NSWCDD/TR-92/447

NONAERODYNAMIC SABOT STRIPPER FOR NSWCDD 40-MM GAS GUN

BY WILLIS MOCK, JR. WILLIAM H. HOLT
WEAPONS SYSTEMS DEPARTMENT

NOVEMBER 1992

NAVAL SURFACE WARFARE CENTER
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FOREWORD

This report describes a nonaerodynamic sabot stripper that has been designed and implemented. The stripper is used with the Naval Surface Warfare Center Dahlgren Division (NSWCDD) gas gun for shock effects in materials. The requirement for the sabot stripper is based on the need to launch objects of different shapes (e.g., cubes, cylinders, and rods) at velocities up to 3100 ft/sec onto selected targets. Funding for this work was provided by the Insensitive Munitions Advanced Development (IMAD) Ordnance Technology Project under Task 3002B–Warhead Case Design Studies (Shock Attenuating Case Designs).

This report was reviewed by W. E. Hoye, Head, Warheads Branch and D. L. Brunson, Head, Missile Systems Division.

Approved by:

David Malyevac

DAVID S. MALYEVAC, Deputy Head
Weapons Systems Department

ABSTRACT

A nonaerodynamic sabot stripper has been designed and implemented for use with the Naval Surface Warfare Center Dahlgren Division (NSWCDD) 40-mm smooth-bore gas gun. The stripper consists of several metal parts to stop and contain the sabot while allowing the carried object to pass unhindered through it. The single-piece sabot is stopped by impacting replaceable layers of 0.750-in.-thick aluminum and steel plates and 0.125-in.-thick rubber sheets. The metal plates and rubber sheets have 1.00- and 1.25-in.-diameter holes, respectively, for passage of the carried object. The sabot stripper is located several inches from the muzzle of the gas gun and is aligned before each shot using a special metal fixture that is inserted into the gun muzzle. Cubes measuring 0.5 in. have been launched in a flat-faced orientation; other shapes (e.g., spheres or cylinders) and orientations could also be used.

Both small- and large-target configurations can be used. Small targets (up to 6-in. on a side) can be positioned in an assembly that attaches to the sabot stripper and is located several inches from it. Most small targets have been 3x3-in. plates of various thicknesses. Large targets (up to several feet on a side) are secured to a steel table that is located approximately 20 ft from the sabot stripper. Twenty-seven experiments using the sabot stripper have been performed to date; 15 using the small-target configuration and 12 using the large-target configuration. The velocity range for the experiments was from 1600 to 3100 ft/sec. The sabot stripper performed satisfactorily.

CONTENTS

TABLE

ILLUSTRATIONS

ILLUSTRATIONS (CONTINUED)

I. INTRODUCTION

Certain types of impact experiments require the separation of the launched sabot from the object being carried and the unperturbed flight and controlled impact of that object with a target. Many impact facilities use a multipiece sabot that is designed for in-flight separation from the carried object using either gun muzzle blast pressure or aerodynamic drag forces.[1,2] Aerodynamic separation requires an extended distance (usually at least several meters) for separation to be accomplished[3] and can introduce perturbations that can change the orientation of the object during flight to the target.

This report describes a compact nonaerodynamic sabot stripper that separates the sabot from the object within a few inches of flight. The stripper was designed to be used with the Naval Surface Warfare Center Dahlgren Division (NSWCDD) 40-mm smooth-bore gas gun.[4] One-piece sabots are used. Cubes measuring 0.5-in. have been launched in a flat-faced orientation. Other shapes (e.g., rods and spheres) and orientations could also be used. A launched sabot is stopped on impact by a series of replaceable energy-absorbing plates, and the cube moves unhindered through the stripper to impact a target. Cubes launched with a flat-surface orientation have traveled as far as 20 ft and impacted flat on a target. The sabot stripper has been used in the 1600- to 3100-ft/sec velocity range.

Figure 1 is a schematic of the 40-mm-bore gas gun showing the location of the sabot stripper. A sabot with an attached cube is loaded into the barrel, and a thin-film mica vacuum cover is attached to the gun muzzle. A small or large target can be mounted and secured for impact. Small-target lateral dimensions are limited by the size of the steel duct to approximately 6 in. The small target is secured in an assembly that attaches to the sabot stripper. A large target that is located in the impact room can be several feet on a side. It is secured on a steel table that can be positioned at several locations along the flight path of the cube. The breech pressure vessel is filled with either helium or nitrogen gas to the desired pressure. The barrel is evacuated before firing the gas gun. The gun is fired by activating the fast-opening

valve, and the gas accelerates the sabot towards the gun muzzle. The sabot velocity is measured at the muzzle with three charged pins in the side of the barrel. The sabot velocity can be varied from 100 to 3200 ft/sec. Figure 2 is an overview of the gas gun from the breech end.

Section II describes the parts for the sabot stripper and the attachable target assembly. Section III describes the installation and alignment procedure for the stripper. Sample results are given in Section IV.

