CUTTING OF MUNITIONS AND REMOVAL OF EXPLOSIVES THROUGH APPLICATION OF WATER JET TECHNOLOGY

George Wilken, Hal Monson, and Mark M. Zaugg
Ammunition Equipment Directorate
Tooele Army Depot, Tooele, Utah, USA
and
Professor Alan Bailey
Chemical Systems Group
Royal Military College of Science
Shrivenham, Swindon, Wilts, England

Presented at the
25TH DoD EXPLOSIVES SAFETY SEMINAR
ANAHEIM HILTON HOTEL, ANAHEIM, CA
18-20 AUGUST 1992

ABSTRACT

Water jet technology has been used for removing explosives and propellants from large munitions and rocket motors. However, for small items where the recovery of the explosives has not been practical, destruction of the items has usually been done in the deactivation furnaces. Many munitions, because of high explosive (HE) content or shaped charge characteristics, require preprocessing by cutting/shearing/disassembly to expose the explosives or remove detonators/fuzes prior to introduction into the furnaces. Such preprocessing has traditionally been accomplished with mechanical disassembly equipment, punches and shears. This presentation covers the developmental work of the Ammunition Equipment Directorate, Tooele Army Depot, Tooele, Utah, USA, and the Royal Military College of Science, Shrivenham, Swindon, Wilts, England, in the use of abrasive water jet technology to open explosive cavities, remove detonating components, or otherwise prepare munitions items for furnace incineration. Based on work performed to date, the removal of explosives for recovery/recycling from small munitions may now be economically feasible using water jet technology.

INTRODUCTION

The origination of the present-day water jet dates back to a patent granted to Dr. Norman Franz, a professor of Forestry at the University of British Columbia, Canada in 1968. He took his idea to Ingersoll-Rand Company and they built the first high pressure water jet (approximately 50,000 psi) as a water-only cutting tool, primarily for use in furniture manufacture. This expanded into the cutting of many non-metal materials. In 1983, Flow International introduced abrasive water jet cutting, which allowed the water jet to be effectively used for the cutting of metals.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE
AUG 1992

2. REPORT TYPE

3. DATES COVERED
00-00-1992 to 00-00-1992

4. TITLE AND SUBTITLE
Cutting of Munitions and Removal of Explosives Through Application of Water Jet Technology

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Ammunition Equipment Directorate, ,Tooele Army Depot,Tooele,UT,84074

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADA260984, Volume I. Minutes of the Twenty-Fifth Explosives Safety Seminar Held in Anaheim, CA on 18-20 August 1992.

14. ABSTRACT
see report

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**14**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

The US Army and Navy have done considerable research into the use of water jet technology for removal of explosives from munitions. Several of these projects were contracted to the University of Missouri at Rolla, where much work has been done to determine and quantify the factors of safety associated with water jet removal of explosives.

A plant has been constructed and is currently operating in Israel to wash out explosives from 105MM and 155MM projectiles. The plant uses a 5,000 psi cavitating water jet with water only as the cutting medium. Thousands of projectiles have been washed out at this plant. Although there have been many demonstrations of water jet removal of explosives, the Israeli plant is the only known production demilitarization facility we could find using a water jet to wash out explosives.

APPLICATION OF WATER JET TECHNOLOGY TO CUTTING OF MUNITIONS

While the majority of the applications of water jet technology to demilitarization have focused on explosive removal, the work of the Ammunition Equipment Directorate (AED), Tooele Army Depot (TEAD), Utah, USA, as tasked by the Ammunition Peculiar Equipment Branch, US Army Armament, Munitions and Chemical Command (AMCCOM) is primarily directed to the cutting of munitions in order to remove fuzes/detonators or to expose the explosive filler so that the munitions items can be incinerated in the deactivation furnace without detonating. At the same time, similar work has been conducted by the Chemical Systems Group, Royal Military College of Science (RMCS), Shrivenham, Swindon, England.

ADVANTAGES/DISADVANTAGES OF WATER JET CUTTING

Previous methods to accomplish the preprocessing of munitions for incineration have involved mechanical shearing, sawing, or punching to remove fuzes/detonators or to expose explosive fillers. Most of this type of equipment that has been developed is specific for a particular munition or family of munitions. The equipment is expensive and time consuming to develop, fabricate, and test. On the other hand, abrasive water jet cutting of munitions has the following advantages:

1. Versatility/adaptability - Water jet cutting is applicable to a wide variety of munitions and munitions components with minor changes to the cutting nozzles, pressures, and locations of the cuts.

2. Mechanical simplicity - The only equipment development necessary to handle the wide variety of items to be cut is the conveying equipment that delivers/removes the items from the cutting head location and holds the item in proper position for cutting.

3. Minimal equipment exposure to potential explosion - Exposure of equipment to potential damaging explosions is limited to the water jet nozzle, the conveying equipment and fixturing in the vicinity of the potential detonation.

4. Relatively low cost equipment - Abrasive water jet equipment is commercially available at a cost that is equal or less than the cost of developing a single piece of punching/shearing/sawing equipment that will handle only a small number of different items.

