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COMPARATIVE EVALUATION OF POWDER ACTUATED STUD DRIVING TOOLS FOR UNDERWATER USE

G. M. Janney, et al

Navy Experimental Diving Unit
Washington, D. C.

18 February 1959

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13. ABSTRACT

Powder actuated, stud driving tools were submitted by three different manufacturers for a comparative evaluation. The purpose of this evaluation was to determine the underwater operating capabilities, the relative ease of operation, and the safety characteristics of each of the tools. The evaluation consisted of laboratory type performance tests and a limited subjective evaluation. Two of the tools were found to be satisfactory and were recommended for field evaluation. The other tool was determined to be unsuitable for use by a diver.

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EVALUATION REPORT 10-59

COMPARATIVE EVALUATION OF POWDER ACTUATED STUD DRIVING TOOLS FOR UNDERWATER USE

PROJECT NS 185-005 SUBTASK 1 TEST 47

18 February 1959

CONDUCTED
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INFORMATION TO BE WITHHELD

COMPARISON OF PRICE QUOTATIONS FOR STUDS AND AMMUNITION OF THE TYPES USED IN THIS EVALUATION

	QUANTITIES OF 500	QUANTITIES OF 1000
TOOL A	$.26 ea.	$.22 ea.
TOOL B	(No quotation was obtained in veiw of the results of the tests on this tool.)	
TOOL C	$.85 ea.	$.75 ea.

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ABSTRACT

Powder actuated, stud driving tools were submitted by three different manufacturers for a comparative evaluation. The purpose of this evaluation was to determine the underwater operating capabilities, the relative ease of operation, and the safety characteristics of each of the tools. The evaluation consisted of laboratory type performance tests and a limited subjective evaluation. Two of the tools were found to be satisfactory and were recommended for field evaluation. The other tool was determined to be unsuitable for use by a diver.

SUMMARY

PROBLEM

Determine the following characteristics of underwater, powder actuated stud driving tools manufactured by the Remington Arms Co., The Mine Safety Appliance Co., and Olin Mathieson Chemical Corporation:

(1) Underwater performance

(2) Ease of Operation by a diver

(3) Safety

FINDINGS

The tools manufactured by the Mine Safety Appliance Co. and Olin Mathieson Chemical Corp. were both found to be satisfactory. The latter tool was found to be easier to operate and maintain. The tool manufactured by The Remington Arms Co. was found to be not suitable for use by a diver.

RECOMMENDATIONS

It is recommended that the tools manufactured by the Mine Safety Appliance Co. and Olin Mathieson Chemical Corp. be given field evaluations. It is also recommended that production models of these tools be manufactured of non-corrosive materials. No further evaluation of the tool submitted by the Remington Arms Co. is recommended.

REFERENCES

(a) Telephone conversation with Mr. Foran (BuShips, Code 638) on 7 March 1958.
(b) BuShips letter S92-(2) (8688) EN 28/A2-11 of 17 February 1942.
(c) General Stores, Philadelphia letter ser 120A of 23 August 1957.
(d) BuShips Notice 9880 ser 538-435 of 4 March 1958.
(e) MinLant letter ser 324 of 2 October 1956.
(f) EODU ONE spdltr ser 326 of 17 October 1956.
(g) Service Force Atlantic Fleet ltr ser 40/9635 of 22 October 1956.
(h) Service Force Pacific Fleet ltr ser 704 of 10 October 1956.
(i) EODU TWO letter ser 354 of 20 October 1956.
(j) Chief of Industrial Div., Panama Canal Co. letter to BuShips of 8 January 1958
(k) EDU letter report 8-55, "Ramset Power Tool"
(l) EDU Evaluation Report 2-56, "Test of Ramset Power Tool Cartridges after Immersion"
(m) U.S. Naval School, Ship Salvage letter report of 24 July 1957.
(n) MIL-T-2792 of 23 August 1951.
(o) Interim Federal Specification GGG-D-00777(NavShips) of 20 April 1954.

ADMINISTRATIVE INFORMATION

The Mine Safety Appliance Co., Olin Mathieson Chemical Corp., and the Remington Arms Co. have developed powder actuated tools for use in underwater salvage and repair work.

Prototype tools and ammunition were submitted by each of the three manufacturers to the Experimental Diving Unit in accordance with the instructions from the Bureau of Ships (Code 638).

By reference (a), the Bureau of Ships directed the Experimental Diving Unit to evaluate these tools in a comparative type of evaluation.

C. M. PRICKETT, GM1(DV), USN was designated as project engineer and ENS G. M. JANNEY, USNR as cognizant Project Officer.

Work commenced on 15 July 1958.

The following breakdown indicates the manpower expended for this project:

DESCRIPTION		MANHOURS
Preliminary preparations		20
Performance tests		150
Subjective tests		30
Photography		4
Report preparation		60
Report typing and duplication		15
	TOTAL	279

This report is issued in the Evaluation Report series, distributed only by the Bureau of Ships. This is the first report for Project NS185-005, Subtask 1, Test 47. Additional reports are anticipated concerning a field evaluation and concerning the evaluation of heavy duty powder actuated tools for underwater use.

Charges incurred were lodged against Project Order 16102/58 and 16102/59.

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1. INTRODUCTION

1.1 Background

1.1.1 Powder actuated tools for underwater use have been available in the U.S. Navy since before World War II. Reference (b) described the tools, listed the allowances for powder actuated tools of the various types of ships, and gave general instructions and safety precautions for their use. One accident which had occurred in the use of a powder actuated tool was mentioned. The tools available at that time included stud divers, cable cutters, rivet removers, wire rope presses, and electric cable presses. The tools were basically Damage Control equipment and the underwater capabilities were secondary.

1.1.2 Reference (c) stated that the use of powder actuated tools in the U.S. Navy since 1946 has been insignificant. Reference (d) announced that the tools were deleted from the allowance list of all ships except repair and salvage types.

1.1.3 The lack of use of powder actuated tools is attributed to the complexity and variety of the tools, a lack of personnel trained in the use of the tools, and apprehension regarding the potential dangers in the use of powder actuated tools.

