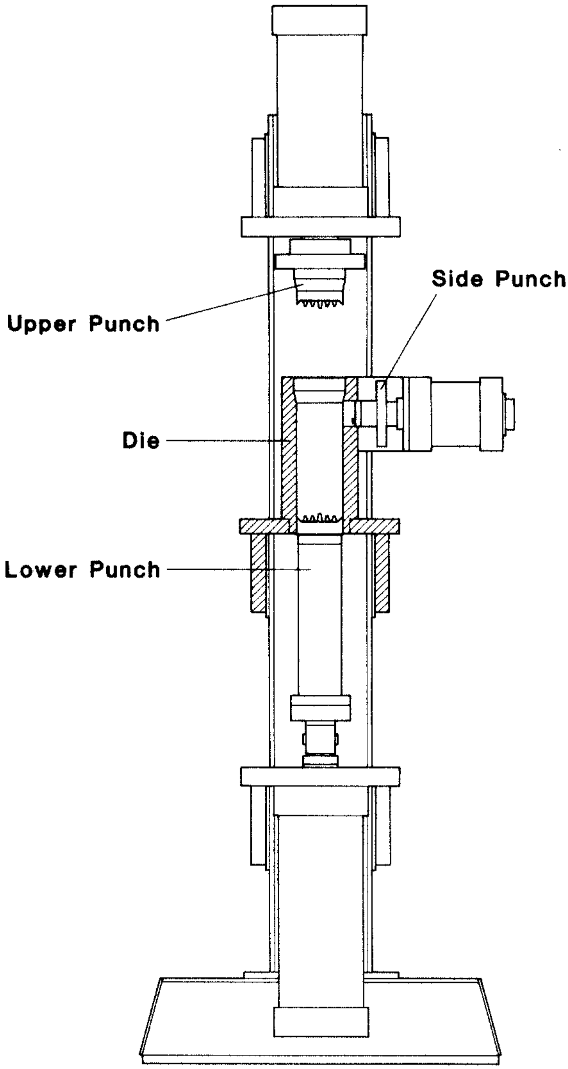

Fig. 4. Consolidation press for RR119/B pellet — Cross section of press, with all punches retracted, in the load position.

then rises under hydraulic pressure, pressing the slug against the die and other punches to form the pellet to the desired configuration. After a predetermined dwell time, the lower punch relaxes and the other two punches retract to their load positions. The lower punch again rises pushing the consolidated pellet completely above the die (Fig. 5). The polycarbonate shield/door opens and the operator manually removes the pellet and places it in an ammunition box inside the polycarbonate box on the table.

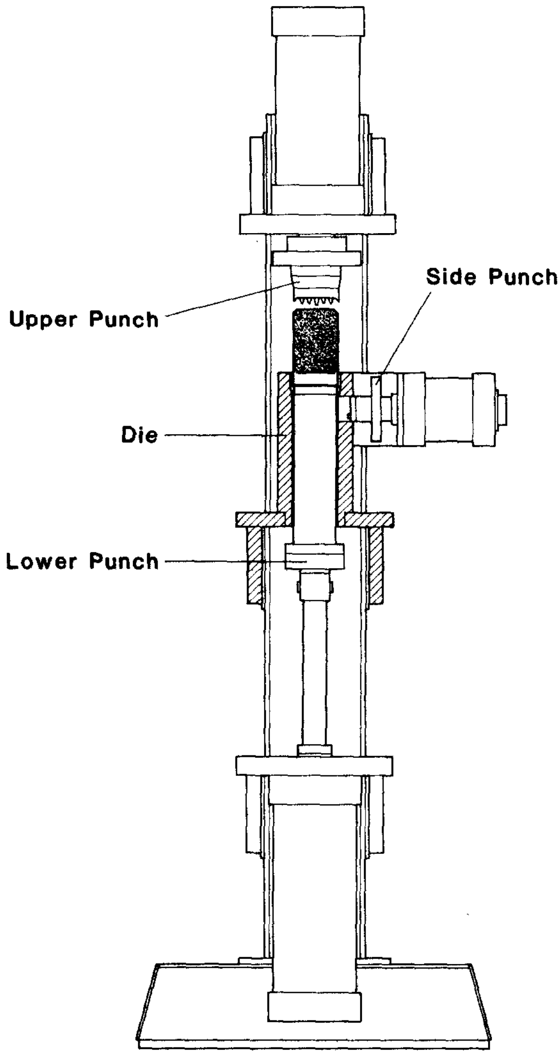

Fig. 5. Consolidation press for RR119/B pellet — Cross section of press with the consolidated pellet resting on the anvil (i.e., as presented to operator for removal from lower punch).