5. Built in quenching/cooling - The water jet provides localized cooling/quenching of materials at the cutting location. In addition, the material being impacted is immediately removed from the cutting location further lessening the propagation of any reaction in the explosives being impacted with the water jet to the surrounding explosive materials. Cooling/quenching is further enhanced if the cutting is done under water.

6. Flexible production - Production rates of cut items can be easily varied with the addition of multiple nozzles and duplicate water jet systems.

The primary disadvantage to abrasive water jet cutting is the water used in the cutting becomes contaminated with explosives, metal particles, and grit. The contaminated water becomes a disposal problem and must be considered a hazardous waste due to the presence of explosives. The ideal solution would be to filter the water for recycling in the cutting process, and handle the filtrate separately as a hazardous waste. This would greatly reduce the volume of hazardous waste that would have to be disposed of, probably by incineration. It should be noted that the filtration of the water for recycling is not a simple task since the allowable particle size in the water supply to the water jet systems used by AED must not exceed 0.5 microns. AED is investigating methods of filtration that will remove both particulates and dissolved explosives, producing water of the appropriate quality for recycling to the water jet systems.

FOCUS OF AED APPLICATION

For the investigative work done by AED, two different water jet systems were procured, one from Jet Edge Corporation, the other from Flow Systems. These two systems are of different sizes and capacities. The Jet Edge system will accommodate only one nozzle, while the Flow Systems unit is capable of powering three nozzles. Tests conducted with these units are not intended to compare one system to the other. Therefore data presented in this paper, such as the time required to cut various items under different conditions, should only be compared when the same system was used.

AED's experimentation initially focused on the M42/M46 grenades, submunitions loaded in 155MM projectiles. These grenades were being punched and incinerated at Mississippi Army Ammunition Plant. Punching of these grenades to expose the explosives did not totally stop the detonations as they were incinerated. It was thought that the water jet could cut away a larger part of the grenade, exposing more explosives area such that the detonations could be eliminated in the deactivation furnace.

Inert grenades were first cut to determine the best ways and locations to make the cuts. The body of the grenade is made of 4140 steel, and the thickness of the body at the location selected for the cut is approximately 0.090 inches. Initial cuts were made by drawing the grenade beneath the water jet nozzle such that the jet would cut through the entire grenade. Garnet grit 80 mesh in size was used and it took 15 seconds to cut the grenade. A considerable amount of the simulated explosive was washed out of the grenade.

Because the effectiveness of the water jet cutting action decreases as the depth of the cut increases, it was determined that the cut would be more effective if the nozzle was positioned so that the cutting jet would be tangential to the grenade wall. This reduced the depth of the cut from the entire 1-3/8" diameter of the grenade, to approximately 0.1". To test this approach, an inert grenade was positioned in a rotating fixture with the water jet tangential to the grenade wall such that the jet would only cut through the thickness of the steel wall. The same water jet parameters, i.e., nozzle size, orifice size, water pressure, and grit size, were used as in the above test, and the grenade was rotated at 48 rpm. The water jet cut a narrow groove around the grenade body until the fuzed top of the grenade separated. The time to cut the grenade was approximately 8 seconds, and the explosive filler was only slightly eroded. Several grenades were cut in this manner and the time to cut each grenade was very repeatable, about 8 seconds.

Of concern in these tests was the sparking that resulted when using the garnet grit to cut the steel grenade casings. Since sparks are not normally considered compatible with explosives, additional tests were conducted using "Copper Blast" grit which is a grit produced from the slag left over from copper smelting operations of Kennecott Copper Corporation. The sparks produced were not significantly decreased, but the cutting time increased from 8 seconds for the garnet grit, to 15 seconds for the "Copper Blast" grit. It is of interest to note that in tests conducted by RMCS, the sparks produced in water jet cutting appear to be "cold" sparks with insufficient energy to ignite explosive concentrations of hydrogen in air. This reduces the concern of the presence of such sparks when cutting explosives filled munitions.

ADVANTAGES/DISADVANTAGES OF CUTTING UNDER WATER

The next tests compared the cutting rates above and under water. Grenades were rotated at 28 rpm maximum. Using the Jet Edge system and the same water jet parameters for each test, it took approximately 15 seconds to cut a grenade above water, and 17.5 seconds to cut a grenade below water. Although the cutting time underwater was slightly longer, it appears to offer the following advantages over open air cutting:

1. Noise is greatly reduced.
2. Overspray and splatter are practically eliminated, thus confining debris to the water tank.
3. Water in the tank essentially eliminates sparking when cutting metal. Any sparks created are short lived due to the rapid quenching of the surrounding water.

The disadvantages of cutting under water are as follows:

1. It is difficult to observe and hear what is happening during the cutting. When cutting in open air, the operator can hear when the water jet has finished the cut by the change in sound. This is not as apparent under water.
2. Cavitation may be created when the high pressure stream encounters the water in the reservoir, although this may not be of much concern in this application.
3. More components of the holding/conveying fixtures will need to be sealed against entry of water.

Evaluating the advantages and disadvantages, it appears that the advantages to underwater cutting greatly outweigh the disadvantages, and will be pursued further by AED.