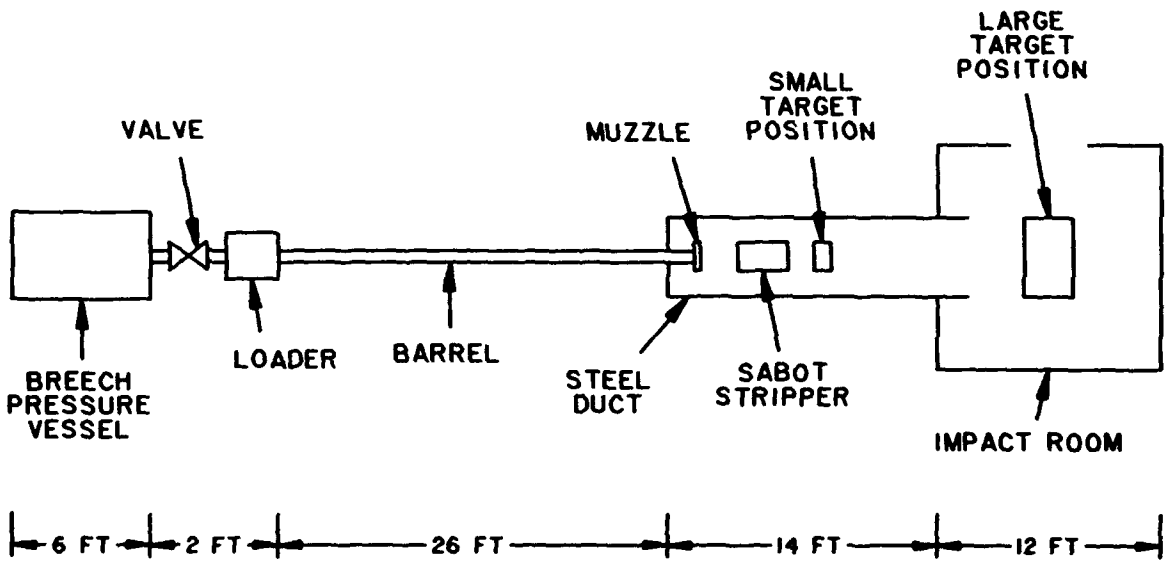


FIGURE 1. SCHEMATIC OF GAS GUN WITH SABOT STRIPPER

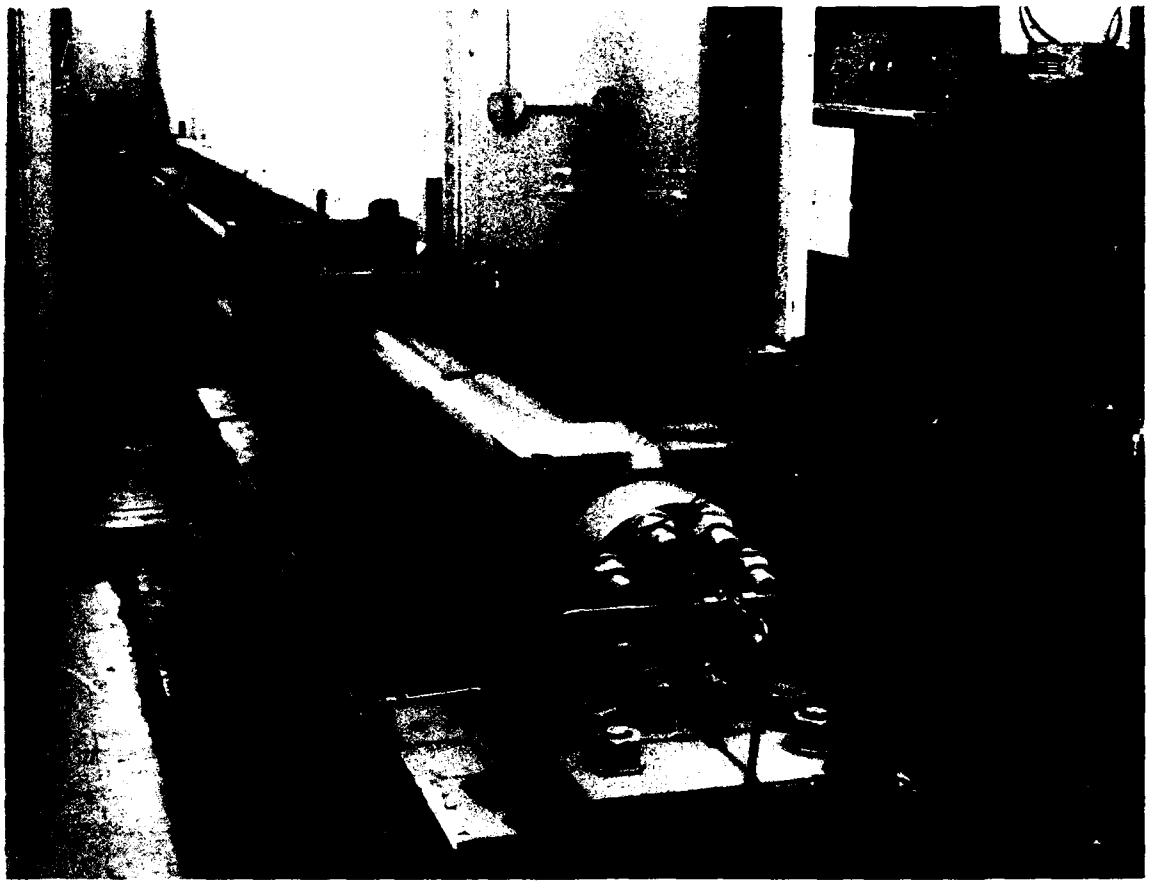


FIGURE 2. OVERVIEW OF GAS GUN FROM BREECH END

II. DESCRIPTION OF PARTS

Figure 3 is a schematic of the sabot stripper with attachable target assembly. A description of the five nonreplaceable metal parts (parts 1 through 5) and the nine replaceable rubber and metal parts is given in this section. Eight 1/2-13 UNC threaded rods (with nuts and washers) hold the parts together, and four 1-8 UNC threaded rods (with nuts and washers) hold the stripper to a steel baseplate at the muzzle of the gas gun. Also shown in Figure 3 is a sabot with a 0.5-in. cube. The parts are described in the order in which they are encountered by the sabot or the 0.5-in. cube that is released from the sabot as it is stopped. Most of the target plates have been 3x3 in. as shown in Figure 3. Parts 1, 2, 4, and 5 were fabricated from mild steel; part 3 was fabricated from armor steel.

Figure 4 shows the sabot entrance part (part 1); the dimensions are 5.294-in. wide, 6.184-in. high, and 2.995-in. thick. The aluminum sabot (1.567-in. outside diameter and 1.657-in. long) passes through the 1.992-in.-diameter entrance hole in this part and then into the sabot containment part. The entrance hole is only slightly larger than the sabot diameter to help ensure that fragments from the impacted sabot do not pass back through the entrance hole to possibly impact the gas gun muzzle flange.

The sabot containment part (part 2), which is shown in Figure 5, has dimensions 5.295-in. wide, 6.184-in. high, and 2.984-in. thick. A 3.500-in.-diameter hole was placed in this part to create a chamber to permit sabot debris fragments to move radially outward prior to being contained.

Figure 6 shows the materials that are impacted by the sabot. These materials are replaced after each shot. Figure 6(a) shows the 0.125-in.-thick rubber sheet pieces[5] that are epoxied to the metal pieces to mitigate the impact shock. The rubber sheet dimensions are nominally 3.4-in. wide and 5.5-in. high; they are always slightly less than the dimensions of the metal parts. Also shown are the two metal punches that were fabricated to cut 1.13- and 2.00-in.-diameter holes in the rubber pieces. The holes are cut by placing a punch and a rubber piece in a hand press. A replaceable 6061-T6 aluminum part is shown in Figure 6(b); the dimensions are 3.550-in. wide, 5.702-in. high, and 0.750-in. thick. A 1.000-in. diameter hole was placed in this part to stop the impacting aluminum sabot and allow the 0.5-in. cube to pass through unimpeded. Epoxied to this part are three front-surface rubber pieces and one back-surface rubber piece (all with 1.13-in.-diameter holes). The back-surface rubber piece is epoxied to the 1018 steel part shown in Figure 6(c). The rubber piece provides a low shock impedance layer between the impacted parts. The dimensions of the steel part are 3.542-in. wide, 5.698-in. high, and 0.750-in thick. This steel part also has a 1.000-in.-diameter hole to allow passage of the 0.5-in. cube through it. The back surface of this part has three rubber pieces epoxied to it to provide some impact isolation from the anvil part that supports it. Two pieces have 1.13-in.-diameter holes, and one piece has a 2.00-in.-diameter hole. The 2.00-in.-diameter hole piece (in contact with the anvil part) is used to allow the steel part to deform freely near the sabot impact area preventing damage to the anvil part.

The three front-surface rubber pieces followed by aluminum and steel parts provide a series of increasing shock impedance layers. They help to ensure that at the

higher impact velocities, the aluminum sabot is decelerated as slowly as possible so that its center portion remains intact, without shear failure.

Figure 7 shows the anvil part of the sabot stripper (part 3); the dimensions are 5.866-in. wide, 6.215-in. high, and 8.720-in. thick. The entrance and exit hole diameters are 1.000 and 2.250 in., respectively. The entrance hole, which extends 5.0 in. into the part, is the same as that for the replaceable aluminum and steel parts. The exit hole diameter is larger to ensure that a cube that may not have been released uniformly from a stopped sabot will not scrape the inside wall of the exit hole. The anvil part is bolted onto the steel baseplate with four 11-in.-long, 1-8 UNC threaded rods and nuts. Four 11-in.-long, 1/2-13 UNC threaded rods screw into the four holes on the front surface side and attach parts 1 and 2 and the replaceable parts to the anvil part [see Figure 7 (a)].

Figure 8 shows the clamp and mounting plates (parts 4 and 5, respectively) for securing a small target prior to impact; the dimensions of the clamp plate are 5.455-in. wide, 5.226-in. high, and 1.004-in. thick, and the dimensions of the mounting plate are 5.465-in. wide, 5.236-in. high, and 1.955-in. thick. Both plates have concentric 2.234-in.-diameter holes. For these experiments, nominally 3x3-in. target plates were epoxied to the front surface of the mounting plate to expedite assembly for cube impact [see Figure 8(b)]. The bottom of the target mounting plate contains two 3/8-16 UNC bolts and locking nuts for initial fine adjustment of the height of the plate above the steel baseplate (see Figure 8). The adjusted height between the baseplate and the bottom of the target mounting plate is 1.115-in. Four 11-in.-long, 1/2-13 UNC threaded rods and nuts are used to bolt the target plate between the clamp and mounting plates and to attach the completed target assembly to the back surface of the anvil part [see Figure 7(b)]. The target assembly is not clamped against the anvil part but is offset 2.25 in. from it to provide shock isolation between the sabot stripper and target assembly.

Table 1 provides the weight of each part for the sabot stripper and attachable target assembly. The principal energy-absorbing parts weigh 84.2 lb (the anvil part, the replaceable aluminum and steel parts, and the seven replaceable rubber pieces). The aluminum sabot weighs 0.2-lb (including two O-rings).