Description of initial incidents

The first fire occurred at this location on July 26, 1983. As a result, two people were burned and lost time from work. The operator had removed the pellet from the press and was turning to put it in the box when she saw that it was on fire. She threw the pellet and it landed on the floor near the legs of another operator. Although this operator was near the safety exit doors, the intensity of the fire caused severe burns to the legs and lower portion of the torso. The operator who removed the pellet received burns to the wrists and neck. The deluge system activated and the alarm was automatically relayed to the fire station. Only minor damage was sustained by the building and equipment.

The operator was wearing proper cotton underclothing, Nomex coveralls, Nomex lab coat and appropriate safety equipment at the time of the incident. Her shoes had conductive soles and had been tested/checked at the start of the shift. The platform had a conductive rubber covering that was checked and showed positive grounding.

An investigation as to the probable cause was started. The material remaining from the mix that included the pellet that burned was tested for impact and friction sensitivity. The mix was tested by standard laboratory techniques for electrostatic sensitivity in both the loose powder and consolidated form. The procedure used in this test was to charge a large oil-filled capacitor and discharge it through the sample. These tests were negative.

No definitive cause could be assigned to this ignition. Mix contamination as a result of using ammunition boxes for more than one production item without adequate cleaning between uses, was considered a prime possibility. Electrostatic discharge was considered, but not felt to be a significant factor. Procedures were established which eliminated the possibility of material cross-contamination. Additionally, we programmed the press to provide a 15 seconds delay between the time the pellet was ejected from the die cavity and the shield door opened. We increased the number of deluge heads in the immediate proximity of the operation and resumed production.

We obtained, on loan, an electrostatic tester from the Franklin Research Institute in Philadelphia, Pennsylvania, and conducted additional tests relevant to the electrostatic sensitivity of magnesium/Teflon/binder compositions. This tester differed in principle from the one mentioned above in that the sample became one of the electrodes (could be either positive or negative). These tests reflected that large pieces of flare composition could withstand repeated and continuous discharges without ignition. Loose powder showed no tendency to ignite under any test conditions. The large pieces are apparently capable of dissipating the energy from the discharge, whereas the loose powder is blown out of the cup by the air heated by the discharge. Samples of flare composition were shaved from a pellet to give a sample thickness of approximately 0.050 cm. These samples readily ignited from the discharge as evidenced by flashes and loud reports. The energy level of the discharge was calculated to be 0.02 joule. The frequency of ignition indicated that the composition would probably ignite at lower energy levels. However, 0.02 joule represented the minimum obtainable with the Franklin Research Institute test apparatus.

Ignitions were more frequent when the sample was connected to the negative lead of the electrostatic tester than when connected to the positive lead. This is attributed to the buildup of excess electrons in the shaving, leading to more efficient energy concentration in the flare sample. This condition more closely approximates the conditions at the press, since excess electrons are present in the pellet and tend to flow through the flashing to jump to ground.

The ignitions did not propagate under the test conditions, but it was obvious that ignitions had occurred. It is likely that propagation is dependent on a rare combination of factors that only occasionally are encountered.

We experienced a similar incident on December 3, 1983. It occurred on the other press in the bay. The operator was removing a pellet from the press with her left hand. The pellet ignited when it was removed from the lower punch. The operator threw the pellet away from her body and the deluge system activated. The intensity of the fire burned through the Nomex coat she was wearing, but did not burn through her Nomex coveralls. She suffered only minor reddening of the skin on her wrists.

In both the July 26 and December 3, 1983 incidents, the operator was sure the pellets ignited on the bottom as they were removed from the lower punch. Using an electrostatic voltmeter, we measured voltages as high as 3600 volts on the top and sides of the pellet as it was ejected from the die cavity. This voltage slowly dissipated to the air.