Tests were then conducted with live M42/M46 grenades loaded with Composition A5 explosive. 200 grenades were cut in open air without incident. The grenades were incinerated in the deactivation furnace where two grenades still detonated, even though the entire top of the grenade had been removed to expose the explosive filler. Since the exposure of more explosive filler area failed to eliminate detonations of the grenades in the furnace, it was decided to add another station to the process where the explosive filler could be removed by non-abrasive water jet. It was demonstrated that a 1 second blast of the water jet removed the explosive filler which could be incinerated separately in the furnace or filtered from the water for recovery/recycling.

FOCUS OF RMCS APPLICATION

RMCS has not only demonstrated water jet cutting of various munitions, but has developed modifications to the conventional method of introducing abrasives into the water jet stream that permits use of lower water pressures, increases the nozzle life, and increases the effective cutting distance with reduced spread of the water jet stream. RMCS determined that the normal method of adding abrasives to the water jet stream at the nozzle introduced considerable air into the stream which decreases the distance that the water jet stream holds its shape, resulting in a corresponding decrease in effective cutting distance. Also, the turbulence in the nozzle caused by the air and grit entrainment resulted in erosion of the nozzle orifice, reducing life of the nozzle.

As a result of their evaluations, RMCS concentrated on modifying the method of adding abrasives to the high pressure water. Figure 1 diagrams the RMCS water jet system which they have patented and market under the trade name DIAJET. A concentrated abrasive slurry is pumped into a supply tank which is pressurized by the high pressure water jet pump. A slight restriction in the water jet line produces a slightly higher pressure in the abrasive slurry tank such that the slurry can be introduced into the water jet line at the appropriate rate through a control valve to produce the desired abrasive concentration in the water jet. This process results in the introduction of abrasive into the water jet without also adding air. Since the water jet stream as it exits the nozzle has no entrained air, the stream retains its shape longer, which results in an increased effective cutting distance. Without the entrained air, the pressures required for cutting can also be significantly reduced. Most of the RMCS cutting of munitions has been accomplished at 5,000 and 10,000 psi.

Another significant development of RMCS is in the patented nozzle design. The nozzle holder shown in Figure 2, has a separation zone which necks down such that the heavier abrasive particles in the water jet are forced to the center of the water jet stream. This creates a film of water around the abrasive such that the abrasive does not contact the nozzle surface as the water jet/abrasive mixture enters the acceleration zone and exits the nozzle. Nozzle life is greatly increased as a result.

Another advantage to the reduced water pressure required for cutting is that flexible rubber tubing/hose can be used between the high pressure pump and the nozzle. Hose length is not critical, making long hose runs possible. This is very desirable in locations such as England where unexploded ordnance is found routinely and the water jet can be used to remotely remove fuzes and otherwise disarm munitions.

OTHER POTENTIAL APPLICATIONS TESTED

Both AED and RMCS have conducted experiments with cutting a variety of munitions. AED cut an inert 90MM projectile in 3 minutes 10 seconds by rotating the projectile under the water jet nozzle positioned off-center on the round so that it cut only to a depth of 5/8". The water jet cut the projectile like a lathe, cutting a greater depth each rotation. This method resulted in only minor erosion of the simulant explosive filler. RMCS has cut munitions up to 5 inches in diameter without rotation because their system can cut greater thicknesses without jet deterioration. They also experienced minor erosion of the explosives.

Another potential application of water jet cutting was demonstrated by AED with the cutting of an inert M55 rocket to separate the motor from the warhead. The cut was made through the fiberglass shipping and firing tube and the steel motor casing in the area of the void in the motor section above the propellant grain. The cut was completed in approximately 45 seconds. Water jet cutting of M55 rockets to separate the motor from the warhead in the event the propellant stability becomes suspect, has the advantage of minimizing handling of the rocket, which would include removing the motor ignitor shunt if the rocket has to be removed from the firing tube for mechanical disassembly. This concept has been accepted by the Army for further process and equipment development as the method to use if it becomes necessary to remove the propellant before the rockets can be destroyed in the Chemical Stockpile Disposal Plants, construction of which has not yet started, except for the Tooele site.

CONCLUSION

Experimentation with water jet cutting of munitions and explosive removal is continuing at AED and RMCS. Based on the past successes, it is felt that the advantages and benefits of using water jet technology for these applications, give it the potential to become one of the most widely used munitions preprocessing methods for demilitarization by explosives removal or incineration.