1.1.4 References (e), (f), (g), (h), and (i) each state that requirements do exist for powder actuated tools for underwater use, and reference (j) states, "Powder Actuated Velocity Power Divers are an essential tool to our salvage activity in making emergency underwater repairs to damaged ships in the Canal Zone."

1.1.5 Several manufacturers have adapted their standard commercial-type tools for light underwater salvage purposes, or have developed a new tool for the purpose. These tools are lighter, simpler, and possess more safety features than the old standard stock tools.

1.1.6 A powder actuated stud driver ("Ramset Power Driver" manufactured by the Olin Mathieson Corp.) was tested at EDU in 1955. This tool was found to be capable of satisfactorily driving studs into mild steel of up to 3/4" thickness. The stud driver was returned to the manufacturer with recommendations for minor modifications. Reference (k) is a report of the tests conducted on this tool. ("Tool C", which is one of the tools tested in this project, is a powder actuated stud driver which was subsequently designed and manufactured by the Olin Mathieson Corp.) Cartridges used in the Ramset Power Driver were tested at EDU in 1956 to determine whether they were adequately water-proofed. Reference (e), is the report of these tests and it states that the water proof seal was satisfactory.

1.1.7 A program for the evaluation of powder actuated tools was established at the former U.S. Navy School, Ship Salvage, Bayonne, N.J. Reference (m) is an informal report concerning this evaluation. Recommendations were made for modifying the tool which was tested (Model 455 Stud Driver, manufactured by the Remington Arms Co., Inc.), and it was further recommended that the tool be issued as a damage control tool. ("Tool B" which is one of the tools tested in this project is a modified version of the Model 455 Stud Driver, incorporating the recommendations of reference (m).)

1.1.8 In March 1958, by reference (a), the Bureau of Ships directed the Experimental Diving Unit to evaluate tools designed or adapted for underwater use by manufacturers of commercial powder actuated tools. Powder actuated tools for this evaluation were submitted by the Mine Safety Appliance Co., Olin Industries Inc., (Ramset Division), and the Remington Arms Co.

1.1.9 Reference (n) is a specification for surface powder actuated tools and reference (o) is a specification covering the old standard stock tools mentioned above. These specificatons were used as a guide where applicable in conducting this evaluation.

1.2 Objective

1.2.1 The objective of this project was to determine the underwater performance capabilities, case of operation, and safety characteristics of three different powder actuated stud driving tools.

1.3 Scope

1.3.1 The scope of the project was restricted to Laboratory type performance tests and a limited number of subjective dives to determine handling and operating characteristics. Evaluation of the tools for general above water, damage-control-type use is not included.

2. DESCRIPTION

2.1 General

2.1.1 The three tools which evaluated in this project are as follows:

Tool A - A modified "Velocity-Power Study Driver" Model GH-1 manufactured by the Mine Safety Appliance Co., Pittsburg, Pa.

Tool B - A modified "Remington Stud Driver" Model 455 manufactured by Remington Arms Co., Inc., Bridgeport, Conn.

Tool C - The prototype of an "Underwater Salvage Tool Model-N2" manufactured by Ramset Fastening System, Winchester-Wester Division of Olin Mathieson Chemical Corp., Cleveland, Ohio.

For convenience, these tools are referred to throughout this report as Tool A, Tool B, and Tool C as designated above.

2.1.2 All three tools are similar to pistol type firearms in general appearance and in the function of component parts. Each consists of the following major components:

(a) pistol grip handle
(b) firing mechanism
(c) barrel

2.1.3 All of the tools operate on the same basic principle; a pointed metal stud is projected from a cylindrical barrel by detonating a powder charge. The stud acquires sufficient velocity to penetrate mild steel, wood, concrete, and other materials.

2.1.4 The tools are operated by placing the muzzle of the barrel against the material into which the stud is to be driven. The powder charge is then detonated, driving the stud out of the barrel, leaving the stud imbedded in the material.

2.2 Tool A

2.2.1 Tool A is a modified version of a commercially available powder actuated study driver, initially designed for above water use. To allow the tool to be used under water, without losing penetrating power, several short grooves have been cut in the inside of the barrel. The grooves allow some of the expanding gases to by-pass the stud, clearing the barrel of water ahead of the stud. This gives the tool essentially the same operating characteristics above water as underwater.

The following is a list of additional modifications which were made to adapt this tool for underwater use:

(a) The handle was made longer and left open at the bottom for easier handling when wearing diver's gloves.

(b) The trigger was lengthened also to facilitate operation with diver's gloves.

(c) A cocking lever was added to provide additional safety from accidental discharge.

(d) A block was attached to the barrel to provide a better grip when wearing diver's gloves.

The tool as modified is shown in figure 1. Figure 2 shows the standard commercial tool disassembled to show the component parts, which are essentially the same as those of the unmodified tool. The tool is approximately 13" long and weighs 7 lbs.

2.2.2 Powder Loads and Studs

Tool A fires 3/8" studs, using a .44 caliber center fire cartridge to drive the stud. The cartridge is attached to a small piston which in turn is attached to the stud. The assembly can be seen in figure 1. The piston serves to eliminate angular deflection of the stud in the barrel and also to make a seal in the barrel so as to make efficient use of the expanding gases. A 1/2" stud driven by a .32 caliber cartridge can be fired by installing a smaller, interchangeable barrel. Only the 3/8" stud and the larger barrel were tested, however.

2.2.3 A variety of stud types can be used in Tool A including studs with solid heads, or with internally or externally threaded heads. Only studs having externally threaded heads were tested.

2.2.4 The cartridges are available in six different powder loads (extra light, light, medium, heavy, extra heavy, and magnum) so that the studs can be correctly driven into different thicknesses and types of materials. The powder charges are identified by color coding of the end of the cartridge. Only the medium powder load (green) was used in this project. This load was suitable for driving a 3/8" stud into 1/2" of mild steel.

2.2.5 Operation

To drive a stud into a work surface, the operator must follow the procedure outlined below:

(a) Rotate the barrel housing 180° clockwise, opening the breech.