Figure 9 shows completed sabots that have been designed to carry a 0.5-in. flat-surface cube and a 0.249-in.-diameter rod. Sabot weights were reduced by placing round holes in the front of the cube-carrying sabot and a uniform recess in the front of the rod-carrying sabot. Empty cube- and rod-carrying sabots weigh 0.19 and 0.15 lb, respectively (not including O-rings). The cube-carrying sabot has a 0.508-in.-square socket that is 0.130-in. deep for the 0.5-in. cube. A central threaded hole (10-24 UNC) in the base of the socket is filled with fast-curing epoxy to secure the cube. The cube is centered in the socket by placing 0.004-in.-thick mica strips between the four side surfaces of the cube and the sides of the socket. The strips are removed after the epoxy has cured to provide a centered cube that only contacts the sabot at the base of the socket. This helps to ensure torque-free separation of the cube from the sabot.

TABLE 1. WEIGHTS OF PARTS FOR SABOT STRIPPER AND ATTACHABLE TARGET ASSEMBLY

Part Name	Weight (lb)
Part 1–sabot entrance part	24.0
Part 2–sabot containment part	18.7
Replaceable aluminum part with four rubber pieces	1.8
Replaceable steel part with three rubber pieces	4.4
Part 3–anvil part	78.0
Part 4–target clamp plate	6.7
Part 5–target mounting plate	13.1
Four 1-8 UNC threaded rods including washers and nuts	10.9
Eight 1/2-13 UNC threaded rods including washers and nuts	9.8

Figure 9 also shows a vacuum cover and a 3x3-in. steel target plate. The vacuum cover permits evacuation of the gas gun barrel to prevent reduction of the sabot velocity by air pressure in the barrel. The vacuum cover is fabricated from a 1.8-in.-inside-diameter polycarbonate support ring and a frangible annulus of 0.004-in.-thick polyester film with a 1.000-in.-diameter center hole. The polyester annulus is covered by a disk of 0.001-in. thick aluminum foil. The polyester film supports the aluminum foil against atmospheric pressure except in the center. The cube only impacts the 0.001-in.-thick aluminum foil as the cube and sabot exit the barrel. Mica sheet (0.004-in. thick) has also been used in place of the aluminum foil.