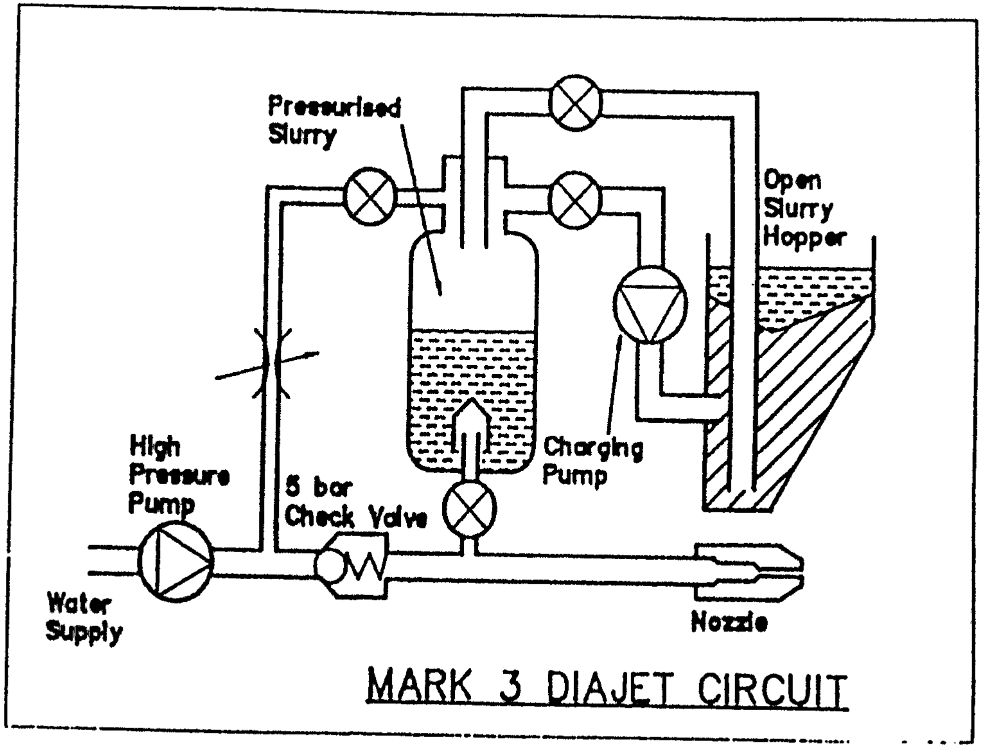


FIGURE 1 RMCS WATER JET SYSTEM