Based upon the statements of the operators, the electrostatic sensitivity tests conducted and the electrostatic voltages measured upon ejection of the pellet from the die, we concluded both fires resulted from electrostatic discharge.

We extended the time between ejecting the pellet from the die to the shield door opening from 15 seconds to 60 seconds to provide more time for the electrostatic charge to dissipate. Other changes included improved personal protective equipment, decreasing the bay personnel limits, and improving the lids on the polycarbonate surge boxes to better prevent ingress of fire into the boxes.

The third incident occurred on January 20, 1984. As the operator removed a pellet from the lower punch with her left hand, the pellet "popped" and ignited into a ball of fire. The operator threw the pellet onto the table and behind the polycarbonate boxes that serviced the press. No other pellets ignited. The personnel evacuated the building, and there were no injuries. There was only minor damage to the bay and equipment.

Tests/Results

After the third incident, tests were run wherein electrostatic voltages were measured on the top, sides, and bottom of pellets, made from several mixes, immediately after ejection from the die cavity, and at periodic intervals of time thereafter. These tests showed the voltage on the top of the pellet after the top punch was withdrawn (the lower punch is in the "up" position with the pellet in place) ranged between 1200 and 3600 volts. This voltage decayed to between 200 and 1400 volts within 30 seconds (Fig. 6). The magnitude of the electrostatic voltage developed varied between mixes. Within a mix, the variation was smaller. The electrostatic voltage on the bottom of the pellet immediately after it was removed from the bottom punch ranged between 1400 and 1800 volts. This was essentially the same whether the pellet was removed immediately after ejection from the die cavity, or allowed to sit on the bottom punch for 60 seconds prior to removal (Fig. 7). Sixty seconds after removing the pellet from the lower punch, the voltage on the bottom had decayed to between 200 and 650 volts. Generally, the voltage reduced by one-half in the first 15 seconds after removal from the punch.

A grounded copper bristle brush was pulled across the pellet as it rested on the lower punch in the press. This was very successful in removing the charge from the top and sides of the pellet. The brush did not remove the charge from the bottom of the pellet except when the brush was pulled across the bottom.

The relative humidity in the press bay is maintained between 50 to 60% RH. Wiping the "slugs" with a mixture of isopropanol, butyl cellusolve, and water prior to final consolidation yielded electrostatic voltages from

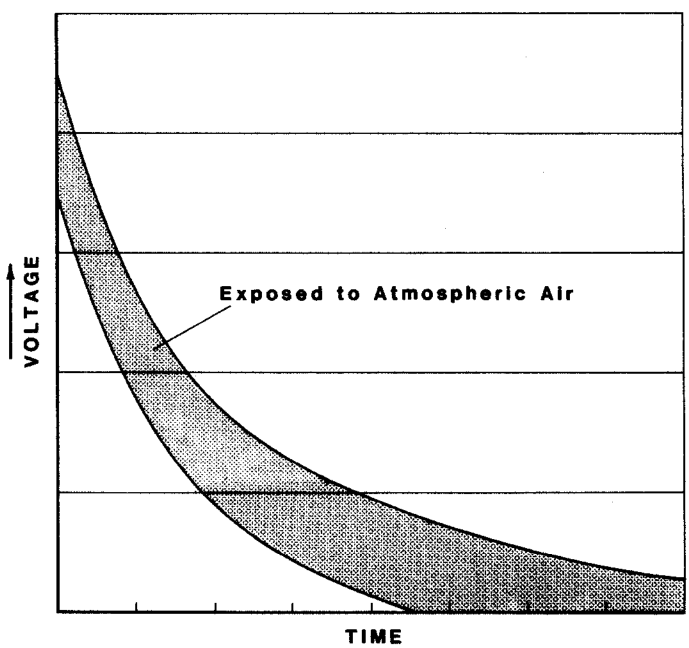

Fig. 6. Generalized voltage/time profile — Generalized graph of electrostatic voltage on pellet surfaces exposed to air as a function of time.