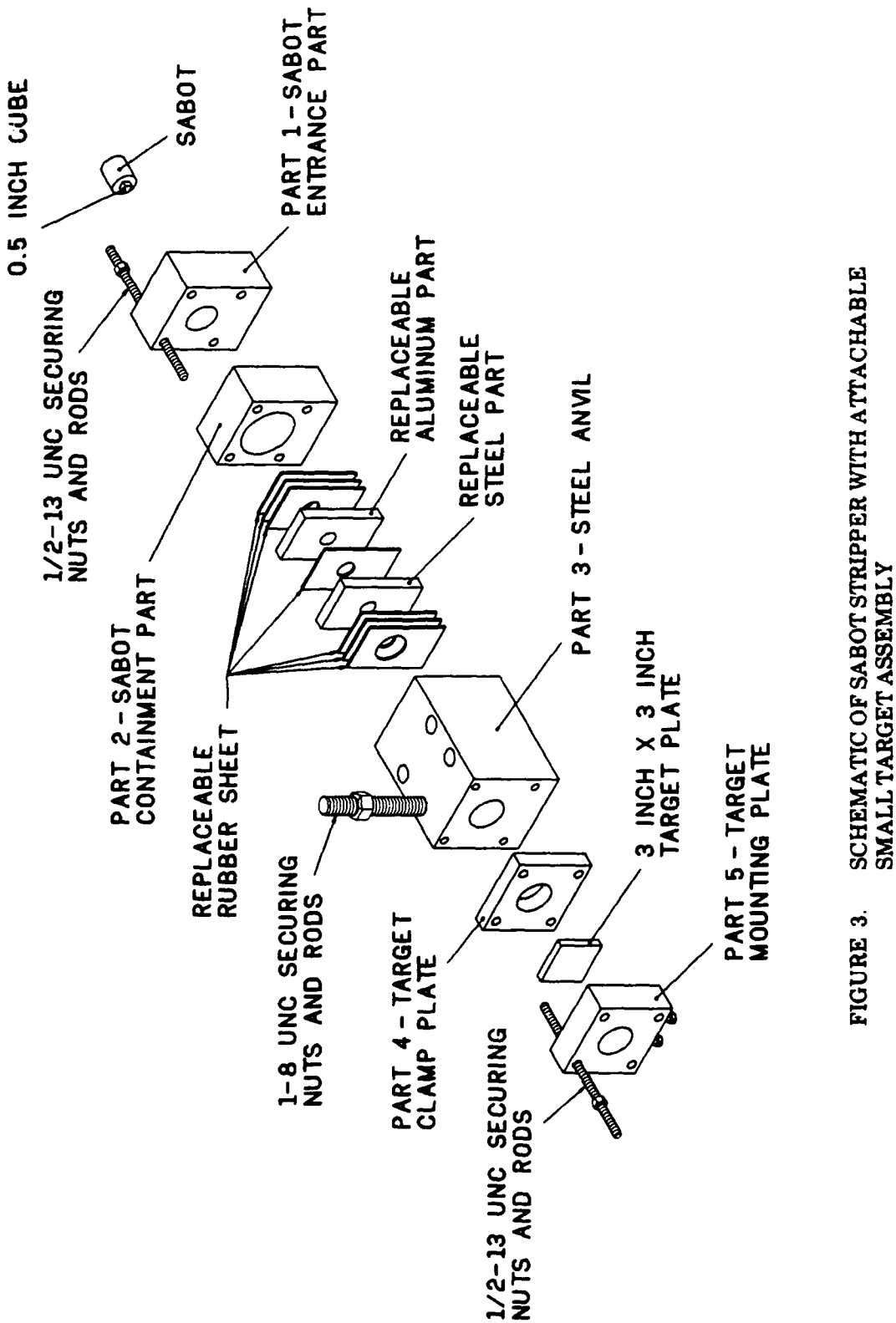


FIGURE 3. SCHEMATIC OF SABOT STRIPPER WITH ATTACHABLE SMALL TARGET ASSEMBLY

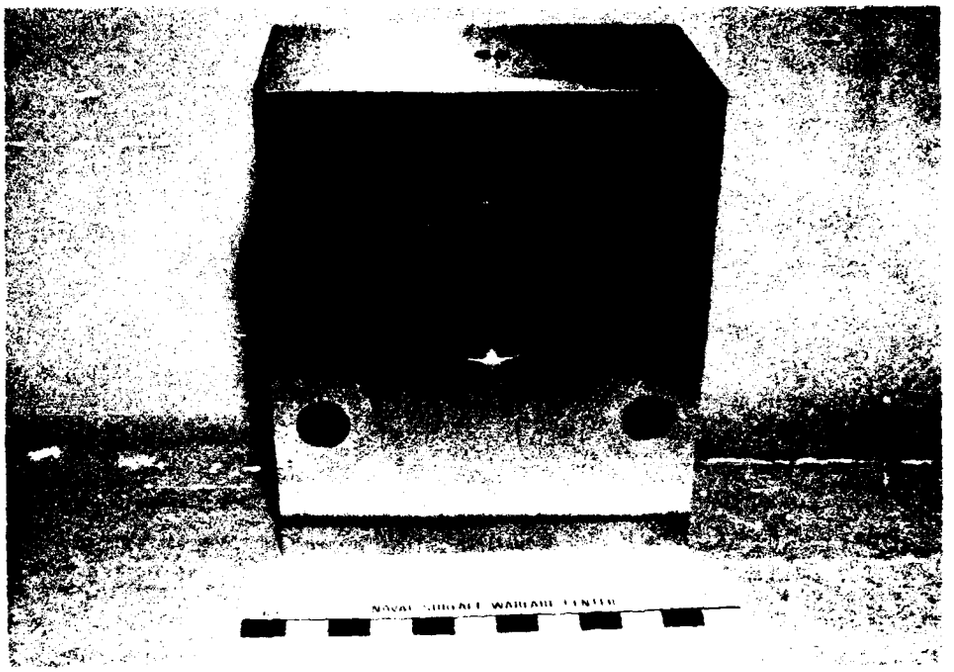


FIGURE 4. PART 1–SABOT ENTRANCE PART

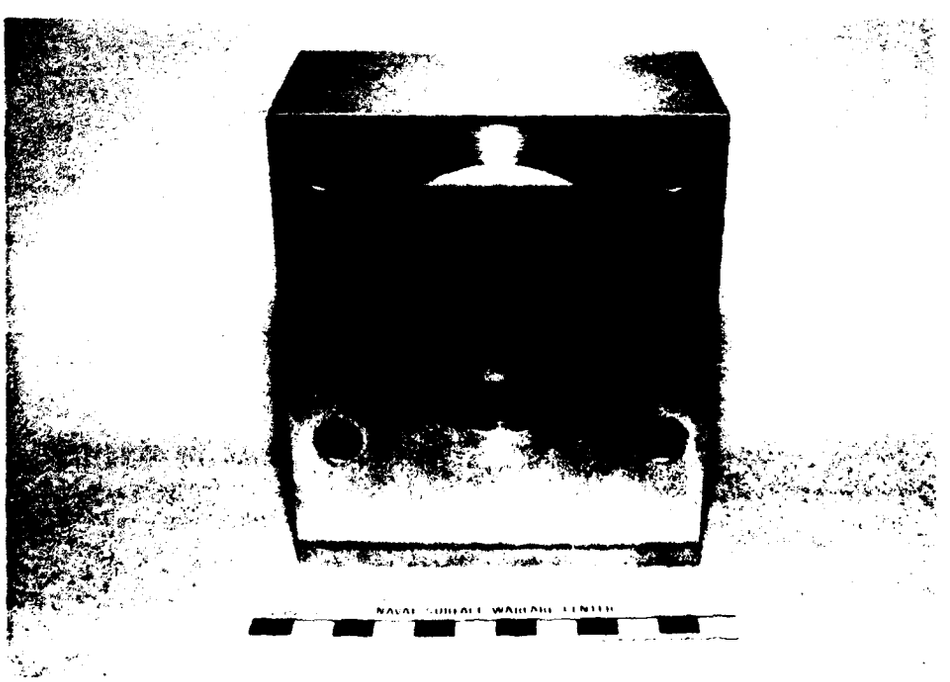
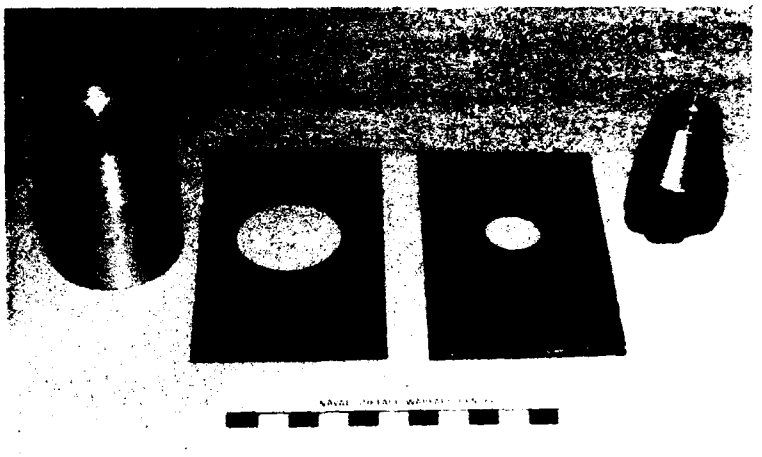
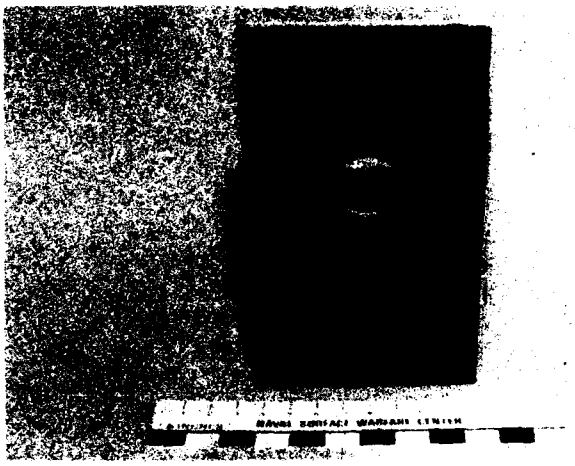