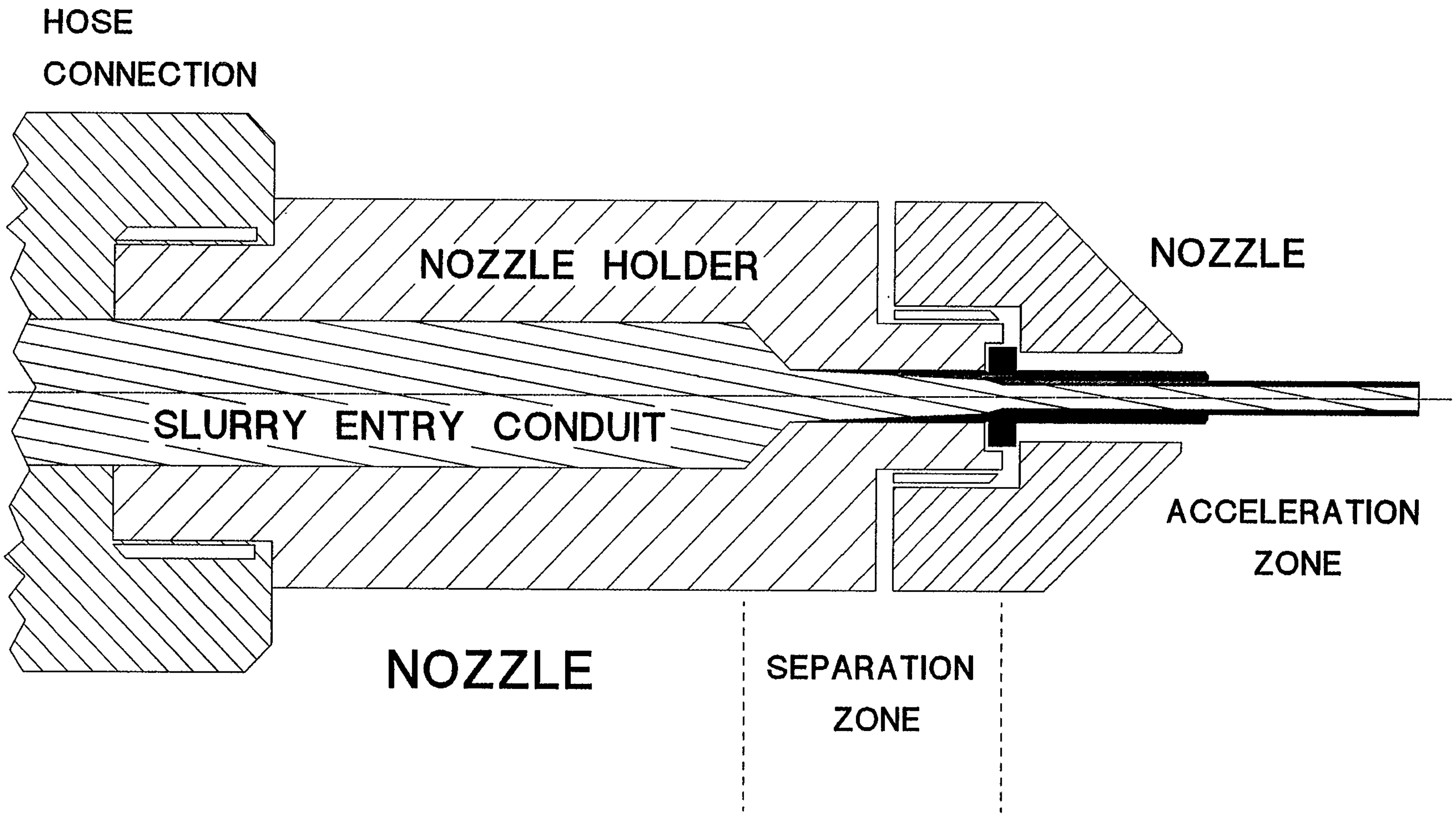