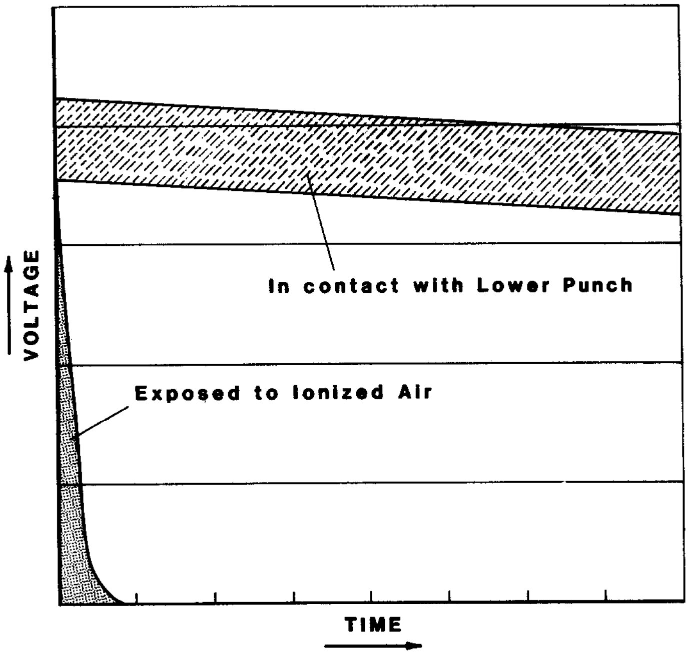

Fig. 7. Generalized voltage/time profile — Generalized graph of electrostatic voltage on pellet surface in contact with lower punch as a function of time and on pellet surfaces washed with ionized air as a function of time.

0 to 200 volts on the bottom of the pellet immediately after removal from the lower punch. Further efforts in this regard were tabled since it was felt the user would require numerous tests on the RR119 decoy flare to establish that the use of a surface treatment would not have deleterious effects on flare performance, shelf life, etc.

The press was programmed to cycle such that the consolidated pellet was ejected from the die cavity. The lower punch was then retracted pulling the pellet back into the tapered part of the die cavity until it reached the smallest part of the die, at which time the punch separated from the pellet. In this condition, the pellet extended approximately 3/8 inch above the top of the die (Fig. 8). When operating in this manner, the voltages on the botttom of the pellet 30 seconds after separating the lower punch, were between 200 and 1000 volts. Sixty seconds after separation, the voltages ranged between 0 and 500 volts.

Tests were run using an ionizing air system to blow ionized air across the surface of the pellets after ejection. This method was very effective in reducing/removing the electrostatic voltage on the top and sides of the pellet in a very short period of time (Fig. 7). To be effective on the bottom of the pellet, it was necessary to expose the bottom of the pellet to the ionizing air stream. This was effected by using a probe on the end of an air-operated cylinder to roll the pellet of the lower punch.

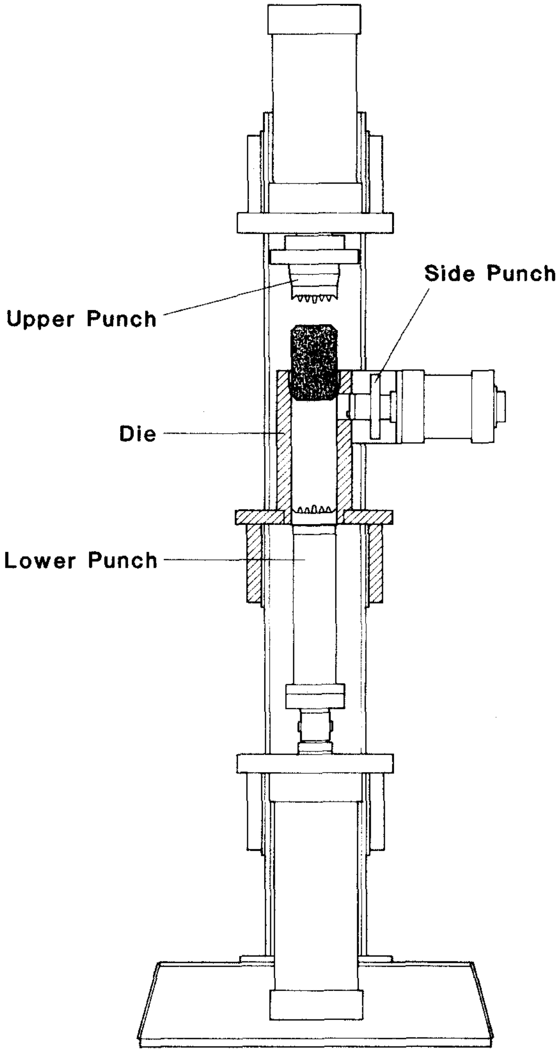

Fig. 8. Consolidation press for RR119/B pellet — Cross section of press showing pellet resting in die after lower punch has been separated.