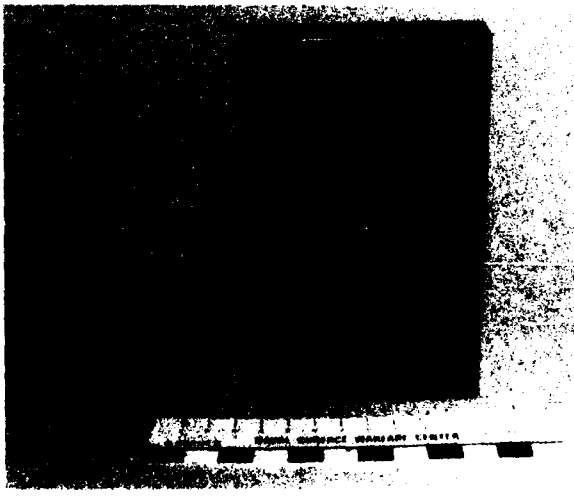
FIGURE 5. PART 2–SABOT CONTAINMENT PART



(a) RUBBER SHEET PIECES WITH METAL PUNCHES FOR CUTTING HOLES

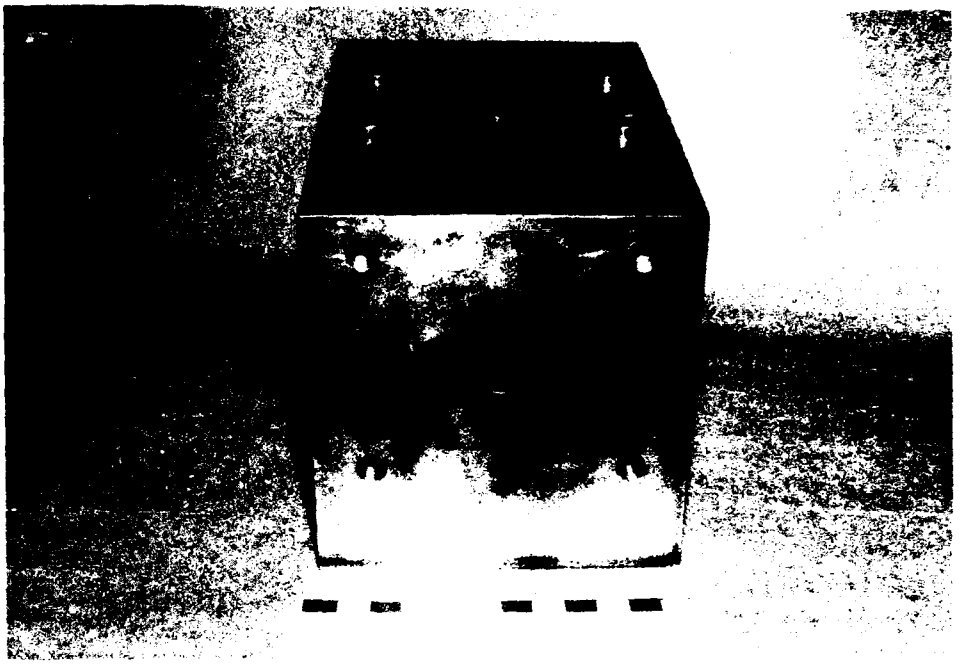


(b) REPLACEABLE ALUMINUM PART WITH THREE ATTACHED FRONT SURFACE RUBBER PIECES

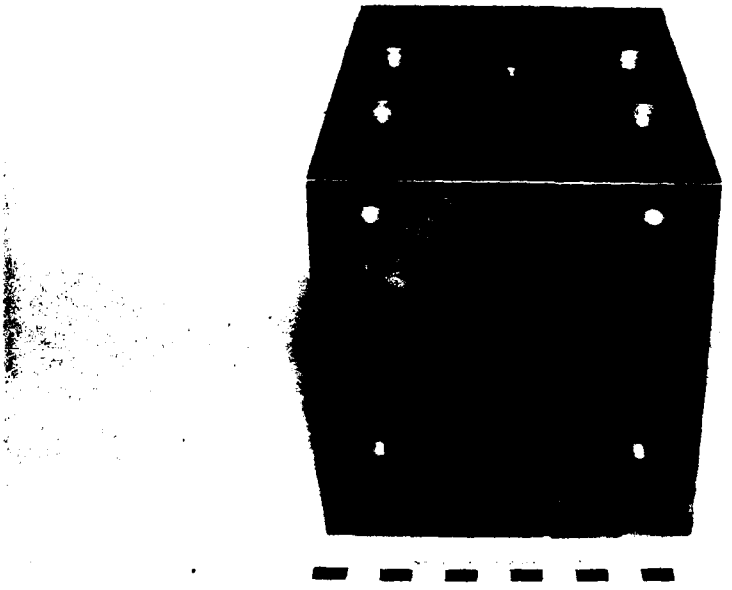


(c) REPLACEABLE STEEL PART WITH THREE ATTACHED BACK SURFACE RUBBER PIECES

FIGURE 6. REPLACEABLE ALUMINUM AND STEEL PARTS

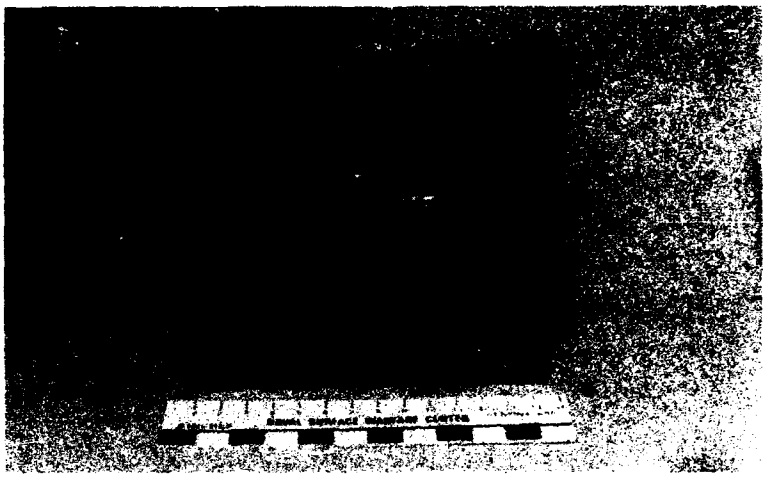


(a) FRONT SURFACE (CUBE ENTRANCE SIDE)

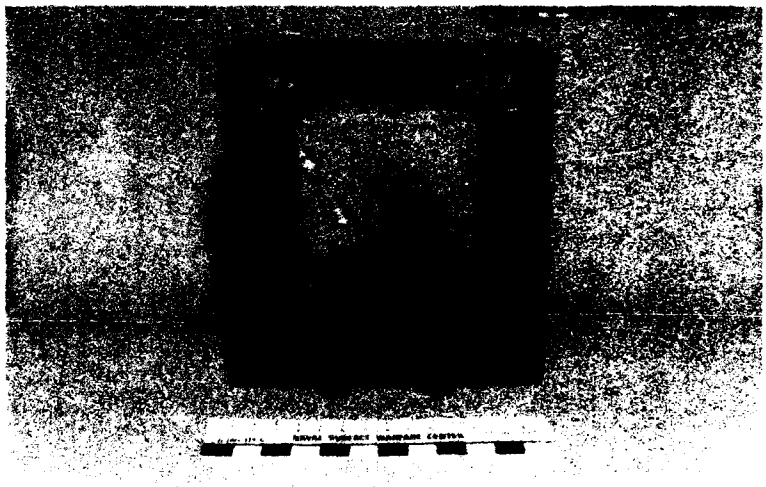


(b) BACK SURFACE (CUBE EXIT SIDE)

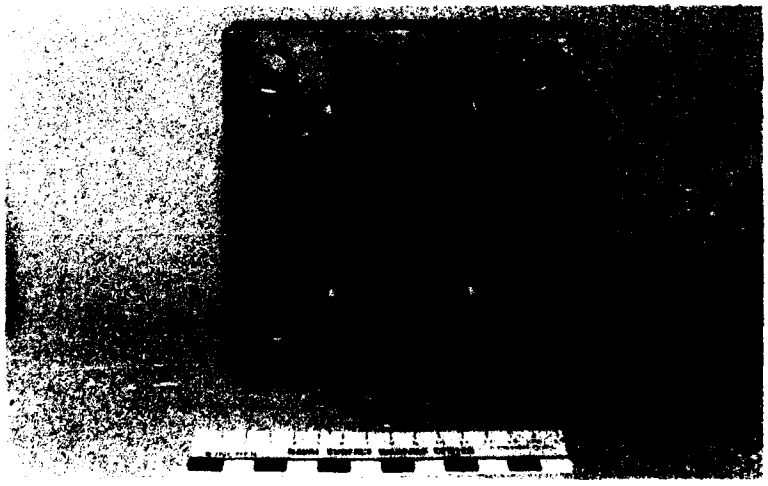
FIGURE 7. PART 3-ANVIL PART



(a) PART 4–TARGET CLAMP PLATE



(b) PART 5–FRONT SURFACE OF TARGET MOUNTING PLATE WITH ATTACHED TARGET



(c) PART 5–BACK SURFACE OF TARGET MOUNTING PLATE WITH ATTACHED TARGET

FIGURE 8. TARGET CLAMP AND MOUNTING PLATES

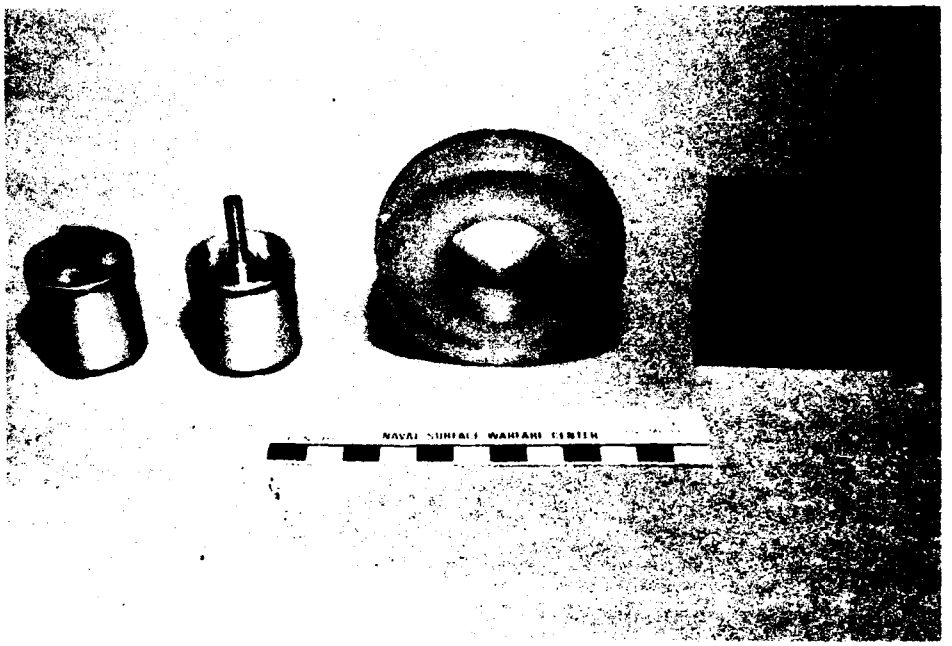


FIGURE 9. COMPLETED SABOTS, MUZZLE VACUUM COVER, AND TARGET PLATE

III. INSTALLATION AND ALIGNMENT PROCEDURE

This section describes the installation and alignment procedure to be used with the stripper parts described in Section II.

Figure 10 shows the 19-in.-wide by 1-in.-thick steel baseplate used for mounting the sabot stripper (the two round shafts and mounting pieces that are seen on the baseplate in this figure are for a different structure and are not part of the sabot stripper). The anvil part of the stripper is first aligned and then attached to the baseplate with the four 1-8 UNC threaded rods and nuts. The alignment tool consists of a 6-in.-long by 0.982-in.-outside diameter brass sleeve that slides with minimum tolerance on a 36-in.-long by 0.938-in.-diameter hard steel rod. The steel rod is aligned with the gas gun bore by inserting the rod into an axial hole in an 11-in.-long by 1.570-in.-diameter aluminum rod that slides into the muzzle end of the barrel. A 0.998-in.-outside diameter brass sleeve around the steel rod end prevents galling of the hole in the aluminum rod. The movable 0.982-in.-outside diameter brass sleeve is placed inside the 1.000-in.-diameter holes in the anvil, steel, and aluminum parts before securing them. This ensures that these parts are aligned with respect to the sabot when it exits the gas gun.