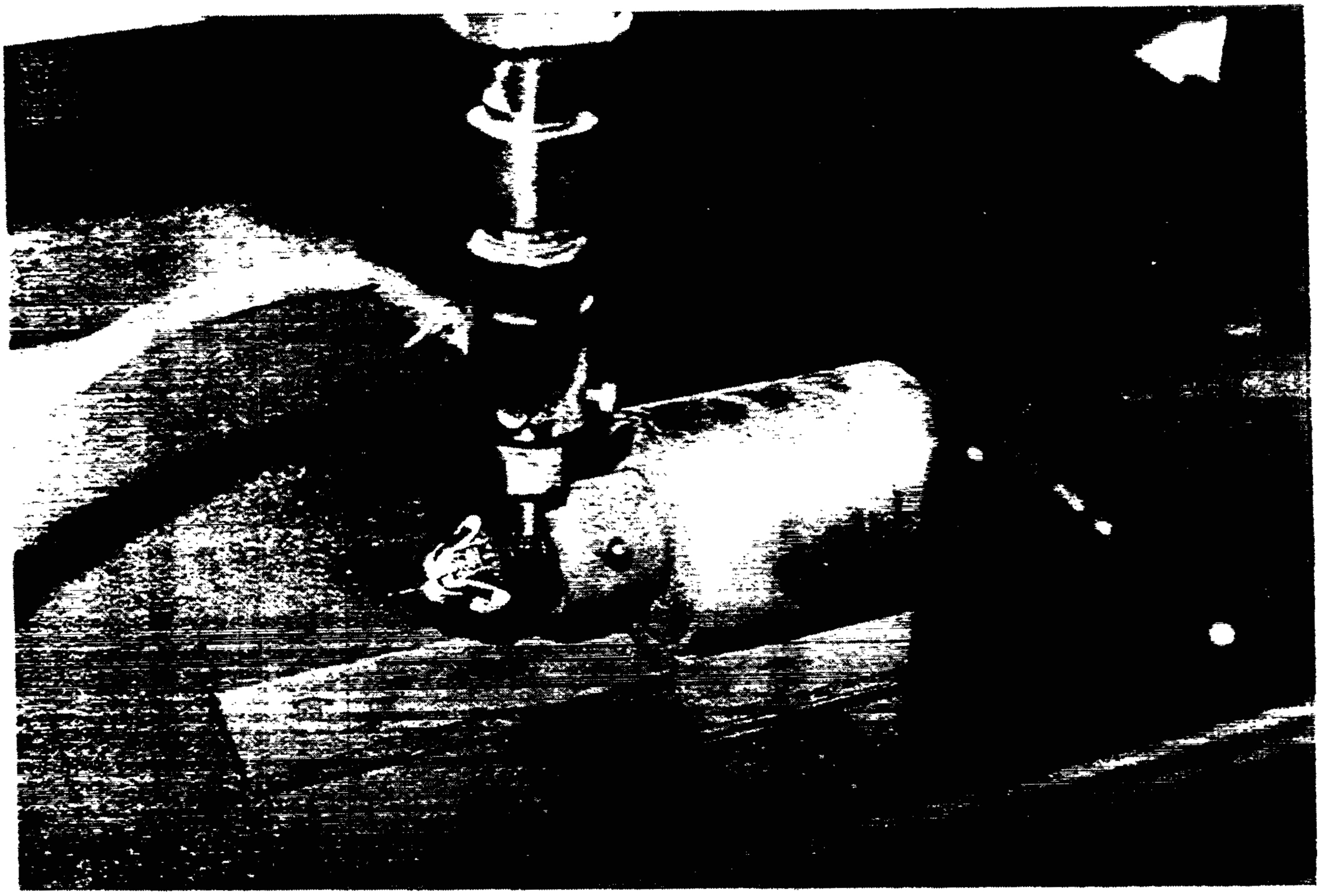
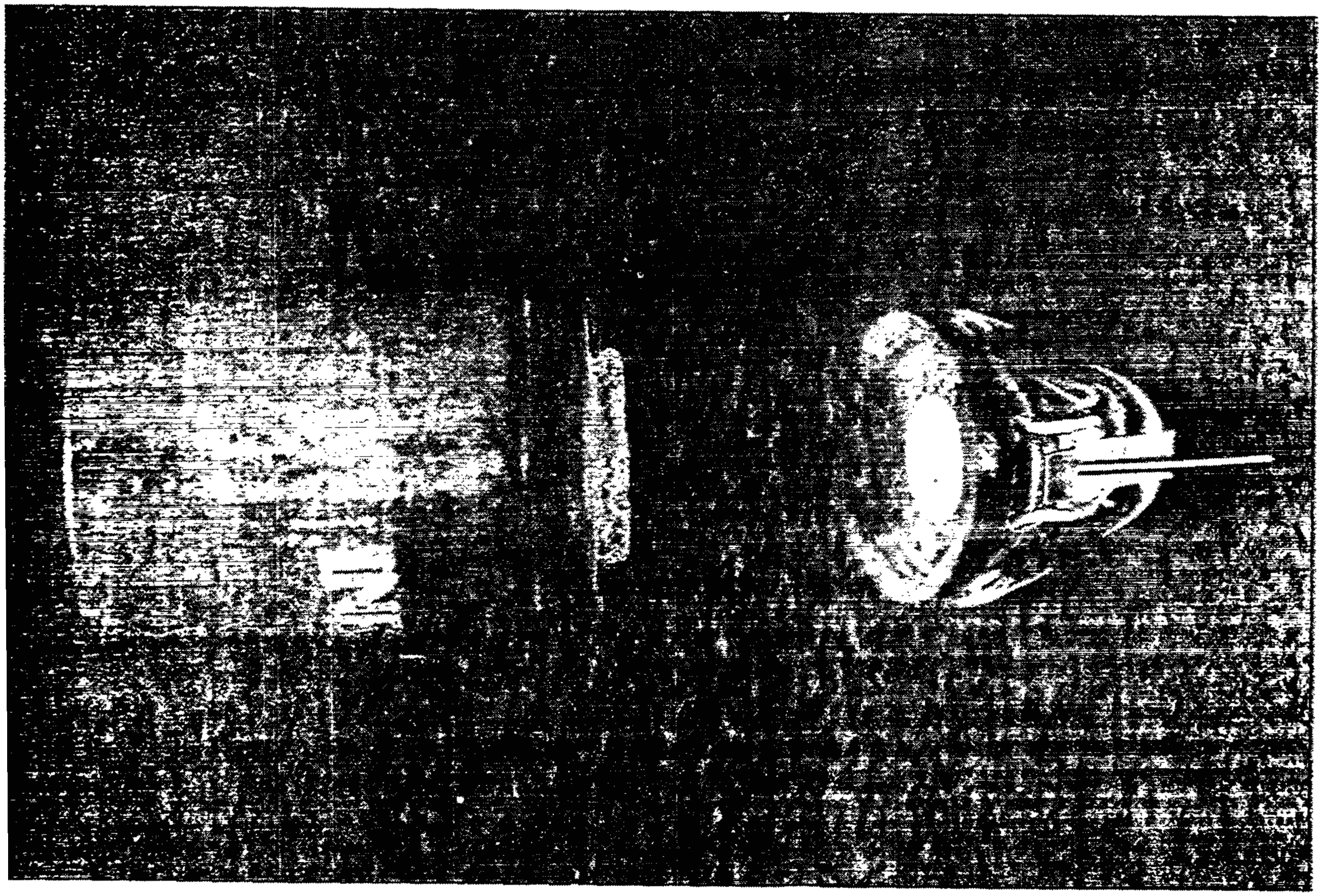