(b) Drop a stud assembly into the breech.

(c) Rotate the barrel housing 180° counterclockwise, closing the breech.

(d) Move the cocking lever away from the barrel housing and then back against the housing (this cocks the firing pin).

(e) Position the tool against the work surface.

(f) Push the tool against the work surface until the barrel is depressed into the housing.

(g) Pull the trigger, firing the stud.

(h) Rotate the barrel housing 180° opening the breech.

(i) Remove the empty cartridge either by grasping with the fingers or by inserting the ramrod (Shown in figure 1) through the muzzle of the tool. The latter method is always necessary when the operator is wearing gloves.

(j) Remove the piston from the end of the stud by knocking it off or pulling with pliers.

2.2.6 Safety features

A safety shield is attached to the muzzle end of the tool. This shield is intended to stop any flying shrapnel. The possibility of unintentional firing is minimized by requiring that the tool has been cocked and that the tool is being pushed against the work surface at the time the trigger is pulled. The requirement that the tool be against a work surface also presents the stud from being fired through the air.

If the tool is tilted more than a small angle (approximately 10°) from the work surface, it will not fire.

2.3 Tool B

2.3.1 Tool B is a modified version of another commercially available powder actuated stud driver, initially designed for above water use. The initial modification was tested for underwater use at the U.S. Naval School, Ship Salvage in Bayonne, New Jersey as reported in reference (m). Modifications were made based on the recommendations of the U.S. Naval School, Ship Salvage, The following modifications from the standard tool are listed below:

(a) The force required to cock the tool was reduceu.

(b) A thumb safety button was added to ensure that the tool would not be unintentionally fired.

(c) Raised ridges on the barrel housing were added to provide a better grip when wearing divers' gloves.

(d) The trigger was lengthened to facilitate operation when wearing divers' gloves.

The tool as modified is shown in figure 3. Figure 4 is a diagram showing the component parts of the standard tool. These are essentially the same for the modified one.

2.3.3 A variety of stud types can also be used with Tool B. Only a 3/8 inch stud with the externally threaded head was used in the tests. This stud is shown in figure 3.

2.3.4 The cartridges are .32 caliber and are available in six different powder loads (extra light, light, medium, heavy, extra heavy and magnum), so that the correct penetration can be achieved in different thicknesses and types of materials. The powder charges are identified by color coding of the wax which is used to seal the open end of the cartridge. Only the extra heavy powder load (purple) was used in this project.

2.3.5 Operation

To drive a stud into the work surface, the operator must follow the procedure outlined below:

(a) Rotate the locking ring counterclockwise.

(b) Pull the handle rearward.

(c) Rotate the handle clockwise.

(d) Drop a stud into the barrel.

(e) Insert a cartridge into the chamber.

(f) Rotate the handle counterclockwise.

(g) Push the handle forward, closing the tool.

(h) Rotate the locking ring clockwise.

(i) Position the tool against the work surface.

(j) Push the tool against the work surface, depressing the barrel into the housing.

(k) Depress the thumb button.

(l) Pull the trigger, firing the stud.

(m) Rotate the locking ring counterclockwise.

(n) Pull the handle rearward.

(o) Rotate the handle clockwise.

(p) Grasp the ejector ring and snap it rearward, ejecting the empty cartridge.

2.3.6 Safety features

A safety shield is attached to the muzzle end of the tool to stop any flying shrapnel.

The possibility of unintentional firing is minimized by requiring that the locking ring has been rotated, the thumb button is being depressed, and that the tool is being pushed against a work surface at the time the trigger is pulled. The requirement that the tool be held against the work surface also prevents firing the stud through the air.

If the tool is tilted beyond a small angle (approximately 10°), the tool will not fire.

2.4 Tool C

2.4.1 Tool C is a prototype model of a powder actuated stud driver designed specifically for underwater use, but with above water capabilities as well. The fundamental difference between this tool and tools B and C is that it employs expendable barrels which contain both the powder charge and the stud. The tool and one of the expendable barrels is shown in figure 5. Figure 6 is a diagram showing the component parts.

2.4.2 The expendable barrels used in Tool C are made of steel tubing. They contain a 1/4 inch steel stud with a plastic guide and a .22 cal. powder cartridge. The powder cartridge seals one end of the barrel and the other end is covered by a plastic cap. A variety of stud types can be obtained and four different powder loads are available (light, medium, heavy, and extra heavy). The powder loads are identified by the color of the plastic cap. Only the heavy powder load (red) and only studs with externally threaded heads were used in the tests.

2.4.3 Operation

In order to drive a stud into a work material, the operator must follow the procedure outlined below:

(a) Insert a factory loaded barrel into the outer barrel. (It will be held from dropping out by a spring loaded ball bearing).

(b) Pull the cocking lever back and release it. This may be done before or after positioning the tool.

(c) Position the barrel against the work surface.

(d) Push the tool against the work surface, depressing the expendable barrel until the shield is flush against the surface.

(e) Pull the trigger.

(f) Remove the expendable barrel by grasping the muzzle end and pulling. (The end of the barrel will protrude about 1 1/2 inches when the tool is lifted from the work surface).

2.4.5 Safety features

A protective shield is attached to the muzzle end of the tool to stop flying shrapnel.

The possibility of unintentional firing is minimized by requiring that the tool has been cocked and is being held against a surface when the trigger is pulled in order for it to fire. This also prevents the tool from firing studs through the air.

The cartridges are recessed in the expendable barrels to reduce the possibility that the cartridges explode if dropped.

If the tool is tilted from the work surface more than 11°, the tool will not fire.

2.5 Material

2.5.1 The materials used in the construction of each of the three tools are not optimum from the standpoint of non-corrosive properties. However, these tools are prototypes and representatives from each of the three manufacturers have stated that production models of their tools could be made entirely of non-corrosive materials.

3. PROCEDURE

3.1 General

3.1.1 The procedure followed in this project was designed primarily to test the capabilities of the stud driving tools as underwater salvage tools. The tests consisted mainly of fastening 1/4" mild steel plates to 1/4" mild steel plates at depths up to 200 feet of water.