Actions taken

The primary areas for pellet ignition in the press by the discharge of static electricity are:

(1) when the top punch is removed from the pellet,
(2) when the side punch is removed from the pellet,
(3) when the pellet is removed from the lower punch.

All three fires occurred while removing the pellet from the press and were felt to have initiated when the pellet was removed from the lower punch. At this time, the negatively charged pellet can arc to the punch, through the flashing on the pellet, when an air gap between the two is generated. This same condition exists when the upper and side punches are withdrawn. No ignitions have occurred as a result of these separations, and if such did occur, it would happen while the pellet is in the die and behind the shield in the press, thereby protecting the operator from direct exposure. Allowing the press cycle to remove the lower punch from the pellet, while not altering the conditions for drawing an arc between the pellet and the punch, does have the pellet in the die and behind the shield in the event ignition occurs. By delaying the opening of the press shield door for 60 seconds after pellet/lower punch separation, then rubbing the top of the pellet with a grounded brass brush prior to pellet removal, the electrostatic charge decreased to a neutral or safe handling level. This operational procedure was instituted during the period of time we were obtaining the authorization to use ionizing air blowers.

The biggest problem encountered with using ionized air was the Army Safety Manual DARCOM-R 385-100, which prohibited the use of ionizing air systems in hazardous environments [1]. To eliminate this as a problem, we developed a system which effectively removed the ionizing air system from the hazardous environment. Our particular situation was best solved by placing several Simco Company ionizing air nozzles fore and aft of the pellet as it sits in the raised position (Fig. 9). We essentially encapsulated the system by maintaining a positive air pressure at all times. This assures sufficient air velocity to prevent the ingress of gaseous or particulate matter around the ionizing electrodes. This system, while not much more effective than the interim procedure of separating the lower punch from the pellet while in the die and delaying the shield door opening 60 seconds, is a much more efficient and economical production approach.

Perplexing to the solution of the problem was discovering that the charge on the bottom of the pellet was bound and did not readily dissipate through the grounded lower punch. To significantly accelerate the energy dissipation, it was necessary to separate the pellet from the punch exposing the charged surface to the air. The ionizing air nozzles, in turn, then neutralized this charge almost immediately. The presses were modified to include a tip over punch which would, upon pellet ejection from the die cavity, tip the pellet over and off the lower punch exposing the bottom of the pellet to the ionized air stream. It was felt that the presence of the ionized air would reduce the discharge intensity of any spark, generated at pellet separation from the lower punch, to a level below that required for pellet ignition. However, in the event ignition did occur, the pellet would burn behind the press shield and personnel would be protected. In September 1984, the presses were equipped with the ionizing air nozzles and ran in this mode without incident until February 7, 1985, at which time a pellet ignited, apparently when the tip over ram tipped the pellet from the lower