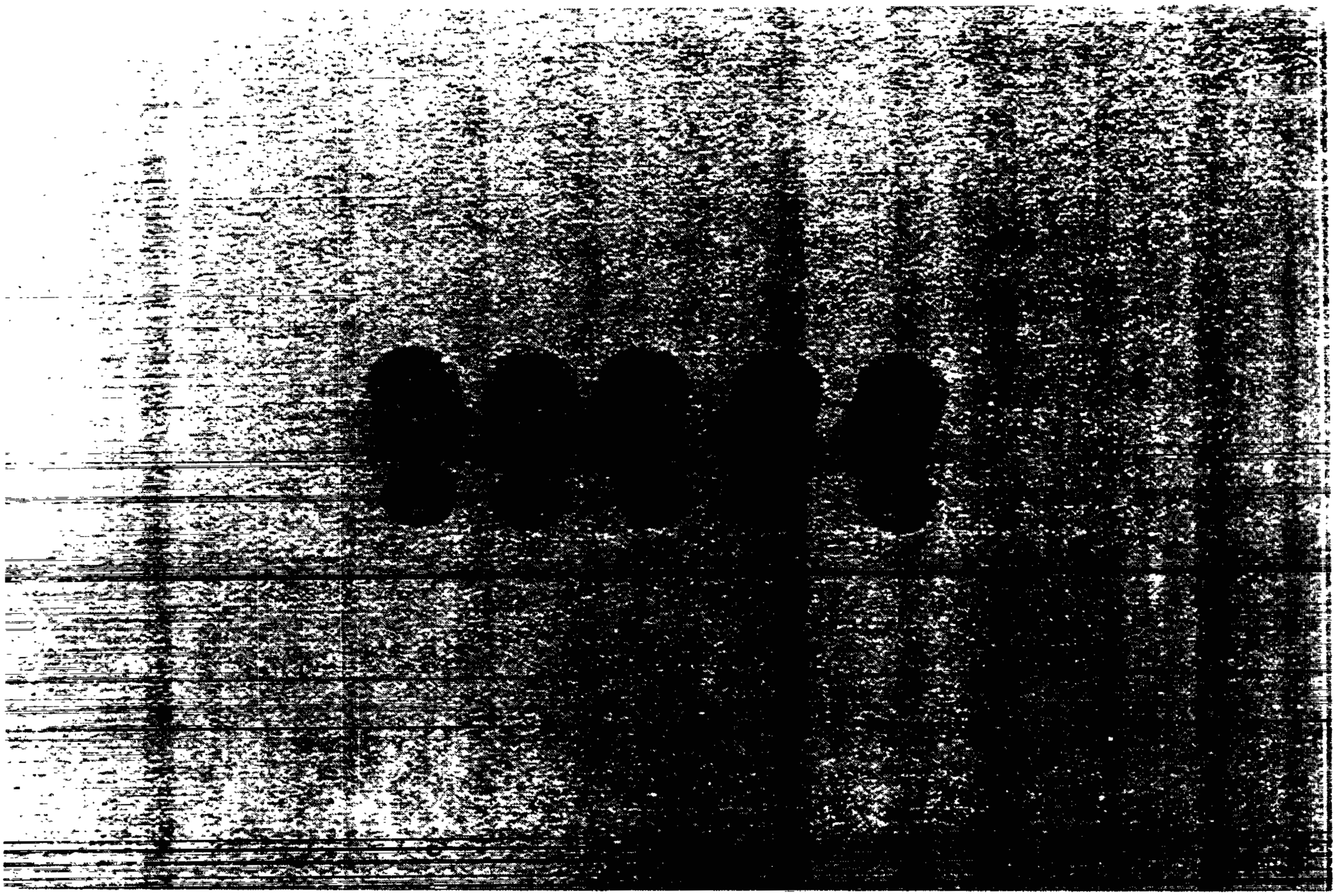
FIGURE 2 DIAJET NOZZLE



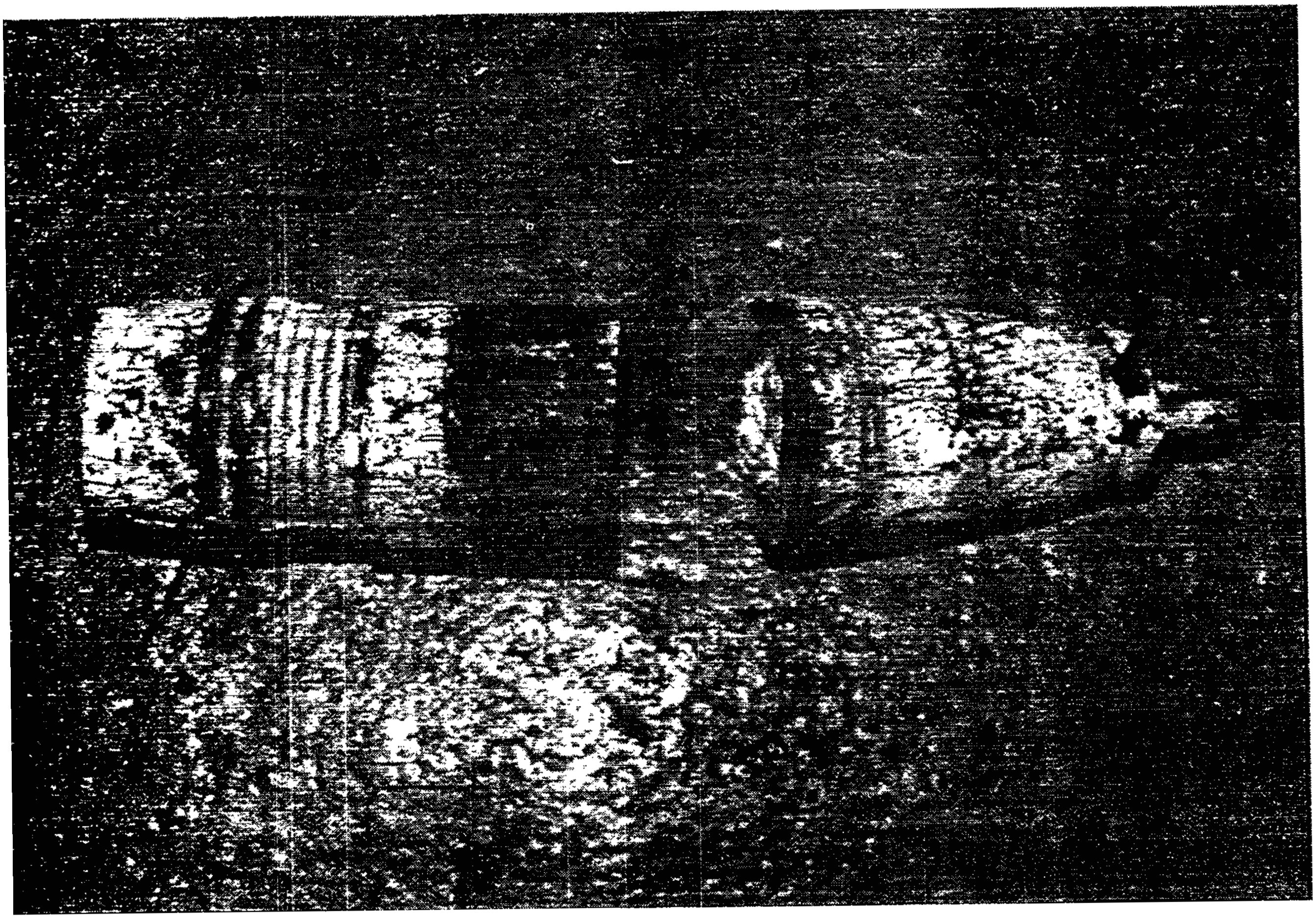
Positioning of water jet nozzle over M42 grenade for cutting. Grenade is in fixture that rotates grenade under nozzle so that cut is made only through steel casing.