3.2 Pressure test of cartridges

3.2.1 Cartridges for each of the three tools were immersed in water and subjected to the following pressures:

Group 1	150 feet for 30 minutes
Group 2	150 feet for 120 minutes
Group 3	300 feet for 30 minutes

Each group consisted of eight cartridges for each tool. Four of the cartridges for each tool from each group were fired immediately after completion of the pressure tests and the other four were fired after being allowed to dry for at least 24 hours. The cartridges were allowed to dry before testing to determine whether or not unused cartridges which had been subjected to water pressure should be retained.

3.3 Pressure test of tools

3.3.1 Each tool was operated underwater in the pressure tank at a pressure equivalent to a depth of sea water of 200 feet.

3.4 Performance of tools

3.4.1 Each tool was used underwater to attempt to fasten two 1/4" mild steel plates together, using a 1/4" rubber gasket between them. Two such sets of plates are shown in figures 7 and 8.

3.4.2 Each tool was used underwater to attempt to fasten a patch consisting of a 1/4" mild steel plate with a 1/4" rubber gasket to a 6" square hole in a pressure tank made of 1/4" mild steel plate. Two such patches are shown in figures 9 and 10. Internal pressure was then applied to the tank to determine whether the patch could hold at least 30 psi.

3.4.3 Tools A and C were used to fasten 1/4" mild steel plates to concrete (tool B was not used for these tests for the reasons explained in part 4).

3.4.4 Two studs from each tool were fired from each tool into two 1/4" plates with a 1/4" rubber gasket above surface and two more from each tool were fired into the plates by each tool underwater, using the same powder loads as for the above surface firing. The plates used for this are shown in figure 11. This was done to determine whether the same load could be used above water as underwater for each tool.

3.5 Performance of Studs

3.5.1 The force required to pull single studs loose from the material in which they were embedded was determined by means of an "MSA Study Tester", loaned to EDU by the Mine Safety Appliance Co. The tester has threaded fitting which is attached to the stud, with the body of the tester resting against the material in which the stud is embedded. Force applied to turn a knob on the top of the tester is multiplied hydraulically and the stud is pulled from the material. The force acting on the stud is read from a gage on the tester which is calibrated in pounds of force.

3.5.2 The following quantities were measured for studs fired by each tool:

(a) The force required to pull single studs from the plates fastened as described in 3.4.1.

(b) The force required to separate one 14" steel plate from another when fastened by a single stud.

(c) The force required to pull steel plates, fastened to concrete by a single stud, from the concrete.

3.6 Operating Position

3.6.1 The tools were operated underwater in the vertical, horizontal, and overhead inverted positions to determine if position affected the operation.

3.7 Subjective Evaluation

3.7.1 Ten experienced divers, wearing deep sea dress with gloves used the tools to fasten two 1/4" steel plates together with a 1/4" rubber gasket in between. This work was done on the bottom of the Anacostia River in soft mud with zero visibility.

3.7.2 These divers then made subjective comments on the tools, concerning ease of operation, degree of operator skill required, and their preference if any.

4. RESULTS

4.1 General

4.1.1 Tool A. Operated satisfactorily in general after it was learned that for underwater use, this tool must be loaded underwater so that the barrel will be completely flooded. Failure to follow this procedure results in loss of power and improperly driven studs.

4.1.2 Tool B. Difficulty was experienced with both the operation of Tool B and with the cartridges. The tool became very difficult to open for loading and finally became impossible to open by hand. The cartridges failed to pass the pressure tests as described below and the powder loads did not provide sufficient power to drive a stud into two 1/4" mild steel plates. Due to these difficulties, the tests on Tool B were not completed.

4.1.3 Tool C. Tool C operated satisfactorily after the initial difficulty which was encountered in removing the expended barrels after firing was eliminated. A new supply of barrels which were manufactured to closer tolerances than the original ones eliminated this problem.

4.2 Pressure Test of Cartridges

4.2.1 Tool A. All of the cartridges which were pressure tested as described in 3.4.1 were successfully fired.

4.2.2 Tool B. Of the cartridges which were used immediately after the pressure test, 2 misfires and 2 successful firings were made from group 1 and group 2. There were no cartridges tested immediately from group 3. Of the cartridges which were allowed to dry for 24 hours after the pressure test, all failed to fire. Water could be squeezed out of several of the cartridges from each group for Tool B, indicating that the seal was definitely inadequate.

4.2.3 Tool C. All of the cartridges which were pressure tested as described in 3.4.1 were successfully fired.

4.3 Pressure Test of Tools

4.3.1 Tool A. Tool A successfully fastened 6 studs in 6 attempts at a depth of 200 feet in the pressure tank when the tool was loaded and fired underwater.

4.3.2 Tool B. The pressure test for Tool B was attempted, using cartridges which had been pressure tested. These cartridges did not fire as stated above. The pressure test was not repeated since the tool subsequently became inoperable.

4.3.3 Tool C. Tool C successfully fastened 6 studs in 6 attempts at a depth of 200 feet in the pressure tank. Tool C can be loaded either in or out of the water.

4.4 Performance of the tools

4.4.1 Tools A and C were each used to fasten two sets of plates as described in 3.4.1. All of the studs driven by both tools were driven uniformly and to the correct depth in this test. Attempts to fasten the plates using tool B were unsuccessful. Insufficient penetration was obtained using the powder loads available. Figures 8 and 9 show one set of plates fastened by tool A and one set fastened by tool C.

4.4.2 Tools A and C were each used to fasten two tank patches as described in 3.4.2. All of the studs were driven correctly. In all four attempts, some difficulty was experienced with the patch lifting on the side opposite the first stud fired. It was necessary to fire one or two additional studs on this side to make an effective seal. Two of these tank patches can be seen in figures 9 and 10. All of the patches successfully held the required 30 psi with only small leakage of air and one fastened by each tool held 60 psi. No tank patches were successfully made using tool B due to insufficient penetration of the studs.

4.4.3 Tools A and C were each used to fasten steel plates to a block of concrete underwater as described in 3.4.3. The studs were all driven to the correct depth. Tool B was not used for this test since it was inoperable.