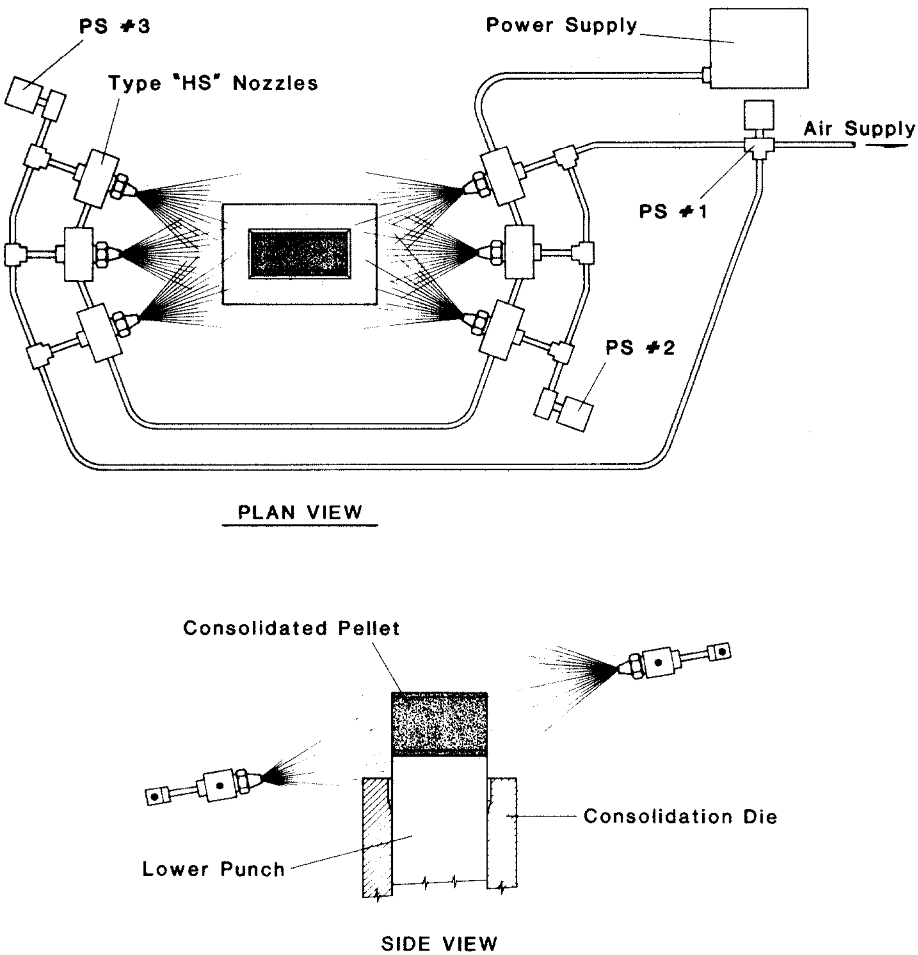

Fig. 9. Ionizing air nozzles — Depiction of the ionizing air nozzles washing the sides and ends of the consolidated pellet.

punch. The deluge activated. No personnel injuries were encountered and very minimal equipment damage was incurred. After investigation of the incident, production was resumed on the unaffected press. On February 8, 1985, the press operator, while watching through the polycarbonate shield door on the press, saw a spark between the bottom of the pellet and lower punch as the pellet was tipped from the punch. No fire resulted from that incident. On February 9, 1985, a pellet did ignite while being tipped from the punch. The press operator was looking at the time and said the ignition occurred at essentially the same point at which he noted the spark the day before. Again the deluge activated and no injuries were encountered. The lower punch was cracked, apparently from rapid heating/cooling resulting from the burning pellet and deluge.

Tests were conducted to verify the results obtained in the 1984 tests, especially with regard to the reduction/elimination of static charge when the pellet surface was treated with a solution of isopropyl alcohol (9%), butyl cellusolve (1%), and water (90%). These results confirmed the earlier test results. Furthermore, we determined a solution of isopropyl alcohol (10%) and water (90%) was equally effective in reducing the electrostatic charge buildup on a surface treated with it prior to consolidation. We proposed to the user that we treat the surface of the slug, in contact with the lower punch, immediately prior to insertion in the die. In addition, we programmed the press so that it again operated in the mode of ejecting the pellet from the die cavity, retracting the punch and pellet back into the die, separating the pellet from the punch, then raising the punch/pellet from the die cavity, and allowing the tip over ram to roll the pellet off the lower punch. It is felt that separating the pellet from the punch initially in a parallel mode, as opposed to the angular mode encountered when tipping, lessens the chances for sparks to contain ignition intensities. Additionally, the edges of the surface where ignition is probable are in contact with the die walls which provide a heat sink lessening the chances of a spark igniting and sustaining combustion. With these changes in effect, we resumed production on February 25, 1985 and continued in this mode without incident to the end of the production program on March 29, 1985.

References

1 Department of the Army, DARCOM Regulation No. 385-100, August 17, 1981, par. 7-9, p. 7-6.