Figure 11 shows the replaceable aluminum and steel parts (with attached rubber pieces) being aligned. Threaded rods and nuts are used to secure these parts between the anvil and containment parts as shown in Figure 12. The entrance part is aligned using a large-diameter brass sleeve (6-in.-long, 1.984-in. outside diameter, and 0.940-in. inside diameter) that slides on the steel alignment rod. Figure 13 shows the alignment of this part.

Figure 14 shows the assembled and aligned sabot stripper after the alignment tool has been removed. The sabot travels approximately 9 in. after exiting the gas gun muzzle before reaching the entrance port. The arrangement in Figure 14 is used for those experiments in which a large target is impacted with a 0.5-in. cube (or other sabot-stripped object). The large target is secured on a metal platform structure approximately 20 ft from the gas gun muzzle. Figure 15 shows a metal plate array target before impact with a 0.5-in. cube. Other targets have been used. The metal cube exits the 1-ft diameter pipe (on the right in Figure 15) to impact the array. If the cube perforates the array, it is soft recovered in the 0.75-in.-thick plywood layers (on the left in Figure 15). A frangible muzzle cover is placed over the end of the gun before firing the shot to permit evacuation of the barrel (see right side of Figure 14). For higher-velocity shots (approximately 3100 ft/sec), the sabot velocity could be reduced by as much as 10 percent if the barrel is not evacuated.

For smaller targets (in this case, 3x3-in. by 0.5-in. thick), the target assembly is attached to the sabot stripper by four 1/2-13 UNC threaded rods and nuts. Figure 16 shows the target mounting plate with attached target and clamp plate before securing them to the cube exit side of the anvil part. Figure 17 shows the completed target assembly attached to and offset from the aligned sabot stripper.

FIGURE 10. OVERHEAD VIEW OF GAS GUN MUZZLE REGION SHOWING STEEL BASEPLATE BEFORE INSTALLATION OF SABOT STRIPPER AND ATTACHABLE TARGETASSEMBLY. (THE SABOT EXITS THE GUN MUZZLE SHOWN ON THE RIGHT.)

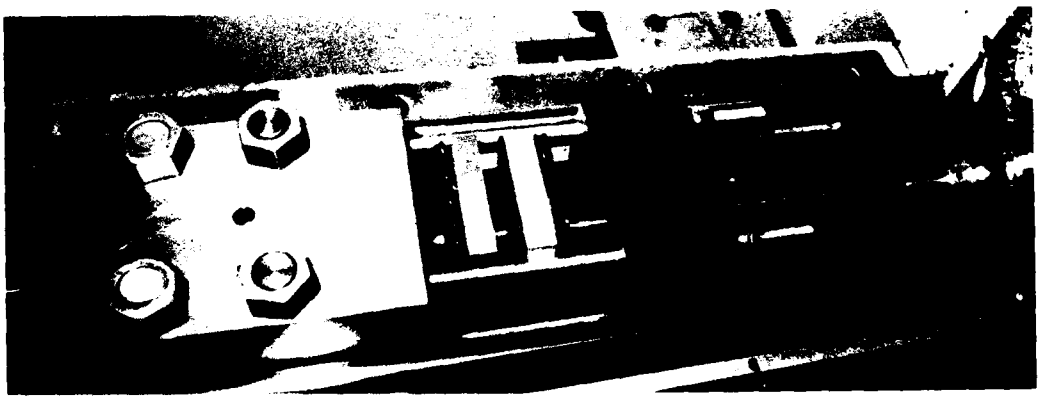


FIGURE 11. ALIGNMENT OF REPLACEABLE STEEL AND ALUMINUM PARTS BETWEEN CONTAINMENT PART AND SECURED ANVIL PART

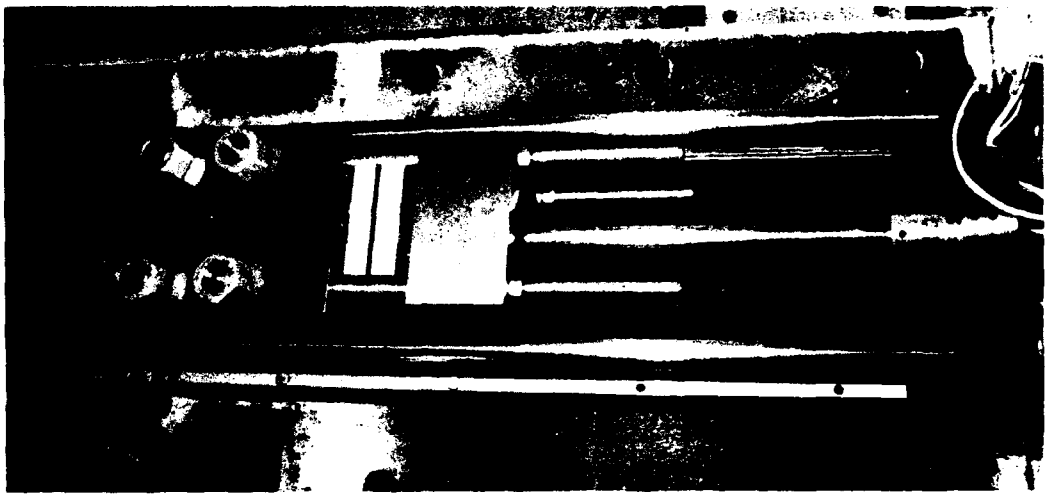


FIGURE 12. SECURED STEEL, ALUMINUM, CONTAINMENT, AND ANVIL PARTS

FIGURE 13. ALIGNMENT OF ENTRANCE PART

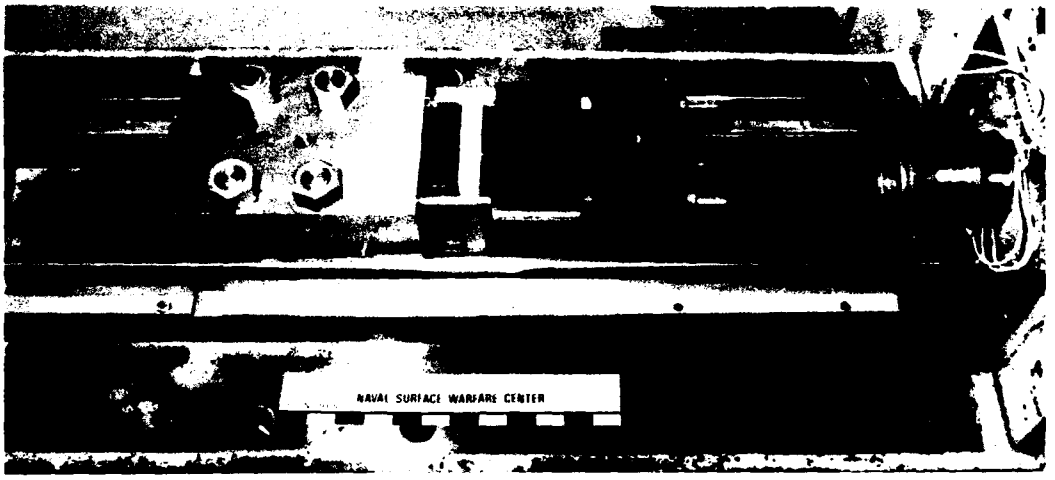


FIGURE 14. ALIGNED SABOT STRIPPER

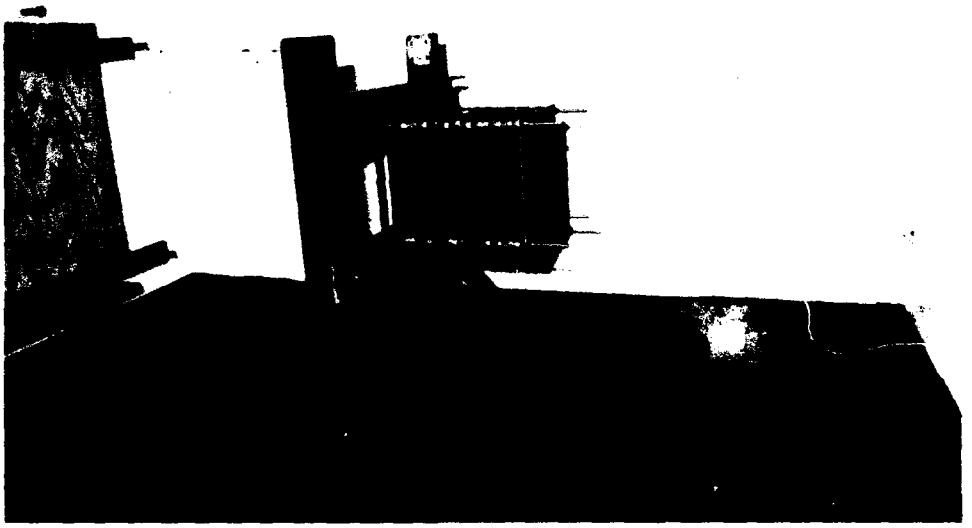


FIGURE 15. EXPERIMENTAL SETUP FOR METAL PLATE ARRAY TARGET BEFORE IMPACT WITH 0.5-IN. STEEL CUBE. (EACH PLATE IS 15x15 IN. THE CUBE EXITS THE 1-FT DIAMETER PIPE ON THE RIGHT.)