4.4.4 The two studs each fired by tools A and C into the steel plates above water and the two fired underwater were driven to the same depth. The two studs driven by tool B above water were driven to the correct depth of penetration, but the stud fired underwater barely penetrated the first plate. The same load was used for both above and underwater firing. Only one stud was driven underwater by tool B for this test since the tool became inoperable after the first stud was fired. Figure 11 shows the set of plates used for this test.

4.4.5 The results of the holding strength tests are summarized below:

No properly fastened studs from tool B were available for these tests.

I - Force required to pull studs from two 1/4" steel plates with 1/4" rubber gasket. (10 studs each)

	TOOL A	TOOL C
Maximum	4000 lbs.	4100 lbs.
Minimum	2600 lbs.	2900 lbs.
Average	3400 lbs.	3420 lbs.

II - Force required to separate two 1/4" plates fastened by a single stud (3 studs each tool)

	TOOL A	TOOL C
#1	2500 lbs.	2700 lbs.
#2	2200 lbs.	2400 lbs.
#3	2800 lbs.	2500 lbs.
Average	2500 lbs.	2550 lbs.

III - Force required to pull 1/4" teel plates from a concrete block; the plates were each fastened by a single stud. Three plates fastened by each tool were tested.

	TOOL A	TOOL C
#1	1700 lbs.	1100 lbs.
#2	1500 lbs.	900 lbs.
#3	(no test since the concrete fractured)	1100 lbs.
Average	1600 lbs.	1033 lbs.

4.5 Operating positions

4.5.1 The tools operated equally well in any position (vertical, horizontal, or overhead).

4.6 Subjective Evaluation

4.6.1 The following is a summary of the comments made by 10 experienced divers after using Tool A and Tool C to fasten two steel plates, working on a very muddy bottom with zero visibility. All of the divers wore deep sea diver's dress with diver's gloves.

4.6.2 The divers reported that tool C was lighter and easier to use and handle than tool A. Several divers commented specifically that the necessity of carrrying and using the rod to eject the empty case from Tool A is objectionable. More time was required to use tool A than to use Tool C, particularly for the loading procedure.

4.6.3 Some difficulty was experienced by several of the divers in getting both tools to fire. This difficulty was attributed primarily to mud getting into the tools and to the instability of the small metal plates, which were being used as work material in the soft mud.

4.6.4 Each of the ten divers expressed a prererence for using tool C.

4.6.5 Tool B was not given the subjective evaluation since it was inoperable. However, it had been used by an experienced diver during the early part of the project. Based on this experience, it is felt that tool B is more difficult to load and operate than either tool A or tool C and that it would be practically impossible to load and use by a man wearing diver's gloves, due to the small size of the cartridge which must be inserted and also due to the complexity of the operations required.

4.6.6 It should be pointed out that the conditions under which the subjective evaluation was conducted were extreme, particularly with respect to mud and visibility. A man without gloves and with good visibility can operate any of the three tools.

4.7 Maintenance

4.7.1 Tool A Tool A requires only cleaning and oiling as a routine maintenance procedure. Disassembly can be accomplished using a screw driver, two hex wrenches, and a threaded drift. During the course of the tests, the trigger grip assembly failed and was replaced by the manufacturer.

4.7.2 Tool B The manufacturer recommends immersing the tool in a rust preventative solution before and after each day's use, particularly when used in salt water. Difficulty was experienced in rotating the locking ring, and this difficulty eventually rendered the tool inoperative. Difficulty was also experienced in removing a set screw to remove the barrel from the tool. Screw drivers and hex wrenches of various sizes are required to disassemble the tool for maintenance. Tool B is by far the most complex of the three tools.

4.7.3 Tool C Cleaning and oiling is all the routine maintenance required by tool C. Disassembly for maintenance is extremely easy, requiring only three sizes of hex wrenches (the manufacturer advises that a production tool will require only one size hex wrench). The tool has very few parts and is the simplest of the three tools to assemble or reassemble.

5. DISCUSSION

5.1 General

5.1.1 Tool A must be loaded underwater if it is to be fired underwater, as mentioned in 4.1.1. If the tool is loaded above water, some air will usually be trapped in the barrel, allowing the barrel to become only partially flooded. The gases which by-pass the stud to clear the barrel of water, as described in 2.2, then only compress the air in the barrel and do not succeed in expelling all of the water fast enough. The stud then strikes the water in the barrel, losing some of its power. The fact that this tool must be loaded underwater should not be any problem, since in most cases when the tool is used underwater, it will be convenient and expedient to load it underwater.

5.1.2 The difficulty in operating tool B is thought to be due to a cam which cocks the firing mechanism. This cam was lengthened once in an attempt to solve this problem, but the amount it could be lengthened was limited by space restrictions and the problem still exists.

5.1.3 The expendable barrels which were initially supplied for use with tool C apparently were slightly undersized and were expanding within the outer barrel, making it difficult to remove them. No such difficulty was experienced with a second supply of barrels which, according to the manufacturer's representative, were manufactured to a closer tolerance.

5.2 Pressure tests of cartridges

5.2.1 The cartridges used in tool A have a metal to metal seal made by the piston and the powder case and the expendable barrels used in tool C are sealed by a plastic cap over the end of the barrel. These seals proved to be satisfactory.

5.2.2 The cartridges used in tool B are waterproofed by a coating of wax on the open end of the powder case. While this type of seal would probably be sufficient for shallow depths, or short immersions, it was not adequate for the depths and times at which the cartridges were tested.

5.3 Performance

5.3.1 The performances of tool A dnd tool C were both satisfactory and no significant differences between the performance capabilities of the two tools were disclosed by the tests. The holding strength tests performed on the studs gave essentially the same results for tool C as for Tool A. This is surprising since the stud used in tool A has a 3/8 inch diameter and the stud used in tool C has only 1/4 inch diameter.

5.3.2 The holding strength tests were performed primarily to determine the order of magnitude of the holding strength of studs used in each tool. No criteria for minimum values was set.