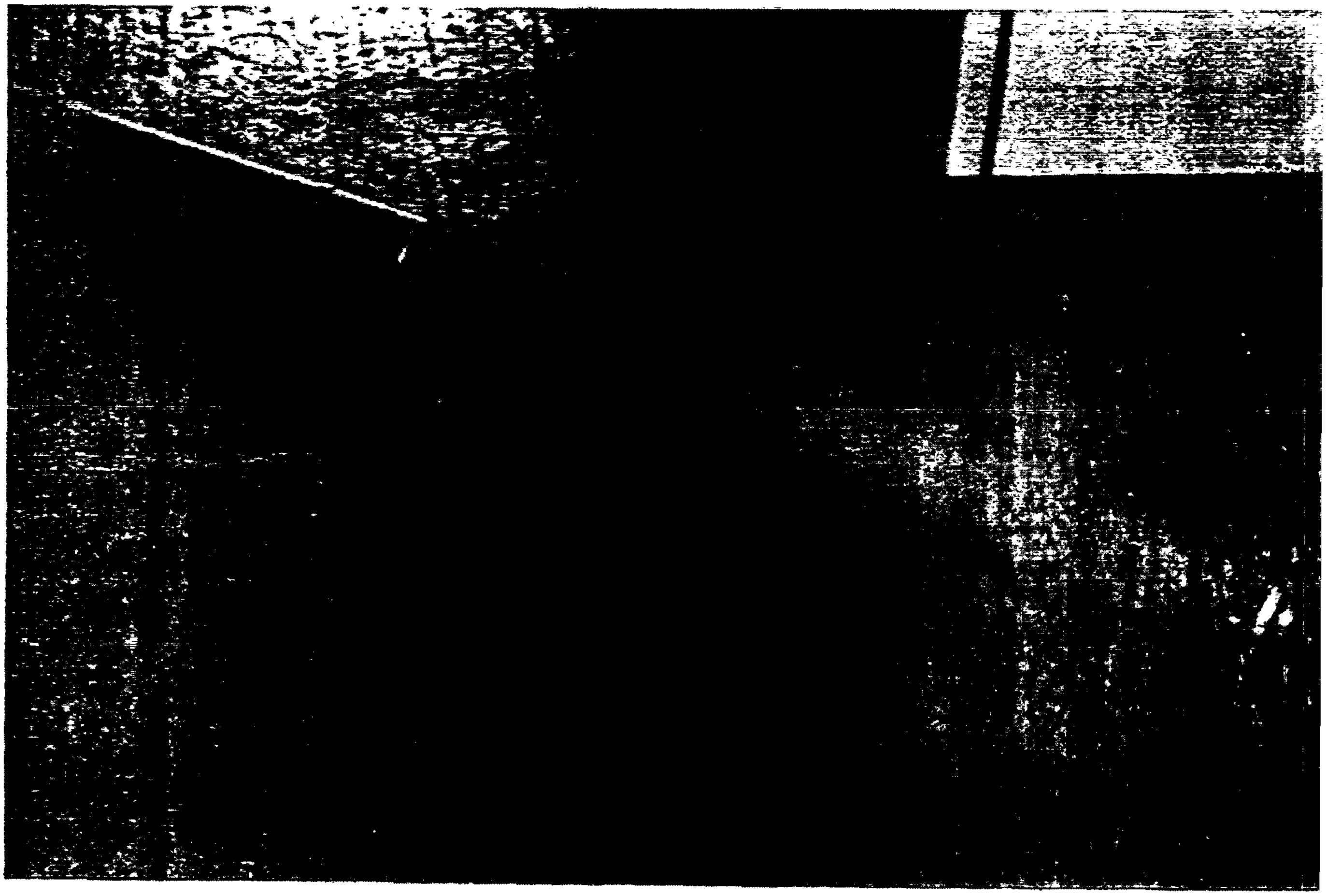
M42 grenade cut with water jet removing fuzed top of grenade. Notice how little simulant explosive is eroded.



M42 grenades after being cut and incinerated in the deactivation furnace.



Inert 90MM projectile cut by water jet in 3 minutes 10 seconds.



Inerted M55 rocket cut with water jet in 45 seconds to demonstrate capability to separate motor from the warhead. Cut was made through fiberglass shipping and firing tube, and steel motor casing in void above the top of the motor grain.