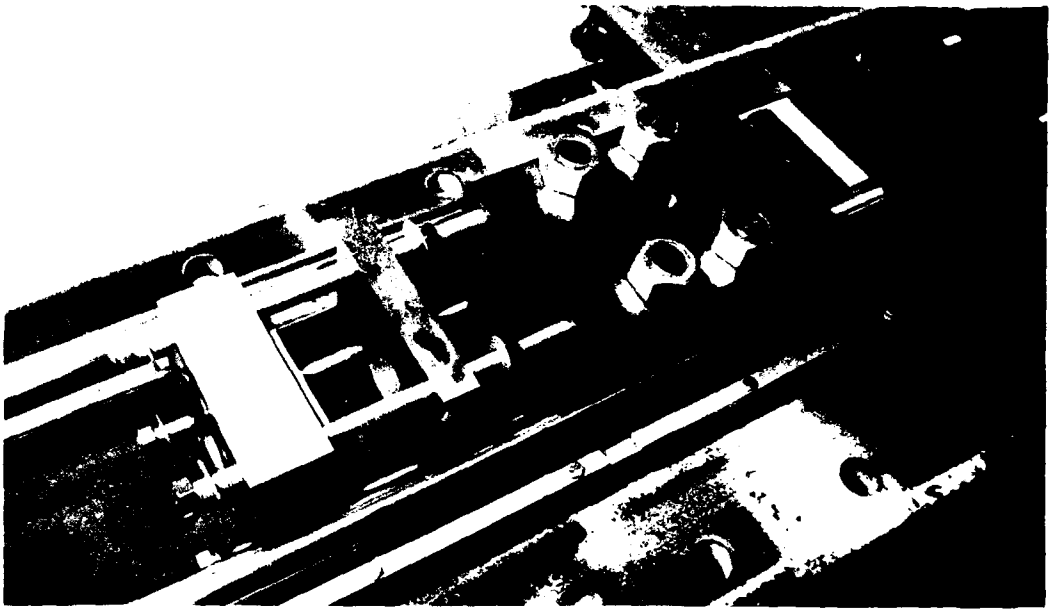


FIGURE 16. INSTALLATION OF CLAMP PLATE AND TARGET-MOUNTING PLATE WITH ATTACHED SMALL TARGET

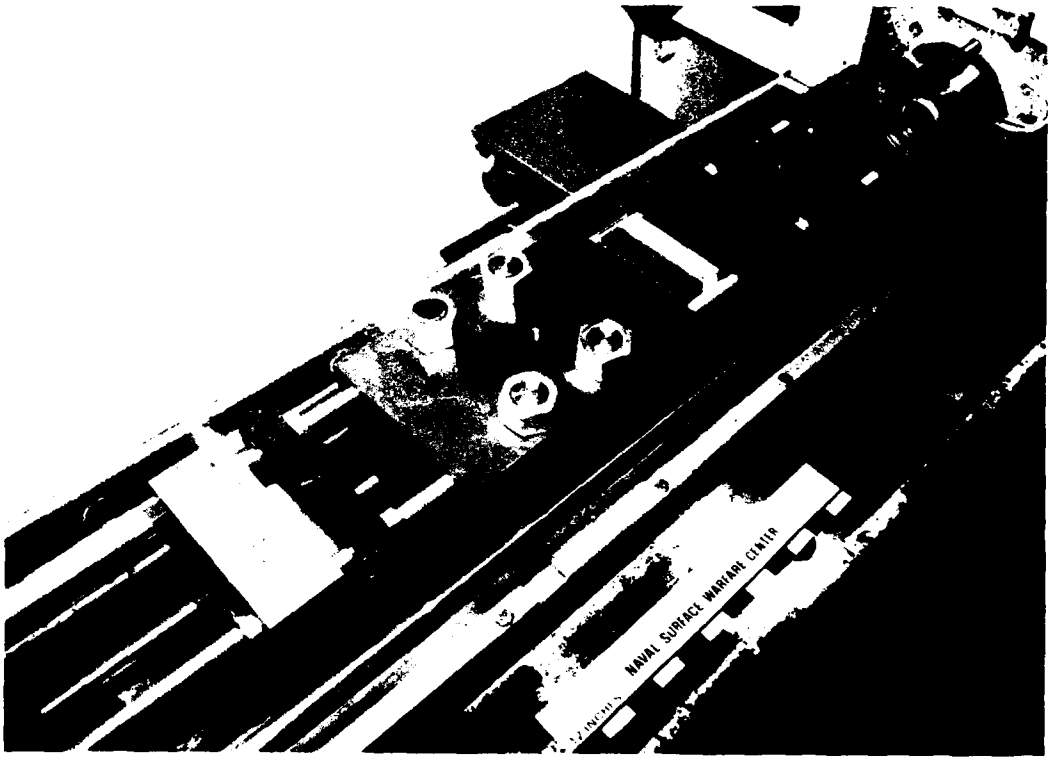


FIGURE 17. ALIGNED SABOT STRIPPER WITH ATTACHABLE SMALL TARGET ASSEMBLY. (A FRANGIBLE VACUUM COVER IS SHOWN ON THE GAS GUN MUZZLE.)

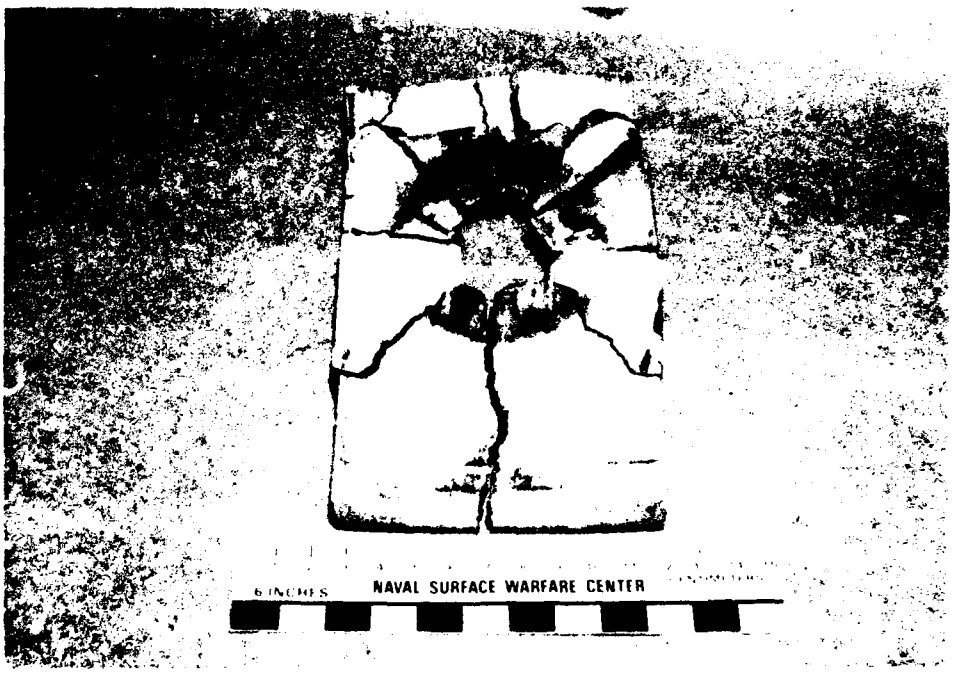
IV. SAMPLE RESULTS

Figure 18 shows the replaceable 6061-T6 aluminum plate after impact with a 3106-ft/sec sabot that carried a 0.5-in. steel cube. Erosion of the plate in the impact area as well as plate fragmentation occurred at this impact velocity [see Figure 18 (a)]. No radial fractures or plate fragmentation occurred in the aluminum plate at a lower sabot impact velocity of 2013 ft/sec. Figure 19 shows the replaceable steel plate for the 3106-ft/sec shot. A permanent out-of-plane deformation of approximately 0.080 in. occurred at this impact velocity [see Figure 19 (c)]. The main sabot remnant stopped in this plate and was partially extruded into the 1-in.-diameter hole. A ring of sabot material is also shown in Figure 19. Other smaller sabot fragments that were captured in the containment part are not shown. The replaceable rubber sheet pieces that were epoxied to the steel and aluminum plates were removed after the experiment to clearly show the damaged plates after sabot impact. The target for the 3106-ft/sec velocity shot was a 3x3-in. steel plate that was secured in the small-target assembly. The cube impacted the target plate in a flat-surface orientation.