5.3.3 Since both tool A and tool B employ a gas filled barrel in which the stud travels before striking the material, no difference in the above water or underwater performance would be expected, and no difference was observed during the tests.

5.3.4 The performance capabilities of tool B were not fully determined. However, significant difference was noted between the penetration of the stud when fired above water and that when fired underwater, using the same powder load. This is the result that would be expected since the stud must travel through a water filled barrel before reaching the work materials. This difference in penetration could have dangerous consequences if a load designed for underwater use were used above water, which would not be an unlikely occurrence for a patch made at the waterline.

5.4 Subjective Evaluation

5.4.1 The ten divers who used tool A and tool C in the subjective evaluation expressed a unanimous preference for tool C. This is no doubt due to several obvious operating advantages which tool C has over tool A. These advantages are listed below:

(a) The ammunition for tool C is larger and therefore easier to handle.

(b) Tool C has no rotating parts.

(c) The fact that tool A has rotating parts is disadvantageous in two respects:

(1) rotating parts tend to jam in mud.
(2) a rotating operation is difficult to perform when wearing diver's gloves.

(d) The empty cartridge can be removed from tool C underwater without the use of a ramrod.

(e) Tool C is smaller and lighter.

5.4.2 The divers were able to use both tool A and tool C successfully in difficult conditions after only a minimum of training.

5.4.3 Tool B has several disadvantages serious from the standpoint of use by a diver:

(a) The ammunition is in two small parts.

(b) A large number of operations is required to load and fire, which require alignment and rotation, both of which are difficult to perform with diver's gloves.

5.5 Maintenance

5.5.1 The maintenance required by each of the three tools consists primarily of keeping the tools clean and lubricated. The manufacturer recommends that tool B be immersed in a rust preventative solution before and after use, particularly when used in salt water.

5.5.2 The maintenance problems which would be expected for these tools differ only in the relative complexity of the individual tools. Tool C is very simple in construction. Tool B is also relatively simple; however, tool B is quite complex by comparision with either tool A or tool C.

5.5.3 Since the tools are intended for underwater use, it would be very desirable to have all of the components of the tool constructed of non-corrosive materials.

6. CONCLUSIONS

6.1 Tool A

6.1.1 The performance of tool A is satisfactory for use underwater to drive studs into steel of 1/2" total thickness and for fastening steel plates to concrete. The tool is also suitable for making pressure patches over holes in 1/4" steel plates.

6.1.2 Tool A is suitable for use to depths of at least 200 ft. of water. There is no reason to believe that the tool would not operate at any depth at which a diver can work.

6.1.3 The cartridges used in tool A are sufficiently waterproofed to be used after being submerged to 300 feet for 30 minutes or 150 feet for 120 minutes. Unused cartridges which have been submerged remain dry and can be used after being out of water for 24 hours.

6.1.4 Tool is easy to maintain.

6.1.5 Tool A is difficult to operate in comparision with tool C.

6.1.6 A minimum of training and operator skill is required to use Tool A properly.

6.1.7 Tool A has adequate safety features to make this tool safe for use by personnel who have been indoctrinated in its use.

6.1.8 Tool A can be used above water or underwater using the same powder load for the same type and thickness of work material.

6.2 Tool B

6.2.1 The tests conducted on tool B were not complete due to the lack of proper powder loads and the fact that the tool became inoperable during the tests.

6.2.2 The cartridges used in tool B are not adequately waterproofed to be used after being immersed in water at a depth of 150 feet for 30 minutes.

6.2.3 Preventive maintenance for tool B is simple and easy. However, corrective maintenance would be much more difficult for tool B than for tool A or tool C since tool B is more complex.

6.2.4 Tool B is relatively difficult to operate in any visibility, and it would be almost impossible to load underwater when wearing diver's gloves.

6.2.5 Tool B has adequate safety features to make this tool safe for use by personnel who have been indoctrinated in its use, except for the possibility discussed in 5.3.4.

6.2.6 Tool B requires different powder loads for above water use than for underwater work, but the tool will operate either underwater or above water.

6.3 Tool C

6.3.1 The performance of tool C is satisfactory for use underwater to drive studs into steel of 1/2" total thickness and for fastening steel plates to concrete. The tool is also suitable for making pressure patches over holes in 1/4" steel plates.

6.3.2 Tool C is suitable for use to depths of at least 200 feet of water. There is no reason to believe that the tool would not operate at any depth at which a diver can work.

6.3.3 The cartridges are sealed in the expendable barrels sufficiently to be used after being submerged to 300 feet for 30 minutes or 150 feet for 120 minutes. Unused cartridges which have been submerged remain dry and can be used after being out of water for 24 hours.

6.3.4 Tool C is very easy to maintain. It is simple in construction and easy to assemble and disassemble.

6.3.5 Tool C is by far the easiest of the three tools to operate, and ban be operated with relative ease even when wearing diver's gloves in poor visibility.

6.3.6 A minimum of training and operator skill is required to use tool C properly.

6.3.7 Tool C has adequate safety features to make this tool safe for use by personnel who have been indoctrinated in its use.

6.3.8 Tool C can be used above water or underwater using the same powder load for the same type and thickness of work material.

6.4 Limitations of tests

6.4.1 The performance tests were all made under ideal conditions; flat plates were fastened to other flat plate or the flat concrete surfaces. This, of course, would not be the case in an actual salvage operation. The use of the tools on an actual salvage operation may reveal that heavier and/or longer studs will be required.

7. RECOMMENDATIONS

7.1 Further evaluation

7.1.1 It is recommended that tool A and tool C be given a field evaluation to determine the performance capabilities of these tools in practical applications and the preference of the forces afloat.

7.1.2 It is recommended that no further evaluation be given to tool B, as it is presently designed, since it is not well suited for use by a diver.

7.1.3 If the field evaluations substantiate the findings of this report that tool C is superior in ease of operation and that it is satisfactory for the performance of underwater salvage work, it is recommended that tool C be procured for use in the U. S. Navy.

7.1.4 It is recommended that tool A not be procured for use in the U. S. Navy unless it is modified so that its ease of operation is made comparable to that of tool C, while maintaining its present performance capabilities.