Figure 20 shows a 3x3-in. aluminum target plate that was impacted by a 0.5-in. steel cube that was launched in the flat-surface orientation at 2010 ft/sec. The target plate was held in the small-target assembly. Note that the shapes of the aluminum shear plug, steel cube, and perforation hole indicate that the flat surface of the cube impacted the aluminum plate.

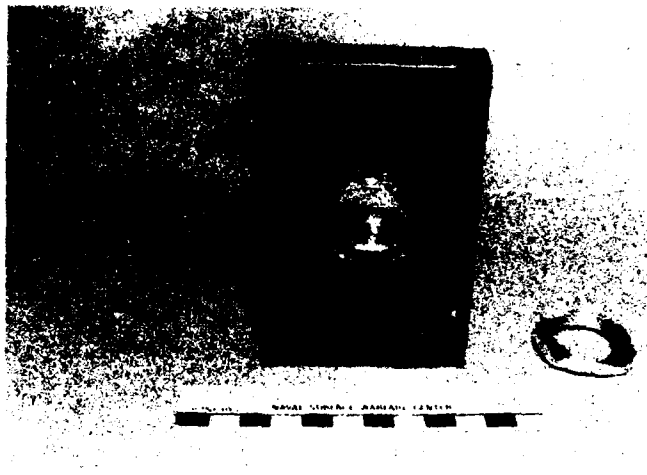
Twenty-seven experiments using the sabot stripper have been performed (15 using the small- and 12 using the large-target configuration). The sabot stripper performed satisfactorily for all experiments.

(a) IMPACT SURFACE

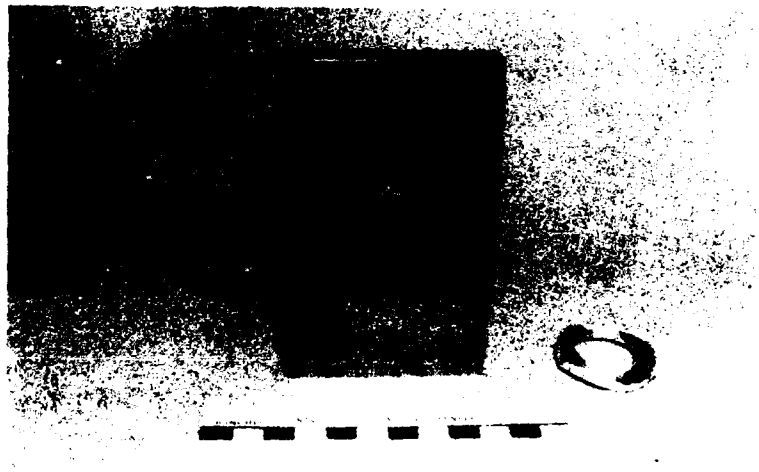


(b) BACK SURFACE

FIGURE 18. REPLACEABLE ALUMINUM PART AFTER IMPACT WITH 3016-FT/SEC SABOT



(a) FRONT SURFACE



(b) BACK SURFACE

(c) SIDE VIEW

FIGURE 19. REPLACEABLE STEEL PART WITH EMBEDDED SABOT AFTER IMPACT AT 3106 FT/SEC

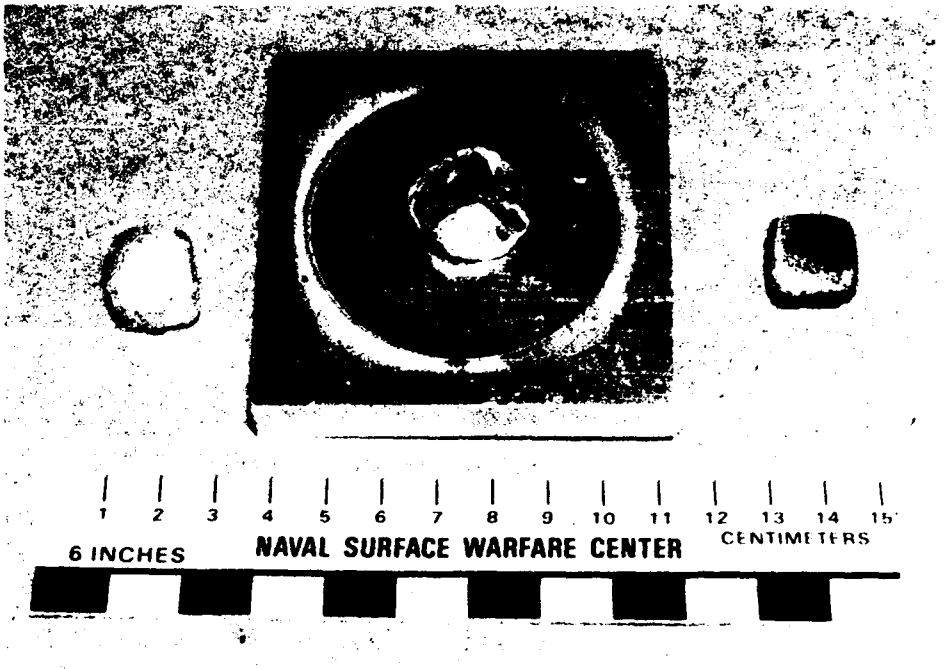


FIGURE 20. BACK SURFACE OF 0.516-IN.-THICK 6061-T6 ALUMINUM TARGET PLATE FOR 1018 STEEL CUBE IMPACT VELOCITY OF 2010 FT/SEC. (THE SHEARED ALUMINUM PLUG IS SHOWN ON THE LEFT AND THE STEEL CUBE IS SHOWN ON THE RIGHT.)

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5. Cloth-inserted rubber sheet that consists of alternate layers of synthetic rubber compound and cotton fabric; Federal Stock Number 5330-00-179-0052; Supplier: Legg Company, Inc., 325 East Tenth Street, Halstead, KS 67056.

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A nonaerodynamic sabot stripper has been designed and implemented for use with the Naval Surface Warfare Center Dahlgren Division (NSWCDD) 40-mm smooth-bore gas gun. The stripper consists of several metal parts to stop and contain the sabot while allowing the carried object to pass unhindered through it. The single-piece sabot is stopped by impacting replaceable layers of 0.750-in.-thick aluminum and steel plates and 0.125-in.-thick rubber sheets. The metal plates and rubber sheets have 1.00- and 1.25-in.-diameter holes, respectively, for passage of the carried object. The sabot stripper is located several inches from the muzzle of the gas gun and is aligned before each shot using a special metal fixture that is inserted into the gun muzzle. Cubes measuring 0.5 in. have been launched in a flat-faced orientation; other shapes (e.g., spheres or cylinders) and orientations could also be used.

Both small- and large-target configurations can be used. Small targets (up to 6-in. on a side) can be positioned in an assembly that attaches to the sabot stripper and is located several inches from it. Most small targets have been 3x3-in.plates of various thicknesses. Large targets (up to several feet on a side) are secured to a steel table that is located approximately 20 ft from the sabot stripper. Twenty-seven experiments using the sabot stripper have been performed to date; 15 using the small-target configuration and 12 using the large-target configuration. The velocity range for the experiments was from 1600 to 3100 ft/sec. The sabot stripper performed satisfactorily.

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