7.2 Material

7.2.1 It is recommended that anypproduction type tools be manufactured from non-corrosive materials.

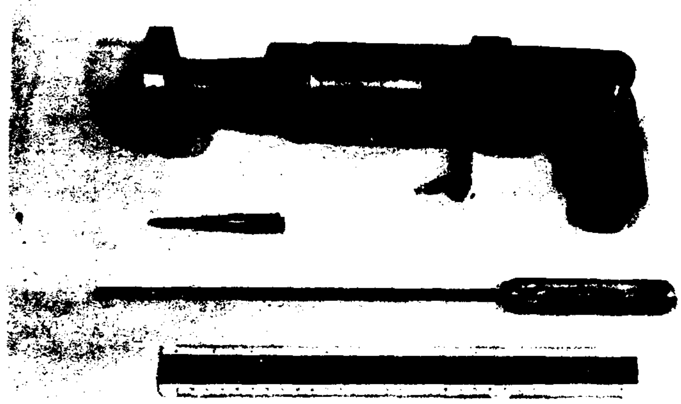

FIG. 1 TOOL A (MODIFIED)

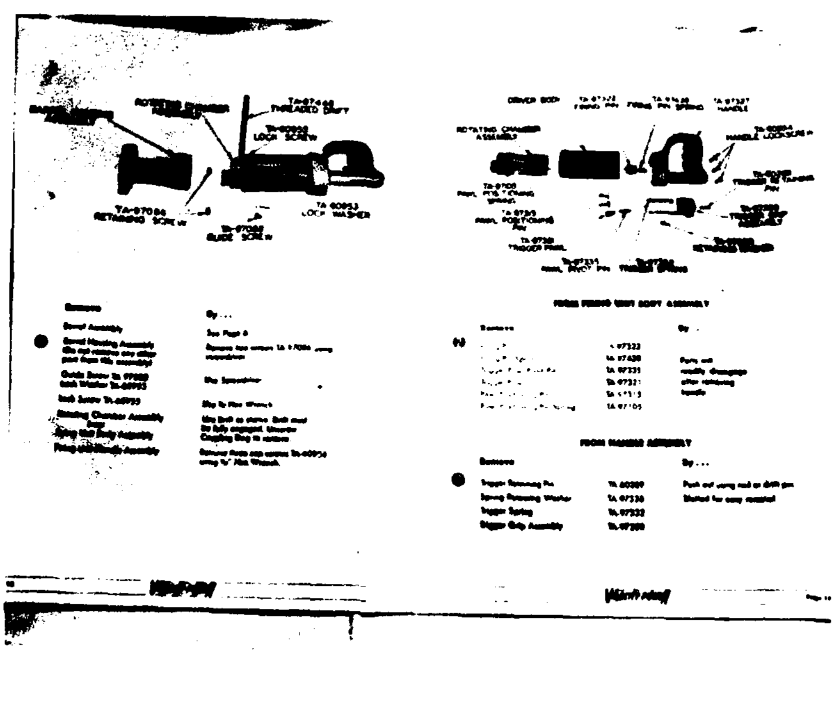

FIG. 2 TOOL A BROKEN DOWN (UNMODIFIED)

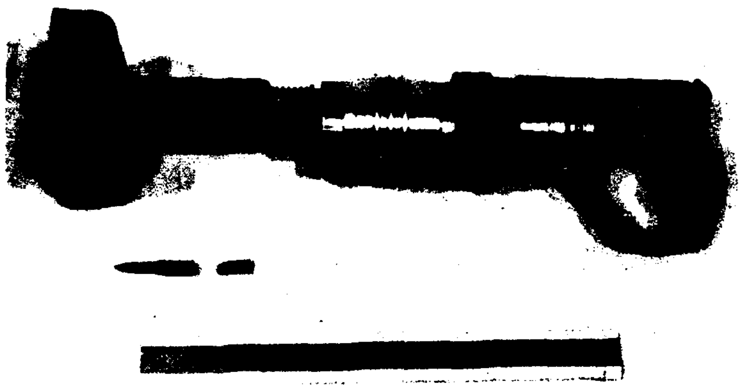

FIG. 3 TOOL B

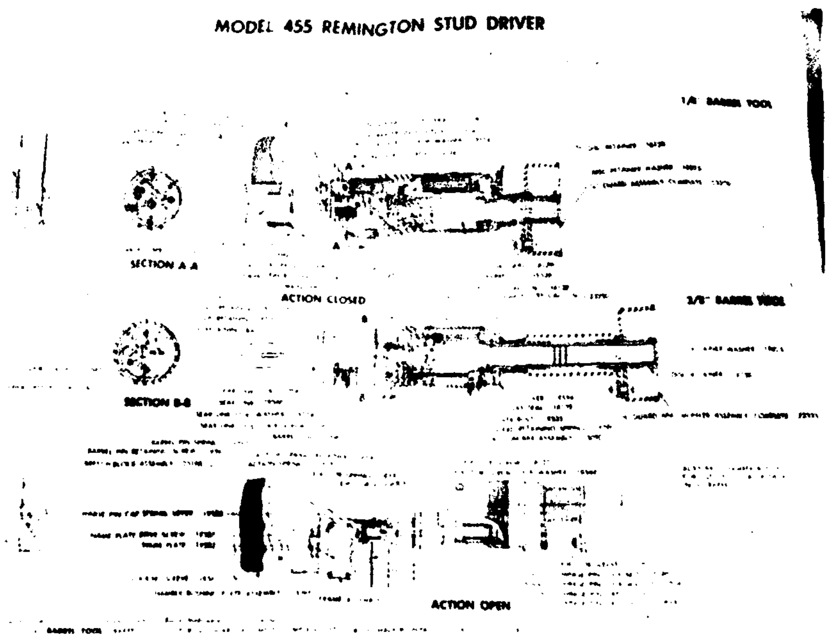

FIG. 4 DIAGRAM OF TOOL B

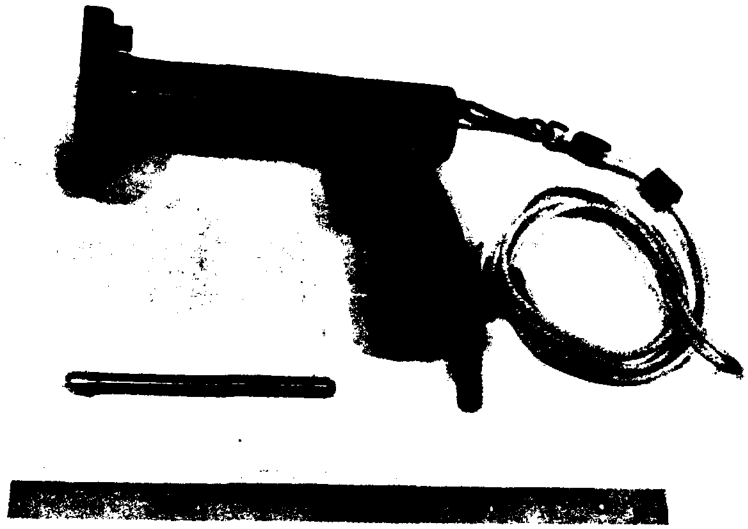

FIG. 5 TOOL C

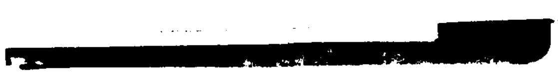

FIG. 6 DIAGRAM OF TOOL C

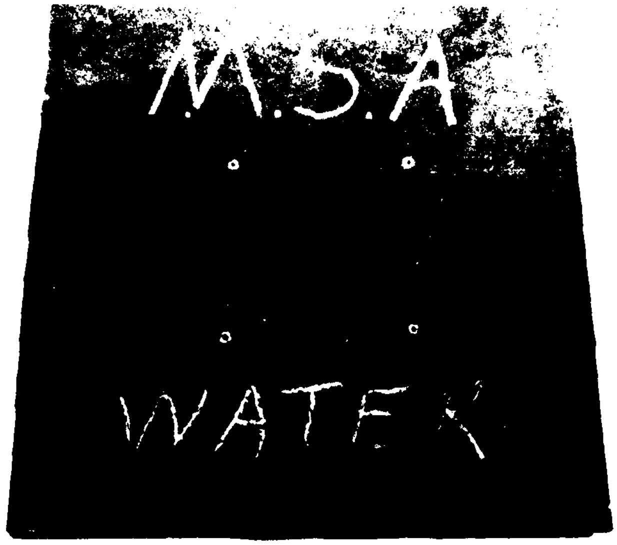

FIG. 7 PLATE ATTACHED USING TOOL A

FIG. 8 PLATE ATTACHED USING TOOL C

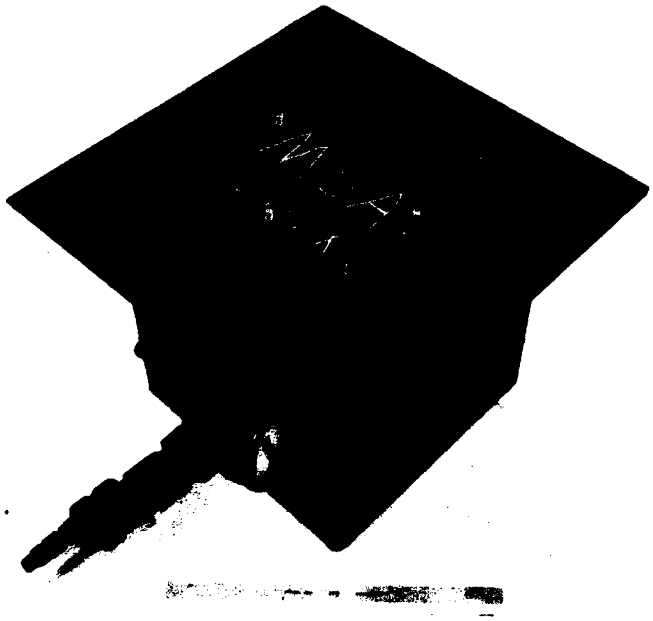

FIG. 9 TANK PATCH FASTENED USING TOOL A

FIG. 10 TANK PATCH FASTENED USING TOOL C

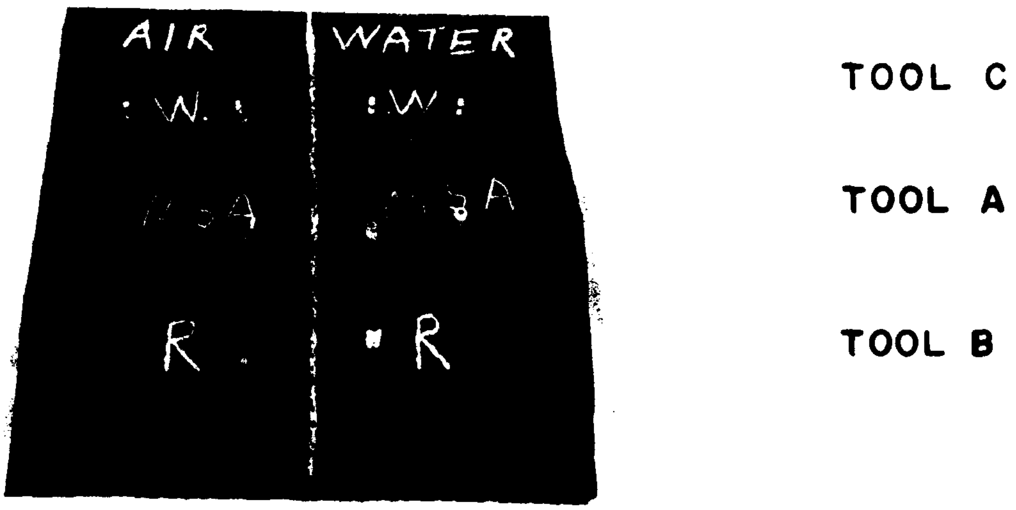

FIG. 11 COMPARISON OF STUDS FIRED ABOVE WATER AND UNDERWATER BY EACH TOOL